CITY OF SURREY
the future lives here.

Final Report: Improving Coastal Flood Adaptation Approaches

Federation of Canadian Municipalities

FCM MCIP 15274

March 2018

Associated Engineering
GLOBAL PERSPECTIVE. LOCAL FOCUS.

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date MARCH 29, 2018 08-18-003

The preparation of this plan was carried out with assistance from the Government of Canada and the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Table of Contents

List of Abbreviations

AE	Associated Engineering
ALC	Provincial Agricultural Land Commission
ALR	Agricultural Land Reserve
APEGBC	Association of Professional Engineers and Geoscientists of British Columbia (now EGBC)
ARDSA	Agricultural and Rural Development Subsidiary Agreement
BCH	BC Hydro (Power Utility)
BCRC	British Columbia Railway Company
BNSF	Burlington Northern Santa Fe Railway
CCG	Canadian Coast Guard
CFAS	City of Surrey's Coastal Flood Adaptation Strategy
CN	Canadian National Railway
CP	Canadian Pacific Railway
CP	Concrete Pipe
DFL	Design Flood Level
EC	Engineers Canada
EGBC	Engineers and Geoscientists of British Columbia (formerly APEGBC)
EPI	EcoPlan International Inc.
FCM	Federation of Canadian Municipalities
ICFAA	Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk (Project Title)
LINT	Landscape Interventions
LS	Lift Station
MOTI	Ministry of Transportation and Infrastructure
MV	Metro Vancouver
NCP	Neighbourhood Concept Plan
NHC	Northwest Hydraulic Consultants
OCP	Official Community Plan
PE	Polyethylene Pipe
PIEVC	Public Infrastructure Engineering Vulnerability Committee
PS	Pump Station
PVC	Polyvinyl Chloride Pipe
ROW	Right of Way
SLR	Sea Level Rise
SP	Steel Pipe
SRY	Southern Railway of British Columbia
TBL	Triple Bottom Line (Consideration of environmental, social, and economic factors in decision-making)
UBC	University of British Columbia
WM	Water Main

1 Coastal Flood Adaptation Strategy

The City of Surrey has long recognized the need to reduce climate vulnerability, and has been engaging in proactive planning to mitigate the impacts climate change on the community.

The City of Surrey's coastal floodplain represents approximately one-fifth of the City's land base. Climate change impacts in this area are anticipated to arise from a combination of sea level rise, and increased precipitation during the winter months. The predicted consequences of these changes include rising groundwater levels, saltwater intrusion, coastal squeeze, increased shoreline erosion, and higher water levels and durations of flood events. These impacts will increase the vulnerability of infrastructure, private properties, agricultural land, and natural areas located in the coastal floodplain over time.

In response to these threats, the City is developing a comprehensive Coastal Flood Adaptation Strategy (CFAS). The CFAS is a higher-level plan that focuses on evaluating both the current and future (with climate change) impacts of flooding within Surrey's coastal floodplain. This is achieved through extensive community engagement, and through identifying short- to long-term adaptation options that may be implemented to mitigate climate change impacts on different sectors within the area.

The coastal flooding impacts faced by the City of Surrey, and the current process for addressing this is summarized in the CFAS Primer Part I: Coastal Flooding in Surrey, available from http://www.surrey.ca/files/CFAS-primerpart1.pdf.

2 Improving Coastal Flood Adaptation Approaches

CFAS is focused on evaluating the impact and effectiveness of potential large-scale adaptation actions that could be applied to the entire floodplain area.

Within the Mud Bay area, there are several infrastructure assets in operation that are vulnerable to the effects of climate change. These include transportation, utility, flood control, and marine infrastructure with local, regional, provincial, national, and international significance. In recognition of this, the City of Surrey initiated the ICFAA process, focusing on a subsection of the Surrey floodplain west of 152 Street. This localized study area was selected because of the number of critical infrastructure assets within it, and because it is the area which is most likely to be affected by future flooding events. The ICFAA was structured as a standalone project, with its own reporting, yet was integrated into the CFAS process. Outcomes from the CFAS process fed into the ICFAA process, and then results of the ICFAA analyses helped to support the progression of the CFAS.

The dominant components of the ICFAA process were two workshops, developed and delivered based on the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. Both workshops were targeted towards organizations that own, operate, or have a direct interest in the infrastructure within the study area (west of 152 Street, to the coast and border with Delta).

The first workshop, held in March 2017, was designed to systematically assess the vulnerability of the infrastructure assets located within the study area, with direct input from infrastructure stakeholders. The workshop involved participants assigning risk scores to each of the 40 major infrastructure components located within the study area. The main finding from the workshop was that a significant proportion of the infrastructure will have an unacceptably high risk in the future, if adaptation measures are not pursued.

During the vulnerability workshop, the attendees had some preliminary discussions about how to adapt, but it was clear that the process would benefit from further exploration of adaptation approaches. This initiated the second workshop, held in October 2017.

The second workshop centered around the theme that, regardless of the adaptation option that the City of Surrey might pursue, each infrastructure sector is responsible for managing their own risk. The workshop focused on assessing two flood adaptation options that were being considered as part of the CFAS project. Participants evaluated how infrastructure would need to respond to each option, and what actions they could take to minimize their own risk, in coordination with the City's preferred large-scale approach. The workshop also considered how each infrastructure organization might decide what types of responses are the most appropriate. To do this, participants used a triple bottom line approach that considered environmental, social, and economic factors.

The two reports describing the process and outcomes of each workshop are provided as individual volumes, appended to this report.

3 Multi-disciplinary Project Involvement

The ICFAA process involved a diverse and multi-disciplinary team. Municipal staff (primarily the core CFAS team) worked closely with the consulting teams to prepare the materials used in, and to help lead, the workshops, as well as a tour of the study area for workshop attendees.

The four multidisciplinary consulting groups (Associated Engineering, Northwest Hydraulic Consultants, EcoPlan International, and Ebbwater Consulting) provided their expertise in hydraulic and hydrologic modelling, infrastructure and asset management, stakeholder engagement, flood management, and communications. The contributions of the team were crucial for the successful preparation, execution, and summarization of the outcomes of the workshops in accessible formats.

4 Supporting Organizations

The ICFAA process was supported by an elected official (Councillor Starchuk), who participated in the first workshop, and expressed full support for the coastal flooding adaptation and risk management work that Surrey has been undertaking.

The Surrey Transportation and Infrastructure Committee endorsed a resolution to share the ICFAA findings, and seek input from those infrastructure sectors at high-risk.

The process of developing the plan included members of other governmental and regional agencies, including the BC Ministry of Transportation and Infrastructure, Provincial Agricultural Land Commission, and Fraser Basin Council.

A neighbouring municipality (City of Delta), which is facing similar problems with coastal flooding collaborated on this project, and is now initiating a similar process for their own coastal floodplain. The workshops were also attended by members of two engineering associations (Engineers Canada and Engineers and Geoscientists of British Columbia) who commended the leadership and exemplary work accomplished in developing this plan.

5 Benefits of the ICFAA Process

The input elicited from stakeholders during the ICFAA process has been an integral component in the development of the overall CFAS plan. The systematic triple bottom line evaluation approach that was used supported the identification and incorporation of environmental, social, and economic benefits related to infrastructure adaptation.

The approach helped bring attention to the often-overlooked environmental considerations in asset management planning and decision-making. The involvement of environmental conservation organizations and the City of Surrey's Parks staff played a crucial role in the process, and helped raise stakeholders' awareness of the importance of the environmental features in the study area, and how these features are impacted by flooding, and by the actions of infrastructure owners.

Social benefits were realized through advanced stakeholder and inter-governmental collaboration, strengthening partnerships with the UBC School of Architecture and Landscape Architecture. The process improved understanding the relationship between the social services that infrastructure provides, including community connectivity, mobility, safety, and emergency services.

Economic objectives were accomplished by identifying how increased vulnerability of critical infrastructure influences not only the local economy, but also the regional, provincial, national, and international economy. The process highlighted the broad economic implications of flood adaptation on the infrastructure sectors, and provided a basis for understanding how potential adverse economic impacts from flooding can be mitigated through proactive planning and collaboration between sectors.

6 CFAS Use of ICFAA Outcomes

The outcomes of the ICFAA process played an important role in the CFAS process, by directly engaging infrastructure sectors. This helped infrastructure organizations to better understand the vulnerability of their assets to coastal flooding and climate change, and opened a dialogue between these organizations and the City of Surrey on how collaboration and communication can improve the effectiveness of adaptation approaches. By understanding the drivers and values of the various infrastructure organizations, the CFAS team was able to better evaluate which options are acceptable, and how they can be effectively implemented.

The results of the ICFAA consultation process have been reflected in the CFAS Primer Part 2: Mud Bay Options prepared by Northwest Hydraulic Consultants and EcoPlan International, available for download from http://www.surrey.ca/files/CFAS-primerpart2.pdf.

The next steps that have been identified during the ICFAA process include the following:

- Shortlisting of adaptation options, where the CFAS team will revisit the proposed adaptation options for Mud Bay and develop a shortlist of the most preferred options. During this process, infrastructure owners should be active participants, so that their needs are understood. This may involve further independent assessment by each infrastructure sector of their own risk thresholds, and development of possible actions they can take to maintain their risk to within acceptable levels.
- Development of an adaptation framework that would support long-term planning by each infrastructure organization. The framework would outline the actions to be taken by the infrastructure sectors to support a coordinated path to adaptation.
- Ongoing monitoring and contingency planning by each infrastructure organization. The infrastructure sectors would benefit from exploring their own coastal flooding risks in greater detail. When an infrastructure investment is being considered, that sector could conduct an additional assessment that accounts not only for future coastal flooding, but also factors such as population growth, service expectations, seismic resilience, and efficiency. These comprehensive risk assessments could help to pinpoint their thresholds, and proactively identify the actions they may need to take.

7 ICFAA Deliverables

This report serves as a central repository for the work completed in support of the ICFAA process, and was prepared with input from the City of Surrey's CFAS team. Appended to this report are six volumes that contain the key deliverables from this process. The contents of each volume are described in Table 1.

Table 1
Overview of Appended Volumes

Volume Number	Deliverable Title	Description
Volume 1	Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop: Summary and Outcomes (Associated Engineering, June 2017).	Summary of the process and outcomes of the first PIEVC workshop held in March 2017, which focused on assessing the vulnerability of key infrastructure sectors to the effects of coastal and riverine flooding.
Volume 2	Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using Engineers Canada PIEVC Protocol: Workshop Summary and Outcomes (Associated Engineering, March 2018).	Summary of the process and outcomes of the second PIEVC workshop held in October 2017, which focused on evaluating the impacts of two of the City's proposed adaptation options through a triple bottom line assessment.
Volume 3	Infrastructure Story Map (Ebbwater Consulting, March 2018).	Overview and link to an interactive online story map that provides an accessible narrative of how transportation infrastructure is affected by flooding.
Volume 4	Presentations (City of Surrey, Associated Engineering).	Compilation of presentations given as part of the ICFAA project. This includes presentations given by the City of Surrey staff at conferences, to infrastructure organizations, and to Surrey's Transportation Infrastructure Committee, as well as the presentations used during the two PIEVC workshops.
Volume 5	Workbooks (Associated Engineering).	Blank copies of the workbooks used to engage participants during the two PIEVC workshops.
Volume 6	Surrey Flood Management System Video Script (City of Surrey, EcoPlan International).	Script and online link to a video about coastal flood management in Surrey, developed to support the technical engagement of infrastructure stakeholders

REPORT

Closure

This report was prepared for the City of Surrey to assist in the development of a comprehensive Coastal Flood Adaptation Strategy (CFAS) by compiling the work completed in support of Improving Coastal Flood Adaptation Approaches (ICFAA).

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:

PROFESSIONAL PROVINCE OF
J. D. KINDRACHUK
46012
BRITISH COLUMBIA
ENGINEER
MARCH 29, 2018

Jason Kindrachuk, P.Eng.
Water Resources Engineer

Reviewed by:

Jeff O'Driscoll, P.Eng., (Manitoba), IRP
Lead Workshop Facilitator

JK/JO/lp

REPORT

Volume 1 – Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop: Summary and Outcomes

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY
the future lives here.

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

JUNE 2017

CFAS

City of Surrey

Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop: Summary and Outcomes

REPORT

APEG Professional Engineers and Geoscientists of BC

Delta

epi

nhc northwest hydraulic consultants water resource specialists

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

engineerscanada ingénieurscanada

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date 15/6/2017

#04-17-037

CONFIDENTIALITY AND © COPYRIGHT

DISCLAIMER

The workshop and this report shall not be construed as any acceptance or assumption of risk, responsibility, or liability by or on behalf of the City of Surrey for ongoing safe construction, operation, use, and maintenance of infrastructure in the floodplain. The full and complete responsibility and liability to ensure the ongoing safe construction, operation, use, and maintenance of infrastructure has been and continues to remain with the infrastructure owners.

Executive Summary

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

In support of Phase 1 of the **Coastal Flood Adaptation Strategy (CFAS)** process, the City engaged Associated Engineering (AE) to plan and deliver a workshop targeted at infrastructure owners and emergency service providers. This workshop was held on March 28, 2017, and was attended by 66 participants representing 28 organizations.

The workshop used the **Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Tool** to assess the infrastructure in the Mud bay study area. The use of the procedure allows for a systematic process of assessing flood vulnerability of the various infrastructure types affected by flooding in the lowlands. The procedure was selected to capture the various infrastructure owners' wealth of information, including system knowledge and risk management expertise.

Workshop Attendee Organizations	
Associated Engineering	FortisBC
BC Ambulance Service	Metro Vancouver
BC Rail Consultant	Ministry of Agriculture
BNSF	Ministry of Community, Sport and Cultural Development
Canadian Coast Guard	Ministry of Environment
CFAS Consulting Team	Ministry of Transportation and Infrastructure
City of Surrey	Mud Bay Dyking District
City of Vancouver	Northwest Hydraulic Consultants
Corporation of Delta	Royal Canadian Mounted Police
Cowichan Valley Regional District	SNC Lavalin
Ducks Unlimited Canada	Southern Railway of BC
Emergency Management BC	Surrey Operations
Engineers Canada	Telus / Shaw

The workshop focused on identifying vulnerabilities to, and interactions between, transportation infrastructure (rail, roads, trails, and runways), utilities (power, gas, sanitary sewers and lift stations), and flood control / marine infrastructure (marinas, private docks, drainage pump stations, sea dams, and dykes) and assessing the consequences of the impacts from flooding.

Flood / Marine	TRANSPORTATION	TRANSPORTATION	UTILITIES
Flood Control Infrastructure	**Local Government Arterial and Collector Roads**	**Regional / International Transportation Infrastructure**	**Sanitary Lift Stations**
City of Surrey Sea Dams (2)	King George Boulevard	4 km of four-lane arterial roadway	City of Surrey: Elgin
15 km of dyking, including ditches and floodboxes	152nd Street	7 km section of Highway 99 linking Peace Arch Border	City of Surrey: South Port
Colebrook Pump Station	Colebrook Road	Highway 91 and 99 Interchange	City of Surrey: Winter Crescent
Maple Pump Station	Corporation of Delta: Ladner Trunk Road	4 km section of Highway 91	City of Surrey: Stewart Farm
Corporation of Delta: Oliver Pump Station	112 Street	6 km dyke trail connecting to parks	Metro Vancouver: Crescent Beach
Ducks Unlimited Canada Serpentine Fen Nature Reserve	**Class 1 Railways**	Delta-Surrey Greenway	**Underground infrastructure**
Water control and irrigation	Class 1 Railways Originating at Port Metro Vancouver (general)	**Runway**	5 km of Metro Vancouver 750 mm diameter Water Transmission Main
Screw pump stations (added)	BNSF Swing Bridge and Trestles	Surrey/King George Airpark Turf Runway	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
Marine Facilities	6 km of BNSF Railway		>10 km of FortisBC Gas Mains
Crescent Beach Marina	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF)		**Overhead Utility Infrastructure**
Wards Marina			BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power
Private docks	Connection to Southern Railway of British Columbia		BC Hydro local overhead distribution lines
Farms			Shaw and Telus telecom lines
Private dairy facilities for more than 1,000 head of Cattle			Green Infrastructure

The flooding scenarios used in the risk assessment are based on the outcome of several floodplain studies developed in the CFAS project. The workshop focused on the following two scenarios:

- **Scenario A:** Coastal dyke breach causing progressive inundation of the coastal floodplain by the ocean.
- **Scenario B:** 200-year return period riverine flooding, with releases to Mud Bay via the sea dams restricted by tidal cycles.

Both scenarios were assessed under both **present-day and year 2100 time horizons**. Climate change is affecting both the intensity and frequency of storms and flood events, causing today's extreme floods to become more frequent in the future. Sea level rise will restrict the amount of time the sea dams and floodboxes can drain. The land in Mud Bay is also subsiding, which will exacerbate the effects of sea level rise.

Risk Assessment Summary

Using the PIEVC process, risk scores were developed for each interaction between infrastructure component and flood scenario. To determine the risk score (R) for each interaction, a probability score (P) was established for each flood scenario and the participants selected a consequence score (C) for each interaction between flood scenarios and infrastructure.

The resulting risk **R = P x C,** is the product of the probability score (P) and the consequence score (C).

- R = >10 — Low Risk — Risk requiring minimal action
- R = 10 – 19 — Medium Risk — Risks that may require future action
- R = 20 – 25 — High Risk — Risks that require action

Flood Scenario A – Coastal Flood with Dyke Breach

- 40 assets assessed per scenario
- Current risks are mostly low and medium
- Future risks increase to medium and high

	Number of Assets in Each Category							
	Flood Scenario A Current				Flood Scenario A Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Future
Low Risk	9	3	5	**17**	3	0	0	**3**
Medium Risk	7	9	5	**21**	2	7	6	**15**
High Risk	0	0	2	**2**	11	5	6	**22**

Flood Scenario B – Riverine Flood

- 40 assets assessed per scenario
- All assets are currently at low risk
- The number of assets subject to medium risk increases to 23 (>50% of the number of assets assessed), while 7 assets (~20%) are at high risk.

	Number of Assets in Each Category							
	Flood Scenario B Current				Flood Scenario B Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Future
Low Risk	16	12	12	**40**	5	3	2	**10**
Medium Risk	0	0	0	**0**	9	6	8	**23**
High Risk	0	0	0	**0**	2	3	2	**7**

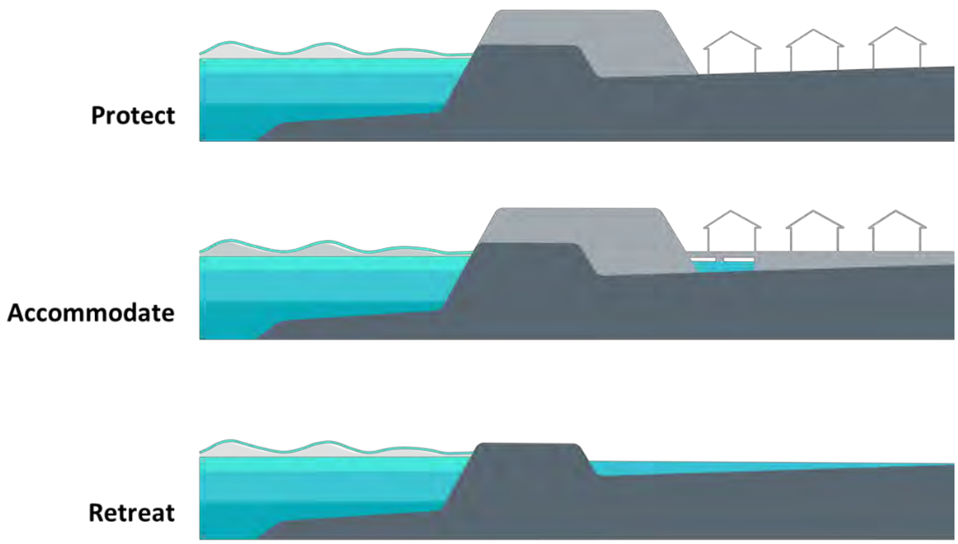
A **summary of flood risk** for the infrastructure is listed below.

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turn Runway	4	5	3	5
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	12	25	3	10
	7 km section of Highway 99 linking Peace Arch Border	16	25	3	10
	Highway 91 and 99 Interchange	12	20	3	10
	4 km section of Highway 91	8	20	3	10
	6 km dyke trail connecting to parks	4	5	3	10
	Delta-Surrey Greenway	4	5	3	10
	Local Government Arterial and Collector Roads				
	King George Boulevard (City of Surrey)	12	25	3	10
	152nd Street (City of Surrey)	4	20	3	5
	112 Street (City of Surrey)	8	15	6	15
	Colebrook Road (City of Surrey)	8	15	6	15
	Ladner Trunk Road (Corporation of Delta)	12	20	9	20
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	16	20		
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	16	25		
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~ 18 trains daily	8	20		
	Connection to Southern Railway of British Columbia	4	20	9	20

Infrastructure		A Current	A Future	B Current	B Future
		Flood Scenario			
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	12	15		
	City of Surrey: South Port	16	20		
	City of Surrey: Winter Crescent	12	15		
	City of Surrey: Stewart Farm	16	20	6	20
	Metro Vancouver: Crescent Beach	16	20		
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	16	20	6	10
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	12	15	6	10
	>10 km of FortisBC Gas Mains	8	10	9	15
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	12	15		20
	BC Hydro local overhead distribution lines	16	20		20
	Shaw and Telus telecom lines	8	10	6	10
	Green Infrastructure (Added)	8	15		15

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	20	20	6	25
	15 km of dyking, including ditches and floodboxes	20	25	9	20
	City of Surrey: Colebrook Pump Station	16	20	6	15
	City of Surrey: Maple Pump Station	16	20	3	15
	Corporation of Delta: Oliver Pump Station	16	25	6	15
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	8	10	3	5
	Water control features to maintain environmentally sensitive area including freshwater irrigation system	12	15		
	Screw Pump Stations (Added)	4	10	3	10
	Marine Facilities				
	Crescent Beach Marina	8	15	6	10
	Wards Marina	8	15	6	10
	Private docks	8	15	9	10
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	16	25	3	10

Following the risk assessment, **adaptation scenarios and strategies** were discussed with an emphasis on high risk interactions on the Mud Bay infrastructure. Three adaptions approaches were discussed; Protect, Accommodate, and Retreat.



Results from the discussions and a follow-up survey were documented and will be used to inform the next phases of the CFAS project.

Representative **adaptation stakeholder comments** include:

- *Accommodate and do incremental upgrades.*
- *Rock groin / breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.*
- *Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).*
- *Without offshore improvements, dyke upgrades will be challenging and will take a long time.*
- *Retreat for highways not considered feasible.*
- *Incremental adaptations are needed to meet changing needs of climate change.*
- *If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?*
- *Build a sea wall across Mud Bay.*
- *Dyking is a good option. Offshore islands are a no-go for Crescent Beach.*
- *Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay.*
- *Raise the dykes - build a barrier wall.*

- *BC Hydro may implement protect or accommodate adaptation features for its infrastructure.*
- *No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland.*
- *What would be a global approach to adopt options to develop strategies against coastal flood risks?*
- *Sea level rise and subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for.*
- *Look at options and evaluate problems they solve instead of vice versa.*
- *Incremental adaptations.*
- *Engage the whole Lower Mainland area.*
- *Yes, engagement with neighbouring municipalities should be needed for this type of workshop.*
- *Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed).*

Table of Contents

1 Introduction

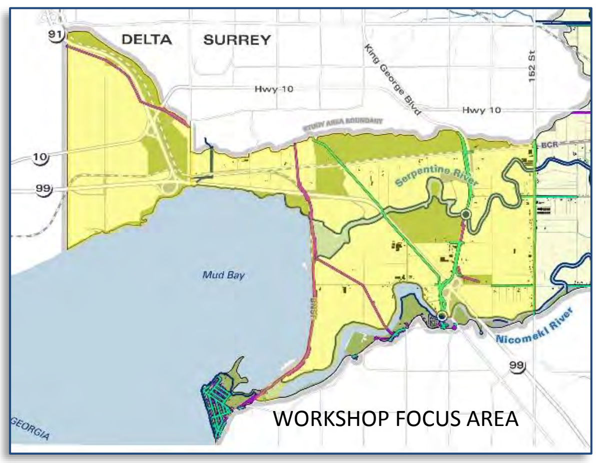
1.1 COASTAL FLOOD ADAPTATION STRATEGY

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

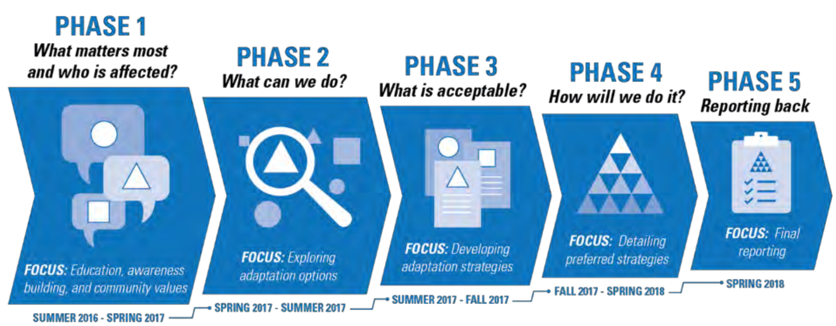
The City's prime consultant responsible for the overall Coastal Flood Adaptation Strategy (CFAS) is Northwest Hydraulic Consultants (NHC) with EcoPlan International, Diamond Head Consulting, and KM Consulting as subconsultants.

The current phase (Phase 1) focuses on education and increasing awareness of the flood hazards faced, and gathering input on the values and needs of various stakeholder groups, including:

- Farmers and the agricultural community;
- Residents, businesses, and community groups;
- Environmental and recreational groups;
- Semiahmoo First Nation; and
- Infrastructure operators, owners, and emergency service providers.

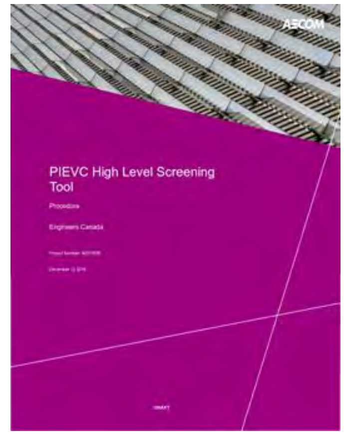


In support of Phase 1 of the CFAS, the City engaged Associated Engineering (AE) to plan and deliver a workshop targeted at the infrastructure owners and emergency service providers. This workshop was held on March 28, 2017, and was attended by 66 participants representing 28 organizations.



This report summarizes the process and outcomes of the workshop. The information collected during the workshop will be used to help inform flood mitigation approaches in later phases of the CFAS.

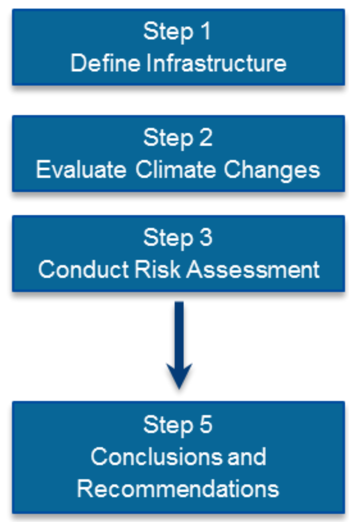
1.2 INFRASTRUCTURE FLOOD VULNERABILITY ASSESSMENT



The infrastructure vulnerability workshop was formulated around the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Tool. The use of this procedure allows for a systematic process for assessing flood vulnerability of the various infrastructure types affected by flooding in the lowlands. The procedure was selected to capture the various infrastructure owners' wealth of information, including system knowledge and risk management expertise. Engineers Canada licensed the PIEVC Tool to the City of Surrey for use on this project.

1.1.1 PIEVC High Level Screening Assessment

The High Level Screening Assessment is based upon four main steps:



In **Step 1**, the infrastructure under evaluation, and the hazards which it can face are scoped. In the case of the Mud Bay Assessment, this is the transportation, utility, flood control and marine infrastructure in the study area.

In **Step 2**, the assessment team determines the probability of future climate change events interacting with their infrastructure. In the Mud Bay Assessment, the two main flood scenarios were explored: Flood Scenario A: Coastal Flood with Dyke Breach; and Flood Scenario B: Riverine Flood.

In **Step 3**, the assessment team evaluates the consequences of the interaction between future climate changes and infrastructure. In the Mud Bay Assessment, this assessment was conducted in a one day workshop with infrastructure stakeholders in the Mud Bay area. The workshop focused on a subset of the overall CFAS project area extending from Mud Bay east to 152 Street.

In **Step 5**, the assessment team provides a portrait of the climate change risks for their infrastructure, and proposes recommended actions and areas of further study. In the case of the Mud Bay assessment, conclusion and recommendations were not developed, but rather, outcomes including **adaptation comments and strategies** were captured for further evaluation in the CFAS Project.

1.1.2 PIEVC Workshop

The workshop was held at Surrey City Hall on March 28, 2017. A total of 66 people representing 28 organizations participated in the workshop. The organizations in attendance were:

- Associated Engineering
- BC Ambulance Service
- BC Hydro
- BC Rail Consultant
- Burlington Northern Santa Fe Railway
- Canadian Coast Guard
- City of Surrey (Various Departments)
- City of Surrey Operations
- City of Surrey Fire
- City of Surrey RCMP
- City of Vancouver
- Corporation of Delta
- Cowichan Valley Regional District
- Ducks Unlimited Canada
- Emergency Management BC
- Engineers Canada
- FortisBC
- Metro Vancouver
- Ministry of Agriculture
- Ministry of Community, Sport and Cultural Development
- Ministry of Environment
- Ministry of Transportation and Infrastructure
- Mud Bay Dyking District
- Northwest Hydraulic Consultants
- Port of Vancouver
- SNC Lavalin
- Southern Railway of BC
- Telus

The workshop focused on identifying vulnerabilities to, and interactions between, transportation infrastructure (rail, roads, trails, and runways), utilities (power, gas, sanitary sewers and lift stations), and flood control / marine infrastructure (marinas, private docks, drainage pump stations, sea dams, and dykes) and assessing consequences of the impacts from flooding.

The day began with roundtable introductions and opening remarks on the CFAS Project and on the Engineers Canada PIEVC risk assessment process. A “History of Flooding” was then presented that outlined past flood impacts in the region and the flood infrastructure that was constructed in the Mud Bay area.

The next series of presentations provided background information on the Flood Scenarios (A and B) and an orientation on the PIEVC risk assessment process. Following this orientation, a series of group exercises were conducted.

These group exercises included facilitated discussions on **flood impacts** to each infrastructure component for each flood scenario and **risk analysis** to assess and quantify the consequence of each flood scenario to these infrastructure components. For the group exercises, workshop participants were provided a workshop workbook to write down comments and rationale. At the completion of each exercise, a group discussion took place to share comments from each individual table to all the workshop participants.

Following the risk assessment exercises, an "Adaptation Background" presentation was completed outlining the adaptation framework the CFAS project was exploring.

This was followed by a facilitated group exercise which asked participants to discuss and document **adaptation options** (protect, accommodate, retreat) for higher risk infrastructure identified in the previous exercises. At the completion of the exercise, a group discussion took place to share comments from each individual table with all the workshop participants.

The day concluded with a question and answer session and a brief presentation on the outcomes of the workshop and next steps of the CFAS project.

2 Step 1 - Infrastructure Definition

2.1 INFRASTRUCTURE DEFINITION

Step 1
Define Infrastructure

In advance of the workshop, potentially vulnerable infrastructure within the study area was identified, and was divided into three categories to assist in the assessment: 1) Transportation Infrastructure; 2) Utilities; and 3) Flood Control / Marine Infrastructure.

Tables were organized for each infrastructure category and workshop participants were assigned to one of the three categories to focus on for the day. Participants from emergency services organizations (City of Surrey Fire, RCMP, and BC Ambulance Service) were divided amongst the tables to provide their perspectives.

2.2 INFRASTRUCTURE IDENTIFICATION

The workshop study area encompasses the region from Mud Bay east to 152 Street. The infrastructure identified within the workshop study area is as follows:

Reference Figure 2-1, Transportation Infrastructure, Figure 2-2, Utilities Infrastructure, 2-3, Flood Control / Marine Infrastructure.

- **Transportation Infrastructure**
  - Runway
    - Surrey / King George Airpark Turf Runway
  - Regional / International Transportation Infrastructure
    - 4 km of four-lane arterial roadway
    - 7 km section of Highway 99 linking Peace Arch Border
    - Highway 91 and 99 interchange
    - 4 km section of Highway 91
    - 6 km dyke trail connecting to parks
    - Delta-Surrey Greenway
  - Local Government Arterial and Collector Roads
    - King George Boulevard (City of Surrey)
    - 152 Street (City of Surrey)
    - Colebrook Road (City of Surrey)
    - Ladner Trunk Road (Corporation of Delta)
  - Class 1 Railways Originating at Port Metro Vancouver
    - Burlington Northern Santa Fe (BNSF) Nicomekl swing bridge and trestles
    - 6 km of BNSF Railway (freight frequencies ~20 trains daily and up to 4 daily Amtrak Cascades trains)
    - Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP, and BNSF, ~18 trains daily)

        - Connection to Southern Railway of British Columbia
- **Utilities**
    - Sanitary Lift Stations
        - Elgin (City of Surrey)
        - South Port (City of Surrey)
        - Winter Crescent (City of Surrey)
        - Stewart Farm (City of Surrey)
        - Crescent Beach (Metro Vancouver)
    - Underground Infrastructure
        - 5 km of Metro Vancouver 750 mm diameter water transmission main
        - 10 km of Metro Vancouver sanitary sewer forcemains (500 mm to 1050 mm diameter)
        - >10 km of FortisBC gas mains
    - Overhead Utility Infrastructure
        - BC Hydro Twin 500kV bulk transmission line providing intertie between BC Hydro and Bonneville Power
        - BC Hydro local overhead distribution lines
        - Shaw and Telus telecommunications lines
- **Flood Control / Marine Infrastructure**
    - Flood Control Infrastructure
        - Serpentine sea dam (City of Surrey)
        - Nicomekl sea dam (City of Surrey)
        - 15 km of dyking, including ditches and floodboxes
        - Colebrook Pump Station (City of Surrey)
        - Maple Pump Station (City of Surrey)
        - Oliver Pump Station (City of Surrey)
        - Ducks Unlimited Canada Serpentine Fen Nature Reserve
        - Water Control Features to maintain environmentally sensitive area, including freshwater irrigation system
    - Marine Facilities
        - Crescent Beach Marina
        - Wards Marina
        - Private docks
    - Farms
        - Private dairy facilities for over 1,000 head of cattle

In advance of the workshop, the **CFAS Primer, Backgrounder and Workshop Questionnaire** were sent to the invitees and twelve responses were received. Copies of these documents are included in Appendix A. Key responses from the questionnaires are summarized as follows:

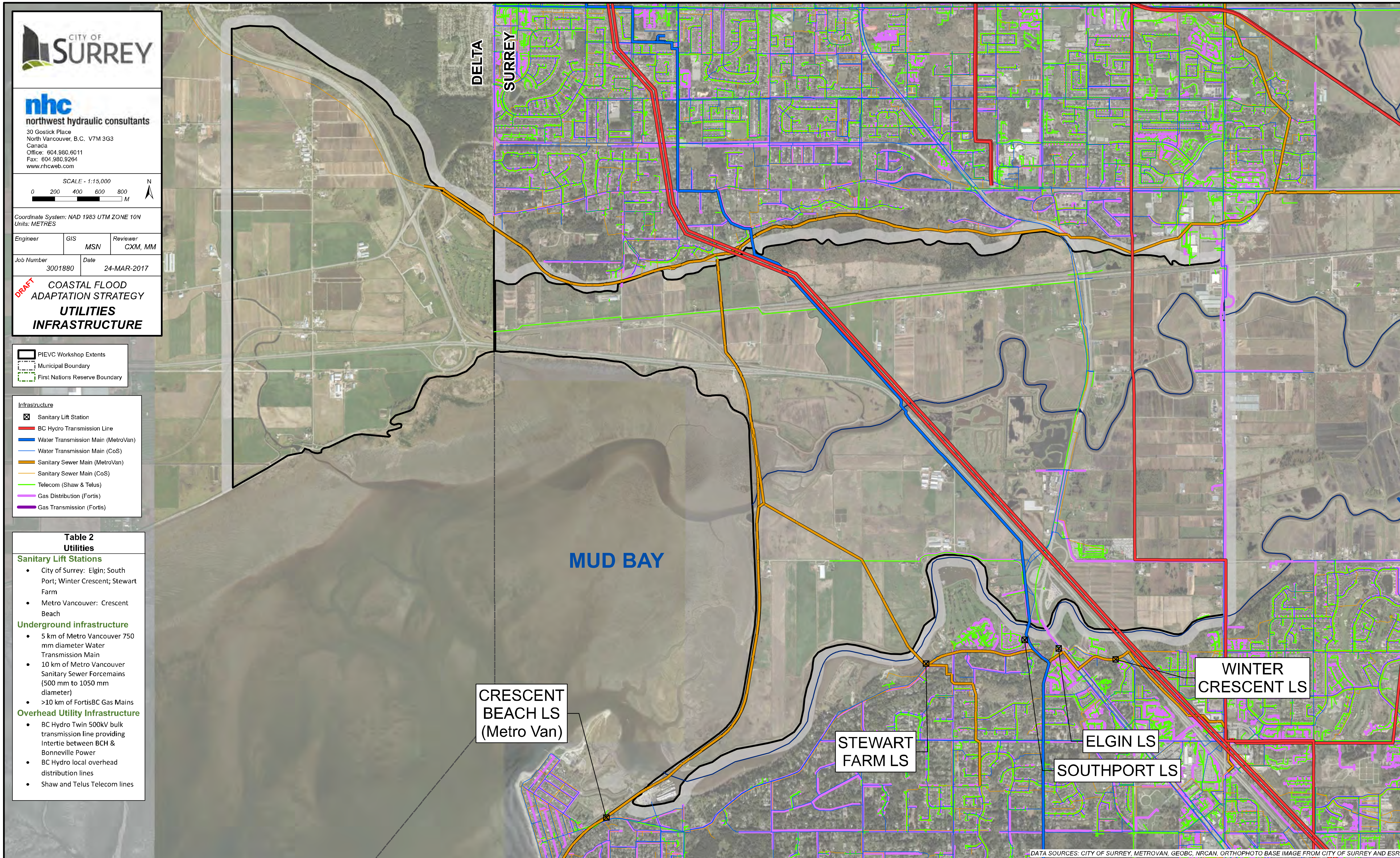
- Metro Vancouver identified one pump station, a dozen valve chambers, and approximately ten kilometres of sewer main within the study area and noted that they have had minimal impacts from flooding to date, other than reduced access.

- The Ministry of Transportation and Infrastructure identified the following structures, but did not identify any known history of overtopping or damage to those structures due to flooding:
  - Peacock Brook culvert on Highway 99
  - Serpentine bridge on Highway 99
  - Nicomekl bridge on Highway 99
  - Bigslough culvert on Highway 99
  - Unknown culvert on Highway 99 west of Mud Bay overpass.
- Fortis identified the presence of high pressure and distribution pressure underground gas lines in the area, and noted that no significant impacts due to flooding have been experienced to date.
- Ducks Unlimited confirmed the presence of water control features at the Serpentine Fen to maintain the environmentally sensitive area.
- BNSF identified that storm surges have impacted the railway from White Rock to Mud Bay, and that they are continuously monitoring and fortifying their infrastructure through the area.

During the workshop, one additional infrastructure type ('green infrastructure') was identified and included in the assessment. Green infrastructure was generally defined as vegetation, and the rationale is that tree and vegetation mortality associated with flooding can be problematic and should be considered.

This page intentionally blank. Formatted for double-sided printing.

CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
TRANSPORTATION INFRASTRUCTURE
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Infrastructure
Airpark
Railway
Provincial Highway
Arterial Road
Local Road Network
Greenway / Trail
Table 1
Transportation
Surrey/King George Airpark Turf Runway
Regional / International Transportation Infrastructure
• 4 km of four-lane arterial roadway
• 7 km section of Highway 99 linking Peace Arch Border
• Hwy 91 and 99 Interchange
• 4 km section of Highway 91
• 6 km dyke trail connecting to parks
• Delta-Surrey Greenway
Local Government Arterial and Collector Roads
• King George Boulevard (City of Surrey)
• 152nd Street (City of Surrey)
• Colebrook Road (City of Surrey)
• Ladner Trunk Road (Corporation of Delta)
Class 1 Railways Originating at Port Metro Vancouver
• Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles
• 6 km of BNSF Railway with freight frequencies between 16 and 20 trains daily and up to 4 daily Amtrak Cascades trains
• Roberts Bank Railway Corridor (BC Railway Company ownership with usage by CN, CP and BNSF) with up to 18 trains daily.
• Connection to Southern Railway of British Columbia.
DELTA
SURREY
Hwy 91
Hwy 10 (58 Ave)
King George Blvd
KING GEORGE AIRPARK
Colebrook Rd
BNSF Rwy
Ladner Trunk Rd
BC Rail
BC Rail
Hwy 99
152 St
King George Blvd
MUD BAY
Crescent Rd
DATA SOURCES: CITY OF SURREY, METROVAN, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.


CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
UTILITIES INFRASTRUCTURE
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Infrastructure
Sanitary Lift Station
BC Hydro Transmission Line
Water Transmission Main (MetroVan)
Water Transmission Main (CoS)
Sanitary Sewer Main (MetroVan)
Sanitary Sewer Main (CoS)
Telecom (Shaw & Telus)
Gas Distribution (Fortis)
Gas Transmission (Fortis)
Table 2
Utilities
Sanitary Lift Stations
City of Surrey: Elgin; South Port; Winter Crescent; Stewart Farm
Metro Vancouver: Crescent Beach
Underground infrastructure
5 km of Metro Vancouver 750 mm diameter Water Transmission Main
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
>10 km of FortisBC Gas Mains
Overhead Utility Infrastructure
BC Hydro Twin 500kV bulk transmission line providing Intertie between BCH & Bonneville Power
BC Hydro local overhead distribution lines
Shaw and Telus Telecom lines
DELTA
SURREY
MUD BAY
CRESCENT BEACH LS (Metro Van)
STEWART FARM LS
SOUTHPORT LS
ELGIN LS
WINTER CRESCENT LS
DATA SOURCES: CITY OF SURREY, METROVAN, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

This page intentionally blank. Formatted for double-sided printing.

CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
FLOOD CONTROL / MARINE INFRASTRUCTURE
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Infrastructure
Marina
Pump Station
Sea Dam
Floodbox
Water Control Feature (Serpentine Fen)
Dike
Drainage Canal/Ditch
Water Body
Large Scale Livestock Operation (Private)
Table 3
Flood Control / Marine
Flood Control Infrastructure
• 2 City of Surrey Sea Dams
• 15 km of dyking including ditches and floodboxes
• City of Surrey: Colebrook and Maple Pump Stations
• Corporation of Delta: Oliver Pump Station
Ducks Unlimited Canada Serpentine Fen
• Water Control Features to maintain environmentally sensitive area including freshwater irrigation system.
Marine Facilities
• Crescent Beach Marina
• Wards Marina
• Private docks
Private Dairy Facilities for over 1,000 head of Cattle
DELTA
SURREY
OLIVER PS
COLEBROOK ROAD PS
Serpentine Fen
MUD BAY
PRIVATE DOCK
WARD'S MARINA
CRESCENT BEACH MARINA
DATA SOURCES: CITY OF SURREY, METROVAN, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

This page intentionally blank. Formatted for double-sided printing.

2.3 INFRASTRUCTURE VULNERABILITY

The functionality of infrastructure in the Mud Bay region is reliant on flood control infrastructure, including sea dams, sea dykes, floodboxes, pump stations, and ditches.

The coastal floodplain is subject to flooding from both coastal processes (high tide, storm surge, wind and wave setup) and riverine processes (heavy precipitation, rain on snow / snow melt, high tides). As time progresses, sea level rise, land subsidence, and upland development will contribute to increased risk of flooding from these processes.

A previous vulnerability assessment of the sea dams, dykes, bridges, roads, and railroads, conducted by NHC, indicated that at the present 200-year flood condition:

- Freeboard would be compromised at the Serpentine Sea Dam;
- The Serpentine left bank dyke downstream of the sea dam would be inundated and freeboard would be compromised at all of the lowland dykes;
- Bridge decks would be inundated at three of the bridges and the low chords submerged at nine other bridges;
- A portion of Highway 99 would be inundated and freeboard compromised at Colebrook Road, with a few sections of railroad having compromised freeboard as well.

In 2100 at the 200-year flood (ignoring potential precipitation increases):

- Both the Serpentine and Nicomekl Sea Dams would be inundated;
- The lowland dykes upstream and downstream of the sea dams would also be inundated and nearly all other dykes would have compromised freeboard;
- The bridge decks would be inundated at seven bridges and the low chords submerged at 10 other bridges;
- Major roads and railroads would have either compromised freeboard or some inundation. Even during moderate present floods, some damage to infrastructure can be expected. Consequences of inundation may include widespread power outages, damage to transportation routes, challenges for emergency services and loss of critical assets such as water and sewage transmission. These primary impacts are likely to lead to cascading impacts outside the floodplain and in neighbouring municipalities.

The workshop participants identified potential impacts due to flooding on each piece of infrastructure. These impacts are summarized in Tables 2-1, 2-2, and 2-3.

Table 2-1: Flood Impacts to Transportation Infrastructure

Infrastructure	Identified Potential Flood Impacts
Surrey / King George Airpark Turf Runway	• Environmental contamination from fuel stored on-site. • Damage to aircraft and facilities. • Loss of access to patients for emergency response.
4 km of Four-Lane Arterial Roadway (including King George Boulevard)	• Inundation or washout of bridges, culverts, and the road structure. • Loss of access for emergency services. • Disruption of potential evacuation route for the public. • Environmental contamination from fuel. • Economic losses due to disruption of commuter traffic movement, congestion. • Loss of access to sea dams and other critical infrastructure. • Public safety issues with people parking cars or equipment on the roadside.
7 km Section of Highway 99 Linking Peace Arch Border	• Inundation or washout of bridges, culverts, and the road structure. • Loss of access for emergency services and maintenance operations on damaged utilities. • Disruption of potential evacuation route for the public. • Environmental contamination from fuel, possible hazardous good transport. • Economic losses due to disruption of commuter traffic. • Economic losses due to disruption of commercial and public access to the Canada / USA border.
Highway 91 and 99 Interchange	• Economic losses due to disruption of commercial and public access to the Canada / USA border. • Potential structural damage to the interchange due to scour, inundation of the foundations.
6 km Dyke Trail Connecting to Parks	• Loss of use due to inundation or partial washout. • Impact to commuter cyclists. • Impeded access to flood control infrastructure for repairs or maintenance.
152 Street	• Loss of access to the region for emergency services, the public, and operations and maintenance staff.
Colebrook Road	• Bridge damage. • Disruption of access to trains.

Infrastructure	Identified Potential Flood Impacts
Ladner Trunk Road	• Disruption of access to airport and hospital.
BNSF Nicomekl Swing Bridge and Trestles	• Economic disruption to the national economy, including goods movement to the US and the Ports. • Damage to the rail line with long recovery time.
6 km of BNSF Railway	• *No specific comments*
Roberts Bank Railway Corridor	• Economic impacts due to the loss of the sole connection to Deltaport.
Connection to Southern Railway of British Columbia	• *No specific comments*

Table 2-2: Flood Impacts to Utilities

Infrastructure	Identified Potential Flood Impacts
Sanitary Lift Stations	• Loss of power to the stations. • Inundation of the controls, shutting the stations down and reducing their capability to function or to be restored. • Potential interactions within the system, where if one on-line pump station goes down the entire system cannot function. • Increased inflow and infiltration (I&I) exceeding the capacity of the pumps and leading to surcharge and potential release of raw sewage to the environment. • Compromised access to the utility to perform maintenance, inspection, or repair. • Flooding of backup generators affects recovery time.
5 km of Metro Vancouver 750 mm diameter water transmission main	• Exposure of the utilities due to scour, potentially triggering a break. • Possible break in the system if the Nicomekl sea dam is compromised and either shifts or fails (the transmission main goes through the dam). • Loss of drinking water supply for communities south of Mud Bay – some redundancy in the system but may be insufficient capacity for demand. • Lost availability of water for firefighting. • Release of chlorinated water into a potentially sensitive receiving environment. • Compromised access to the utility to perform maintenance, inspection, or repair.

Infrastructure	Identified Potential Flood Impacts
	• Flooding of PRVs in the lowlands. • Corrosion due to saltwater.
10 km of Metro Vancouver sanitary sewer forcemains (500 mm to 1050 mm diameter)	• Release of raw sewage if the capacity is overwhelmed due to increased I&I, or if upstream users do not adjust their behavior. • Loss of capability to convey sewage. • Exposure of the utilities due to scour, potentially triggering a break. • Corrosion due to saltwater. • Compromised access to the utility to perform maintenance, inspection, or repair.
>10 km of FortisBC gas mains	• Exposure of the gas mains due to scour, potentially triggering a break and release of gas into the environment. • Potential loss of up to five stations. • No backfeed. • Corrosion of the gas mains due to saltwater. • Compromised access to the utility to perform maintenance, inspection, or repair.
BC Hydro Twin 500kV bulk transmission line providing intertie between BC Hydro and Bonneville Power	• Scour along the base of the towers could lead to failure of this power transmission (internationally regulated) with a long recovery time. • Compromised access to the transmission lines to perform maintenance, inspection, or repair. • Economic loss to BC Hydro due to the inability to sell power to the USA. • Potential corrosion of the towers due to saltwater. • Widespread power loss to the region. • Reduction in overhead clearance.
BC Hydro local overhead distribution lines	• Failure of the poles due to scour or wood rot. • Loss of power to the public with a long restoration time. • Loss of power to drainage pump stations and sanitary lift stations, compromising those utility functions. • Loss of power to streetlights and traffic control, exacerbating congestion and disrupting traffic and evacuations. • Compromised access to the distribution system to perform maintenance, inspection, or repair.

Infrastructure	Identified Potential Flood Impacts
Shaw and Telus telecom lines	• Failure of the poles due to scour or wood rot (poles are shared with BC Hydro). • Loss of routine and emergency communication capabilities. • Compromised access to the lines to perform maintenance, inspection, or repair. • Potential loss of SCADA control communication to pump stations.
Green infrastructure	• Loss of root stability leading to damage of above-ground utilities, and reduction in available leaf-area for rainwater interception.

Table 2-3: Impacts to Flood Control / Marine Infrastructure

Infrastructure	Identified Potential Flood Impacts
Sea dams	• Potential failure due to scour, destabilization, overtopping, and an inability to inspect or repair because of access and/or inundation. • Damage to utilities passing through the sea dam including Metro Vancouver water transmission main. • Inability for the dams to open and release water to relieve upstream flooding. • Seepage and saltwater intrusion affecting agricultural land and sensitive utilities upstream of the dam.
15 km of dyking, including ditches and floodboxes	• Potential scour and erosion of the dykes, or overtopping contributing to failure and cascading increases to flood magnitudes. • Inability to drain fields for an extended period of time, impacting agricultural lands and property upstream. • Compromised ability to access pump stations and dykes to conduct inspection and repair.
Drainage pump stations	• Potential for pumps to operate on a near-continuous basis for an extended period, resulting in excess wear, increased maintenance, and / or shortened service life. • Loss of power to the pump stations, limiting the ability to drain the upstream lands and contributing to cascading increases in flood impacts. • Inundation of stations damaging controls or flooding backup generators and resulting in long recommissioning timelines.
Ducks Unlimited Canada	• Shift to less productive brackish marsh due to saltwater intrusion.

Infrastructure	Identified Potential Flood Impacts
	• Potential for environmental contamination and loss of filtration capability of the system, resulting in degraded water quality. • Damage to critical habitat for Canada's largest wintering waterfowl populations.
Water Control Features to maintain environmentally sensitive area including freshwater irrigation system	• Loss of ability to manage water levels in the environmentally sensitive area. • Damage to electrical pumps and erosion or failure of flood culverts. • Saltwater intrusion into freshwater system.
Crescent Beach Marina	• Potential loss of secondary emergency responder access by the Coast Guard. • Public safety for people on the docks. • Potentially severe damage to infrastructure.
Wards Marina	• Public safety for people on the docks. • Potentially severe damage to infrastructure.
Private docks	• Significant damage and loss of the docks, potentially contributing to debris hazards elsewhere in the system.
Private dairy facilities for over 1,000 head of cattle	• Interruption of feed production with effects on long-term sustainability of the facility. • Death of livestock (estimated 2,400).

General notes:

- Transportation corridors severely impacted, affecting access to the various utilities for repairs, access by emergency responders, and access to repair critical flood control infrastructure. Detours, evacuations, and congestion likely to be a major problem. Impacts are similar for all of the roads, magnitude of the problem depends in part on which roads are affected and whether alternate routes are available.
- Coastal breach scenario is most likely to occur around Christmas to New Years (the time when king tides typically occur), delayed response by utility operators.

3 Step 2 - Climate Parameters

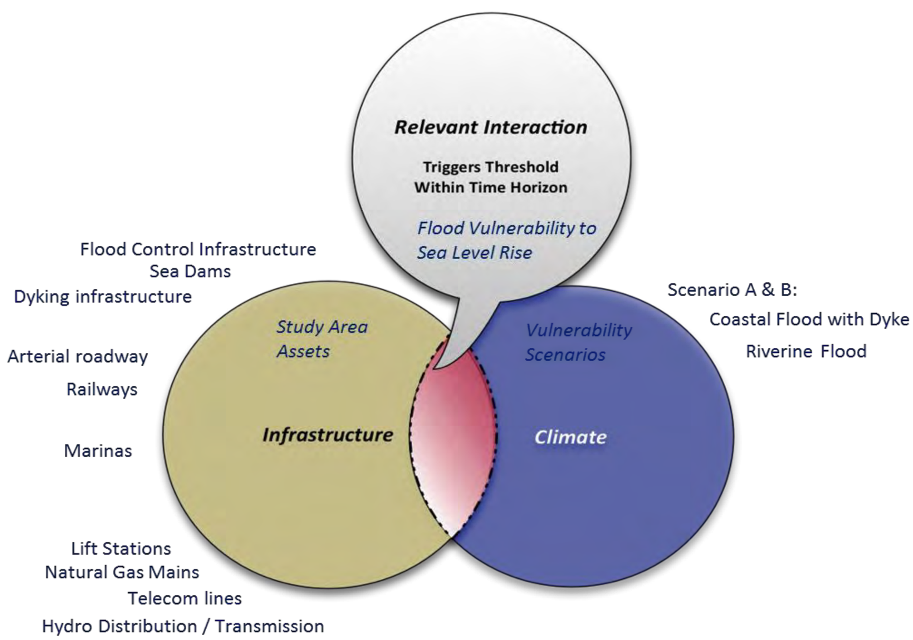
Step 2
Evaluate Climate Changes

The flooding scenarios used in the risk assessment are based on the outcome of several floodplain studies developed by NHC. The workshop focused on the following two scenarios:

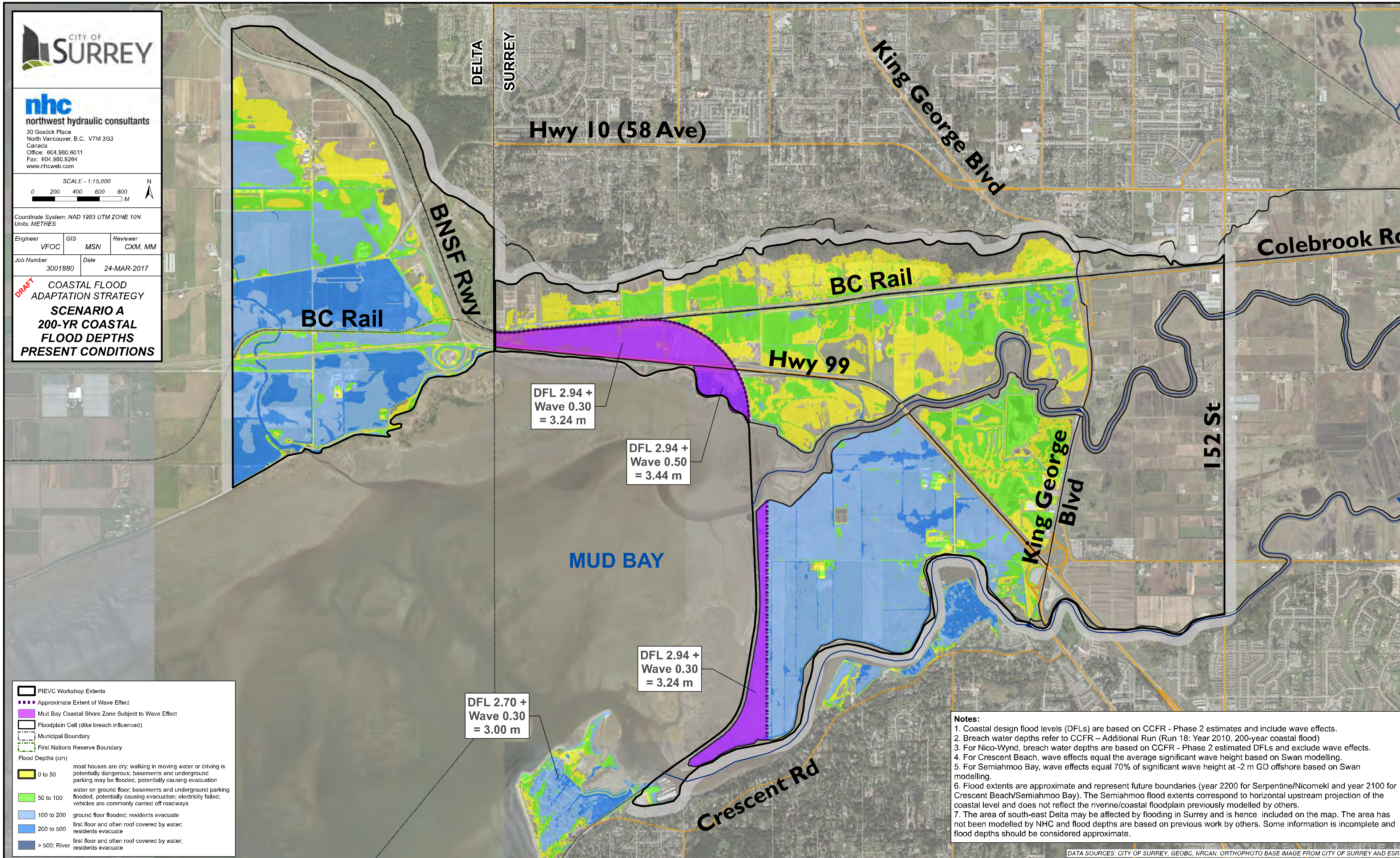
- **Scenario A:** Coastal dyke breach causing progressive inundation of the coastal floodplain by the ocean.
- **Scenario B:** 200-Year return period riverine flooding, with releases to Mud Bay via the sea dams restricted by tidal cycles.

Both scenarios were assessed for both the present-day and the year 2100 time horizons. Climate change is affecting both the intensity and frequency of storms and flood events, causing today's extreme floods to become more frequent in the future. Sea level rise will restrict the amount of time the sea dams and floodboxes can drain by gravity. The land in Mud Bay is also subsiding, which will exacerbate the effects of sea level rise.

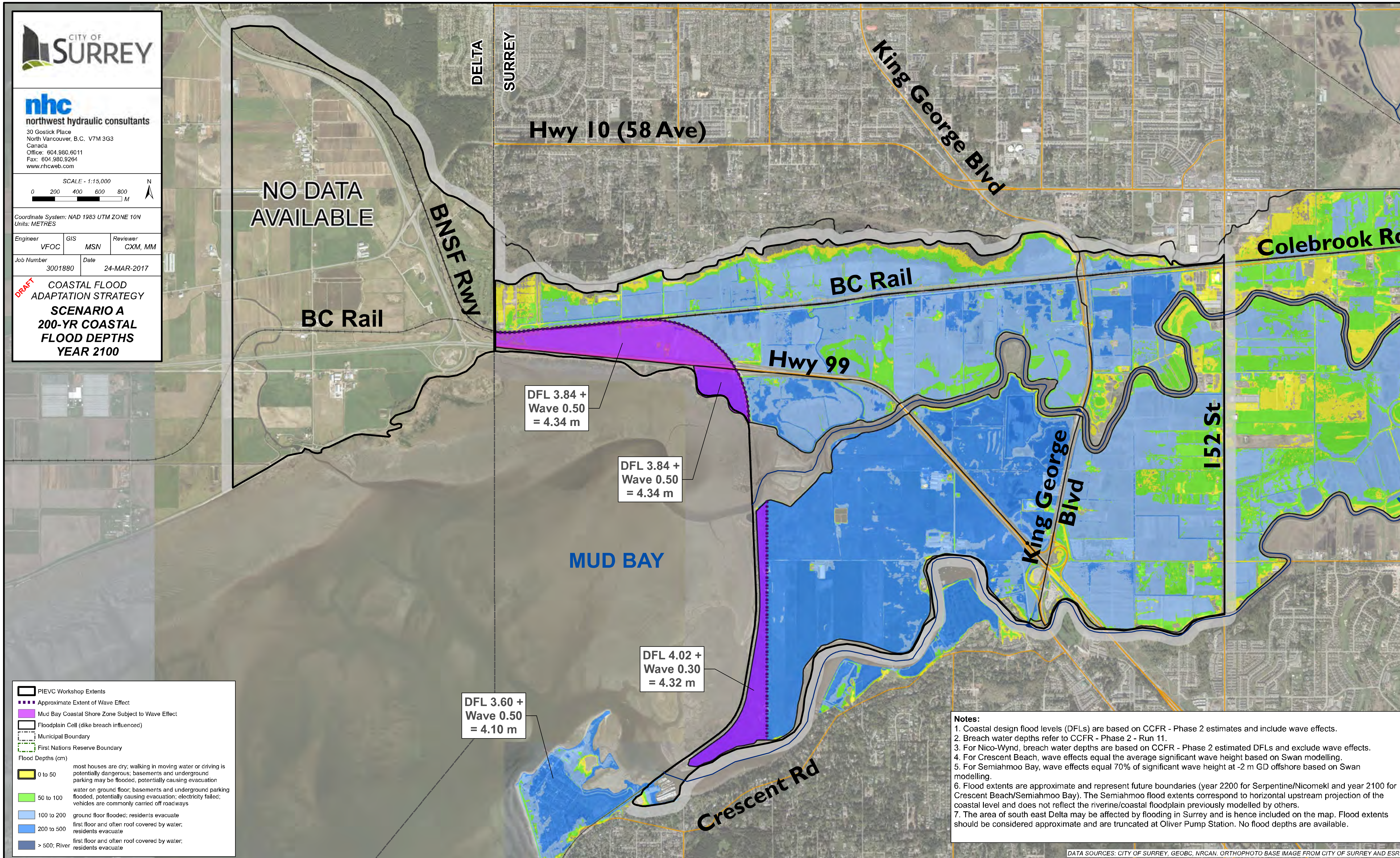
Reference Figure 3-1, Scenario A – Current, Figure 3-2, Scenario A – Future, Figure 3-3, Scenario B – Current, Figure 3-4, Scenario B – Future.



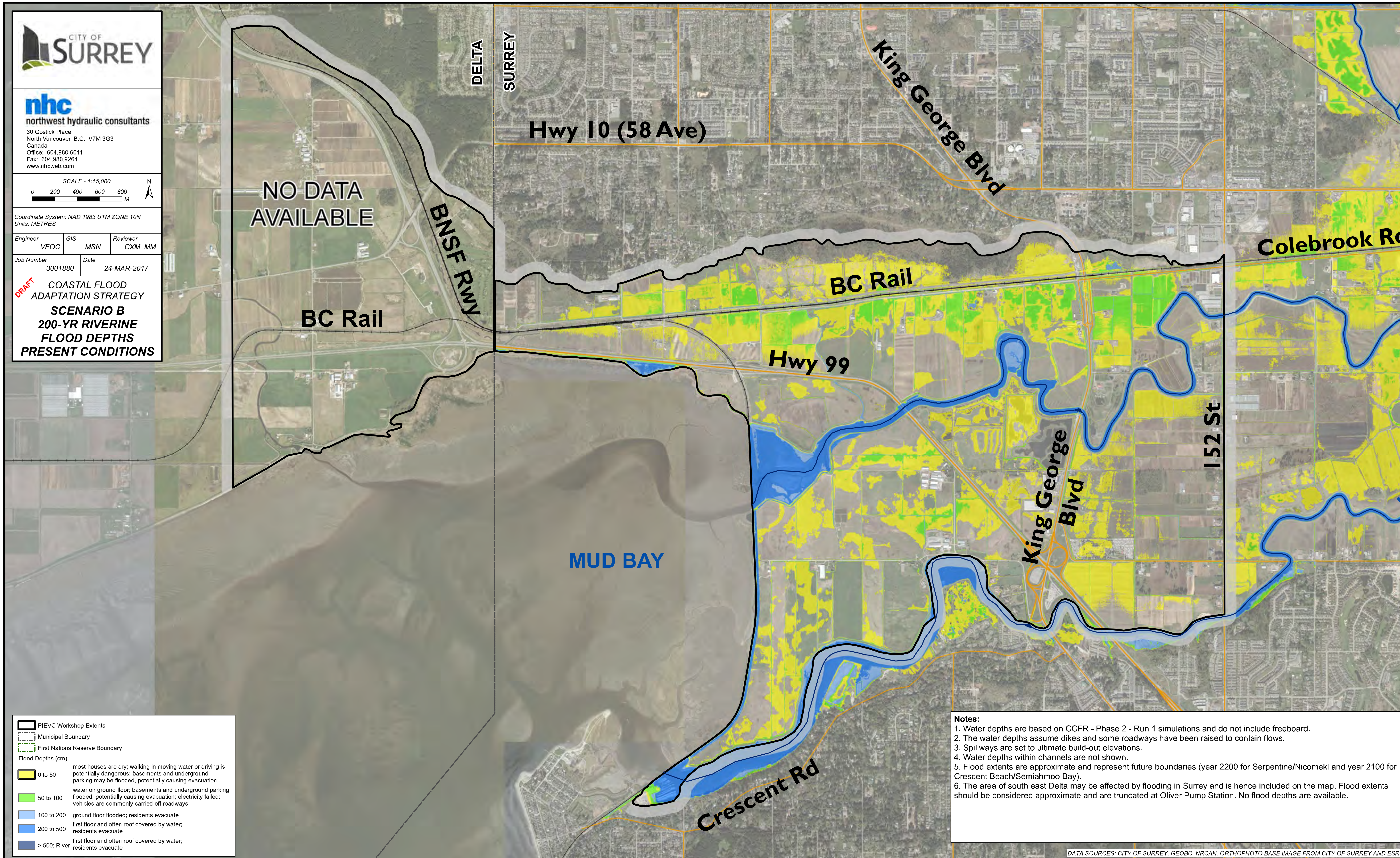
This page intentionally blank. Formatted for double-sided printing.



CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer VFOC
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO A
200-YR COASTAL FLOOD DEPTHS
PRESENT CONDITIONS
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
BNSF Rwy
BC Rail
Colebrook Rd
BC Rail
Hwy 99
DFL 2.94 + Wave 0.30 = 3.24 m
DFL 2.94 + Wave 0.50 = 3.44 m
152 St
King George Blvd
MUD BAY
DFL 2.94 + Wave 0.30 = 3.24 m
DFL 2.70 + Wave 0.30 = 3.00 m
Crescent Rd
PIEVC Workshop Extents
Approximate Extent of Wave Effect
Mud Bay Coastal Shore Zone Subject to Wave Effect
Floodplain Cell (dike breach influenced)
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 ground floor flooded; residents evacuate
200 to 500 first floor and often roof covered by water; residents evacuate
> 500; River first floor and often roof covered by water; residents evacuate
Notes:
1. Coastal design flood levels (DFLs) are based on CCFR - Phase 2 estimates and include wave effects.
2. Breach water depths refer to CCFR – Additional Run (Run 18: Year 2010, 200-year coastal flood)
3. For Nico-Wynd, breach water depths are based on CCFR - Phase 2 estimated DFLs and exclude wave effects.
4. For Crescent Beach, wave effects equal the average significant wave height based on Swan modelling.
5. For Semiahmoo Bay, wave effects equal 70% of significant wave height at -2 m GD offshore based on Swan modelling.
6. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay). The Semiahmoo flood extents correspond to horizontal upstream projection of the coastal level and does not reflect the riverine/coastal floodplain previously modelled by others.
7. The area of south-east Delta may be affected by flooding in Surrey and is hence included on the map. The area has not been modelled by NHC and flood depths are based on previous work by others. Some information is incomplete and flood depths should be considered approximate.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

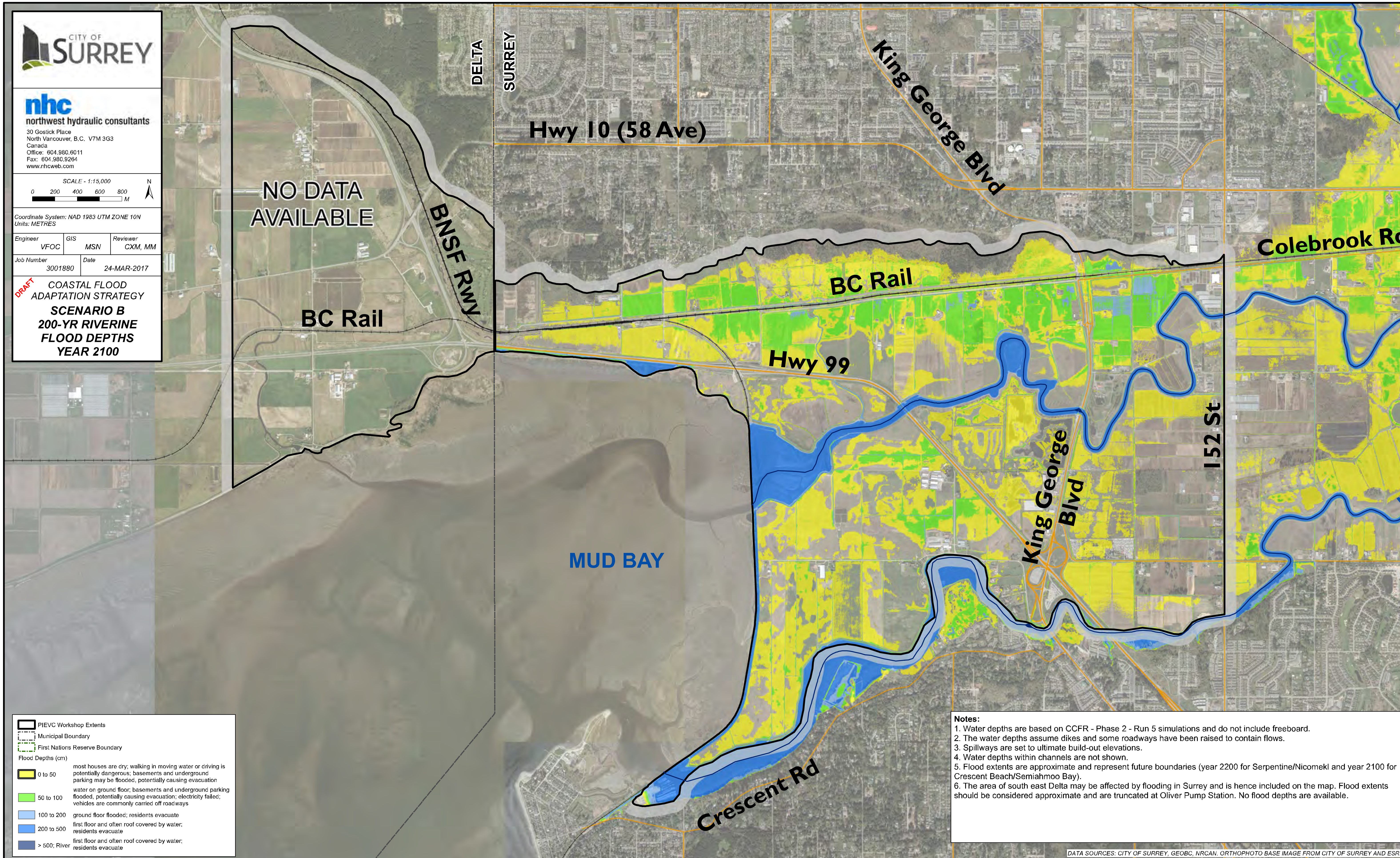

CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer VFOC
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO A
200-YR COASTAL FLOOD DEPTHS
YEAR 2100
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
NO DATA AVAILABLE
BNSF Rwy
BC Rail
BC Rail
Colebrook Rd
Hwy 99
152 St
King George Blvd
MUD BAY
Crescent Rd
DFL 3.84 + Wave 0.50 = 4.34 m
DFL 3.84 + Wave 0.50 = 4.34 m
DFL 4.02 + Wave 0.30 = 4.32 m
DFL 3.60 + Wave 0.50 = 4.10 m
PIEVC Workshop Extents
Approximate Extent of Wave Effect
Mud Bay Coastal Shore Zone Subject to Wave Effect
Floodplain Cell (dike breach influenced)
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 — most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 — water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 — ground floor flooded; residents evacuate
200 to 500 — first floor and often roof covered by water; residents evacuate
> 500; River — first floor and often roof covered by water; residents evacuate
Notes:
1. Coastal design flood levels (DFLs) are based on CCFR - Phase 2 estimates and include wave effects.
2. Breach water depths refer to CCFR - Phase 2 - Run 11.
3. For Nico-Wynd, breach water depths are based on CCFR - Phase 2 estimated DFLs and exclude wave effects.
4. For Crescent Beach, wave effects equal the average significant wave height based on Swan modelling.
5. For Semiahmoo Bay, wave effects equal 70% of significant wave height at -2 m GD offshore based on Swan modelling.
6. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay). The Semiahmoo flood extents correspond to horizontal upstream projection of the coastal level and does not reflect the riverine/coastal floodplain previously modelled by others.
7. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

This page intentionally blank. Formatted for double-sided printing.



CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer VFOC
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO B
200-YR RIVERINE
FLOOD DEPTHS
PRESENT CONDITIONS
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
NO DATA AVAILABLE
BNSF Rwy
BC Rail
Colebrook Rd
Hwy 99
152 St
MUD BAY
Crescent Rd
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 ground floor flooded; residents evacuate
200 to 500 first floor and often roof covered by water; residents evacuate
> 500; River first floor and often roof covered by water; residents evacuate
Notes:
1. Water depths are based on CCFR - Phase 2 - Run 1 simulations and do not include freeboard.
2. The water depths assume dikes and some roadways have been raised to contain flows.
3. Spillways are set to ultimate build-out elevations.
4. Water depths within channels are not shown.
5. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay).
6. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

This page intentionally blank. Formatted for double-sided printing.


CITY OF SURREY
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:15,000
0 200 400 600 800 M
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES
Engineer VFOC
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO B
200-YR RIVERINE FLOOD DEPTHS
YEAR 2100
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
NO DATA AVAILABLE
BNSF Rwy
BC Rail
BC Rail
Colebrook Rd
Hwy 99
King George Blvd
152 St
MUD BAY
Crescent Rd
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 ground floor flooded; residents evacuate
200 to 500 first floor and often roof covered by water; residents evacuate
> 500; River first floor and often roof covered by water; residents evacuate
Notes:
1. Water depths are based on CCFR - Phase 2 - Run 5 simulations and do not include freeboard.
2. The water depths assume dikes and some roadways have been raised to contain flows.
3. Spillways are set to ultimate build-out elevations.
4. Water depths within channels are not shown.
5. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay).
6. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

4 Step 3 - Risk Assessment

Step 3
Conduct Risk Assessment

The workshop participants, working in table groups, completed a risk assessment of the Mud Bay infrastructure based on the two flood scenarios (A and B) using the PIEVC Screening Tool.

To determine the risk score (R) for each interaction, a probability score (P) was established for each flood scenario and the participants selected a consequences score (C) for each interaction between flood scenarios and infrastructure.

The resulting risk **R = P x C,** is product of the probability score (P) and the consequence score (C).

Flood mapping, and probability and consequence tables, and other resources were provided the participants to assist in the determination.

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic

The probability (P) scores for each scenario and time horizon were assigned in advance of the workshop by AE in collaboration with NHC. The probability scores were 4 and 3 for Scenario A and B, respectively under existing conditions; and were 5 for both scenarios under future conditions.

A resulting risk score is established where:

- R = >10 — Low Risk — Risk requiring minimal action
- R = 10 – 19 — Medium Risk — Risks that may require future action
- R = 20 – 25 — High Risk — Risks that require action

5	CONSEQUENCE	Catastrophic	0	5	10	15	20	25
4		Major	0	4	8	12	16	20
3		Moderate	0	3	6	9	12	15
2		Minor	0	2	4	6	8	10
1		Insignificant	0	1	2	3	4	5
0		No Effect	0	0	0	0	0	0
			Negligible Not Applicable	Highly Unlikely Improbable	Remotely Possible	Possible Occasional	Somewhat Likely Normal	Likely Frequent
			PROBABILITY					
			0	1	2	3	4	5

4.1 RISK ASSESSMENT RESULTS

4.1.1 Group Results

The workshop participants risk assessment results are summarized in Tables 4-1, 4-2, and 4-3.

Table 4-1: Transportation Infrastructure Risk Assessment Results

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turn Runway	4	5	3	5
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	12	25	3	10
	7 km section of Highway 99 linking Peace Arch Border	16	25	3	10
	Highway 91 and 99 Interchange	12	20	3	10
	4 km section of Highway 91	8	20	3	10
	6 km dyke trail connecting to parks	4	5	3	10
	Delta-Surrey Greenway	4	5	3	10
	Local Government Arterial and Collector Roads				
	King George Boulevard (City of Surrey)	12	25	3	10
	152nd Street (City of Surrey)	4	20	3	5
	112 Street (City of Surrey)	8	15	6	15
	Colebrook Road (City of Surrey)	8	15	6	15
	Ladner Trunk Road (Corporation of Delta)	12	20	9	20
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	16	20		
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	16	25		
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~ 18 trains daily	8	20		
	Connection to Southern Railway of British Columbia	4	20	9	20

Table 4-2: Utilities Infrastructure Risk Assessment Results

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	12	15		
	City of Surrey: South Port	16	20		
	City of Surrey: Winter Crescent	12	15		
	City of Surrey: Stewart Farm	16	20	6	20
	Metro Vancouver: Crescent Beach	16	20		
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	16	20	6	10
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	12	15	6	10
	>10 km of FortisBC Gas Mains	8	10	9	15
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	12	15		20
	BC Hydro local overhead distribution lines	16	20		20
	Shaw and Telus telecom lines	8	10	6	10
	Green Infrastructure (Added)	8	15		15

Table 4-3: Flood Control / Marine Infrastructure Risk Assessment Results

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	20	20	6	25
	15 km of dyking, including ditches and floodboxes	20	25	9	20
	City of Surrey: Colebrook Pump Station	16	20	6	15
	City of Surrey: Maple Pump Station	16	20	3	15
	Corporation of Delta: Oliver Pump Station	16	25	6	15
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	8	10	3	5
	Water control features to maintain environmentally sensitive area including freshwater irrigation system	12	15		
	Screw Pump Stations (Added)	4	10	3	10
	Marine Facilities				
	Crescent Beach Marina	8	15	6	10
	Wards Marina	8	15	6	10
	Private docks	8	15	9	10
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	16	25	3	10

4.1.2 Risk Assessment Summary

- 40 assets assessed per scenario

- **Flood Scenario A – Coastal Flood with Dyke Breach**
    - Current risks are mostly low and medium
    - Future risks increase to medium and high

	Number of Assets in Each Category							
	Flood Scenario A Current				Flood Scenario A Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Future
Low Risk	9	3	5	**17**	3	0	0	**3**
Medium Risk	7	9	5	**21**	2	7	6	**15**
High Risk	0	0	2	**2**	11	5	6	**22**

- **Flood Scenario B – Riverine Flood**
  - All assets are currently at low risk
  - The number of assets subject to medium risk increases to 23 (>50% of the number of assets assessed), while 7 assets (~20%) are at high risk.

	Number of Assets in Each Category							
	Flood Scenario B Current				Flood Scenario B Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Future
Low Risk	16	12	12	**40**	5	3	2	**10**
Medium Risk	0	0	0	**0**	9	6	8	**23**
High Risk	0	0	0	**0**	2	3	2	**7**

This page intentionally blank. Formatted for double-sided printing.

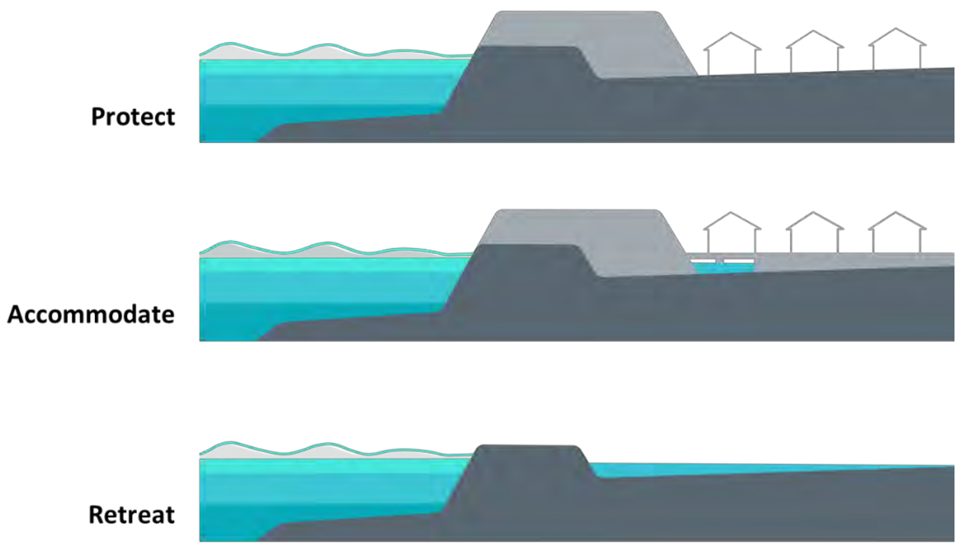
5 Step 5 - Outcomes and Integration

Step 5
Adaptation Comments and Strategies

Following the risk assessment, adaptation scenarios and strategies were discussed with an emphasis on high risk interactions on the Mud Bay infrastructure.

Prior to the discussion, the City of Surrey presented some background information on adaption options and some general ideas of strategies that could be considered in reducing risk to the Mud Bay and surrounding infrastructure.

In the context of the CFAS project, three adaptions approaches were presented: Protect, Accommodate, and Retreat.



5.1 ADAPTATION ASSESSMENT RESULTS

5.1.1 Group Results

The summary results of the workshop participants' adaptation options discussions are included in Appendix B. The tables in Appendix B summarize comments on the individual adaptation options that were considered, as well as broader general comments.

It is worth noting that the adaptation options discussion was influenced by the presentation of the adaptation options being considered for the area, and so alternate adaptation options beyond those presented were not brainstormed or explored. Additionally, because the workshop focus was on risk assessment, full exploration of the benefits and constraints associated with each adaptation option was not feasible, considering the breadth of the topic.

During the discussion, many participants found it challenging to commit to firm answers, and important points were raised, such as: '*at what time does ongoing protection and accommodation become too* *infeasible or costly, such that retreat becomes the only viable option? If retreat is the only applicable ultimate solution, then perhaps a stepped progression towards that end needs to be pursued'.*

Further exploration of adaptation options is recommended, but the comments received provide insight into the opinions of the participants on adaptation measures. A selection of representative adaptation comments is listed below. See Appendix B for the remainder of both option-specific and general adaptation comments.

- *Accommodate and do incremental upgrades.*
- *Rock groin / breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.*
- *Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).*
- *Without offshore improvements, dyke upgrades will be challenging and will take a long time.*
- *Retreat for highways not considered feasible.*
- *Incremental adaptations are needed to meet changing needs of climate change.*
- *If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?*
- *Build a sea wall across Mud Bay.*
- *Dyking is a good option. Offshore islands are a no-go for Crescent Beach.*
- *Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay.*
- *Raise the dykes - build a barrier wall.*
- *BC Hydro may implement protect or accommodate adaptation features for its infrastructure.*
- *No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland.*
- *What would be a global approach to adopt options to develop strategies against coastal flood risks?*
- *Sea level rise and subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for.*
- *Look at options and evaluate problems they solve instead of vice versa.*
- *Incremental adaptations.*
- *Engage the whole Lower Mainland area.*
- *Yes, engagement with neighbouring municipalities should be needed for this type of workshop.*
- *Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed).*

5.1.2 Post Workshop Survey Comments

The workshop participants post-workshop survey comments are summarized in Table 5-1. The comments are in response to the survey question: "Are there any adaptation options or strategies you would like to see explored further related to infrastructure in the area?".

Table 5-1: Infrastructure Adaptation Comments

Infrastructure	Adaptation Comments
Transportation / Utilities / Flood Control / Marine	• Foreshore dyke. • Off-shore dyke with multiple uses. • Feasibility of off-shore options. • Offshore barrier islands? Raise Highway 99 as a dyke? • Look at development strategies and policies to assure net-zero surface flow post/predevelopment. Low-impact development strategies. Buy / lease back land options. • The great Mud Bay dyke / wall to reclaim more land. • Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay. • Raise the dykes - build a barrier wall. • BC Hydro may implement protect or accommodate adaptation for its infrastructure. • Green infrastructure. • No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland. • What would be a global approach to adopt options to develop strategies against coastal flood protections. • Sea level rise & subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for. • Look at options and evaluate problems they solve instead of vice versa. • PIEVC has good risk ranking procedure to suit outstanding priorities • Options analysis for all 3 options. • Incremental adaptations. • Engage the whole Lower Mainland area. • Yes, engagement with neighboring municipalities should be needed for this type of workshop. • Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed). • All that we discussed. Very valuable!

Further information on the post-workshop survey responses are included in Appendix C.

This page intentionally blank. Formatted for double-sided printing.

6 Next Steps

The findings based on the information obtained in the infrastructure flood vulnerability assessment will be used in the next steps of the CFAS study in conjunction with other feedback from stakeholders in other engagement sessions and workshops.

The information will also be shared with the workshop participants and the public to engage in further dialog on the CFAS project.

This project focused on the first three steps in the PIEVC process, namely the definition of infrastructure (Step 1), evaluation of climate changes (Step 2), and a risk / vulnerability assessment (Step 3). The overall CFAS project would benefit from further engineering analysis on each of the sectors defined here (transportation, utilities, flood control, marine), and follow-up risk assessments. This would follow Step 4 of the PIEVC protocol. The initial broader adaptation options developed as part of the CFAS project could then be refined to develop improved micro-scale adaptation options for high-risk infrastructure sectors. These options could be analyzed and discussed during a follow-up workshop with stakeholders to better define conclusions and recommendations (Step 5 of the protocol).

This page intentionally blank. Formatted for double-sided printing.

Closure

This report was created by Associated Engineering to summarize the outcomes of the Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop, held on March 28, 2017 at Surrey City Hall.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:

Jeff O'Driscoll, P.Eng., (Manitoba), IRP
Lead Workshop Facilitator

Jason Kindrachuk, EIT
Water Resources Engineer

Reviewed by:

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, M.R. MacLATCHY 24939

June 15/2017

Michael MacLatchy, Ph.D., P.Eng.
Project Manager

JD/JK/MM/fd

Appendix A - Workshop Backgrounder, Primer, and Questionnaire

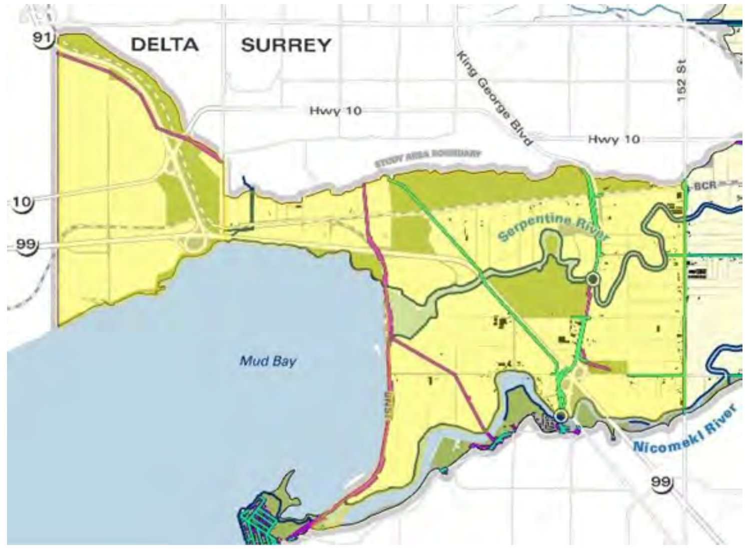
This page intentionally blank. Formatted for double-sided printing.

INFRASTRUCTURE WORKSHOP SAVE THE DATE

Join us on Tuesday, March 28, 2017 for an important stakeholder workshop to explore the impacts of sea level rise on public infrastructure in the Mud Bay area (see yellow area below).

Time & location

Date: Tuesday, March 28, 2017
Location: Surrey City Hall, 2nd Floor
13450 104 Ave, Surrey
Time: 8:30 – 4:30 (lunch provided)



Moving toward a Coastal Flood Adaptation Strategy (CFAS)

Surrey's coast is changing. Our coast can expect more frequent and severe flooding from sea level rise and storm surges. About 20% of Surrey's land base is in the coastal floodplain with a wide array of infrastructure assets, ranging from transportation corridors to power transmission infrastructure.

Surrey is developing a Coastal Flood Adaptation Strategy for our coastal floodplain area in order to prepare our communities and infrastructure for the future. The three-year project builds on recent and ongoing work Surrey has undertaken in the project area.

We need your infrastructure knowledge

As part of this process, Surrey is planning a workshop to explore infrastructure vulnerability to sea level rise in a portion of the project area (see map), to navigate a path towards adaptation. We are requesting your input as an infrastructure asset manager in the process, and will be holding this workshop to identify critical assets and identify resilient strategies for adaptation. The workshop will be structured around the Engineers Canada Public Infrastructure Vulnerability Committee (PIEVC) Engineering Protocol to assess vulnerability.

Who should attend and why?

Representative(s) in your organization that plan, manage and operate the infrastructure and who can speak to the level of service and engineering vulnerability of the systems related to flooding, current or future. Why? We need to collectively develop an adaption strategy for all affected in the Mud Bay area.

What can you do?

- Review the attached primer and project backgrounder.
- Identify personnel you would like to be involved in the workshop.
- Complete the attached questionnaire to identify your critical infrastructure, and any issues related to flooding.
- Join us for an interactive workshop on infrastructure vulnerability on March 28.

Please RSVP by March 17, 2017 to attend here, or at 604-591-4340.

For more information, please contact Matt Osler at 604-591-4657 or coastal@surrey.ca. If confidentiality is an issue in responding and participating, please call Matt to discuss. **We want you to be involved.**

CITY OF SURREY
the future lives here.

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

BACKGROUNDER

Infrastructure Asset Managers, Operators and Emergency Services

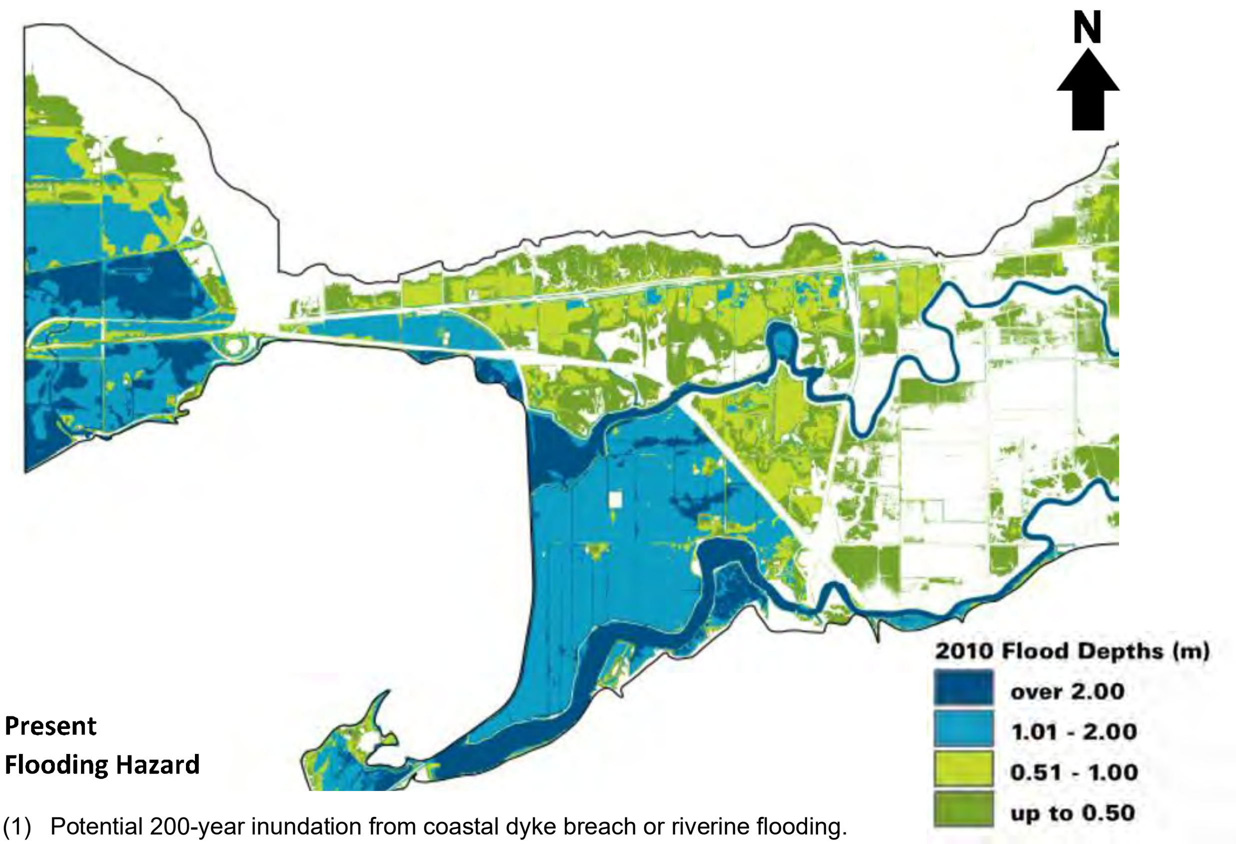
CFAS

What are the present flood hazards?

The City of Surrey lowlands are prone to flooding from high ocean levels, peak flows on the Serpentine/ Nicomekl Rivers, or a combination of the two. The area was settled in the 1800's and in the early 1900's sea dams were built near the mouth of each river to prevent salt water from inundating fertile farmland. Over time, coastal and riverine dykes were built and upgraded to improve the degree of flood protection. The riverine dykes upstream of the sea dams are unique in the sense that they include spillways, intended to overflow and equitably distribute flood waters at medium flood flows, with return periods in the order of 10-15 years. At extreme flows, such as the 200-year flood, the system would be overwhelmed, resulting in extensive flooding. The side slopes of the river dykes are too steep, making them vulnerable to failure even before they overtop. Similarly, the coastal dykes do not meet 200-year flood protection standards and locations exposed to wave action are at risk of failing during relatively frequent events. The seismically-unstable sea dams are aging structures, requiring extensive upgrading or replacement in the near term.

Severe floods usually occur in the winter months. High coastal water levels are a result of high tides, so called King Tides, in combination with storm surge events caused by low atmospheric pressures, and severe wind storms generating high waves and wind set-up. River flows are also highest in the winter, and are typically the result of long duration rainfall or rain-on-snow events. River flows can drain through the sea dams only while ocean levels are below river levels. Consequently, the lowlands upstream of the sea dams experience the worst flooding when high ocean levels and river flows coincide.

There is an extensive history of past floods and associated dyke failures in the area. In December of 1982, a storm surge coincided with high tides resulting in water levels overtopping a dyke in Mud Bay Dyking District, inundating agricultural fields. Large waves during that same event caused overtopping of the boulevard at Crescent Beach and logs washing up inland. In January of 2009, a rain-on-snow event caused extensive flooding of the lowlands upstream of the sea dams, while an October 2003 rain storm flooded the upper river basins.



Present Flooding Hazard

(1) Potential 200-year inundation from coastal dyke breach or riverine flooding.

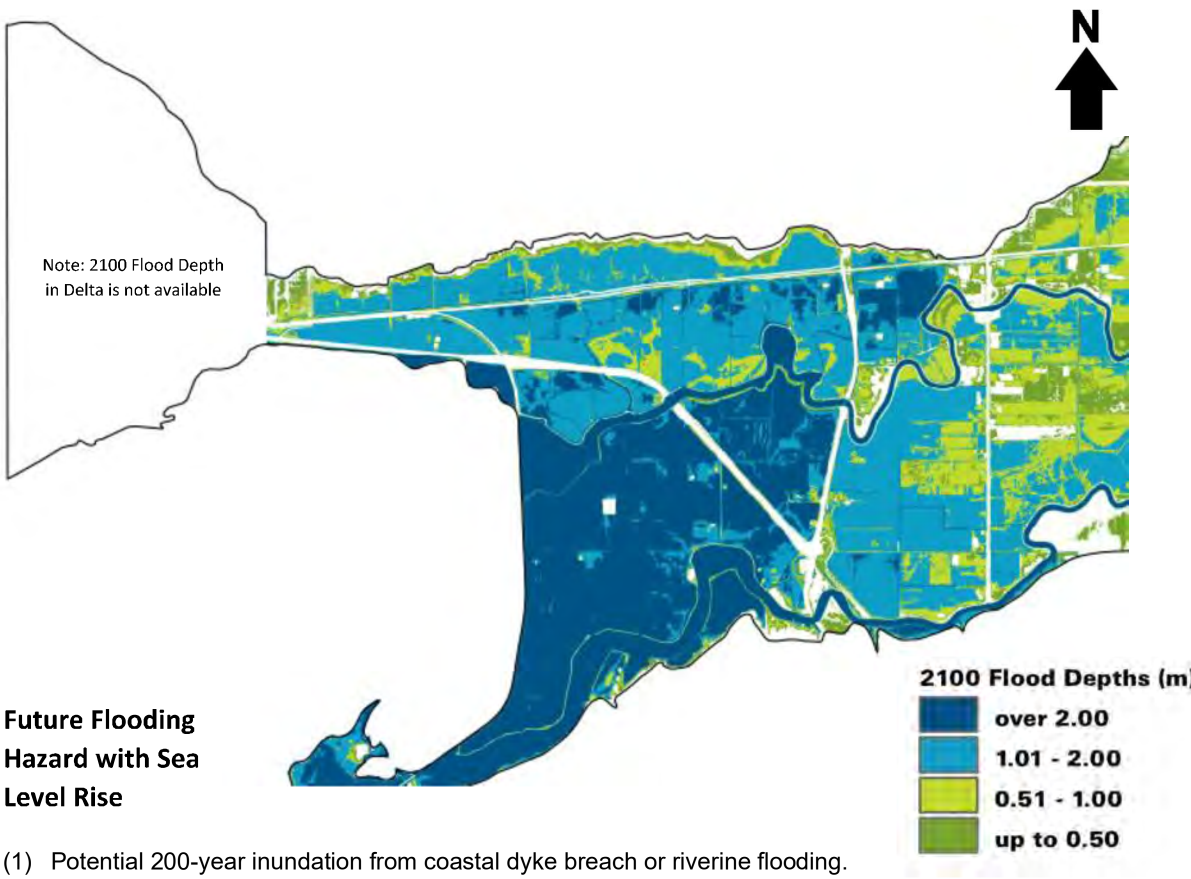
(2) Coastal flooding assumes coastal dyke breaching, riverine flooding assumes riverine dykes remain intact.

What will the future hold?

Climate change will exacerbate flood hazards, primarily through sea level rise, increased storminess and increased precipitation during the winter months. Sea level rise estimates vary, with present Provincial Guidelines recommending that an increase of 1.0 m from year 2000 to 2100 be considered for coastal design projects. Past research suggests increases in storminess and also variations in wind patterns; however, specific design values have not been proposed. Provincial legislated flood assessment guidelines recommend increasing design flood flows by 10% unless more detailed analysis is performed. Estimates of future precipitation intensities imply more significant peak flow increases for the Serpentine/Nicomekl Rivers.

The Surrey lowlands are gradually subsiding. Subsidence rates vary with location but will average about 1 mm/year within the floodplain, resulting in a predicted relative sea level rise over this century of 1.1 m.

Due to the flat topography of the floodplain and relatively steep valley walls, the areal extent of flooding will increase only marginally by the end of the century. Instead, the depth of flooding and, more importantly, the frequency of flooding is expected to increase dramatically. The present 200-year flood level will have a return period of less than two years in the area just upstream of the sea dams in year 2100.



Future Flooding Hazard with Sea Level Rise

(1) Potential 200-year inundation from coastal dyke breach or riverine flooding.

(2) Coastal flooding assumes coastal dyke breaching, riverine flooding assumes riverine dykes remain intact.

What will be the impacts on infrastructure?

A previous vulnerability assessment of the sea dams, dykes, bridges, roads and railroads indicated that at the **present 200-year flood condition**:

- Freeboard would be compromised at the Serpentine Sea Dam;
- The Serpentine left bank dyke downstream of the sea dam would be inundated and freeboard would be compromised at all of the lowland dykes;
- Bridge decks would be inundated at three of the bridges and the low chords submerged at nine other bridges;
- A portion of Highway 99 would be inundated and freeboard compromised at Colebrook Road, with a few sections of railroad having compromised freeboard as well.

In other words, extensive infrastructure upgrades are required for current conditions.

In **2100 at the 200-year flood condition**, ignoring potential precipitation increases:

- Both the Serpentine and Nicomekl Sea Dams would be inundated;
- The lowland dykes upstream and downstream of the sea dams would also be inundated and nearly all other dykes would have compromised freeboard;
- The bridge decks would be inundated at seven bridges and the low chords submerged at 10 other bridges;
- Major roads and railroads would have either compromised freeboard or some inundation. Even during moderate present floods, some damage to infrastructure can be expected. Consequences of inundation may include widespread power outages, damage to transportation routes, challenges for emergency services and loss of critical assets such as water and sewage transmission. These primary impacts are likely to lead to cascading impacts outside the floodplain and in neighbouring municipalities.

What is the Infrastructure?

Flood Control Infrastructure

- 2 City of Surrey Sea Dams
- 15 km of dyking including ditches and floodboxes
- City of Surrey: Colebrook and Maple Pump Stations
- Corporation of Delta: Oliver Pump Station

Ducks Unlimited Canada Serpentine Fen

- Water Control Features to maintain environmentally sensitive area including freshwater irrigation system.

Sanitary Lift Stations

- City of Surrey: Elgin; South Port; Winter Crescent; Stewart Farm
- Metro Vancouver: Crescent Beach

Underground infrastructure

- 5 km of Metro Vancouver 750 mm diameter Water Transmission Main
- 10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
- >10 km of FortisBC Gas Mains

Overhead Utility Infrastructure

- BC Hydro Twin 500kV bulk transmission line providing Intertie between BCH & Bonneville Power
- BC Hydro local overhead distribution lines
- Shaw and Telus Telecom lines

Marine Facilities

- Crescent Beach Marina
- Wards Marina
- Private docks

Regional / International Transportation Infrastructure

- 4 km of four-lane arterial roadway
- 7 km section of Highway 99 linking Peace Arch Border
- Hwy 91 and 99 Interchange
- 4 km section of Highway 91
- 6 km dyke trail connecting to parks
- Delta-Surrey Greenway

Local Government Arterial and Collector Roads

- King George Boulevard (City of Surrey)
- 152nd Street (City of Surrey)
- Colebrook Road (City of Surrey)
- Ladner Trunk Road (Corporation of Delta)

Class 1 Railways Originating at Port Metro Vancouver

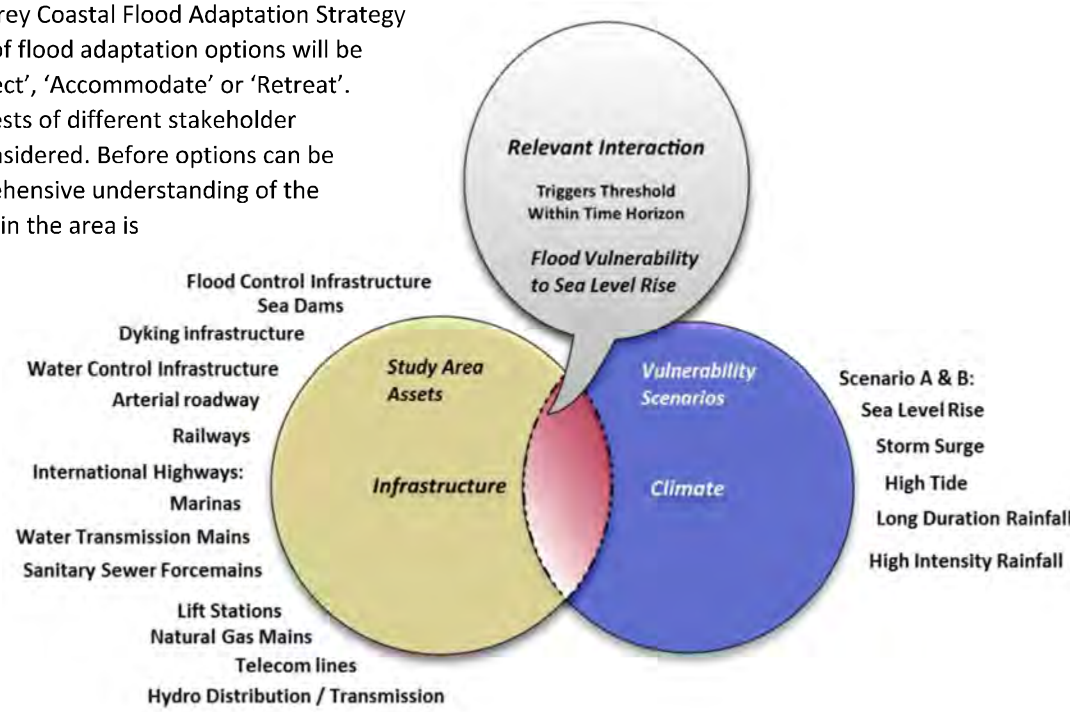
- Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles
- 6 km of BNSF Railway with freight frequencies between 16 and 20 trains daily and up to 4 daily Amtrak Cascades trains
- Roberts Bank Railway Corridor (BC Railway Company ownership with usage by CN, CP and BNSF) with up to 18 trains daily.
- Connection to Southern Railway of British Columbia.

Surrey/King George Airpark Turf Runway

Private Dairy Facilities for over 1,000 head of Cattle

How can we participate?

As part of the Surrey Coastal Flood Adaptation Strategy (CFAS), a variety of flood adaptation options will be explored to 'Protect', 'Accommodate' or 'Retreat'. The diverse interests of different stakeholder groups will be considered. Before options can be studied, a comprehensive understanding of the vulnerable assets in the area is needed.



A **PIEVC workshop** occurring **March 28, 2017** will involve infrastructure managers early on and solicit input to the project. Infrastructure vulnerability from two potential coastal flooding scenarios will be explored.

The scenarios include:

A) a 200-year riverine flood scenario with the water level at the ocean boundary reflecting sea level rise, and

B) a 200-yr coastal flood scenario that accounts for dyke breach and wave effects.

Both scenarios will be considered at multiple time scales from the present year to 2100. The anticipated outcomes of this workshop will be a relative risk rating of the infrastructure components and recommendations of remedial or management actions for medium- to high-risk infrastructure, which will feed into the development of the adaptation strategy.

Want more information?

For more information, please visit www.surrey.ca/coastal or email coastal@surrey.ca.

CITY OF SURREY
the future lives here.

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER

CFAS

PROJECT OVERVIEW

SURREY IS PREPARING FOR CLIMATE CHANGE AND SEA LEVEL RISE WITH THE DEVELOPMENT OF A COASTAL FLOOD ADAPTATION STRATEGY (CFAS). TO BE DEVELOPED OVER THREE YEARS, THE FINAL STRATEGY WILL IDENTIFY THE CURRENT AND POTENTIAL IMPACTS OF CLIMATE CHANGE-DRIVEN SEA LEVEL RISE ON SURREY'S COASTLINE, AND THE LONG-TERM ADAPTATION OPTIONS AVAILABLE TO ADDRESS THE IMPACTS AND ADAPT TO THE CHANGES CLIMATE CHANGE WILL BRING IN THE FUTURE.

Making up about 20% of Surrey's entire land area, the coastal floodplain is a large low-lying area that stretches from Boundary Bay and Mud Bay along the Nicomekl and Serpentine Rivers towards Cloverdale and Newton. The area also includes the Campbell River/Semiahmoo Bay area near White Rock and Semiahmoo First Nation. It is home to historic and important neighbourhoods, farms and businesses, critical infrastructure and transportation corridors, and internationally recognized bird and wildlife habitat.

CFAS TIMELINE

The CFAS project is broken into five general phases that will be completed over the next three years. This Primer is part of Phase 1, but will be used in future phases. It is intended to help build awareness of sea level rise and Surrey's coastal flooding challenge, and to help residents and others stakeholders actively engage in the CFAS project.

▲ Coastal floodplain and study area




Communities and People

- Many residential areas and neighbourhoods, including Crescent Beach, Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, Nico-Wynd/Crescent Road
- Semiahmoo First Nation
- 1,500+ residents
- Approximately 20% of Surrey's land area

Local and Regional Economy

- Over 30km² of agricultural land in production
- 700+ jobs
- Over $100 million in annual farm gate revenue
- Over $1 billion in assessed property value
- Almost $25 billion annual truck and rail freight traffic

Parks and Environment

- Regional and City parks, beaches and recreation areas, including Surrey's only public ocean beach
- Significant natural areas with very high biodiversity values, including foreshore, riparian and coastal areas
- Internationally important migratory bird habitat

Infrastructure

- Over 10km of Provincial Highways
- Over 200,000 vehicle trips a day
- Over 30km of railway (freight and passenger)
- Regional sewer and water lines
- Major power transmission lines
- Natural gas pipelines

PHASE 1: summer 2016 - spring 2017
WHAT MATTERS MOST AND WHO IS AFFECTED? Education, awareness building, and community values

PHASE 2: spring 2017 - summer 2017
WHAT CAN WE DO? Exploring adaptation options

PHASE 3: summer 2017 - fall 2017
WHAT IS ACCEPTABLE? Developing adaptation strategies

PHASE 4: fall 2017 - spring 2018
HOW WILL WE DO IT? Detailing preferred strategies

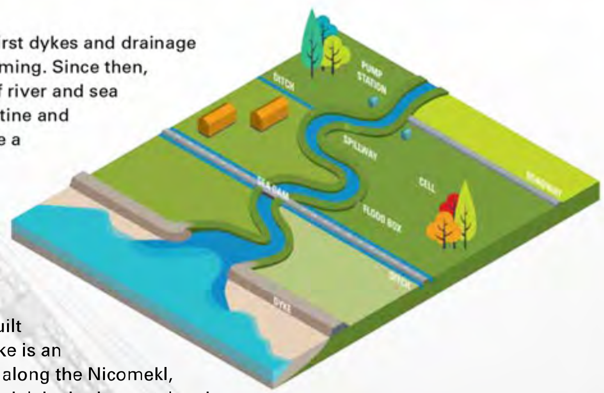
PHASE 5: spring 2018
REPORTING BACK Final reporting

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 RAPID SNOW MELT. RIVER FLOODING CAN ALSO BE INFLUENCED BY HIGH TIDES AND STORM SURGES.

WHAT'S KEEPING US DRY TODAY?

European settlement in the 1890's saw the first dykes and drainage ditches being created to reclaim land for farming. Since then, Surrey has developed a complex network of river and sea dykes along the coast and along the Serpentine and Nicomekl Rivers. Working with the dykes are a system of drainage ditches, spillways and pumps that help move water from behind dykes.



DYKES

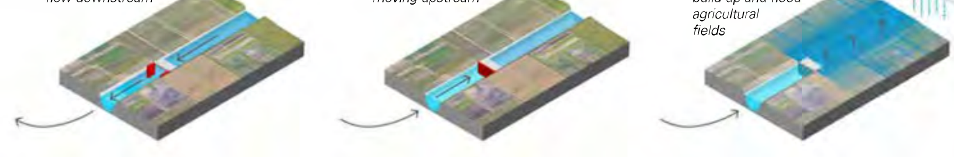
A sea dyke is a long wall or embankment built to prevent flooding from the sea. A river dyke is an embankment built to prevent river flooding along the Nicomekl, and Serpentine Rivers. Most of Surrey's floodplain, both coastal and inland sections, are protected by dykes. Many dykes in Surrey are also popular walking trails and bicycle routes.

- *Background image: Construction of dyke at Mud Bay, c.1890. Photo courtesy Surrey Archives and Museum.*
- *Below: Dyke and recreation path at Mud Bay Park today.*

Wondering why we spell dyke with a 'y'?
In 1912, early settlers to the Municipality of Surrey formed the Surrey Dyking District, using the preferred spelling at that time. While dike is now the preferred spelling, in recognition of the extensive work done to improve drainage by the all the dyking districts over the past 100-years, Surrey continues to spell dyke in Old English, when referring to flood control works. In the USA, the term levee is generally used as an alternative to dyke.

SEA DAMS

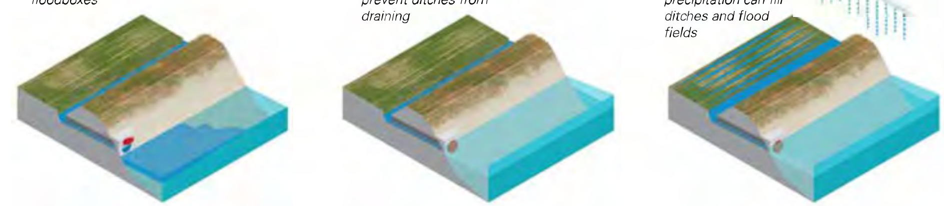
Sea dams are constructed along tidal rivers, like the Nicomekl and Serpentine Rivers, to keep salty ocean water from moving upstream where it could have detrimental effects on agricultural irrigation. Sea dams are tidally influenced and gravity-fed, with the incoming tide pushing their gates closed (B) and the river pushing them open once the tide moves out (A). The Nicomekl and Serpentine sea dams were first built in 1912 and 1913.



A. The gravity-fed sea dam opens as tides recede, allowing river water to flow downstream
B. The sea dam closes as tides rise, preventing ocean water from moving upstream
C. When the sea dam is closed, excess precipitation can build up and flood agricultural fields

DITCHES, FLOODBOXES AND PUMPS

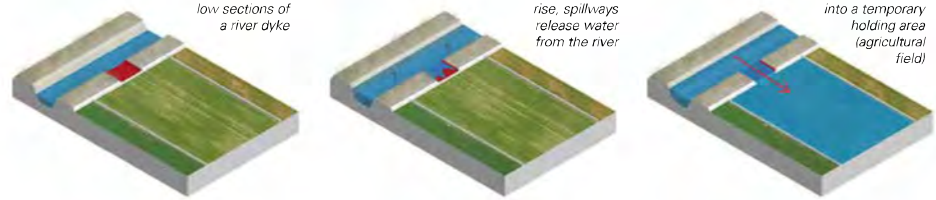
Surface water flows into drainage ditches which then direct water through floodboxes located along the river. During low tides and when the river water is low enough, the water drains into the river by gravity-fed flap gates (A). When river levels are higher the flood boxes are submerged and their gates are closed (B). During high tides or when sea dams are closed, electrically powered pumps, like the Maple Pump Station in Crescent Beach, are used to help push the water into the rivers.



A. When river levels are low, ditches drain through floodboxes
B. When river levels are high, submerged floodboxes prevent ditches from draining
C. When floodboxes are submerged, excess precipitation can fill ditches and flood fields

SPILLWAYS

A spillway is a low section of a river dyke (A) where, during floods, water can spill over into a holding area called a cell (B&C). These cells are located on agricultural fields and typically only used in winter months when the fields are fallow. Once the flood event has ended and river level returns to normal, water stored in the cells will drain back into the river through floodboxes or with the assistance of pumps.



A. Spillways are low sections of a river dyke
B. As water levels rise, spillways release water from the river
C. The water spills over into a temporary holding area (agricultural field)

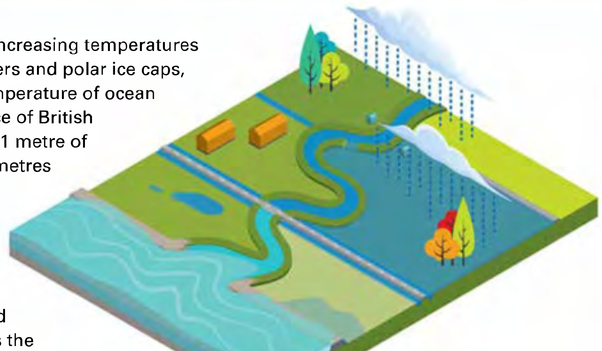
THE CHANGING CLIMATE MEANS THAT THE HISTORIC CONTROLS THAT HAVE BEEN PUT IN PLACE WILL LIKELY NOT PERFORM WELL IN THE FUTURE WITH RISING SEA LEVELS, MORE FREQUENT STORM SURGES, AND INCREASED PRECIPITATION. WITH SEA LEVEL RISE, THE DURATION THAT RIVERS CAN FREELY DRAIN WILL BE SHORTER.

CLIMATE CHANGE, CLIMATE HAZARDS, AND COASTAL FLOODING

AS WITH MANY COASTAL FLOODPLAINS AROUND THE WORLD, THE TWO PRINCIPAL CAUSES OF INCREASED FLOODING IN SURREY'S COASTAL FLOODPLAIN ARE SEA LEVEL RISE AND INCREASED MAGNITUDE AND INTENSITY OF RAIN. THE EFFECTS OF SEA LEVEL RISE ARE 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.



INCREASED RAINFALL

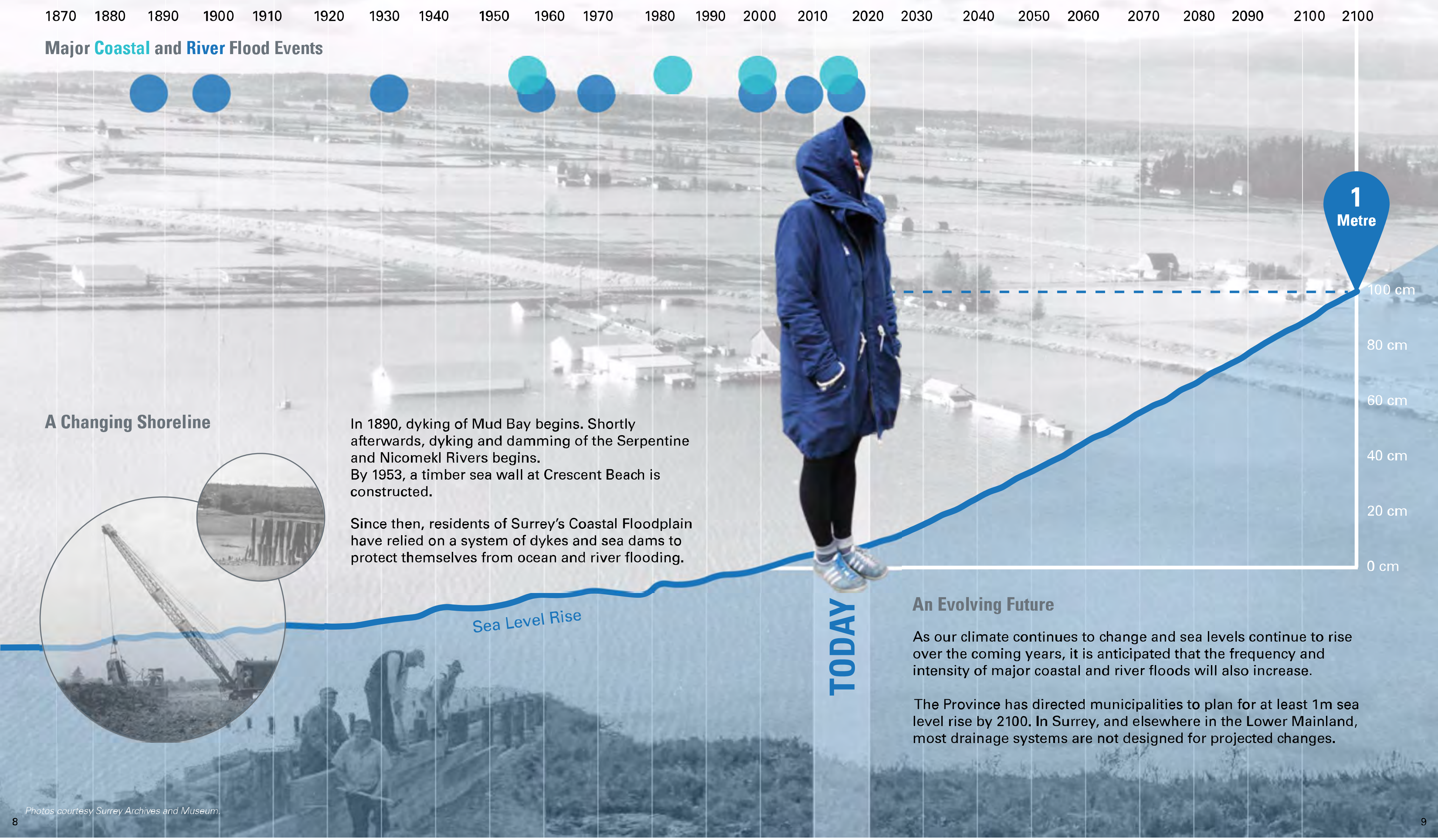
With the changing climate, we can expect more extreme weather conditions. For example, in Surrey, winters are expected to have fewer wet days, but on the wet days the rainfall amounts will be much greater than in the past. This will result in increased flooding, as more runoff flows into the Nicomekl,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

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.

FLOOD HAZARD IMPACTS

	TODAY	FUTURE
OCEAN FLOOD HAZARDS	· *High tides* · *Storm surges*	· *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	· *Long duration and intense rainfall or rain-on-snow event*	· *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*

COASTAL AND RIVER FLOODING



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.

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.

Photos courtesy Surrey Archives and Museum.

AGRICULTURE AND FARMING

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 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 PROJECT STUDY AREA IS A LARGE AND IMPORTANT PART OF SURREY'S AGRICULTURAL SECTOR.

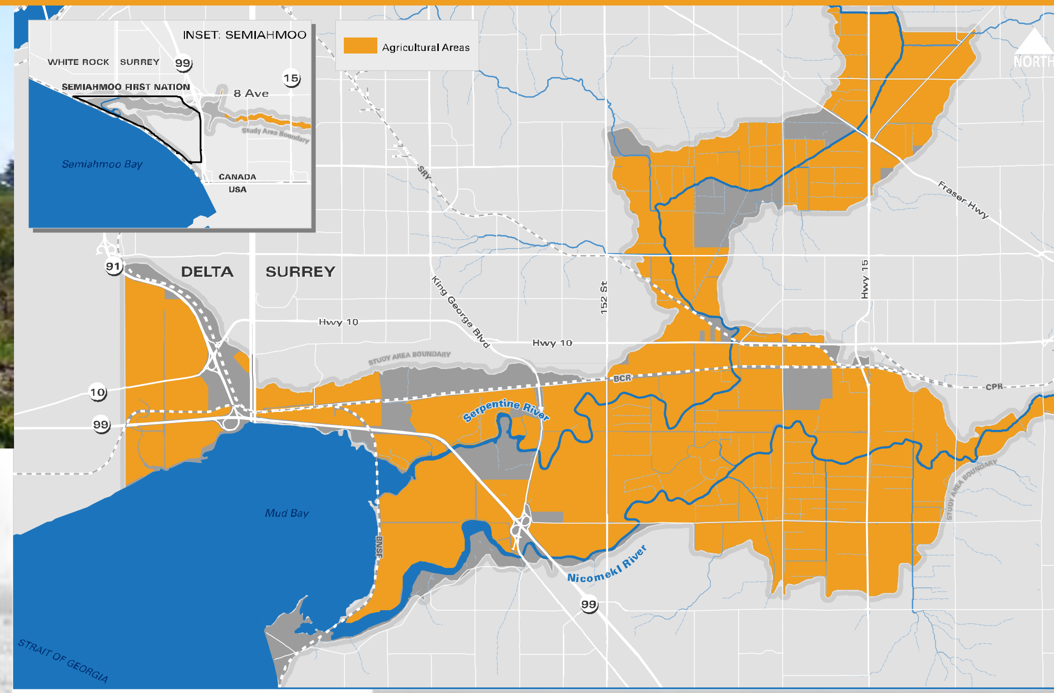
FACTS

- *Over 30km² of Agriculture Land in production*
- *Over $100 million in annual farm gate revenue (or about 60% of Surrey's total farm gate revenue)*
- *Diversified crops and production – dairy, berries, field crops, mushrooms*

Background image: Farmer rescuing pumpkins floating in a flooded field, c.1955. Photo courtesy Surrey Archives and Museum.

CLIMATE CHANGE IMPACTS

- *Increased flooding (from higher, climate change-driven precipitation and river levels)*
- *Poor and reduced field drainage (pumps and drainage system impeded by increased flooding)*
- *Increased risk to coastal areas from coastal flooding (seawater inundation leaves residues of salts, such as sodium, on the soil – high concentrations of which can damage soil structure for years)*
- *Increased precipitation, storm frequency and intensity can delay or impact field crop planting, growing season, and harvesting*



COMMUNITY AND RESIDENTIAL

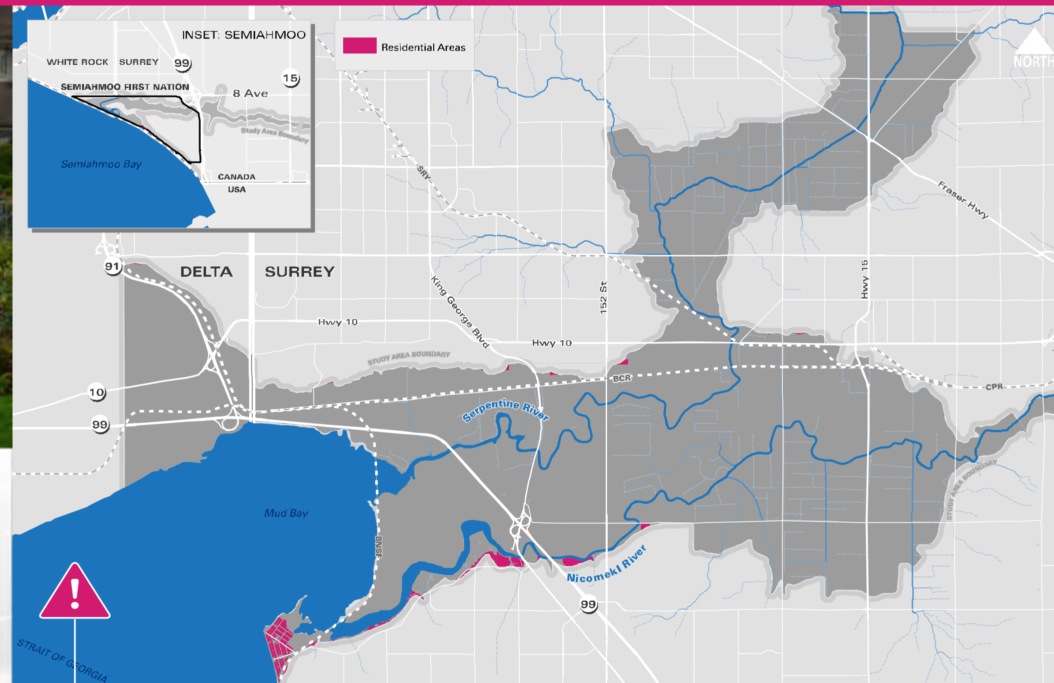
WHILE THE STUDY AREA IS LARGELY AGRICULTURAL, IT IS STILL HOME TO SEVERAL SMALLER RESIDENTIAL DEVELOPMENTS AND THE LARGER, HISTORIC COMMUNITY OF CRESCENT BEACH. BEGINNING AS COTTAGE COMMUNITY, CRESCENT BEACH IS ONE OF SURREY'S BEST KNOWN AND BEST LOVED NEIGHBOURHOODS. HOME TO ABOUT 1,200 PEOPLE AND 400 HOMES, THE COMMUNITY IS ALSO HOME TO SEVERAL COMMERCIAL BUSINESSES AND RESTAURANTS, ALEXANDRA NEIGHBOURHOOD HOUSE AND THE CRESCENT BEACH SWIM CLUB.

THE CAMPBELL RIVER AREA IS HOME TO SEMIAHMOO FIRST NATION, WHOSE MAIN RESERVE IS ON THE MOUTH OF THE RIVER.

FACTS

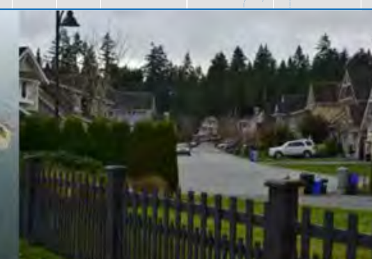
- *About 1,500 residents in total in study area.*
- *Semiahmoo First Nation is home to about 50 members*
- *Alexandra Neighbourhood House started out as a camp for orphaned children from Vancouver in 1916 and has since grown into a diversified community service agency.*
- *There are three strata developments in the study area - Nico Wynd, SouthPort, and Anderson Walk – which together include about 250 residences*
- *Surrey developed a comprehensive stormwater management strategy for Crescent Beach to help prepare the community for increased flooding behind its protective dykes*

Background image: Alexandra Orphanage Camp, c.1926. Photo courtesy Surrey Archives and Museum.



CLIMATE CHANGE IMPACTS

- *Catastrophic flooding will become frequent (without future improvements)*
- *Surface ponding and so-called nuisance flooding may become near permanent over time in Crescent Beach*
- *Increased chance of road closures and lengthy detours from flooding and overtopping during storm surges*
- *Property damage – residential and commercial*
- *Business interruptions*



ENVIRONMENTAL AND RECREATION

THE CFAS PROJECT AREA IS HOME TO SEVERAL POPULAR SURREY AND METRO VANCOUVER PARKS THAT INCLUDE SEVERAL KILOMETRES OF SHORELINE TRAILS WITH INCREDIBLE VIEWS OF BOUNDARY BAY. DIVERSE WILDLIFE HABITATS, INCLUDING EELGRASS MEADOWS, MUD FLATS, SALT MARSH AND OLD FIELDS, MAKE IT ONE OF THE BEST WILDLIFE VIEWING AREAS IN SURREY. IT IS ALSO HOME TO PROVINCIALLY AND FEDERALLY PROTECTED WILDLIFE AREAS AND THE SPECIES AT RISK THAT LIVE THERE (SEE BELOW). THOUSANDS OF MIGRATORY BIRDS USE MUD BAY AND THE LARGER 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.

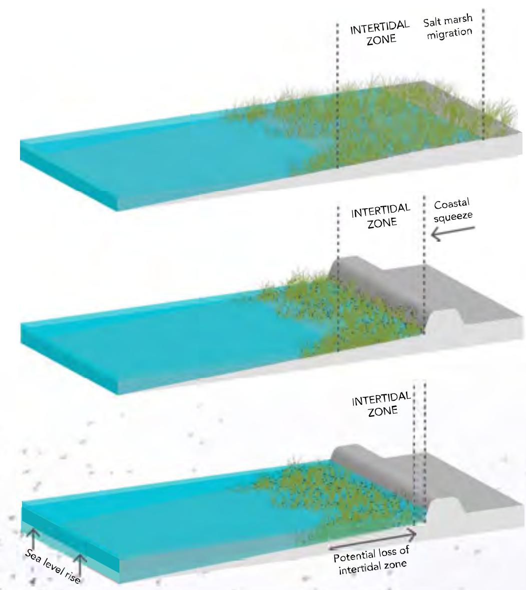
FACTS

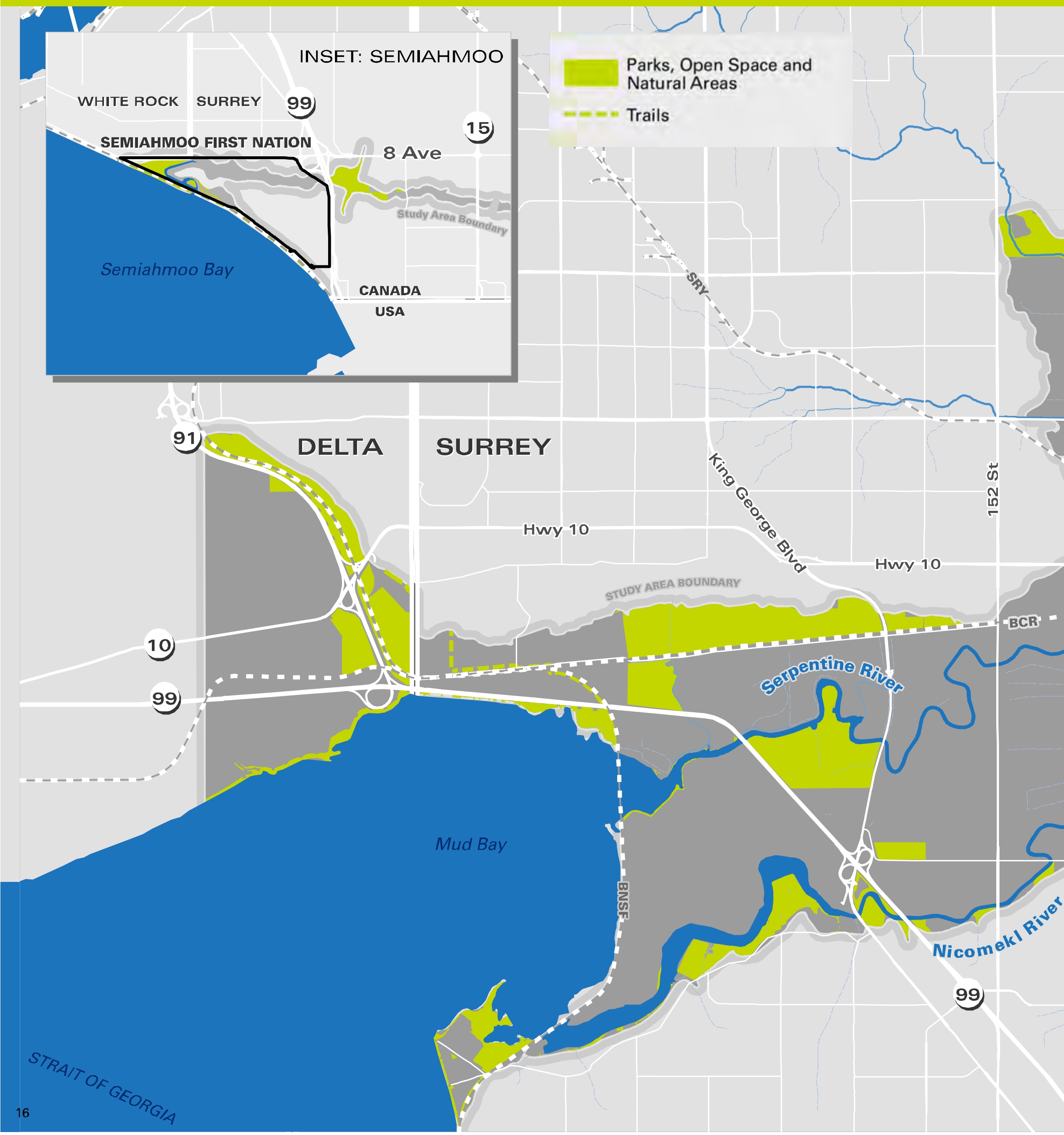
- *Almost 100,000 visitors a year walk, jog, wheel and bike the trails at Mud Bay Park and along Colebrook Dyke trail*
- *Internationally recognized wildlife area - Migratory Bird Sanctuary (federal), National Wildlife Area (federal), Provincial Wildlife Management Area, Ramsar Site (Wetland of International Significance), Western Hemisphere Shorebird Reserve Network*
- *Several Red Listed and Blue Listed species at risk, including birds, animals, fish and plants*

COASTAL SQUEEZE

Coastal habitats are being trapped and "squeezed" between dykes and rising sea levels, reducing the amount of the important foreshore and coastal habitat over time.

- *Thousands of migratory birds use Mud Bay 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*





CLIMATE CHANGE IMPACTS

- Foreshore and coastal habitat loss from sea level rise
- Riverbank habitat loss from river flooding and erosions
- Species loss (and extirpation) due to habitat loss
- Increased predation of spawning salmon trapped on ocean-side of closed sea dams
- Impacts to popular recreation areas (access, trail closures and detours, loss of beaches)
- Impacts to, and loss of, habitat areas with very high biodiversity values (Surrey Biodiversity Conservation Strategy)

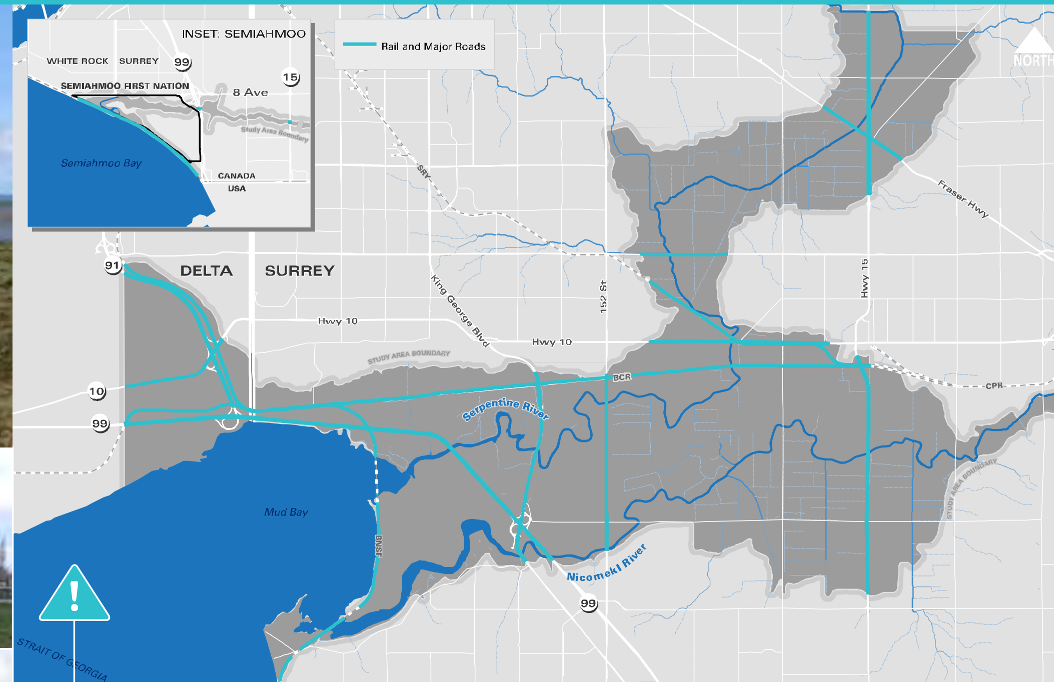
TRANSPORTATION AND INFRASTRUCTURE

MAJOR INFRASTRUCTURE, INCLUDING RAIL LINES, HIGHWAYS AND UTILITY CORRIDORS, ALL PASS THROUGH THE CFAS PROJECT 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 PROTECT AND PREPARE THE COMMUNITY FOR INCREASED COASTAL FLOODING AND CLIMATE CHANGE WHICH INCLUDES A NEW PUMP STATION (MAPLE PUMP STATION), NEW STORM SEWERS, AND A PLAN TO RAISE KEY ROADS ~0.3M METRES AS A FIRST STEP IN A LONG-TERM ROAD RAISING STRATEGY.

Surrey has also embarked upon a $15 million project with support from the Province to upgrade and raise about 8 kilometres of dyke along Colebrook Road from King George Boulevard to Delta and along Mud Bay. The area is considered one of the Surrey's most vulnerable areas for flooding because of its sinking soils, low-level dykes, wind and wave exposure and king tides.

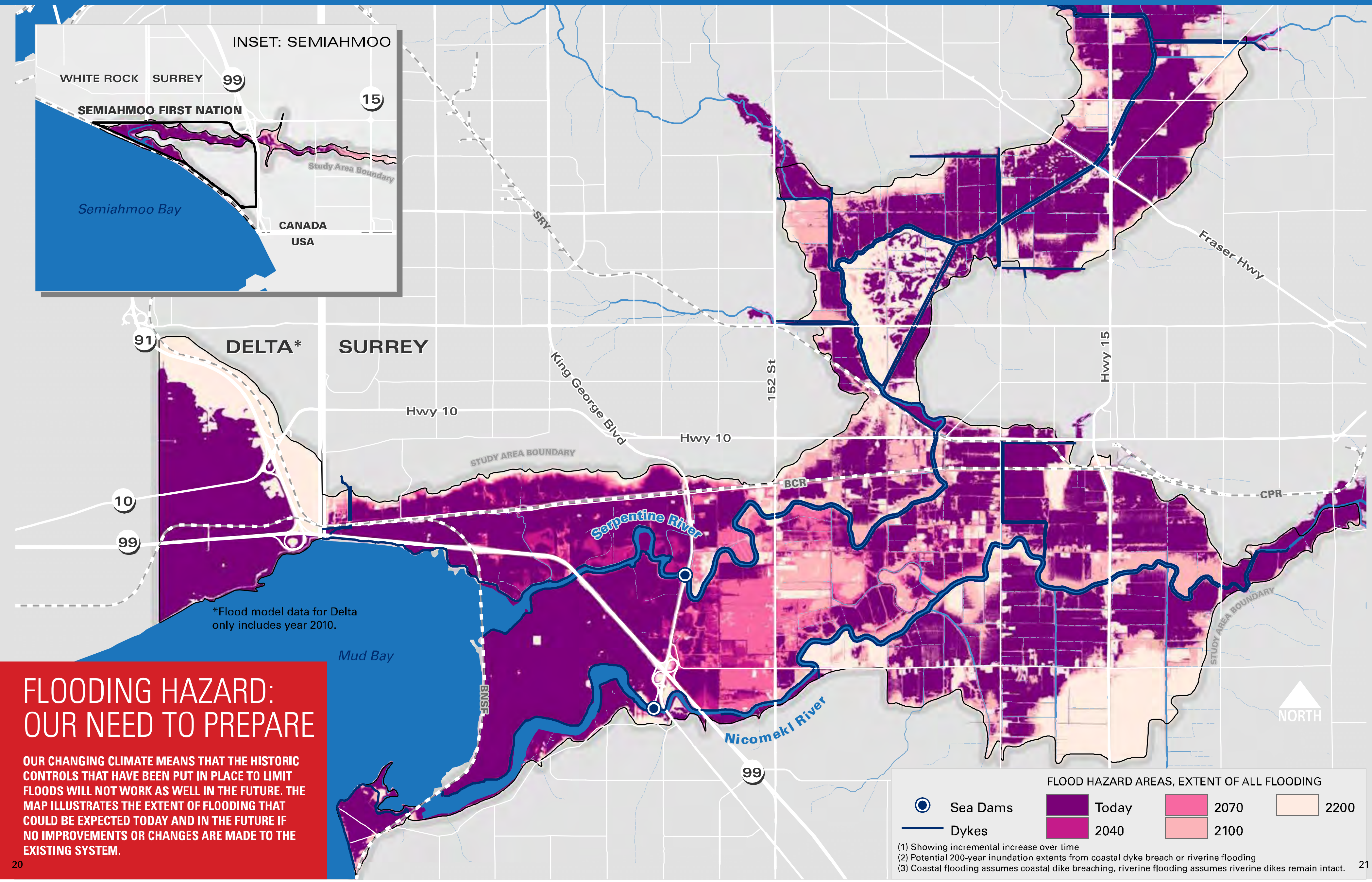
FACTS

- *Major international utility corridors – BC Hydro and Fortis*
- *Major regional utilities – Metro Vancouver water supply and sewage lines*
- *Over 10 km of Provincial Highways*
- *Over 200,000 vehicle trips a day*
- *Over 30 km of railway (BNSF freight and Amtrak passenger)*
- *Almost $25 billion annual truck and rail freight traffic*



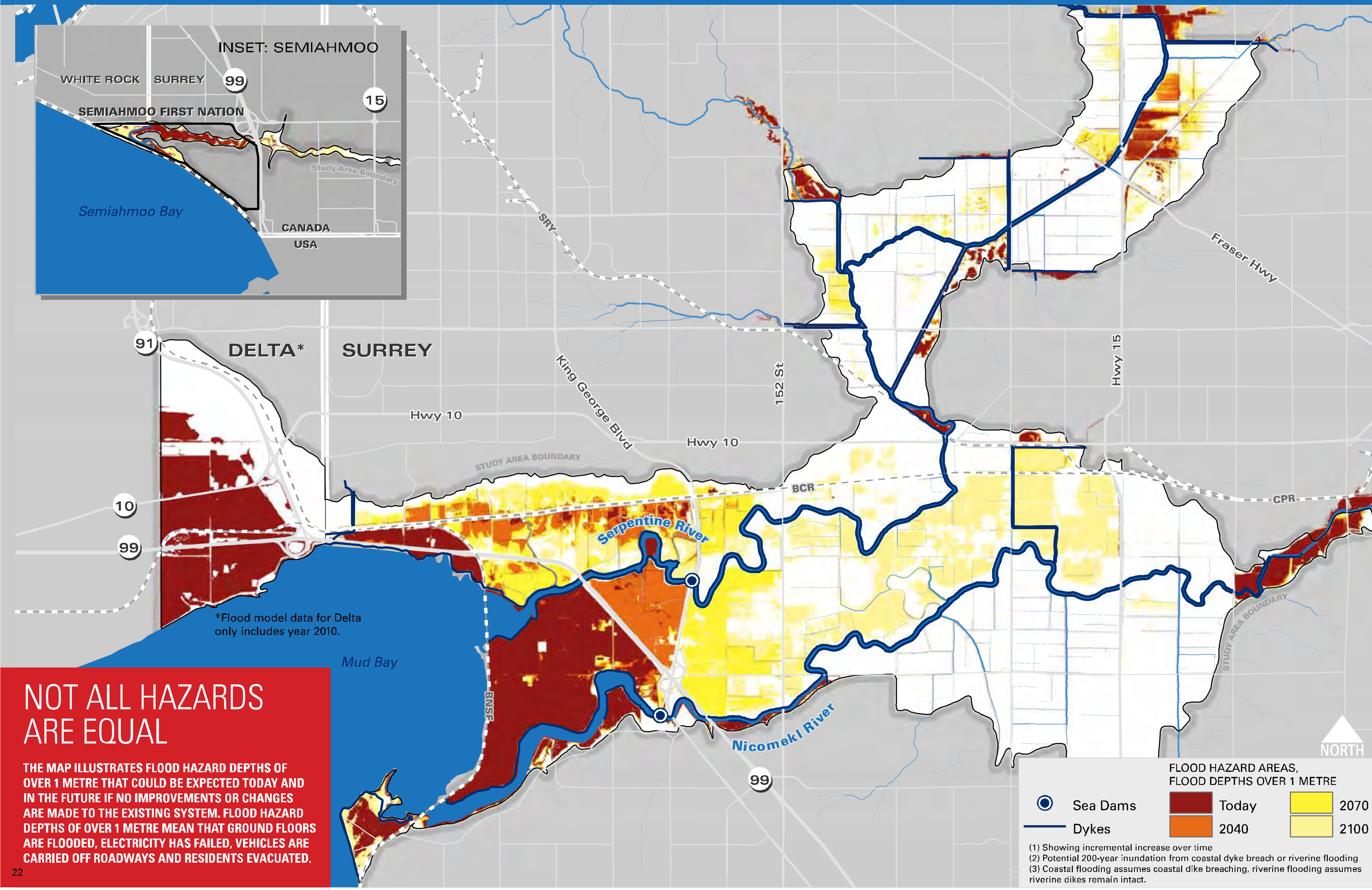
CLIMATE CHANGE IMPACTS

- *Serpentine and Nicomekl dykes are not high enough to protect against anticipated 2100 flood levels*
- *Serpentine sea dam is not seismically sound*
- *Few of the Serpentine and Nicomekl River dykes will meet the Provincial 200-year standard by 2020.*
- *By 2070, it is expected that all dykes will be overtopped multiple times per year, with overtopping likely resulting in dyke failure.*
- *At present, under the 200-year flood condition, a portion of Highway 99 would be inundated, including bridge decks at three locations*
- *Erosion, interruption of railway operations and goods movement*



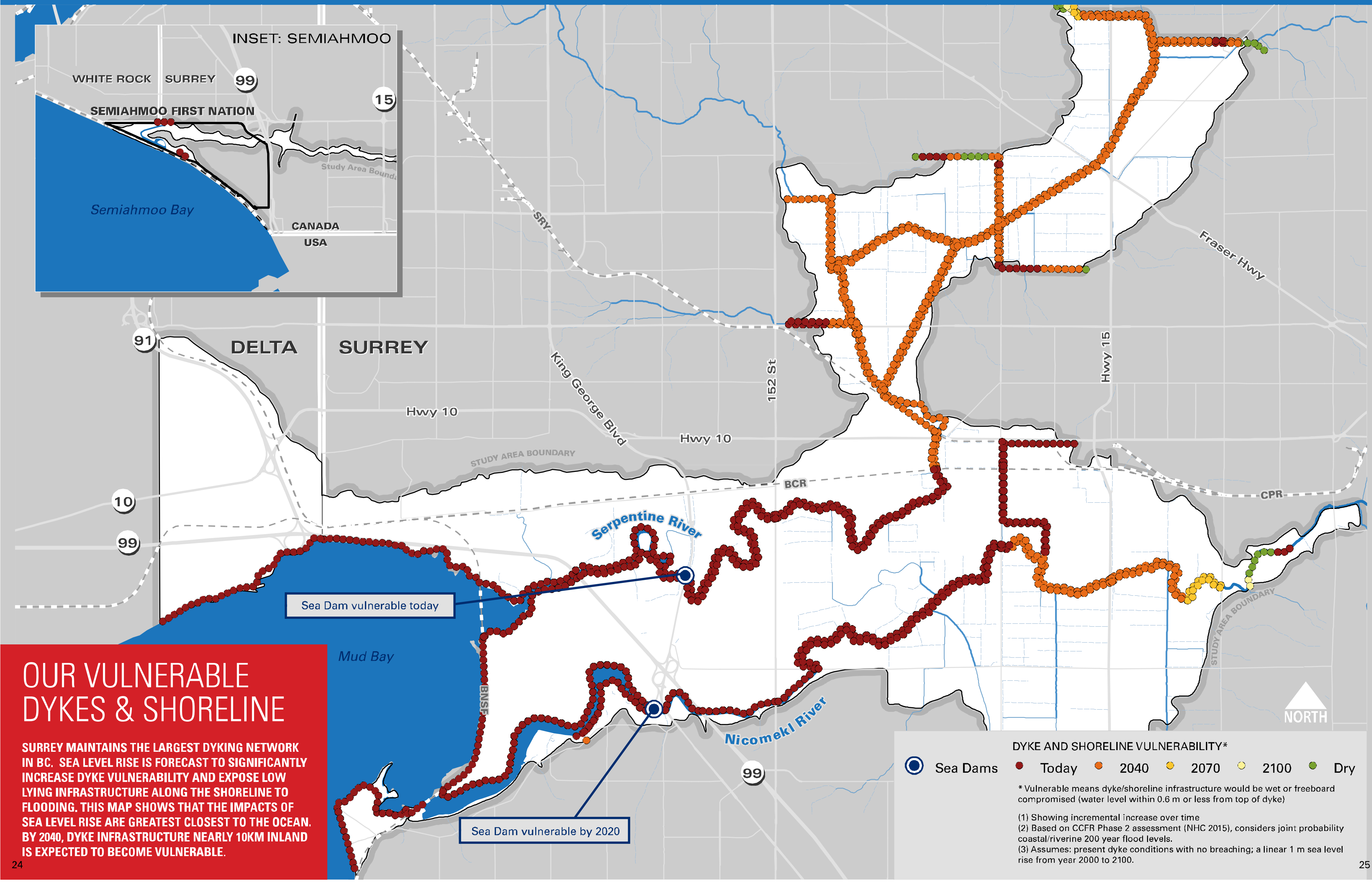
FLOODING HAZARD: OUR NEED TO PREPARE

OUR CHANGING CLIMATE MEANS THAT THE HISTORIC CONTROLS THAT HAVE BEEN PUT IN PLACE TO LIMIT FLOODS WILL NOT WORK AS WELL IN THE FUTURE. THE MAP ILLUSTRATES THE EXTENT OF FLOODING THAT COULD BE EXPECTED TODAY AND IN THE FUTURE IF NO IMPROVEMENTS OR CHANGES ARE MADE TO THE EXISTING SYSTEM.



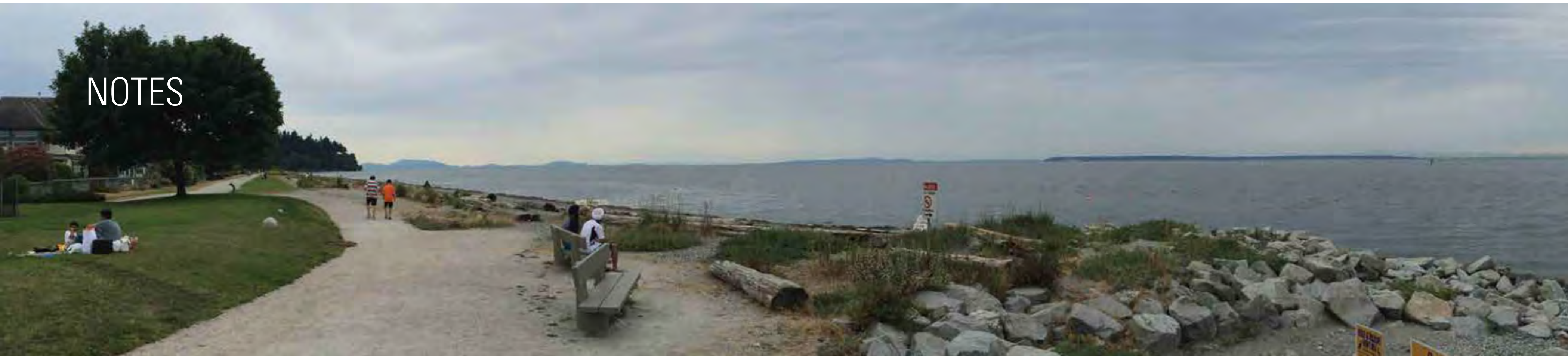
NOT ALL HAZARDS ARE EQUAL

THE MAP ILLUSTRATES FLOOD HAZARD DEPTHS OF OVER 1 METRE THAT COULD BE EXPECTED TODAY AND IN THE FUTURE IF NO IMPROVEMENTS OR CHANGES ARE MADE TO THE EXISTING SYSTEM. FLOOD HAZARD DEPTHS OF OVER 1 METRE MEAN THAT GROUND FLOORS ARE FLOODED, ELECTRICITY HAS FAILED, VEHICLES ARE CARRIED OFF ROADWAYS AND RESIDENTS EVACUATED.



OUR VULNERABLE DYKES & SHORELINE

SURREY MAINTAINS THE LARGEST DYKING NETWORK IN BC. SEA LEVEL RISE IS FORECAST TO SIGNIFICANTLY INCREASE DYKE VULNERABILITY AND EXPOSE LOW LYING INFRASTRUCTURE ALONG THE SHORELINE TO FLOODING. THIS MAP 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.



NOTES

WHAT'S NEXT?

Engagement with residents, stakeholders, and other project partners is paramount to the success of the CFAS project. A range of stakeholder engagement activities and opportunities for feedback and participation will be provided throughout the multi-year process. If you or your organization are interested in learning more about the project, or are interested in a presentation, let us know (see contact information).

All project information, including dates for upcoming presentations and events, and all CFAS project materials (videos, information materials, reports) will be posted on the project website. This Primer is also available on the website.

www.surrey.ca/coastal

There will be a second round of feedback sessions later this spring to present back what was heard at the kick-off Focus Groups.

CONTACT US

For more information, please contact:
Matt Osler
Project Engineer
City of Surrey
coastal@surrey.ca
604.591.4657

CFAS

CITY OF SURREY
the future lives here.

This page intentionally blank. Formatted for double-sided printing.

Surrey Coastal Flood Adaptation Strategy (CFAS) Infrastructure Asset Managers, Operators and Emergency Services Questionnaire

We invite you to fill out the following questionnaire to identify the critical infrastructure in the study area that you manage or rely on to delivering services in the Mud Bay area. This information will assist us in the preparation of the stakeholder workshop.

Who are you?

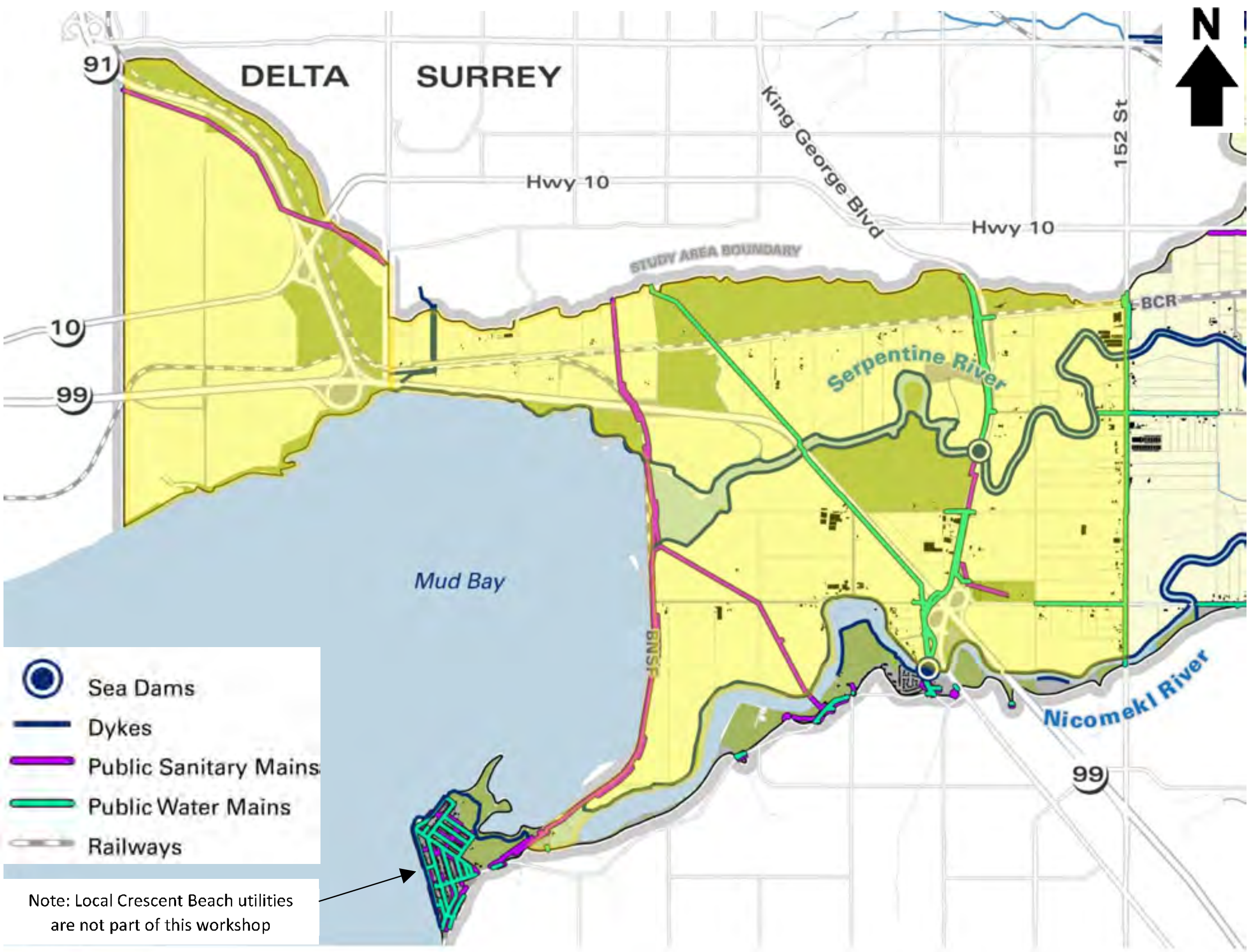
Organization:

Position:

Tell us about the infrastructure?

What infrastructure/ assets do you manage or rely on, in the Mud Bay area?

(To assist in this, please reference the infrastructure listing in the backgrounder and the area map below. Is the information complete? If not please provide additional details or corrections.)



PLEASE TURN OVER

Surrey Coastal Flood Adaption Strategy (CFAS)
Infrastructure Asset Managers, Operators and Emergency Services Questionnaire

What is your experience with flooding?

How has flooding affected your organization's infrastructure or delivery of services in the Mud Bay area?

What is your knowledge of current and future flood risk?

What are you doing about it?

What steps are you taking to adapt to increased flood risk?

Other issues?

Are there other areas of concerns or issues in the area that may be of interest in the workshop?

Thank you for your input. If you have any questions, please contact Matt Osler at 604-591-4657.

Please return this survey to MFOsler@surrey.ca by March 17, 2017.

Appendix B - Participant Risk Score and Adaptation Comments

PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Infrastructure Components	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
TRANSPORTATION	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Runway																		
Surrey/King George Airpark Turf Runway	Y	4	1,1,1,1,1,2,1	4	Y	5	1,1,1,1,1,1,1,4,1	5	Fuel on-site: environmental issue. Mostly private impacts. Low due to it being a recreational facility. Fuel on site - private site. Fuel stored on site. Oil / gas stored at site. Fuel stored on site. Grass runway is fairly resilient. Most aircraft can be flown out with advance notice.	Y	4	1,1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,1	5	Impacts very little for very few. Costs / risks borne privately. Private. Not for the overall communities - private, few people. Not catastrophic for anyone other than those effected (few people). Not regionally significant. Private, few people.
Regional / International Transportation Infrastructure																		
4 km of four-lane arterial roadway	Y	4	3,3,3,3,3,4,3	12	Y	5	4,5,5,5,5,5,5	25	Lower impact in today's conditions. Infrastructure damages. Commuter traffic.	N	4				5			Interpreted as King George below.
7 km section of Highway 99 linking Peace Arch Border	Y	4	3,4,4,4,4,4,3,4,4	16	Y	5	4,5,5,5,5,5,4,5,5	25	Today infrastructure would be intact if damaged. At higher flood levels, impact on Hwy 99 is elevated. Major consequence of highway closure due to flooding. Major corridor; structural damage; main commerce thruway. Major corridor. Major damages to infrastructure / commerce. Bridges. Major corridor & source of commerce. International customs alternate crossings at Hwy 15. Connection to US border tourism, local emergency response, truck trade, scouring at bridges (typical for Hwy 99 and 91)	Y	4	4,4,4,4,4,3,4	16	Y	5	5,5,5,5,5,5,5	25	International border - N/S link. If we lose the bridge, takes longer to recover. 2 bridges + 2 culverts, approaches. Wave impacts, approaches, structural loss, scour. 2 (older) bridges, 2 culverts. Many months if lost a bridge. Corrosion (culverts etc) - wave impacts. 2 major bridges / wave impacts existing / major routes. Waves impacts during existing. Bridges and culverts.
Highway 91 and 99 Interchange	Y	4	4,3,3,3,3,4,3,3	12	Y	5	4,4,4,4,5,4,4,4,4	20	Interchange is elevated and higher than dyke, but impact is mostly on Hwy 99. Interchange at higher elevation - depends on connections. Assumptions: no data for future; dependent on connections. Major corridor / commerce. No data - connectivity issue. Structural. Assumption no data; dependent network connectivity. Wave impacts damage / erosion / drawdown. Spread footing damage, EPS flotation at approaches.	N	4			Y	5	5,5,5,5,5,5,5	25	Erosion from wave impact - possible structural issue. Major. Structural. Approaches are gone. Both highway - high foundation. Rotational failure. Structural. Major route / may impact approaches. Wave impacts / approaches / structural loss (scour).
4 km section of Highway 91	Y	4	2,1,1,1,1,5,1	8	Y	5	3,1,1,1,4,1,5,5,1	20	No data for future. Traffic impacts. Can be used for serviceability / access. Highway likely closed, maybe used to direct traffic to ? No data for future. Traffic congestion. Limited data. No data. No way around.	N	4			Y	5	4,4,4,4,4,4,4	20	Time to recover. Major. No way around. Ways around it - less time to recover. Alternate routes. Major route, can bypass. Ways around easier / time to recover.
6 km dyke trail connecting to parks	Y	4	1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,2,1	5	Loss of trail itself is inconvenience, dyke is another issue as far as impact. If trail isn't replaced, loss of public asset and quality of life impacted. Trail loss / recreational loss. Rated as a trail, not as a dyke - 1 million visitors / year. Dyke 'significant' - trail perspective ' insignificant' Rated as trail. Rated as trail - could effect community quality of life. Some environmental damage. loss of trail use an inconvenience only - cost to rebuild, quality of life (typical for Delta Surrey Greenway)	Y	4	1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,1	5	Local. Local impact. Local impact. Local impacts. Not significant to region for short term. Local impact not high.
Delta-Surrey Greenway	Y	4	1,1,1,1,1,1,1	4	Y	5	2,1,1,1,1,1,2,1	5	Loss of trail itself is inconvenience, dyke is another issue as far as impact. If trail isn't replaced, loss of public asset and quality of life impacted. Loss of connectivity . Rated as a trail, not a dyke - 1 million visitors / year. Consideration of quality of life - 1M visitors / year. Local.	N	4			Y	5	1,1,1,1,1,1,1	5	Local. Local. Local impacts. Not significant to region for short term. Local impact not high.
Crescent Road																		
Local Government Arterial and Collector Roads																		
King George Boulevard (City of Surrey)	Y	4	4,3,3	12	Y	5	4,5,5	25	Considered duplicate of #6 for many responses. Lower impact in today's conditions. Bridges.	N	4			Y	5	5,5,5,5,5,5,5	25	N/S link. 2 bridges. Major ? For King George Boulevard, Bridges (1 old 1 new). Access / egress for emergency vehicles. 1 new bridge / 1 old - major road. 2 bridges - time to recover.
152nd Street (City of Surrey)	Y	4	1,1,1,1,1,1	4	Y	5	4,4,4,4,3,4,3,4	20	Important network connection. Divide line - emergency services; network reliability. Network reliability. Community divide line - access to South Surrey / White Rock. Volume of services; network reliability. No current risk but yes in future.	N	4			Y	5	3,4,3.5,3.5,3,3.5	20	Time to recover is less. Less time to recover. Congestion? Major impact to traffic - slower velocity, less water. Less waves / depth easier to recover.
Colebrook Road (City of Surrey)	Y	4	2,1,1,1,1,3,1,2,1	8	Y	5	3,3,3,3,2,3,3,3	15	Not a critical link, few people and bus. Access to properties.	Y	4	2,2,2,2,2,2,2	8	Y	5	2,2,2,2,2,2,2	10	Local - limited area and use. Minor - affects local people only. Local. Local road - affect limited area. Local farm road - affects limited area. Other ways around - not as critical. Local affects limited area.

This page intentionally blank. Formatted for double-sided printing.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**
Ladner Trunk Road (Corporation of Delta)	Y	4	3,3,3,3,1,3,3,3	12	Y	5	4,4,4,1,5,4,4,4	20	Large - significant for Delta - airport / hospital.	Y	4	3,3,3,3,3,3,3	12	Y	5	5,5,5,5,5,5,5	25	Access to -- very limited access out. Major for Delta (hospital, airport). Might use for airport access / hospital. Significant - access airport & hospital. Major route to Delta, may not be reinstated. Significant for Delta / access to airport and hospital.
112 Street (added)	Y	4	2,2,2,2,2	8	Y	5	3,3,3,3,3	15	Access to properties; hard to tell level to which road itself is affected. Rated with respect to access to properties. Only west end at crescent beach.		4				5			
Class 1 Railways Originating at Port Metro Vancouver																		
Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	Y	4	2,2,2,2,2,2,2,2	8	Y	5	4,4,4,4,5,4,4,4	20	Not the limiting piece of infrastructure here. Future will have more shutdown. Inundation - time to repair (typical for all rail crossings). Effects not captured accurately on maps.	Y	4	4,4,4,4,4,4,4	16	Y	5	4,5,5,5,5,5,5	25	Swing bridge, how to sustain trade in your area. Wave effects. Months to recover. Unintentional dike - wave effects. Wave effects / critical route for trade to USA. Wave effects existing / catastrophic bigger.
6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	Y	4	4,4,4,4,4,4,4,4	16	Y	5	5,5,5,5,5,5,5,5	25	Impact to highway if you have to raise railroad at underpass. Potential Hwy 99: raise if railway raise. Wave action vs saturation. Potential impact to the highway.	Y	4	4,4,4,4,4,4	16	Y	5	4,5,5,5,5,5,4	25	Lost all USA connections. Wave effect / critical route for trade to USA / acts as dyke. Wave effects existing / catastrophic bigger.
Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	Y	4	2,2,2,2,2,2,2,2	8	Y	5	4,4,4,4,5,4,4,4	20	Weakest link is western portion. Damage to infrastructure, but would likely stay intact. Impact operations for storing trains at BNSF. Economic and structural impacts. Constrained by BNSF at Hwy 91 / 99 - I/C east, low water both sides. Constrain operation of Mud Bay siding and Oliver siding. No high waves hitting the tracks. Constraints of section and water on both sides - compromises to siding. Weakest link NR Colebrook	Y	4	2,2,2,2,2,2,2	8	Y	5	4,5,5,5,5,5,4	20	Train more likely to be in the area. Minor for Scenario A - consequence is high. Train more likely present, minor. Lost all USA connections. Wave effects / one of major exits to Canada. Train more likely present (minor in existing).
Connection to Southern Railway of British Columbia	Y	4	1,1,1,1,1,1,1,1	4	Y	5	1,1,1,1,4,1,1,1	5	Impacts on rail network. Low consequence. Outside study area, minimal impact. Outside study area. Outside study area.	N	4			Y	5	4,4,4,4,4,4,4	20	Future. Loss all USA connections. Not affected by sea event currently. Will be affected in future, will get back in service quicker. Actual connection at 192

This page intentionally blank. Formatted for double-sided printing.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
UTILITIES	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Sanitary Lift Stations																		
City of Surrey: Elgin	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	3,3,3,3,3,2	12	Y	5	3,3,3,3	15	Affected by flooding at Stewart.
City of Surrey: South Port	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	4,4,4,4,4,2	16	Y	5	4,4,4,3	20	Affected by flooding at Stewart
City of Surrey: Winter Crescent	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	3,3,3,3,3,3	12	Y	5	3,3,3,3	15	Affected by flooding at Stewart
City of Surrey: Stewart Farm	Y	4	2,2,2	8	Y	5	3,4,4	20	Sewer backup. In floodzone, services ~200 properties.	Y	4	4,4,4,4,4,4	16	Y	5	4,4,4,4	20	Affected directly by flooding. Chain effect of failures. Interconnected - all stations would fail. Highest consequence because it is on the series - starts chain reaction upstream. Possible cascade of failing of the pump stations.
Metro Vancouver: Crescent Beach	Y	4	2,2,2,2	8	Y	5	4,4	20	Sewage overflows. If PS completely flooded and genset fails, sanitary sewer overflows.	Y	4	3,4,4,3,3,3	16	Y	5	3,4,4,3,2	20	Inflow through flooding of sewers. L/S itself wouldn't flood. Indirectly impacted in existing conditions. Inflow from Crescent Beach. Impact partly dependent on response of public (not flushing toilets)
Underground infrastructure																		
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	4	2	8	Y	5	3	15	Low probability of failure - welded steel; flooded valve chambers.	Y	4	4,4,4,4,4,4	16	Y	5	4,4,4,4	20	Local PRVs vulnerable to flooding / MV reroute supply. Erosion concern = potential break. Water more important than sanitary (fire). Chlorinated water released if break. Impact would be on the local system. Some routing around could be done, but would be limited supply. Nicomekl sea dam has w/m through it. Questionable supply. Water is the most important can reroute through south Surrey. Farm lands can be flushed (chlorine)
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	4	2,2	8	Y	5	3,3	15	If valve chambers flood, reduced O&M access and corrosion of valves and equipment. If dike abandoned, then pipe at risk of erosion and flotation, so may need relocation.	Y	4	3,3,4,3,3	12	Y	5	3,3,4,3	15	As long as PS can release to ocean. Environmental impacts mitigated by tide in and out. Impacts to residents from backup.
>10 km of FortisBC Gas Mains	Y	4	2,2,2,2	8	Y	5	3,3,3,3,3	15	Minimal infrastructure loss and min. customers affected (higher consequence in the winter). Number of customers lost - insignificant. Damage to infrastructure is minimal. Number of customers lost (2 more such comments)	Y	4	2,2,2,2,2	8	Y	5	2,2,2,2	10	Limited impact because not much infrastructure is affected, and usually has several shutoff locations.
Overhead Utility Infrastructure																		
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Y	4	2	8	Y	5	4	20	Extended power outage over large area.	Y	4	3,1	12	Y	5	3,4,3,3,1	15	Ground clearance can be an issue. Issue with tower at Serpentine river. Transmission lines may need to be refurbished, raised, armored. Present consequence insignificant - if lost, lost revenue. Rerouting not possible in real time. Could be scour / erosion around pedestals. Possible flow past footings
BC Hydro local overhead distribution lines	Y	4	2,4	12	Y	5	4,4	20	Extended power outage. Long restoration time (for the ranking of 4)	Y	4	4,4,4,4,3	16	Y	5	4,4,4,3	20	Pump station affected and cannot pump. If poles are flooded, difficult to inspect. Could fail, loss of power to pump stations. Issue for sanitary pump station. Power loss to streetlights would contribute to traffic congestion - affect emergency response and evacuation.
Shaw and Telus telecom lines	Y	4	2,2,2	8	Y	5	2,5,2,2	10 (25)	Essential for communication. Communication infrastructure affect many different interested parties - loss of communication can cause a number of different problems (for the ranking of 5). O&M: need access to site to operate and maintain. ER: cannot call for help if loss of service.	Y	4	2,2,2,2	8	Y	5	2,2,2,2	10	Affect communications in operations. From operating and monitoring perspective. Communications for SCADA infrastructure.
Green Infrastructure (Added)	Y	4	2	8	Y	5	3	15	Erosion / deposition of soil leads to increased need to dredge / maintain other infrastructure to remove buildup; reduced oxygen production in region; reduced carbon sequestration; urban heat island effect increased.									

PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Associated Engineering

Table Group A

Infrastructure Components: Flood / Marine	Flood Scenario A - Current: Y/N	P	C	R	Flood Scenario A - Future: Y/N	P	C	R	Rational For Consequence
Flood Control Infrastructure									
City of Surrey Sea Dams (2)	Y	4	4,4,4,4,4,4	16	Y	5	5,5,5,5,5,5	25	Velocities high with dam breaches Debris potential, salt intrusion, loss of life in 2100
15 km of dyking, including ditches and floodboxes	Y	4	4,4,4,4,4	16	Y	5	5,5,5,5,5	25	
City of Surrey: Colebrook Pump Station	Y	4	2,2,2,2,2,2	8	Y	5	2,2,2,2,2	10	Power loss, longer salt water, blueberries
City of Surrey: Maple Pump Station	Y	4	2,2,4,2,2,2	8	Y	5	3,2,2,2,2,4,2	15	Pump station services primarily people and property Breach and break slows recovery Pump station is ineffective during breach
Corporation of Delta: Oliver Pump Station	Y	4	2,2,2,2,2	8	Y	5	2,2,2,2,2	10	Pump station services primarily agricultural land Pump station is ineffective during breach
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	4	1,1,1,1,2	4	Y	5	1,1,2,2,2	10	Birds will relocate during event. Rodents will also relocate. Pump station is ineffective during breach
Water control features to maintain environmentally sensitive area including freshwater irrigation system	Y	4	1,1,1,2,2	4	Y	5	1,1,2,2	10	Salt intrusion
Marine Facilities									
Crescent Beach Marina	Y	4	2,2,2,2,2,2	8	Y	5	2,2,2,3,2,2	10	Possible use by CCG as landing spot / patient transfer Boats might seek refuge here - not large marinas
Wards Marina	Y	4	2,2,2,2,2	8	Y	5	2,2,2,3,2,2	10	Boats might seek refuge here - not large marinas
Private docks	Y	4	2,2,2,1,2	8	Y	5	2,2,2,3,2	10	Boats might seek refuge here
Farms									
Private dairy facilities for over 1,000 head of Cattle	Y	4	4,4,4,4,4,4	16	Y	5	5,5,5,5,5	25	Cattle will be relocated to Cloverdale Race Track. During future scenario, people's lives likely lost. Food insecurity, lives at risk. Current condition, cattle should survive. Not in 2100.

Table Group B

Infrastructure Components: Flood / Marine	Flood Scenario A - Current: Y/N	P	C	R	Flood Scenario A - Future: Y/N	P	C	R	Rational For Consequence
Flood Control Infrastructure									
City of Surrey Sea Dams (2)	Y	4	5,2,2,2,5,2,5,2	20		5	2,1,3,4,4,5,4	20	Sea dam will continue to operate but will be less effective. Sea dam will return to function post-event. Can't function as efficiently as when there is no flood. Future, loss of functionality - harder to repair. Not really affected (current ranking of 2). Future major damage possible as water recedes (erosion). Wide effect & consequence to City / region. Road access for emergency services, water resources for fish, agricultural impacts. Future: sea dam will need major repair, access road over seadam will be affected.
15 km of dyking, including ditches and floodboxes	Y	4	5,4,4,4,4,5,5,4	20		5	5,4,5,5,5,5	25	Dyking is allowing water over, ditches / floodboxes not effective. Failure to protect Crescent Beach / farmland. Crescent Beach - loss of homes, damage, debris, cannot temporary repair, higher economic impact in future. Major flooding, economic loss, evacuation, major dikes damage (current). Widespread flooding, larger economic loss (future). Wide effect & consequence to City / region. Compromised integrity and function to protect - $up
City of Surrey: Colebrook Pump Station	Y	4	5,3,1,3,4,3,3,4	16		5	4,3,5,4,4,5	20	Pumps should continue operating provided power / backup power is not affected. Potential damage to housing structure. Should survive / function in current scenario, doubtful in future. Elevation of backup generator, maintenance an issue. Extra time (24/7) to pump out water. Still generally functioning
City of Surrey: Maple Pump Station	Y	4	5,3,1,3,4,3,3,4	16		5	4,2,5,4,4,5	20	Rebuilt and updated Damage to building holding the pumps. Damage to power / backup power, ability to repair. Major repairs probably required. Still generally functioning.
Corporation of Delta: Oliver Pump Station	Y	4	5,3,1,3,4,3,3,4	16		5	4,3,5,5,4,5	25	No immediate effect - post flood requirement. Difficult access, not function as intended. Needed to be serviceable for recovery. Lengthy post-flood recovery, potential irreparable damage. Major PS in Delta. Will not keep up with flooding (current). Genset may be flooded (future) . Still generally functioning.
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	4	2,1,2,1,4,1,2	8		5	2,1,2,2,2,4	10	Large / significant waterfowl refuge area. Saltwater will affect vegetation. Environmental impact minor - somewhat designed to handle flooding. Flooding is a natural process for a fen but salt water intrusion may be harmful. Environmental damage - difficult to reverse. Critical habitat for pacific flyway, Canada's largest wintering waterfowl populations.
Water control features to maintain environmentally sensitive area including freshwater irrigation system	Y	4	3,4,2,2,4,1,2	16		5	3,4,3,2,4,3	15	More effective area as fresh water marsh. Difficult to reverse salt water in short / medium term - potential fisheries impacts. Intrusion into freshwater habitat, complete loss of functionality. Difficult to reverse damage. More study of impacts required, fisheries impact, increased pollution, lower biological productivity, highly social impact. Distribution system is not essential. Environmental damage - difficult to reverse. Contaminated water for long time.
Marine Facilities									
Crescent Beach Marina	Y	4	1,1,1,2,2,1,1	4		5	3,4,3,3	15	Marinas are not protected by the dyke system Difficult access / debris damage (current) - flood damage to marina / docks (future) Damage to buildings, wharfs - higher in future scenario. Boats & docks floating unfettered may cause damage to other infrastructure or cause oil spills. Private property - limited effect on others. Building damage.
Wards Marina	Y	4	1,1,1,2,2,1,1	4		5	3,4,3,3	15	Most of infrastructure can accommodate the water. Difficult access / debris damage (current) - flood damage to marina / docks (future). Private property - limited effect on others. Building damage.
Private docks	Y	4	1,1,1,1,3,1,1	4		5	4,3,2,3	15	Difficult access / debris damage (current) - flood damage to marina / docks (future) Longer time to get back access, perhaps higher damage and cost to repair - future scenarios. Private property - limited effect on others.
Farms									
Private dairy facilities for over 1,000 head of Cattle	Y	4	4,3,5,4	16		5	5,5,5	25	Entire farm area and livestock would be affected. Potential to evacuate the animals, high risk of harm - cattle evacuation route (current). Less potential to save animals - high mortality expected (future). Evacuation necessary, cannot drink water. High value economic impact of interrupted production, cow health & safety, sustainability very questionable in long run. Destruction of animal life & generations old, large regional / national / international dairy business (unless there is some higher ground.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	**Flood Scenario B - Current**				**Flood Scenario B - Future**				**Rational For Consequence**	**Flood Scenario B - Current**				**Flood Scenario B - Future**				**Rational For Consequence**
TRANSPORTATION	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Runway																		
Surrey/King George Airpark Turf Runway	Y	3	1,1,1,1	3	Y	5	1,1,1,1,1	5		Y	3	1,1,1,1,1,1	3	Y	5	1,1,1,1,1	5	Local airport impacted but not significant to regional issues.
Regional / International Transportation Infrastructure																		
4 km of four-lane arterial roadway	Y	3	1,1,1,1	3	Y	5	2,2,2,2,2	10			3				5			
7 km section of Highway 99 linking Peace Arch Border	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		Y	3	1,1,1,1,2,1,1	3	Y	5	1,2,2,3,2,2	10	But minor. Highways are not greatly impacted by standing water in farm fields.
Highway 91 and 99 Interchange	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		N	3			N	5			
4 km section of Highway 91	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		N	3			N	5			
6 km dyke trail connecting to parks	Y	3	1,1,1	3	Y	5	2,2,2	10		N	3			N	5			Dyke is not overtopped. Trails not affected.
Delta-Surrey Greenway	Y	3	1,1,1	3	Y	5	2,2,2	10		Y	3	1,1,1	3	Y	5	1,1,1,1,1	5	Trails not affected.
Crescent Road																		
Local Government Arterial and Collector Roads																		
King George Boulevard (City of Surrey)		3	1,1	3		5	2,2	10	Often interpreted as duplicate of #6	N	3			N	5			Major city roads not affected, similar to highway.
152nd Street (City of Surrey)	Y	3	1,1,1,1,1	3	Y	5	1,1,1,2,1	5	Congestion impacts	N	3			N	5			
Colebrook Road (City of Surrey)	Y	3	2,2,2,2,2	6	Y	5	3,3,3,3,3	15	Access issues, contaminants from cars.	Y	3	2,2,2,2,1,2,2		Y	5	2,3,3,3,2,3,3		Minor inconvenience - affects local roads. More often future & longer to clean.
Ladner Trunk Road (Corporation of Delta)	N	3			N	5				Y	3	2,3,3,3,3,2		Y	5	2,5,4,5,3		Minor inconvenience - affects local roads.
112 Street (added)	Y	3	2,3,2,2	6	Y	5	3,3,3,3	15	Access issues, contaminants from cars.		3				5			
Class 1 Railways Originating at Port Metro Vancouver																		
Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			

PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			Not affected by rainfall (typical of other rail crossings except Southern Railway)
Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			
Connection to Southern Railway of British Columbia	Y	3	3,3,3	9	Y	5	4,4	20	Vulnerable connection.	Y	3	3,3,3,3,3,3	9	Y	5	4,4,4,4,4,4	20	Railway is impacted by seawater and rainfall events.

This page intentionally blank. Formatted for double-sided printing.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
UTILITIES	**Y/N**	**P**	**C**	**R**	**Y/N**	**P**	**C**	**R**	
	Table Group A								
Sanitary Lift Stations									
City of Surrey: Elgin	N	3			N	5			
City of Surrey: South Port	N	3			N	5			
City of Surrey: Winter Crescent	N	3			N	5			
City of Surrey: Stewart Farm	Y	3	2,2,2	6	Y	5	4,4,4	20	Not protected by a dyke.
Metro Vancouver: Crescent Beach	N	3			N	5			
Underground infrastructure									
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	3	2		Y	5	2		Valve chamber flooding. Fresh water okay.
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	3	2,2,2,2	6	Y	5	3,2,2,2	10	Erosion over creek crossings. May have tougher time accessing pipe & valve chamber but any flooding would be fresh water so no corrosion.
>10 km of FortisBC Gas Mains	Y/N	3	1	3	Y	5	4,4,4	20	One response identified Y for current - remainder N.
Overhead Utility Infrastructure									
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power		3				5	4	20	Extended power outage over a large area.
BC Hydro local overhead distribution lines		3				5	4,4	20	Extended power outage. Long restoration time.
Shaw and Telus telecom lines		3				5	1	5	If any customers are out of service due to flood it may impede maintenance / repair vehicles.
Green Infrastructure (Added)							3,3		Larger / frequent events detrimental to plant / tree growth. Erosion / deposition of soil leads to increased need to dredge / maintain other infrastructure to remove buildup; reduced oxygen production in region; reduced carbon sequestration; urban heat island effect increased.

Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
UTILITIES	**Y/N**	**P**	**C**	**R**	**Y/N**	**P**	**C**	**R**	
	Table Group B								
Sanitary Lift Stations									
City of Surrey: Elgin	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm. Based on Stewart not being an online pump station.
City of Surrey: South Port	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm.
City of Surrey: Winter Crescent	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm.
City of Surrey: Stewart Farm	Y	3	3,3,3,3,1	9	Y	5	3,3,3,1	15	May or may not be affected by flooding at all. If the pump station is within the flood area - location was not exact. Possible water impact of overtopping of the 2100 flood event.
Metro Vancouver: Crescent Beach	N	3				5			
Underground infrastructure									
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	3	2,2,2,2	6		5	2,2,2	10	Likely the only impact is on CoS local connections. Lower risk of scour versus sea flooding. Not significant risks (slow moving water).
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	3	2,2,2,2,1	6		5	2,2,2,1	10	Loss of line is not a doomsday scenario. Localized flood areas could effect.
>10 km of FortisBC Gas Mains	Y	3	3,2,3,3	9		5	3,2,3,3	15	Number of Fortis Stations affected. Modest consequence. Based on Fortis comments. Possible break in lines.
Overhead Utility Infrastructure									
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Y	3	2,3,2,2	6		5	2,3,3,2	15	Towers are close to the river and may be affected. Erosion of tower near Serpentine River. Towers are 70 m or less from bank. If the river's water velocity is significant, it could erode foundations. Could be erosion risks, destabilization.
BC Hydro local overhead distribution lines	Y	3	3,3,3,3,2	9		5	3,3,3,3	15	Affected in local areas only. Saturated soil and high winds.
Shaw and Telus telecom lines	Y	3	3,1,2,2	6		5	3,1,2	10	Share poles with Hydro distribution. Impact is the same. Similar impact as distribution lines, because they usually follow beneath.
Green Infrastructure (Added)									

This page intentionally blank. Formatted for double-sided printing.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Table Group A

Infrastructure Components – Flood / Marine	Flood Scenario B - Current Y/N	P	C	R	Flood Scenario B - Future Y/N	P	C	R	Rational For Consequence
Flood Control Infrastructure									
City of Surrey Sea Dams (2)	Y	3	2,2,2,2,2	6	Y	5	3.5,3,3.5,3.5	25	Extended duration may require larger floodboxes or pumping at sea dam. Increased pressure on sea dams. Scour hole on Serpentine sea dam.
15 km of dyking, including ditches and floodboxes	Y	3	3,3,3,3	9	Y	5	4,4,4,4	20	The dykes need to be raised. Larger footprint. Stability. Assuming dykes are raised, much less impact. Velocity increases therefore erosion becomes more of a problem. Geotech, seepage issues.
City of Surrey: Colebrook Pump Station	Y	3	2,2,2,1,1,1	6	Y	5	3,3,3,3,3,3	15	Consequences based on not upgrading pump station. Impact on agricultural. Pump duration will be increased due to sea level rise.
City of Surrey: Maple Pump Station	Y	3	1,1,1,1,1,1	3	Y	5	3,3,3,2,2	15	Consequences based on not upgrading pump station. Pump duration will be increased due to sea level rise. Discharge gates submerged more.
Corporation of Delta: Oliver Pump Station	Y	3	2,1,2,1,1,1	6	Y	5	3,3,3,2,3	15	Consequences based on not upgrading pump station. Pump duration will be increased due to sea level rise.
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	3	1,1	3	Y	5	1,1	5	
Water control features to maintain environmentally sensitive area including freshwater irrigation system	N	3			N	5			
Screw pump stations (added)	Y	3	1,1,1,1	3	Y	5	2,2,3	10	Pumping stations improved to same standard as dykes. Assume upgrades at same standard as dykes. Limited by height ability / chosen for environmental status.
Marine Facilities									
Crescent Beach Marina	N	3			N	5			
Wards Marina	N	3			N	5			
Private docks	N	3			N	5			
Farms									
Private dairy facilities for over 1,000 head of Cattle	Y	3	1,1,1	3	Y	5	2,2,1,2	10	

Table Group B

Infrastructure Components – Flood / Marine	Flood Scenario B - Current Y/N	P	C	R	Flood Scenario B - Future Y/N	P	C	R	Rational For Consequence
Flood Control Infrastructure									
City of Surrey Sea Dams (2)	Y	3	1,1,2	3	Y	5	3,1,1	15	Should not be greatly affected - operation will be reduced as sea levels rise. One responded not affected - passive structures, but SLR occurrence decreases their window of opening. Reduced functionality - take longer to drain the area. Reliant on pumping for internal drainage. May be affected by increased water pressure.
15 km of dyking, including ditches and floodboxes	Y	3	1,1,5,5	15	Y	5	3,1,2,1	10	Raised - improved capacity. Shorter low tide interval in future. Shorter time to gravity flow out of FB. Stress on dykes could lead to breach. Flooding may be from a breach, higher risk of breach.
City of Surrey: Colebrook Pump Station	Y	3	2,1,2,2,3,5	9	Y	5	3,2,1,2,2	10	Increased maintenance due to increased use (all pump stations). Need to replace & upgrade capacity per lifecycle requirements (low cons) Longer service cycle - operate for longer periods. Working full time (if at all).
City of Surrey: Maple Pump Station	Y	3	2,2,2	6	Y	5	3,2,1,2,2	10	
Corporation of Delta: Oliver Pump Station	Y	3	2,2,2	6	Y	5	3,2,1,2,2	10	
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	3	2,1,1,2,2,2	6	Y	5	2,1,1,1	5	Water flow change affect wildlife. Minor biologic impacts, debris, garbage. Limited impact. Reduced ability to manage water levels, different depths for dabbling vs diving ducks. Increased overland garbage floating in and pollutants.
Water control features to maintain environmentally sensitive area including freshwater irrigation system	Y	3	2,1,2,2,2		Y	5	2,1,1,2	10	Potential garbage / debris impacting system. Minor impacts, debris, garbage. Limited impact.
Screw pump stations (added)									
Marine Facilities									
Crescent Beach Marina	Y	3	2	6	Y	5	1,2	10	Will require adaptation for water levels / flows (all marine facilities)
Wards Marina	Y	3	2,2	6	Y	5	1,2	10	Some damage but limited.
Private docks	Y	3	2,3	9	Y	5	1,2	10	
Farms									
Private dairy facilities for over 1,000 head of Cattle	Y	3	1,2	6	Y	5	1,2	10	Moderate floodin+Y98:AQ114g to grazing land. Reduced grazing areas. Limited damage.

Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turf Runway	Retreat	Retreat	Retreat	Retreat
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	Full wall / sea barrier - Crescent Beach to Delta Border alignment		Accommodate: education and effective response systems	
	7 km section of Highway 99 linking Peace Arch Border	Enhance existing dyke system with new sea dams at mouth of river. Build up as dyke.			
	Highway 91 and 99 Interchange	Highway 99 new dyke alignment and retreat; move sea dam to Highway 99			
	4 km section of Highway 91	Combination of options			
	6 km dyke trail connecting to parks				
	Delta-Surrey Greenway				
	Crescent Road				
	Local Government Arterial and Collector Roads				
	Local Government Arterial and Collector Roads (general)				
	King George Boulevard (City of Surrey)				
	152nd Street (City of Surrey)				
	112 Street (City of Surrey)				
	Colebrook Road (City of Surrey)				
	Ladner Trunk Road (Corporation of Delta)				
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles.				
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains).				
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.				
	Connection to Southern Railway of British Columbia				

This page intentionally blank. Formatted for double-sided printing.

Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	Add gen-sets where necessary. Add off-line emergency storage (Surrey only). Raise buildings and electrical (typical comment for all Sanitary Lift Stations and Scenarios). Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: South Port	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: Winter Crescent	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: Stewart Farm	Coffer dam - floodproof. Flood protect. Flood proof - dam?	Dyke unprotected pump station. Raise elevation of pump station. May need to be raised. Raise station.	Coffer dam - floodproof. Flood Protect. Floodproof - dam?	Dyke unprotected pump station. Coffer dam - floodproof. May need to be raised. Raise station.
	Metro Vancouver: Crescent Beach	Use stainless steel at chambers. If needed, raise existing electrics and controls higher in building. Dykes around community. Offshore islands. Floodproof.	When it is time to replace the PS, design and construct to take into account the flood and sea level rise scenario. Dykes around community. Offshore islands. Raise as capital replacement.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Not affected. None required. (Consensus).	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B.
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Modify valve chambers as required. Upgrade already planned. Address scour in design criteria.	Upgrade already planned. Address scour in design criteria. Address during replacement by MV.	Upgrade already planned. Address scour in design criteria.	Upgrade already planned. Address scour in design criteria. Address during replacement by MV.
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm dia.)	Upgrade as required. Use stainless steel at valve chambers. Address scour in next design criteria.	When it is time to upgrade pipes, design and construct to account for flood & sea level rise scenario. Also design and construct valve chambers that are not susceptible to salt water ingress. Armour river crossings if not already done. If the sea dyke is removed, then moving the sewer line to safety would be considered, but very $$. Address scour in next design criteria.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Address scour in next design criteria.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Address scour in next design criteria.
	>10 km of FortisBC Gas Mains	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Common comment: add valves as isolation strategy, evaluate the crossings, stations elevated. Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Raise stations. Add more valves to isolate shorter reaches Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Raise stations. Add more valves to isolate shorter reaches Not affected
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Not affected. Protect. Divert current at base to protect towers.	Reinforce foundation. Raise the towers. Protect towers near rivers. Accommodate (Raise).	Not affected.	Raise the towers. Accommodate (raise).
	BC Hydro local overhead distribution lines	Change to fibreglass poles in wet areas. Do nothing (listed for all scenarios) No action.	Change to fibreglass poles in wet areas. Replace poles with fibreglass (rot). Program to replace poles - poly/fibre? Accommodate (raise).	Change to fibreglass poles in wet areas. No action.	Change to fibreglass poles in wet areas. Replace poles with fibreglass (rot). Replace poles - poly / fibre? Accommodate (raise, FRP poles)
	Shaw and Telus telecom lines	Change to above ground in flood areas. Accommodate (listed for all scenarios): most of TELUS infrastructure is aerial any future design in accordance to the City can be designed above ground as well to minimize damage. Can't do much about existing infrastructure. Will replace as necessary. Not affected.	Change to above ground in flood areas. Keep services aerial. Some existing underground cables - would replace with aerial if / when there is an issue. Keep all plant aerial; all new developments should be serviced aerially. Not affected. Work in conjunction with BCH	Change to above ground in flood areas. Can't do much about existing infrastructure. Will replace as necessary. Not affected.	Change to above ground in flood areas. Keep all plant aerial; all new developments should be serviced aerially. Not affected. Work / replace in conjunction with BCH.
	Green Infrastructure (Added)	Adapt: plant salt tolerant / flood tolerant species. Protect: encourage tree / shrub growth. Retreat: let nature take its course (for all scenarios)			

This page intentionally blank. Formatted for double-sided printing.

Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	Series of sea dams. What areas do we want to protect Replace & upgrade. Seismic upgrade - bigger gates, add pumps (Protect). Replace & upgrade (Protect). Protection strategy (sea dams and dyking infra). Replace sea dams. Replace for seismic reasons if nothing else (protect).	Augment with pumps.	Don't increase development Pumps (listed for Current & Future) Include pumping capacity. Protect.	Add pumping capacity at sea wall to increase drainage rate. Protect.
	15 km of dyking, including ditches and floodboxes	Upgrade (also listed for Colebrook, Maple (Scenario A Current; Crescent Beach Marina, Wards Marina, Private Dock all scenarios) Upgrade / better floodboxes / deeper ditch (Protect). Increase capacity. Offshore islands.	Consider retreat or accommodation (listed for Colebrook, Maple for both Scenario A and Scenario B Future scenarios). Accommodate? Protect? Offshore islands, raise dykes, other. Add more pumping stations. Offshore islands to reduce heights required. Offshore islands	Pumps (listed for Colebrook, Maple Current). Increase pumping capacity.	Accommodation and upgrades Add more pumping stations.
	City of Surrey: Colebrook Pump Station	Upgrade as required - rebuild with increased capacity.	Increase capacity, raise. Build higher & increase capacity. Upgrade. Accommodate (listed for all PS).		Accommodation and upgrades Accommodate. (listed for all PS)
	City of Surrey: Maple Pump Station		Build higher & increase capacity Abandon		Accommodation and upgrades
	Corporation of Delta: Oliver Pump Station		Upgrade.	Maintain	Accommodation and upgrades Raise water control structures.
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	Accommodate - increase discharge capacity of saltwater.	Relocate west of Highway 99. Expand - transition upland to wetland long-term leases with phases for evaluation for retreat / accommodate.	Maintain	Raise water control structure levels.
	Water control features to maintain environmentally sensitive area including freshwater irrigation system				
	Screw pump stations				
	Marine Facilities				
	Crescent Beach Marina	Accommodate - as infrastructure is replaced / upgrades. Protect / accommodate (listed for all marine facilities current Scenario A and B)	Retreat? Or accommodate. Accommodate. Accommodate (listed for all future condition Scenario A and B)		Accommodate.
	Wards Marina				
	Private docks	Accommodate.			
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	Accommodate (raise buildings, roads, build 'mounds' for cattle retreats). Protect / accommodate (listed for Current Scenario A and B)	Retreat / abandon. Accommodate (listed for Future Scenario A and B)		

Associated Engineering

General Adaptation Comments

Transportation Tables

- Retreat for highways not considered feasible – unless sacrificing land.
- Consider co-benefits of approaches such as: retention / detention ponds – could be irrigation in summer.
- Offshore solution, rock groins, trestles, relocate BNSF
- Onshore: pumps capacity, higher elevations.
- Retreat common option for airpark.
- Accommodate: education and effective response systems.
- Elevate some local roads to prioritize movement.
- Combination of options likely required.
- If BNSF decides to remove their dyke crossing of Mud Bay, this could initiate a retreat, accommodate, or replace the dyke with another superstructure.
- Incremental adaptations are needed to meet changing needs of climate change.
- If the sea dams are upgraded or an offshore dyke barrier is constructed, how will this accommodate future climate changes?
- If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?
- There are too many unknowns. For example, if temperature rises due to climate change, blueberries might not be able to grow. Might not need to prevent the agriculture land. Should continue to monitor the changes over years.
- Do not think it is practical to raise the river dyke.
- Build dyke on the land side, and use Hwy 99 as buffer.
- 152 St will be widened in the future. There is an opportunity to raise 152 St to act as barrier as a secondary flood barrier.
- Retreat for highways not considered feasible – unless sacrificing land.
- Consider co-benefits of approaches such as: retention / detention ponds – could be irrigation in summer.
- Offshore solution, rock groins, trestles, relocate BNSF.
- Onshore: pumps capacity, higher elevations.
- Retreat common option for airpark.
- Accommodate: education and effective response systems.
- Elevate some local roads to prioritize movement.
- Combination of options likely required.
- If BNSF decides to remove their dyke crossing of Mud Bay, this could initiate a retreat, accommodate, or replace the dyke with another super structure.
- Incremental adaptations are needed to meet changing needs of climate change.
- If the sea dams are upgraded or an offshore dyke barrier is constructed, how will this accommodate future climate changes?
- If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be ok with intermittent road closures during high tide?
- There are too many unknowns. For example, if temperature rises due to climate change, blueberries might not be able to grow. Might not need to prevent the agriculture land. Should continue to monitor the changes over years.
- Do not think it is practical to raise the river dyke.
- Build dyke on the land side, and use Highway 99 as buffer.
- 152 St will be widened in the future. There is an opportunity to raise 152 St to act as barrier as a secondary flood barrier.

Utilities Tables

- Upgrade to Metro Vancouver watermain is planned. Address flood issues (especially scour / erosion) in design.
- Build a sea wall across Mud Bay.
- Relocate BNSF (helps White Rock) use new structure of BNSF piles as foundation for a new wall on that same alignment.
- BCH and Shaw/Telus share poles – distribution network prone to rot / destabilization. Can be accommodated by replacing with fibre-reinforced poly poles.
- Dyking good option. Offshore islands are no-go for Crescent Beach
- Need better understanding of sediment transport and flushing and how offshore options would affect this.
- Sewage transmission line to Annacis is needed for now – needs to go through the floodplain. Potential for utility through sea wall rather than through floodplain (risky).
- BCH does resiliency assessments on their transmission lines – approximately 45-year replacement cycle.
- Mainly accommodate.
- Retreating is NOT an option.
- No access to infrastructure.
- Infrastructure permanently submerged.
- Can't maintain infrastructure.
- If retreat from ocean – MV forcemain would be on ocean side of dyke and would be vulnerable. Replacement of forcemain further east. Valve chambers – could use stainless steel.
- Hydro check integrity of wood poles every 10 years, dig 2 feet down and check pole integrity.

Flood Control / Marine Tables

- Focus on off-shore options.
- Accommodate and do incremental upgrades.
- Options are largely driven by rail line management beyond jurisdiction of City.
- Protect seems to be leading contender (with little consideration of $)
- Assumption that dykes are raised in Scenario B – implies protect / accommodate – at what point is retreat considered – eventually will have to. Dyking affects everything else.
- Severity of Scenario B can be partly attenuated through upstream watershed management – decrease peak flow from new developments, or magnified by increases in precipitation
- Offshore solutions:
    - Rock groin\breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate. (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.
    - Offshore Segmental wall – Geotechnical concerns.
    - Trestle (could extend beyond White Rock, BNSF could sell property and build raised trestle) – this would knock down wave height, but not surge and rising sea levels and provide many decades of protection.
    - Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).
    - Without offshore improvements dyke upgrades will be challenging and will take a long time.

This page intentionally blank. Formatted for double-sided printing.

Appendix C - Workshop Exit Survey Responses

Exit Survey Responses

Compiled by City of Surrey

You understood the information that was presented	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	12	21	0	0	0
	36%	64%	0%	0%	0%
	Agree		Undecided	Disagree	
	100%		0%	0%	

The logistics (location, time) of the Workshop were suitable:	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	13	18	1	1	0
	39%	55%	3%	3%	0%
	Agree		Undecided	Disagree	
	94%		3%	3%	

You felt your opinion was heard?	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	11	21	0	1	0
	33%	64%	0%	3%	0%
	Agree		Undecided	Disagree	
	97%		0%	3%	

You will like to continue to be involved in the CFAS planning process:	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	7	13	12	0	0
	22%	41%	38%	0%	0%
	Agree		Undecided	Disagree	
	63%		38%	0%	

The length of the workshop was:	Much too short	Too short	Just right	Too long	Much too long
	0	0	27	6	0
	0%	0%	82%	18%	0%
	Short		Just Right	Long	
	0%		82%	18%	

To what extent is coastal flooding a concern for you and your family?	Low	Medium	High
	4	15	20
	10%	38%	51%

Do you feel that your top concerns about coastal flooding were captured today?	Yes	No
	37	4
	90%	10%

Do you have a greater awareness of the impacts of flooding on infrastructure in Mud Bay?	Yes	No
	37	1
	97%	3%

Response Statistics	
Participant Attendance	59
Submitted Exit Survey	38
Exit Survey Response Rate	64%
Submitted Workbooks	42
Workbook Response Rate	71%

Question 3	Question 5	Question 11
If your main concerns were not addressed, could you please tell us what are your top concerns?	Are there any adaptation options or strategies you would like to see explored further related to infrastructure in the area	Please provide any further comments on today's meeting (Feb 3, 2017)
Foreshore Dyke	Foreshore Dyke	
Yes & no.		
		As a federal response agency, I did not have much input other than to make aware the Coast Guard as a response option. Thank you for including us in the discussion
	Look at development strategies and policies to assure net zero surface flow post/pre development. Low impact development strategies. Buy/lease back land options	
Green infrastructure & its potential to provide solutions	Green infrastructure	Too slow developing and running through scenarios
	Feasibility of the offshore option	
		Great presentations - very informative
	Offshore barrier islands. Raise highway 99 as a dyke	
	No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the lower mainland	Good cross section of stakeholder representations for awareness and future engagement on this subject matter...thank you
	What would be a global approach to adopt options to develop	
	Sea level rise & subsidence are long term processes that will continue indefinately. Protect options buy time, rather than provide permanent protection. You must consider how long protection options will be effective for	
		Well put together
Growing population in south surrey, impact on the network. Traffic congestion on alternate route not able/delay to get to work		
	PIEVC has good risk rank procedure to sort outstanding priorities	Very practical workshop but few more presentations would have been more helpful
	Options analysis for all 3 options	Job well done
	1. Incremental adaptions 2. Engage the whole lower mainland area	
Serpentine river basin rainfall outcomes on the upper basin; river basin dyke assumptions on "Part B" directed the conversation too quickly away from river issues.	The great mud bay dyke/wall to reclaim more land	Great facilitation by associated engineering
Emergency Services & impact on residents	All that we discussed	
	Look at options and evaluate problems they solve instead of vice versa	
	Yes, engagement with neighbouring municipalities should be needed for this type of workshop	
	Raise the dyke - build the a barrier wall	
	BC Hydro may implement protect or accommodate adaptation for its infrastructure	Environmental impacts: I didn't see much info on this in the workshop
	Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay	Could have been accomplished in 3/4 of a day
Focus on people, infrastructure, ACR lands over Mud Bay environmental impacts	As per #3	Very good timely discussion, need Langely to come to the table. Delta should have remained after lunch

REPORT

Volume 2 – Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using Engineers Canada PIEVC Protocol (ICFAA): Workshop Summary and Outcomes

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY
the future lives here.

Associated Engineering
GLOBAL PERSPECTIVE.
LOCAL FOCUS.

CFAS

MARCH 2018

Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using Engineers Canada PIEVC Protocol (ICFAA)

Workshop Summary and Outcomes

REPORT

epi
nhc northwest hydraulic consultants
Delta
ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA
BRITISH COLUMBIA Ministry of Transportation and Infrastructure
engineerscanada ingénieurscanada

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date MARCH 29, 2018 08-18-003

CONFIDENTIALITY AND © COPYRIGHT

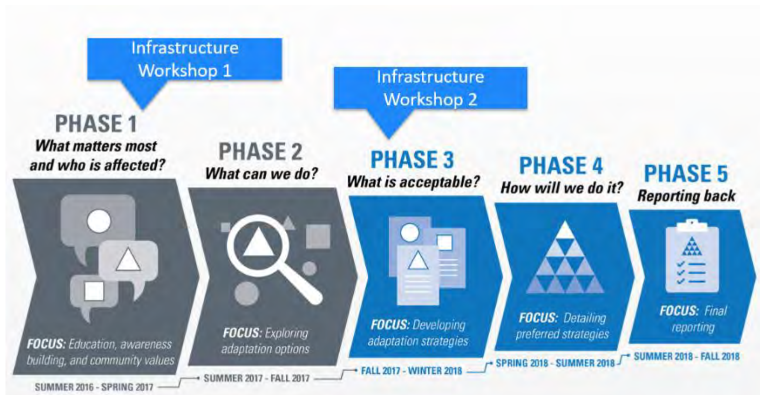
Executive Summary

1 COASTAL FLOOD ADAPTATION STRATEGY

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

The overall Coastal Flood Adaptation Strategy (CFAS) is being led by Northwest Hydraulic Consultants (NHC), with EcoPlan International, Diamond Head Consulting, and KM Consulting as subconsultants.

The first phase of the overall CFAS process consisted of extensive education and awareness of the flood hazards that exist, and involved gaining input from stakeholders on their values and objectives. This involved the engagement of residents, environmental and First Nations groups, and infrastructure asset owners and emergency responders.



The second and third phases of the CFAS process are ongoing, and consist of the developing and evaluating several adaptation strategies that the City could potentially implement. The options were developed and evaluated by the CFAS team based on technical criteria, and on how well they meet the values criteria of the various stakeholders.

Associated Engineering's (AE) involvement has been to provide support to the CFAS project by engaging infrastructure asset owners with respect to risk and adaptation through two workshops, described below.

2 INFRASTRUCTURE VULNERABILITY WORKSHOP

In support of the first phase of the CFAS process, the City engaged AE to develop and lead a workshop designed around the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol, specifically targeted at assessing the risk to infrastructure in the Mud Bay area. The first workshop found that without adaptation, a significant proportion of the infrastructure will have unacceptably high risk in the future.

During the workshop, there was some initial discussion surrounding how infrastructure might adapt, however one of the recommendations was to explore adaptation in further detail.

3 IMPROVING COASTAL FLOOD ADAPTATION APPROACHES WORKSHOP

The outcome of the first workshop identified the need to continue to engage infrastructure organizations throughout CFAS Phases 2 and 3, which involve the comparison of various adaptation options the City may undertake. The options being considered each have implications on infrastructure located in Mud Bay. Some of the options are centered around retreat, which would leave the infrastructure exposed to coastal flood hazards, and would necessitate action from the individual infrastructure owners to manage their own risks to within levels they deem acceptable. Other proposed options would only work if certain key pieces of infrastructure were integrated directly into the strategy itself.

In recognition of this, the City engaged AE, with support from the CFAS project team (NHC and EcoPlan), to develop and deliver a second workshop targeted at infrastructure owners. The workshop builds on the first workshop that was held in March 2017, and focuses on how the City-led adaptation strategies can be enhanced through active participation by the infrastructure owners in the area.

This report outlines the basis for, and the outcomes of the second workshop, which was titled Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk (ICFAA for short).

The ICFAA workshop centered around evaluating two options being considered by the City:

- Coastal realignment to 152 Street, and
- River realignment

We note that the two options represent only a subset of the options that the City has been considering. The project team decided that the workshop would be most effective if participants could discuss two options in detail, rather than eight options at a high level. The options were selected because they each have substantially different implications for existing infrastructure in the area, and the discussions around benefits and challenges were thought to be applicable to many of the other adaptation options being considered. We note that neither of the two options reviewed in the workshop are necessarily the City's preferred options.

The workshop exercises were designed to allow participants to review the assumptions made in developing both options, and to discuss challenges and opportunities in implementing them, from the perspective of transportation, utilities, flood control, and marine infrastructure sectors.

The workshops used further steps of the PIEVC Protocol, including a triple bottom line approach to identify factors that are most strongly influential in the decision-making process of the individual organization, considering environmental, social, and economic factors. By qualitatively identifying the factors with the greatest influence, the results could be brought into the multi-factor analysis being used by the CFAS team in evaluating all the potential adaptation options, to further support decision-making.

4 KEY COMMENTS FROM INFRASTRUCTURE STAKEHOLDERS

Section 3 of this report summarizes the participants' comments on each adaptation option. A selection of some of the key general comments include the following:

- **Cost-sharing and collaboration is a high priority** because of the scale of the infrastructure impacted. These opportunities need to be mutually beneficial.
- **The changes being considered provide the opportunity to explore multi-purpose enhancements,** including mass transit, HOV lanes, greenways, recreational trails, and environmental features that will improve public acceptance of the changes.
- **Shared utility corridors allow for cost-sharing**, and lessen the amount of land needed for relocations; however, this can impose a new risk, where if one utility fails, it can impact others in the corridor.
- **Relocation and redesign of infrastructure allows the opportunity to meet other objectives** of the sectors, including seismic resilience, and efficiency improvements.

5 KEY INSIGHTS FOR FUTURE DECISION-MAKING

Section 5 provides a detailed summary of the workshop findings. In general, it was found that regardless of the adaptation option pursued by the City, initiatives by the individual infrastructure sectors will be required to maintain an acceptable level of risk. A selection of the key insights that influence decision making are summarized as follows:

- **Much of the key infrastructure in the Mud Bay area is adaptable**. Therefore, the City could choose an option that meets their own needs, and allow infrastructure owners to adapt in ways that suit their organizational needs.
- **Flood protection infrastructure and transportation infrastructure are strongly related**. Significant gaps in the flood control infrastructure cannot be resolved unless railways and highways are relocated. Coordination with these entities, and with the adjacent municipality is essential.
- **Further work by individual utility and service providers is needed.** Infrastructure sectors need to evaluate their thresholds of tolerable risk, develop plans for adapting their assets, and monitor their level of risk to determine when to act.

- **Implementing adaptation strategies would benefit from coordinated regulatory applications.** Many of the strategies will require non-standard features that will require special approval from various regulatory agencies. A coordinated effort is needed to ensure that design standards and guidelines support what is proposed.

6 NEXT STEPS

The ICFAA workshop is one of many stakeholder workshops that is feeding into the overall CFAS decision-making process. The workshop focused on a subset of the potential options being considered, and so the outcomes and findings are intended to guide the CFAS.

The next steps in the process could include the following:

- Shortlisting of adaptation options. This would involve not only shortlisting of the City's adaptation options by the CFAS team, but also further investigation by individual infrastructure sectors on how they can adapt.
- Development of an adaptation framework. This would involve developing an implementation framework for the preferred option, involving both the City and infrastructure sectors. This would outline the actions to be taken by the sectors, and would guide long-term planning for each organization.
- Ongoing monitoring by the City as well as infrastructure organizations. This would include not only monitoring of how the risk profile is changing, but also monitoring the actions of individual infrastructure organizations to ensure a cohesive path to adaptation is followed.

Table of Contents

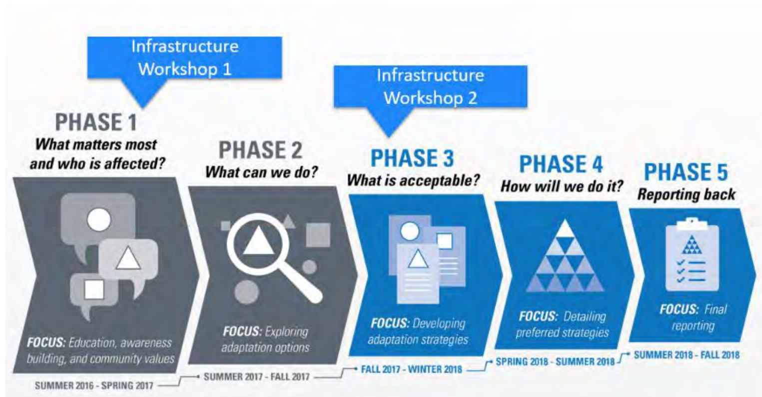
1 Introduction

1.1 COASTAL FLOOD ADAPTATION STRATEGY

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

The overall Coastal Flood Adaptation Strategy (CFAS) is being led by Northwest Hydraulic Consultants (NHC), with EcoPlan International, Diamond Head Consulting, and KM Consulting as subconsultants.

The first phase of the overall CFAS process consisted of extensive education and awareness of the flood hazards that exist, and involved gaining input from stakeholders on their values and objectives. This involved the engagement of residents, environmental and First Nations groups, and infrastructure asset owners and emergency responders.



The second and third phases of the CFAS process are ongoing, and consist of developing and evaluating several adaptation strategies that the City could potentially implement. The options were developed and evaluated by the CFAS team based on technical criteria, and on how well they meet the values criteria of the various stakeholders.

Associated Engineering's (AE) involvement has been to provide support to the CFAS project by engaging infrastructure asset owners with respect to risk and adaptation through two workshops, described below.

1.2 INFRASTRUCTURE VULNERABILITY WORKSHOP

In support of the first phase of the CFAS process, the City engaged AE to develop and lead a workshop specifically targeted at assessing the risk to infrastructure in the Mud Bay area. Full details on this process can be found in the *Mud Bay Infrastructure Assessment PIEVC Workshop: Summary and Outcomes* report (Associated Engineering, June 2017; available at http://www.surrey.ca/files/CFAS-PIEVC-Workshop.pdf)

This workshop was held on March 28, 2017, and followed the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) process. The workshop involved assigning risk scores to each of the 40 major infrastructure components west of 152 Street (the study area).

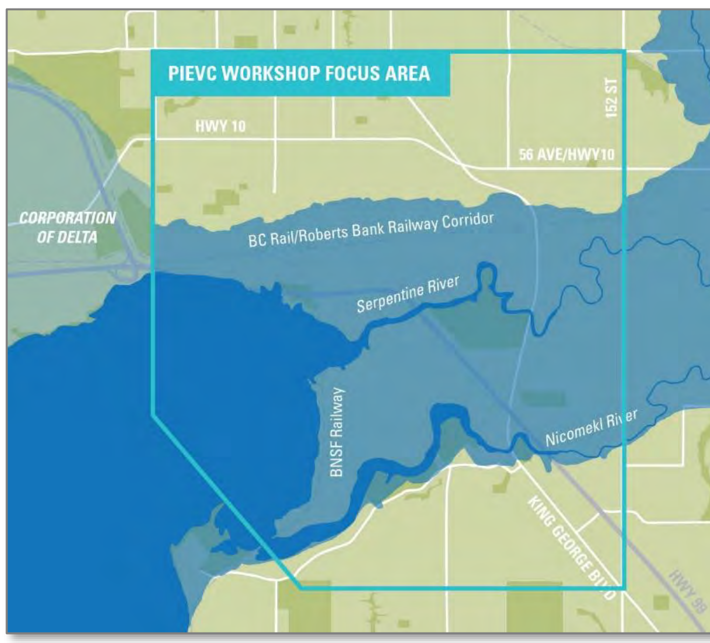
A total of 66 participants representing 28 organizations attended the workshop. The first workshop found that without adaptation, a significant proportion of the infrastructure will have unacceptably high risk in the future.

During the workshop, there was some initial discussion surrounding how infrastructure might choose to adapt, however one of the recommendations was to explore adaptation in further detail.

1.3 IMPROVING COASTAL FLOOD ADAPTATION APPROACHES

The adaptation options developed by the CFAS project team as part of Phases 2 and 3 have implications on the infrastructure located in Mud Bay. Some of the options are centered around retreat, which would leave the infrastructure exposed to coastal flood hazards, and necessitate action from the individual infrastructure owners to manage their own risks to within acceptable levels. Other proposed options would only work if certain key pieces of infrastructure were integrated directly into the strategy itself.

In recognition of this, the City engaged AE, with support from the CFAS project team (NHC and EcoPlan), to develop and deliver a second workshop targeted at infrastructure owners. The workshop builds on the first workshop that was held in March 2017, and focuses on how the City-led adaptation strategies can be enhanced through active participation by the infrastructure owners in the area.



This report outlines the basis for, and the outcomes of the second workshop, which was titled Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk (ICFAA for short). NHC provided details on the adaptation scenarios used in the workshop, and EcoPlan developed the graphics and compiled the Workshop Backgrounder. A weblink to this document is provided in Appendix A.

1.4 ACKNOWLEDGEMENT

We would like to acknowledge the City of Surrey in preparation of this work as well project sponsors, Engineers Canada (EC), Engineers and Geoscientists British Columbia (EGBC), Federation of Canadian Municipalities (FCM) and Associated Engineering's partnering consultants on the project; Northwest Hydraulic Consultants (NHC) and EcoPlan International. In addition, we would like to acknowledge the project assessment team from a variety of organizations, including:

Name	Organization
Neal Aven	City of Surrey
Carrie Baron	City of Surrey
Monica Mannerstrom	Northwest Hydraulic Consultants
Charlie Bartlett	Associated Engineering
Don Buchanan	City of Surrey
Tugce Conger	University of British Columbia
Danielle Daigneault	RCMP
Elena Farmer	Ministry of Transportation and Infrastructure
Lotte Flint-Petersen	Emergency Management BC
Richard Foth	SRY Rail Link
Mariya Ivanytska	Representing Surrey Board of Trade
Khalid Khan	Ministry of Transportation and Infrastructure
Cher King-Scobie	Fraser Basin Council
Kamelli Mark	Agricultural Land Commission
Shelley Morris	City of Surrey Fire Service
Brit Naylor	University of British Columbia
Matt Osler	City of Surrey
Mujib Rahman	FortisBC
Sean Smith	Vancouver Fraser Port Authority
Chad Taylor	Corporation of Delta
Cindy Tse	City of Surrey
Shawna Wilson	Agricultural Land Commission

2 Workshop Background and Basis

2.1 CONTINUATION OF THE PIEVC PROCESS

The ICFAA workshop builds upon the vulnerability assessment workshop conducted in March 2017. The flow of the process is shown in Figure 2-1.

In evaluating adaptation strategies, the decision-making process should not only integrate engineering criteria, but also consider economic, environmental and social factors, known as triple bottom line factors (TBL). The various infrastructure owners will apply different criteria in making decisions regarding their assets than would stakeholder groups engaged through other CFAS workshops.

To assist in this process, the PIEVC Protocol provides a triple bottom line decision-making module that helps to establish, in broad terms, environmental, social and economic factors to aid decision-makers in selecting appropriate adaptation actions and strategies. The use of a TBL-support tool is a means of priority setting; it helps decision-makers balance competing interests to provide the greatest overall return on investment that extends beyond purely financial terms.

In the context of PIEVC, the TBL analysis is a decision-support system designed to aid organizations in determining a course of action to reduce vulnerability of infrastructure assets and services to climate change impacts. The goal of the Protocol is to help organizations assess the vulnerability of an infrastructure system and its components. Once vulnerabilities are identified, solutions to adapting the infrastructure system can be developed. If more than one solution can be developed, they can be compared based on environmental, social, and economic criteria.

The TBL analysis, like other decision-support systems, is designed to help organizations make better-informed decisions. Its structured process helps organizations explicitly consider the issues that arise in a decision-making process, and their importance to the overall decision. It provides a framework and documentation support to help organizations undertake a decision-making process, and record important aspects along the way. The application of a TBL analysis also promotes organizational learning; educating participants on the issues is as important as arriving at a recommended course of action. Using workshops and meetings, decision-makers, specialists and other stakeholders are brought together to discuss and debate issues, thereby maximizing the learning potential offered by the process. This is important because the learning process itself constitutes a form of adaptation to climate change. Improving participant knowledge enhances organizational resilience and increases its ability to make informed decisions and act in the face of a changing climate.

The TBL analysis is a high-level planning and screening exercise that relies heavily on professional judgment for its execution. This is justified for several reasons. First, participants possess in-depth knowledge about infrastructure responses to climate events and have experience in engineering, management and operations. Second, participants with different roles and experiences are brought together through meetings and workshops. This helps to cross-stimulate the generation of ideas, encourages non-silo thinking and checks ideas through the diversity of expertise present. Finally, professional judgment should allow participants to assess a multitude of options quickly, and in a manner that is sufficient to set the general directions for the organization in terms of actions, engineering and further analyses. Given the early stage of planning in which the TBL analysis is situated, and for the reasons just exposed, the reliance on professional judgment is reasonable.

2.2 TBL ANALYSIS METHODOLOGY

The PIEVC Protocol's Steps 1 through 5 were completed during the first workshop in March 2017, with the exception of Step 4 (Engineering Analysis).

For the CFAS ICFAA workshop, Step 4, Step 6 and elements of Step 7 were explored. The TBL analysis is incorporated into these steps. Step 8, recommendations and follow-up will be explored into the next phases of the CFAS project. The flowchart of the TBL analysis proposed in this guide is presented in Figure 2-1.

Step 4 involves engineering analysis. This step was omitted from the high-level screening assessment that was followed for the first workshop, but was incorporated as advance work to support the second workshop. The analysis involved infrastructure experts with specialized background in flood control and drainage, utilities, and transportation, reviewing the options being considered in the workshop. The intent of the analysis was to review the assumptions made in developing the options to be workshopped, and to further refine the details of each option. Step 6, Developing Adaptation Scenarios, is a preparatory activity that guides the practitioner in the development of solutions (adaptation approaches), to address infrastructure system and service vulnerabilities. In Step 7, TBL Comparative Assessment, practitioners are guided in the setup and execution a multi-factor analysis to compare adaptation scenarios. This is a key step in identifying the factors that influence decision-making within each infrastructure organization, and provides a qualitative assessment of which of those factors are the most influential. Finally, in Step 8, the recommendations and follow-up to the TBL analysis are determined. The flowchart of the TBL analysis proposed in this guide is presented in Figure 2-1.

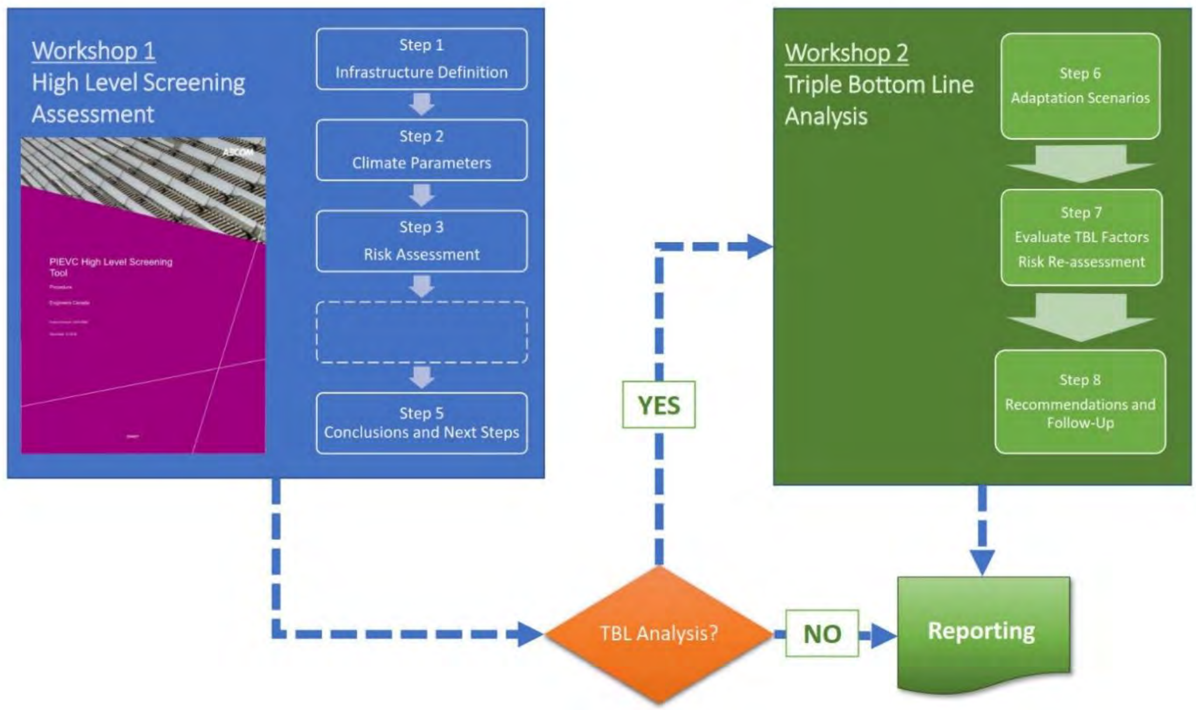


Figure 2-1
Infrastructure Vulnerability and Adaptation Workshop Process

2.3 STUDY AREA TOUR

Three weeks before the workshop (on September 25, 2017), the City of Surrey and EcoPlan hosted a chartered bus tour of the study area. During the tour, participants were introduced to the two adaptation options that would be discussed in the workshop. Throughout the tour, the location of key infrastructure was pointed out to the attendees.

The tour stopped at the Serpentine River sea dam, and the Burlington Northern Santa Fe (BNSF) swing bridge on the Nicomekl River. During these stops, attendees broke into groups to discuss the following:

- How will this landscape change in the future as one of the two adaptation options discussed are implemented?
- What are some of the benefits and opportunities you see from the changes in the landscape? What are some of the drawbacks you see from the changes in the landscape?
- What sort of infrastructure renewal might occur here over the next 80 years (underground, overhead, and surface infrastructure; amenities; agriculture)?
- What would your organization / agency / business need to do to adapt to this changing landscape?

In general, there was a desire for more details about the two options. Key points from the discussion are highlighted below. Additional attendee comments along with additional site photos are included in Appendix B.

- Regional and interjurisdictional coordination is needed.
- Significant costs are associated with both options, and so the opportunity for cost-sharing is important.
- Regulators would need to be on board with the strategy from the start, and political will would need to exist for any strategy to be achievable.
- Opportunities to improve the overall resilience of infrastructure to address other factors like seismic design exist and should be explored.
- Adaptability over time and phasing will be important.

2.4 ICFAA WORKSHOP

The ICFAA workshop was held at Surrey City Hall on October 10, 2017. A total of 58 people attended, representing 23 organizations. The workshop agenda is included in Appendix A.

ICFAA Workshop Attendee Organizations	
Agricultural Land Commission	Fraser Basin Council
Associated Engineering	Metro Vancouver
BC Agriculture and Food Climate Action Initiative	Ministry of Environment
BC Hydro	Ministry of Transportation and Infrastructure
City of Surrey	Northwest Hydraulic Consultants
City of Surrey Fire Service	RCMP
Corporation of Delta	Surrey Board of Trade Representative
EcoPlan	SRY Rail Link
Emergency Management BC	Thrive Consulting
Engineers and Geoscientists BC	University of British Columbia
Engineers Canada	Vancouver Fraser Port Authority
FortisBC	

The day began with round-table introductions, followed by presentations by AE, the City of Surrey, and EcoPlan. The presentations outlined the purpose of the workshop, the overall CFAS process, and introduced the adaptation options that would be the focus of the workshop exercises.

The workshop exercises included the evaluation of two adaptation options (described in the following sections). The first two exercises of the day focused on refining the TBL factors developed by AE in advance of the workshop, and reviewing how each of the infrastructure sectors might choose to respond to the adaptation options presented to manage their own risk.

In the third and final exercise, the participants discussed what next steps would be the most effective in making the implementation of the CFAS successful. In this discussion, considerations around monitoring risks, identifying thresholds and triggers for action, and collaboration for decision making were explored.

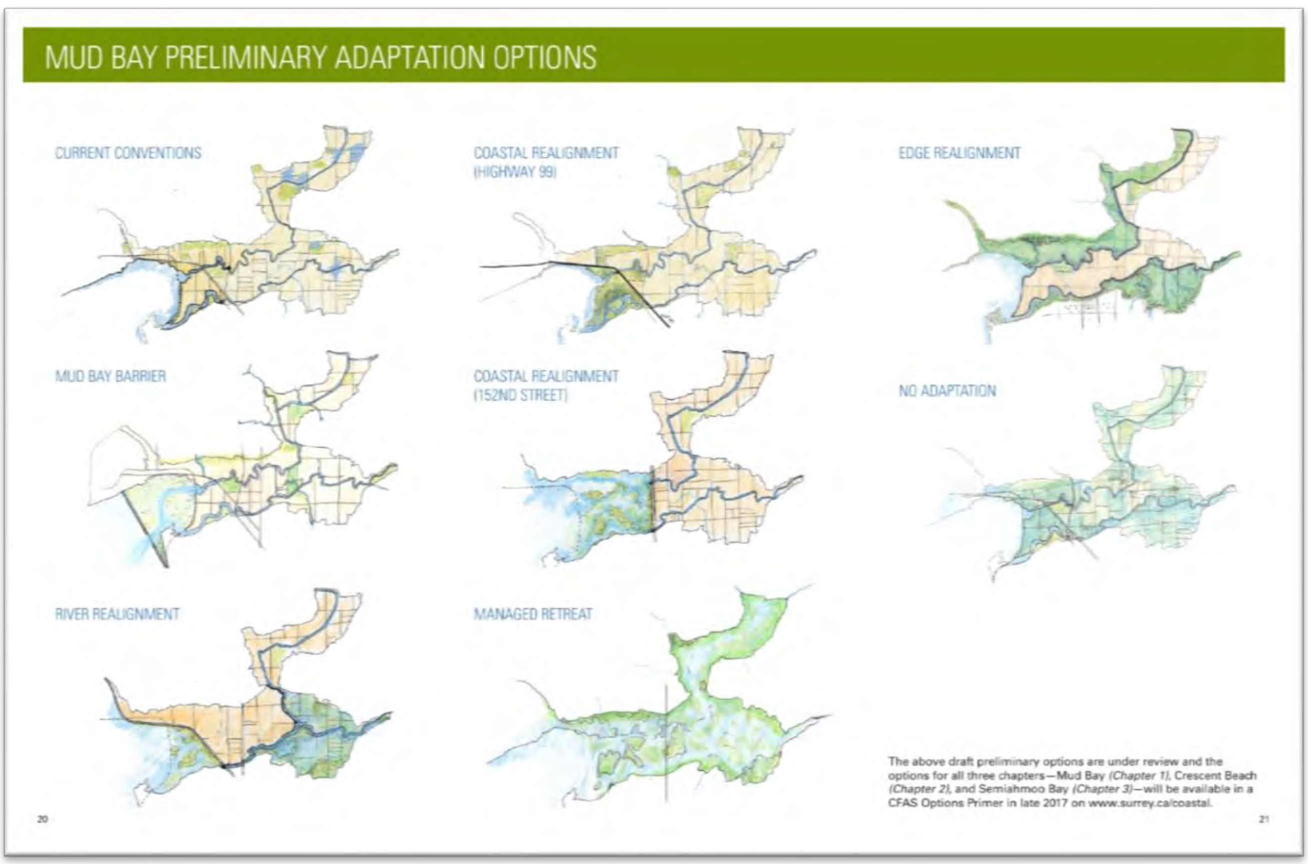
A copy of the presentation used during the workshop is available at http://www.surrey.ca/files/CFAS%20Infrastructure%20Vulnerability%20Workshop%20Presentation%20March%2028%202017.pdf.

3 Step 6 - Adaptation Scenarios

Step 6 of the PIEVC Triple Bottom Line module involves identifying and evaluating adaptation scenarios to address the risks identified in earlier stages. We adapted the principles of this stage to suit the CFAS project process.

As part of Phase 2 of the overall CFAS project, the CFAS project team has developed eight adaptation options within Mud Bay. The eight options are summarized in the Workshop Backgrounder included in Appendix A, and consist of the following:

- Current Conventions
- Mud Bay Barrier
- River Realignment
- Coastal Realignment to Highway 99
- Coastal Realignment to 152 Street
- Managed Retreat
- Edge Realignment
- No Adaptation



The CFAS project team evaluated each of the eight options based on how well they satisfied certain technical criteria, and values criteria of the various stakeholder groups.

In acknowledgement of the complex relationship between the eight flood adaptation options being evaluated and the infrastructure located in Mud Bay, further attention on the infrastructure was warranted, and triggered the need for this second workshop.

The workshop focused on the impact to infrastructure under two of the eight proposed adaptation options:

- Coastal realignment to 152 Street, and
- River realignment.

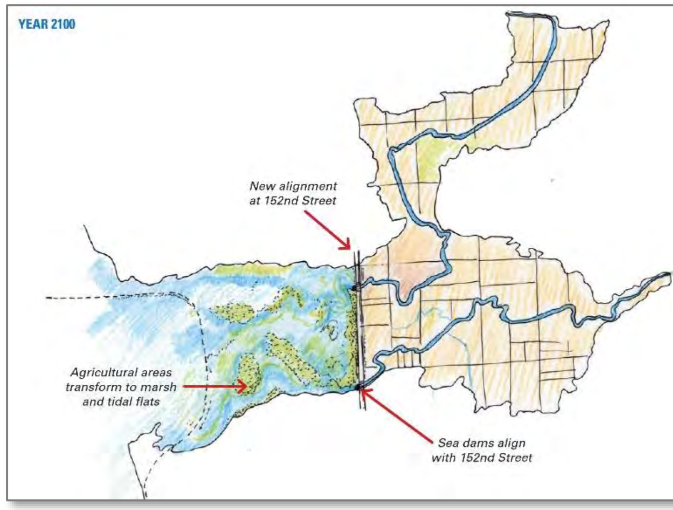
We note that the two options represent only a subset of all of the options that the City has been considering. The project team decided that the workshop would be most effective if participants could discuss two options in detail, rather than eight options at a high level. The options were selected because they each have substantially different implications for existing infrastructure in the area, and the discussions around benefits and challenges were thought to be applicable to many of the other adaptation options being considered. We note that neither of the two options reviewed in the workshop are necessarily the City's preferred options.

Depending on the option the City would decide to pursue in the overall CFAS, based on input from all stakeholders and partners, it would require some or all infrastructure owners to take their own actions to either integrate with the proposed option, or to undertake their own adaptation approaches to maintain their coastal flood risks within acceptable thresholds.

The workshop was designed to review the assumptions on how infrastructure might respond for each of the two adaptation options. This review identifies whether the assumed actions are realistic or not, which influences whether an option is viable. It also enables the CFAS project team, the City of Surrey, and infrastructure organizations to better understand the types of local and regional collaboration needed to progress the strategy successfully.

The two options that were the focus of the workshop are summarized in the following subsections. Additional details are included in the Workshop Backgrounder in Appendix A.

3.1 COASTAL REALIGNMENT TO 152 STREET

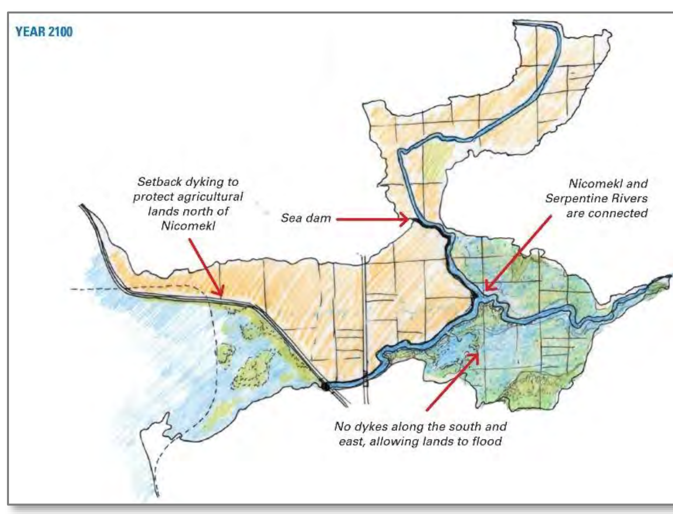


The first adaptation option considered for the workshop was the coastal realignment to 152 Street. Under this option, the City would abandon their current flood control infrastructure, and construct a new coastal dyke along the alignment of 152 Street. This would leave the infrastructure west of 152 Street exposed to coastal flooding. Any measures to reduce risk to the exposed infrastructure would need to be done by the organizations themselves.

One of the initial assumptions for this option was that Highway 99 and King George Boulevard would both be realigned along the 152 Street alignment, and so be protected by the new dyke. Relocating Highway 99 was found to be not feasible for the following reasons:

- Relocating Highway 99 along the north side of the floodplain would be prohibitively expensive;
- Merging different road classifications (highway, arterial, and local) is not acceptable from a traffic operations perspective, and there is no room for the interchanges that would be needed;
- Gaining public support for such a major road modification would be challenging, if not impossible;
- There would be no alternate routes available for emergency response.

3.2 RIVER REALIGNMENT



The second adaptation option considered was the merging of the Serpentine and Nicomekl Rivers into a single, larger system, following the current alignment of the Nicomekl River.

In this option, a new coastal super dyke would be constructed along the current alignment of Highway 99.

Infrastructure to the west of Highway 99 would be unprotected and exposed to coastal flooding. Infrastructure to the east would generally be protected, but would need to be extensively reconfigured in some areas to make the option functionally achievable. This would require a coordinated effort between the City and the various infrastructure owners for it to be plausible.

The option assumes that King George Boulevard would be merged with 152 Street. The workshop participants noted this is unnecessary, and that it could remain on its current alignment, if minor changes were made to the interchange with Highway 99, because the new superdyke would protect the section of King George Boulevard between Crescent Road and Highway 99.

Another initial assumption was that the Serpentine River would be infilled. Participants agreed that the river should be maintained to help drain the local uplands, improve drainage of the agricultural fields, and potentially serve as a water storage reservoir for irrigation. This would change the function of the channel to carry low flows, with perhaps a high flow bypass where the proposed new channel would be constructed to join with the Nicomekl River and drain to the ocean.

3.3 WORKSHOP DISCUSSION OUTCOMES

For each of the two adaptation scenarios, the workshop participants were presented with the preliminary assumptions of how the infrastructure categories would likely respond to maintain their own risk within acceptable tolerances. The first two workshop exercises involved reviewing and providing commentary on these assumptions.

Some of the key general comments (applicable to both options) are as follows:

- Cost-sharing and collaboration is a high priority because of the scale of the infrastructure impacted. These opportunities need to be mutually beneficial.
- The changes provide the opportunity to explore multi-purpose enhancements, including mass transit, HOV lanes, greenways, recreational trails, and environmental features that will improve public acceptance of the changes.
- Shared utility corridors allow for cost-sharing and lessen the amount of land needed for relocations, however this can impose a new risk, where if one utility fails, it can impact others in the corridor.
- Relocation and redesign of infrastructure allows the opportunity to meet other objectives of the sectors, including seismic resilience, and efficiency improvements.

Tables 3-1 and 3-2 summarize the participants' comments on the adaptation scenarios for each infrastructure category.

Table 3-1: Workshop Commentary by Infrastructure Category
Adaptation Option 1: Coastal Realignment to 152 Street

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 1 – Coastal Realignment to 152 Street
Major Roads (City of Surrey) King George Boulevard Highway 99 152 Street	Merge 152 Street and King George Boulevard, protected by, or located on top of super-dyke. Highway 99 either merged with 152 Street and King George Boulevard, or raised (earthen embankment with several equalization culverts, or a supported 'wetland' structure). Issues include land available for interchanges, mixing of conflicting traffic classifications. Regional context needed to consider Highway 91, Ladner Trunk Road, future traffic needs.	• Regional transportation plans to 2100 need to be coordinated within this option, including projected traffic demands, congestion, alternative transportation methods. • Whether Highway 99 is relocated or remains in place, it will need to be raised all the way through Delta and needs to be coordinated beyond the Mud Bay study area. • All the TBL factors have a strong influence on the decision-making process for road projects. • Public perception is critical, and will be influenced by any loss of agricultural land, environmental habitat, traffic capacity, recreational trails, emergency response capability, etc. • Because of the regional connections to the USA and South Surrey, disruption of commerce is a concern that will need to be mitigated through appropriate phasing and possibly constructing new routes or features off-line. • Adding a lane to a highway is generally \$1.1M to \$1.2M per km, but high embankments and poor soil conditions can greatly raise this cost. These conditions are expected in Mud Bay.
Major Roads (Corporation of Delta) Highway 91 Highway 99 Ladner Trunk Road	Raise, or reroute; coordinate with regional planning needs.	• Through Delta, realignment of roads as the sole adaptation measure is not feasible because the entire region is floodplain. • Raising and/or protecting is likely the only option through Delta.
Railway Infrastructure BNSF Embankment Trestles Swing Bridge BCRC Embankment	Continuous trestle over flooded area; raised embankment with several equalization culverts, or regional relocation east of 152 Street.	• BNSF recently invested significantly to upgrade their infrastructure, which is likely to influence their willingness to relocate before 2100, and cost-sharing and collaboration opportunities may need to be explored. Opportunities may exist for provincial or federal funding given the economic importance of the network. During the Study Area Tour, this investment was estimated at less than \$50M. • Raising in place would extend impacts well beyond study area. • Decisions made by BNSF to raise or relocate will influence BCRC and Southern Railway tie-ins.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 1 – Coastal Realignment to 152 Street
		• Rails are generally replaced on a 10 – 20-year cycle, but the embankments remain in place.
Sanitary Lift Stations	Raise and protect; dependent on reconfiguration of sanitary mains.	• On the fringes of the floodplain, but reconfigurations will depend on modifications to the local system and to the Metro Vancouver main. • Disturbance during upgrades will need to be mitigated to maintain positive public perception, but will generally be unnoticed provided level of service is retained.
Metro Vancouver Sanitary Main	Accommodate: reduce leakage potential, recognizing constant inundation; access chambers elevated above flood level with provisions for boat access; redesign as submarine crossings, but challenging given seismic event / shifting soils. Retreat: relocation allows consideration of seismic needs in design; could utilize shared ROW corridor in collaboration with other utilities.	• Natural replacement timelines are approaching; provides the opportunity to relocate or design as a submarine crossing. If retrofit, would have access issues and would need to provide access for maintenance. Challenging if local roads no longer exist. • Regulatory compliance may be a greater issue if the line is relocated, rather than retrofit, but either could provide an opportunity to improve the seismic resilience of the system. • Regular submergence could attract the attention of public and environmental groups. • Likely approach would be to maintain until the end of its service life and then relocate.
Metro Vancouver Water Main	Accommodate: Design as a marine crossing, access chambers and valves with surfaces above flood elevation; corrosion sensitive Retreat: WM constructed in 1977, end of life approaching; relocation allows consideration of seismic needs; could utilize shared utility ROW corridor in collaboration with other utilities.	• Steel watermain approaching the end of its functional life. Steel crossing can manage some submergence, but regular inundation would require retrofit to accommodate. • Access becomes difficult, especially if local access roads are not available. This is problematic because of the importance of the main for emergency response. • Likely approach is to maintain the current convention for as long as is practical, and then relocate outside of the flood risk zone (Newton Reservoir to Sunnyside). There could be potential sharing of a utility corridor, especially if Highway 99 is built as a bridge.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 1 – Coastal Realignment to 152 Street
FortisBC Gas Mains	Response dependent on residence and businesses remaining or retreating from the area.	• Dependent on what remains within the flooded area, and so is generally responsive to demand. • Pipelines would be abandoned in place once the demand in the coastal floodplain is removed; once replacement timelines are reached, could realign along the new 152 Street corridor to service customers as needed.
BC Hydro Transmission Lines	Allow inundation along the base of the towers; provide adequate protection from destabilization due to scour / corrosion. Build up bases into islands and harden against salt water. Explore shared utility ROW / corridor with other relocated utilities. Confirm clearance to wires remains within allowable limits, or restring / raise towers. Regular maintenance is typically from air.	• Moving towers generally costs $0.5M per tower, and requires 100 m swath. Realignments through inhabited areas will be impossible because of public perception. • Raising towers in place through the coastal floodplain is estimated to cost $15M - $30M, and a submarine crossing would be in the $100M - $300M range. • The nearest alternative is in Cranbrook, and capital cost is the primary driver for any decision.
Drainage Pump Stations, Ditches, Floodboxes	Ditches, pump stations, and floodboxes west of 152 Street abandoned or drastically reconfigured.	• Decommissioning would be required, and this cost should not be overlooked. • Reconfiguration of the drainage system would be required, with the pump stations, dykes, and channels needing to be relocated towards the fringes of the floodplains to service drainage from the upland areas. • New pump stations would be required at the relocated sea dams.
King George Airpark	Abandoned.	• Regulatory compliance is an important decision-maker, and abandonment may require decontamination, fuel tank management. • RCMP operates at the airpark.
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	Abandoned.	• Loss of recreational trails would be met with pushback from the public, but with appropriate planning new improved trails and greenways can be implemented with other infrastructure in the area, so can be managed.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 1 – Coastal Realignment to 152 Street
Local roads	Abandoned.	• Decommissioning of roads would be needed, and this raises questions about disposal and contaminated sites designation. • Local roads would need to be maintained to service any users that remain, including agriculture, utility services, contaminated sites management.
Local power distribution, Telecom	Abandoned.	• Decommissioning would be needed, but would generally need to occur in response to loss of demand. • If local distribution networks need to remain to service pump stations, contaminated sites management, or remnant users, could move towards fiberglass poles that can withstand inundation better than wood.
Serpentine Fen and Water Control Features	Abandoned.	• The loss of the managed environmental area could be met with resistance from the public and environmental groups, but it is likely that this could be managed because of the establishment of extensive salt-marshes as a core of this plan.
Marinas, Private Docks	Abandoned.	• Marinas and private docks would likely remain until a major event, and then either relocate or abandon the area. Decommissioning would be required, and it could open the opportunity for alternative uses of the upland lots.
Dairy Farm	Abandoned.	• Abandonment would have huge capital cost implications, and it would be hard to relocate or find an alternative. If relocation is feasible, there would be a disruption of commerce to be considered. • Public perception and agricultural impacts are major decision makers because of food security, loss of local business, agricultural land reserve loss. • Removal of land from the Agricultural Land Reserve (ALR) requires consultation with the Agricultural Land Commission (ALC). Exclusion of land from the ALR requires an ALC application, and there is no guarantee of approval. • It is likely that if the flood risk is tolerable, the system may not be abandoned, in which case other services like power, gas, and local roads would need to be maintained until abandonment proceeds.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 1 – Coastal Realignment to 152 Street
		• Some adaptation is already being done through selective crop modification, but this approach may not be feasible in the long term with sea level change.

Table 3-2: Workshop Commentary by Infrastructure Category
Adaptation Option 2: River Realignment

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 2 – River Realignment
Major Roads (City of Surrey) King George Boulevard Highway 99 152 Street	Highway 99 raised or protected by super-dyke; King George Boulevard likely remains on current alignment, tying into Highway 99 (new interchange required); 152 Street to remain as-is. Requires consideration of bridge over Nicomekl River, and Highway 99 and King George Blvd. interchange.	• The shared function of Highway 99 as a dyke could make the road more vulnerable because of the more direct exposure than if it were setback. • Concerns were raised about maintainability of the highway if it was shared with a dyke because of the needs to satisfy the Inspector of Dikes for all maintenance activities. • If Highway 99 is not raised, then it will be behind a 4 – 5 m high embankment, which may be met with public pushback. Alternatively, raising the road would need to be done offline of the current alignment to avoid disruption of traffic and commerce. Risk tolerance and maintainability are important factors if it remains unmodified because measures to improve the highway's resilience could not be pursued. • Regional integration becomes a major driver. The option assumes that raising Highway 99 would continue through Delta's coastal floodplain, or that Delta would upgrade their coastal dykes to the same standard as the proposed super-dyke. • Merging King George Boulevard with 152 Street is deemed unnecessary, and should instead remain on its current alignment with modification to the interchange at Highway 99.
Major Roads (Corporation of Delta) Highway 91 Highway 99 Ladner Trunk Road	Either protected by coastal super-dyke through regional coordination, or exposed with need to relocate.	• See above concerns on regional integration. • Highway 91 and Ladner Trunk Road could be protected if the entire Highway 99 alignment is converted to a superdyke through Delta.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 2 – River Realignment
Railway Infrastructure BNSF Embankment Trestles Swing Bridge BCRC Embankment	Continuous trestle over flooded area, raised embankment with several equalization culverts, or regional relocation. Needs to consider crossing of rail and Highway 99.	• The crossing of the rail and the proposed superdyke poses a major challenge. The rail line would need to be raised to cross over the dyke, which would have significant impacts beyond the study area and on all the regional rail tie-ins. If the rail cannot be raised, then there will be a gap in the new flood protection infrastructure, and the rail would need to be closed periodically, which may have unacceptable economic consequences. This needs to be addressed to determine whether this option is feasible. • Relocation behind the new coastal dyke may be the best option, but this could result in the loss of agricultural land because of the new footprint required. Use of land in the Agricultural Land Reserve for relocation of railway infrastructure would require an application to the Agricultural Land Commission, and there is no guarantee of approval. • The smaller rail companies may not have the same legal power or financial capabilities to undertake a significant realignment, or to accommodate disruptions to service. Given the economic importance, there may be opportunities for provincial or federal funding.
Sanitary Lift Stations	Raise and protect; dependent on reconfiguration of sanitary mains.	• On the fringes of the floodplain, but reconfigurations will depend on modifications to the local system and to the Metro Vancouver main. • Disturbance during upgrades will need to be mitigated to maintain positive public perception, but will generally be unnoticed provided level of service is retained. • There may be physical encroachment of the widened Nicomekl River that directly impacts the sanitary stations and requires them to be relocated.
Metro Vancouver Sanitary Main	Mostly exposed Accommodate: Reduce leakage potential recognizing constant inundation; access chambers elevated above flood level with provisions for boat access; redesign as submarine crossings, but	• Natural replacement timelines are approaching; provides the opportunity to relocate or design as a submarine crossing. If retrofit, would have access issues and would need to provide access for maintenance. Challenging if local roads no longer exist. • Regulatory compliance may be a greater issue if the line is relocated, rather than retrofit, but either could provide an opportunity to improve the seismic resilience of the system. • Regular submergence could attract the attention of public and environmental groups.

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 2 – River Realignment
	challenging given seismic event / shifting soils. Retreat: Relocation allows consideration of seismic needs in design; could utilize shared utility ROW corridor in collaboration with other utilities.	• Likely approach would be to maintain until the end of its service life and then relocate. If it is relocated through land in the Agricultural Land Reserve, it would require an application to the Agricultural Land Commission.
Metro Vancouver Water Main	End of life approaching, goes through sea dam at Nicomekl; Needs coordination with Highway 99, super-dyke, and river design. Alternate alignment is likely most favourable; allows seismic design; consider shared utility ROW corridor.	• Steel watermain approaching the end of its functional life. Part of the watermain is located behind the proposed dyke, and part of it would be directly under the proposed dyke, and so needs to be coordinated with construction.
FortisBC Gas Mains	Response dependent on residence and businesses remaining or retreating from the area. Reconfiguration of the system likely needed.	• Strongly dependent on demand, and the importance of the public perception factor depends on the number of residences affected. The primary drivers will be level of service and cost.
BC Hydro Transmission Lines	Only one tower remains exposed; extra long line over Nicomekl River.	• One set of towers would be affected by the widening of the Nicomekl River, but restringing the line would likely be the approach taken.
Drainage Pump Stations, Ditches, Floodboxes	Reconfiguration of drainage system to support agriculture. Drainage pump stations, floodboxes redesigned with drainage system; potential for leaving Serpentine River channel in place (irrigation storage, reverse flow direction for drainage channel, etc.).	• The agricultural lands behind the proposed dyke will need to be serviced by a reconfigured drainage and irrigation network. Using irrigation water from the new Nicomekl lake may not be acceptable. The existing pump stations will need to be removed and new ones installed. • Maintaining the Serpentine River instead of filling it would have benefits from a drainage perspective, and could potentially act as a reservoir for irrigation water, provided salinity concerns are addressed. • If the Serpentine River is infilled, the land could be proposed for inclusion into the Agricultural Land Reserve (ALR); however, the inclusion of land into the ALR requires an Agricultural Land Commission application, and there is no

Infrastructure Item	Assumed Response to Adaptation Option	Workshop Commentary Adaptation Option 2 – River Realignment
		guarantee of approval. The material used to fill the Serpentine River would need to be of similar composition to the other surficial soils in the area.
King George Airpark	Protected.	• Can likely remain in place with little to no modification needed.
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	Abandoned.	• Loss of recreational trails would be met with pushback from the public, but with appropriate planning new improved trails and greenways can be implemented with other infrastructure in the area, so can be managed.
Local roads	Most protected, some abandoned.	• Decommissioning of roads west of the new dyke would be needed, and this raises questions about disposal and contaminated sites designation. • Local roads behind the dyke may require some reconfiguration to service the area.
Local power distribution, Telecom	Adaptable – would abandon / reconfigure as needed to service residents / businesses.	• The lines follow Highway 99 and other local roads, and so rebuilding in place with those modifications would be the likely approach, rather than relocation.
Serpentine Fen and Water Control Features	Abandoned.	• The loss of the Serpentine Fen area could be met with resistance from the public and environmental groups, and it may not be possible to allow the loss of it without compensation elsewhere. There is the potential for the new Nicomekl Lake to fill this need.
Marinas, Private Docks	Modified or abandoned.	• Marinas and private docks would need to be reconfigured to accommodate the widened Nicomekl River and sea level change.
Dairy Farm	Abandoned.	• Abandonment would have huge capital cost implications, but it is possible that the facilities could be relocated to the area behind the new dyke and use the land formerly occupied by the Serpentine Fen area.

4 Step 7 - Multi-Factor Analysis

Triple bottom line (TBL) assessments are generally used to support decision making on complex problems. They use multiple factors to allow for a systematic review of environmental, social, and economic influences on decision-making. The process typically consists of defining relevant factors, assigning weights of importance, and then assigning scores to each factor for the alternatives being considered. When the score and weight is multiplied, it provides an overall score that provides a consistent comparison between alternatives.

The workshop focused on defining the factors within each TBL category that might influence how infrastructure organizations make decisions. The participants were asked to rank each factor based on how influential it would be in an organization's decision-making process (high, medium or low). Typically, this process would be done by the individuals or groups within an organization that have direct decision-making power, and using numeric weightings. However, having the workshop participants take a first cut at the rankings provides insight that can be used to refine or eliminate certain adaptation options that might not be acceptable.

We note that the CFAS project team has been using a multi-factor decision support system that considers technical feasibility, and stakeholder values, and has hosted numerous workshops to elicit input on the considerations relevant to different stakeholders. The ICFAA workshop looks specifically at the factors relevant to infrastructure, which is important given the diverse interests of the multiple organizations within that stakeholder group, and their significant investment in assets within the study area.

4.1 EVALUATION OF TRIPLE BOTTOM LINE ELEMENTS

During the first two exercises in the workshop, the participants reviewed the factors developed by AE, representing environmental, social, and economic aspects of decision-making. The workshop groups evaluated the influence of each factor on each infrastructure category, assigning a ranking of low, medium, or high.

Each table interpreted the exercise differently. Some focused on the general decision-making process by each sector, while others focused on specific actions within a scenario. The organizations represented were not solely infrastructure asset owners, and included regulatory agencies, emergency response, and various government agencies. As a result, there was considerable variability in the significance of the factors, across sectors, and by individual participants. However, we identified general trends, and developed a final list of the proposed TBL factors that can be used by individual infrastructure sectors to guide their own adaptation to coastal flood risks.

Ultimately, each organization would need to assign their own weighting to help decide which option is preferred, and the level of cost sharing that would be appropriate for a given option. The addition of sector-specific weighting can help in the decision-making process, and is generally a key component to TBL analysis; however, this exercise was intended to be more of a qualitative assessment of the drivers of decision-making.

The key findings relating to the TBL factors are as follows:

- Public perception has a very strong influence on the decision-making process for major roads. Other social, environmental, and economic factors that could influence public perception thus have a cascading effect. This can limit the range of viable options.
- Regulatory compliance has a high influence on nearly every infrastructure category. This can be addressed through careful planning to meet applicable standards, and proactive engagement of regulatory agencies throughout the process.
- For infrastructure sectors where public perception is relevant, its influence is exceptionally high.
- Cost-sharing and collaboration were identified as being distinct, and so were separated for the final list of factors.
- Cultural factors, including First Nations concerns and archaeologic potential were identified as factors of high importance for all infrastructure categories, and so have been added to the list.

Table 4-1 summarizes the proposed final list of TBL factors, and provides brief interpretations of each.

Table 4-1
Proposed List of TBL Factors

Category	Factor	Interpretation
Environmental	Regulatory Compliance	Ability to meet regulatory requirements
	Biodiversity / Habitat	Potential to impact biodiversity or habitat
	Climate Change Mitigation / Adaptation	Integration with other climate change initiatives
Social	Public Perception	How the public perceives an action
	Community Involvement	Involvement of the local community in the decision-making process
	Acceptable Level of Service and Risk	Maintenance of acceptable level of service to the public
	Emergency Response	Effect on emergency response
	Agricultural Impacts	Impacts to agricultural land
	First Nations / Archaeology	Potential for cultural impacts
Economic	Capital Cost	Cost of design and construction
	Cost-Sharing	Opportunities for cost-sharing with others or external funding
	Collaboration	Opportunities for collaboration
	Resilience and Maintainability	Ability to maintain or adapt in the future

Category	Factor	Interpretation
	Disruption of Commerce	Internal or external economic impacts due to disruption
	Risk Tolerance / Asset Lifecycle	Opportunities to renew infrastructure that is not yet deficient

An overview of the TBL ratings assigned by the workshop participants is provided in Appendix C. As discussed above, there is considerable variability in the interpretation of the importance of the TBL factors, attributed to the diverse cross-section of workshop attendee's backgrounds. In many cases, the factors where there was considerable spread (i.e. the factor was ranked as low, medium, and high by attendees) are the ones that warrant the most careful consideration by the infrastructure owners to improve the outcomes of adaptation planning. In general, the 'Economic' category saw the most consistent rankings between participants.

Factors that stood out as having a high level of importance across multiple sectors are summarized in Table 4-2.

Table 4-2
TBL Factor Importance by Sector

Category	Factor	Sectors
Environmental	Regulatory Compliance	All
	Biodiversity / Habitat	Highways, Roads, Railway, Utilities, Drainage
Social	Public Perception	Highways, Roads, Regional Sanitary Mains, Power, Trails
	Acceptable Level of Service and Risk	Highways, Roads, Utilities, Drainage
	Emergency Response	Highways, Roads, Regional Water Mains, Power
	First Nations / Archaeology	All
Economic	Capital Cost	Highways, Roads, Railway, Utilities, Dairy
	Cost-Sharing	All
	Resilience and Maintainability	Railways, Roads, Highways, Utilities, Drainage
	Disruption of Commerce	Highways, Railways, Power, Dairy
	Risk Tolerance / Asset Lifecycle	Highways, Roads, Railways, Utilities

4.2 INFRASTRUCTURE ADAPTATION

Regardless of the direction of the outcome of the City's Coastal Flood Adaptation Strategy, infrastructure owners must recognize the implications of climate change and coastal flooding on the level of service of their infrastructure, and take steps to adapt.

Presently, none of the infrastructure sectors have adopted specific adaptation strategies within the Mud Bay area to guide how they will adapt.

The City of Surrey has been working with the University of British Columbia (UBC) and Landscape Interventions (LINT) to explore innovative and multi-purpose adaptation ideas that could be considered by various infrastructure sectors. Students from the UBC School of Architecture and Landscape Architecture were engaged in this project through their instructor Dr. Kees Lokman, and several attended the workshop. Development of multiple alternative adaptation concepts that can be used by the various infrastructure sectors is important, and supports the cyclical nature of infrastructure adaptation planning.

Some of the concepts developed by the UBC-LINT team are shown for information in Appendix D. Infrastructure owners must be aware of the implications of coastal flooding and climate change on their assets, and determine appropriate long-term adaptation approaches that are appropriate to their individual needs, regardless of the direction that the City's CFAS progresses. The concepts provided are strictly illustrative concepts, intended to stimulate further discussion among infrastructure sectors.

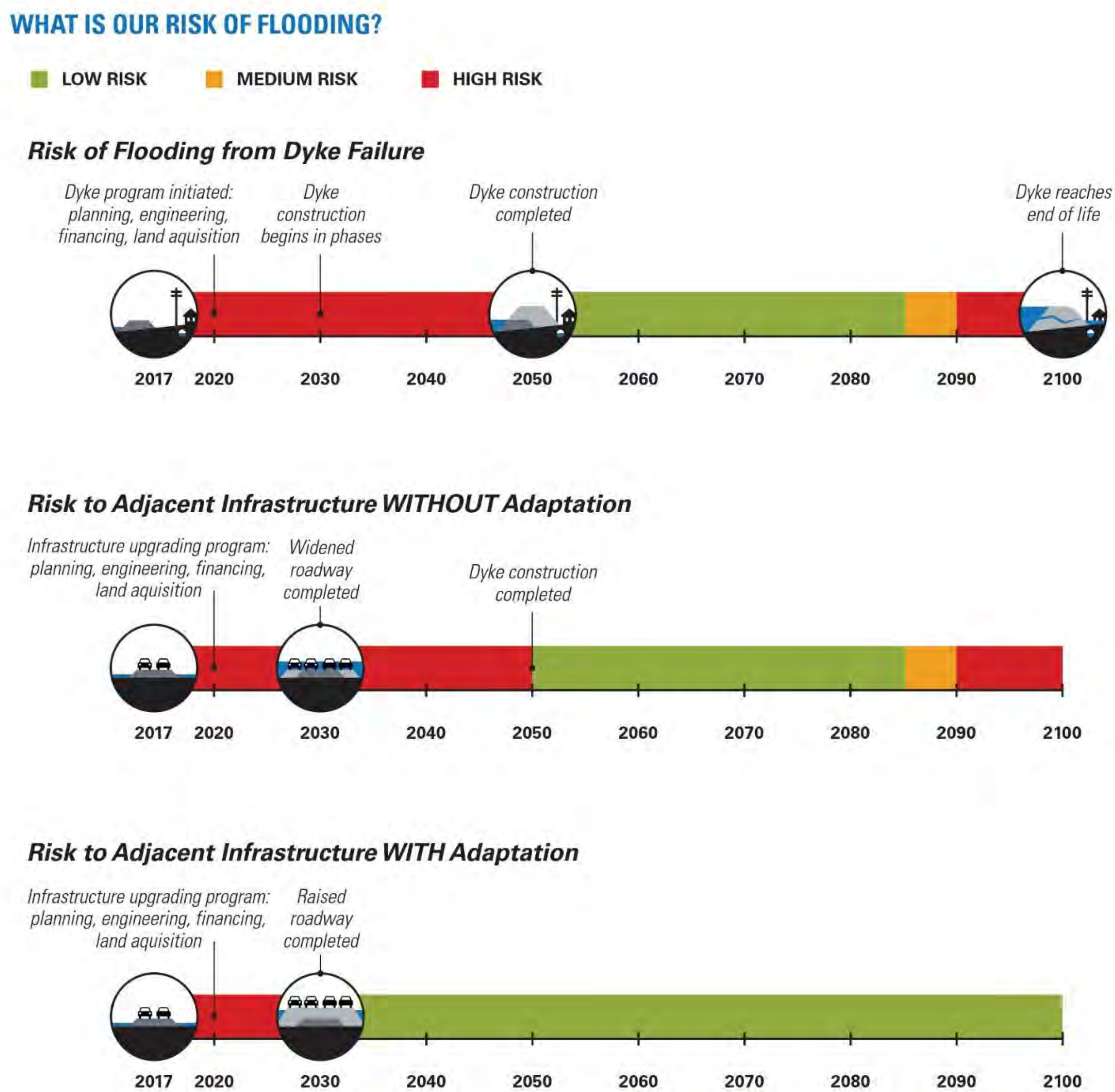


Figure 4-1
Illustrative Example of How Infrastructure Actions Supports Improved Adaptation

4.3 INFRASTRUCTURE RISK REASSESSMENT

To compare how the two options could influence infrastructure risk, we revisited the risk assessment process used in the March 2017 workshop.

We compared the baseline coastal flood risk with the following possible outcomes:

1. No adaptation for coastal flood risks is done by the City or infrastructure owners
2. The City pursues the coastal realignment to 152 Street option, but the infrastructure takes no action to adapt their own infrastructure.
3. The City pursues the coastal realignment to 152 Street option, and the infrastructure adapts on their own and/or collaboratively.
4. The City pursues the river realignment option, but the infrastructure takes no action to adapt their own infrastructure beyond reconfigurations necessary to make the option work.
5. The City pursues the river realignment option and the infrastructure adapts on their own and/or collaboratively.

The risk assignments follow the process used in the March 2017 workshop, where we assigned a probability (P) and a consequence (C) to each infrastructure, and the product (P x C) produced the risk score (R). Based on the risk score, we assigned a risk classification to each asset, as follows:

- Low (<10);
- Medium (10 – 19); or
- High (>20).

RISK = PROBABILITY x CONSEQUENCE

	CONSEQUENCE (1 - 5)							
5	Catastrophic	0	5	10	15	20	25
4	Major	0	4	8	12	16	20
3	Moderate	0	3	6	9	12	15
2	Minor	0	2	4	6	8	10
1	Insignificant	0	1	2	3	4	5
0	No Effect	0	0	0	0	0	0
		Negligible / Not Applicable	Highly Unlikely / Improbable	Remotely Possible	Possibly / Occasional	Somewhat Likely / Normal	Likely / Frequent
	PROBABILITY (1 - 5)	0	1	2	3	4	5

Table 4-3 provides the high-level risk scoring, and an overview of the risk distribution for each of the two case study flood and adaptation scenarios. Note that we used the revised infrastructure categories from the second workshop for this evaluation, and so a total of 21 pieces of infrastructure were evaluated, as opposed to 43 during the March 2017 workshop.

The table does not represent a detailed risk assessment of each individual infrastructure component; rather, it is a high-level evaluation of how the risk profile for infrastructure in the Mud Bay area might vary. The table illustrates the following important points:

- The current (baseline) probability of a coastal dyke breach is 'somewhat likely' (4), and will increase to 'likely frequent' (5) by the year 2100. This causes a shift in risk to infrastructure from low-to-medium to medium-to-high if no actions to adapt are taken by the City or by the infrastructure sectors in the area.
- The adaptation options being considered by the City (including Coastal Realignment to 152 Street and River Realignment) do not reduce the risk to all infrastructure sectors in the area.
- If infrastructure sectors take actions to adapt their own infrastructure, their risks can be managed to remain within acceptable thresholds.

Table 4-4 summarizes the general findings of Table 4-3 (attached).

Table 4-4
Risk Summary of Potential Options (21 Infrastructure Pieces)

Risk Classification	Pieces of Infrastructure in Each Risk Classification		
	No Adaptation Year 2100	Coastal Realignment to 152 Street	River Realignment
Low	2	4	11
Medium	6	6	5
High	13	11	5

*The risks shown in Table 4-4 represent risk to the year 2100, without additional adaptation by individual infrastructure sectors.

The risk reassessment is based only on a subset of the options that the City is considering as part of the CFAS, and correspond to the adaptation options considered during the ICFAA workshop. The results overall demonstrate that the City's actions alone will not eliminate coastal flood risks to infrastructure in Mud Bay. They also demonstrate that considerable reduction in the flood risk to infrastructure is possible through adaptation at the sector level. These findings are applicable to each of the options the City is considering, and so continued involvement from the owners is needed.

Table 4-3
Risk Reassessment

CFAS Option:	Baseline				No Adaptation								Coastal Realignment to 152 Street								River Realignment							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation				No Adaptation by Infrastructure				With Infrastructure Adaptation				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome	P	C	R	Outcome	P	C	R	Outcome	P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		5	5	25	Loss	1	5	5	Protected	1	5	5	Protected	1	5	5	Protected	1	5	5	Protected	1	5	5	Protected
Highway 99	4	4	16		5	5	25	Loss	1	5	5	Protected	5	5	25	Loss	1	5	5	Protected	1	5	5	Protected	1	5	5	Protected
152 Street	4	1	4		5	4	20	Loss	1	4	4	Protected	1	4	4	Protected	1	4	4	Protected	1	4	4	Protected	1	4	4	Protected
Highway 91	4	2	8		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	1	4	4	Protected	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected	5	5	25	Loss	1	5	5	Protected	5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	5	3	15	Partial Loss	1	3	3	Protected
Sanitary Lift Stations	4	4	16		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	3	4	12	Partial Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	1	4	4	Protected	1	4	4	Protected
FortisBC Gas Mains	4	2	8		5	2	10	Loss	1	2	2	Protected	5	2	10	Loss	1	2	2	Protected	3	2	6	Partial Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	1	3	3	Protected	1	3	3	Protected	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	1	4	4	Protected	3	2	6	Modified	1	2	2	Protected
King George Airpark	4	1	4		5	1	5	Loss	1	1	1	Protected	5	1	5	Loss	5	5	25	Abandoned	1	1	1	Protected	1	1	1	Protected
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		5	1	5	Loss	1	1	1	Protected	5	1	5	Loss	5	5	25	Abandoned	3	1	3	Partial Loss	1	1	1	Protected
Local roads	4	2	8		5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	5	5	25	Abandoned	3	3	9	Partial Loss	1	3	3	Protected
Local Power Distribution, Telecom	4	4	16		5	4	20	Loss	1	4	4	Protected	5	4	20	Loss	5	5	25	Abandoned	3	4	12	Partial Loss	1	4	4	Protected
Serpentine Fen and Water Control Features	4	3	12		5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	5	5	25	Abandoned	5	5	25	Abandoned	1	1	1	Protected
Marinas, Private Docks	4	2	8		5	3	15	Loss	1	3	3	Protected	5	3	15	Loss	5	5	25	Abandoned	5	3	15	Loss	1	3	3	Protected
Dairy Farm	4	4	16		5	5	25	Loss	1	5	5	Protected	5	5	25	Loss	5	5	25	Abandoned	5	5	25	Loss	5	5	25	Abandoned
Risk Distribution			#	%			#	%			#	%			#	%			#	%			#	%			#	%
Low Risk			8	38%			2	10%			21	100%			4	19%			14	67%			11	52%			20	95%
Medium Risk			13	62%			6	29%			0	0%			6	29%			0	0%			5	24%			0	0%
High Risk			0	0%			13	62%			0	0%			11	52%			7	33%			5	24%			1	5%

Notes:

1) The risk scores for the 'Baseline' and 'No Adaptation' scenarios are based on the March 2017 PIEVC workshop results, and represent a high-level assessment of risk to infrastructure in the Mud Bay study area.

2) The 'Coastal Realignment' and 'River Realignment' risk scores were assigned by reducing the probability and/or consequence scores, based on the narratives developed for the ICFAA workshop, and whether an infrastructure sector was considered to be protected or partially protected by that option.

3) The 'low risk' scores associated with 'Infrastructure Adaptation' assume that the sectors take action to fully protect their assets. The feasibility of this level of protection depends on each infrastructure sector. This scenario has not been workshopped, and so the scores represent a 'best-case' scenario, which is likely to be very costly.

4) The specific adaptation details for any infrastructure component and the coastal flood risks in this table should be considered high-level and preliminary.

5 Recommendations and Next Steps

5.1 WORKSHOP FINDINGS

For the Coastal Flood Adaptation Strategy to be successful, it is critical that the organizations that manage infrastructure are closely involved. Key takeaways from the workshop are summarized below.

- The City could choose an option that meets their own needs, and much of the infrastructure would be flexible enough to respond to that decision to manage their risk. Two notable exceptions are the Ministry of Transportation and Infrastructure (MoTI) and the railway companies. Some of the options that the City is considering will not be possible without the direct cooperation of these organizations:
    - MoTI's decision-making process is influenced by many factors, and it cannot be assumed that major reconfigurations are possible. The feasibility of raising, relocating, adding bridges, and having the highway embankment also act as a dyke needs to be determined.
    - Raising the railways above the required dyke elevations or relocating the lines would have cascading effects well-beyond the study area, and may not be possible. Sections where rail crosses a newly proposed dyke would be a gap in the flood protection system. This gap would need to be physically closed when coastal flood risks are high. This disruption might not be acceptable. If coordination between the City and rail companies is not possible, then options that rely on this are not viable, so this should be determined early.
- Coordination with the Corporation of Delta is important, so that their intended approach for managing their coastal flood risk is understood. If their coastal dyking system is not upgraded, it may pressure the infrastructure (roads, rail) in the area to adapt on their own, which would influence tie-ins within the City of Surrey's borders.
- Collaboration between infrastructure organizations is essential to the success of a strategy. Each organization needs to be on board with the framework, and understand how their long-term planning integrates into the strategy.
- Mutually-beneficial opportunities for cost-sharing should be explored. Much of the infrastructure is regionally, provincially, nationally, and internationally significant, and so various funding sources might be available, that can be used for multi-purpose adaptation.
- Whatever strategy is adopted, it will involve many non-standard features that will require special approval from various regulatory agencies. There will need to be a coordinated effort to ensure design standards and guidelines support what is proposed. Coordinated, bulk regulatory submissions would also support a smoother process.
- When evaluating potential options, the details of abandonment should not be overlooked. Decommissioning would be required, and the cost of this should be accounted for. It is also uncertain whether some infrastructure would require contaminated sites classifications, or whether access for monitoring and/or remedial work would need to be maintained. If this is the case, it could prevent the full decommissioning of local roads and power.

5.2 NEXT STEPS

The ICFAA workshop is one of many stakeholder workshops that is feeding into the overall CFAS decision-making process. Continued engagement of the infrastructure sectors is important for the CFAS to be successful, and for infrastructure owners to further evaluate the risks to their infrastructure and develop plans to adapt. The workshop also only considers two of the many options being considered, and the outcomes are intended to guide the CFAS.

5.2.1 Shortlisting of Adaptation Options

We understand that the next steps in the CFAS project are for the team to revisit the proposed adaptation options for Mud Bay, and develop a shortlist of two or three of the most preferred options.

To support this, further input from infrastructure owners will be required. Consultation with MOTI and the railway companies is recommended. This will allow the CFAS project team to eliminate or refine the assumptions for the eight options being considered. The overall decision-making process will also involve consideration of the other stakeholders, and the technical viability of each option, which will extend beyond the study area of the workshop.

With respect to the other stakeholders, it is important they recognize the benefit in actively participating in the CFAS process so their needs are understood, and their risks are properly managed. It is expected that each of the infrastructure owners in the area will evaluate how their assets are affected by the proposed broad CFAS options, and take a proactive role in determining how to best adapt their infrastructure to coastal flooding risks in Mud Bay.

5.2.2 Development of an Adaptation Framework

Once the preferred option is established, the City could then proceed to develop an implementation framework along with the infrastructure sectors. This framework would outline the actions to be taken by the infrastructure sectors in the area, and would guide long-term planning for each organization. Any deviations from this framework would need to be carefully considered. Incrementally, the City, the Corporation of Delta, and other infrastructure organizations could work to implement the strategy through Memoranda of Understanding and other mechanisms.

5.2.3 Ongoing Monitoring

With the coastal flood adaptation framework established, a monitoring program should be developed to allow for adaptive management and contingency planning.

The coastal flooding scenario that has been considered reflects a 200-year return period event (by 2010 standards). It is expected that this could become as frequent as a 2-year return period by the year 2100. The effects of climate change could be experienced more rapidly than predicted, necessitating a more urgent risk management response. There also exists the risk of a severe coastal flood occurring before substantial adaptation progress can be made. There needs to be a plan in place so that short-term recovery actions can be done in a way that does not compromise the long-term strategy.

Ongoing monitoring cannot solely be the responsibility of the City of Surrey, and infrastructure organizations can explore their own coastal flooding risks in greater detail. When an infrastructure investment is being considered, that sector could conduct an additional assessment that accounts for future coastal flooding, but also population growth, service expectations, and so on. These comprehensive risk assessments conducted by the infrastructure sectors can help to pinpoint their thresholds, beyond which they need to act.

In addition to monitoring the progression of climate change, monitoring the actions of the individual infrastructure organizations is also important. Close communication between the City and the organizations should be maintained to ensure that all actions in the area are in line with the assumptions of the strategy. Presently, there is no coordinating body and each sector is essentially on their own. The formalization of a coordinating body would help make the CFAS implementation more effective, but this needs dedicated involvement from most or all sectors in the area.

REPORT

Closure

This report was prepared for the City of Surrey to summarize the outcomes of the workshop held at Surrey City Hall on October 10, 2017, titled Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using the PIEVC Protocol.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, J. B. KINDRACHUK # 46012

MARCH 29, 2018

Jason Kindrachuk, P.Eng.
Water Resources Engineer

Reviewed by:

Jeff O'Driscoll, P.Eng. (Manitoba), IRP
Lead Workshop Facilitator

JO/JK/lp

Appendix A - Workshop Backgrounder and Agenda

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

WORKSHOP BACKGROUNDER

Infrastructure Owners, Managers and Emergency Responders

OCTOBER 10, 2017

INTRODUCTION

As part of Phase 1 of the Costal Flood Adaptation Strategy (CFAS) project, City of Surrey developed the "Backgrounder for Infrastructure Asset Managers, Operators and Emergency Services" document to describe present and projected end-of-century flood hazards. The backgrounder outlined potential impacts on infrastructure under a "Current Convention" scenario where the City of Surrey continues raising current dykes to meet projected flood protection requirements and describes both present and future flood hazards from a coastal dyke breach. The first infrastructure workshop on Mar 28, 2017 used Engineers Canada PIEVC™ High Level Screening Tool to receive input on infrastructure flood risks and adaptation. The three adaptation options explored here are neither the preferred nor shortlisted options.

While Phase 1 of the CFAS project explored who would be affected by flooding and to what extent, current Phases 2 and 3 have developed a range of preliminary mitigation options for Mud Bay, Crescent Beach and Semiahmoo Bay as outlined in the "Options Primer", to be released shortly. The options focus on flood control infrastructure and do not explore adaptation of other infrastructure sectors.

The purpose of the second PIEVC workshop on Oct 10, 2017 is to explore what impacts a baseline with no adaptation and two selected adaptation options may have on key infrastructure and land-use located in the Mud Bay Study Area that extends from the Serpentine & Nicomekl Lowlands in the East, including the Colebrook and Mud Bay Dyking Districts, and Mud Bay in the West. The PIEVC workshops focus on the area west of 152nd Street. The results of the workshop will assist in fine-tuning options and clarifying infrastructure owners' priorities and values. By providing specific feed-back, infrastructure owners can guide the direction of CFAS.

The baseline "No Adaptation" and two different adaptation options, "Coastal Realignment to 152nd Street" and "River Realignment" are described in in this Backgrounder. For each adaptation option, activities during the lead-up time to the flood are described, including construction activities and their impact on infrastructure. Next, the flood and its impacts are outlined, as well as the aftermath following the flood.

These two adaptation options are not all the options the City of Surrey is exploring. In the appendix of the document you can find a summary of the eight options the City is exploring for Mud Bay, which will be described in more detail in the "Options Primer" document. Neither are the three adaptation options explored here the preferred or shortlisted options. These three options where selected for the second PIEVC workshop because they affect infrastructure in substantially different ways and the City wants to better understand the implication of these adaptation options on infrastructure located in the study area.

The second PIEVC workshop will explore and validate these two adaptation options, and detail types of factors, applying Triple-Bottom Line (TBL) principles, that are most important when making decisions.

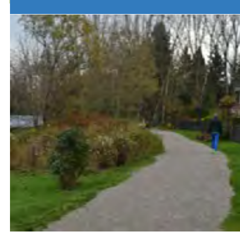
These factors might include:

ENVIRONMENTAL FACTORS
- Regulatory compliance
- Effects on biodiversity and habitat
- Climate change mitigation and adaptation

SOCIAL FACTORS
- Public perception
- Sense of community involvement
- Maintenance of an acceptable level of service and public risk
- Emergency response
- Agricultural impacts

ECONOMIC FACTORS
- Capital cost
- Cost-sharing and collaboration between different types of assets
- Resilience and maintainability
- Disruption of commerce
- Risk tolerance around level of service provision and asset lifecycle from economic perspective

STUDY AREA




INFRASTRUCTURE WORKSHOP OUTCOMES

ENVIRONMENTAL SUSTAINABILITY

Current outcomes:
- Involvement of environmental conservation organization such as Ducks Unlimited Canada
- Provides framework for discussions of potential co-benefits to manage flood risk with biodiversity conservation strategy
- Advanced understanding of past flood risk
- Involvement of City of Surrey Parks Managers
- Evaluated Green Infrastructure risk
- Improved flood risk understanding related to regional and local Parks
- Protection of Green Infrastructure considered in development of adaptation options
- Strengthened planning linkages to 10-year Parks, Recreation and Culture Strategic Plan and Biodiversity Conservation Strategy
- Strengthened planning linkages to railway relocation planning underway

Projected outcomes:
- Adaptation approaches identified might provide positive co-benefits related to protection of important environmental features
- Identification of co-benefits for ecosystem servicing and biodiversity conservation and exploration of coastal buffers using green infrastructure
- Establish decision making criteria using triple bottom line approach for environmental perspective
- Triple Bottom Line approach accounts for the often-overlooked environmental considerations in asset management planning and decision making
- Consider potential environmental contamination from flood risk

SOCIAL SUSTAINABILITY

Current outcomes:
- Identification of vulnerable critical infrastructure for mobility and community connectivity
- Advanced inter-governmental collaboration
- Advanced collaboration between emergency managers (fire, police, ambulance, coast guard) and capital planners (local government and provincial)
- Identified $15 million of annual dairy sales from 2,500 head of cattle
- Identified up to 10-yr recovery time for extensive blueberry farms
- Strengthened partnerships with University of British Columbia's School of Architecture and Landscape Architecture by involving graduate students
- Improved safety through Emergency Service involvement and knowledge exchange
- Involved local land owners through a site tour with stakeholders

Projected outcomes:
- Establish risk tolerance around level of service provision and asset lifecycle from social perspective
- Adaptation of infrastructure identified as vulnerable will ensure services provided by these assets are not interrupted (benefits to local and regional communities)
- Proactively manage and adapt to the impacts of sea level rise: over 10km of Provincial Highways, which account for over 200,000 vehicle trips per day
- Protect sewage and water services to over 100,000 Surrey residents
- Establish decision making criteria using triple bottom line approach

ECONOMIC SUSTAINABILITY

Current outcomes:
- Identified critical importance of twin 500kV electrical intertie to United States of America to entire BC Hydro System integrity
- Identified cascading effects of infrastructure vulnerability to economy
- Identified that 53 % of currently low/medium risk infrastructure sectors become high risk by year 2100 with sea level rise.

Projected outcomes:
- Increased awareness of infrastructure that protects over $100 million in annual farm gate revenues through flood control and irrigation service delivery
- Increased resilience and recover of billions of dollars of critical infrastructure through emergency service provider input and education
- Economically sound infrastructure management based on understanding of the vulnerability of infrastructure assets
- Identification of thresholds for adapting infrastructure
- Exploration of integrated design of critical infrastructure across asset owners
- Identification of shared responsibility to reduce service interruption and recovery costs from coastal flooding
- Protection of transportation infrastructure which provides over $20 billion in annual truck and rail freight traffic (over 10 km of Provincial Highways and over 30 km of railway)
- Protection of primary electrical connection to the United States of America with annual electrical flow valued well over $100 million
- Establish risk tolerance around level of service provision and asset lifecycle from economic perspective

INFRASTRUCTURE RENEWAL PLANNING TOGETHER

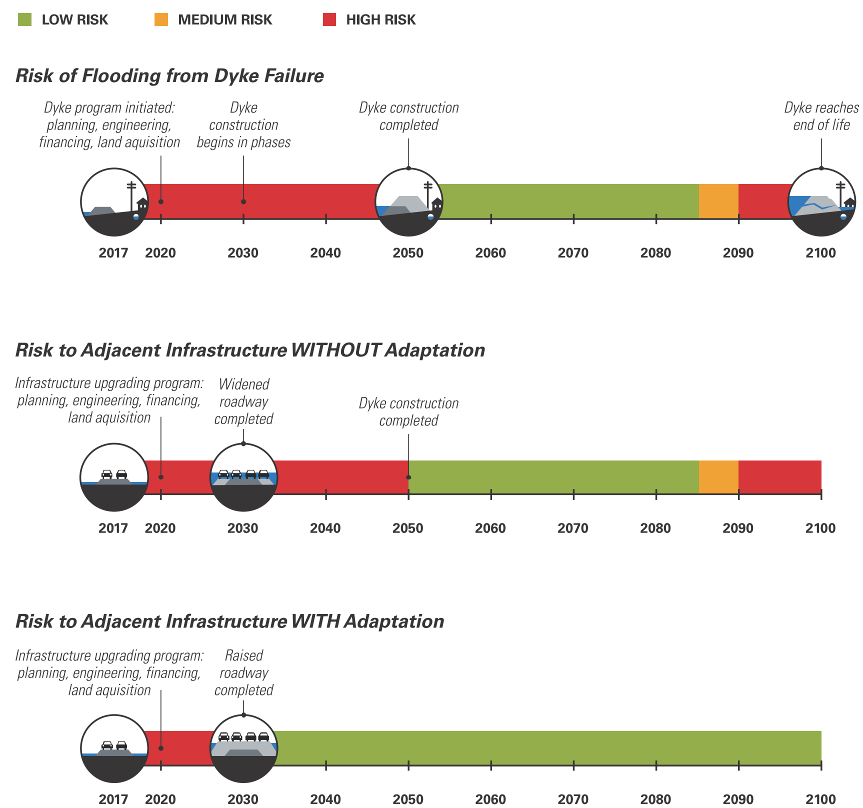
The existing 30 km dyke network providing flood protection does not meet Provincial Guidelines and with sea level rise is increasingly becoming at risk. A single weak point in the dyke network if breached, can result in adjacent infrastructure flooding. Previous work estimated that for present conditions, the existing Colebrook Dyke (north side of bay) has a design return period of 22 years, the Mud Bay Dyke (sheltered area along Serpentine) of 28 years and the BNSF Railway (not a regulated Dyke) of just 7 years. As a result of sea level rise, these values will reduce overtime with overtopping occurring annually (return period of less than a year) at all locations by 2070. When the crests are overtopped, the dykes are likely to breach, causing sudden, widespread inundation. The figure on the following page shows that a comprehensive dyke upgrade cycle requiring the coordination of many organizations in challenging technical conditions may require over 30 years to fully implement.

The extent of service interruption and risk to adjacent infrastructure in the future will depend on whether adjacent infrastructure adapts. Adjacent infrastructure over time will be renewed, providing opportunities to adapt to achieve a lower risk profile in the future, that may be realized both before a dyke upgrade cycle is complete, and also extend the lower risk profile beyond the dyke end of life, resulting in a low risk beyond 2100. The upgrade cycle will vary by infrastructure sector, but will be much shorter than a dyke upgrade cycle when organizations are able to plan and implement adaptive measures as part of their existing infrastructure renewal cycles.

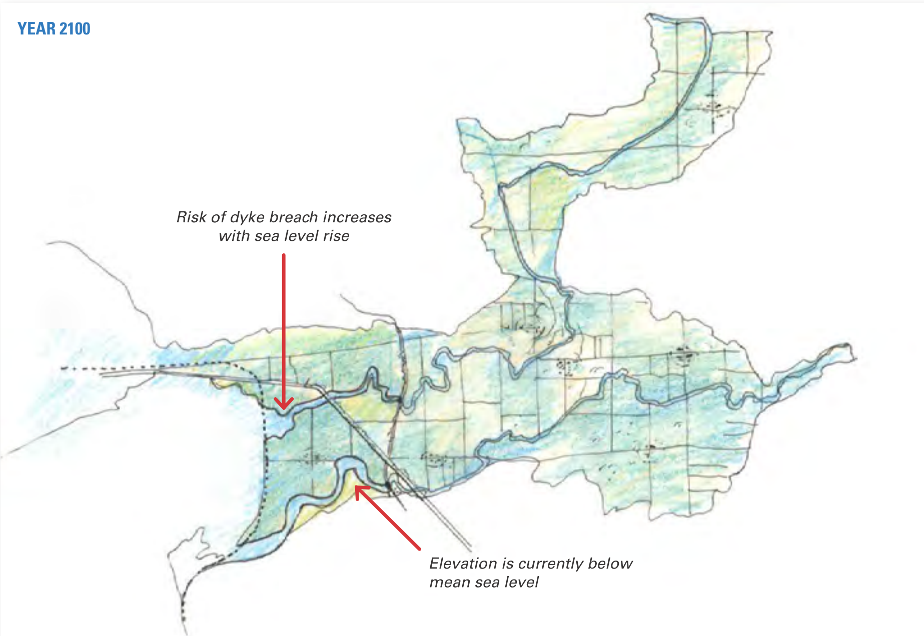
When adjacent infrastructure chooses not to adapt through infrastructure renewal, the flood risk is linked to the dyke upgrade cycle. New infrastructure becomes exposed to increased risk and with population growth, the consequences of a flood increase.

Given the flood risk link between dykes and adjacent infrastructure, infrastructure owners, operators and the emergency service providers who rely on transportation infrastructure will be impacted by flood management decisions. The following sections provide a narrative of different coastal flood adaptation options.

WHAT IS OUR RISK OF FLOODING?



NOTE: WITHOUT ADAPTATION, ADJACENT INFRASTRUCTURE IS EXPOSED TO MANY DECADES OF INCREASING RISK OF FLOODING. IS THIS RISK EXPOSURE ACCEPTABLE?



WHAT THIS COULD LOOK LIKE

Removable flood barriers

Evacuation routes

Increased nuisance flooding

Major flood event

LEAD-UP:

Surrey continues to annually spend roughly $1M on flood protection maintenance. There are no major floods and consequently no significant failures. No upgrades are introduced although temporary flood protection (sandbags and aqua-dams) are applied when extreme high tides are predicted. Any increases to the maintenance budget are denied and the system gradually deteriorates.

THE FLOOD:

Let's assume it is mid-December and snow has been falling for several days. An unusually high King Tide is predicted and the City's Engineering Operation's crews and Fire Department have additional staff on standby. An extreme low-pressure system (Pineapple Express) is approaching the west coast, bringing sudden warm temperatures and torrential rains. Unfortunately, the peak of the storm closely coincides with the King Tide. Strong south-westerly winds result in unprecedented wave run-up along the coast. The warm temperatures cause rapid snowmelt which combines with the rain runoff. The ground is saturated and has no remaining absorption capacity. In 2010, the event would have been referred to as the 200 year flood, now it is considered a more frequent event.

THE OUTCOME:

The coastal dykes fail in multiple locations. The Serpentine South Dyke and the Nicomekl North dykes are breached and the land between the dykes completely inundated. Through traffic on Hwy 99 and BNSF railway is suspended. Near the breaches, some lives are likely lost if people continue to live and work in Mud Bay. Remaining residents are evacuated and most structures in the area are destroyed. A large number of cattle are killed. Soils become salinated, affecting future crops for several years. The Nicomekl South Dyke is overtopped, the golf course is inundated and nearby housing partly damaged. The marinas along Nicomekl sustain heavy damage.

Sections of Highway 99 are overtopped, traffic can no longer be maintained. The low chords of the Serpentine and Nicomekl Bridges at Highway 99 and the the Nicomekl Bridge at King George Boulevard are submerged. There is some damage from debris. Freeboard at both sea-dams is compromised (water is within 30 cm of overtopping the structures) however, water does not overflow the dams. Dyke spillways are activated and the floodplain is completely inundated. Low-lying road sections are underwater (this includes Highway 10, portions of 152nd and 184th Street and 80th and 88th Avenue) rendering emergency evacuations difficult. The land takes weeks to drain. Housing and businesses are extensively damaged. Sewer lines and lift stations may be impacted, also the water supply infrastructure.

BASELINE:

NO ADAPTATION

Freeboard along the BC Rail line is compromised, the embankment is saturated and rail traffic comes to a halt. The BNSF line has partly failed and trains cannot pass before extensive repairs are performed. Indirect losses resulting from transport disruptions exceed $100M/week.

THE AFTERMATH:

The coastal flood protection requires extensive repairs and construction to a higher standard would likely be called for. Flooded areas would either be abandoned or new set-back dyking would need to be built. Construction would be difficult due to frequent inundation of the work sites. Some infrastructure may get relocated. Residents may choose to move and many businesses permanently close. In addition to rebuilding costs; economic, social and environmental losses would be significant. Agricultural losses are considerable and even with extensive soil amendment and replanting, land takes 3 to 5 years for yields to return and established blueberry crops may take 10 years for full production to be restored.

During the first PIEVC workshop, the 'no adaptation' scenario was tested under the "Flood Scenario A" (coastal dyke breach). Without adaptation, the number of assets at high risk increases from 2% to 55%, as shown in Table 1.

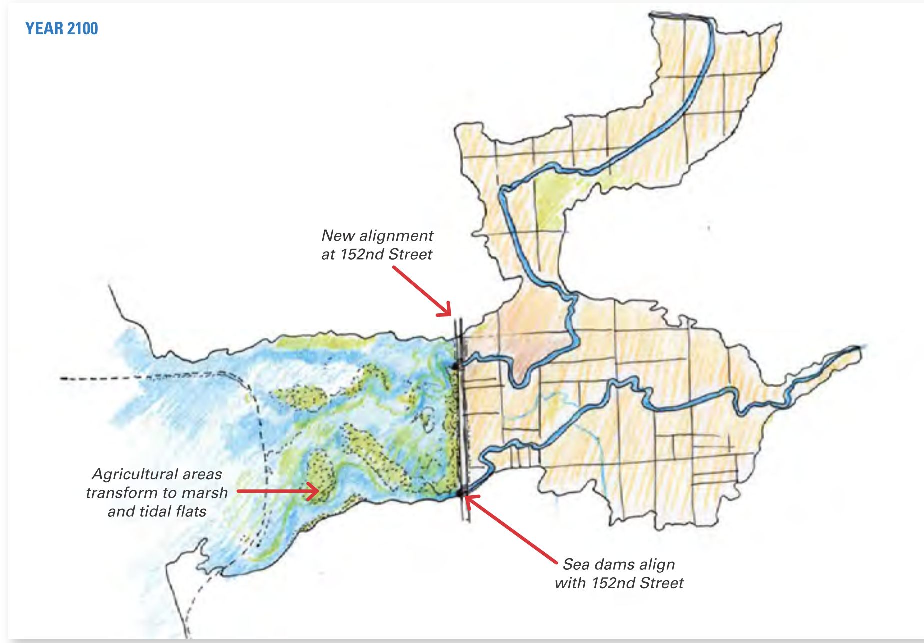
Because of the risks associated with no adaptation, it is not an option. On the following pages, two sample adaptation options are presented to demonstrate the need for collaboration by all parties in order to reduce overall infrastructure risks to acceptable levels. These two adaptation options will be explored during the second PIEVC workshop, so the City can better understand the decision making processes, objectives, and values of the various asset owners, and look for opportunities for collaboration and coordinated planning. These two daptation options are a subset of several options being considered.

TABLE 1: Summary of asset risk by infrastructure sector, identified during First PIEVC Workshop.

	NUMBER OF ASSETS IN EACH CATEGORY							
	FLOOD SCENARIO A: CURRENT				FLOOD SCENARIO A: FUTURE			
	Transportation	Utilities	Flood Control / Marine	TOTAL	Transportation	Utilities	Flood Control / Marine	TOTAL
LOW RISK	9	3	5	17	3	0	0	3
MEDIUM RISK	7	9	5	21	2	7	6	15
HIGH RISK	0	0	2	2	11	5	6	22

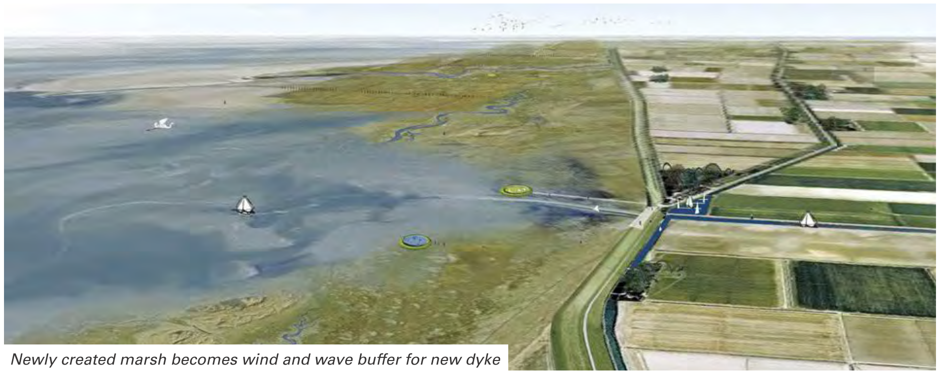
ADAPTATION OPTION #1:

COASTAL REALIGNMENT (152ND STREET)



WHAT THIS COULD LOOK LIKE

Raised highway becomes flood barrier



Newly created marsh becomes wind and wave buffer for new dyke

LEAD-UP:

A long-range plan to retreat to 152nd Street is advanced; gradually removing all infrastructure and development, returning lands between 152nd Street and Mud Bay to saltmarsh. The option would be introduced as follows:

- A super-dyke is built immediately west of 152nd Street. A strip of land must be left between the toe of the dyke and the toe of the road embankment to avoid settlement issues. The dyke is built to projected end of century flood levels with an allowance for future raising (i.e. with an oversized base width). The land for the super-dyke footprint is purchased and development is cleared from the strip. Any east-west roads are detoured. The ground is preloaded to meet geotechnical criteria. The ocean-side has a side-slope of 5H: 1V (to reduce future wave run-up) and the land-side a slope of 3H: 1V, resulting in 8m of width for every 1m increase in height. Erosion protection is installed on the ocean side.
- New sea-dams are constructed in line with the super-dyke on the Serpentine and Nicomekl Rivers. The dams will be designed for end of century conditions and include significant pumping capacity to limit increases in agriculture flooding.
- Highway 99, King George Boulevard and 152nd Street are merged into one thoroughfare located on top of the super-dyke with bridges at the two sea-dams. Outside the floodplain, new approach roads will be built. (Land will need to be acquired and culverts provided for cross-directional creek flows.
- Cooperation and cost-sharing between MOTI and Surrey is envisioned. Operation and maintenance agreements will need to be developed.
- Buyout plans are presented to residents, farmers and businesses located west of the new dyke alignment.
- BNSF is informed that inundation will become the norm on both sides of the rail-line and geotechnical problems such as erosion may result. The rail-line may look at adaptation through building a continuous trestle across the coastal floodplain or relocating east of 152nd Street. Similarly, the Roberts Bank Railway is considering elevating or relocating their tracks outside of the floodplain.
- Water-, sewer- and transmission-line owners will need to decide on appropriate action to prepare for regular inundation which will hinder maintenance and emergency response to the infrastructure, accelerate corrosion and increase erosion.
- A clean-up of potential contaminants will be carried out west of the dyke alignment. Highway 99 and King George Boulevard road embankments will be removed and the fill used to optimize habitat values. As sea levels continue to rise, modifications to the marsh area may be required. East-west roads (eg. Colebrook Road) within the floodplain will be abandoned. The old sea-dams will be demolished and removed.
- Strategic openings will be introduced in the present flood protection to allow saltwater inflow and habitat improvements to gradually take place. At high tide, the ocean will extend to the north and south edges of the floodplain and to the new super-dyke to the east.
- River dykes upstream of the new sea-dams are improved as required to meet ARDSA standards throughout the century.

Main advantages:

- Roughly 30 km of sub-standard dykes will no longer be maintained or upgraded and is replaced by a 4 km long super-dyke built to future standards near 152nd Street. The sea-dams are replaced by modern structures, also near 152nd Street. A few lowland pump-stations are abandoned, and the outdated sea dams removed. Surrey and the Mud Bay Dyking District no longer own or maintain flood protection in this difficult to protect area.
- Flood risks are significantly reduced.
- Environmental values within a portion of the Surrey floodplain can gradually be increased and habitat improvements introduced. Carefully developed plans would be required to optimize environmental and recreational values of the area.

Main disadvantages:

- Roughly 16 km^2 of farmland would be taken out of production and some 250 residences relocated. Families who have lived in the area a long time would need to move. Some businesses and marinas would also be impacted.
- The cost of the new dyke, sea-dams, combined highway with new approach roads and clean-up/ habitat improvements would be very high.

THE FLOOD:

Flood conditions identical to the "No Adaptation" scenario are assumed.

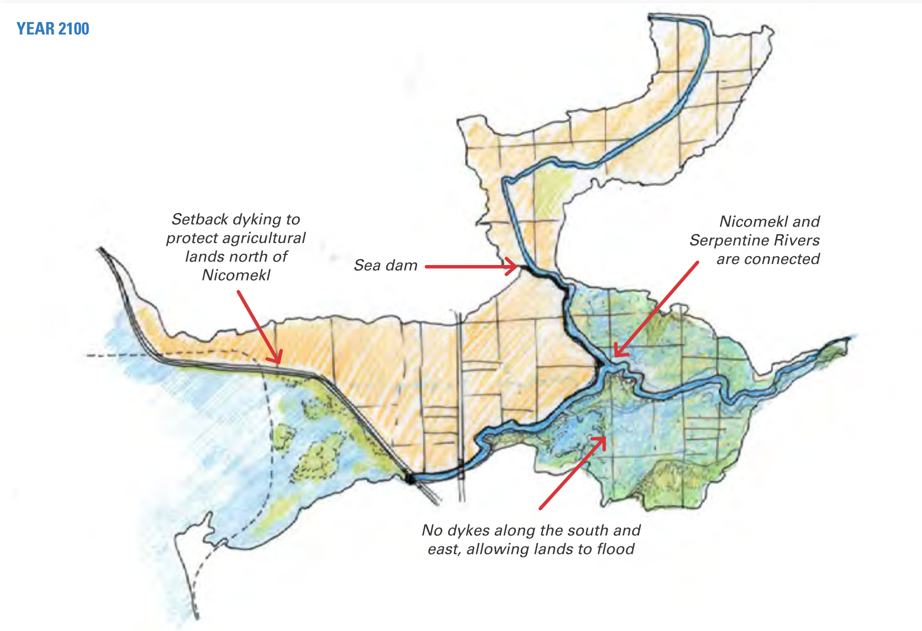
THE OUTCOME:

Assuming all construction is completed before the flood, damage would be limited. There would be some natural rearrangement of the saltmarsh west of the super-dyke and possible erosion of any raised land areas. Depending on the pumping capacity at the new sea-dams and river dyke improvements introduced upstream of the sea-dams, ARDSA standards may be fully met.

THE AFTERMATH:

Overall losses are minimal. Some additional habitat and recreational area improvements may be required.

YEAR 2100



WHAT THIS COULD LOOK LIKE


Inundation of Hunze River, NL


Coastal Marshes, BC

ADAPTATION OPTION #2:
RIVER REALIGNMENT

Rendering of study area at high tide, 2100

LEAD-UP:

A long-range plan is introduced to retreat to Highway 99; gradually removing development and returning lands between the highway and Mud Bay to saltmarsh. The Serpentine River is rerouted to merge with the Nicomekl River at roughly 168th Street and a lake is allowed to form south of the river confluence. The option would be introduced as follows:

- A super-dyke is built immediately east or west of Highway 99 and the highway is located on top of the dyke. (If the dyke is built on the east side, the old embankment becomes a wave buffer. If the dyke is built on the west side, the dyke will extend into Mud Bay at the north end of the bay. In either case, there will be challenges at the BNSF rail crossing and relocating the railway would be encouraged.) A strip of land must be left between the toe of the dyke and the toe of the road embankment to avoid settlement issues. The dyke is built to projected end of century flood design levels with an allowance for future raising (i.e. oversized base width). Note that raising the dyke is more challenging with the highway located on top of the dyke. The land for the super-dyke footprint (approx. 100m wide if incorporating 10 lanes plus road shoulders) is purchased and development is cleared from the strip. Any east-west roads are detoured. The ground is preloaded to meet geotechnical criteria. The ocean-side has a side-slope of 5H: 1V (to reduce future wave run-up) and the land-side a slope of 3H: 1V, resulting in 8m of width for every 1m increase in height. Erosion protection is installed on the ocean side as required. Provision for widening the Nicomekl River is made and a new bridge is built across the river at the future highway location. A gap, to be filled in later, is left at the Serpentine River.
- A higher set-back dyke is built along the north bank of the Nicomekl. The dyke is continued along the proposed Serpentine diversion channel to near the south end of Boise Island and is tied into high ground. Necessary land purchases take place. An opening is left in the dyke at the Serpentine River. Provision is made for future widening of the Nicomekl River by removing a portion of the south dyke. Based on a preliminary geomorphic analysis, a stable channel width of 85 m, with minimum 40 m wide floodplain strips on each side are envisioned (total width of 165 m).
- King George Boulevard and 152nd Street are merged into one thoroughfare at 152nd Street and a new (longer) bridge is built at the Nicomekl River.
- Residents and businesses in the future Nicomekl Lake area (east of 160th Street) are relocated. The Nicomekl Lake future outlet channel is constructed and given a natural appearance (meanders are maintained, strips of natural floodplain are introduced on each side adhering with "room-for-river" concepts).
- A new sea-dam is constructed in line with the super-dyke at Highway 99 (Nicomekl Lake becomes a primarily freshwater pond). The dam will be designed for end of century conditions and may need to include pumping capacity, working in conjunction with the water storage provided by Nicomekl Lake to maintain ARDSA drainage for agriculture. (Nicomekl Lake provides additional agricultural irrigation storage throughout the summer.)
- Cooperation and cost-sharing between MOTI,

RIVER REALIGNMENT

environmental groups, other stakeholders and Surrey is envisioned. Operation and maintenance agreements will need to be developed.

- Water-, sewer- and transmission-line owners decide on appropriate action for their affected infrastructure. (With the widening of Nicomekl River, a transmission tower may be impacted.)
- A 1,100 m long diversion channel is dug for the Serpentine River from the sharp bend near the corner of 52nd Avenue and 164th Street to near the corner of 48th Avenue and 168th Street. The channel is given a natural appearance and a minimum width similar to the existing Serpentine channel. Any development in the path of the channel is relocated.
- Existing development within the Nicomekl Lake area is removed and a clean-up completed. Landscaping is performed in preparation of inundation.
- A clean-up of potential contaminants will be carried out west of the super-dyke alignment. As sea levels continue to rise modifications to the marsh area may be required.
- During low flows, the old Nicomekl north dyke (from ocean to the Serpentine diversion channel) and the Nicomekl south dyke (from ocean to about 184th Street) are removed and the lake begins to fill. The plug from the Serpentine diversion channel is removed and the Serpentine flows start draining south. The old Serpentine channel is blocked off, and the old Serpentine sea-dam is permanently closed. The Serpentine opening in the new set-back dyke is filled in. The Serpentine sea-dam is demolished and the super-dyke opening at the Serpentine channel is filled. The Serpentine abandoned channel is filled in using adjacent dyke material. The old Nicomekl sea-dam is demolished and removed.
- Strategic openings will be introduced in the present flood protection downstream of Highway 99 to allow saltwater inflow and habitat improvements to gradually take place. At high tide, the ocean will extend to Highway 99.

Main advantages:

- Roughly 17 km of sub-standard dykes along the Serpentine and 19 km of substandard dykes along the Nicomekl no longer need to be maintained or upgraded. New dykes would include 8 km of super-dyke and 8 km of setback dyke, capable of withstanding future design events. The sea-dams are replaced by one modern structures. A number of lowland pump-stations can be abandoned or some relocated to the flood protected area north of the Nicomekl.
- Flood risks are reduced.
- Environmental values within a portion of the Surrey floodplain can gradually be increased and habitat improvements introduced. Carefully developed plans would be required to optimize environmental and recreational values of the coastal and lake/tidal basin areas.

Main disadvantages:

- Roughly 16 km^2 of farmland would be taken out of production and about 300 residences relocated. Families who have lived in the area a long time would need to move. Some businesses and marinas would also be impacted.
- The cost of the new dykes, sea-dam, road improvements, excavated channels and clean-up would be very high.

THE FLOOD:

Flood conditions identical to the "No Adaptation" scenario are assumed.

THE OUTCOME:

Assuming all construction is completed before the flood, damage would be limited. There would be some natural rearrangement of the salt marsh west of the super-dyke and possible erosion of raised land areas. Depending on the pumping capacity at the new sea-dam the current level of drainage service (ARDSA standards) may be fully met in the upstream area.

THE AFTERMATH:

Overall losses are minimal. Some additional habitat and recreational area improvements may be required.

EVALUATING OPTIONS

COMPARISON OF ADAPTATION OPTIONS

The table below provides an overview level comparison of the various components of the two adaptation options.

TABLE 2: Option comparison.

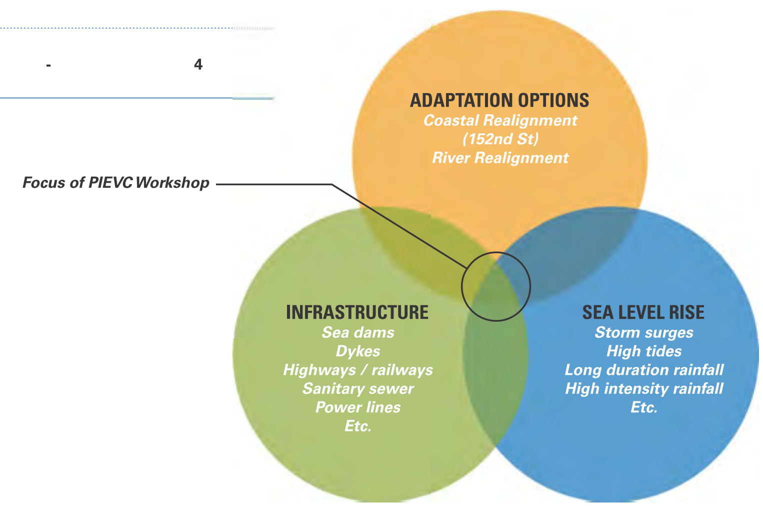
	OPTIONS	
COMPONENTS	COASTAL REALIGNMENT TO 152ND STREET	RIVER REALIGNMENT
Area converted to habitat (km^2)	16	16
Number of residences relocated	250	300
Length of old dyking abandoned (km)	30	36
Length of new dykes constructed (km)	4	16
Length of new major road (km)	12	8
Number of new sea-dams	2	1
Length of excavated new channels (km)	-	4

HOW CAN WE PARTICIPATE?

During the workshop, the *triple bottom line* decision making factors of infrastructure owners will be explored in detail. We expect that a pragmatic and effective means of adapting to coastal flood risks can be achieved with all stakeholders working together towards a common goal of risk reduction.

The adaptation options presented above represent only a snapshot of the options being considered. Moving forward with Surrey's Coastal Flood Adaptation Strategy (CFAS), it will be important to maintain engagement of infrastructure owners.

Each asset has different lifecycle renewal needs, and coordinating how each individual organization makes decisions around investing or divesting is most effectively done in consideration of adjacent infrastructure owners. With collaboration, a more effective strategy for mitigating risks of coastal flooding and climate change can be developed and implemented to maintain public safety and economic security.



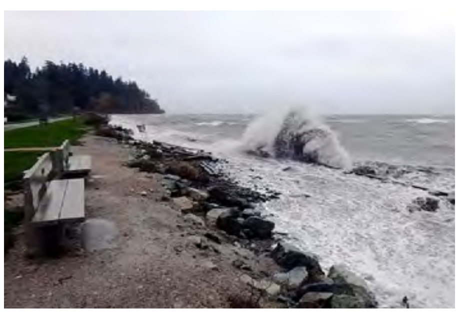
APPENDICES

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Climate change will be 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 at limiting flood damage in future as sea levels rise. In the short-term, we can expect more frequent and severe flooding from sea level rise and 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 the spring of 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 agricultural community, and neighbouring jurisdictions.



FLOOD ADAPTATION OPTIONS

This Options Primer presents 17 preliminary coastal flood adaptation options developed for the three areas that make up the CFAS project area—Mud Bay *(Chapter 1)*, Crescent Beach *(Chapter 2)*, and Semiahmoo Bay *(Chapter 3)*. The options were developed through extensive community consultation, project engineers, partnership with UBC and Dutch landscape architects and engineers, as well as City of Surrey staff.

Although each of the areas includes two similar options—"no adaptation" (i.e., maintaining existing flood control systems as is) and "current conventions" (i.e., raising existing dykes where they exist, improving existing pump stations, rebuilding existing sea dams)—the other options range considerably in scale, scope and flood management focus (i.e., protect, accommodate, retreat, combinations of options is also possible).

The Options Primer provides a short summary description of all options along with some images of the adaptation approach from other areas and jurisdictions. A sketch plan of the option is also provided, **illustrating potential conditions in 2100**, which is when sea levels in BC are projected to have risen by 1 metre.

The Options Primer also provides a short **preliminary** summary of how each option performs against ***six technical criteria*** and ***six values criteria***.

The following criteria are commonly used to evaluate the technical feasibility of flood adaptation options. The options are scored from very poor to very good under all the technical criteria, except for Capital Cost, where the budget bin of the option has been identified

- **FLOOD DAMAGE PREVENTION:** *How well would the option reduce or prevent flood damage from sea level rise and storm surges?*
- **OUTCOME OF A FAILURE:** *If the option failed, what would the consequences be to people, infrastructure and the environment?*
- **GEOTECHNICAL STABILITY:** *How effective would the option be at withstanding hazard events given the soil's stability?*
- **ADAPTABILITY OVER TIME:** *How well can the option be adjusted or phased to changing sea level rise?*
- **OPERATION & MAINTENANCE COST:** *What are the operation and maintenance costs for the City of implementing the option?*
- **CAPITAL COST:** *What are the capital costs for the City of implementing the option?*

The six values criteria capture what people and partners in the study area care most about. They were developed with project partners and stakeholders 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 stakeholders, such as the South Nicomekl Irrigation District, and environmental organizations, such as 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 the Surrey Speaks platform; and other outreach.

For this preliminary review, a single indicator was selected for each of six values criteria, which are scored from *best* to *worst* against one another, include:

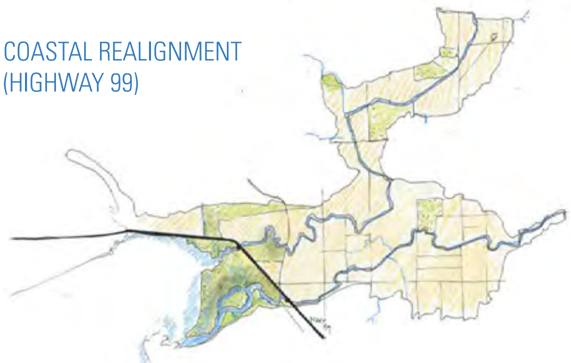
- **RESIDENTS:** *Number of people permanently displaced by the option.*
- **AGRICULTURE:** *Amount of agricultural land permanently lost due to the option.*
- **ENVIRONMENT:** *Anticipated impact (positive and negative) to wetland habitats, freshwater fish habitat and riparian areas that could be expected from the option.*
- **INFRASTRUCTURE:** *Anticipated service/ transportation infrastructure made vulnerable by 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.*

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

MUD BAY PRELIMINARY ADAPTATION OPTIONS

CURRENT CONVENTIONS

COASTAL REALIGNMENT (HIGHWAY 99)

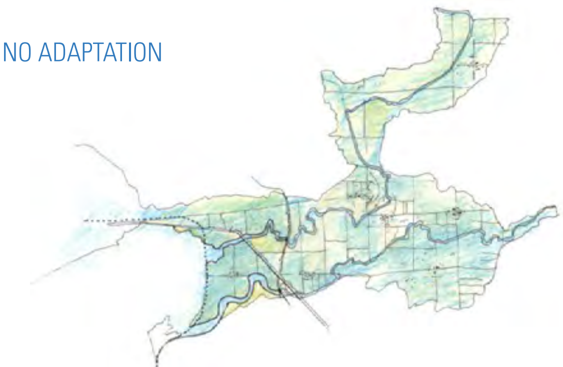


EDGE REALIGNMENT

MUD BAY BARRIER

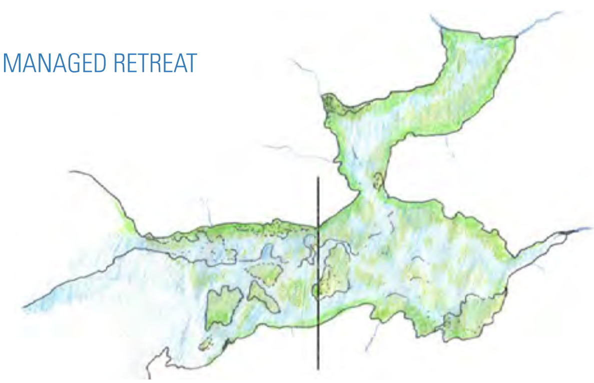
COASTAL REALIGNMENT (152ND STREET)

NO ADAPTATION



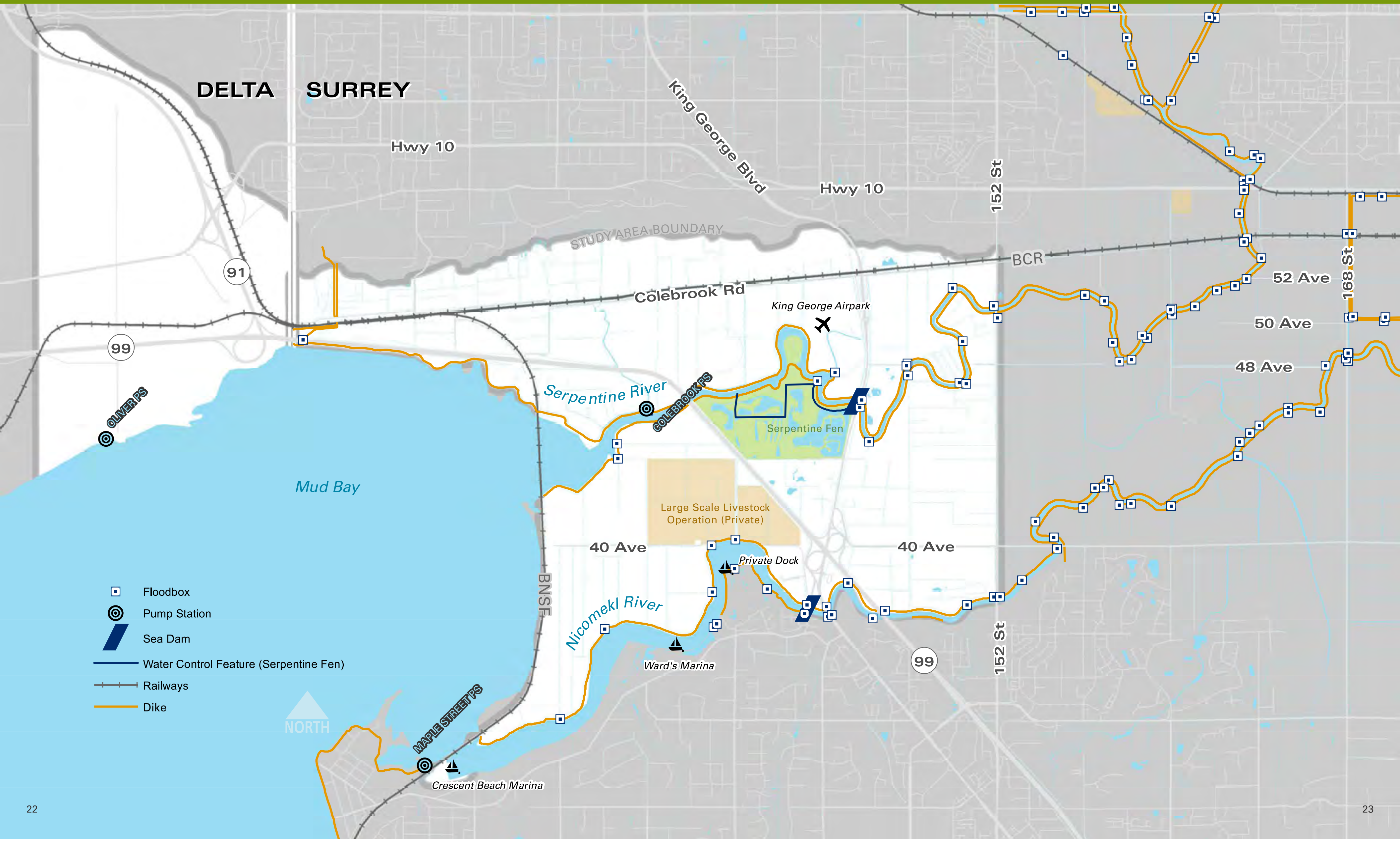
RIVER REALIGNMENT

MANAGED RETREAT

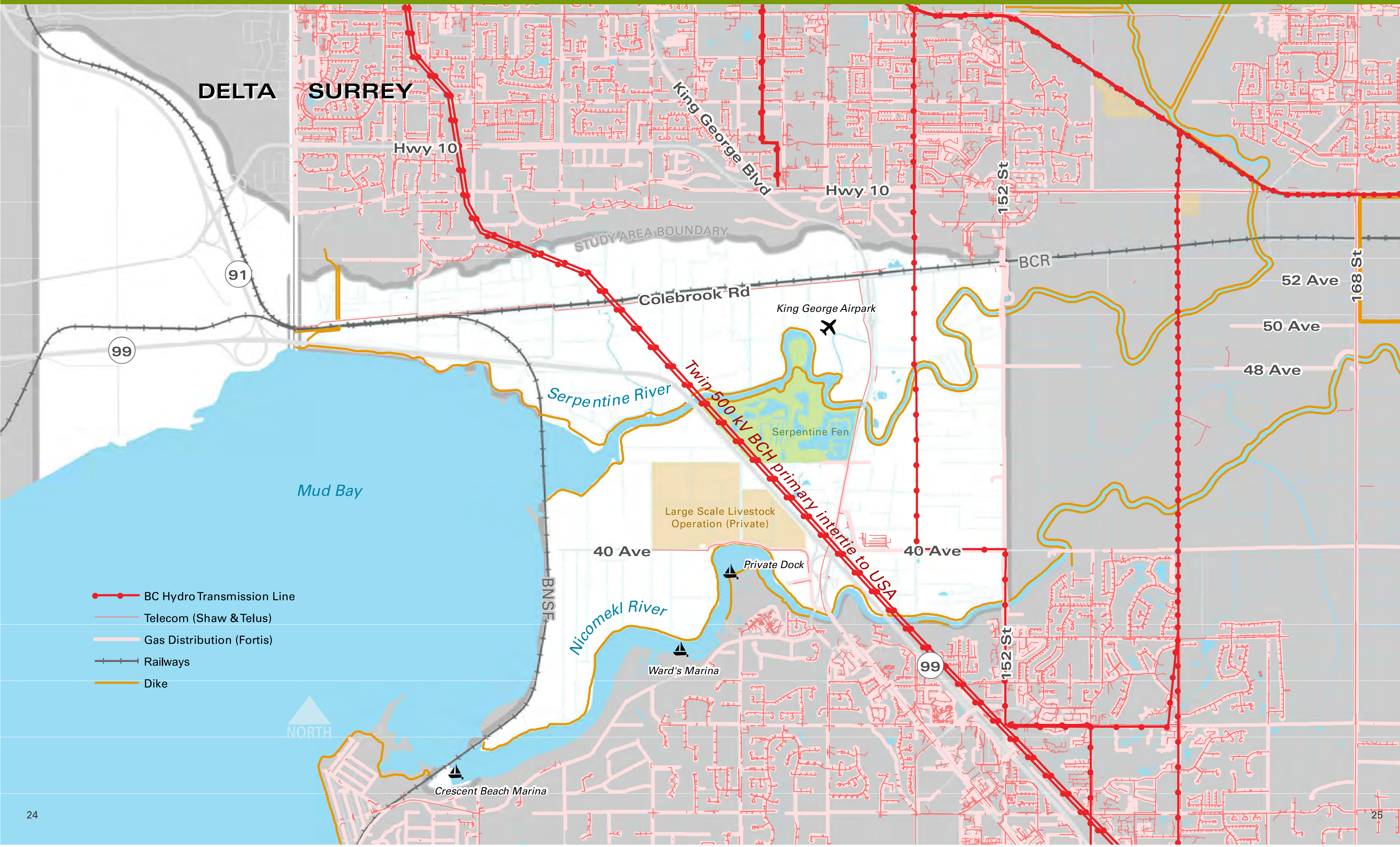


The above draft preliminary options are under review and the options for all three chapters—Mud Bay *(Chapter 1)*, Crescent Beach *(Chapter 2)*, and Semiahmoo Bay *(Chapter 3)*—will be available in a CFAS Options Primer in late 2017 on www.surrey.ca/coastal.

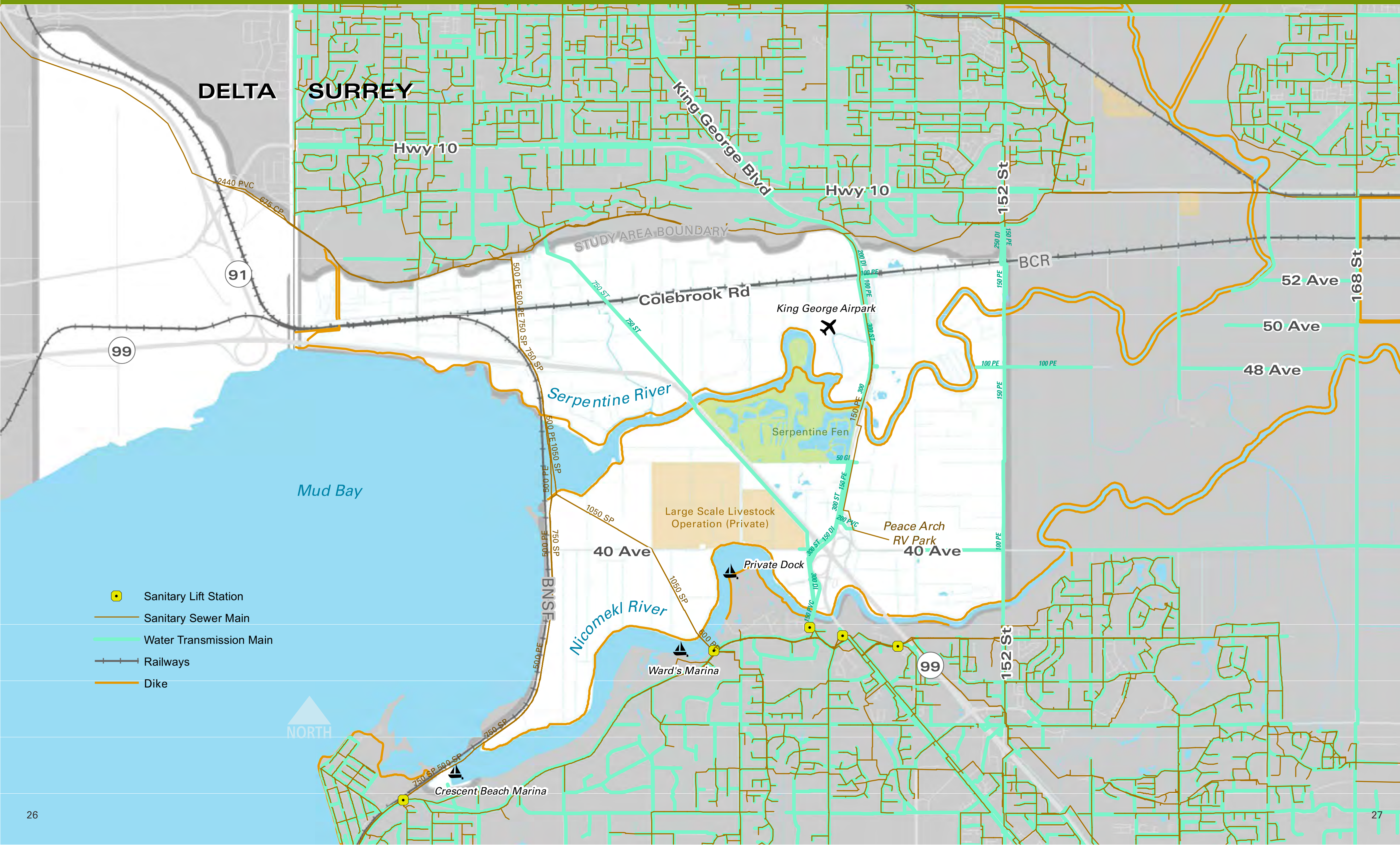
FLOOD CONTROL INFRASTRUCTURE



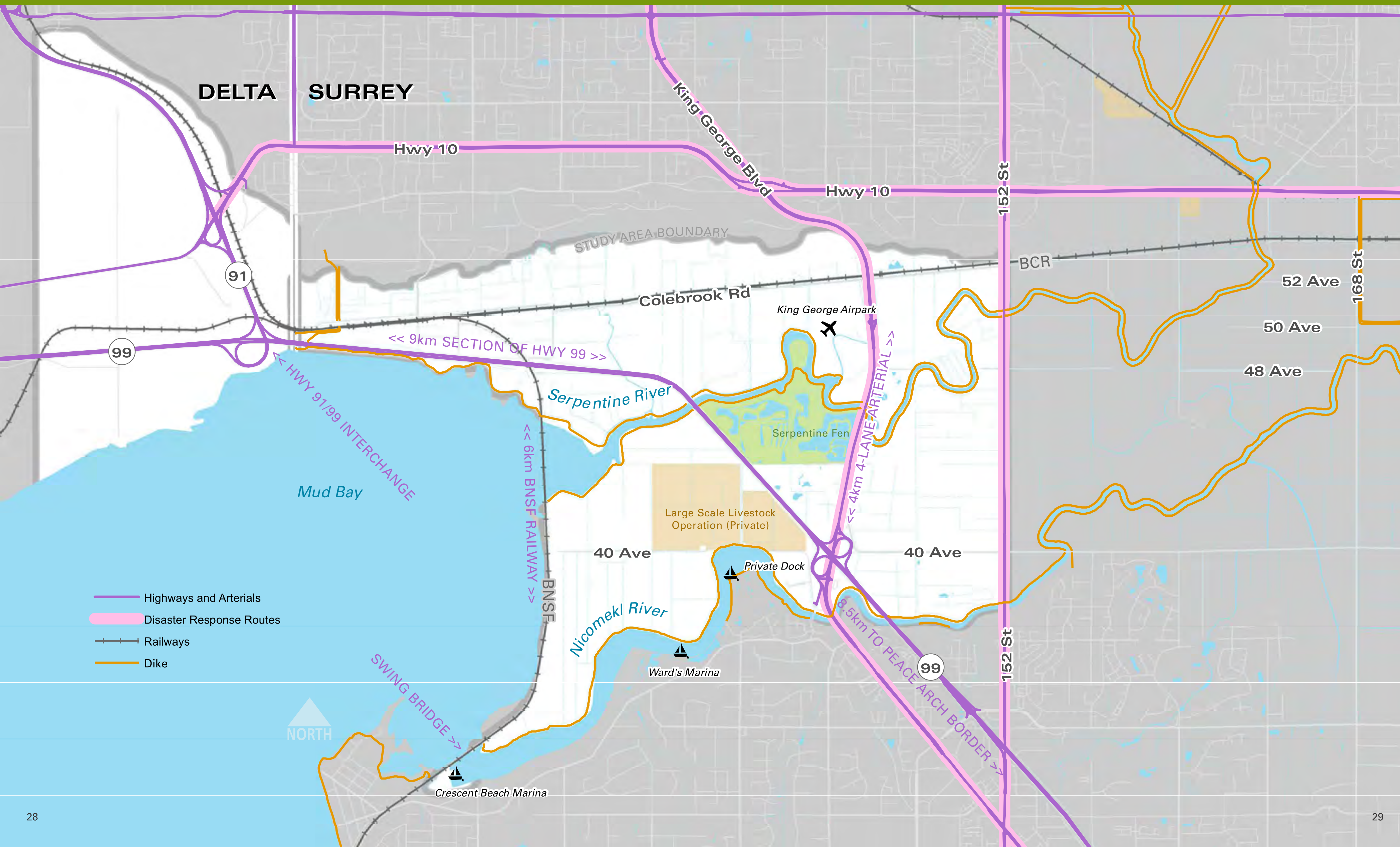
ENERGY AND COMMUNICATIONS INFRASTRUCTURE



SANITARY AND WATER INFRASTRUCTURE



TRANSPORTATION INFRASTRUCTURE



NOTES

NOTES

DISCLAIMER

Please note that this workshop shall not be construed as an acceptance or assumption of risk, responsibility, or liability by or on behalf of the City for the ongoing safe construction, operation, use, and maintenance of infrastructure in the floodplain. The full and complete responsibility and liability to ensure the ongoing safe construction, operation, use, and maintenance of infrastructure has been and continues to remain with the infrastructure owners.

MORE INFORMATION

All project information, including dates for upcoming presentations and events, and all CFAS project materials (videos, information materials, reports) will be posted on the project website.

www.surrey.ca/coastal

For more information, please contact:
Matt Osler
Project Engineer
City of Surrey
coastal@surrey.ca
604.591.4657

CFAS | CITY OF SURREY

2017-0.2

October 10, 2017

Surrey Coastal Flood Adaptation Strategy (CFAS)
Infrastructure Stakeholder Adaptation Options Workshop
Agenda

8:30 - 9:00	Registration
9:00 - 9:15	Introductions and Opening Remarks
9:15 - 10:15	CFAS Update - March 2017 PIEVC Vulnerability Workshop - CFAS Overview - Study Tour Overview - Preliminary Adaptation Options
10:15 - 10:30	Break
10:30 - 10:45	PIEVC Engineering and Triple Bottom Line Analysis
10:45 - 12:15	Adaptation Introduction and Group Exercise 1 - Adaptation Option 1: Costal Realignment to 152nd Street - Group Discussion
12:15 - 1:00	Lunch
1:00 - 2:45	Group Exercise 2 - Adaptation Option 2: River Realignment - Group Discussion
2:45 - 3:00	Break
3:00 - 3:45	Exercise 3 - Option Evaluation and Next Steps
3:45 – 4:00	Closing Remarks

Appendix B - Study Area Tour Comments

PIEVC Infrastructure Study Tour – September 25 2017 – Summary Notes (questions, concerns, implications for infrastructure organizations)

[Compiled by the City of Surrey]

- Would like to know more details about the two options
- Provide the rationale for why the two options were chosen for the Workshop (explain that they are not favoured)
- Comparisons between options (areas affected, environmental impact, costs related to infrastructure relocation/modification)
- Projection of the timelines
- How are we communicating/integrating other municipalities (interjurisdictional aspect)?
- Storage of fresh water by the two options?
- Include considerations of an earthquake
- Balance between total and partial retreat with respect to infrastructure?
- Who is paying?
- Organizations need more information to determine what they need to do with regards to two options
- CoS working hard to implement a BIG solution; Maybe it's time to invest in resilient infrastructure?
- CoS should take a lead on this innovative movement
- Should strongly consider adaptability over time
- Emergency services not able to reach people, access routes blocked (with flooding)
- 152nd Street widening and new Nicomekl Bridge are planned for the next 10-year servicing plan (cross-departmental integration)
- Parks do not see this as an opportunity to expand parkland
- Need for relocation of utilities, many mains go along roads

Overall Concerns:

- Need to protect agricultural land (concerns that it might be "cheaper" to buy out agricultural land than residents/homes, so that's why ag. land is being sacrificed)
- Need to provide agricultural land elsewhere (if this removed); removing other uses from areas zoned for agriculture
- Risks to large dykes (seismic events)

Overall Benefits:

- Environmental benefits, land enhancement opportunity
- Would provide more wetland/salt marshes
- Recreational opportunities

River Realignment:

- May be better for agricultural land, land use largely maintained
- May protect homes more
- Protects more infrastructure
- Work with nature, not against it – higher impact to nature/environment
- The preferred option for BC Hydro as it has less impact on their lines (it would be very expensive to relocate powerline towers, $0.5m per tower)
- Major changes, effects on fishing and salmon migration in the area
- Gas mains not affected

- Less perceived capital cost related to infrastructure relocation/modification
- Higher degree of approval required (different agencies)
- The lake created may pose environmental issue OR have opportunities for more recreation/park land

Coastal Realignment:

- Displacing more farmland
- Major impact on the economy
- Major BC Hydro corridor along Hwy 99 – (power towers –reinforce foundations, raise them; distribution lines – replace with FRP poles and raise) - expensive, would affect electricity rates
- Gas mains can be incorporated in existing infrastructure corridors – FortisBC could wait to see what the City will decide to do and then adapt – FortisBC matches their 20 year plans to the City's OCP and NCPs
- Could put isolation valves to shut off affected areas (unless relocated) – some areas/customers may end up being sacrificed
- Many FortisBC lines going to greenhouses, cathodically protected network; largest feed on 152^{nd}
- More marsh lands, bird sanctuaries, improved wetland areas
- Higher natural capability to dilute contaminant, etc.

Appendix C - TBL Factor Ratings

Infrastructure Components	TBL Factors (High / Medium / Low)													
	Environmental			Social						Economic				
	Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation	Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts	First Nations / Archaeology	Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle
Group Exercise 1 - Adaptation Option 1 - Coastal Realignment to 152nd Street														
Major Roads King George Boulevard Highway 99 152 Street	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPLIT	SPREAD		UPPER	UPPER	UPPER	UPPER	SPREAD
Major Roads Roads within Corporation of Delta Highway 91 Highway 99 Ladner Trunk Road	UPPER	SPREAD	SPREAD	UPPER	UPPER	UPPER	SPREAD	UPPER		UPPER	UPPER	UPPER	UPPER	SPREAD
Railway Infrastructure BNSF embankment Trestles Swing Bridge BCRC Embankment	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOWER	SPLIT		SPLIT	SPREAD	SPREAD	SPREAD	SPREAD
Sanitary Lift Stations	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOW		SPREAD	SPREAD	SPREAD	SPLIT	SPREAD
Metro Vancouver Sanitary Main	SPREAD	SPLIT	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOWER		SPLIT	UPPER	SPLIT	LOWER	SPREAD
Metro Vancouver Water Main	UPPER	SPLIT	SPREAD	LOW	LOWER	SPREAD	SPREAD	LOWER		UPPER	UPPER	UPPER	SPREAD	UPPER
FortisBC Gas Mains	SPLIT	LOW	LOWER	SPLIT	SPLIT	SPLIT	SPREAD	LOWER		SPREAD	SPREAD	SPLIT	SPLIT	SPREAD
BC Hydro Transmission Lines	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD		UPPER	SPREAD	UPPER	SPREAD	SPREAD
Drainage Pump Stations, Ditches, Floodboxes	SPREAD	SPREAD	SPREAD	SPREAD	SPLIT	SPREAD	LOWER	SPREAD		SPREAD	SPREAD	SPREAD	SPREAD	SPREAD
King George Airpark	LOWER	LOWER	SPREAD	SPREAD	LOWER	LOWER	LOWER	LOWER		SPREAD	SPREAD	LOWER	LOWER	LOWER
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOWER	LOWER	LOWER		LOWER	LOWER	SPREAD	SPREAD	LOWER
Local roads	LOW	LOW	LOW	LOW	LOW	LOW	LOW	SPREAD		LOWER	LOWER	LOWER	LOW	LOW
Local Power Distribution, Telecom	SPREAD	LOW	LOW	LOW	LOW	LOW	LOW	LOWER		LOWER	SPLIT	SPLIT	LOW	LOW
Serpentine Fen and Water Control Features	LOWER	SPREAD	SPREAD	LOWER	LOWER	LOWER	LOWER	LOW		LOWER	SPREAD	LOWER	LOW	LOWER
Marinas, Private Docks	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOWER	LOW		UPPER	UPPER	SPREAD	SPREAD	LOWER
Dairy Farm	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	LOW	SPLIT		UPPER	UPPER	SPLIT	HIGH	SPREAD

HIGH HIGH

UPPER MEDIUM AND HIGH

MEDIUM MEDIUM

LOWER MEDIUM AND LOW

LOW LOW

SPREAD HIGH, MEDIUM, AND LOW

SPLIT HIGH AND LOW

**Note: First Nations / Archaeology factor was added during the workshop and was ranked only by one table, and only for Adaptation Option 2.*

Group Exercise 2 - Adaptation Option 2 - River Realignment

Infrastructure Components	TBL Factors (High / Medium / Low): Environmental			Social						Economic				
	Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation	Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts	First Nations / Archaeology	Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle
Major Roads King George Boulevard Highway 99 152 Street	UPPER	UPPER	SPREAD	UPPER	UPPER	SPREAD	SPREAD	SPREAD	HIGH	UPPER	UPPER	UPPER	SPREAD	UPPER
Major Roads Roads within Corporation of Delta Highway 91 Highway 99 Ladner Trunk Road	UPPER	SPREAD	SPLIT	UPPER	UPPER	SPREAD	SPREAD	SPREAD	HIGH	HIGH	UPPER	UPPER	SPREAD	SPREAD
Railway Infrastructure BNSF embankment Trestles Swing Bridge BCRC Embankment	HIGH	SPREAD	SPLIT	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD	HIGH	HIGH	UPPER	HIGH	UPPER	UPPER
Sanitary Lift Stations	SPREAD	SPREAD	SPREAD	SPREAD	LOWER	SPREAD	SPREAD	LOWER	HIGH	SPLIT	SPLIT	SPREAD	LOWER	SPLIT
Metro Vancouver Sanitary Main	SPREAD	SPREAD	UPPER	SPREAD	SPREAD	UPPER	UPPER	LOWER	HIGH	SPREAD	UPPER	SPREAD	LOW	SPREAD
Metro Vancouver Water Main	SPREAD	LOWER	LOWER	LOW	LOWER	SPREAD	SPREAD	LOWER	HIGH	SPREAD	SPREAD	SPREAD	SPREAD	SPREAD
FortisBC Gas Mains	SPREAD	LOWER	SPLIT	LOW	LOWER	SPREAD	LOW	LOWER	MEDIUM	LOWER	LOWER	LOWER	LOWER	SPREAD
BC Hydro Transmission Lines	SPREAD	LOW	LOW	SPREAD	LOWER	LOW	LOW	LOWER	MEDIUM	SPLIT	LOW	SPREAD	SPLIT	SPLIT
Drainage Pump Stations, Ditches, Floodboxes	UPPER	UPPER	UPPER	SPREAD	SPLIT	SPREAD	SPREAD	SPREAD	HIGH	SPREAD	SPREAD	SPREAD	SPREAD	SPLIT
King George Airpark	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW		LOW	LOW	LOW	LOWER	LOWER
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	SPREAD	LOWER	LOWER	SPREAD	UPPER	LOWER	LOW	SPREAD		LOWER	LOW	LOW	LOWER	LOWER
Local roads	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOWER		LOW	LOW	LOW	LOWER	LOWER
Local Power Distribution, Telecom	LOWER	LOW	LOW	LOW	LOW	LOW	LOW	LOWER		LOW	LOW	LOW	LOWER	LOWER
Serpentine Fen and Water Control Features	LOWER	SPREAD	SPREAD	UPPER	MEDIUM	LOWER	LOW	SPLIT		UPPER	SPLIT	SPREAD	SPLIT	LOWER
Marinas, Private Docks	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT		UPPER	MEDIUM	LOWER	SPREAD	LOWER
Dairy Farm	SPREAD	LOW	SPLIT	LOWER	SPREAD	SPREAD	SPLIT	SPREAD		UPPER	UPPER	SPREAD	UPPER	SPREAD

HIGH HIGH

UPPER MEDIUM AND HIGH

MEDIUM MEDIUM

LOWER MEDIUM AND LOW

LOW LOW

SPREAD HIGH, MEDIUM, AND LOW

SPLIT HIGH AND LOW

**Note: First Nations / Archaeology factor was added during the workshop and was ranked only by one table, and only for Adaptation Option 2.*

Infrastructure Components	TBL Factors (High / Medium / Low)													
	Environmental			Social						Economic				
	Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation	Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts	First Nations / Archaeology	Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle
Combined Results														
Major Roads King George Boulevard Highway 99 152 Street	SPLIT	SPLIT	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT	SPREAD		UPPER	UPPER	UPPER	SPLIT	SPLIT
Major Roads Roads within Corporation of Delta Highway 91 Highway 99 Ladner Trunk Road	UPPER	SPREAD	SPLIT	UPPER	UPPER	SPLIT	SPREAD	SPLIT		SPLIT	UPPER	UPPER	SPLIT	SPREAD
Railway Infrastructure BNSF embankment Trestles Swing Bridge BCRC Embankment	SPLIT	SPREAD	SPLIT	SPREAD	SPREAD	SPREAD	SPLIT	SPLIT		SPLIT	SPLIT	SPLIT	SPLIT	SPLIT
Sanitary Lift Stations	SPREAD	SPREAD	SPREAD	SPREAD	SPLIT	SPREAD	SPREAD	SPLIT		SPLIT	SPLIT	SPREAD	SPLIT	SPLIT
Metro Vancouver Sanitary Main	SPREAD	SPLIT	SPLIT	SPREAD	SPREAD	SPLIT	SPLIT	LOWER		SPLIT	UPPER	SPLIT	SPLIT	SPREAD
Metro Vancouver Water Main	SPLIT	SPLIT	SPLIT	LOW	LOWER	SPREAD	SPREAD	LOWER		SPLIT	SPLIT	SPLIT	SPREAD	SPLIT
FortisBC Gas Mains	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	LOWER		SPLIT	SPLIT	SPLIT	SPLIT	SPREAD
BC Hydro Transmission Lines	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT	SPLIT	SPLIT	SPLIT		SPLIT	SPLIT	SPLIT	SPLIT	SPLIT
Drainage Pump Stations, Ditches, Floodboxes	SPLIT	SPLIT	SPLIT	SPREAD	SPLIT	SPREAD	SPLIT	SPREAD		SPREAD	SPREAD	SPREAD	SPREAD	SPLIT
King George Airpark	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT	SPLIT		SPLIT	SPLIT	SPLIT	LOWER	LOWER
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT	LOWER	SPLIT	SPLIT		LOWER	SPLIT	SPLIT	SPLIT	LOWER
Local roads	LOW	LOW	LOW	LOW	LOW	LOW	LOW	SPLIT		SPLIT	SPLIT	SPLIT	SPLIT	SPLIT
Local Power Distribution, Telecom	SPLIT	LOW	LOW	LOW	LOW	LOW	LOW	LOWER		SPLIT	SPLIT	SPLIT	SPLIT	SPLIT
Serpentine Fen and Water Control Features	LOWER	SPREAD	SPREAD	SPLIT	SPLIT	LOWER	SPLIT	SPLIT		SPLIT	SPLIT	SPLIT	SPLIT	LOWER
Marinas, Private Docks	SPREAD	SPLIT	SPLIT	SPREAD	SPLIT	SPLIT	SPLIT	SPLIT		UPPER	SPLIT	SPLIT	SPREAD	LOWER
Dairy Farm	SPREAD	SPLIT	SPLIT	SPLIT	SPREAD	SPREAD	SPLIT	SPLIT		UPPER	UPPER	SPLIT	SPLIT	SPREAD

HIGH HIGH

UPPER MEDIUM AND HIGH

MEDIUM MEDIUM

LOWER MEDIUM AND LOW

LOW LOW

SPREAD HIGH, MEDIUM, AND LOW

SPLIT HIGH AND LOW

**Note: First Nations / Archaeology factor was added during the workshop and was ranked only by one table, and*

Appendix D - UBC-LINT Infrastructure Concepts

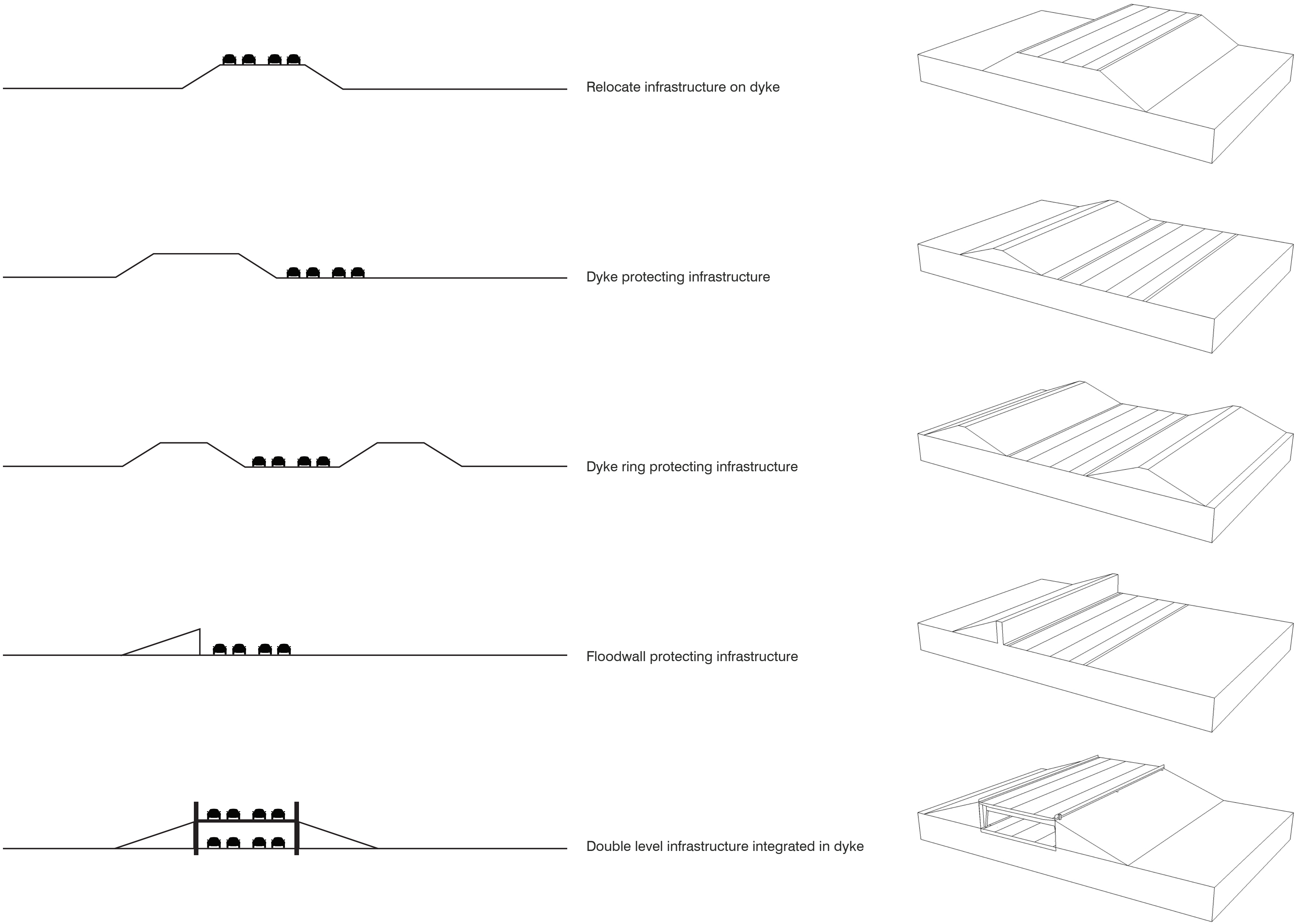
MUD BAY SURREY
INFRASTRUCTURE STUDY

CONCEPT VERSION
OCTOBER 2017

THE UNIVERSITY OF BRITISH COLUMBIA

LINT
landscape interventions

INFRASTRUCTURE PROTECTS AGAINST FLOODING



INFRASTRUCTURE PROTECTS AGAINST FLOODING

Hoogwatergeul Veessen - Wapenveld

image:http://www.ijsselweide.com

Elevated road

image: http://guardianlv.com/wp-content/uploads/2013/12/florida_marsh_300.jpg

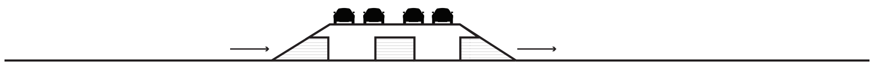
Raised highway on dyke

image: http://www.landezine.com/index.php/2012/02/vienna-detzlhofer-landschaftsarchitektur/landform-by-the-vienna-highway-ring-by-detzlhofer-landschaftsarchitektur-05

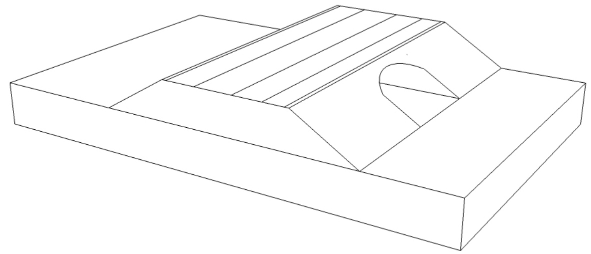
Raised road structures

image: http://refugeassociation.org/wp-content/uploads/2014/03/ding.jpg

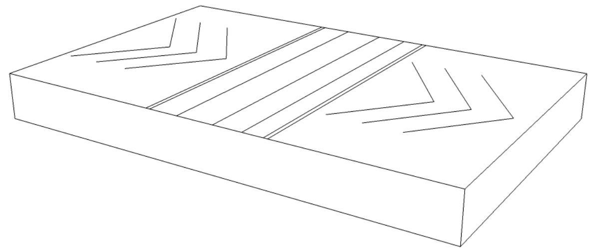
INFRASTRUCTURE ACCOMMODATES FLOODING

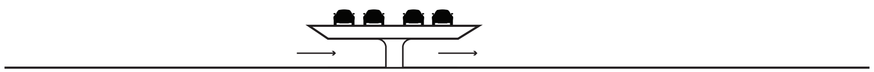


Semipermeable dyke structure

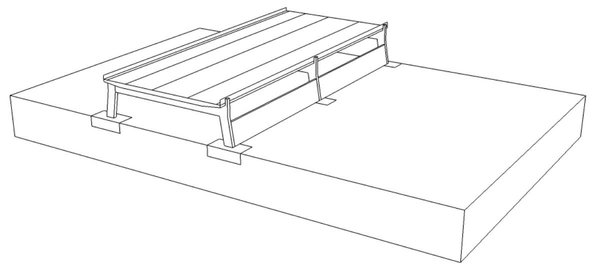


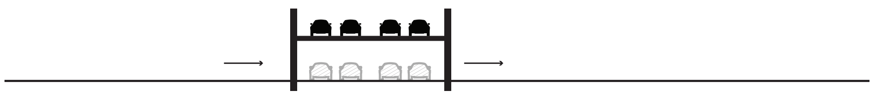
Floodable infrastructure



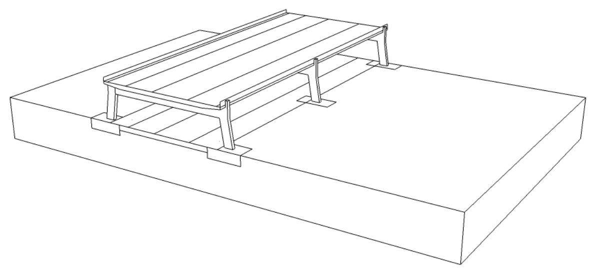


Elevated highway





Double level highway with floodable bottom part



INFRASTRUCTURE ACCOMMODATES FLOODING

Elevated road above floodable area

image: http://www.luttjeboer.nl/projecten/stuwen-inlaten/hoogwatergeul-veessen-wapenveld/

Hoogwatergeul Veessen-Wapenveld, NL

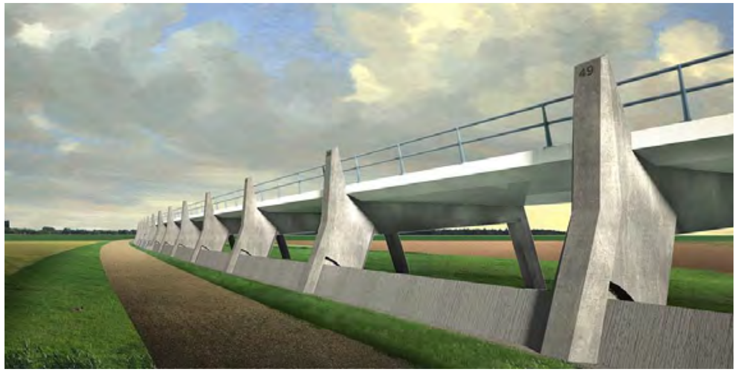
image: https://architectenweb.nl/media/illustrations/2014/02/5304076e-64ed-40f5-bbc9-27dd19295a5c.jpg

Elevated highway

image: http://www.rondreis.nl/media/blog/2209/2209_1000x670.jpg

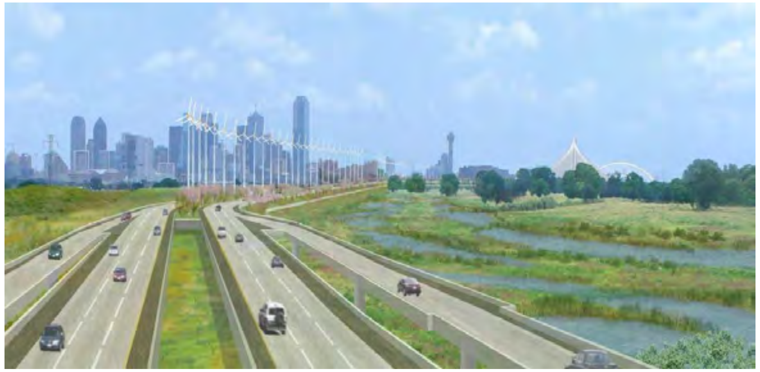
Room for the River, Nijmegen, NL

image: http://www.prorailpersberichten.nl/bericht/799/



Hoogwatergeul Veessen-Wapenveld, NL

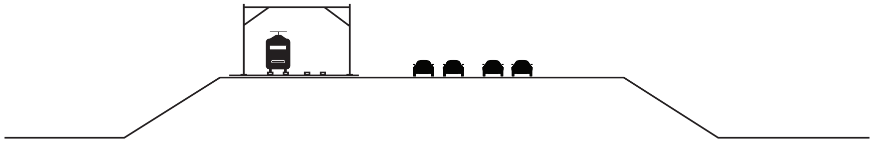
image: http://www.zus.cc/__we_thumbs__/2111_2_232_HoogwatergeulKerkdijk_vanaf-fietspad.jpg



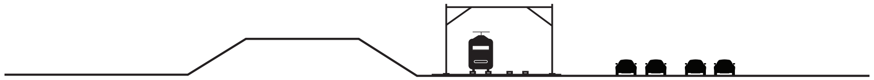
Elevated road

image: https://images1.dallasobserver.com/imager/u/745xauto/7268713/toll_road1.jpg

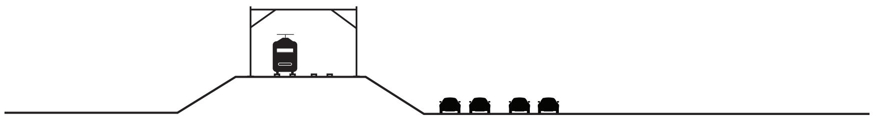
COMBINED INFRASTRUCTURE



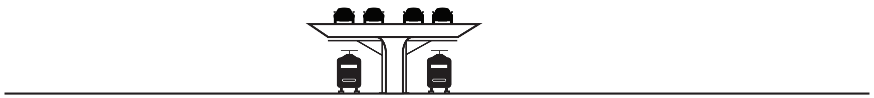
Relocate both railway and highway on top of a superdyke



Relocate railway along highway, protection by new dyke



Protection highway by new dyke, relocate railway on top of new dyke

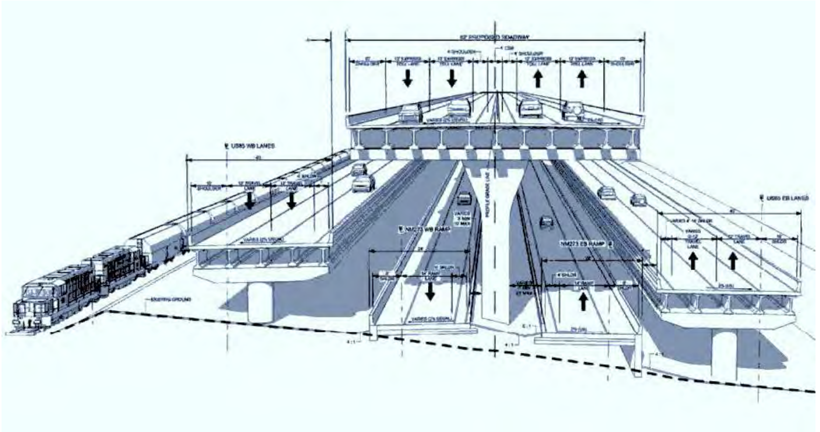


Elevated highway in combination with floodable railway

COMBINED INFRASTRUCTURE

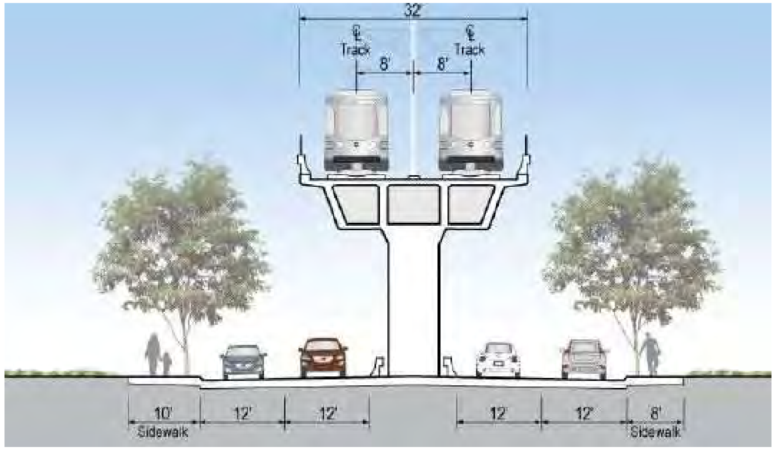
Combination train and highway

image: https://www.bart.gov/sites/default/files/images/basic_page/06_Sustainability_565x377.jpg



Combination train and highway

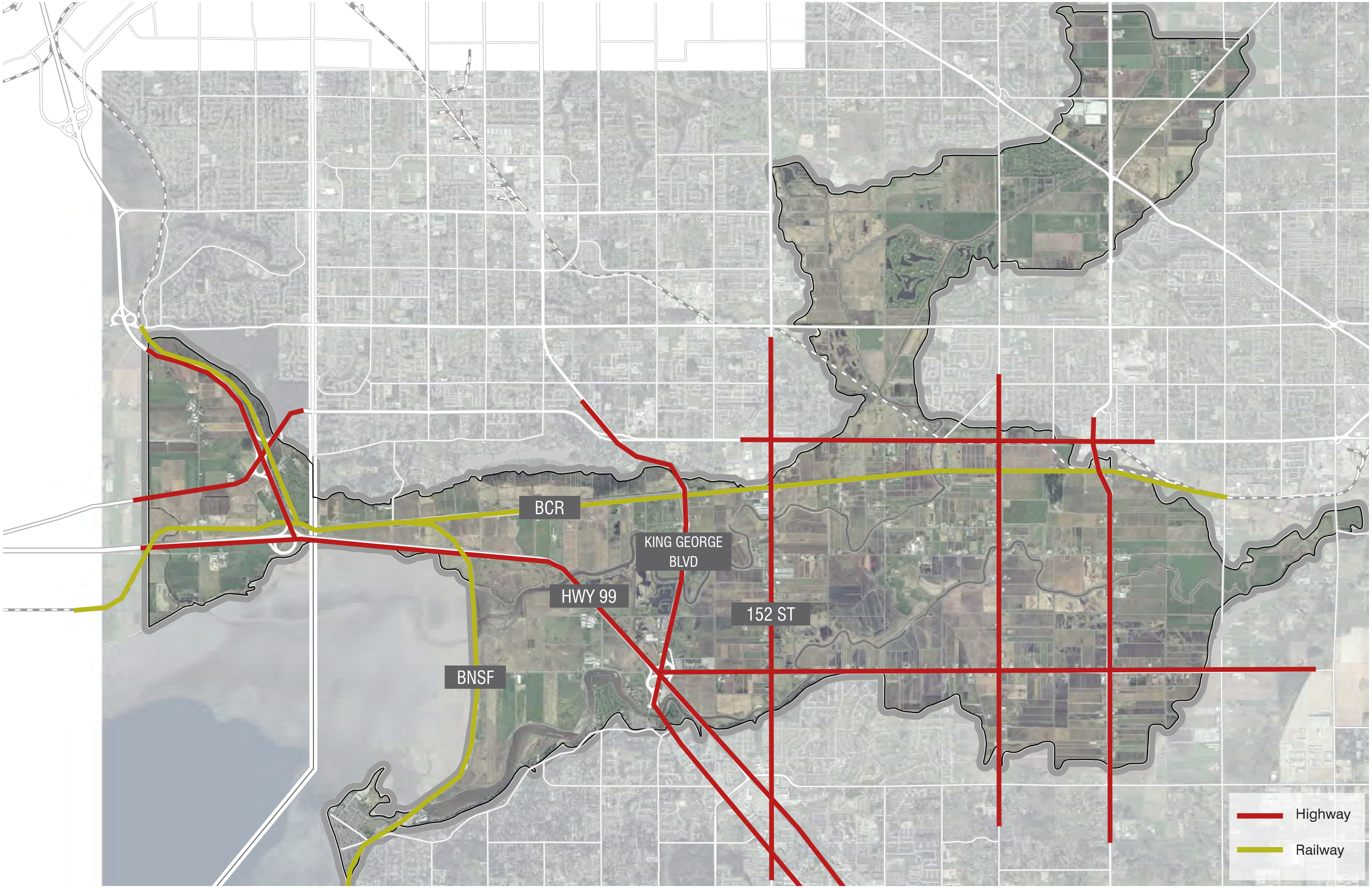
image: http://1.bp.blogspot.com/-CCpJBg26Tho/UYht8lGTJQI/AAAAAAAACks/eVRX2nyeC5M/s1600/BHW+01.jpg



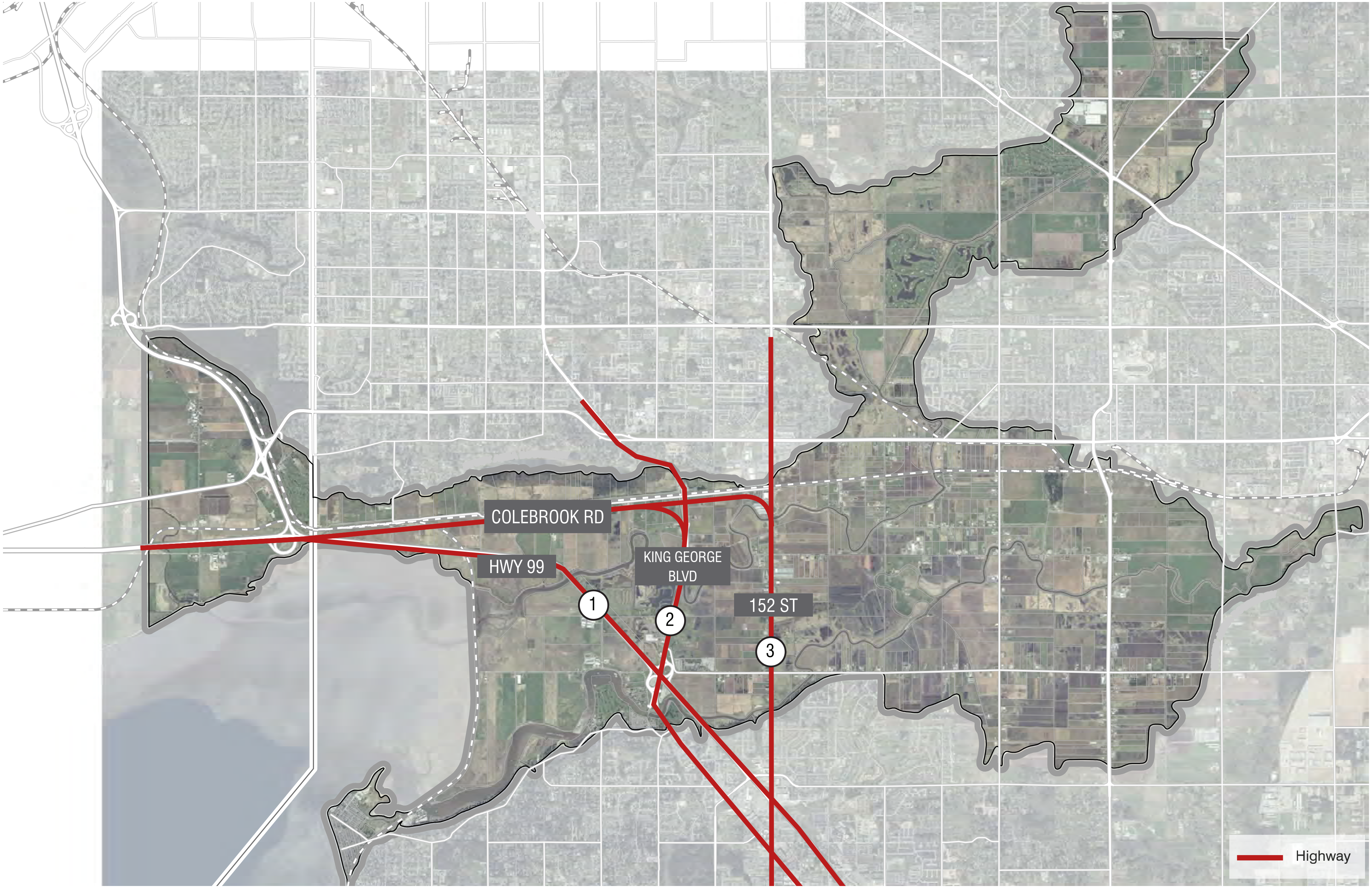
Combination train and highway

image: http://lh5.googleusercontent.com/-FMtWI6_ZhYc/UQgTAfHzZBI/AAAAAAAAfeg/YZpK6XgZQNk/s535/lrt.
JPG?gl=US

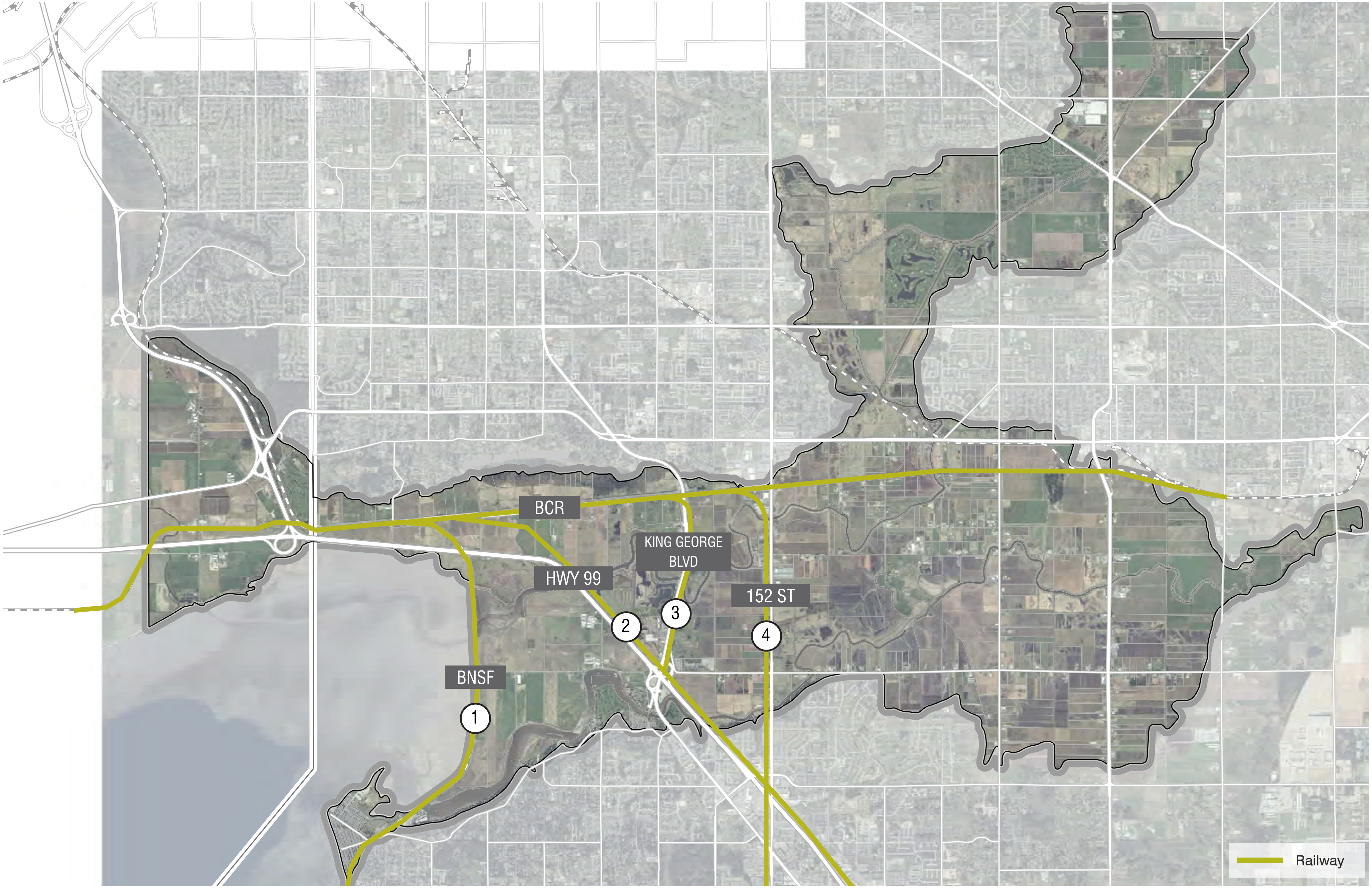
INFRASTRUCTURE CURRENT SITUATION



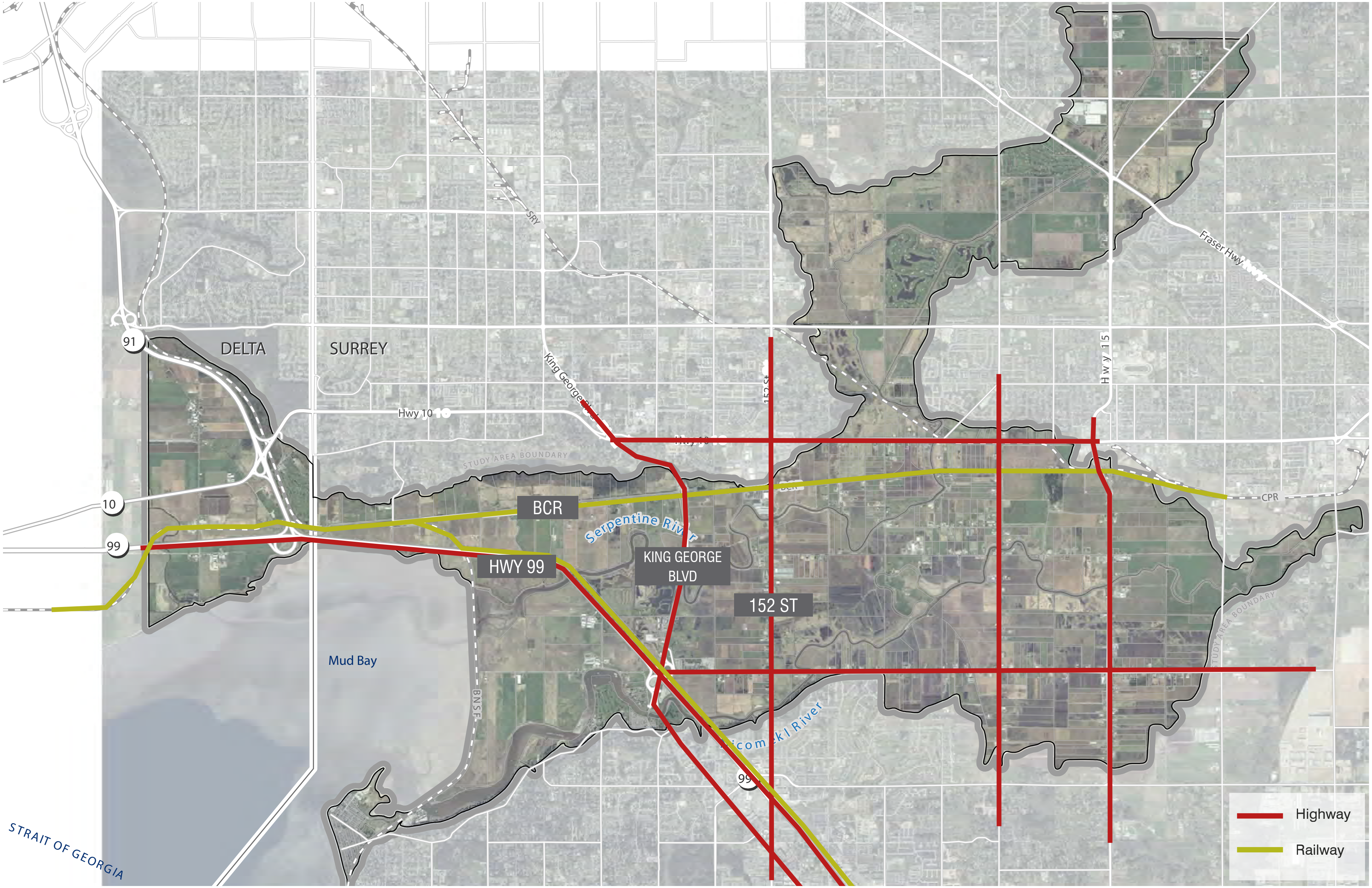
INFRASTRUCTURE ROUTES CAR



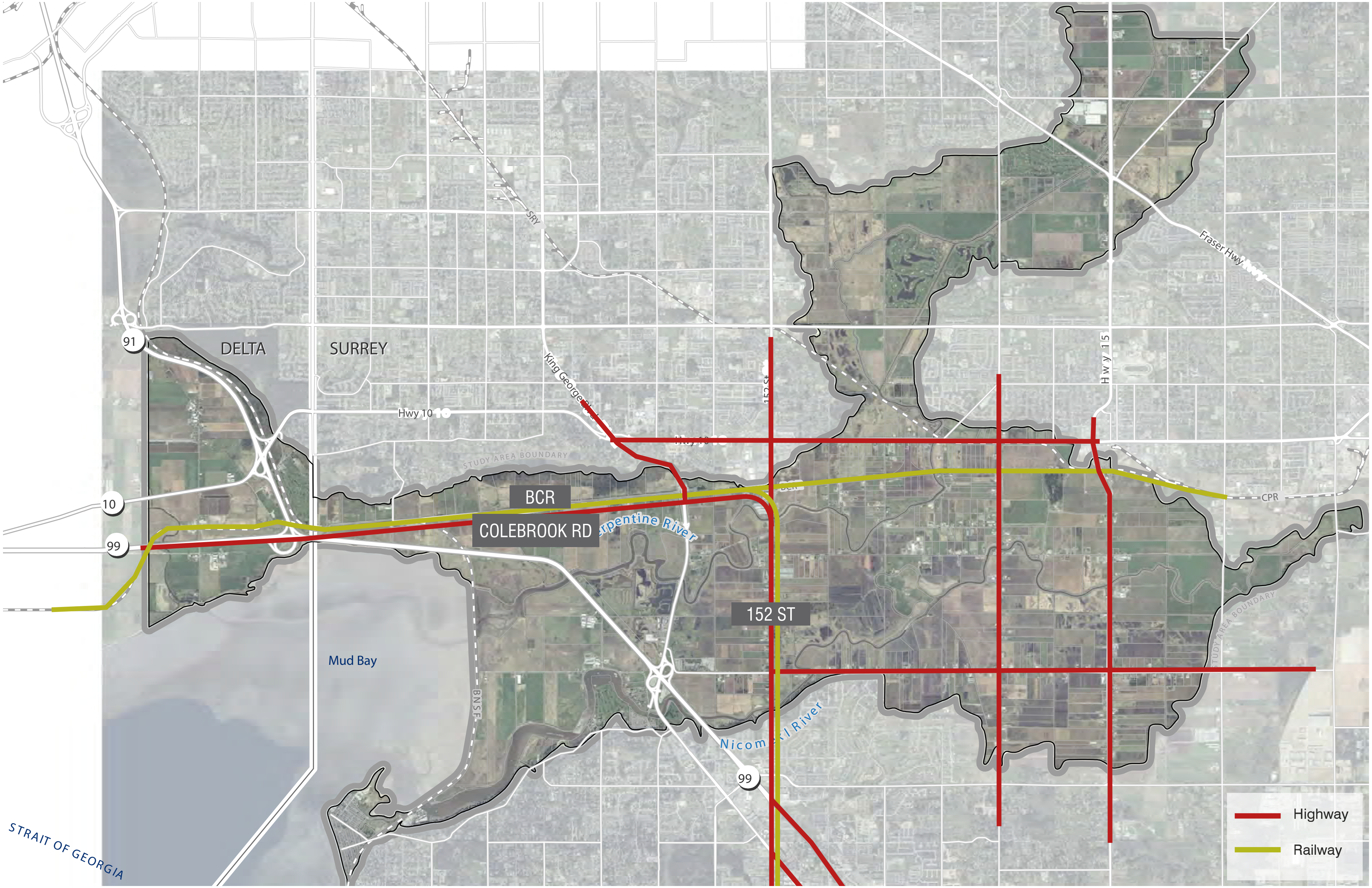
INFRASTRUCTURE ROUTES TRAIN



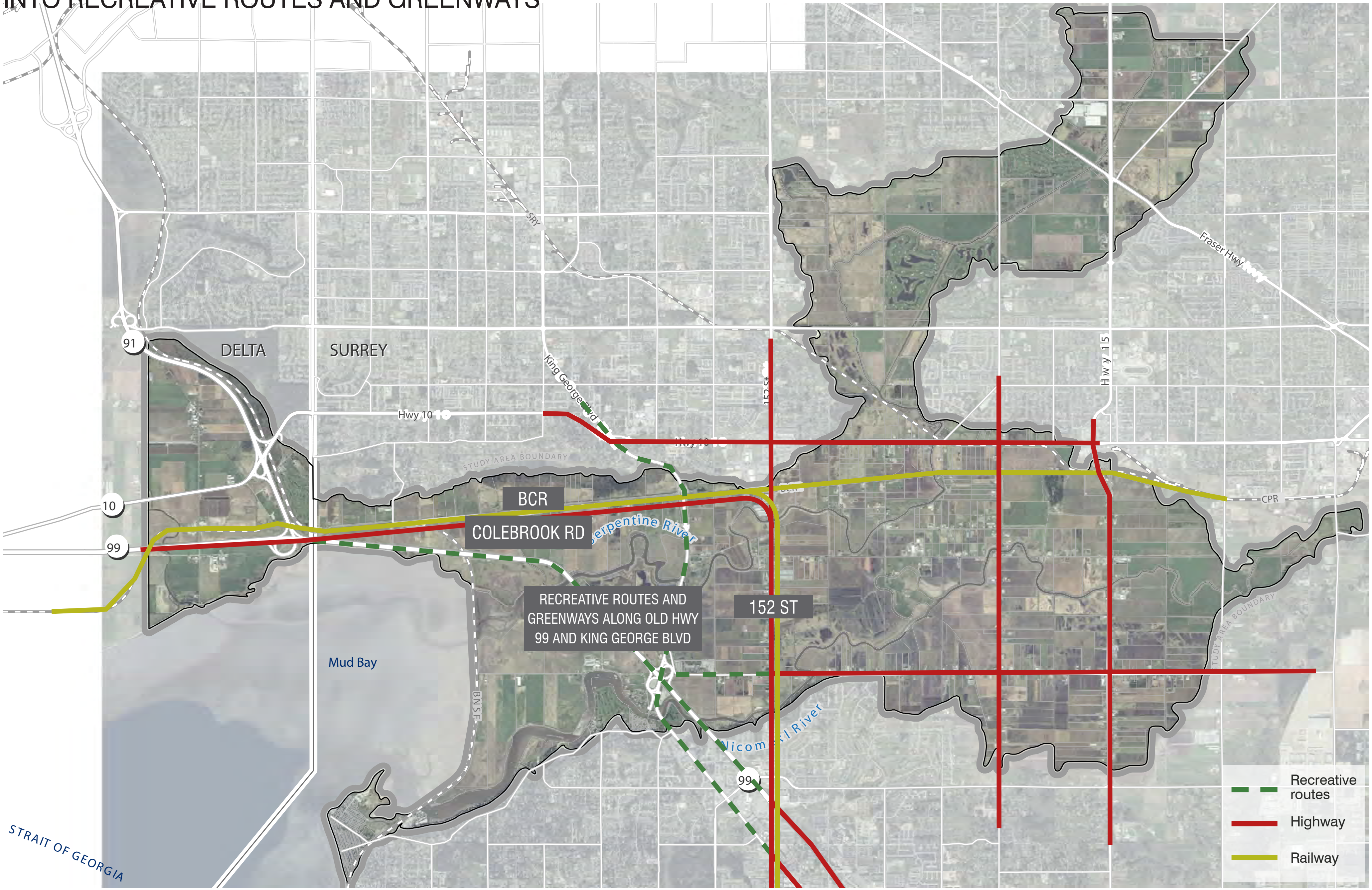
OPTION 1: COMBINATION HIGHWAY +RAILWAY AT HIGHWAY 99



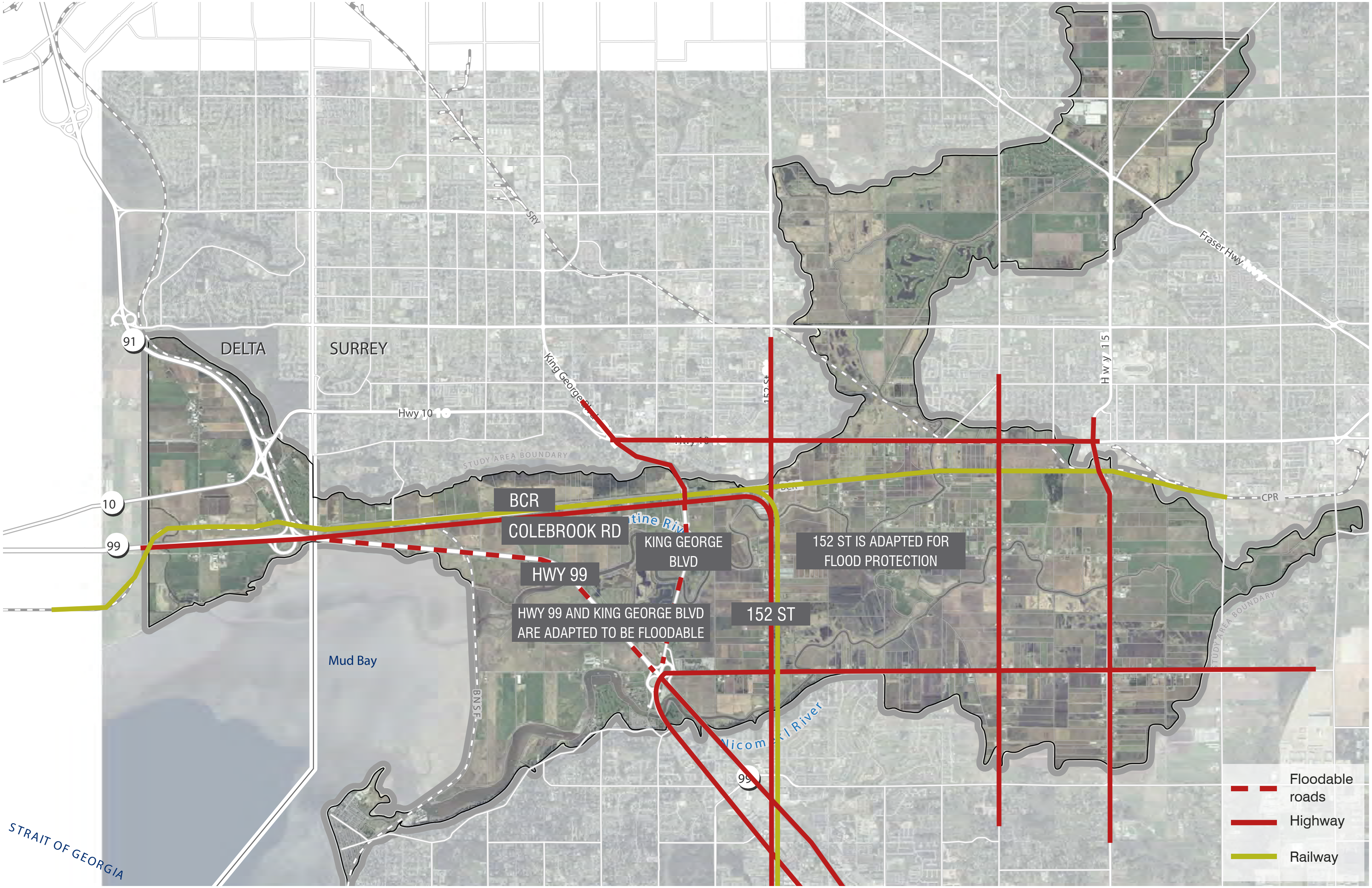
OPTION 2: COMBINATION HIGHWAY +RAILWAY AT 152 ST, REMOVAL HIGHWAY 99 AND KING GEORGE BLVD



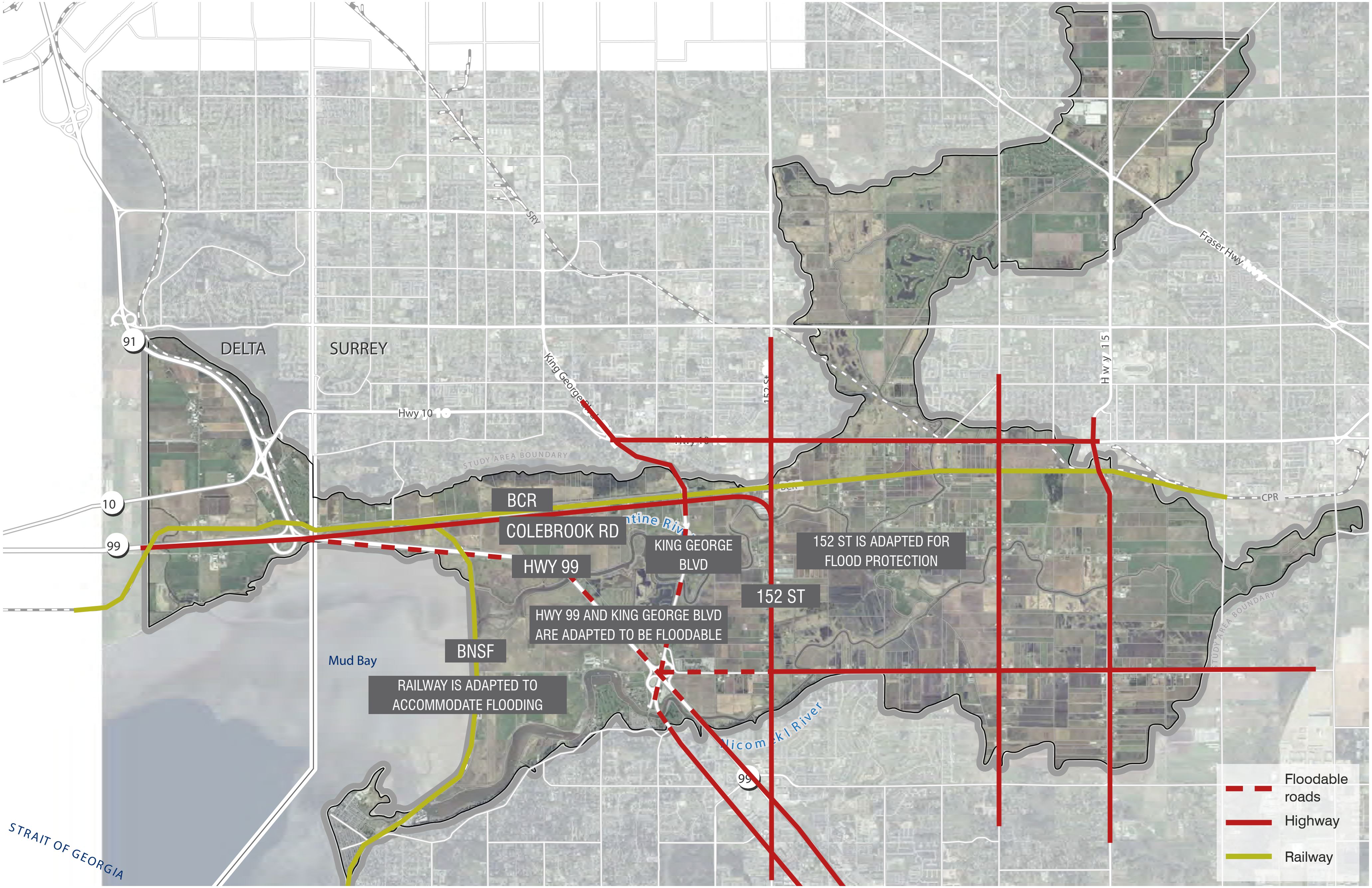
OPTION 3: COMBINATION HIGHWAY +RAILWAY AT 152 ST, HIGHWAY 99 AND KING GEORGE BLVD ARE TRANSFORMED INTO RECREATIVE ROUTES AND GREENWAYS



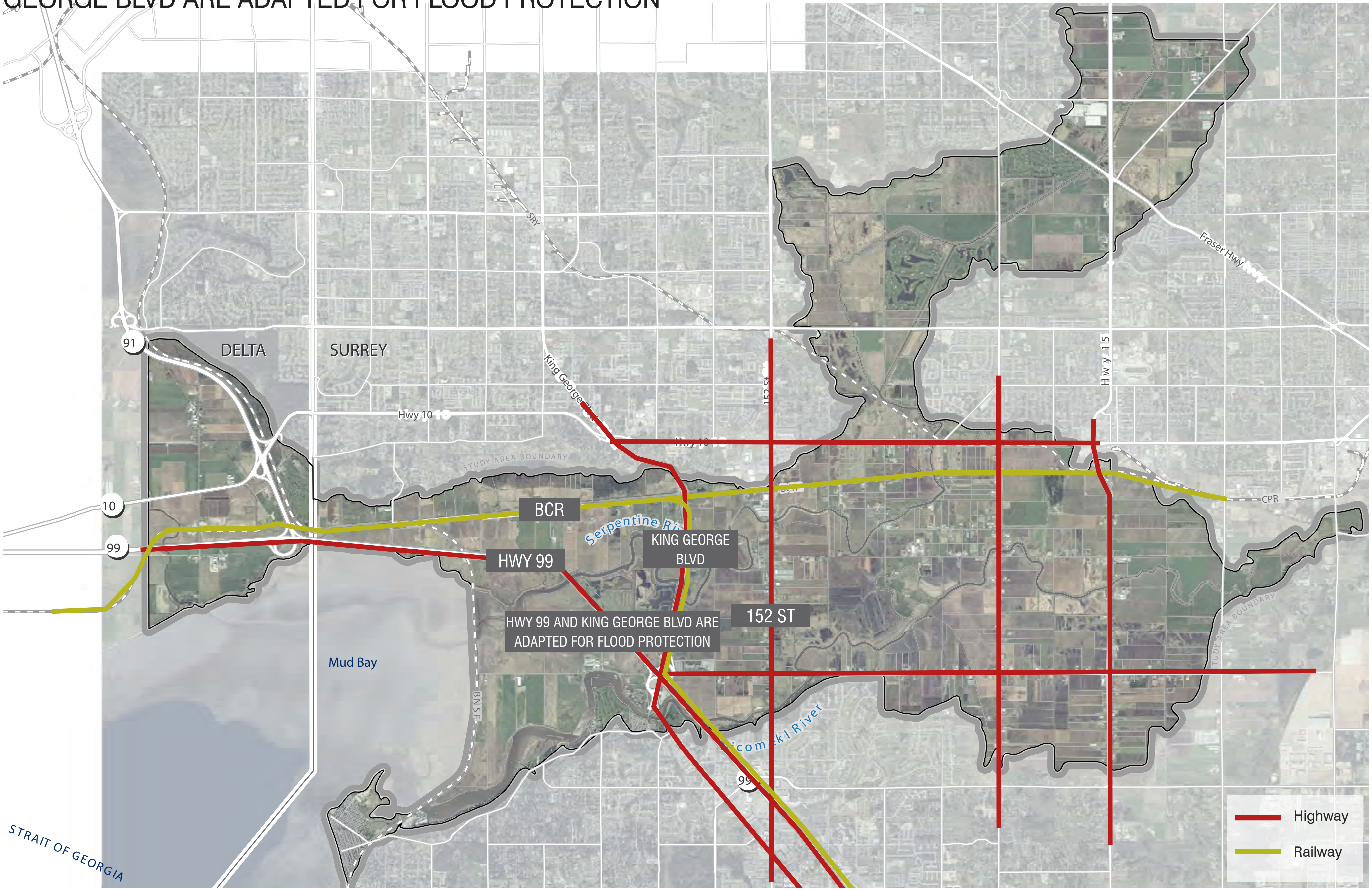
OPTION 4: COMBINATION HIGHWAY +RAILWAY AT 152 ST, HIGHWAY 99 AND KING GEORGE BLVD BECOME FLOODABLE



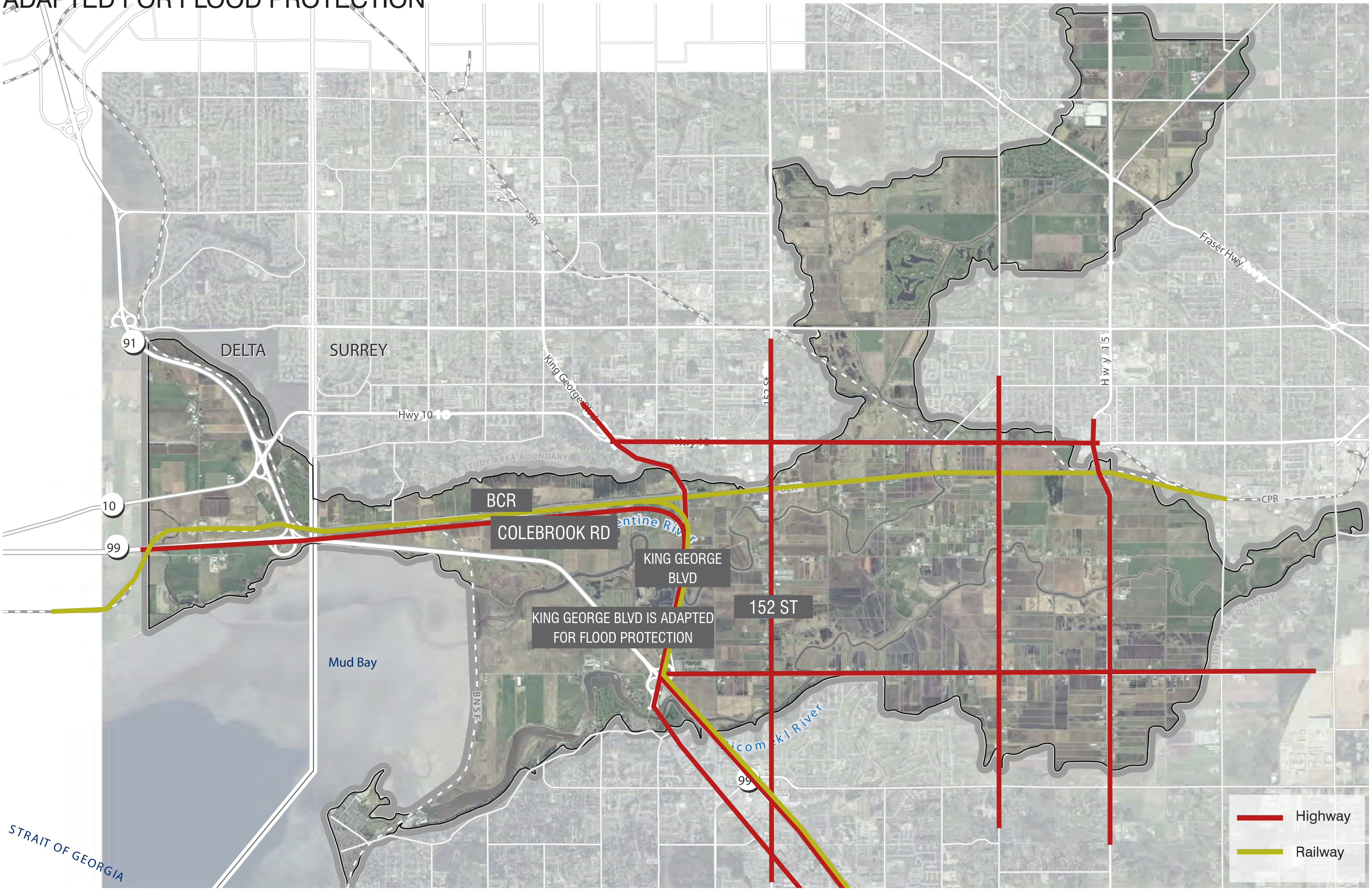
OPTION 5: ADAPT 152 ST + KING GEORGE BLVD & HIGHWAY 99 ARE FLOODABLE



OPTION 6: RELOCATE RAILWAY TO KING GEORGE BOULEVARD, HIGHWAY 99 AND KING GEORGE BLVD ARE ADAPTED FOR FLOOD PROTECTION



OPTION 7: RELOCATE RAILWAY AND HIGHWAY 99 TO KING GEORGE BOULEVARD, AND ADAPTED FOR FLOOD PROTECTION



Appendix E - Workshop Exit Survey Responses

Improving Coastal Flood Adaptation Approaches Workshop; Exit Survey Responses

	Low	Medium	High		
To what extent is coastal flooding a concern to your organization?	1 3.7%	4 14.8%	19 70.4%		

	Yes	No	Yes and No		
Do you feel that your top concerns or ideas surrounding infrastructure adaptation were captured today?	22 81.5%	1 3.7%	3 11.1%		

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
You understood the information that was presented?	8 29.6%	14 51.9%	1 3.7%	0 0.0%	0 0.0%

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
The logistics (location, time) of the workshop were suitable?	15 55.6%	8 29.6%	0 0.0%	0 0	0 0

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
You felt your opinion was heard?	14 51.9%	7 25.9%	2 7.4%	0 0.0%	0 0.0%

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
You will like to be involved in the CFAS planning process?	12 44.4%	9 33.3%	2 7.4%	0 0.0%	0 0.0%

	Much too short	Too short	Just right	Too long	Much too long
The length of the workshop was?	0 0.0%	0 0.0%	22 81.5%	1 3.7%	0 0.0%

58 Participants	
23 Organizations	
27 Exit Surveys Received	47%
44 Notebooks Received	76%
20 for Assessment Team	34%

Appendix F - Terms of Reference

SCHEDULE "A"

Engineering Department

Drainage Project No. 4817-401

Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using Engineers Canada PIEVC Protocol (ICFAA)

Draft Terms of Reference

July 2017

Draft Terms of Reference
Improving Coastal Flood Adaptation Approaches to Minimize Infrastructure Risk Using Engineers Canada PIEVC Protocol (ICFAA)
4817-401

1.0 INTRODUCTION

The City of Surrey (the "City") is seeking to retain the services of a professional consultant (the "Consultant") to perform services for developing improved approaches to reducing flood risk to infrastructure assets in Mud Bay, an area that will be increasingly prone to coastal flooding if flood mitigation is not updated to reflect the anticipated sea level rise. See Appendix I for figures depicting the coastal flood hazard under both a dyke breach and no dyke breach for current and future conditions under a severe water level with a 0.5 % annual chance of exceedance.

The work requested for ICFAA will build on the results of the Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop (see Appendix II for Executive Summary of the report). Various infrastructure owners that were engaged and involved in the flood vulnerability assessment workshop earlier this year will be invited to attend a second workshop (the "Adaptation Workshop") to further apply the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC^{TM}) Engineering Protocol (the "Protocol"), this time to explore applied short- and long-term flood protection options and discuss possible monitoring plans for high risk assets based on risk tolerance levels.

The Consultant will provide the following services in accordance with the information provided within this Terms of Reference document:

- Overall project management;
- Workshop delivery; and
- Summary reporting and recommendations.

2.0 PROJECT DESCRIPTION

2.1 Project Purpose and Background

The Protocol is to assist in improving the adaptive capacity of a diverse group of infrastructure owners vulnerable to coastal flooding and initiate dialogue across different organizations and jurisdictions to develop a shared understanding of risk exposure. The Protocol will assist in identifying key risk management objectives for managing coastal flood hazard under climate change, and how to achieve them.

The engagement through the Adaptation Workshop is to draw from and contribute to Phases 2 and 3of developing a Coastal Flood Adaptation Strategy (CFAS). The City's Prime Consultant delivering the overall CFAS project is Northwest Hydraulic Consultants with EcoPlan International, Diamond Head Consulting and KM Consulting as sub-consultants. Phase 1 was focused on education and awareness building of coastal flood hazards and defining objectives and values of stakeholders and partners. Phases 2 and 3 are exploring large-scale coastal flood adaptation by developing alternative option and developing adaptation strategies. These adaptation options are being refined through an engaging process with the CFAS Advisory Group that consists of stakeholders from different segments.

Recognizing that the various Mud Bay infrastructure owners have a wealth of information including system knowledge and risk management expertise, the Protocol was selected to leverage this technical expertise by providing a systematic process to assess the vulnerabilities of complex infrastructure systems and develop a shared understanding across infrastructure owners of the vulnerabilities. The initial PIEVC^{TM} workshop identified these infrastructure vulnerabilities and revealed the need to continue the engagement with infrastructure stakeholders to investigate risk-mitigating strategies through exploration of adaptation and monitoring approaches, as they relate to selected adaptation options currently being explored through CFAS.

The infrastructure risks documented thus far, and the flood adaptation options identified during the Adaptation Workshop will then be used in CFAS to propose detailed flood mitigation approaches in later phases. The overall CFAS phasing is depicted below, the current phases are emphasized:

Key goals of the CFAS are:

- Minimizing risks and vulnerabilities from climate change impacts;
- Building adaptive capacity to respond effectively to climate change impacts over time;
- Increasing awareness and engagement among external stakeholders and City staff to build understanding and capacity related to adaptation and risk perception;
- Co-creating viable coastal flood adaptation options through a continuum of time with stakeholders;
- Linking with regional flood management initiatives;
- Strengthening relations between City of Surrey and external stakeholders; and
- Establishing a preferred approach for managing flood resiliency and the mitigation of coastal flood hazards through a continuum of time.

The CFAS will advance the following items from Surrey's Climate Action Strategy (CoS, 2013):

1) The Engineering Department will be able to initiate the task “Develop drainage and flood control strategies based on cost-benefit analyses and site-specific needs” (Climate Adaptation Strategy Item FL-2.2).
2) The Planning & Development Department and Engineering Department will be able to “Review and revise regulatory bylaws and design standards to account for and minimize the impacts of climate change” (Climate Adaptation Strategy Item FL-2.5).
3) There will be support for the Fire Department to “Continue to build community capacity to respond effectively in an emergency” which was established as an action for immediate action (Climate Adaptation Strategy Item GS-4.1).

CFAS is a participatory; community based planning approach that is using the following structure:

2.2 PIEVC™ Workshop Organizing Committee

The Adaptation Workshop is to be planned and delivered in partnership with the following organizations with PIEVC™ experience participating in the Organizing Committee:

- Association of Professional Engineers and Geoscientists of BC (APEGBC);
- Corporation of Delta;
- Engineers Canada; and
- Ministry of Transportation and Infrastructure (MoTI).

The Organizing Committee was established during the initial PIEVC™ Workshop earlier this year. It will reconvene for the purpose of planning and delivering the Adaptation Workshop; however, it is specific to these two one-day workshops.

2.3 Study Area

Appendix III provides a two page overview of the broader coastal study area for the development of Surrey's overarching CFAS. For the purpose of the PIEVC™ workshop, more focus is needed and the assessment will be limited to the area shown by Appendix IV. The CFAS Consultant will use the workshop results to make generalizations on infrastructure to the broader coastal study area.

As identified during the initial the PIEVC™ workshop, the key infrastructure assets within the Adaptation Workshop study area include:

- Transportation Infrastructure
  - Runway
    - Surrey / King George Airpark Turf Runway
  - Regional / International Transportation Infrastructure
    - 4 km of four-lane arterial roadway
    - 7 km section of Highway 99 linking Peace Arch Border
    - Highway 91 and 99 interchange
    - 4 km section of Highway 91
    - 6 km dyke trail connecting to parks
    - Delta-Surrey Greenway
  - Local Government Arterial and Collector Roads
    - King George Boulevard (City of Surrey)
    - 152 Street (City of Surrey)
    - Colebrook Road (City of Surrey)
    - Ladner Trunk Road (Corporation of Delta)
  - Class 1 Railways Originating at Port Metro Vancouver
    - Burlington Northern Santa Fe (BNSF) Nicomekl swing bridge and trestles
    - 6 km of BNSF Railway (freight frequencies ~20 trains daily and up to 4 daily Amtrak Cascades trains)
    - Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP, and BNSF, ~18 trains daily)
    - Connection to Southern Railway of British Columbia
- Utilities

- Sanitary Lift Stations
  - Elgin (City of Surrey)
  - South Port (City of Surrey)
  - Winter Crescent (City of Surrey)
  - Stewart Farm (City of Surrey)
  - Crescent Beach (Metro Vancouver)
- Underground Infrastructure
  - 5 km of Metro Vancouver 750 mm diameter water transmission main
  - 10 km of Metro Vancouver sanitary sewer forcemains (500 mm to 1050 mm
  - diameter)
  - >10 km of FortisBC gas mains
- Overhead Utility Infrastructure
  - BC Hydro Twin 500kV bulk transmission line providing intertie between BC Hydro
  - and Bonneville Power
  - BC Hydro local overhead distribution lines
  - Shaw and Telus telecommunications lines

- Flood Control / Marine Infrastructure
  - Flood Control Infrastructure
    - Serpentine sea dam (City of Surrey)
    - Nicomekl sea dam (City of Surrey)
    - 15 km of dyking, including ditches and floodboxes
    - Colebrook Pump Station (City of Surrey)
    - Maple Pump Station (City of Surrey)
    - Oliver Pump Station (City of Surrey)
    - Ducks Unlimited Canada Serpentine Fen Nature Reserve
    - Water Control Features to maintain environmentally sensitive area, including
    - freshwater irrigation system
  - Marine Facilities
    - Crescent Beach Marina
    - Wards Marina
    - Private docks
  - Farms
    - Private dairy facilities for over 1,000 head of cattle

2.4 Project Stakeholders

The Adaptation Workshop will involve a diverse group of stakeholders, ideally the same group that was engaged during the initial risk assessment workshop. The primary stakeholders will be those with infrastructure asset ownership within the coastal floodplain who will be requested to complete pre-workshop infrastructure questionnaire. The following are organizations, which were in attendance at the initial risk assessment workshop, who will also be invited for the proposed Adaptation Workshop:

1) Associated Engineering
2) BC Ambulance Service
3) BC Hydro
4) BC Rail Consultant
5) Burlington Northern Santa Fe Railway
6) Canadian Coast Guard
7) City of Surrey (Various Departments)
8) City of Surrey Operations
9) City of Surrey Fire
10) City of Surrey RCMP
11) City of Vancouver
12) Corporation of Delta
13) Cowichan Valley Regional District
14) Ducks Unlimited Canada
15) Emergency Management BC
16) Engineers Canada
17) FortisBC
18) Metro Vancouver
19) Ministry of Agriculture
20) Ministry of Community, Sport and Cultural Development
21) Ministry of Environment
22) Ministry of Transportation and Infrastructure
23) Mud Bay Dyking District
24) Northwest Hydraulic Consultants
25) Port of Vancouver
26) SNC Lavalin
27) Southern Railway of BC
28) Telus

The maximum occupancy for the workshop is 75 people at Surrey City Hall. A slightly larger room has been reserved for October 10th to conduct the workshop to allow more working space for participants.

2.5 Vulnerability Scenarios

Flood adaptation options are to be considered in the context of two overarching vulnerability scenarios. Each scenario will increase in severity due to the combination of regional sea level rise and local ground subsidence. The PIEVC^{TM} assessment is to explore the impacts of three adaptation scenarios under a severe flood. Initial thoughts are to either pick only the severe coastal dyke breach scenario to test the adaptation scenarios against or to use a composite of the two that depicts the worst case scenario.

2.6 Existing Flood Control Infrastructure and Regional Infrastructure

The City does not have control over all flood protection works that provide flood mitigation within the Mud Bay coastal floodplain. Many areas are without engineered flood protection.

Close to 2 km of flood control is provided by a railway embankment. 7.4 km of dykes are in the process of being upgraded to achieve current provincial dyke standards without any allowance for sea level rise. 8.6 km of dykes are managed by the Mud Bay Dyking District with subsidy from City of Surrey. Appendix VI depicts the various areas of both regulated and unregulated flood protection and the ownership, along with key regional infrastructure crossing the floodplain (Railway, Highway, Electricity, Gas, Water and Sanitary Sewer).

2.7 Flood Adaptation Options and Monitoring in the Context of Current CFAS Draft Options

Risk-mitigating options that the Adaptation Workshop will examine will be based on a selection of draft coastal flood adaptation options currently being considered and refined as part of the broader CFAS. These draft options will be used as starting points to develop and analyze micro-scale adaptation options for high risk infrastructure sectors and assets and then discussed with stakeholders during the Adaptation Workshop, following steps 4-5 of the PIEVC[TM] Tool. The selection of draft adaptation options to be considered during the Workshop has tentatively been established as Retreat to Hwy 99, No Adaptation by City and River Realignment.

For each adaptation option, a plan and typical section drawing is required that incorporates engineering analysis and initial input from the initial PIEVC workshop. For No Adaptation, additional drawings may be required to allow sufficient detail for high risk infrastructure sectors to adequately score infrastructure risk.

Based on the proposed conceptual infrastructure adaptation reduction in risk and when compared to risk thresholds, a monitoring plan is to be developed to provide guidance on moving forwards in how infrastructure sectors can manage risk by adapting themselves (No Adaptation By City), or a combination of CFAS implementation and infrastructure specific adaptation (under Retreat to Hwy 99 or River Realignment approaches).

NHC will provide appropriate flood depths and frequency information as needed to support the workshop. Required information should be identified in the proposal to allow review of expectations and coordination by the City.

The Workshop will also include a discussion of possible monitoring plans for high risk assets. Depending on the interest expressed by the stakeholders, plans could be developed that will enable infrastructure owners to include a more detailed risk assessment as part of ongoing asset management.

3.0 PROJECT MANAGEMENT AND GENERAL INSTRUCTION

3.1 Project Management

1. Actively and diligently progress leading to the work timely completion of the project.
2. Review and update the project schedule on a monthly basis.
3. Schedule bi-weekly progress review conference calls with the Project Manager and separate calls as needed with the Organizing Committee, and prepare and distribute

meeting minutes. It is recommended that applications such as Skype, Lync or Teleconferencing be utilized to minimize travel time and costs.

4. One half day preparatory meeting in advance of the workshop with organizing committee members and table facilitators to prepare activities and review workshop materials and content two weeks prior to the event.
5. Prepare and submit monthly invoices including progress status reports identifying previously invoiced, current invoice, total to date and projected amounts, versus budget on a task by task or project area basis. Consultant shall not exceed budget nor proceed with any scope change without prior written approval from the City.
6. Coordinate with all required City Departments as required.
7. Conduct site visits to ascertain features and constraints that may impact the design.
8. Provide the City with all documents (survey, CAD files, model files, reports, etc.) prepared for the project without copyright restrictions.

4.0 ADAPTATION WORKSHOP DELIVERY

4.1 Pre-workshop Materials, Questionnaire and Initial Data Gathering

1. Review updated background information from CFAS and comments from baseline risk assessment.
2. In collaboration with Northwest Hydraulic Consultants, prepare scenario backgrounder with selected adaptation scenarios. EcoPlan will provide graphic layout.
3. Conduct engineering analysis based on sectors (transportation, utilities, marine, flood control).
4. Prepare graphics for mail outs and for viewing on the City's website. Draft an invitation to all stakeholders with information on the project to date and to request participation from their organization with appropriate staff.
5. The City will setup an online registration form or use Eventbrite to track registrations and provide name tags for all registrants.
6. Summarize results of pre-workshop questionnaire to support workshop activities and table exercises.

4.2 Planning

1. Prepare a detailed workshop plan. This is to include list of materials/resources, staff responsibilities, key points for presenters and event agenda.

   A very cursory agenda is outlined below and the Consultant is to propose a revised agenda:

7:30	Staff briefing
8:30-9:00	Registration
9:00-9:30	Round Table Introductions and Opening Remarks (Engineers Canada)
9:30-9:45	Brief PIEVC™ introduction, focus on Steps 4 and 5 (Facilitator)
9:45-10:00	Summarize baseline risk assessment results
10:00-10:10	Introduce Adaptation #1 River Realignment

10:10-11:00	Table exercise to discuss impacts to infrastructure operational concerns. Rotate tables twice to discuss vulnerabilities of different infrastructure types.
11:00-11:15	Introduce Adaptation #2: No Adaptation by City with high risk sector based adaptation
11 15-11:30	Table Exercises
11:30-12:00	Introduce Adaptation #3: Retreat to Hwy 99
12:00-12:30	Table Exercises
12:30-1:00	Lunch
1:00-1:30	Risk Tolerances
1:30-2:30	Tipple Bottom Line Assessment
2:30-3:00	Group discussion on challenges and questions. Document objectives that infrastructure owners have in managing flood risk and business continuity planning. Identify cross cutting issues and cascading effects that impact multiple assets such as power or transportation impacts.
3:00-4:00	Closing Remarks and Next Steps (Facilitator)

Design of table exercises and material to work through the infrastructure adaptation approaches will be needed. Depending on the number of workshop registrants, up to five tables may be required. EcoPlan and NHC to provide 3 facilitators under a separate budget and AE provide 2 and City staff to provide note takers. Table facilitators and note takers for each table will be provided from organizations part of the organizing committee.

Host a meeting at Surrey City Hall to run through all workshop logistics, review presentation content for feedback and refinement and to view the workshop venue. All table facilitators and assistant table facilitators will be present to be trained and practice workshop table exercises prior to the workshop.

A chartered coach will be made available to participants to see some of the hot spots for adaptation in Mud Bay. Where possible participants will see and describe the sites themselves prior to the workshop. Surrey and EcoPlan will facilitate this activity, however at least one ICFAA representative should be present.

4.3 Workshop Facilitation

The consulting team will include an experienced PIEVC™ workshop facilitator to be the MC for the day. A note-taker to support issuing meeting minutes to participants will be provided by the consulting team. Prepare an exit questionnaire on the workshop and summarize responses.

EcoPlan prepared a 3 minute summary video on CFAS (https://www.youtube.com/watch?v=xrU7Zo_6_PI&feature=youtu.be) and are finalizing a 3 minute overview video of Surrey's existing coastal drainage system to help get stakeholders up to speed as quickly as possible during the workshop.

4.4 Post-workshop Follow Up and Final Data Gathering

Data gaps will be flagged based on the draft assessments co-developed in the workshop. Where possible, gaps will be filled in with input from experts after the workshop. All materials will be digitized and collated for reporting by the consulting team. Where appropriate, comments will be tracked spatially.

5.0 SUMMARY REPORTING AND RECOMMENDATIONS

Provide a draft summary report and participate in a summary report review meeting with the Organizing Committee. The summary report is to include key objectives of infrastructure owners and emergency planners based on the PIEVC^{TM} risk mitigation processes. Unresolved data gaps and aspects of particular uncertainty should be highlighted with prioritized recommendations to refine risk understanding and management by asset type. Due to the high level nature of this risk mitigation approach, recommendations on next steps for specific stakeholders or asset types are anticipated to better inform Surrey's CFAS.

Results of tipple bottom line (TBL) assessment and high risk sector risk thresholds to be documented. CFAS in phase 3 (what is acceptable) is conducting a broad stakeholder based values assessment and technical merit assessment. The TBL is to provide another form of comparison between the options to help select a preferred approach to adaptation.

The risk thresholds will be used by CFAS in Phase 4, detailing *How will we do it?* as well as to inform a high level risk based monitoring plan to be recommended to infrastructure owners.

A one page 3 ft x 4 ft poster suitable for use at a CFAS Open House is to be provided.

A digital story map will be prepared and a summary of key risks by another consultant similar to the one for the Agricultural History here. The consultant is to provide high level input and content review as this develops.

Cascading effects and cross cutting issues that impact multiple stakeholders should be reported. The final report is to be provided in digital formats suitable for print publishing as well as CFAS project website. The report is to be consistent with City of Surrey Design Standards.

This project is being submitted for the 2018 Sustainable Communities Award under the Asset Management Category and has been accepted for presentation at the 2017 APEGBC Annual Conference.

5.1 PowerPoint Presentation

Provide a draft Transportation and Infrastructure Committee (TIC) 10 minute overview PowerPoint presentation to update representatives of Surrey City Council on the findings of the Adaptation Workshop and the overall PIEVC^{TM} assessment.

EcoPlan has been allocated budget to either develop a single infrastructure summary video to either support the PowerPoint or a number of short clips to support the StoryMap web application.

6.0 STAFF AND EXPERIENCE

Provide a list of key team members (Project Manager, Lead Facilitator, Alternate Facilitator, Transportation Engineer, Coastal Engineer, etc.) with resumes. Attempt to keep each resume to a maximum of three (3) pages.

Provide details (scope, client info, project reference number, year completed, location, etc.) for three (3) projects with similar scope to this proposed project, completed by the team members.

Demonstrated experience facilitating PIEVC™ workshops is essential for a variety of infrastructure types.

7.0 EFFORT & FEES

The proposal shall indicate a clearly defined fee structure for preliminary and detail design stages with man hours identified per task and per team memberHourly rates shall remain fixed for a period of two (2) calendar years following acceptance/award of the proposal. Within the proposal, include a copy of all sub-consultants' proposals.

The upset project budget for this work has been set $53,300 plus GST. A rough budget breakdown by tasks is as follows.

Pre-workshop and workshop:

Review Background Information from CFAS, Build on Comments from Baseline Risk Assessment	$ 2,400
Prepare Scenario Backgrounder With Adaptation Scenarios (NHC & AE)	$ 1,500
Conduct Engineering Analysis Based on Sector (Transportation, Utilities, Marine, Flood Control)	$ 6,000
Meeting with the Workshop Organizing Committee	$ 2,100
Meeting with the Organizing Committee Members and Table Facilitators	$ 1,300
Prepare Detailed Workshop Plan	$ 3,000
Workshop Dry Run Meeting at City Hall with Table Facilitators	$ 2,300
Stakeholder Study Tour with Chartered Coach (the week before Oct 10)	$ 800
Coastal Adaptation Workshop Facilitation, Administration, Technical Assistance (Oct 10)	$ 9,900

Post Workshop

Workshop Reporting and Data Gathering	$ 1,100
Exit Survey Digitization and Analysis	$ 500
Analysis and Synthesis of Adaptation Options and Recommendations	$ 8,600
Infrastructure Adaptation Option Improvement and Revised Visualizations	$ 7,500
Draft Report	$ 3,000

PowerPoint Presentation Document	$ 500
Draft Report Meeting	$ 700
Final Report	$ 2,100
TOTAL	**$ 53,300**

8.0 SCHEDULE

The consultant team shall be fully committed to the team members and to the project schedule. The anticipated timing of key activities is listed below:

1. Submit proposal for Engineering Services	August 8, 2017
2. Appointment of Consultant	August 15, 2017
3. Draft Pre-workshop materials submission	September 15, 2017
4. Organizing Committee Conference Call/Meeting	September 22, 2017
5. Workshop Materials Finalized	September 29, 2017
6. Table Facilitator Training and Logistics Meeting	October 3, 2017
7. Workshop	October 10, 2017
8. Draft Summary Report PDF	October 27, 2017
9. Draft PowerPoint	November 3, 2017
10. Final Report soft and hard copies	November 24, 2017

The Consultant shall determine submission dates in their proposal for the preliminary and detailed design submission. Please allow for a two (2) week review period by the City and Organizing Committee for each submittal. The Consultant will also indicate measures and recommendations to accelerate the schedule if required by the City.

9.0 AVAILABLE INFORMATION

City of Surrey, 2016. Coastal Flood Adaptation Strategy Project Website.
www.surrey.ca/coastal
City of Surrey, 2013. Surrey Climate Adaptation Strategy.
http://www.surrey.ca/community/14146.aspx
City of Surrey, 2008. Surrey Graphic Standards.
http://www.surrey.ca/files/3004Att6graphicstandards.pdf
Series of Coastal Flood Hazard Maps previously provided as Appendix I

a) Severe coastal dyke breach (joint probability water level with annual exceedance probability of 0.5% resulting from tides, storm surge, wave and wind effect). Current Conditions and 2100 have been included, while the maps of intermediate time horizons for years 2020, 2040 and 2070 will be available in January, 2017.
   3001880_Map_Flood_CST2010_20161207.pdf
   3001880_Map_Flood_CST2100_20161207.pdf

b) Severe water levels, no dyke breach (joint probability water level with annual exceedance probability of 0.5% resulting from rainfall, tides, and storm surge) for current conditions and 2100.

3001880_Map_Flood_RIV2010_20161128.pdf
3001880_Map_Flood_RIV2100_20161128.pdf
City of Surrey, 2017. CFAS Options Primer, Chapter 1: Mud Bay attached to email invitation
City of Surrey 2017. FCM MCIP funding application for ICFAA
g:\wp-docs\2016\utilities\drainage\12160909mo tor.docx
CLR 3/20/18 11:34 PM

Appendix G - Open House Board Input

Input to Open House Board

In support of the City's Coastal Flood Adaptation Strategy, two workshops targeted at Infrastructure asset owners and emergency responders were held.

The first workshop took place in March 2017, and had participants assess the impact of coastal and riverine flooding on a variety of infrastructure, including transportation, utilities, flood control, and marine facilities, and how this risk profile might change in the future given climate change. The workshop was attended by 66 people representing 28 organizations.

The second workshop, held in October 2017, further explored how the risk profile of each infrastructure sector might change, depending on the City of Surrey's decisions on how to adapt to coastal flooding. The workshop reviewed two potential adaptation options in detail (Coastal Realignment to 152 Street, and River Realignment), evaluating what actions each sector would need to take to facilitate the adaptation option. Participants also reviewed the factors that influence decision-making within each infrastructure sector, using a Triple Bottom Line approach that considers the environmental, social, and economic factors.   This workshop was attended by 58 people representing 23 organizations.

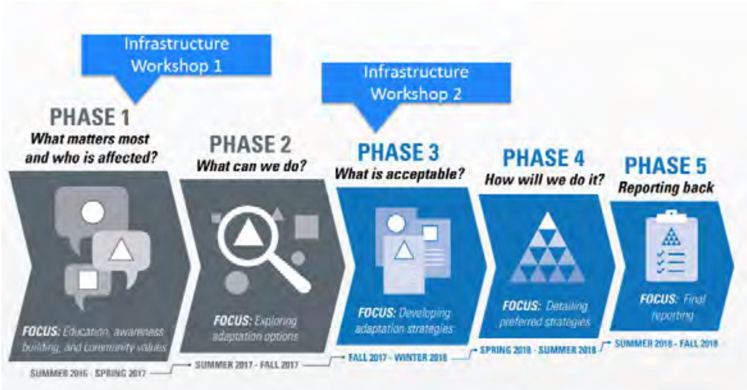
Key comments from the infrastructure stakeholders during the workshop included the following:

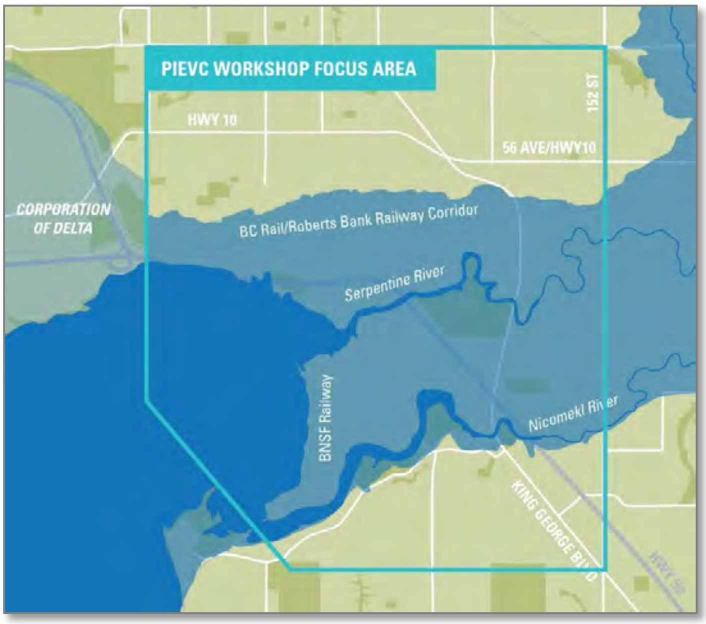
- Finding opportunities for cost-sharing and collaboration between infrastructure owners is a high priority, and multi-purpose enhancements that facilitate public acceptance of the changes should be included in these efforts.
- Identification and use of shared utility corridors may be a good way to reduce the cost of infrastructure adaptation.
- Opportunities for adapting infrastructure during regular asset renewal cycles should be actively sought out, and co-benefits, including seismic resiliency and efficiency improvements can be incorporated into these efforts.

The workshop identified important insights into the decision-making process of infrastructure owners, and identified important considerations for the CFAS team when evaluating the array of coastal flood adaptation options:

- Most of the key infrastructure in the area is adaptable. The City should pursue an adaptation option that meets their needs, and engage infrastructure sectors along the way to allow them to adapt their own infrastructure in a way that meets their needs.
- The flood infrastructure and transportation infrastructure span multiple jurisdictions, and the effect of adaptation in Mud Bay will have cascading effects elsewhere in the region. Long-term coordination is required between the City of Surrey and the City of Delta.
- Utility owners need to be aware of their internal thresholds for acceptable risk, monitor their coastal flood risk, and have a plan on how to respond if these thresholds are exceeded.\

Graphic Inputs:



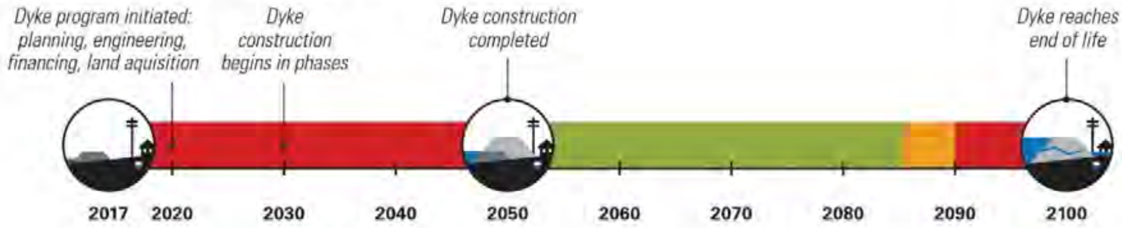


ICFAA Workshop Attendee Organizations	
Agricultural Land Commission	Fraser Basin Council
Associated Engineering	Metro Vancouver
BC Agriculture and Food Climate Action Initiative	Ministry of Environment
BC Hydro	Ministry of Transportation and Infrastructure
City of Surrey	Northwest Hydraulic Consultants
City of Surrey Fire Service	RCMP
Corporation of Delta	Surrey Board of Trade Representative
EcoPlan	SRY Rail Link
Emergency Management BC	Thrive Consulting
Engineers and Geoscientists BC	University of British Columbia
Engineers Canada	Vancouver Fraser Port Authority
FortisBC	

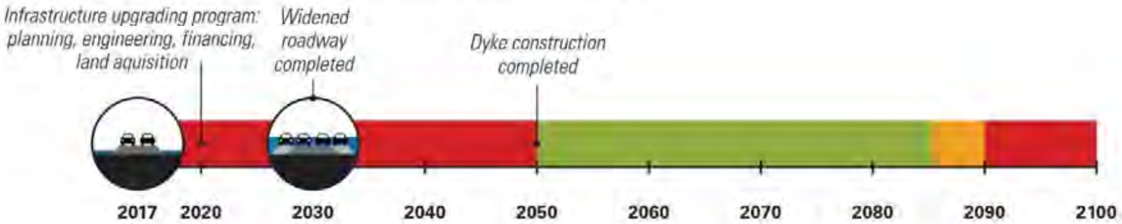
WHAT IS OUR RISK OF FLOODING?

LOW RISK   MEDIUM RISK   HIGH RISK

Risk of Flooding from Dyke Failure



Risk to Adjacent Infrastructure WITHOUT Adaptation



Risk to Adjacent Infrastructure WITH Adaptation

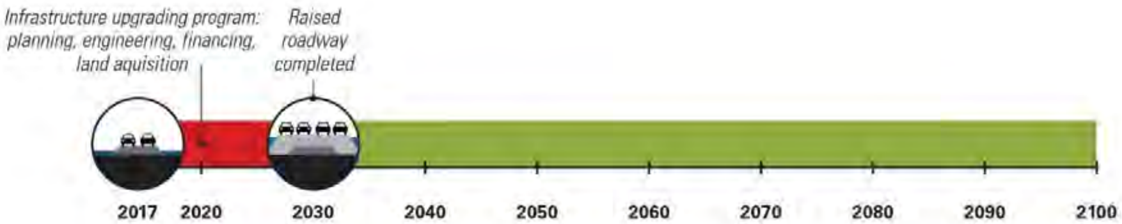


Table Inputs

Importance of Decision-Making Factors to Infrastructure Sectors

Category	Factor	Sectors
Environmental	Regulatory Compliance	All
	Biodiversity / Habitat	Highways, Roads, Railway, Utilities, Drainage
Social	Public Perception	Highways, Roads, Regional Sanitary Mains, Power, Trails
	Acceptable Level of Service and Risk	Highways, Roads, Utilities, Drainage
	Emergency Response	Highways, Roads, Regional Water Mains, Power
	First Nations / Archaeology	All
Economic	Capital Cost	Highways, Roads, Railway, Utilities, Dairy
	Cost-Sharing	All
	Resilience and Maintainability	Railways, Roads, Highways, Utilities, Drainage
	Disruption of Commerce	Highways, Railways, Power, Dairy
	Risk Tolerance / Asset Lifecycle	Highways, Roads, Railways, Utilities

Flood risk to infrastructure by the year 2100 if infrastructure sectors do not undertake adaptation beyond the City's adaptation option.

Flood Risk	No Adaptation Year 2100	Coastal Realignment to 152 Street	River Realignment
Low	2	4	11
Medium	6	6	5
High	13	11	5

REPORT

Volume 3 – Transportation Story Map

Associated Engineering

GLOBAL PERSPECTIVE.
LOCAL FOCUS.

To: City of Surrey (Matt Osler)	From: Heather Murdock, Tamsin Lyle
Date: March 15th 2018	File Number: P097
Subject: Story Map Overview and Citations	

Transportation StoryMap

The City of Surrey is preparing for climate change and sea level rise by developing a coastal flood adaptation strategy (CFAS). An important element of this strategy is communicating coastal flood risks to the public.

This StoryMap tells the narrative of how transportation infrastructure is affected by flooding, and what this will look like under a future climate. To do this, the StoryMap draws on maps, photos, videos and links to additional resources.

Key themes explored as part of the StoryMap include:

- How transportation infrastructure has developed and expanded in the Surrey Lowlands since the late nineteenth century;
- Current flood hazard management strategies in the Surrey Lowlands that protect transportation and infrastructure;
- How climate change will significantly increase the flood hazard, and impact transportation in the Surrey Lowlands;
- That with a changing climate, the region must adapt to an increased flood hazard that threatens transportation infrastructure.

The StoryMap includes narrative text, interactive maps, graphics and links to additional information.

The StoryMap was developed by Ebbwater Consulting between October 2017 and March 2018 with support from City of Surrey staff.

Link to online application:
https://surrey.maps.arcgis.com/apps/MapSeries/index.html?appid=cbd03c3fb60540a1947d0e6ba06c234b

Citations and Credits

Various City of Surrey images (provided by City staff and the City Archives) have been used in the StoryMap. Details of these images are provided in the StoryMap outline below.

1. INTRO
   - i. Photo: CN Trains crossing Mud Bay (_MG_9743.jpg)

2. TRANSPORTATION ACROSS THE FLOODPLAIN
   - a. Surrey Lowlands
     - i. Map: Surrey Lowlands with Future Coastal Dyke Breach Flood Vulnerabilities for Infrastructure
   - b. From Rivers…
     - i. Photo: Steam Boat on the River (RiversBar1.jpg)
   - c. …and Trails
     - i. Map: Surrey Lowlands with Transportation Layers for Railways, Historical Railway, Historical Trails and Rivers
   - d. …to Rails
     - i. Photo: Logging Railway (RailBar2.jpg)
   - e. "last spike": Connection & Growth
     - i. Photo: Last Spike Ceremony with text about the event (LastSpike_Rail_lines.jpg)
   - f. Along the Seashore
     - i. Photo: Train Crossing Mud Bay (Train_Sea.jpg)
   - g. …and Roads
     - i. Photo: Highway shortly after completion (RoadsSlide6.jpg)

3. FLOOD MANAGEMENT: PAST & PRESENT
   - a. A History of Flooding
     - i. Timeline: (Link https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1ngn5P3b2GTLh7tODXTk9HAmK7ancHik6GL_Ckohn2uA&font=Default&lang=en&initial_zoom=2&height=650)
   - b. Why Does it Flood?
     - i. Photo: Flooded Road (FloodBar1.jpg)
   - c. How does flooding happen?
     - i. GIF: Flood Hazards (Flood Hazards.gif)

   d. Dykes, Dams, and Drains – Government Response
      i. Map: Surrey Lowlands with Flood Control Infrastructure
   e. Dyke breaches…
      i. Photo: Dyke Breach
   f. Sea Level Rise and Risk of Dyke Overtopping
      i. Map: Current Coastal Dyke Breach Flood Vulnerabilities
   g. Dams
      i. Photo: River Dam (DrainsBar3.jpg)
   h. Coastal Flood Management
      i. Video: Coastal Flood Management in Surrey https://www.youtube.com/watch?v=bn4RQQaEfV8

4. LOOKING AHEAD: CLIMATE CHANGE AND THE FLOODPLAIN
   a. Climate Change: What's happening?
      i. Photo: From CFAS Primer (SeaLevelPrise_Timeline.jpg)
   b. Extent of flooding now and in the future
      i. Map: Flood Hazard Levels Map (Serp_Nic_Floodplain-FutureFlooding)
   c. Failing Flood Controls
      i. GIF: Animation of Flood Infrastructure (Infrastructure Animation90.gif)
   d. Infrastructure Today and Tomorrow
      i. Map: Current Floodplain and Infrastructure (Transportation_and_Flood)
   e. A Shared Problem: Direct and cascading impacts on transportation
      i. Photo: Cars on Flooded Road (1968_FloodedHwy.jpg)

5. FINDING SOLUTIONS
   a. What now?
      i. Video: Coastal Flooding in Surrey (https://www.youtube.com/watch?v=Q3hYUtQQhAc)
   b. Working Together
      i. Photo: Participants at CFAS Workshop (CFASDotmocracy.jpg)
   c. Staying Ahead of Sea Level Rise
      i. Photo: Front Cover of Preliminary Options Primer (PreliminaryOptions2.jpg)

6. WHAT DO YOU THINK?
   a. Contact info to connect

REPORT

Volume 4 – Presentations

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Workshop Presentations

Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop Presentation

March 28, 2017

Available for download from
http://www.surrey.ca/files/CFAS%20Infrastructure%20Vulnerability%20Workshop%20Presentation%20March%2028%202017.pdf

Improving Coastal Flood Adaptation Approaches Stakeholder Workshop Presentation

October 10, 2017

Available for download from http://www.surrey.ca/files/PresentationsCFAS.pdf

Associated Engineering

Engineers and Geoscientists of British Columbia Conference Presentation by Matt Osler (City of Surrey)

October 17, 2017

ENGINEERS &
GEOSCIENTISTS
BRITISH COLUMBIA

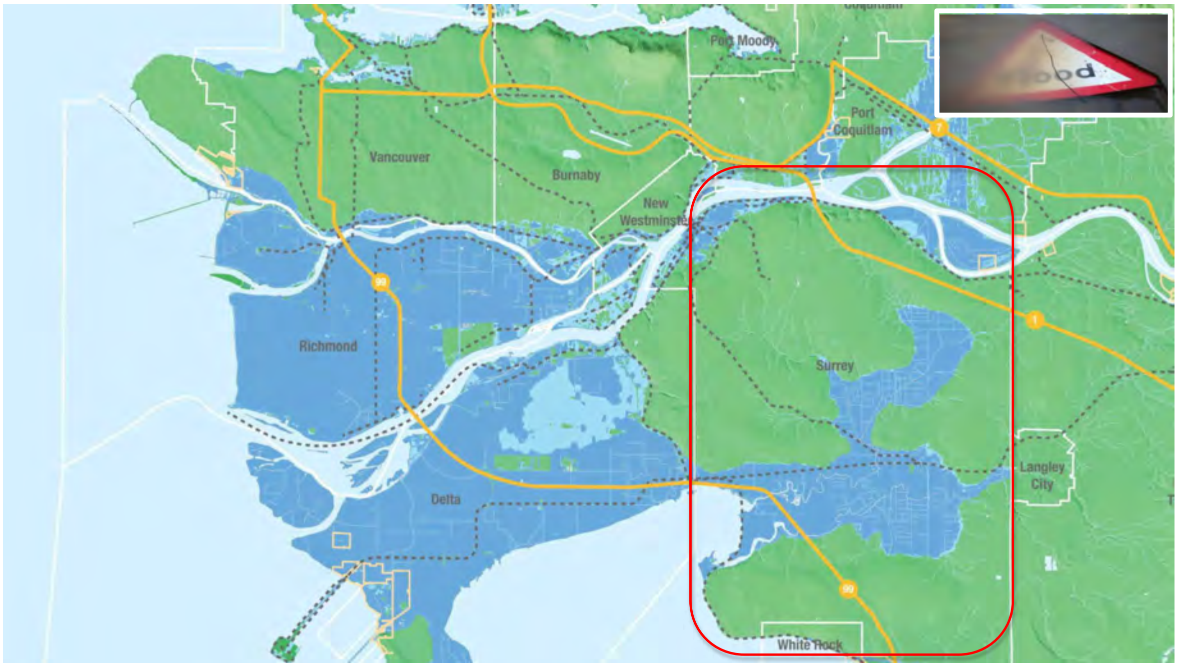
City of Surrey Coastal Flood Adaptation Updates

Matt Osler, P. Eng., MBA

October 17, 2017

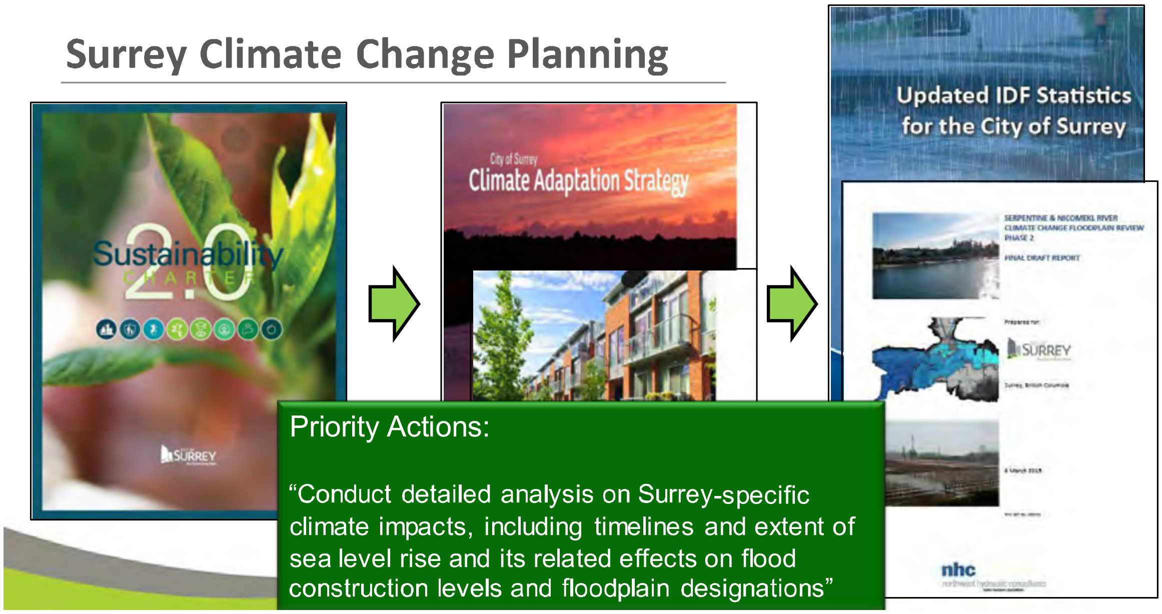
Surrey's Journey into Climate Change

- Began in 2008
- Involved all City Departments starting in 2011 through Advisory Team
- Has become part of how we do business
- Climate Change and Flooding is City's Greatest Risk



Evolving Information on Climate Change

- Provincial reports
- ICLEI Methodology


Surrey Climate Change Planning
Sustainability 2.0 Charter
SURREY
City of Surrey
Climate Adaptation Strategy
Updated IDF Statistics for the City of Surrey
SERPENTINE & NICOMEKL RIVER CLIMATE CHANGE FLOODPLAIN REVIEW PHASE 2
FINAL DRAFT REPORT
SURREY
nhc
Priority Actions:
“Conduct detailed analysis on Surrey-specific climate impacts, including timelines and extent of sea level rise and its related effects on flood construction levels and floodplain designations”


Surrey Climate Change Planning
SURREY
2016 SHADE TREE MANAGEMENT PLAN
PLANSURREY2013
OFFICIAL COMMUNITY PLAN
DEVELOPMENT PERMIT
SENSITIVE ECOSYSTEMS
The Urban Heat Island Effect in the City of Surrey:
Managing Urban Temperatures in the Context of Climate Change
CLOSING THE LOOP
SEE HOW IT WORKS
AGRICULTURE
PROTECTION AND ENHANCEMENT STRATEGY
SURREY

Climate Change and Flood Management

Uplands Flooding	Coastal & River Flooding

Uplands Flooding

Annually & monthly rainfall are increasing

Rainfall statistics show precipitation has increased over 31% in some Surrey areas

Average increase in projected rainfall statistics:

Planning Horizon	Lower Band (max. of means)	Upper Band (max. of 95 %'s)
2030's	20%	72%
2050's	35%	96%
2080's	68%	154%

Coastal & River Flooding

200 year events become <2 year events by 2100 (lower reaches)

10 out of 13 bridges across the floodplain will be submerged or partially submerged in the future – structures have not been designed for this condition

Table 4. Storm runup values for each of the coastal locations for selected years from 2010 to 2100.

Site	Location	2010	2020	2040	2070	2100
1a	Colebrook - Serpentine	inundation	inundation	inundation	inundation	inundation
1b	Crescent Beach East	0.17	0.17	inundation	inundation	inundation
1c	Mud Bay - Serpentine	0.33	inundation	inundation	inundation	inundation
1d	Mud Bay - Nicomekl	0.23	0.20	inundation	inundation	inundation
2	Colebrook (Highway 99)	0.51	0.55	inundation	inundation	inundation
3	Crescent Beach North	0.65	0.63	inundation	inundation	inundation
4	Crescent Beach South	0.69	0.69	0.74	0.76	inundation
5	BNSF Railway	0.70	0.71	inundation	inundation	inundation
6	8th Avenue at Campbell	inundation	inundation	inundation	inundation	inundation

10 Year Servicing Plan

Funding for the 10 Year Plan is from :

- Drainage Utility Fees collected on all properties
- Development Cost Charges charged new development

10 Year Plan also includes new infrastructure & renewals which will need to be designed to new flood standards within the project budgets separate from study funding.

SURREY CITY energy

Separate 10 year Budget Process

System developing with flexibility to incorporate Low Carbon Energy, to meet carbon intensity targets. Cost recovery based on utility rates and connection fees.

City of Surrey Actions

The 2014 - 10 Year Servicing Plan included a new component in the Drainage Utility for Climate Change investigations & strategy development. The 2016 plan update includes:

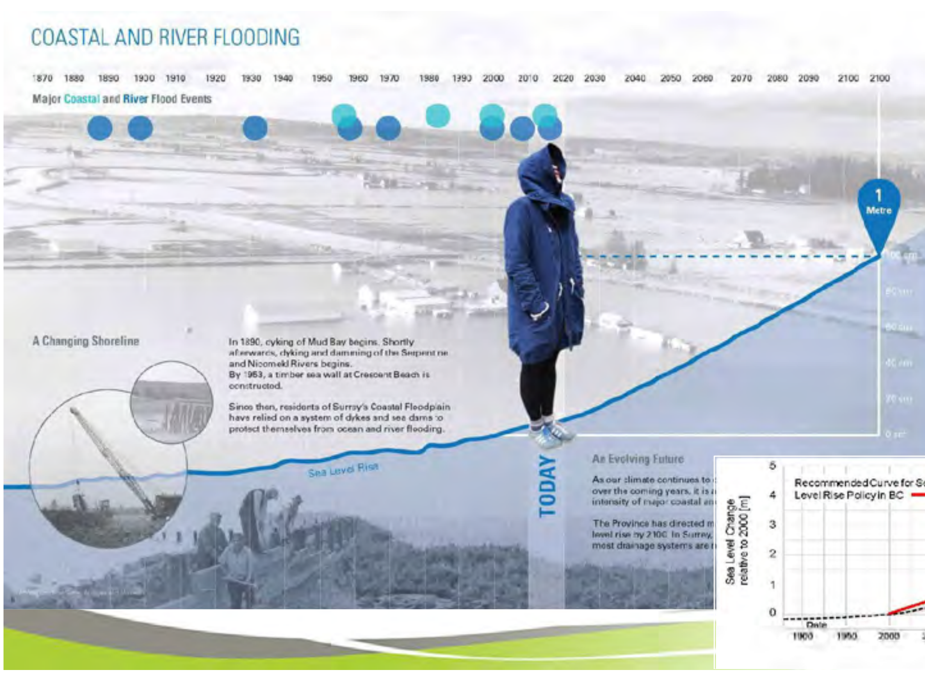
- Trending & sea level rise studiesand strategy $3,700,000
- Seismic Investigations / models $200,000
- Floodplain Mapping $600,000
- Regional Partnership

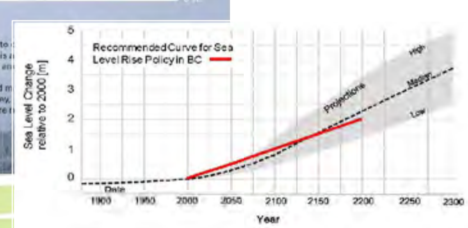
Total 2016 – 2025

Total 2017 – 2026

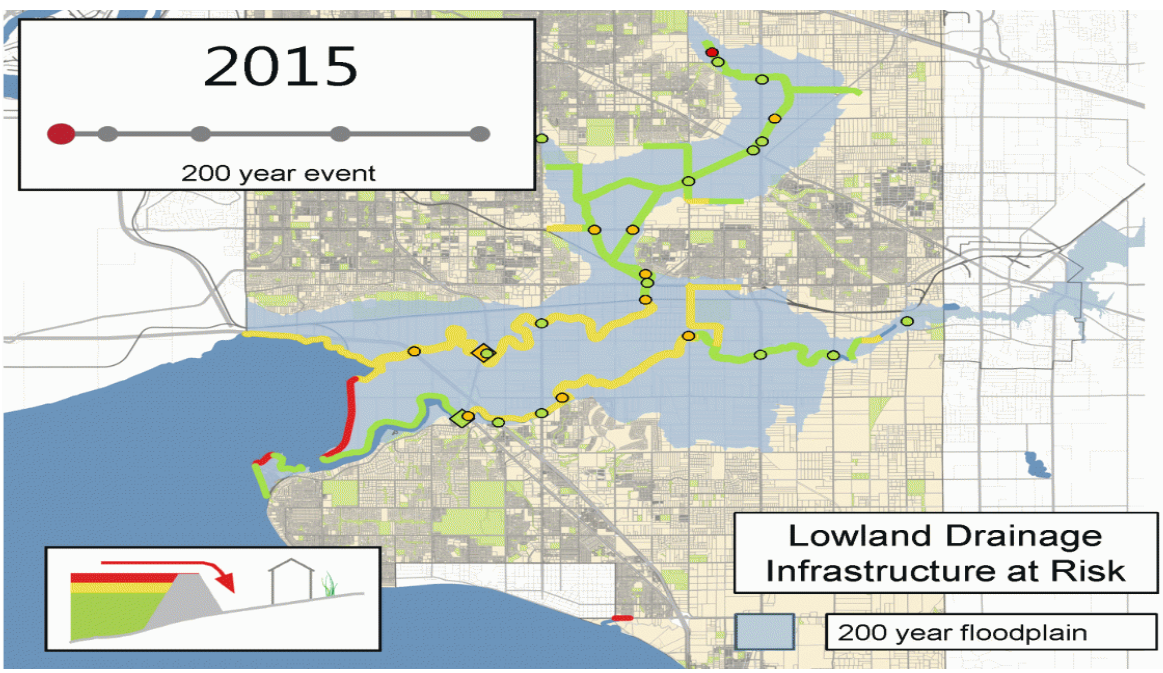
Program 1683 – Climate Change Adaptation

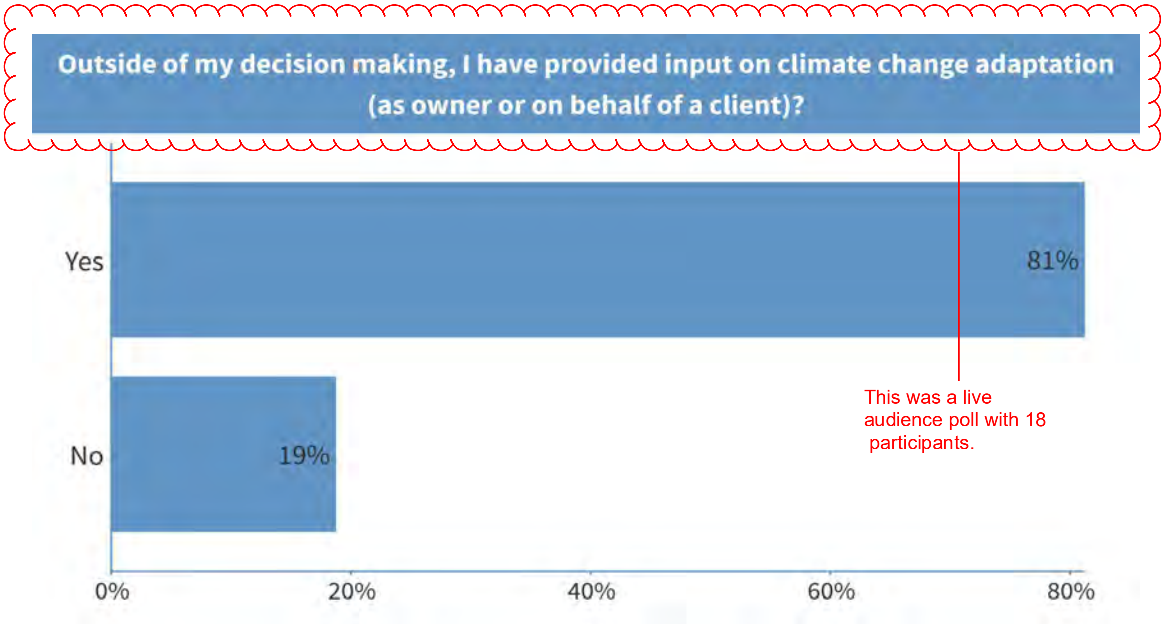
New information and design considerations have come from the Province regarding potential impacts from climate change, in particular sea level rise. Rising seas and potential increases in precipitation will impact existing drainage systems. The projects in this program are meant to identify potential impacts, timing of potential vulnerabilities, work towards new strategies to address climate change in the drainage program, and times of asset renewal. In this plan, all the projects are study based and are in support of the City's Climate Adaptation Strategy.





Video available: https://youtu.be/bn4RQQaEfV8



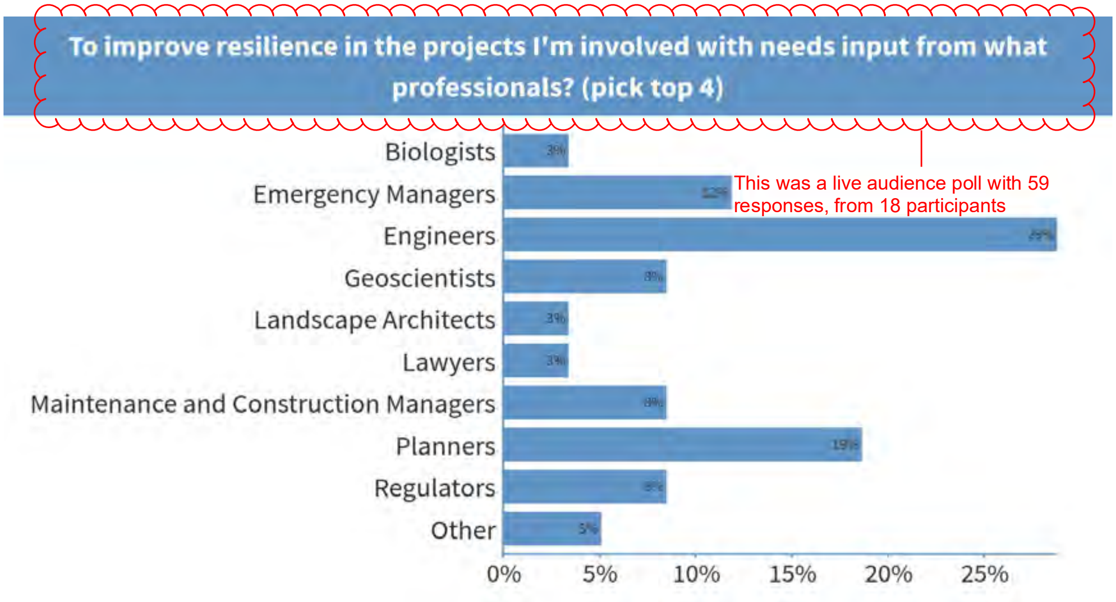


Coastal Flood Vulnerability Workshop

- 66 participants from 28 organizations assessed 43 assets
- Workshop utilized the PIEVC™ Protocol
  - Developed by Engineers Canada and adopted by BC MoTI
- Identified 53% of currently low/medium risk infrastructure assets become high risk by 2100
- Positive feedback from participants

Improving Coastal Flood Adaptation Approaches Workshop

- 58 participants from 23 organizations assed 16 infrastructure sectors
- Workshop utilized the PIEVC™ Triple Bottom Line Module
  - Social
  - Economic
  - Environment
- Funding for workshop granted by FCM MCIP
- Positive feedback from participants



Adaptation Through Collaboration

Sector based engagement

- Agriculture, environment, infrastructure focus groups
- Education to increase capacity – Green Shores & PIEVC
- Local tours with diverse stakeholders to discuss the issues and build understanding
- Online through web based information, surveys, social media

Collaboration

- Across departments through staff steering committee
- Across external groups through a project advisory group
- Post secondary institutions and global experts
- Community Charrettes and community groups

Broad engagement

- Libraries, public spaces, school district, contests

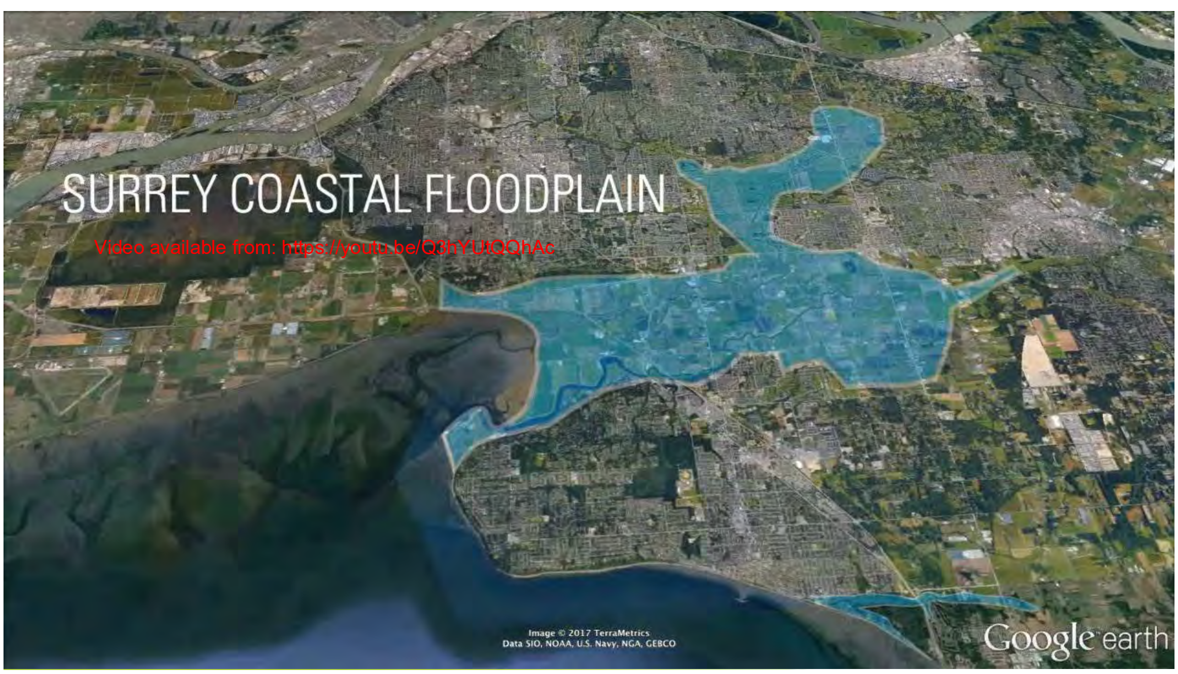
CITY OF SURREY

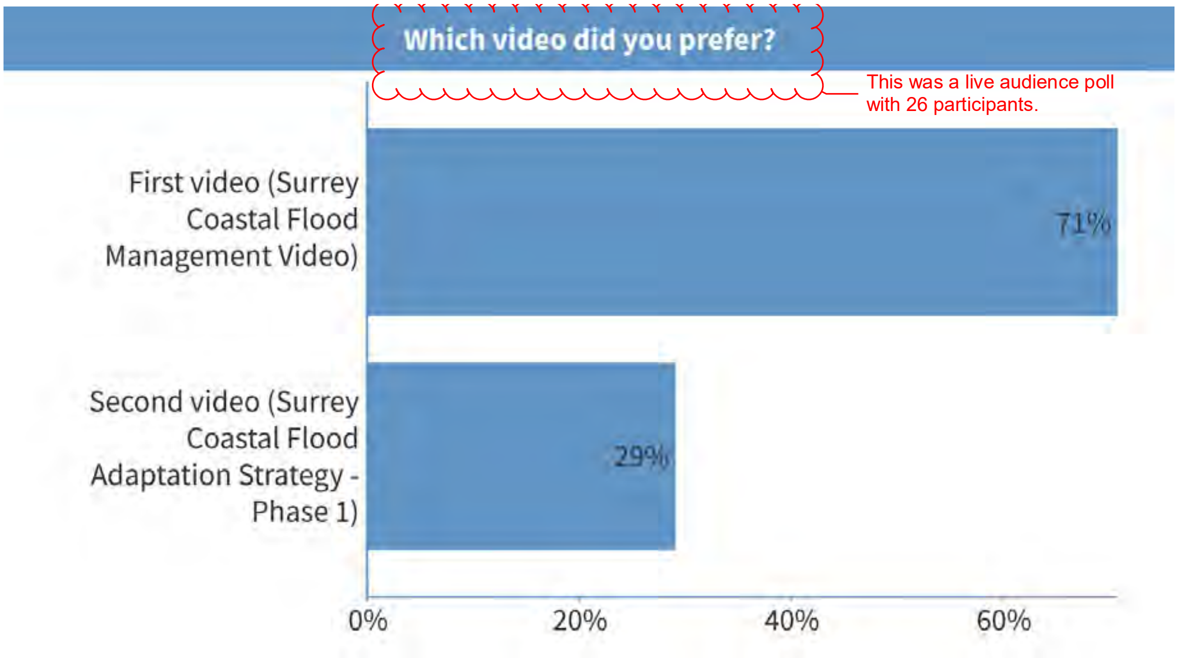
Building Partnerships for Adaptation

Semiahmoo First Nation · Engineers & Geoscientists British Columbia · Fraser Basin Council · SFU · Green Shores · Conserving Canada's Wetlands · Climate Action Initiative BC Agriculture & Food · engineerscanada ingénieurscanada · Delta · The University of British Columbia · Stewardship Centre for British Columbia · Friends of Semiahmoo Bay Society · Holland · West Coast environmental law

MetroVancouver

FCM Federation of Canadian Municipalities Fédération canadienne des municipalités · City of Surrey





IAP2 Spectrum of Public Participation

Adapting Now

Resilient infrastructure

Resilient dwellings

Resilient land use planning

Matt Osler, P.Eng., MBA
Sr. Project Engineer
coastal@surrey.ca
604-591-4657

Acknowledgements:

- Northwest Hydraulic Consultants & EcoPlan Int'l
- Associated Engineering
- Ebbwater Consulting
- ACT SFU, WCEL
- UBC CALP & SALA

Surrey Transportation and Infrastructure Committee (TIC) Presentation by Matt Osler (City of Surrey), and Meeting Minutes

December 11, 2017

Associated Engineering

Transportation and Infrastructure Committee Minutes

2E - Community Room B
City Hall
13450 -104 Avenue
Surrey, B.C.
MONDAY, DECEMBER 11, 2017
Time: 2:02 p.m.

Present:

Councillor Gill, Chair
Councillor LeFranc
Councillor Woods
K. Rana (Youth Rep.)

Absent:

R. Dhaliwal (Youth Rep.)

Staff Present:

F. Smith, General Manager, Engineering
J. Boan, Manager, Transportation
P. Bellefontaine, Manager, Transportation Planning
P. Lee, LRT Program Manager
D. Harkness, Parking Services Manager
M. Osler, Senior Project Engineer
L. Blake, Legislative Services

A. ADOPTION OF MINUTES

1. The committee is requested to pass a motion adopting the minutes of November 27, 2017

It was Moved by Councillor LeFranc
Seconded by Councillor Gill
That the minutes of the Transportation and Infrastructure Committee meeting held November 27, 2017, be adopted as presented.

Carried

B. DELEGATIONS

C. OUTSTANDING BUSINESS

Procedural note: Councillor Woods entered the meeting at 2:03 p.m.

1. **Pattullo Bridge Update**

Philip Bellefontaine, Transportation Planning Manager, provided the following update regarding the Pattullo Bridge:

- Staff will communicate the Committee's recommendation from the November 27, 2017 meeting regarding the Major Road Network and Pattullo Bridge widening triggers to TransLink.

- Staff are currently waiting for TransLink to provide revised design plans, which include reduced road connectors. Staff will write to TransLink to formally share feedback from the Committee regarding widening the bridge deck on Surrey's side of the bridge.

- The effects of the toll removal on local bridges have been similar since September:

- o 152 Street has experienced a 10% reduction in volume.
- o There has been an increase of 10% in volume along King George Boulevard.

In response to questions from the Committee, staff advised that it is not clear if the removal of bridge tolls have resulted in drivers being on roads for less time. Bridge performance contributes to a driver's route choice, and the Port Mann remains competitive and performs well. There could still be a balancing of volumes in the future.

2. LRT Update

Paul Lee, LRT Program Manager provided the following update regarding Light Rail Transit (LRT):

- Preparation for LRT is currently focusing on early works.
- A report regarding Bear Creek Bridge will be forwarded to Council on December 18, 2017, with work anticipated to commence in early January 2018.
- Staff have confirmed that BC Hydro powerlines are scheduled to be raised at 92nd Avenue and King George Boulevard and 104th Avenue.
- Work on the watermain has been divided into two phases. A tender for the first phase will close on December 13, 2017, and the tender for the second phase will be placed the same day.
- A tender for storm sewer work will be placed in January 2018, with work expected to begin in Spring 2018. Work on storm sewers will be completed away from sensitive areas in Hawthorne Park.

In response to a question from the Committee, staff advised that work to be completed around Hawthorn Park will include fencing and monitoring to address any potential disobedience associated with the project. Staff noted that while there was a positive reception to the 105 Avenue Corridor proposal at a December 6, 2017 open house, there is a still a group of residents who are opposed to the planned road improvements. The December 6 Open House was the conclusion of the public consultation portion for the 105 Avenue Corridor project, and there is still further consultation for Hawthorne Park improvements to be completed.

D. NEW BUSINESS

1. Surrey Coastal Flood Adaptation Strategy - Results from Infrastructure Workshops

Matt Osler, Senior Project Engineer provided a PowerPoint presentation regarding results from infrastructure workshops regarding the Surrey Coastal Flood Adaptation Strategy. The following information was highlighted:

- It is estimated that a $9.5 billion investment is needed in the Lower Mainland to address rising sea levels, with $1.5 billion required in Surrey.

- A series of Surrey Coastal Flood Adaptation Strategy workshops have taken place. Two workshops that explored infrastructure took place and focused on Mud Bay. Infrastructure that was assessed included highways, railways, force mains and hydro lines in the area. Two flood scenarios were presented in the first workshop: coastal flooding with a dyke breach and riverine flood with no dyke breach. Each scenario was assessed a risk score.

- The second workshop only involved participants with selected vulnerable infrastructure. The workshop analyzed environmental, social and economic impacts of flooding. Exercises were completed to see how different flood preparation scenarios could affect infrastructure.

- A Study Area Bus Tour was also organized, and visited two sites.

- General comments received from infrastructure stakeholders include: cost-sharing and collaboration is a high priority; sharing utility corridors could be considered; and, opportunities for improvement should be identified.

- Insights that will inform the development of the Surrey Coastal Flood Adaptation include: key infrastructure is adaptable; infrastructure owners are mostly reactive without specific adaptation plans; and, flood infrastructure and transportation infrastructure are heavily interconnected.

- The next steps of the multi-phased Strategy include identifying a preferred option for flood adaptation, linking with the Lower Mainland Flood Management Strategy, and seeking early buy-in from decision makers to support cost-sharing options.

In response to questions from the Committee, staff provided the following information:

- Transport Canada has the jurisdiction to regulate BNSF, including their infrastructure. The City of Surrey provided studies completed on Mud Bay and sea level rise however their Mud Bay trestle was replaced at the same elevation. BNSF plans for improvements and upgrades to their railway are on-going and expected to proceed independent of the Coastal Flood Adaptation Strategy.

- It is anticipated that sea levels will rise by one centimeter per year. Global sea level rise is currently experiencing approximately three millimeters of rising sea levels per year; however, land in Surrey is also subsiding. The net level of rising sea levels in Surrey's lowlands is approximately half of a centimeter per year, with those levels expected to increase in the next few decades.

It was Moved by Councillor LeFranc
Seconded by Councillor Woods
That the Transportation and Infrastructure Committee recommend that Council request that Mayor Hepner request input from key infrastructure owners with the highest risk of flooding impacts.
Carried

2. Road & Traffic Safety Levy Update

Jaime Boan, Manager, Transportation, reviewed how additional 0.25% increases to the Road and Traffic Safety Levy would impact funding.

In response to questions from the Committee, staff provided the following information:

- Increasing the levy would not significantly impact the timeline for major projects, such as overpasses, as they are primarily funded through DCC's and external funding.

The Committee noted the following comments:

- Support was expressed for a 1.25% levy, as it provides a noticeable increase to the Infrastructure Reserve Balance.
- It was suggested that north/south and east/west connections in the city be advanced as much as possible.
- The 10 Year Plan should be reviewed and additional information regarding how the Levy addresses the Plan is required.
- There is insufficient road infrastructure for current residents and thus staff should investigate greater funding for infrastructure from general revenue sources.
- As the city experiences continued growth, there will be more strain on roads and sidewalks. Concerns were expressed regarding the lack of funding for road and sidewalks.

The Committee requested that the 10 Year Plan be brought forward for review, as well as information regarding proposed north/south and east/west connections, including locations and associated costs. The Committee also requested that staff bring forward a Levy scenario that meets all of the transportation needs and what the associated costs would be.

3. Intersection Safety Update

Philip Bellefontaine, Transportation Planning Manager, provided a PowerPoint presentation update regarding intersection safety and highlighted the following information:

- The following are the top three collision sites in Surrey, as well as the future plans to address safety issues:
  - o 88 Avenue and King George Boulevard will receive a comprehensive intersection redesign as part of the LRT project;
  - o 96 Avenue and Fraser Highway will be upgraded as part of the Fraser Highway widening project; and,
  - o 72 Avenue and King George Boulevard will be identified within the Pilot DDACTS (Data Driven Approach to Crime and Traffic Safety) program and will also receive a comprehensive intersection redesign as part of the LRT project. New safety measures have already been introduced at this location, including signal upgrades and protected left turns.

- Additional projects completed in 2017 to increase intersection safety were implemented at 64 Avenue and Fraser Highway, King George Boulevard and 128 Street plus 80 Avenue and 128 Street. Measures included the installation of new pavement markings, 12 inch lenses for signal heads, improved street lighting, high friction pavement, and improved right turn channelization.

In 2018, a further 7 intersections will receive safety improvements.

- These projects mean that all of the top 15 collision intersection sites have either planned improvements to be made, or have already received improvements.

- The city is also actively implementing a range of safety improvements with continued conversion of High Pressure Sodium lights to LED, speed reader board installation at 15 locations, left turn bay extensions implemented at three sites, 15 new flashing amber crosswalks, uninterrupted power supply at 25 more signalized intersections and road safety review of all road capital construction projects.

In response to questions from the Committee, staff provided the following information:

- A before and after analysis of intersections is undertaken where safety measures have been installed to assess the impact of the improvements and the cost effectiveness of them.

- Additional information, such as traffic volumes through each intersection and the number of collisions is available up to 2015.

- Staff confirmed that an additional 15 RRFB (rectangular rapid flashing boards) will be implemented in 2018.

- The Committee requested that staff provide further information with respect to top collision locations to provide better context.

4. City Centre Parking Study

Dave Harkness, Parking Services Manager, provided a PowerPoint presentation regarding the City Centre Parking study and highlighted the following information:

- The objective of the study is to determine parking utilization in City Centre and potential changes to the parking minimums that apply to new development.

- The research process assessed parking utilization at apartment buildings that have been occupied for at least one year consisting of more than 20 units with secured underground parking. Parking counts were conducted between Monday and Wednesday from 11:00 p.m. to 3:00 a.m.

- The results of the study indicate the following:
  - City Centre has an over-supply of parking, with one-third of parking vacant;
  - There is less than one car per apartment;
  - On- and off-street parking functions as a system, and is influenced by the availability of free on-street parking Pay parking or time restrictions encourage residents to park in their building's underground parking;
  - There is negligible difference between owned and rental buildings; and
  - There is low utilization of tandem parking stalls.

- The next steps in the study include:
  - reviewing on-street parking utilization throughout City Centre;
  - comparing Surrey's parking policies with other municipalities;
  - ongoing participation with Metro Vancouver Apartment Parking Study Advisory Group;
  - consultation with internal and external stakeholders; and
  - policy drafting.

  An update will be provided to the Committee, as well as the consideration of bylaw amendments.

- Preliminary policy options include expanding on-/off-street parking management, reduction of Zoning Bylaw minimum parking requirements, and the expansion of cash-in-lieu contributions for parking revisions.

In response to questions from the Committee, staff advised that a report will be brought forward with recommendations for minimum requirements for electric vehicle infrastructure for new buildings. It was noted that many cities are now requiring a 100% supply of electric vehicle chargers. In addition, staff noted that the City provides a parking reduction for developments that include parking for car-share companies; however, few developments have taken advantage of car-share parking stalls, as car-share companies have indicated that underground parking locations are not optimal for usage. There has also been little uptake of other alternatives to parking requirements, such as annual transit passes.

Council suggested that parking supply be an on-going study and address the following questions:

- The effect of new development in relation to on-street parking;
- The correlation between the unbundling of residential units and parking spots in strata developments;
- How the City encourages the inclusion of bicycles and bicycle lockers in developments; and
- Whether there are parking utilization differences with buildings over 5 years old (as they tend to limit rentals at that point)

The Committee suggested consideration be given to reduced parking rates for affordable housing. The Committee also expressed an interest in the parking situation at Vancouver's west end developments that were built with no parking.

E. ITEMS REFERRED BY COUNCIL

F. CORRESPONDENCE

G. INFORMATION ITEMS

H. OTHER BUSINESS

I. NEXT MEETING

The next meeting of the Transportation and Infrastructure Committee will be held on Monday, January 29, 2018, at 2:00 p.m.in 2E Community Room A.

K. ADJOURNMENT

It was

Moved by Councillor LeFranc
Seconded by Councillor Woods
That the Transportation and Infrastructure Committee meeting do now adjourn.

Carried

The Transportation and Infrastructure Committee adjourned at 3:39 p.m.

Jane Sullivan, City Clerk

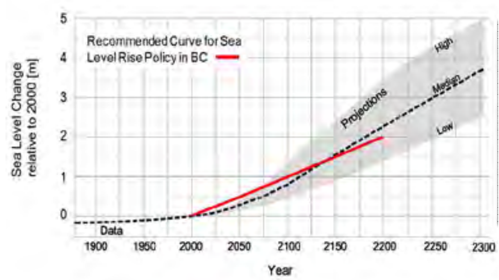
Councillor Gill, Chair

Project Overview

- 2011 Provincial Guidelines on sea level rise published
- Outlined expected sea level rise and flood protection requirements
- 2012 report estimated the cost to adapt flood protection to meet the rise in sea level predicted by 2100
- $9.5 Billion estimate for Lower Mainland
  - Estimate of works in Surrey, $1.5B

SURREY

Provincial
Recommended Sea Level Rise Curve (2011)



CFAS SURREY

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

- Mayor & Council adopted recommendations to develop a Coastal Strategy Feb 22, 2016 under Corporate Report No. R034;2016
  - Continuing commitment to participatory planning
- CFAS anticipated to be complete by end of 2018
- Large study area with many communities, stakeholders and partners

SURREY

Vulnerability Assessment

Workshop 1

- As part of the CFAS engagement process, Mud Bay infrastructure operators, owners & emergency service providers participated in a one day workshop on March 28, 2017.
- Workshop included 66 participants from 28 organizations
- Workshop utilized the PIEVC Protocol
  - Developed by Engineers Canada and heavily used by Ministry of Transportation and Infrastructure

CFAS SURREY

Workshop 1 Objectives

- Build shared understanding of sea level rise and its impacts on coastal and riverine flooding in relation to infrastructure in Mud Bay
- To identify issues, concerns and potential vulnerabilities of the Mud Bay infrastructure
- Explore preliminary options for addressing coastal flood hazards

CFAS SURREY

Workshop 1 Stakeholders

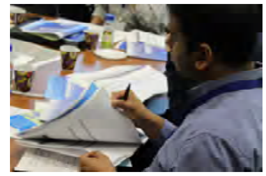
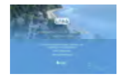
- Mud Bay infrastructure operators, owners & emergency service providers

Workshop Attendee Organizations	
Associated Engineering	FortisBC
BC Ambulance Service	Metro Vancouver
BC Rail Consultant	Ministry of Agriculture
BNSF	Ministry of Community, Sport and Cultural Development
Canadian Coast Guard	Ministry of Environment
CFPS Consulting Team	Ministry of Transportation and Infrastructure
City of Surrey	Mud Bay Dyking District
City of Vancouver	Northwest Hydraulics Consultants
Corporation of Delta	Royal Canadian Mounted Police
Cowichan Valley Regional District	SNC Lavalin
Ducks Unlimited Canada	Southern Railway of BC
Emergency Management BC	Surrey Operations
Engineers Canada	Telus/Shaw

CFAS

Workshop 1 - Group Exercises

- Working in groups
  - Flood / Marine (2 groups)
  - Transpiration (2 groups)
  - Utilities (2 groups)
- Participants
  - Identified flood impacts
  - Assessed the risk on the infrastructure
  - Commented on adaptation approaches


Infrastructure

- Infrastructure in the Mud Bay area assessed
  - Flood Control / Marine

CFAS

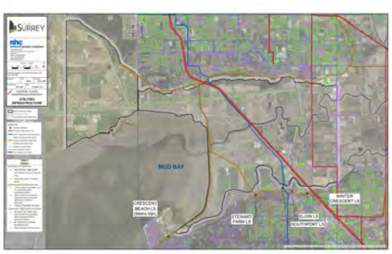
Infrastructure

- Infrastructure in the Mud Bay area assessed
  - Transportation

CFAS

Infrastructure

- Infrastructure in the Mud Bay area assessed
  - Utilities



CFAS

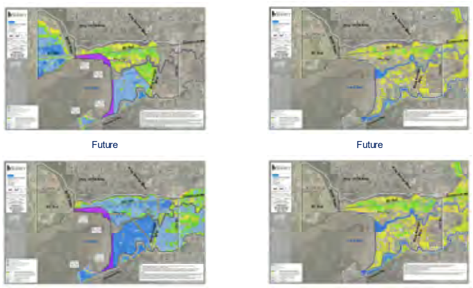
Infrastructure

Flood / Marine	TRANSPORTATION	TRANSPORTATION	UTILITIES
Flood Control Infrastructure	**Local Government Arterial and Collector Roads**	**Regional / International Transportation Infrastructure**	**Sanitary Lift Stations**
City of Surrey Sea Dams (2)	King George Boulevard	4 km of four-lane arterial roadway	City of Surrey: Elgin
15 km of dyking, including ditches and floodboxes	152nd Street	7 km section of Highway 99 linking Peace Arch Border	City of Surrey: South Port
Colebrook Pump Station	Colebrook Road	Highway 91 and 99 Interchange	City of Surrey: Winter Crescent
Maple Pump Station	Corporation of Delta: Ladner Trunk Road	4 km section of Highway 91	City of Surrey: Stewart Farm
Corporation of Delta: Oliver Pump Station	112 Street	6 km dyke trail connecting to parks	Metro Vancouver: Crescent Beach
Ducks Unlimited Canada Serpentine Fen Nature Reserve	**Class 1 Railways**	Delta-Surrey Greenway	**Underground infrastructure**
Water control and irrigation	Class 1 Railways Originating at Port Metro Vancouver (general)	**Runway**	5 km of Metro Vancouver 750 mm diameter Water Transmission Main
Screw pump stations (added)	BNSF Swing Bridge and Trestles	Surrey/King George Airpark Turf Runway	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
Marine Facilities	6 km of BNSF Railway		>10 km of FortisBC Gas Mains
Crescent Beach Marina	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF)		**Overhead Utility Infrastructure**
Wards Marina			BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power
Private docks	Connection to Southern Railway of British Columbia		BC Hydro local overhead distribution lines
Farms			Shaw and Telus telecom lines
Private dairy facilities for more than 1,000 head of Cattle			Green Infrastructure

Flood Scenarios

Flood Scenario A: Coastal Flood With Dyke Breach

Flood Scenario B: Riverine Flood

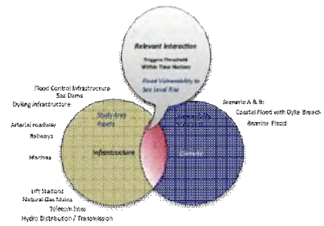


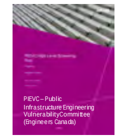
CFAS

SURREY

PIEVC Risk Assessment

- High Level Screening Assessment
  - PIEVC Process is designed to help infrastructure owners gain a high level and quick overview of the potential risk posed by climate change to their infrastructure.





High Level Screening Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

CFAS

SURREY

PIEVC Risk Assessment

- Risk (R) is defined as the product of the probability (P) of an event and the consequence (C) of that event – should it occur.

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic

R = P X C

CFAS

SURREY

PIEVC Risk Assessment

- A resulting Risk score is established.
  - R = >10 | Low Risk | Risks requiring minimal action
  - R = 10 – 19 | Medium Risk | Risks that may require future action
  - R = 20 – 25 | High Risk | Risks that require action

CFAS

SURREY

PIEVC Risk Assessment

- Risk Summary: 43 assets assessed
  - Flood Scenario A – Coastal Flood with Dyke Breach
    - Current risks are mostly low and medium
    - Future risks increase to medium and high

	Flood Scenario A - Current	Flood Scenario A - Future
Low Risk	20	6
Medium Risk	21	15
High Risk	2	22

CFAS

SURREY

PIEVC Risk Assessment

- Risk Summary
  - Flood Scenario B – Riverine Flood
    - Current risks are all low
    - Future risks increase to medium and with a few high risks

	Flood Scenario B - Current	Flood Scenario B - Future
Low Risk	43	14
Medium Risk	0	22
High Risk	0	7

CFAS

SURREY

PIEVC Risk Assessment

- High Risk Summary

CFAS

SURREY

Adaptation Approaches

Workshop 2

- As part of the CFAS engagement process, Mud Bay infrastructure operators, owners & emergency service providers participated in a second one day workshop on October 10, 2017.
- Workshop included 58 participants from 23 organizations
- Workshop utilized the PIEVC Protocol triple bottom line decision-making module

CFAS

SURREY

Workshop 2 Objectives

- To explore what impacts selected adaptation options may have on key infrastructure and land-use located in the Mud Bay Study Area.

CFAS

SURREY

Workshop 2 Stakeholders

- Mud Bay infrastructure operators, owners & emergency service providers

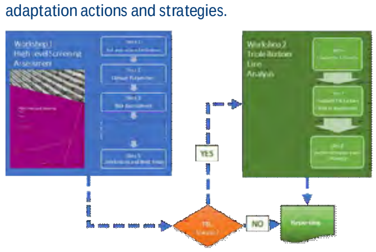
ICFAA Workshop Attendee Organizations	
Agricultural Land Commission	Fraser Basin Council
Associated Engineering	Metro Vancouver
BC Agriculture and Food Climate Action Initiative	Ministry of Environment
BC Hydro	Ministry of Transportation and Infrastructure
City of Surrey	Northwest Hydraulic Consultants
City of Surrey Fire Service	RCMP
Corporation of Delta	Surrey Board of Trade Representative
EcoPlan	SRY Rail Link
Emergency Management BC	Thrive Consulting
Engineers and Geoscientists BC	University of British Columbia
Engineers Canada	Vancouver Fraser Port Authority
FortisBC	

CFAS

SURREY

Workshop 2 PIEVC TBL Analysis

- Triple Bottom Line (TBL) Analysis
  - The PIEVC Protocol provides a triple bottom line decision-making module that helps to establish, in broad terms, environmental, social and economic factors to aid decision-makers in selecting appropriate adaptation actions and strategies.



CFAS

SURREY

PIEVC Engineering and Triple Bottom Line Analysis Orientation

CFAS

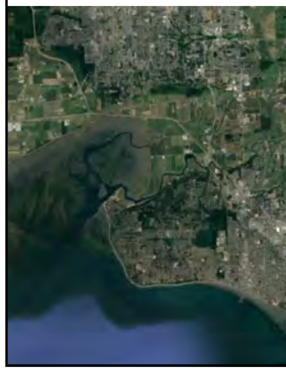
SURREY

TBL Evaluation Factors

Category	Factor	Interpretation
Environmental	Regulatory Compliance	Ability to meet regulatory requirements
	Biodiversity / Habitat	Potential to impact biodiversity or habitat
	Climate Change Mitigation / Adaptation	Integration with other climate change initiatives
Social	Public Perception	How the public perceives an action
	Acceptable Level of Service and Risk	Maintenance of acceptable level of service to the public
	Emergency Response	Effect on emergency response
	Agricultural Impacts	Impacts to agricultural land
	First Nations / Archaeology	Potential for cultural impacts
Economic	Capital Cost	Cost of design and construction
	Cost-Sharing	Opportunities for cost-sharing with others or external funding
	Collaboration	Opportunities for collaboration
	Resilience and Maintainability	Ability to maintain or adapt in the future
	Disruption of Commerce	Internal or external economic impacts due to disruption
	Risk Tolerance / Asset Lifecycle	Opportunities to renew infrastructure that is not yet deficient

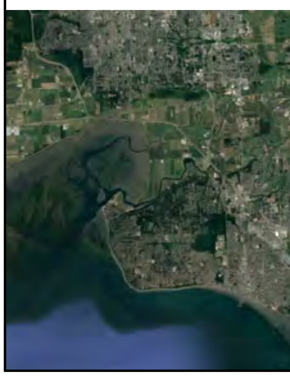
CFAS SURREY

Preliminary Options Overview



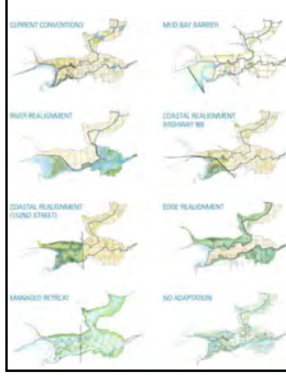
- Developed with stakeholder input and in collaboration with UBC-LINT (Dutch Firm)
- 10,000 ft view: Large area with many possibilities/options
- Only presenting options that are significantly different from each other
- Options are preliminary and not public
- Details and phasing come at a later point

Preliminary Options Overview



1. Current Convention
2. Mud Bay Barrier
3. River Realignment
4. Coastal Realignment to Highway 99
5. Coastal Realignment to 152nd Street
6. Edge Realignment
7. Managed Retreat
8. No Adaptation

Preliminary Options Overview



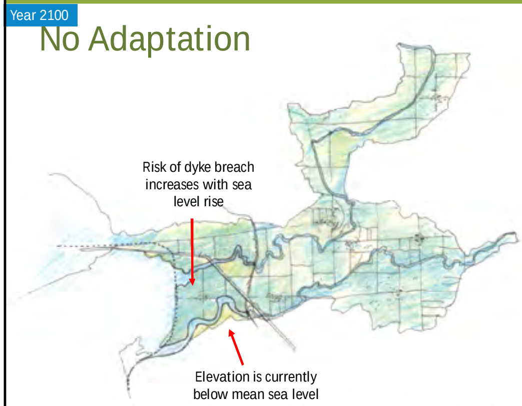
3. River Realignment

5. Coastal Realignment to 152nd Street

8. No Adaptation

Year 2100

No Adaptation



No Adaptation

WHAT THIS COULD LOOK LIKE

Removable flood barriers

Evacuation routes

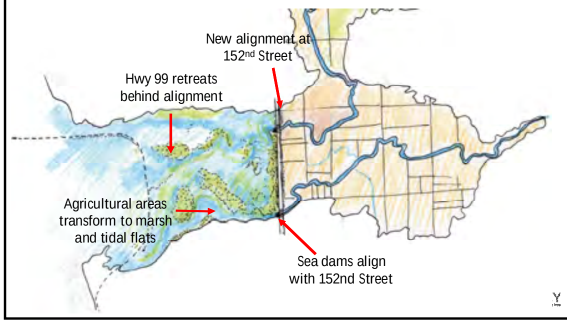
No Adaptation

WHAT THIS COULD LOOK LIKE

Hwy 99 Adapts

Year 2100

Coast Realignment (152^{nd} St)



Coast Realignment (152^{nd} St)

WHAT THIS COULD LOOK LIKE

Newly created marsh becomes wind and wave buffer for new dyke

Coast Realignment (152^{nd} St)

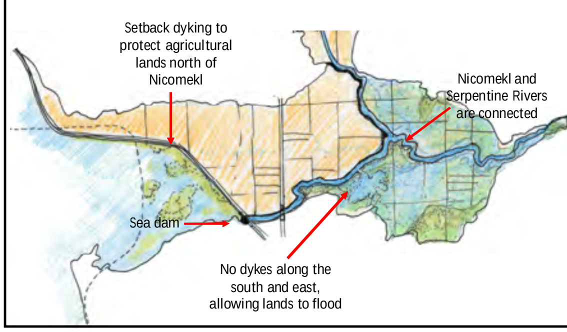
WHAT THIS COULD LOOK LIKE

CFAS

SURREY

Year 2100

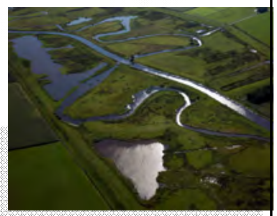
River Realignment



River Realignment

WHAT THIS COULD LOOK LIKE

Improved Riparian Corridors



Inundation of Hunze River, NL

Study Area Bus Tour – What Did We Hear?

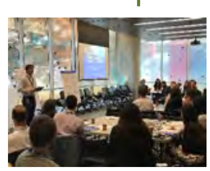
(A brief sample)

- Regional and interjurisdictional coordination is needed
- Significant costs associated with both options, opportunity for cost-sharing important
- Need to get regulators on board and have political will
- Consider overall resilience of solutions to multiple hazards
- Adaptability over time

Workshop 2 - Group Exercises

- Working in groups
  - Review Adaptation Option Details and Considerations
  - Review each Infrastructure Component
  - Review and Identify TBL Factors considered in making a decision including Indicate the degree of importance
  - Provide overall comments and on option and identify thresholds

Workshop 2 - Group Exercises



Workshop 2 – Results

- Some of the key general comments (applicable to both options) are as follows:
  - Cost-sharing and collaboration is a high priority because of the scale of the infrastructure impacted. These opportunities need to be mutually beneficial.
  - The changes provide the opportunity to explore multi-purpose enhancements, including mass transit, HOV lanes, greenways, recreational trails, and environmental features that will improve public acceptance of the changes.
  - Shared utility corridors allow for cost-sharing and lessen the amount of land needed for relocations, however this can impose a new risk, where if one utility fails, it can impact others in the corridor.
  - Relocation and redesign of infrastructure allows the opportunity to meet other objectives of the sectors, including seismic resilience, and efficiency improvements.

Results - No Adaptation

CFAS Option:	Baseline				No Adaptation							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		5	5	25	Loss	1	5	5	Protected
Highway 99	4	4	16		5	5	25	Loss	1	5	5	Protected
152 Street	4	1	4		5	4	20	Loss	1	4	4	Protected
Highway 91	4	2	8		5	4	20	Loss	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	4	20	Loss	1	4	4	Protected
Sanitary Lift Stations	4	4	16		5	4	20	Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		5	4	20	Loss	1	4	4	Protected
FortisBC Gas Mains	4	2	8		5	2	10	Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		5	3	15	Loss	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		5	4	20	Loss	1	4	4	Protected
King George Airpark	4	1	4		5	1	5	Loss	1	1	1	Protected
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		5	1	5	Loss	1	1	1	Protected
Local roads	4	2	8		5	3	15	Loss	1	3	3	Protected
Local Power Distribution, Telecom	4	4	16		5	4	20	Loss	1	4	4	Protected
Serpentine Fen and Water Control Features	4	3	12		5	3	15	Loss	1	3	3	Protected
Marinas, Private Docks	4	2	8		5	3	15	Loss	1	3	3	Protected
Dairy Farm	4	4	16		5	5	25	Loss	1	5	5	Protected
Risk Distribution			#	%			#	%			#	%
Low Risk			8	38%			2	10%			21	100%
Medium Risk			13	62%			6	29%			0	0%
High Risk			0	0%			13	62%			0	0%

Results - Coast Realignment (152nd St)

CFAS Option:	Baseline			
Time Horizon:	Current Coastal Flood Risk (~2010)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure			
Infrastructure Components	P	C	R	
King George Boulevard	4	3	12	
Highway 99	4	4	16	
152 Street	4	1	4	
Highway 91	4	2	8	
Ladner Trunk Road	4	3	12	
BNSF Embankment	4	4	16	
BNSF Swing Bridge and Trestles	4	4	16	
BCRC Embankment	4	2	8	
Sanitary Lift Stations	4	4	16	
Metro Vancouver Sanitary Main	4	4	16	
Metro Vancouver Water Main	4	4	16	
FortisBC Gas Mains	4	2	8	
BC Hydro Transmission Lines	4	3	12	
Drainage Pump Stations, Ditches, Floodboxes	4	4	16	
King George Airpark	4	1	4	
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4	
Local roads	4	2	8	
Local Power Distribution, Telecom	4	4	16	
Serpentine Fen and Water Control Features	4	3	12	
Marinas, Private Docks	4	2	8	
Dairy Farm	4	4	16	
Risk Distribution			#	%
Low Risk			8	38%
Medium Risk			13	62%
High Risk			0	0%

[illegible]

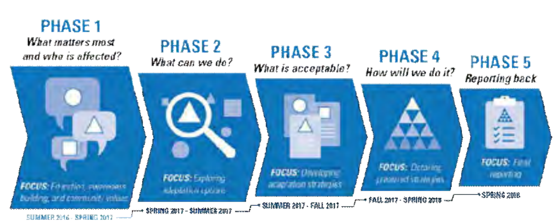
Results - River Realignment

CFAS Option:	Baseline				River Realignment							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		1	5	5	Protected	1	5	5	Protected
Highway 99	4	4	16		1	5	5	Protected	1	5	5	Protected
152 Street	4	1	4		1	4	4	Protected	1	4	4	Protected
Highway 91	4	2	8		1	4	4	Protected	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	3	15	Partial Loss	1	3	3	Protected
Sanitary Lift Stations	4	4	16		3	4	12	Partial Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		1	4	4	Protected	1	4	4	Protected
FortisBC Gas Mains	4	2	8		3	2	6	Partial Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		1	3	3	Protected	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		3	2	6	Modified	1	2	2	Protected
King George Airpark	4	1	4		1	1	1	Protected	1	1	1	Protected
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		3	1	3	Partial Loss	1	1	1	Protected
Local roads	4	2	8		3	3	9	Partial Loss	1	3	3	Protected
Local Power Distribution, Telecom	4	4	16		3	4	12	Partial Loss	1	4	4	Protected
Serpentine Fen and Water Control Features	4	3	12		5	5	25	Abandoned	1	1	1	Protected
Marinas, Private Docks	4	2	8		5	3	15	Loss	1	3	3	Protected
Dairy Farm	4	4	16		5	5	25	Loss	5	5	25	Abandoned
Risk Distribution			#	%			#	%			#	%
Low Risk			8	38%			11	52%			20	95%
Medium Risk			13	62%			5	24%			0	0%
High Risk			0	0%			5	24%			1	5%

Workshop 2 – Results

- Some of the key general comments (applicable to both options) are as follows:
  - Cost-sharing and collaboration is a high priority because of the scale of the infrastructure impacted. These opportunities need to be mutually beneficial.
  - The changes provide the opportunity to explore multi-purpose enhancements, including mass transit, HOV lanes, greenways, recreational trails, and environmental features that will improve public acceptance of the changes.
  - Shared utility corridors allow for cost-sharing and lessen the amount of land needed for relocations, however this can impose a new risk, where if one utility fails, it can impact others in the corridor.
  - Relocation and redesign of infrastructure allows the opportunity to meet other objectives of the sectors, including seismic resilience, and efficiency improvements.

Surrey CFAS Process



Presentation to BC Hydro by Matt Osler (City of Surrey)

January 18, 2018

Associated Engineering

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

CFAS

Infrastructure Asset Managers, Operators and Emergency Services Stakeholders PIEVC Workshops Summary

BCH

January 18, 2018

Agenda

- Staff introductions
- Coastal Flood Adaptation Strategy (5 mins)
- Scenarios and risk assessment (10 mins)
- Triple bottom line and decision making (10 mins)
- Preferred options for Mud Bay (15 mins)
- Questions and discussion (20 mins)

CFAS SURREY

Introduction

- 2011 Provincial Guidelines on sea level rise published
- Outlined expected sea level rise and flood protection requirements
- 2012 report estimated the cost to adapt flood protection to meet the rise in sea level predicted by 2100
- $9.5 Billion estimate for Lower Mainland
  - Estimate of works in Surrey, $1.5B
  - Excluded majority of Surrey's dykes that are upstream of sea dams

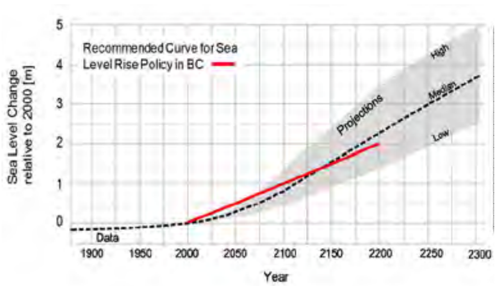
SURREY

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

- Mayor & Council adopted recommendations to develop a Coastal Strategy Feb 22, 2016 under Corporate Report No. R034;2016
  - Continuing commitment to participatory planning
- CFAS anticipated to be complete by end of 2018
- Large study area with many communities, stakeholders and partners

SURREY

Provincial
Recommended Sea Level Rise Curve (2011)

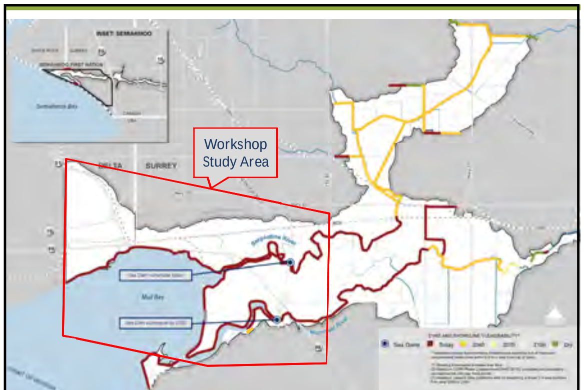


CFAS SURREY

Surrey CFAS Process

- Many stakeholders and partners
  - Farmers and agricultural community
  - Residents, businesses, community groups
  - Environmental and recreational groups
  - Regulators
  - Semiahmoo First Nation
  - Infrastructure operators and owners

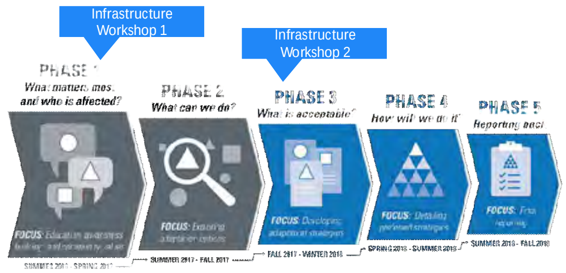
CFAS SURREY



CFAS

SURREY

Surrey CFAS Process



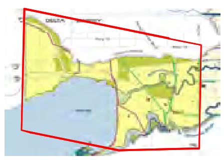
CFAS

SURREY

Vulnerability Assessment

Workshop 1: March 28, 2017

- Mud Bay infrastructure operators, owners & emergency service providers participated in a one day workshop
- Workshop included 66 participants from 28 organizations
- Workshop utilized the PIEVC Protocol
  - Developed by Engineers Canada and heavily used by Ministry of Transportation and Infrastructure



Organizing Committee Established

Delta

metrovancouver

CFAS

SURREY

PIEVC Workshop 1 Objectives

- Build shared understanding of coastal flooding impacts to infrastructure in Mud Bay
- To identify issues, concerns and potential vulnerabilities of the Mud Bay infrastructure
- Obtain feedback on approaches for addressing coastal flood hazards

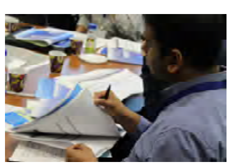
CFAS

10

SURREY

Workshop 1 Stakeholders

- Stakeholders in 3 sectors assessed their vulnerabilities:
  - Flood / Marine (2 groups)
  - Transportation (2 groups)
  - Utilities (2 groups)



Workshop Attendee Organizations		
Associated Engineering	Cowichan Valley Regional District	Ministry of Environment
BC Ambulance Service	Ducks Unlimited Canada	Ministry of Transportation and Infrastructure
BC Rail Consultant	Emergency Management BC	Mud Bay Dyking District
BC Hydro	Engineers Canada	Port of Vancouver
BNSF	FortisBC	Royal Canadian Mounted Police
Canadian Coast Guard	Metro Vancouver	SNC Lavalin
CFPS Consulting Team	Ministry of Agriculture	Southern Railway of BC
City of Surrey	Ministry of Community, Sport and Cultural Development	Surrey Operations
City of Vancouver		Telus/Shaw
Corporation of Delta		

Infrastructure Assessed

12

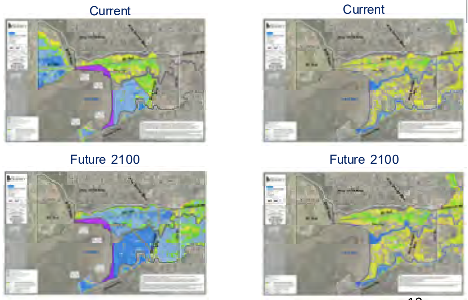
Flood Scenarios

Flood Depths (cm)
- 0 to 50
- 50 to 100
- 100 to 200
- 200 to 500
- Zone Subject to Wave Effec

Coastal Flood With Dyke Breach | **Riverine Flood no Dyke Breach**

Current | Current

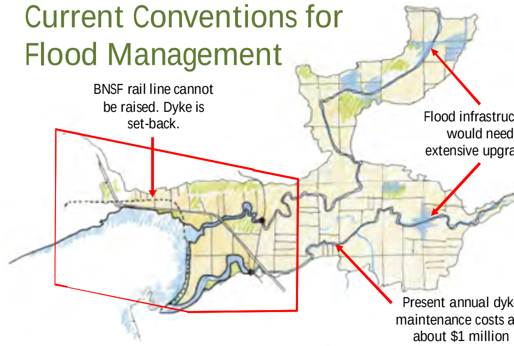
Future 2100 | Future 2100



CFAS 13 SURREY

Year 2100

Assessment based on Current Conventions for Flood Management



Risk Assessment

- Risk Scores established for all infrastructure to prioritize concerns and identify sectors most vulnerable
  - R = > 10 Low Risk Risk requiring minimal action
  - R = 10 – 19 Medium Risk Risks that may require future action
  - R = 20 – 25 High Risk Risks that require action

CFAS SURREY

Risk Assessment Results

- Risk Summary: 43 assets assessed
  - Coastal Flood with Dyke Breach

Flood Risk	Coastal Flood with Dyke Breach Current	Coastal Flood with Dyke Breach 2100
Low	20	6
Medium	21	15
High	2	22

CFAS 16 SURREY

Risk Assessment Results

- Risk Summary: 43 assets assessed
  - Riverine Flood no dyke breach

Flood Risk	Riverine Flood Current	Riverine Flood 2100
Low	43	14
Medium	0	22
High	0	7

- Results of both flood scenarios identified vulnerable key infrastructure for second workshop

CFAS 17 SURREY

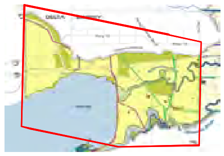
Report Completed

CFAS SURREY

Adaptation Approaches

Workshop 2: October 10, 2017

- To explore what impacts selected adaptation options may have on vulnerable key infrastructure and land-use located in the Mud Bay Study Area.
- Workshop included 58 participants from 23 organizations
- Workshop utilized the PIEVC Protocol triple bottom line decision-making module
- Optional pre-workshop study tour September 25, 2017



New stakeholders participating:

- Agricultural Land Reserve
- BC Agriculture and Food Climate Action Initiative
- Engineers and Geoscientists BC
- Fraser Basin Council
- Surrey Board of Trade
- University of British Columbia

CFAS

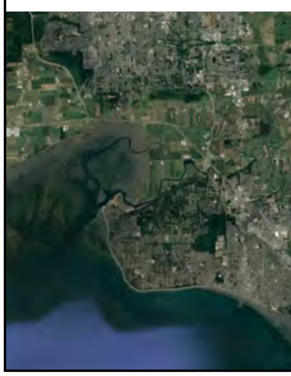
SURREY

Triple Bottom Line Analysis

Helps to establish, in broad terms, environmental, social and economic factors to aid decision-makers in selecting appropriate adaptation actions and strategies.

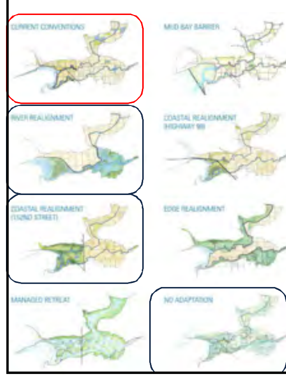
Category	Factor	Interpretation
Environmental	Regulatory Compliance	Ability to meet regulatory requirements
	Biodiversity / Habitat	Potential to impact biodiversity or habitat
	Climate Change Mitigation / Adaptation	Integration with other climate change initiatives
Social	Public Perception	How the public perceives an action
	Acceptable Level of Service and Risk	Maintenance of acceptable level of service to the public
	Emergency Response	Effect on emergency response
	Agricultural Impacts	Impacts to agricultural land
	First Nations / Archaeology	Potential for cultural impacts
Economic	Capital Cost	Cost of design and construction
	Cost-Sharing	Opportunities for cost-sharing with others or external funding
	Collaboration	Opportunities for collaboration
	Resilience and Maintainability	Ability to maintain or adapt in the future
	Disruption of Commerce	Internal or external economic impacts due to disruption
	Risk Tolerance / Asset Lifecycle	Opportunities to renew infrastructure that is not yet deficient

Preliminary Options Overview



- Developed with stakeholder input and in collaboration with UBC-LINT (Dutch Firm)
- 10,000 ft view: Large area with many possibilities/options
- Only presenting options that are significantly different from each other
- Options are preliminary and for year 2100
- Details and phasing come at a later point in CFAS
- Public release planned for February

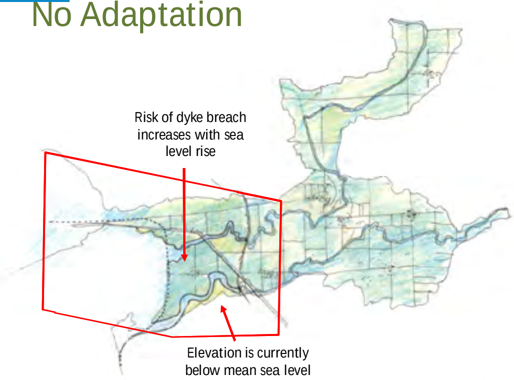
Preliminary Options Overview



1. Current Convention (1st workshop)
3. River Realignment (2nd workshop)
5. Coastal Realignment to 152nd Street (2nd workshop)
8. No Adaptation (2nd workshop)

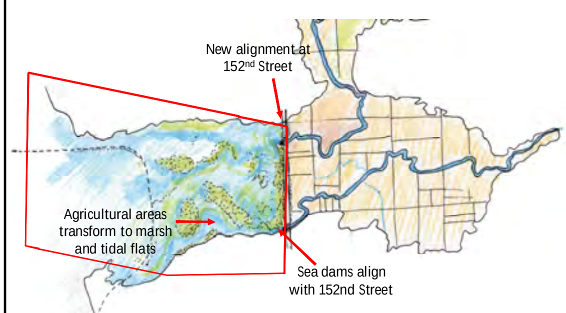
Year 2100

No Adaptation



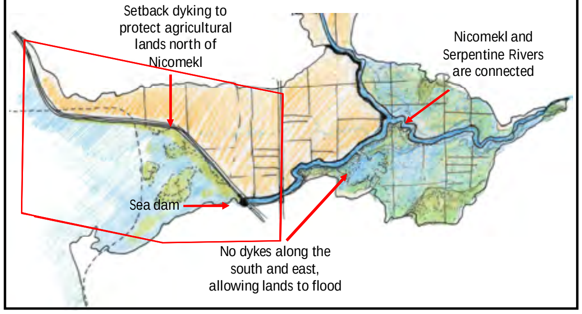
Year 2100

Coast Realignment (152nd St)



Year 2100

River Realignment



Study Area Bus Tour – Sept 25, 2017

- Reviewed options in groups and visited two sites

What Did We Hear? (A brief sample)

- – Regional and interjurisdictional coordination is needed
- – Significant costs associated with both options, opportunity for cost-sharing important
- – Need to get regulators on board and have political will
- – Consider overall resilience of solutions to multiple hazards
- – Adaptability over time

Workshop 2 - Group Exercises



CFAS

SURREY

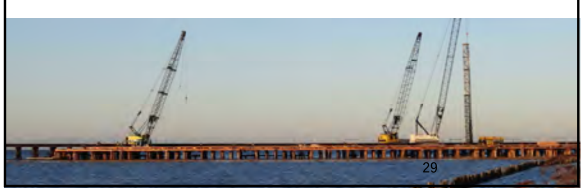
Triple Bottom Line Findings

- Considerable variability in significance of various factors across sectors and by individual participants for individual factors
- Each organization would need to assign their on weighting to make a decision on their preferred option, or level of cost sharing for a specific option
- Agreement on top factors identified by stakeholders were centred around Economic category

Category	Factor	Sectors
Environmental	Regulatory Compliance	Railways, Roads, Highways, Drainage
	Biodiversity / Habitat	Drainage
Social	Public Perception	Roads, Irrigation
	Acceptable Level of Service and Risk	Regional Sanitary Mains
	Emergency Response	Regional Sanitary Mains
	First Nations / Archaeology	Utilities, Transportation
Economic	Capital Cost	Roads, Highways, Sewers, Dairy
	Cost-Sharing	Regional Sanitary, Dairy, Irrigation
	Resilience and Maintainability	Railways, Roads, Highways
	Disruption of Commerce	Highways, Railways, Dairy
	Risk Tolerance / Asset Lifecycle	Highways, Railways

Risk Assessment Findings

Flood Risk	No Adaptation 2100	Coastal Realignment to 152 St 2100	River Realignment 2100
Low	2	4	11
Medium	6	6	5
High	13	11	5

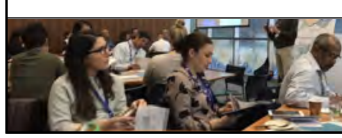


29

Workshop 2 – General Comments

From Infrastructure Stakeholders:

1) Cost-sharing and collaboration is a high priority
   - -Seek co-benefits
2) Considerations of shared utility corridors
   - -Reduces costs
   - -Can increase risk
3) Opportunities for improvement
   - -Resulting from adaptation, or
   - -Capital renewal creates opportunities for adaptation

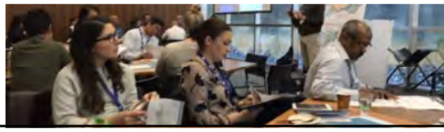



30

Workshop 2 – General Comments

General comments from Infrastructure Stakeholders:

1) Cost-sharing and collaboration is a high priority Adaptation provides the opportunity to explore multi-purpose enhancements (co-benefits) to improve public acceptance of the changes.
2) Shared utility corridors allow for cost-sharing and lessen the amount of land needed for relocations, however this can impose a new risk, where if one utility fails, it can impact others in the corridor.
3) Relocation and redesign of infrastructure allows the opportunity to meet other objectives of the sectors, including seismic resilience, and efficiency improvements.



Final Report pending

CFAS SURREY

Insights for CFAS Decision Process

1) Key infrastructure is adaptable
   – CFAS Options have the potential to minimize infrastructure risk
2) Infrastructure owners are mostly reactive without specific adaptation plans and City should choose option that meets its needs
3) Flood infrastructure and transportation infrastructure are heavily interconnected and cooperation will be required across sectors
   – Significant gaps in existing flood control alignment cannot be resolved unless railways and highways are raised or relocated
   – Long-term coordination is required between City of Delta and Surrey

33

CFAS Advisory Group

- Agricultural Land Commission
- A Rocha Canada
- Anderson Walk (BCS2382) Strata
- Bird Studies Canada
- City of Surrey
- Corporation of Delta
- Crescent Beach Property Owners Association
- Delta Farmers Institute
- Ducks Unlimited Canada
- Engineers and Geoscientists BC
- Fraser Valley Real Estate Board
- Friends of Semiahmoo Bay Society
- Hopkins Berry Farm
- Kooldale Farms Ltd.
- Lindrian Farms
- Little Campbell Watershed Society
- M&M Pacific Coast Farms
- Metro Vancouver
- Ministry of Agriculture
- Ministry of Transportation & Infrastructure
- Mud Bay Dyking District
- Nicomekl Enhancement Society
- Residents at large
- Surrey Board of Trade
- Surrey Environmental Partners
- Surrey Heritage Advisory Commission
- School District #36
- UBC School of Architecture and Landscape Architecture
- Westland Insurance Group
- White Rock
- Winners Holstein Ltd.

CFAS SURREY

CFAS Evaluation Criteria

RESIDENTS: Are people permanently displaced?

INFRASTRUCTURE: Is service/transportation infrastructure made vulnerable?

AGRICULTURE: Is there permanent loss of agriculture land?

ECONOMY: Is there a permanent loss of business?

ENVIRONMENT: Are there impacts (positive & negative) to wetland habitats, freshwater fish habitat & riparian areas?

RECREATION: Is there a diversity of recreational activities (positive & negative)?

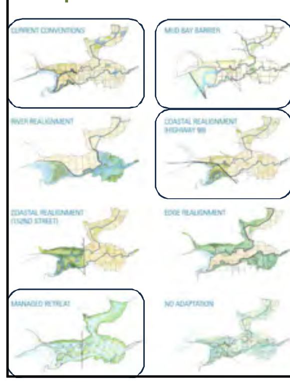
CULTURE: Are there Semiahmoo First Nation cultural impacts that could be expected?

OVERALL RISK: What is the likelihood and consequences of:

- Overtopping
- Erosion
- Earthquake
- Mechanical Failure
- Seepage
- Heavy Rainfall

CAPITAL COST | OPERATION & MAINTENANCE COST | INFRASTRUCTURE MARGINAL COST | COST TO FUTURE GENERATIONS

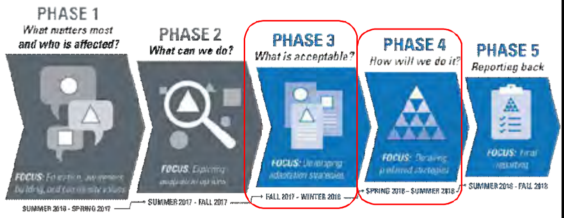
Options Shortlist



1. Current Convention
2. Mud Bay Barrier
3. River Realignment
4. Highway 99 Realignment
5. Coastal Realignment to 152nd Street
6. Edge Realignment
7. Managed Retreat
8. No Adaptation

CFAS Next Steps

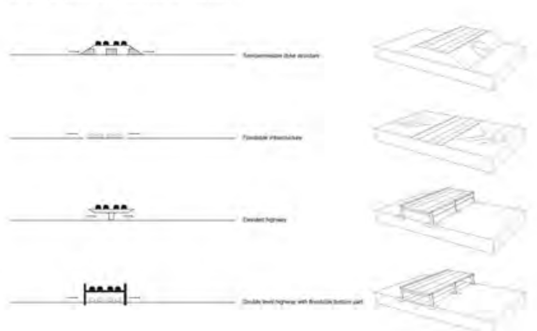
- Meet with specific infrastructure owners (ongoing)
- Public survey on Mud Bay options (February)
- Project Advisory Group meeting (March 9th, 2018)
- Open House to present findings in March 2018 and obtain additional public input to inform Phase 4



Infrastructure Adaptation

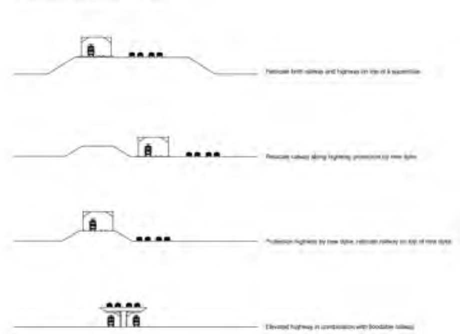
Infrastructure Adaptation: Accommodate

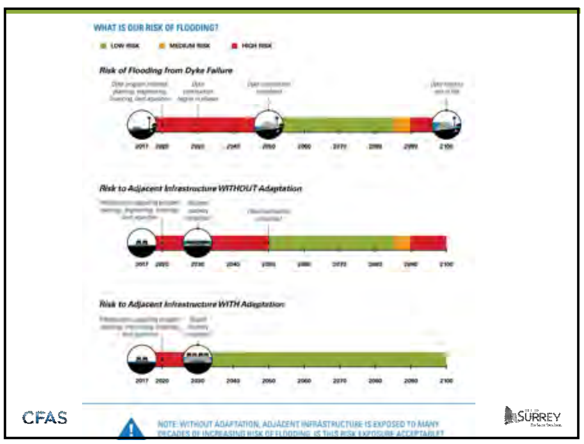
INFRASTRUCTURE ACCOMMODATES FLOODING



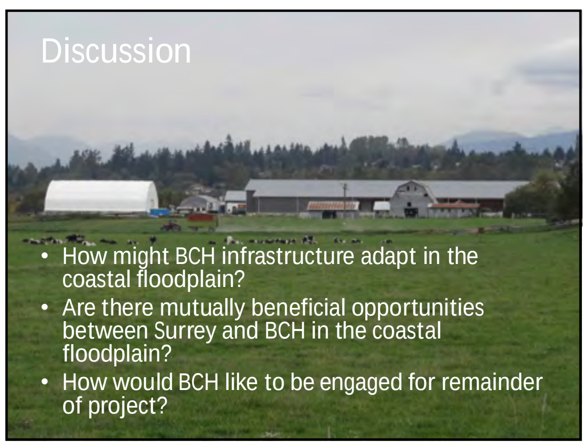
Infrastructure Adaptation: Combined

COMBINED INFRASTRUCTURE





Discussion



- How might BCH infrastructure adapt in the coastal floodplain?
- Are there mutually beneficial opportunities between Surrey and BCH in the coastal floodplain?
- How would BCH like to be engaged for remainder of project?

CFAS

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Infrastructure Asset Managers, Operators and Emergency Services Stakeholders PIEVC Workshop Summary

BCH Presentation

Annex Slides

CFAS

Infrastructure

- Infrastructure in the Mud Bay area assessed
  - Flood Control / Marine

CFAS

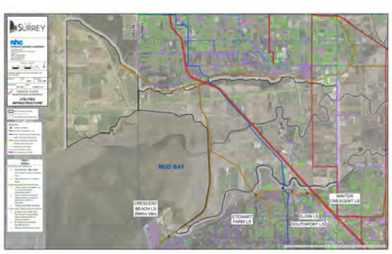
Infrastructure

- Infrastructure in the Mud Bay area assessed
  - Transportation

CFAS

Infrastructure

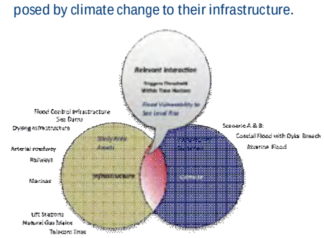
- Infrastructure in the Mud Bay area assessed
  - Utilities

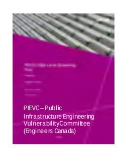


CFAS

PIEVC Risk Assessment

- High Level Screening Assessment
  - PIEVC Process is designed to help infrastructure owners gain a high level and quick overview of the potential risk posed by climate change to their infrastructure.





High Level Screening Assessment

Step 1 Define Infrastructure

Step 2 Evaluate Climate Changes

Step 3 Conduct Risk Assessment

Step 5 Conclusions and Recommendations

CFAS

PIEVC Risk Assessment

- Risk (R) is defined as the product of the probability (P) of an event and the consequence (C) of that event – should it occur.

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic

R = P X C

CFAS

SURREY

Results - No Adaptation

CFAS Option:	Baseline				No Adaptation							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		5	5	25	Loss	1	5	5	Protected
Highway 99	4	4	16		5	5	25	Loss	1	5	5	Protected
152 Street	4	1	4		5	4	20	Loss	1	4	4	Protected
Highway 91	4	2	8		5	4	20	Loss	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	4	20	Loss	1	4	4	Protected
Sanitary Lift Stations	4	4	16		5	4	20	Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		5	4	20	Loss	1	4	4	Protected
FortisBC Gas Mains	4	2	8		5	2	10	Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		5	3	15	Loss	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		5	4	20	Loss	1	4	4	Protected
King George Airpark	4	1	4		5	1	5	Loss	1	1	1	Protected
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		5	1	5	Loss	1	1	1	Protected
Local roads	4	2	8		5	3	15	Loss	1	3	3	Protected
Local Power Distribution, Telecom	4	4	16		5	4	20	Loss	1	4	4	Protected
Serpentine Fen and Water Control Features	4	3	12		5	3	15	Loss	1	3	3	Protected
Marinas, Private Docks	4	2	8		5	3	15	Loss	1	3	3	Protected
Dairy Farm	4	4	16		5	5	25	Loss	1	5	5	Protected
Risk Distribution			#	%			#	%			#	%
Low Risk			8	38%			2	10%			21	100%
Medium Risk			13	62%			6	29%			0	0%
High Risk			0	0%			13	62%			0	0%

CFAS

SURREY

Results - Coast Realignment (152nd St)

CFAS Option:	Baseline				Coastal Realignment to 152 Street							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		1	5	5	Protected	1	5	5	Protected
Highway 99	4	4	16		5	5	25	Loss	1	5	5	Protected
152 Street	4	1	4		1	4	4	Protected	1	4	4	Protected
Highway 91	4	2	8		5	4	20	Loss	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	4	20	Loss	1	4	4	Protected
Sanitary Lift Stations	4	4	16		5	4	20	Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		5	4	20	Loss	1	4	4	Protected
FortisBC Gas Mains	4	2	8		5	2	10	Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		5	3	15	Loss	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		5	4	20	Loss	1	4	4	Protected
King George Airpark	4	1	4		5	1	5	Loss	5	5	25	Abandoned
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		5	1	5	Loss	5	5	25	Abandoned
Local roads	4	2	8		5	3	15	Loss	5	5	25	Abandoned
Local Power Distribution, Telecom	4	4	16		5	4	20	Loss	5	5	25	Abandoned
Serpentine Fen and Water Control Features	4	3	12		5	3	15	Loss	5	5	25	Abandoned
Marinas, Private Docks	4	2	8		5	3	15	Loss	5	5	25	Abandoned
Dairy Farm	4	4	16		5	5	25	Loss	5	5	25	Abandoned
Risk Distribution			#	%			#	%			#	%
Low Risk			8	38%			4	19%			14	67%
Medium Risk			13	62%			6	29%			0	0%
High Risk			0	0%			11	52%			7	33%

CFAS

SURREY

Results - River Realignment

CFAS Option:	Baseline				River Realignment							
Time Horizon:	Current Coastal Flood Risk (~2010)				Future Coastal Flood Risk (2100)				Future Coastal Flood Risk (2100)			
Infrastructure Adaptation Response:	No Adaptation by Infrastructure				No Adaptation by Infrastructure				With Infrastructure Adaptation			
Infrastructure Components	P	C	R		P	C	R	Outcome	P	C	R	Outcome
King George Boulevard	4	3	12		1	5	5	Protected	1	5	5	Protected
Highway 99	4	4	16		1	5	5	Protected	1	5	5	Protected
152 Street	4	1	4		1	4	4	Protected	1	4	4	Protected
Highway 91	4	2	8		1	4	4	Protected	1	4	4	Protected
Ladner Trunk Road	4	3	12		5	4	20	Loss	1	4	4	Protected
BNSF Embankment	4	4	16		5	5	25	Loss	1	5	5	Protected
BNSF Swing Bridge and Trestles	4	4	16		5	4	20	Loss	1	4	4	Protected
BCRC Embankment	4	2	8		5	3	15	Partial Loss	1	3	3	Protected
Sanitary Lift Stations	4	4	16		3	4	12	Partial Loss	1	4	4	Protected
Metro Vancouver Sanitary Main	4	4	16		5	3	15	Loss	1	3	3	Protected
Metro Vancouver Water Main	4	4	16		1	4	4	Protected	1	4	4	Protected
FortisBC Gas Mains	4	2	8		3	2	6	Partial Loss	1	2	2	Protected
BC Hydro Transmission Lines	4	3	12		1	3	3	Protected	1	3	3	Protected
Drainage Pump Stations, Ditches, Floodboxes	4	4	16		3	2	6	Modified	1	2	2	Protected
King George Airpark	4	1	4		1	1	1	Protected	1	1	1	Protected
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	4	1	4		3	1	3	Partial Loss	1	1	1	Protected
Local roads	4	2	8		3	3	9	Partial Loss	1	3	3	Protected
Local Power Distribution, Telecom	4	4	16		3	4	12	Partial Loss	1	4	4	Protected
Serpentine Fen and Water Control Features	4	3	12		5	5	25	Abandoned	1	1	1	Protected
Marinas, Private Docks	4	2	8		5	3	15	Loss	1	3	3	Protected
Dairy Farm	4	4	16		5	5	25	Loss	5	5	25	Abandoned
Risk Distribution			#	%			#	%			#	%
Low Risk			8	38%			11	52%			20	95%
Medium Risk			13	62%			5	24%			0	0%
High Risk			0	0%			5	24%			1	5%

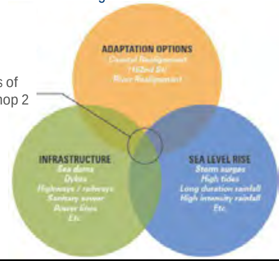
CFAS

SURREY

Purpose of Triple Bottom Line Analysis

Helps to establish, in broad terms, environmental, social and economic factors to aid decision-makers in selecting appropriate adaptation actions and strategies.

Focus of Workshop 2



CFAS

SURREY

BC Water and Waste Association Annual Conference, Accepted Abstract for Presentation by Matt Osler (City of Surrey) and Jason Kindrachuk (Associated Engineering)

May 15, 2018

Associated Engineering

BCWWA Annual Conference 2018 Abstract Submission

Matt Osler (City of Surrey)
Jason Kindrachuk (Associated Engineering)

Presentation Title	Risk Based Collaborative Infrastructure Planning using PIEVC in City of Surrey
Abstract	In response to increasing infrastructure vulnerability in a changing climate, City of Surrey commissioned a series of workshops to engage infrastructure owners, operators and emergency responders from over 30 organizations to develop a shared understanding of risk. Applying the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) process as a framework, Associated Engineering planned and facilitated two workshops to provide input into a larger, participatory planning process to develop a broad, Coastal Flood Adaptation Strategy (CFAS) led by Northwest Hydraulic Consultants. The first PIEVC workshop identified that 53% of the transportation, utilities, flood control and marine infrastructure assets currently assessed to be low/medium risk under the assessed coastal flood scenario become high risk by year 2100 with 1 metre of sea level rise. Initial results of the workshop helped secure funding through the Federation of Canadian Municipalities, Municipalities for Climate Innovation Program, to deliver a follow up study tour and a second workshop. The study area tour and second workshop explored illustrative adaptation scenarios being considered as part of the broader CFAS project, to review how each option affects the infrastructure in the area. Using the triple bottom line module of the PIEVC tool, common decision-making drivers across infrastructure sectors were identified. The project provided an effective means of engaging infrastructure owners, and has informed the broader CFAS study in establishing what types of climate change adaptation options are acceptable, and how these can be effectively implemented.
Key Point 1	Develop an understanding for how risk based decision making helps resolve complex inter-jurisdictional problems.
Key Point 2	Use of collaborative processes to prepare for adverse events through facilitated group exercises
Key Point 3	Preparing infrastructure for climate change through workshops and systematic risk analysis using Engineers Canada PIEVC Protocol for linear and non-linear infrastructure.

Jason Kindrachuk

From: Osler, Matt <MFOsler@surrey.ca>
Sent: Friday, March 23, 2018 1:52 PM
To: Jason Kindrachuk
Subject: FW: 2018 BCWWA Annual Conference Abstract Confirmation

Just in case I forgot to send this to you.

I rsvped for both of us.

Matt

From: Emma Kenny [mailto:Ekenny@bcwwa.org]
Sent: March 2, 2018 1:42 PM
To: Osler, Matt
Subject: 2018 BCWWA Annual Conference Abstract Confirmation

Good afternoon Matthew Osler,

Our volunteer technical experts have reviewed the 2018 BCWWA Annual Conference abstracts and have confirmed this year's program.

We are pleased to announce your presentation, "Risk Based Collaborative Infrastructure Planning using PIEVC in City of Surrey", has been selected as part of the Annual Conference education program! Your presentation is currently scheduled on Tuesday, May 15, 2:45 - 3:15, please check the BCWWA 2018 Education Session Schedule prior to confirming.

Next steps. Click this link to provide the following information via Web Form: 2018 Annual Conference Speaker Confirmation

1. Review the attached education schedule and confirm you can present at your scheduled time. If you have more than one abstract confirmed, please complete a form for each abstract. (Please note, the schedule is subject to change and your time slot may be altered. We will inform you of any changes.)
2. Indicate if you will be co-presenting with another person (max of two presenters per session).
3. Please respond no later than noon on Thursday March 8th

A presenter information package will be emailed to you by the end of March. The package will include details on the format for your presentation, room set-up, how to register for the conference and cost, etc.

We are looking forward to an informative educational program this year and appreciate your participation in being a part of its success.

Thank you,

Emma Kenny
Events Assistant

BC Water & Waste Association

REPORT

Volume 5 - Workbooks

Associated Engineering

GLOBAL PERSPECTIVE.
LOCAL FOCUS.

CFAS

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Infrastructure Asset Managers, Operators and Emergency Services Stakeholders

PIEVC Workshop

Exercise Workbook

CITY OF SURREY
the future lives here.

Name:

Organization:

Are you interested in being a part of the Assessment Team?

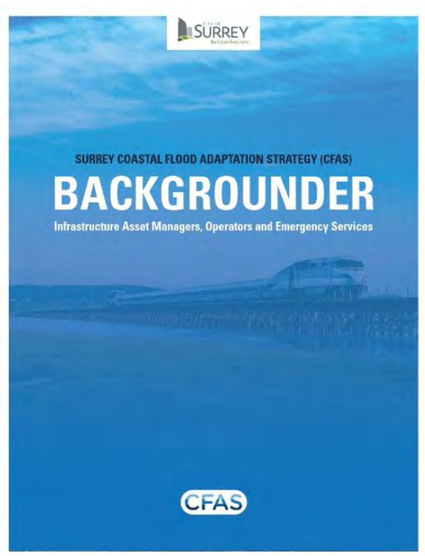
Yes No

Reference and Resources for Exercises

5	CONSEQUENCE	Catastrophic	0	5	10	15	20	25
4		Major	0	4	8	12	16	20
3		Moderate	0	3	6	9	12	15
2		Minor	0	2	4	6	8	10
1		Insignificant	0	1	2	3	4	5
0		No Effect	0	0	0	0	0	0
			Negligible Not Applicable	Highly Unlikely Improbable	Remotely Possible	Possible Occasional	Somewhat Likely Normal	Likely Frequent
			PROBABILITY					
			0	1	2	3	4	5

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic



Group Exercise 1

Instructions - For Flood Scenario A - Costal Flood with Dyke Breach, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

	Infrastructure Components	Flood Impacts
1	**TRANSPORTATION**	
2	**Runway**	
3	Surrey/King George Airpark Turf Runway	
4		
5	**Regional / International Transportation Infrastructure**	
6	4 km of four-lane arterial roadway	
7	7 km section of Highway 99 linking Peace Arch Border	
8	Highway 91 and 99 Interchange	
9	4 km section of Highway 91	
10	6 km dyke trail connecting to parks	
11	Delta-Surrey Greenway	
12		
13	**Local Government Arterial and Collector Roads**	
14	King George Boulevard (City of Surrey)	
15	152nd Street (City of Surrey)	
16	Colebrook Road (City of Surrey)	
17	Ladner Trunk Road (Corporation of Delta)	
18		
19	**Class 1 Railways Originating at Port Metro Vancouver**	
20	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	
21	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	
22	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	
23	Connection to Southern Railway of British Columbia	
24		
25		

Group Exercise 1

Instructions - For Flood Scenario A - Costal Flood with Dyke Breach, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

	Infrastructure Components	Flood Impacts
1	**UTILITIES**	
2	**Sanitary Lift Stations**	
3	City of Surrey: Elgin	
4	City of Surrey: South Port	
5	City of Surrey: Winter Crescent	
6	City of Surrey: Stewart Farm	
7	Metro Vancouver: Crescent Beach	
8		
9	**Underground infrastructure**	
10	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	
11	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	
12	>10 km of FortisBC Gas Mains	
13		
14	**Overhead Utility Infrastructure**	
15	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	
16	BC Hydro local overhead distribution lines	
17	Shaw and Telus telecom lines	
18		
19		
20		
21		
22		
23		
24		
25		

Group Exercise 1

Instructions - For Flood Scenario A - Costal Flood with Dyke Breach, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

	Infrastructure Components	Flood Impacts
1	**Flood / Marine**	
2	**Flood Control Infrastructure**	
3	City of Surrey Sea Dams (2)	
4	15 km of dyking, including ditches and floodboxes	
5	City of Surrey: Colebrook Pump Station	
6	City of Surrey: Maple Pump Station	
7	Corporation of Delta: Oliver Pump Station	
8	Ducks Unlimited Canada Serpentine Fen Nature Reserve	
9	Water control features to maintain environmentally sensitive area including freshwater irrigation system	
10		
11	**Marine Facilities**	
12	Crescent Beach Marina	
13	Wards Marina	
14	Private docks	
15		
16	**Farms**	
17	Private dairy facilities for over 1,000 head of Cattle	
18		
19		
20		
21		
22		
23		
24		
25		

Notes:

Group Exercise 2

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	**TRANSPORTATION**																		
2	**Runway**																		
3	Surrey/King George Airpark Turf Runway											4				5			
4																			
5	**Regional / International Transportation Infrastructure**																		
6	4 km of four-lane arterial roadway											4				5			
7	7 km section of Highway 99 linking Peace Arch Border											4				5			
8	Highway 91 and 99 Interchange											4				5			
9	4 km section of Highway 91											4				5			
10	6 km dyke trail connecting to parks											4				5			
11	Delta-Surrey Greenway											4				5			
12																			
13	**Local Government Arterial and Collector Roads**																		
14	King George Boulevard (City of Surrey)											4				5			
15	152nd Street (City of Surrey)											4				5			
16	Colebrook Road (City of Surrey)											4				5			
17	Ladner Trunk Road (Corporation of Delta)											4				5			
18																			
19	**Class 1 Railways Originating at Port Metro Vancouver**																		
20	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles											4				5			
21	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)											4				5			
22	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.											4				5			
23	Connection to Southern Railway of British Columbia											4				5			
24																			
25																			

Group Exercise 2

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	**UTILITIES**																		
2	**Sanitary Lift Stations**																		
3	City of Surrey: Elgin											4				5			
4	City of Surrey: South Port											4				5			
5	City of Surrey: Winter Crescent											4				5			
6	City of Surrey: Stewart Farm											4				5			
7	Metro Vancouver: Crescent Beach											4				5			
8																			
9	**Underground infrastructure**																		
10	5 km of Metro Vancouver 750 mm diameter Water Transmission Main											4				5			
11	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)											4				5			
12	>10 km of FortisBC Gas Mains											4				5			
13																			
14	**Overhead Utility Infrastructure**																		
15	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power											4				5			
16	BC Hydro local overhead distribution lines											4				5			
17	Shaw and Telus telecom lines											4				5			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

Group Exercise 2

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

CFAS

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	**Flood / Marine**																		
2	**Flood Control Infrastructure**																		
3	City of Surrey Sea Dams (2)											4				5			
4	15 km of dyking, including ditches and floodboxes											4				5			
5	City of Surrey: Colebrook Pump Station											4				5			
6	City of Surrey: Maple Pump Station											4				5			
7	Corporation of Delta: Oliver Pump Station											4				5			
8	Ducks Unlimited Canada Serpentine Fen Nature Reserve											4				5			
9	Water control features to maintain environmentally sensitive area including freshwater irrigation system											4				5			
10																			
11	**Marine Facilities**																		
12	Crescent Beach Marina											4				5			
13	Wards Marina											4				5			
14	Private docks											4				5			
15																			
16	**Farms**																		
17	Private dairy facilities for over 1,000 head of Cattle											4				5			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

Notes:

Group Exercise 3

Instructions - For Flood Scenario B - Riverine Flood, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

	Infrastructure Components	Flood Impacts
1	**TRANSPORTATION**	
2	**Runway**	
3	Surrey/King George Airpark Turf Runway	
4		
5	**Regional / International Transportation Infrastructure**	
6	4 km of four-lane arterial roadway	
7	7 km section of Highway 99 linking Peace Arch Border	
8	Highway 91 and 99 Interchange	
9	4 km section of Highway 91	
10	6 km dyke trail connecting to parks	
11	Delta-Surrey Greenway	
12		
13	**Local Government Arterial and Collector Roads**	
14	King George Boulevard (City of Surrey)	
15	152nd Street (City of Surrey)	
16	Colebrook Road (City of Surrey)	
17	Ladner Trunk Road (Corporation of Delta)	
18		
19	**Class 1 Railways Originating at Port Metro Vancouver**	
20	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	
21	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	
22	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	
23	Connection to Southern Railway of British Columbia	
24		
25		

Group Exercise 3

Instructions - For Flood Scenario B - Riverine Flood, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

CFAS

	Infrastructure Components	Flood Impacts
1	**UTILITIES**	
2	**Sanitary Lift Stations**	
3	City of Surrey: Elgin	
4	City of Surrey: South Port	
5	City of Surrey: Winter Crescent	
6	City of Surrey: Stewart Farm	
7	Metro Vancouver: Crescent Beach	
8		
9	**Underground infrastructure**	
10	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	
11	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	
12	>10 km of FortisBC Gas Mains	
13		
14	**Overhead Utility Infrastructure**	
15	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	
16	BC Hydro local overhead distribution lines	
17	Shaw and Telus telecom lines	
18		
19		
20		
21		
22		
23		
24		
25		

Group Exercise 3

Instructions - For Flood Scenario B - Riverine Flood, please discuss and record impacts of flooding on the Infrastructure Component or delivery of service in the area.

	Infrastructure Components	Flood Impacts
1	**Flood / Marine**	
2	**Flood Control Infrastructure**	
3	City of Surrey Sea Dams (2)	
4	15 km of dyking, including ditches and floodboxes	
5	City of Surrey: Colebrook Pump Station	
6	City of Surrey: Maple Pump Station	
7	Corporation of Delta: Oliver Pump Station	
8	Ducks Unlimited Canada Serpentine Fen Nature Reserve	
9	Water control features to maintain environmentally sensitive area including freshwater irrigation system	
10		
11	**Marine Facilities**	
12	Crescent Beach Marina	
13	Wards Marina	
14	Private docks	
15		
16	**Farms**	
17	Private dairy facilities for over 1,000 head of Cattle	
18		
19		
20		
21		
22		
23		
24		
25		

Notes:

CFAS

Group Exercise 4

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

CFAS

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	**TRANSPORTATION**																		
2	**Runway**																		
3	Surrey/King George Airpark Turf Runway											3				5			
4																			
5	**Regional / International Transportation Infrastructure**																		
6	4 km of four-lane arterial roadway											3				5			
7	7 km section of Highway 99 linking Peace Arch Border											3				5			
8	Highway 91 and 99 Interchange											3				5			
9	4 km section of Highway 91											3				5			
10	6 km dyke trail connecting to parks											3				5			
11	Delta-Surrey Greenway											3				5			
12																			
13	**Local Government Arterial and Collector Roads**																		
14	King George Boulevard (City of Surrey)											3				5			
15	152nd Street (City of Surrey)											3				5			
16	Colebrook Road (City of Surrey)											3				5			
17	Ladner Trunk Road (Corporation of Delta)											3				5			
18																			
19	**Class 1 Railways Originating at Port Metro Vancouver**																		
20	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles											3				5			
21	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)											3				5			
22	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.											3				5			
23	Connection to Southern Railway of British Columbia											3				5			
24																			
25																			

Group Exercise 4

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

CFAS

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	UTILITIES																		
2	**Sanitary Lift Stations**																		
3	City of Surrey: Elgin											3				5			
4	City of Surrey: South Port											3				5			
5	City of Surrey: Winter Crescent											3				5			
6	City of Surrey: Stewart Farm											3				5			
7	Metro Vancouver: Crescent Beach											3				5			
8																			
9	**Underground infrastructure**																		
10	5 km of Metro Vancouver 750 mm diameter Water Transmission Main											3				5			
11	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)											3				5			
12	>10 km of FortisBC Gas Mains											3				5			
13																			
14	**Overhead Utility Infrastructure**																		
15	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power											3				5			
16	BC Hydro local overhead distribution lines											3				5			
17	Shaw and Telus telecom lines											3				5			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

Group Exercise 4

Instructions - For each Infrastructure Component: **Step 1** - Check relevant response(s), **Step 2** - Indicate a Yes 'Y' or No 'N' if the Infrastructure Component is affected, **Step 3** - Where there is a 'Y' indicate the Consequence Value (0-5) of the impact, **Step 4** - Calculate the Risk Score (R=PxC) **Step 5** - Record the Rational for the Consequence Value.

	Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
		Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
1	**Flood / Marine**																		
2	**Flood Control Infrastructure**																		
3	City of Surrey Sea Dams (2)											3				5			
4	15 km of dyking, including ditches and floodboxes											3				5			
5	City of Surrey: Colebrook Pump Station											3				5			
6	City of Surrey: Maple Pump Station											3				5			
7	Corporation of Delta: Oliver Pump Station											3				5			
8	Ducks Unlimited Canada Serpentine Fen Nature Reserve											3				5			
9	Water control features to maintain environmentally sensitive area including freshwater irrigation system											3				5			
10																			
11	**Marine Facilities**																		
12	Crescent Beach Marina											3				5			
13	Wards Marina											3				5			
14	Private docks											3				5			
15																			
16	**Farms**																		
17	Private dairy facilities for over 1,000 head of Cattle											3				5			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

Notes:

Group Exercise 5

Instructions - For each Flood Scenario, please discuss and record adaptation options or strategies.

	Infrastructure Components	Adaptation Options Scenario A - Current	Adaptation Options Scenario A - Future	Adaptation Options Scenario B - Current	Adaptation Options Scenario B - Future
1	**TRANSPORTATION**				
2	**Runway**				
3	Surrey/King George Airpark Turf Runway				
4					
5	**Regional / International Transportation Infrastructure**				
6	4 km of four-lane arterial roadway				
7	7 km section of Highway 99 linking Peace Arch Border				
8	Highway 91 and 99 Interchange				
9	4 km section of Highway 91				
10	6 km dyke trail connecting to parks				
11	Delta-Surrey Greenway				
12					
13	**Local Government Arterial and Collector Roads**				
14	King George Boulevard (City of Surrey)				
15	152nd Street (City of Surrey)				
16	Colebrook Road (City of Surrey)				
17	Ladner Trunk Road (Corporation of Delta)				
18					
19	**Class 1 Railways Originating at Port Metro Vancouver**				
20	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles				
21	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)				
22	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.				
23	Connection to Southern Railway of British Columbia				
24					
25					

Group Exercise 5

Instructions - For each Flood Scenario, please discuss and record adaptation options or strategies.

CFAS

	Infrastructure Components	Adaptation Options Scenario A - Current	Adaptation Options Scenario A - Future	Adaptation Options Scenario B - Current	Adaptation Options Scenario B - Future
1	UTILITIES				
2	**Sanitary Lift Stations**				
3	City of Surrey: Elgin				
4	City of Surrey: South Port				
5	City of Surrey: Winter Crescent				
6	City of Surrey: Stewart Farm				
7	Metro Vancouver: Crescent Beach				
8					
9	**Underground infrastructure**				
10	5 km of Metro Vancouver 750 mm diameter Water Transmission Main				
11	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)				
12	>10 km of FortisBC Gas Mains				
13					
14	**Overhead Utility Infrastructure**				
15	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power				
16	BC Hydro local overhead distribution lines				
17	Shaw and Telus telecom lines				
18					
19					
20					
21					
22					
23					
24					
25					

Group Exercise 5

Instructions - For each Flood Scenario, please discuss and record adaptation options or strategies.

	Infrastructure Components	Adaptation Options Scenario A - Current	Adaptation Options Scenario A - Future	Adaptation Options Scenario B - Current	Adaptation Options Scenario B - Future
1	**Flood / Marine**				
2	**Flood Control Infrastructure**				
3	City of Surrey Sea Dams (2)				
4	15 km of dyking, including ditches and floodboxes				
5	City of Surrey: Colebrook Pump Station				
6	City of Surrey: Maple Pump Station				
7	Corporation of Delta: Oliver Pump Station				
8	Ducks Unlimited Canada Serpentine Fen Nature Reserve				
9	Water control features to maintain environmentally sensitive area including freshwater irrigation system				
10					
11	**Marine Facilities**				
12	Crescent Beach Marina				
13	Wards Marina				
14	Private docks				
15					
16	**Farms**				
17	Private dairy facilities for over 1,000 head of Cattle				
18					
19					
20					
21					
22					
23					
24					
25					

Notes:

CFAS

CFAS

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Improving Coastal Flood Adaptation Approaches (ICFAA)

Infrastructure Owners, Managers and Emergency Responders

Exercise Workbook

CITY OF SURREY
the future lives here.

Name:

Organization:

Are you interested in being a part of the Assessment Team?

Yes No

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
Group Exercise 1 - Adaptation Option 1 - Coastal Realignment to 152nd Street																		
Major Roads King George Boulevard Highway 99 152 Street	Merge 152 Street and King George Boulevard, protected by, or located on top of super-dyke. Highway 99 either merged with 152 st. and King George Blvd., or raised (earthen embankment with several equalization culverts, or a supported 'wetland' structure). Issues include land available for interchanges, mixing conflicting traffic classifications. Regional context needed to consider Highway 91; Ladner Trunk Road; future traffic needs																	
Major Roads Roads within Corporation of Delta Highway 91 Highway 99 Ladner Trunk Road	Raise, or reroute; coordinate regional planning needs.																	
Railway Infrastructure BNSF embankment Trestles Swing Bridge BCRC Embankment	Continuous trestle over flooded area, raised embankment with several equalization culverts, or regional relocation east of 152 Street																	
Sanitary Lift Stations	Raise and protect; dependent on reconfiguration of sanitary mains.																	

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
Metro Vancouver Sanitary Main	Accommodate: Reduce leakage potential recognizing constant inundation; access chambers elevated above flood level with provisions for boat access; redesign as submarine crossings, but challenging given seismic event / shifting soils. Retreat: Relocation allows consideration of seismic needs in design; could utilize shared utility ROW corridor in collaboration with other utilities.																	
Metro Vancouver Water Main	Accommodate: Design as a marine crossing, access chambers and valves with surfaces above flood elevation; corrosion sensitive Retreat: WM constructed in 1977, end of life approaching; relocation allows consideration of seismic needs; could utilize shared utility ROW corridor in collaboration with other utilities.																	
FortisBC Gas Mains	Response dependent on residence and businesses remaining or retreating from the area.																	
BC Hydro Transmission Lines	Allow inundation along the base of the towers; provide adequate protection from destabilization due to scour / corrosion. Build up bases into islands and harden against salt water. Explore shared utility ROW / corridor with other relocated utilities. Confirm clearance to wires remains within allowable limits, or restring / raise towers. Regular maintenance is typically from air.																	

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
Drainage Pump Stations, Ditches, Floodboxes	Ditches, pump stations, and floodboxes west of 152 Street abandoned or drastically reconfigured																	
King George Airpark	Abandoned																	
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	Abandoned																	
Local roads	Abandoned																	
Local Power Distribution, Telecom	Abandoned																	
Serpentine Fen and Water Control Features	Abandoned (area returned to salt marsh)																	
Marinas, Private Docks	Modified or abandoned																	
Dairy Farm	Abandoned																	

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
Group Exercise 2 - Adaptation Option 2 - River Realignment																		
Major Roads King George Boulevard Highway 99 152 Street	Highway 99 raised or protected by super-dyke; King George Boulevard likely remains on current alignment, tying into Highway 99 (new interchange required); 152 Street to remain as-is. Requires consideration of bridge over Nikomekl River, and Highway 99 and King Geroge Blvd. interchange.																	
Major Roads Roads within Corporation of Delta Highway 91 Highway 99 Ladner Trunk Road	Either protected by coastal super-dyke through regional coordination, or exposed with need to relocate.																	
Railway Infrastructure BNSF embankment Trestles Swing Bridge BCRC Embankment	Continuous trestle over flooded area, raised embankment with several equalization culverts, or regional relocation. Needs to consider crossing of rail and Highway 99.																	
Sanitary Lift Stations	Raise and protect; dependent on reconfiguration of sanitary mains.																	

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
Metro Vancouver Sanitary Main	Mostly exposed Accommodate: Reduce leakage potential recognizing constant inundation; access chambers elevated above flood level with provisions for boat access; redesign as submarine crossings, but challenging given seismic event / shifting soils. Retreat: Relocation allows consideration of seismic needs in design; could utilize shared utility ROW corridor in collaboration with other utilities.																	
Metro Vancouver Water Main	End of life approaching, goes through sea dam at Nicomekl; Needs coordination with Highway 99, super-dyke, and river design. Alternate alignment is likely most favourable; allows seismic design; consider shared utility ROW corridor.																	
FortisBC Gas Mains	Response dependent on residence and businesses remaining or retreating from the area. Reconfiguration of the system likely needed.																	
BC Hydro Transmission Lines	Only one tower remains exposed; extra long line over Nicomekl River.																	
Drainage Pump Stations, Ditches, Floodboxes	Reconfiguration of drainage system to support agriculture. Drainage pump stations, floodboxes redesigned with drainage system; potential for leaving Serpentine River channel in place (irrigation storage, reverse flow direction for drainage channel, etc.).																	

Infrastructure Components	Adaptation Details and Considerations	TBL Factors (High / Medium / Low)																Comments
		Environmental				Social						Economic						
		Regulatory Compliance	Biodiversity / Habitat	Mitigation and Adaptation		Public Perception	Community Involvement	Acceptable Level of Service and Risk	Emergency Response	Agricultural Impacts		Capital Cost	Cost-sharing and collaboration	Resilience and Maintainability	Disruption of Commerce	Risk Tolerance / Asset Lifecycle		
King George Airpark	Protected																	
Recreational Trails (Mud Bay Dyke, Delta-Surrey Greenway)	Abandoned / modified																	
Local roads	Most protected; some abandoned																	
Local Power Distribution, Telecom	Adaptable – would abandon / reconfigure as needed to service residents / businesses																	
Serpentine Fen and Water Control Features	Abandoned																	
Marinas, Private Docks	Modified or abandoned																	
Dairy Farm	Abandoned																	

Group Exercise 3 - Evaluation and Next Steps

REPORT

Volume 6 – Surrey Flood Management System Video Script

Associated Engineering

GLOBAL PERSPECTIVE.
LOCAL FOCUS.

Surrey Flood Management System Video

To support technical engagement with infrastructure stakeholders, a short video on coastal flood management was prepared by EcoPlan International with video clips provided by City of Surrey.

The final video available for viewing at: https://youtu.be/bn4RQQaEfV8

Table below shows the final script and storyboard

Narration	Images
Surrey's Coastal Floodplain is home to vibrant residential areas, agricultural land, and world class environmental habitat and recreational sites.	• Montage of uses/ users
As a natural floodplain, it is also prone to regular flooding from high tides, storm surges, and precipitation driven flooding from the Nicomekl and Serpentine Rivers.	• Montage of flood footage
Efforts to better control and manage flooding date back over 100 years, when the first river and ocean dykes were constructed by farmers keen to farm the floodplain's rich soil. Today, the City of Surrey manages the largest flood control system in the province.	• Montage of historic and current construction images/ footage • Current construction footage
Making up approximately 20% of Surrey's land base, the Coastal Floodplain is a large, low-lying area that stretches from Boundary Bay and Mud Bay towards Cloverdale and Newton along the Nicomekl and Serpentine Rivers.	• Google Map of area, with Coastal Floodplain boundary highlighted; animated to appear extending from west to east • Labels animated as mentioned (Boundary Bay, rivers, etc.)
Lying almost entirely below high-tide, the area is protected by an extensive and integrated flood management system comprised of dykes, sea dams, spillways, flood boxes, and pumps. This system enables the movement of salmon and trout to reach critical spawning habitat in Surrey.	• Animation over map of "system" (from last video) • Photos bubbles or graphics "pop-up" as components are mentioned • 3 second underwater fish clip from the Campbell River
All of Surrey's coastal floodplain is protected by dykes, the first line of flood protection.	• All but these bubbles/graphic fade
Built along the coast and river banks, dykes are long walls or embankments to prevent flooding from the sea, or rivers.	• Zoom in on dyke bubble/graphic • Footage of sea and river dykes
Sea dams are located close to the mouths of the Nicomekl and Serpentine Rivers. The gravity fed gates close as tides rise, preventing salty ocean water from flowing upstream, and open as tides recede, allowing the rivers to flow to the sea.	• Animated graphic of sea dam • Sea dam shot time-lapse
Spillways are lower sections of river dykes that allow high water to spill over into a designated holding area, or cell, until river levels recede.	• Animated graphic • Spillway release footage
Ditches work together with floodboxes, and pumps to move water from behind dykes into the rivers.	• Animated graphics • GIFs and timelapse of system at work
Surface water collects in ditches and is carried to gravity-fed floodboxes, which release the water when river levels are low.	• Animated GIF of floodbox • Timelapse of floodbox releasing water
Pumps provide a similar function to floodboxes. During high tides or flood events, these electrically powered pumps help push the water out to sea or into the rivers as needed.	• Pump GIF • Other images as pumphouse as needed
Today, the City operates and maintains over 100 km of dykes, over 100 km of flood management ditches, 25 pump stations, 14 spillways and 300 floodboxes. Working together, this integrated system protects some of Surrey's most valuable assets.	• Montage of footage of flood protection • Montage of people recreating, living, farming, etc.