

Integrated Flood Hazard Management Plan

# River Flood Hazards & Mitigation Concepts

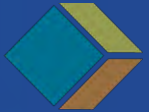
Council Update #7

February 16, 2016



KERR WOOD LEIDAL  
consulting engineers

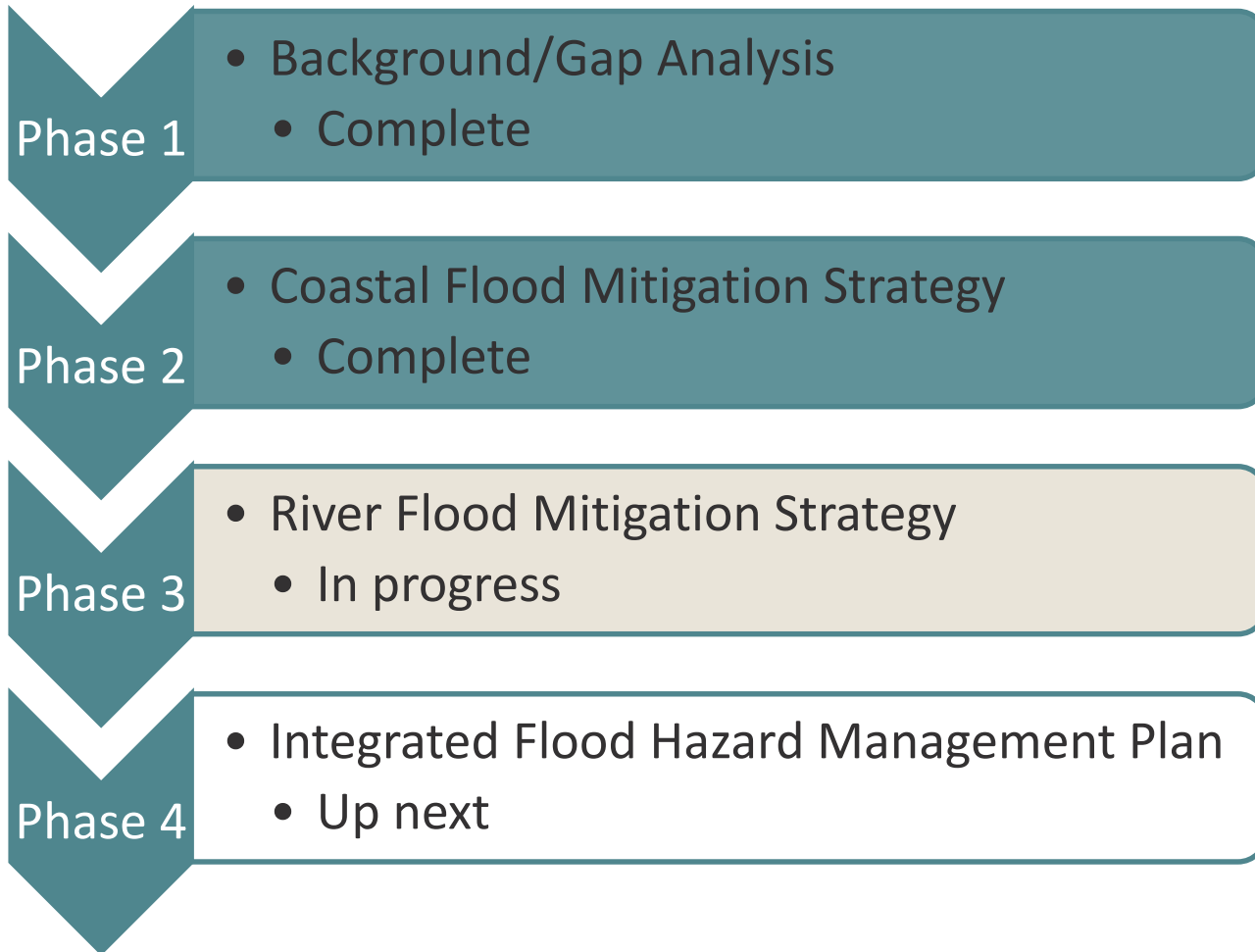
Arlington  
Group  
Planning + Architecture Inc.



# Agenda

- Background
- Guiding Principles
- Risk & Mitigation
- Public Engagement
- Online Survey
- Stawamus Floodplain
- Cheakamus Floodplain
- Squamish/Mamquam Floodplain
- Discussion

# Integrated Flood Hazard Management Plan



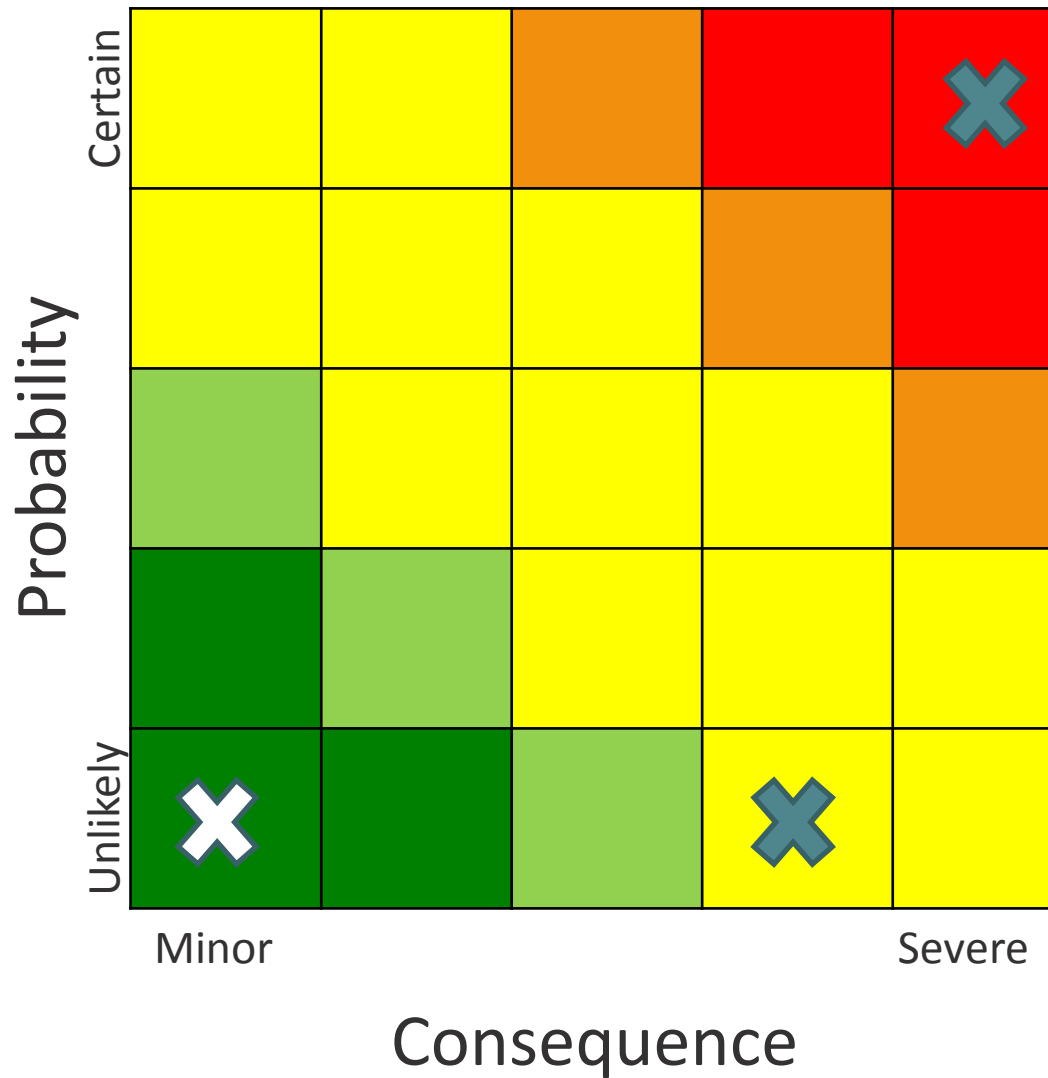


# Guiding Principles

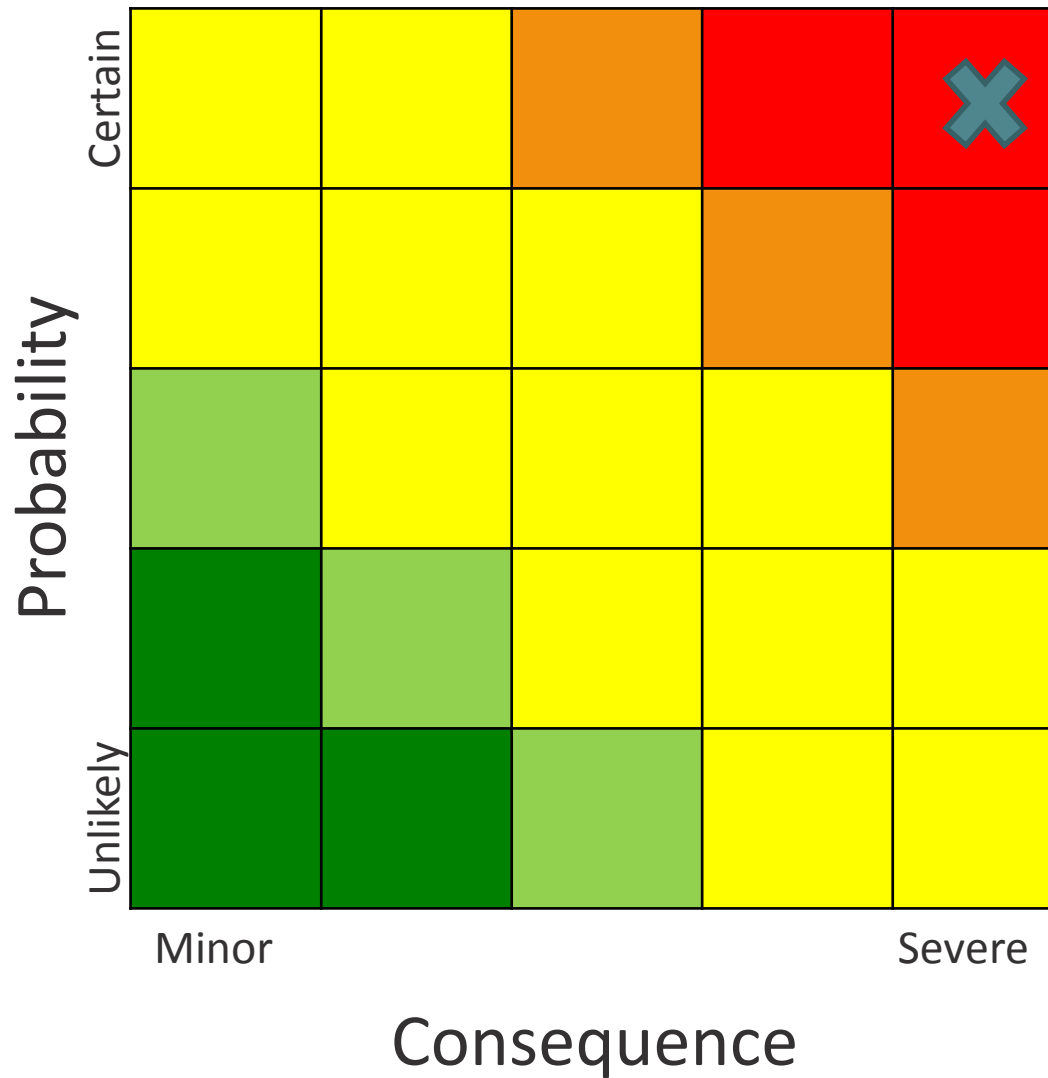
An aerial photograph of a mountain valley. In the foreground, a river flows through a lush green forest. A small town with numerous houses and buildings is situated in the middle ground, nestled between the river and the mountains. The background features majestic, snow-capped mountain peaks under a clear blue sky with scattered white clouds. The overall scene is a beautiful representation of a mountain community.

- Reduce flood risk
- Identify development opportunities
- Make sustainable decisions
- Design achievable solutions

# Risk & Mitigation Strategies

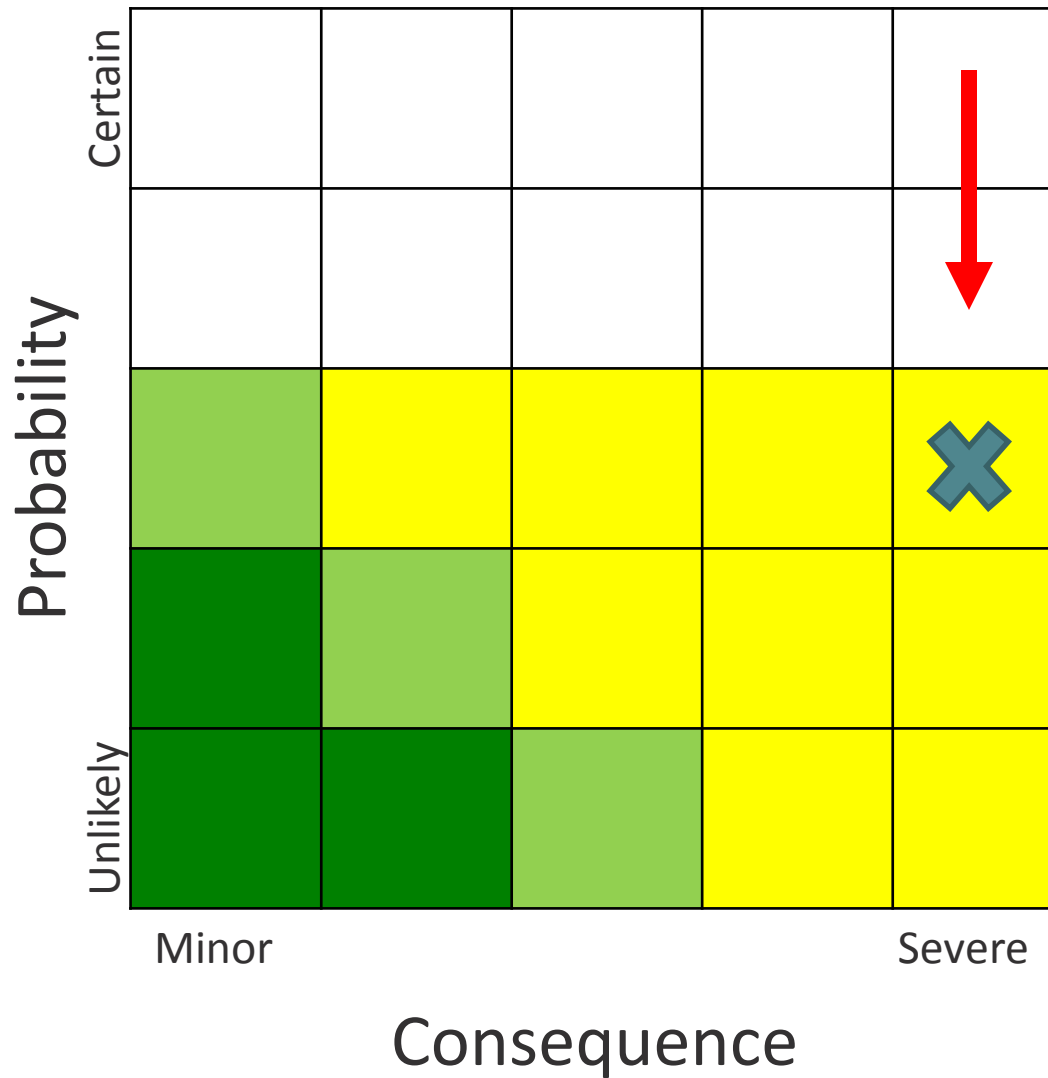


# Risk & Mitigation Strategies



Community in  
floodplain with no  
protection

# Risk & Mitigation Strategies

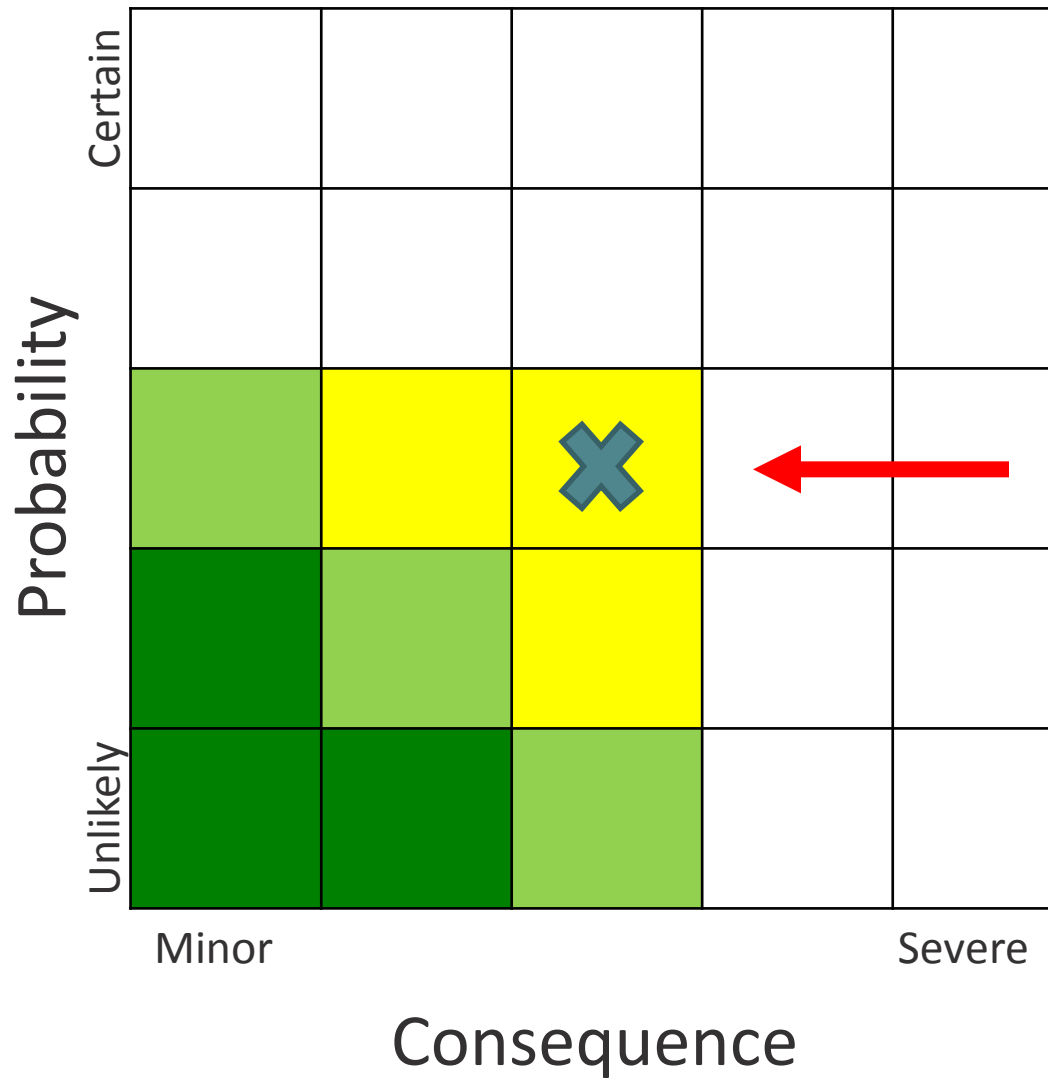


## Protect

- Dikes



# Risk & Mitigation Strategies



## Protect

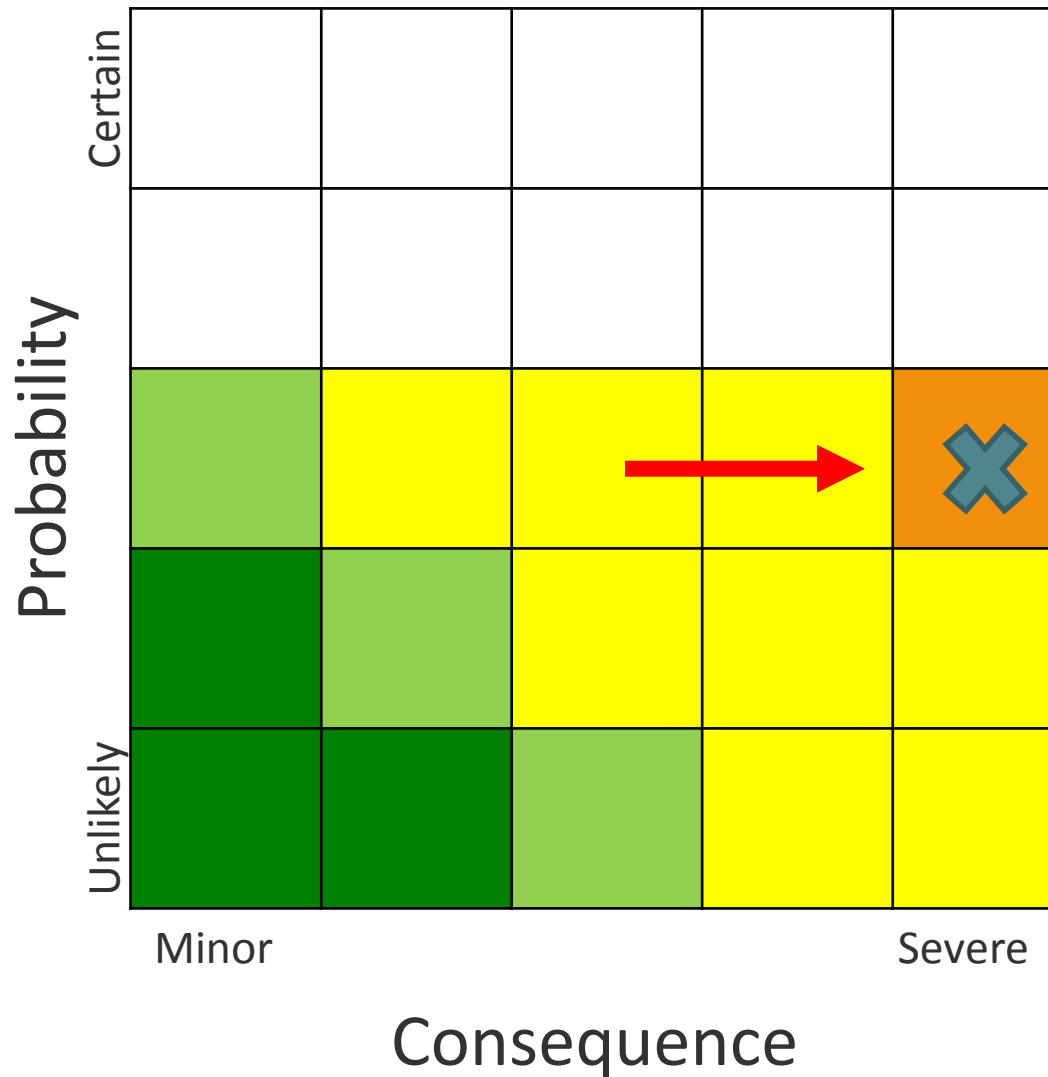
- Dikes

## Accommodate

- FCL



# Risk & Mitigation Strategies



# Protect

- Dikes

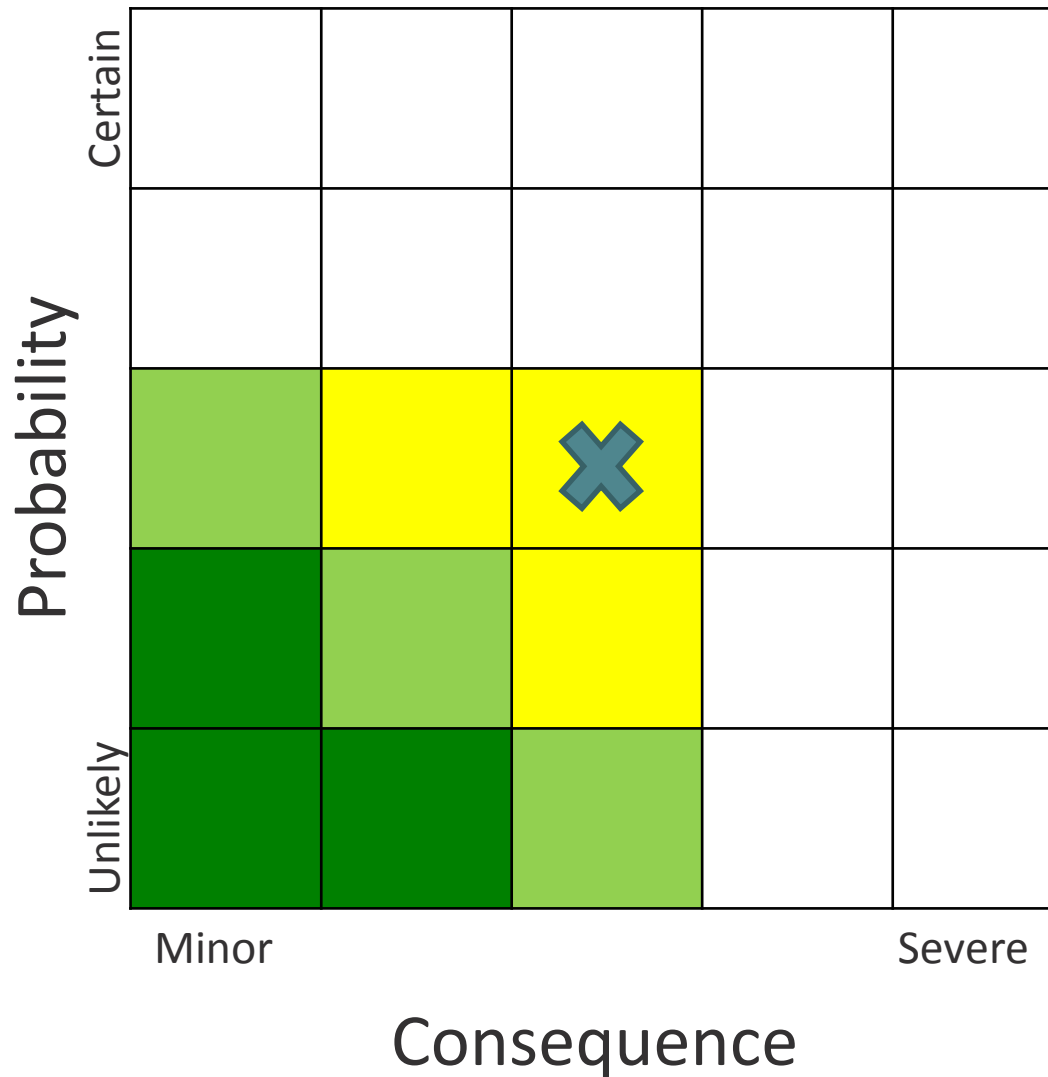
# Accommodate

- FCL

## Future Scenario

- Growth in floodplain

# Risk & Mitigation Strategies



## Protect

- Dikes

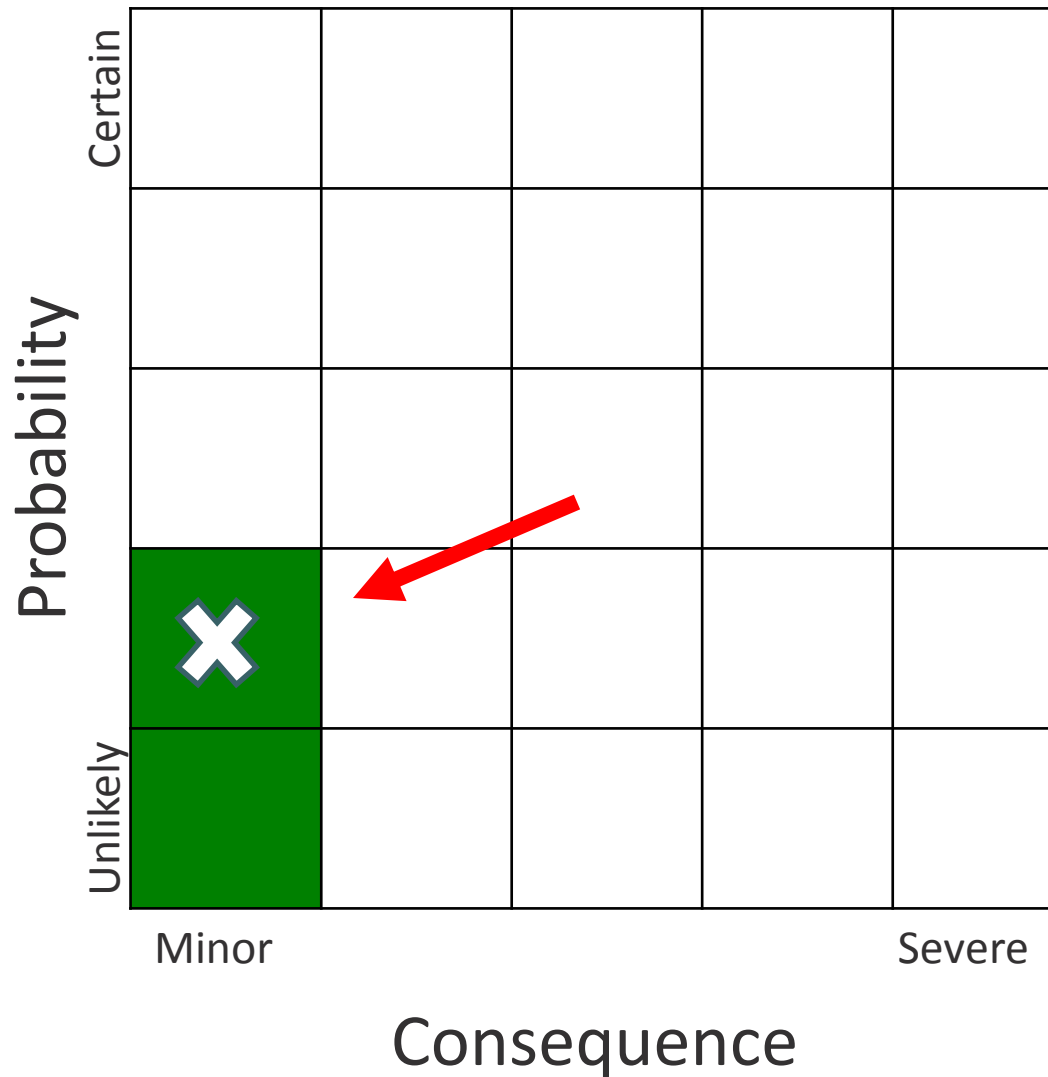
## Accommodate

- FCL

## Avoid

- Growth outside floodplain

# Risk & Mitigation Strategies



## Protect

- Dikes

## Accommodate

- FCL

## Avoid

- Growth outside floodplain

## Retreat

- Withdraw assets

# Risk & Mitigation Strategies

Probability	Certain				
	Unlikely				
		Minor			Severe
Consequence					

## Protect

- Dikes

## Accommodate

- FCL

## Avoid

- Growth outside floodplain

## Retreat

- Withdraw assets

## Accept

- Residual Risk



# Risk Mitigation

	Reduce Probability	Reduce Consequence
Driving		

# Risk Mitigation

	Reduce Probability	Reduce Consequence
Driving	Drive speed limit Stay sober Avoid bad conditions Good tires Anti-lock breaks Traction control	

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	Reduce Probability	Reduce Consequence
Driving	Drive speed limit Stay sober Avoid bad conditions Good tires Anti-lock breaks Traction control	Wear seatbelt Air bags Booster seats Infant Rear Facing Car Seat Crumple zones

# Risk Mitigation

	Reduce Probability	Reduce Consequence
Driving	Drive speed limit Stay sober Avoid bad conditions Good tires Anti-lock breaks Traction control	Wear seatbelt Air bags Booster seats Infant Rear Facing Car Seat Crumple zones
Flooding		



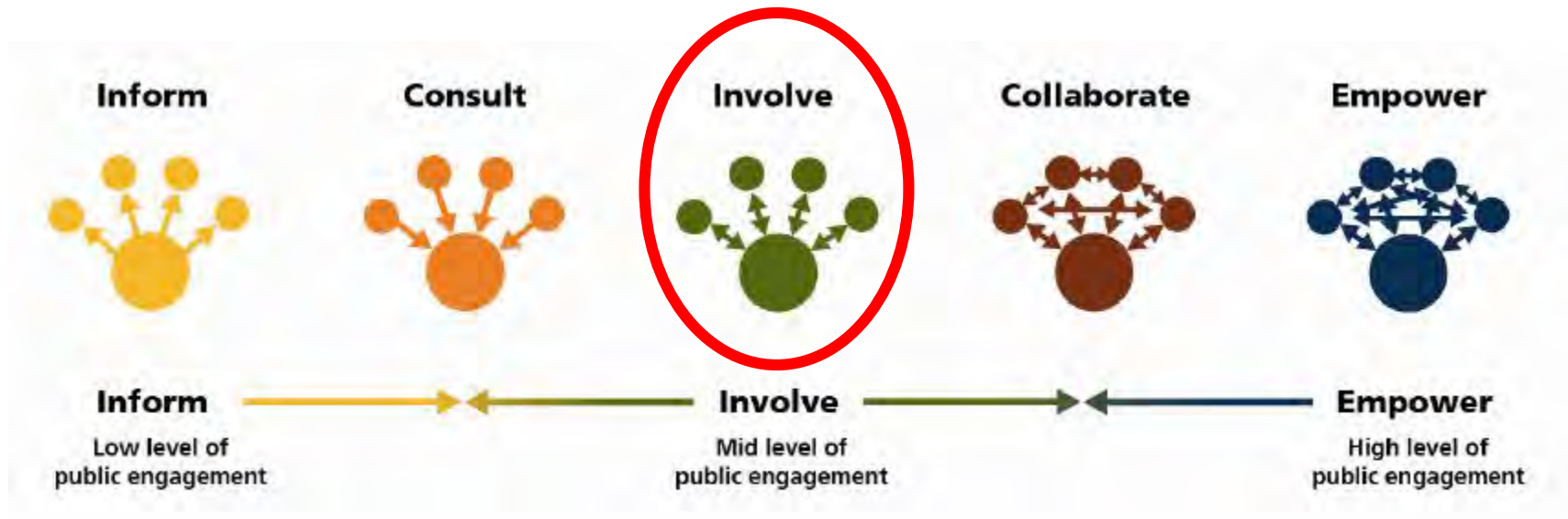
# Risk Mitigation

	Reduce Probability	Reduce Consequence
Driving	Drive speed limit Stay sober Avoid bad conditions Good tires Anti-lock breaks Traction control	Wear seatbelt Air bags Booster seats Infant Rear Facing Car Seat Crumple zones
Flooding	Increase dike height Address dike deficiencies Dike Inspections Seismic assessment Toe Berm Erosion protection	

# Risk Mitigation

	Reduce Probability	Reduce Consequence
Driving	Drive speed limit Stay sober Avoid bad conditions Good tires Anti-lock breaks Traction control	Wear seatbelt Air bags Booster seats Infant Rear Facing Car Seat Crumple zones
Flooding	Increase dike height Address dike deficiencies Dike Inspections Seismic assessment Toe Berm Erosion protection	Avoid development in high risk areas Establish FCLs Direct growth to low risk areas Preserve floodplain conveyance Develop Emergency Response Plan

# Public Engagement



# Public Engagement

Month	Activities
Nov 2015	Workshops <ul style="list-style-type: none"><li>• Squamish Nation</li><li>• Highly Affected Stakeholder</li><li>• Residents/Stakeholders</li></ul> Online Survey
Dec 2015	Project Team Workshop
Feb 2016	Residents/Stakeholders Workshop Technical Working Group Meeting <b>Council Presentation (Today)</b> Public Open House
March 2016	Squamish Nation Presentation Online Survey
April 2016	Council Presentation Technical Working Group Meeting



# Online Survey

- 117 responses
- Support for mitigation strategies:
  - **Protect** (Dikes) 89%
  - **Accommodate** (FCL) 83%
  - **Avoid** (Developing High Risk) 82%
  - **Retreat** (Relocated Development) 33%
- Utilize all practical approaches 90%
- Do not rely on a single approach 92%
- Avoid/discourage intensive development in high risk areas 82%

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- Cheakamus Floodplain
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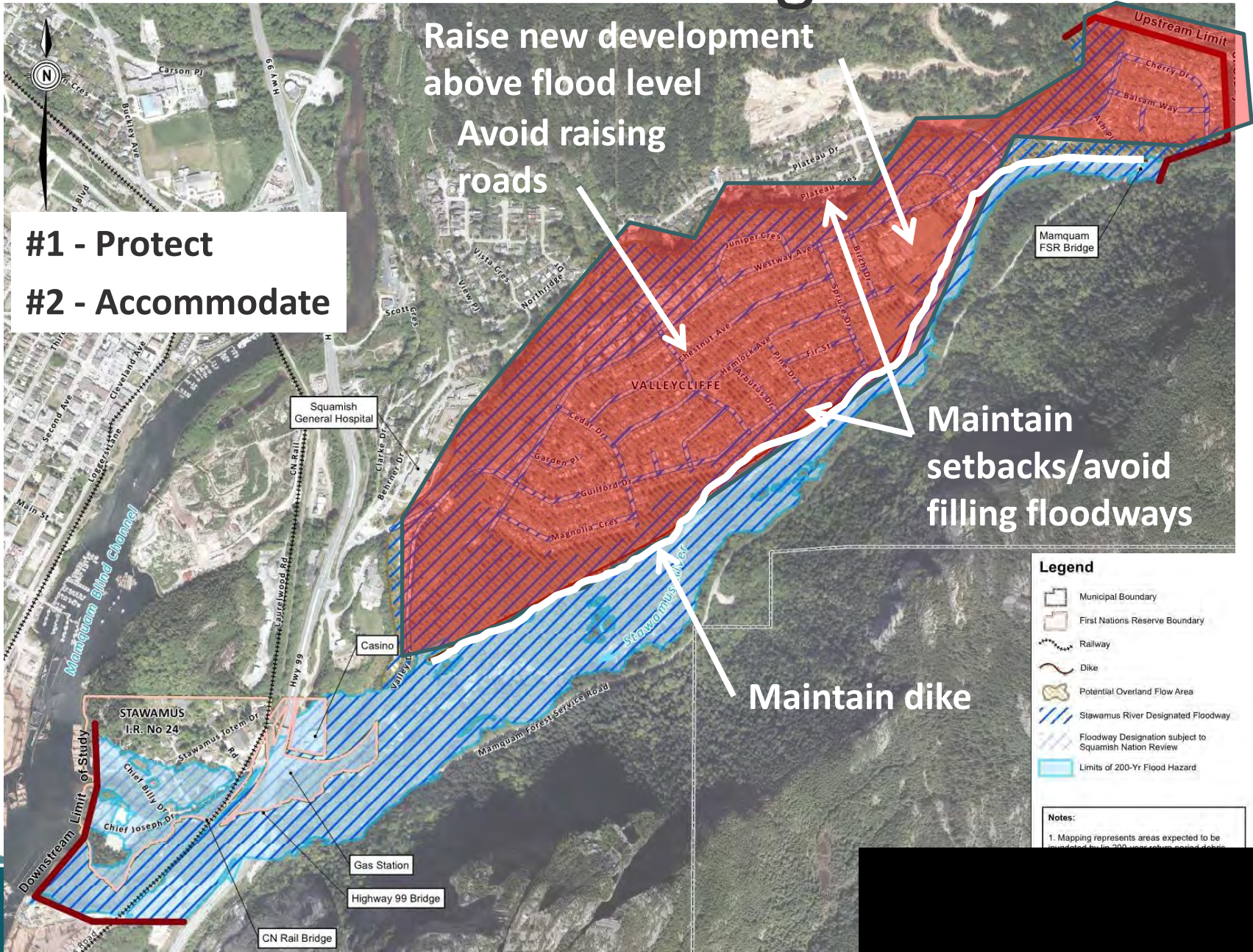


This aerial map illustrates the Mamquam River watershed and the proposed dam site. The map shows the river flowing from the top right towards the bottom left. The 'Upstream Limit of Study' is marked at the top right, and the 'Downstream Limit of Study' is marked at the bottom left. The 'Mamquam Forest Service Road' runs along the right side of the river. The 'End of dike' is indicated by a white arrow pointing to the riverbank. 'Highway/CN constrictions' are highlighted with a white arrow pointing to the area near the 'Casino' and 'Squamish General Hospital'. The 'Mamquam FSR Bridge' is shown crossing the river. Various residential streets are labeled, including 'Juniper Cres', 'Westway Ave', 'Birch Dr', 'Spice Dr', 'Cedar Dr', 'Garden St', 'Mullford Dr', 'Magnolia Cres', 'Chestnut Ave', 'Hemlock Ave', 'Pine Dr', 'Fir St', 'Vista Cres', 'Village Dr', 'Northridge', 'Scotts', 'Hunter Pl', 'Pemberton Ave', 'Cleveland Ave', 'Greenwich St', 'Main St', 'Second Ave', 'Third Ave', 'Englewood Blvd', 'Carson Pl', 'Buckley Ave', 'Hwy 99', 'CN Rail', 'Burgess Rd', 'Stawamus Totem Pole', 'Chief Joseph Dr', 'Gas Station', and 'CN Rail Bridge'. A circular inset highlights the area around the dam site, showing the 'Stawamus Totem Pole' and 'Chief Joseph Dr'.

This aerial map illustrates the Mamquam River watershed and the proposed dam site. The river flows from the top right towards the bottom left. The proposed dam is located near the 'End of dike' and 'Highway/CN constrictions'. The map shows the 'Mamquam Forest Service Road' and the 'Mamquam FSR Bridge'. The 'Upstream Limit of Study' is marked at the top right, and the 'Downstream Limit of Study' is marked at the bottom left. The map also shows the 'Squamish General Hospital' and the 'Casino'. The 'Mamquam River' is labeled in blue. The 'Mamquam Forest Service Road' is labeled in white. The 'Mamquam FSR Bridge' is labeled in white. The 'Upstream Limit of Study' is labeled in white. The 'Downstream Limit of Study' is labeled in white. The 'Squamish General Hospital' is labeled in white. The 'Casino' is labeled in white. The 'Mamquam River' is labeled in blue. The 'Mamquam Forest Service Road' is labeled in white. The 'Mamquam FSR Bridge' is labeled in white. The 'Upstream Limit of Study' is labeled in white. The 'Downstream Limit of Study' is labeled in white. The 'Squamish General Hospital' is labeled in white. The 'Casino' is labeled in white.

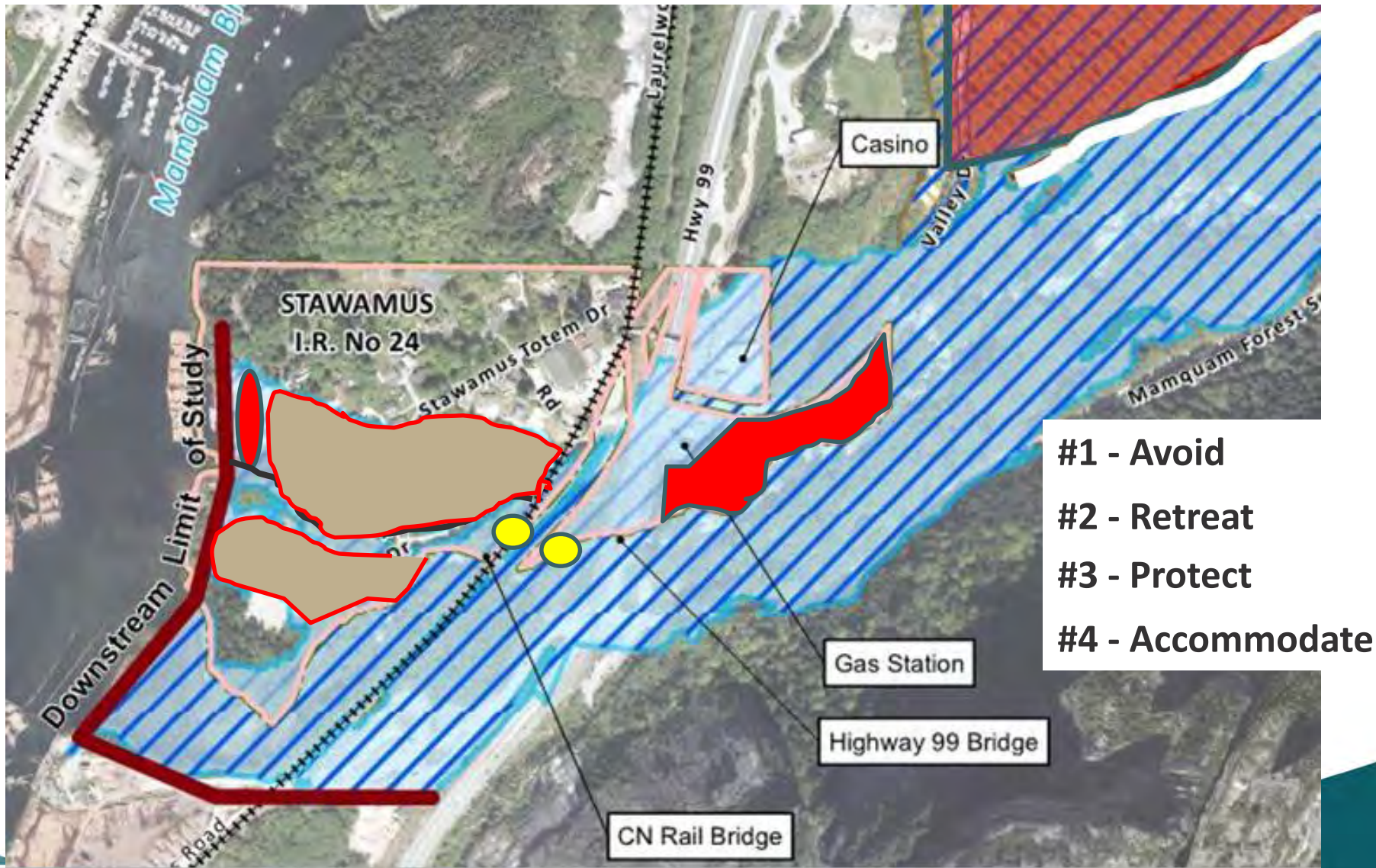


# Stawamus Mitigation





# Stawamus Mitigation



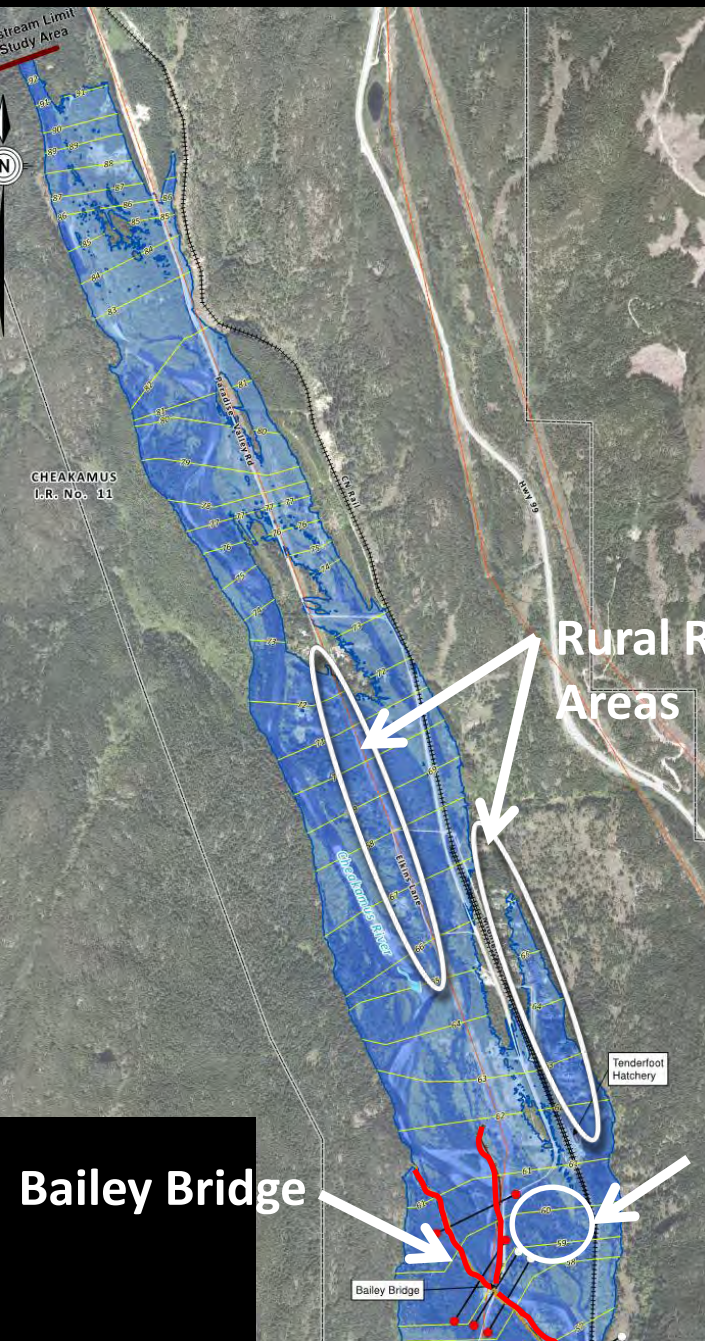
- #1 - Avoid
- #2 - Retreat
- #3 - Protect
- #4 - Accommodate

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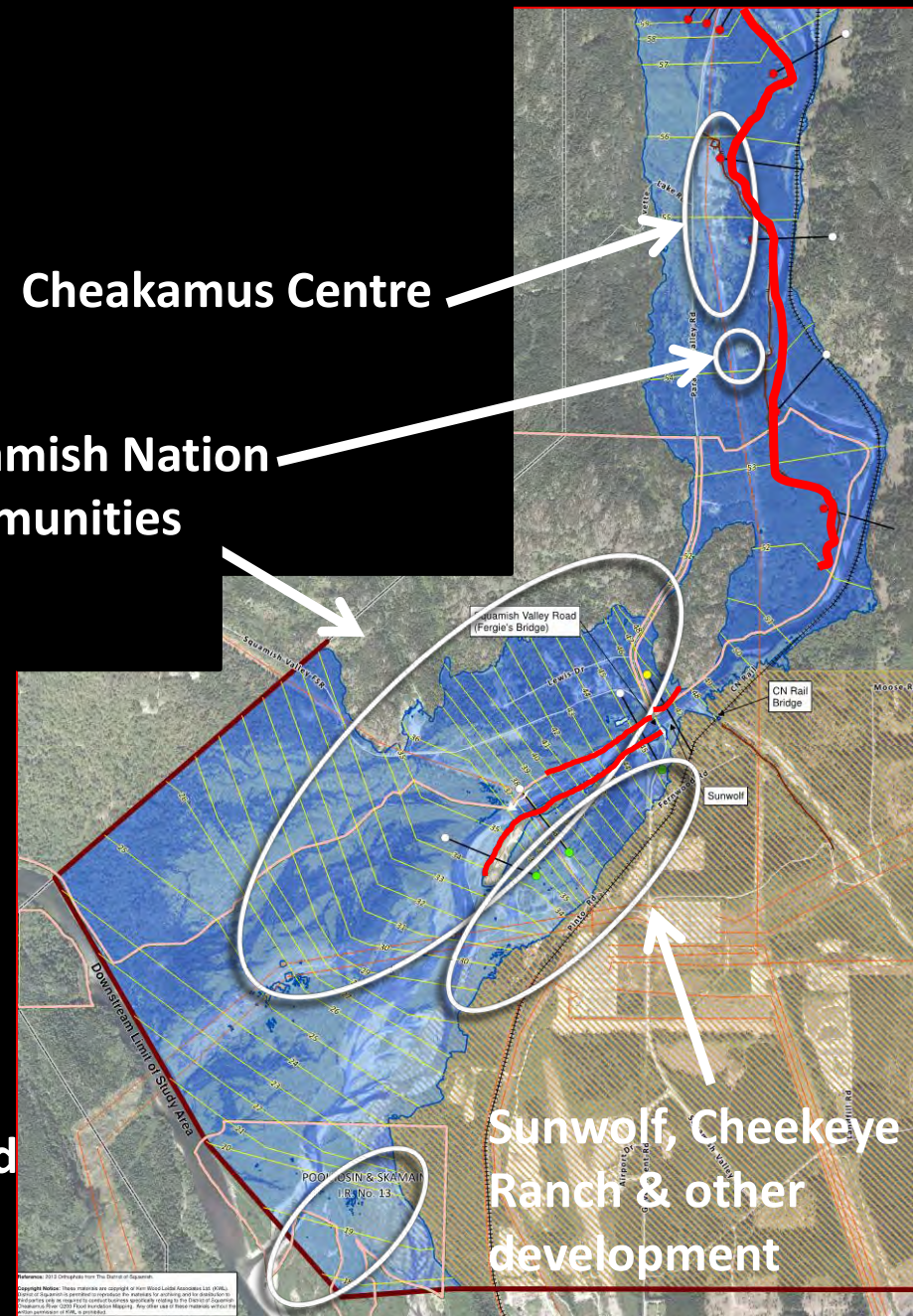


# Cheakamus Floodplain



**Cheakamus Centre**

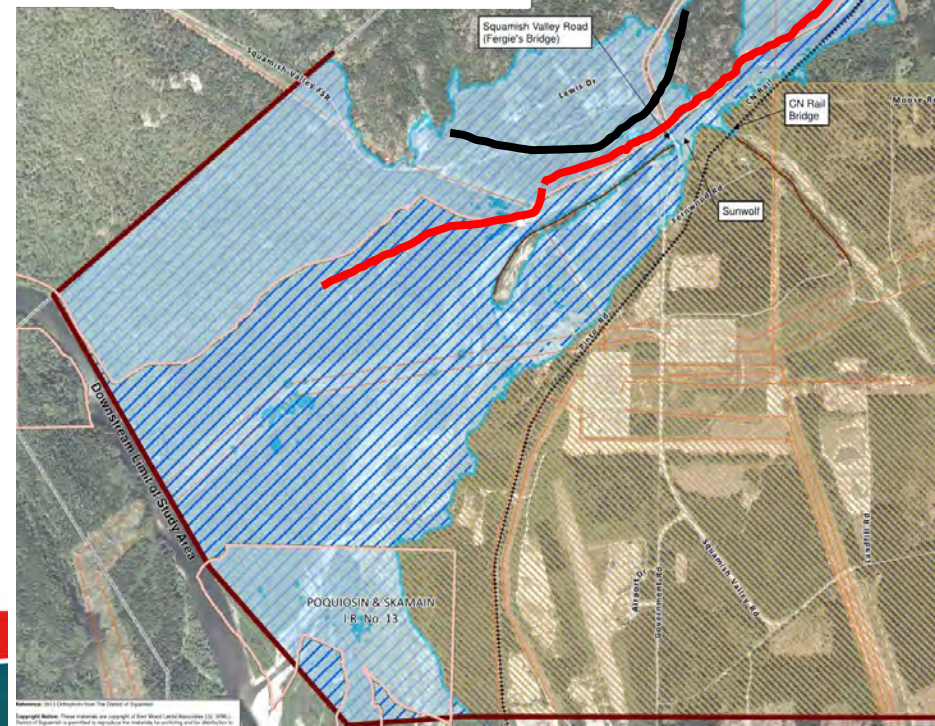
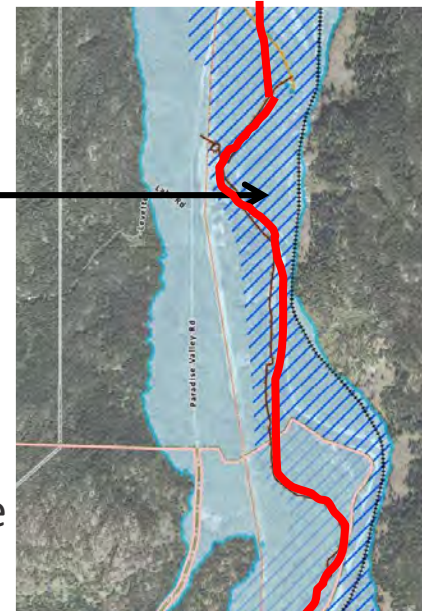
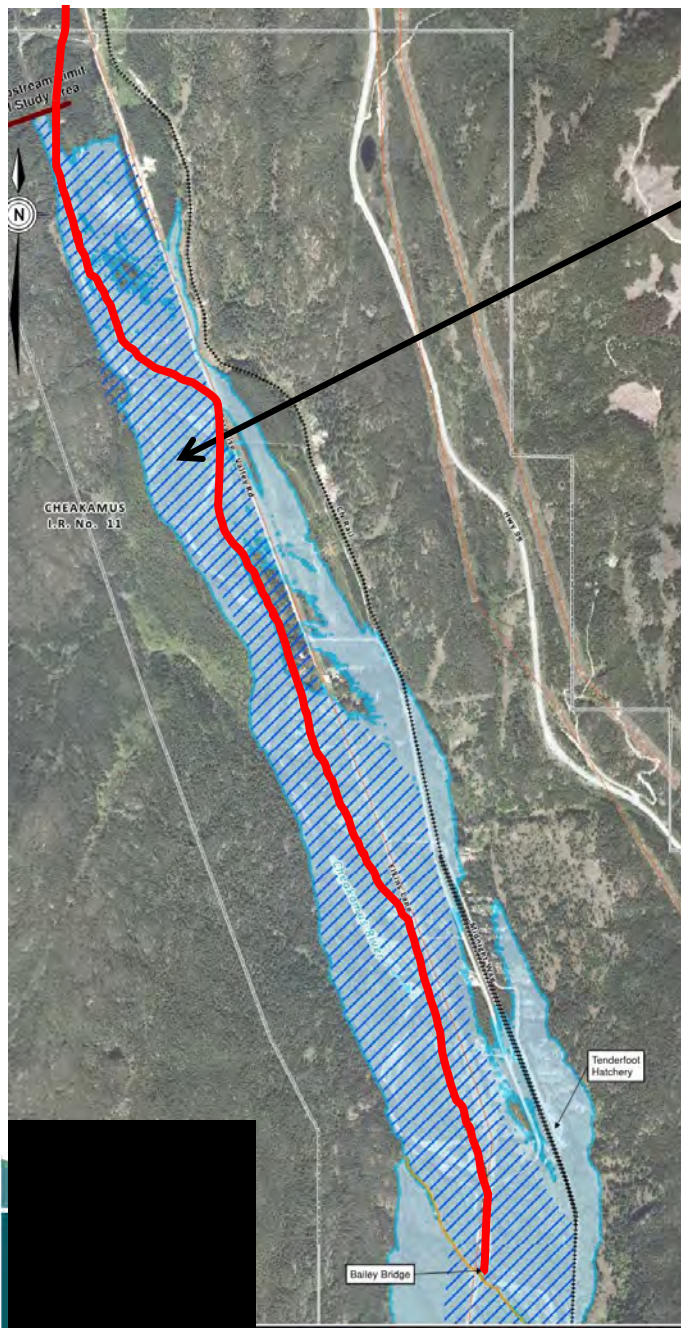
**Squamish Nation communities**





# Cheakamus Mitigation

- 1) Avoid densification through rezoning
  - Avoid development in floodway
- 2) Accommodate hazards
  - Setbacks, raise buildings above 1:200 flood level
- 3) No new diking
  - Don't accept new dikes to protect new development
  - Protect transportation
- 4) Work with Squamish Nation on dike proposal



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# Squamish/Mamquam Floodplain

## Modeling Overview

### Inputs:

- 1:200 year river flows
- Topographic data
- Dike breach locations
- Year 2100 development conditions

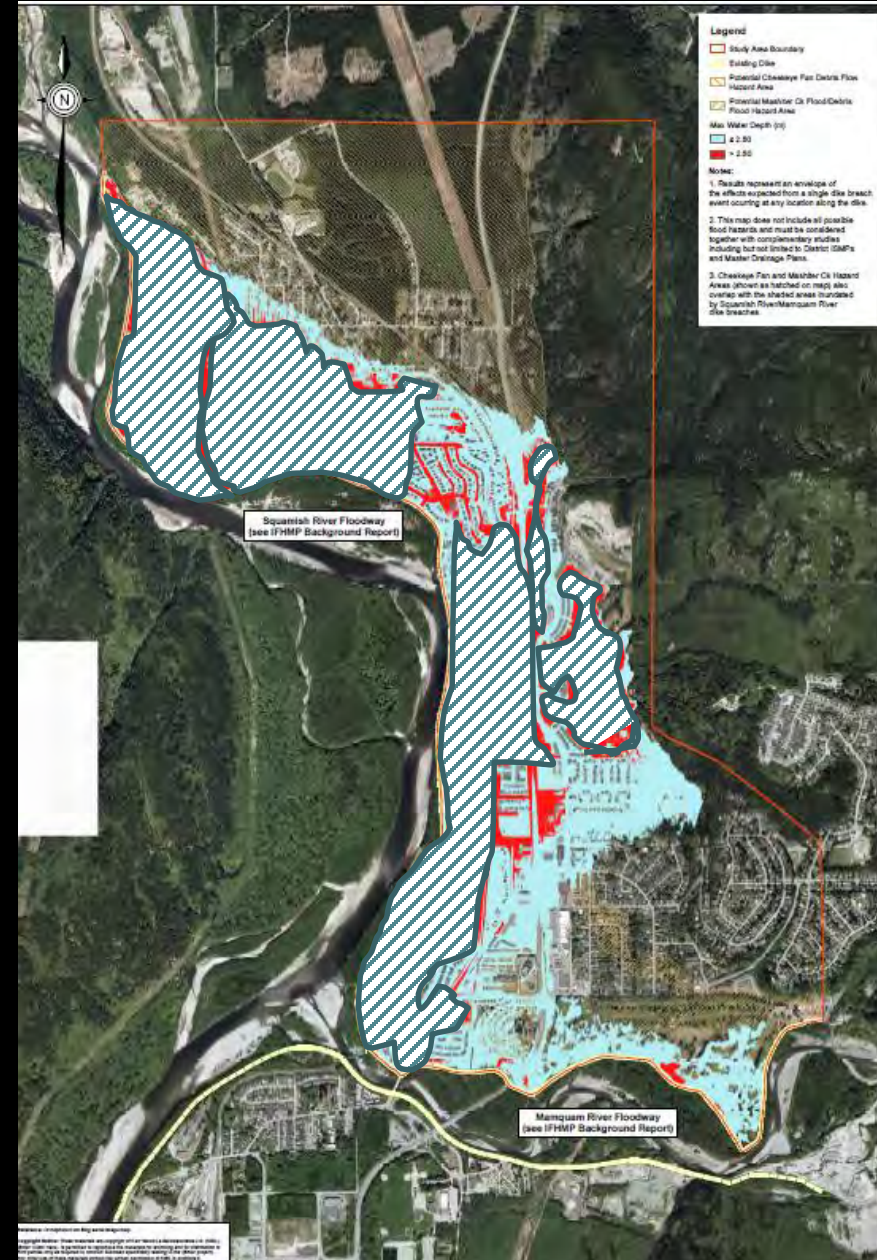
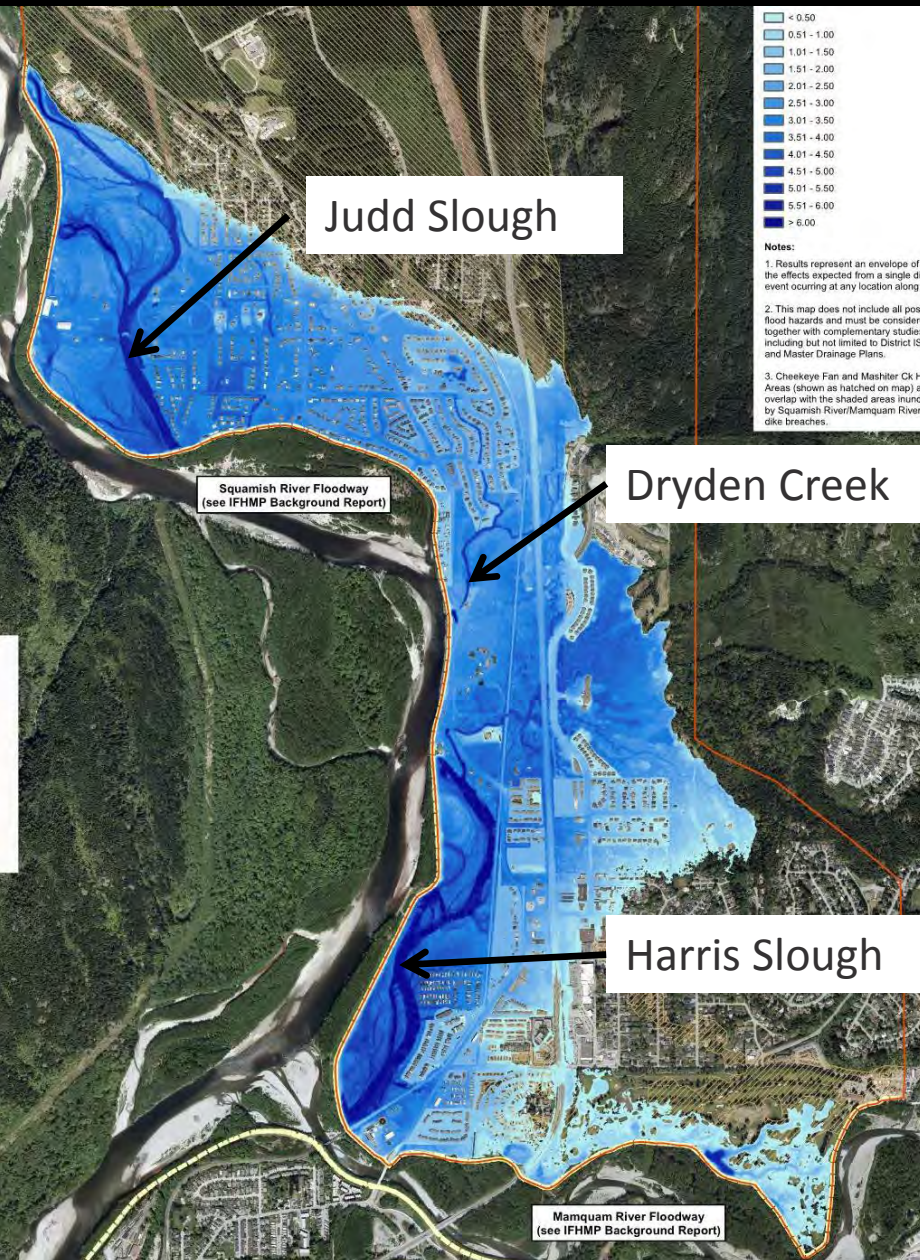
### Outputs:

- “Composite” Floodplain mapping



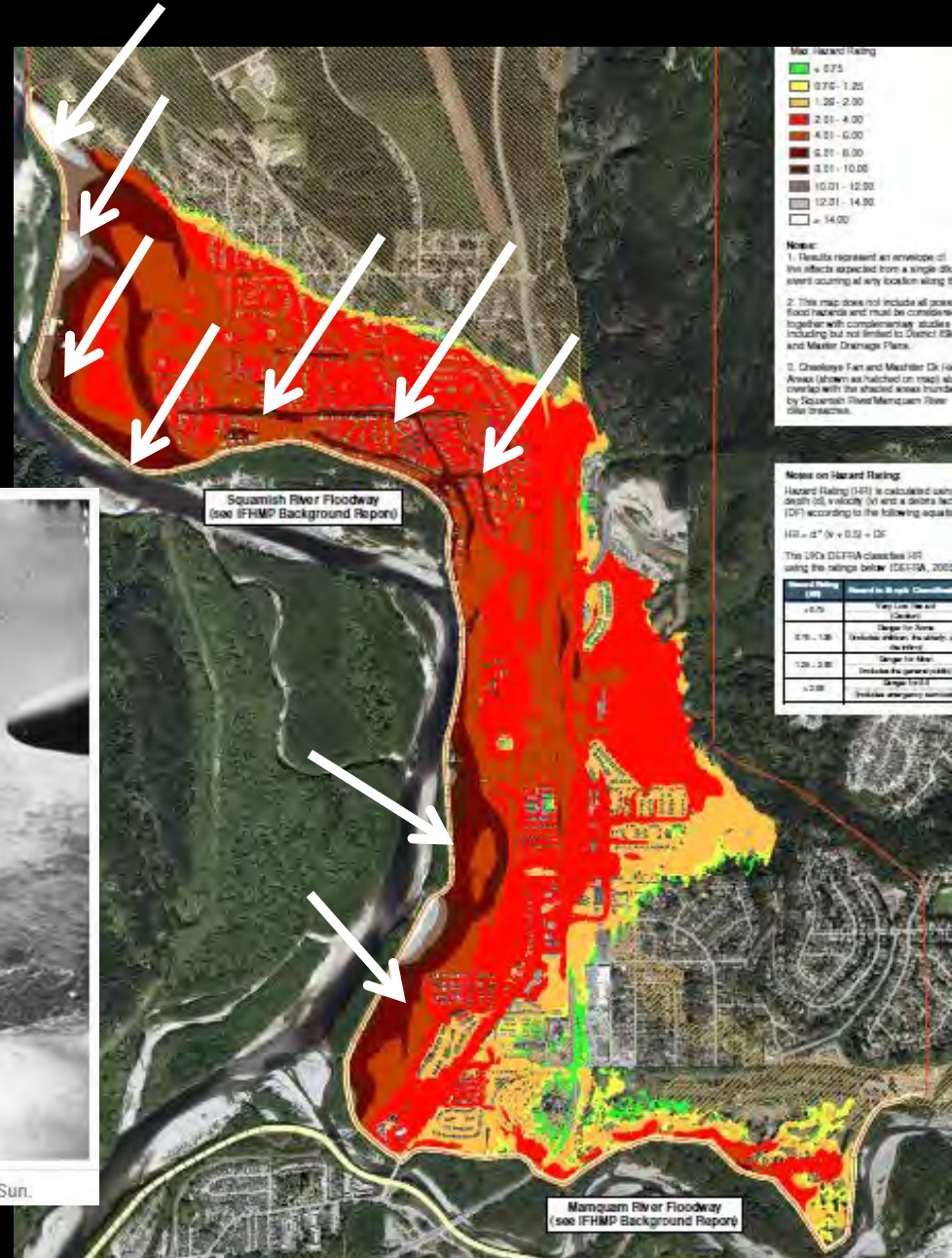


# Upper Floodplain Results (Extents, Depth)





# Upper Floodplain Results (Depth, Hazard Rating)

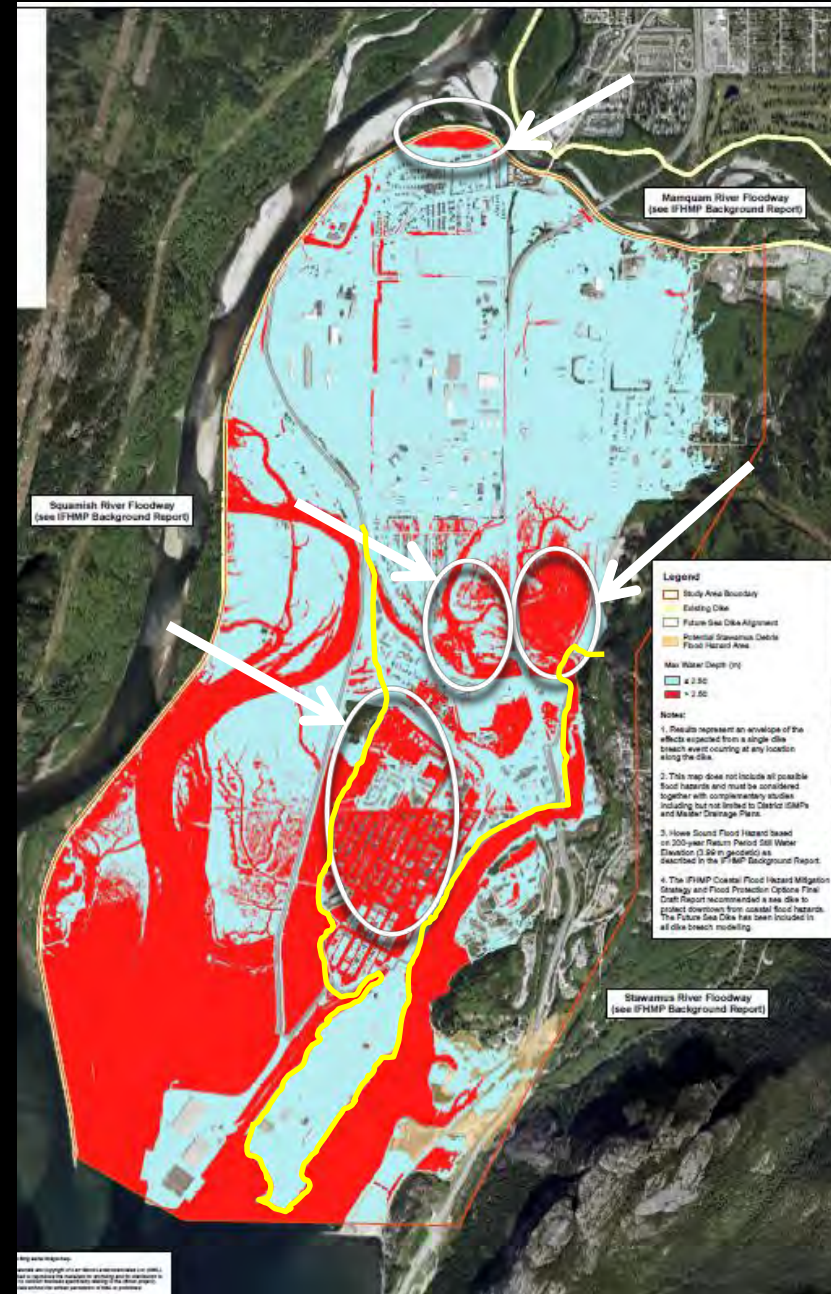
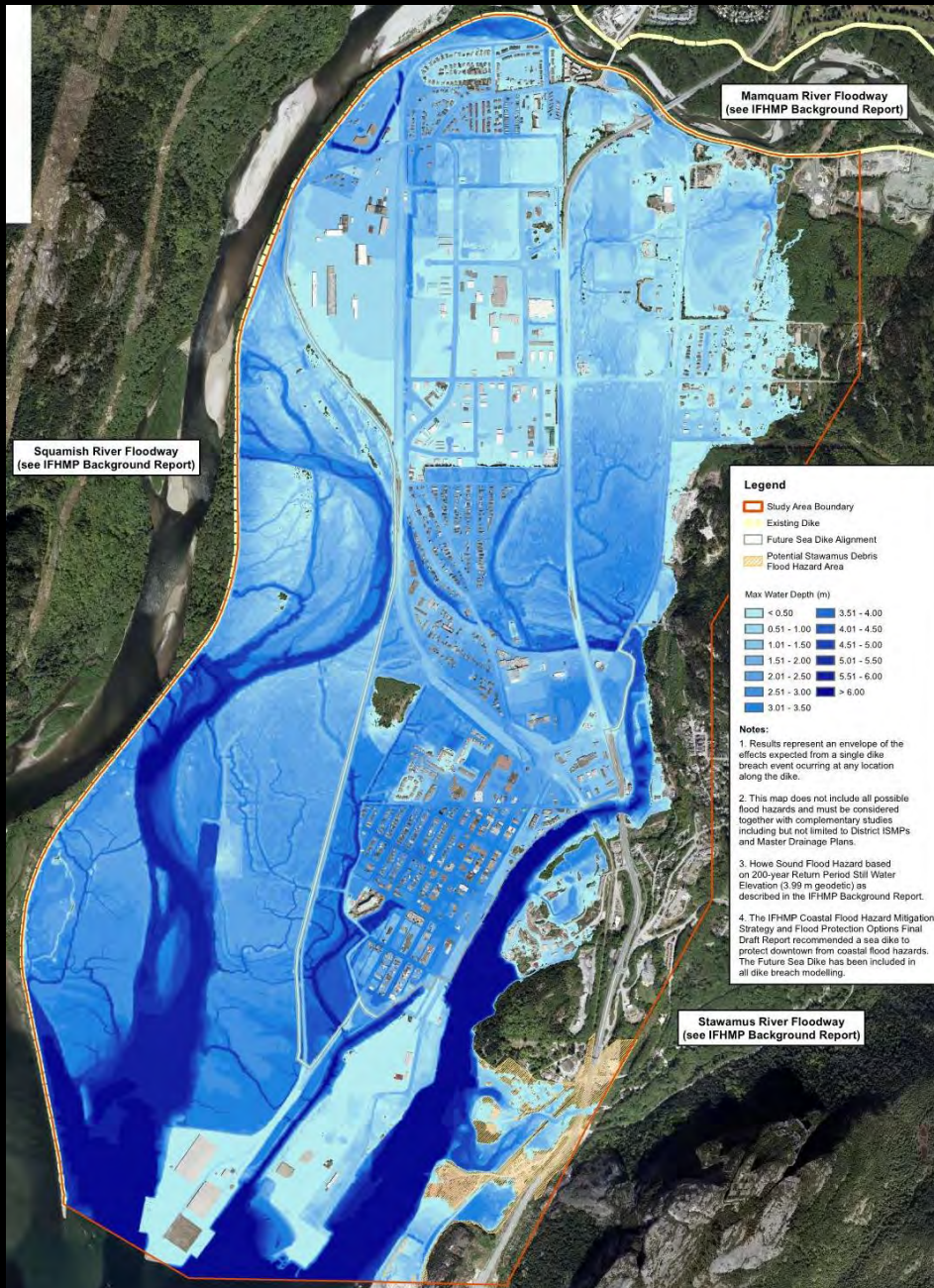


June 3, 1948: The Fraser River flood at Hatzic Lake where the dike broke. Photo: Dave Buchan/Vancouver Sun.





# Lower Floodplain Results (Extents, Depth)





# Social/Environmental Consequences

- Community Impacts
  - Social
    - Public safety
    - People displaced
    - Emergency response
    - Core services impacted
    - Infrastructure damage
    - Employment disruption
  - Environmental





# Economic Consequences

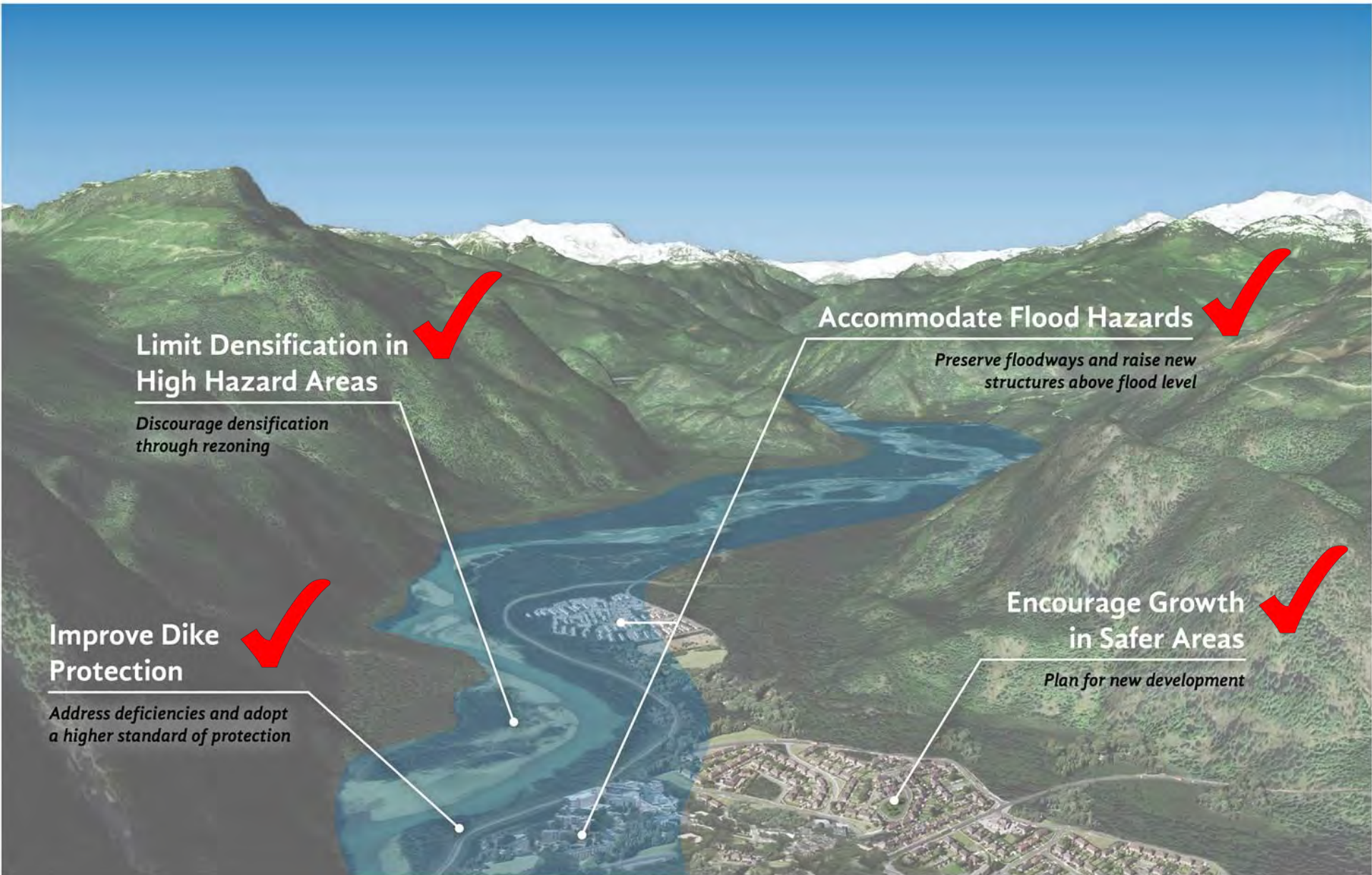
- Upper Floodplain:
  - \$190 million (mostly residential)
  - 7,000 displaced
- Lower Floodplain:
  - \$257 million (half residential)
  - 3,400 displaced
- Building damage and inventory only → lower bound estimate



*High River, AB 2013*



# Squamish / Mamquam Mitigation





# Improve Protection

- Correct all known deficiencies (ongoing)
  - Dike too low → Raise dike to 1:200yr
  - Lack of land tenure → Acquire SROWs
  - No access → Ensure adequate access
  - Oversteepened slopes → Flatten slopes
  - Too narrow → Widen
  - Poor quality/missing erosion protection → Fix
  - Etc, etc, etc

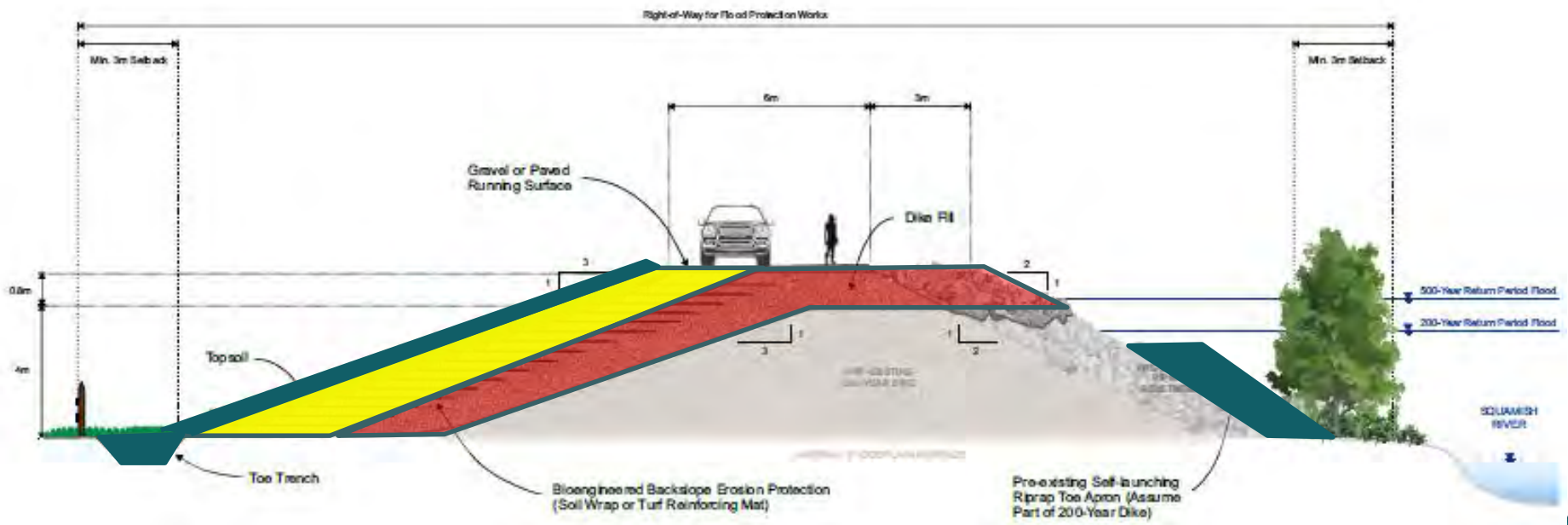
## Challenge Areas: Judd Slough/Eagle Viewing Area



Reduced probability= Reduced Risk

# Squamish River Super Dike

- Long term: Adopt higher level of protection
  - Implement: Opportunistic/planning
- Higher, wider, stronger than provincial standard



# “Super Dike” Benefit-Cost Analysis

- Cost for “super dike” upgrades: ±\$40M
- B-C analysis results:

Design Life	Effective Discount Rate				
(years)	-1%	0%	1%	2%	3%
50	2.34	1.79	1.41	1.13	0.92
75	4.04	2.69	1.89	1.39	1.07
100	6.21	3.59	2.26	1.55	1.13
200	23.18	7.17	3.10	1.76	1.19

- Stakeholder consultation indicates support

# Accommodate Flood Hazards

- Implement new Flood Construction Levels (FCL)
  - Process for granting variances in hardship
- Establish building requirements
- Establish/preserve floodways



# Establish/Preserve Floodways

**Restrict Development**

**Regulate Development**

## Legend

- Existing Dike
- Planning Area for Long-Term Dike Upgrades
- Designated Internal Floodways
- Limited Denatification Zone
- Special Policy Area
- Limits of 200-Year Dike Breach Flood Hazard
- Study Area Boundary
- Potential Cheekways Fan Distributions Flow Hazard Area
- Potential Mashiter Ck Flood/Cheekways Flood Hazard Area
- BC Hydro Transmission Lines (Approximate Location)

## Notes:

1. Results represent an envelope of the effects expected from a single dike breach event occurring at any location along the dike.
2. This map does not include all possible flood hazard areas and must be considered together with complementary studies including but not limited to District ISMPs and Master Drainage Plans.
3. Cheekways Fan and Mashiter Ck Hazard Areas (shown as hatched on map) also overlap with the coastal areas inundated by Squamish River and Marquahan River dike breaches.
4. Limitations on denatification will occur as a result of restrictions on regrading to increase density. Denatification will still occur through fill, small subdivisions and regrading at equivalent density.
5. Lands within Special Policy Area may be required for denatification where erosion-protected locations (i) where a contiguous portion of the lands completely out of the Flood Hazard Area without increasing flood risk at other locations. Fill must substantially be in with areas where natural grade exceeds the MBE.

Alignment of Internal Floodways may be adjusted to accommodate future redevelopment

## Legend

- Existing Dike
- Proposed Sea Dike (Final Alignment to be confirmed)
- Proposed Intentional Sea Dike Breaches
- Planning Area for Long-Term Dike Upgrades
- Designated Internal Floodways
- Limited Denatification Zone
- Limits of Coastal and 200-Year Dike Breach Flood Hazard
- Study Area Boundary
- BC Hydro Transmission Lines (Approximate Location)

## Notes:

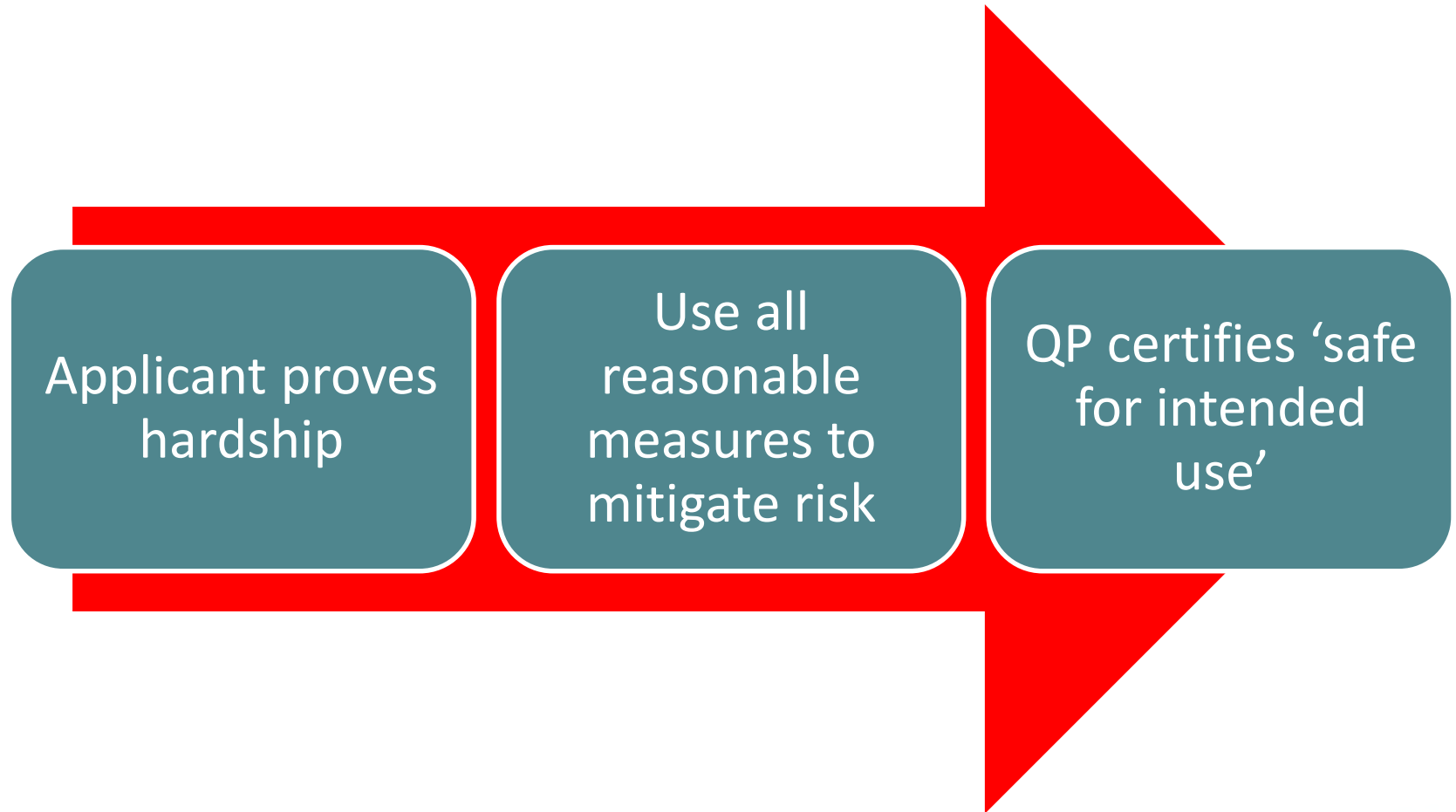
1. The IFHMP Coastal Flood Hazard Mitigation Strategy and Flood Protection Options Final Draft Report recommended a sea dike to protect downtown from coastal flood hazards. The Future Sea Dike has been included in all dike breach modelling.
2. This map does not include all possible flood hazard areas and must be considered together with complementary studies including but not limited to District ISMPs and Master Drainage Plans.
3. All roads west of Loggers Lane and all roads south of Mayne Street are also considered floodways.
4. Limitations on denatification will occur as a result of restrictions on regrading to increase density. Denatification will still occur through fill, small subdivisions and regrading at equivalent density.

Map created using ArcGIS

Map created using ArcGIS. All rights reserved. All other trademarks are the property of their respective owners. All other trademarks are the property of their respective owners. All other trademarks are the property of their respective owners.



# Variance Process



# FCL Exemption for Downtown Area



- Continue exemption for ground-level businesses
- All other variance requirements apply
- Mitigation measures
  - Diking upgrades
  - Emergency response
  - Flood insurance





Calgary, 2013



# Calgary, 2013





Canmore, 2013

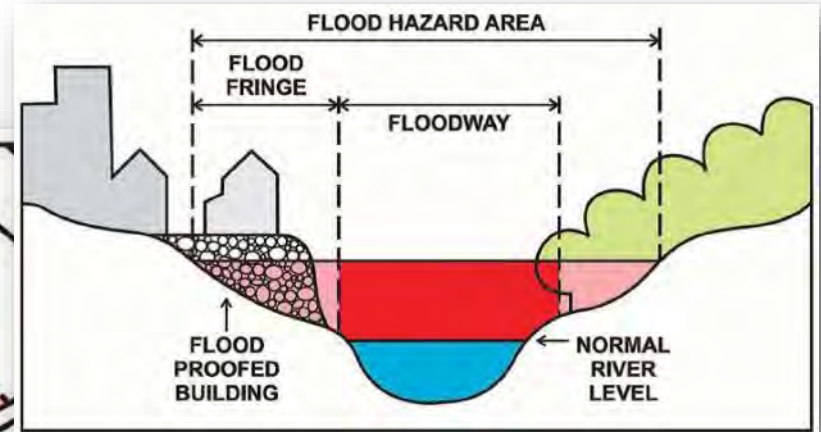
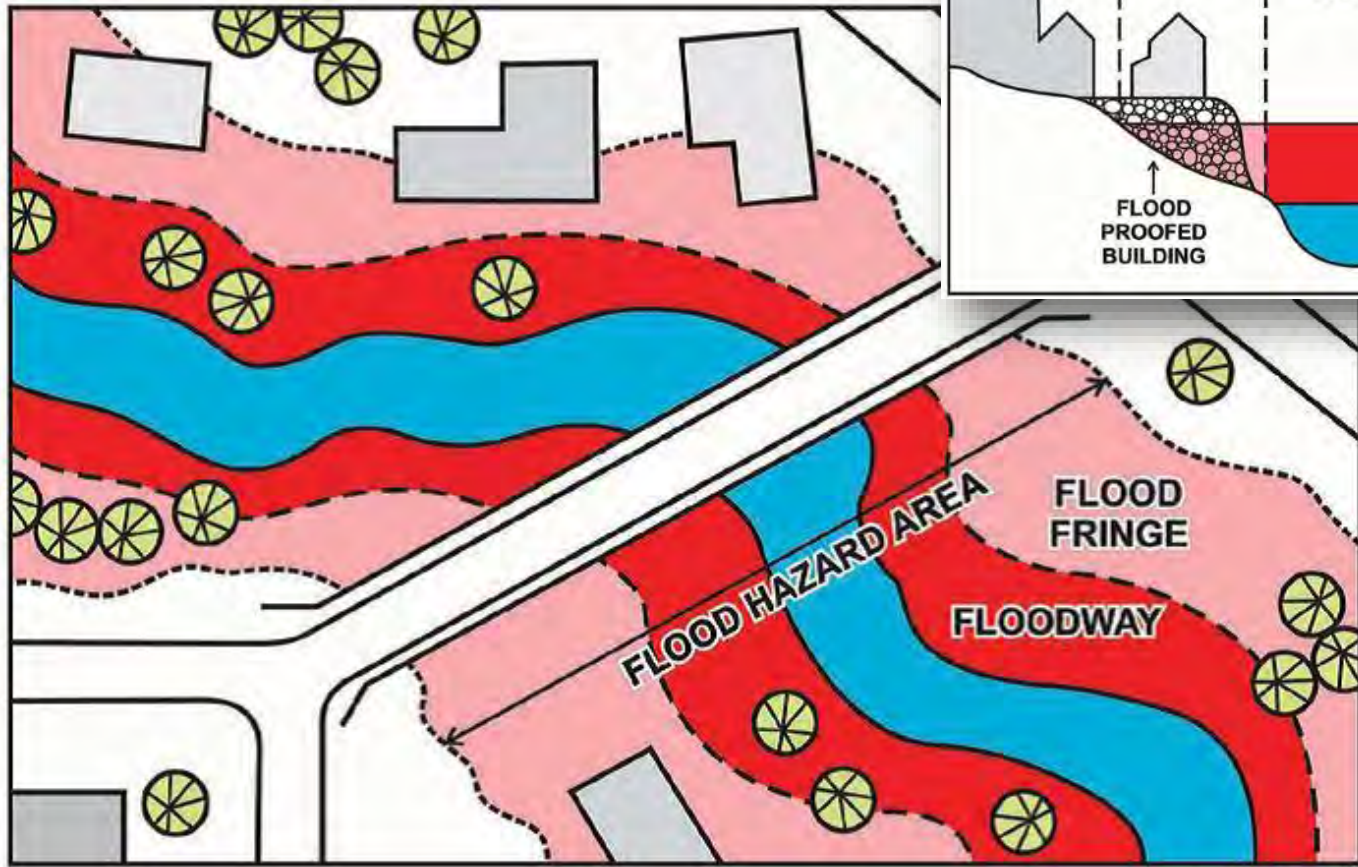






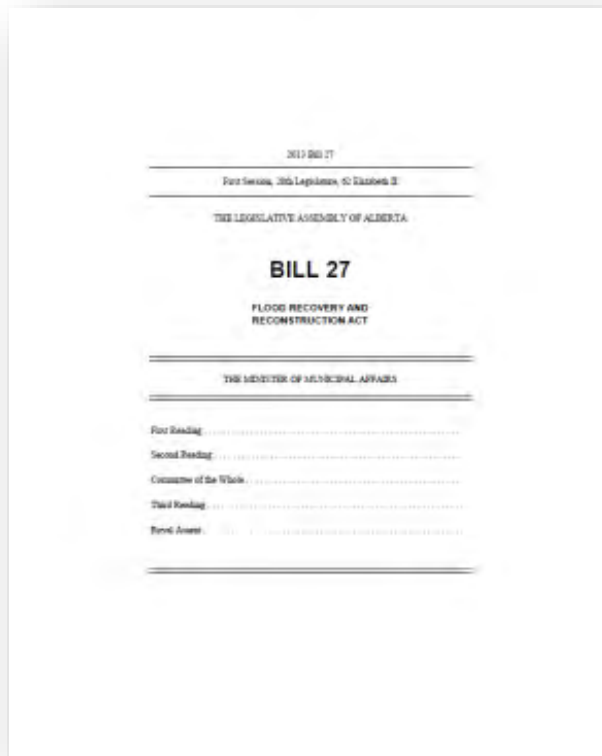
**High River, 2013**

# Floodways





# Bill 27 and Floodway Development Regulations

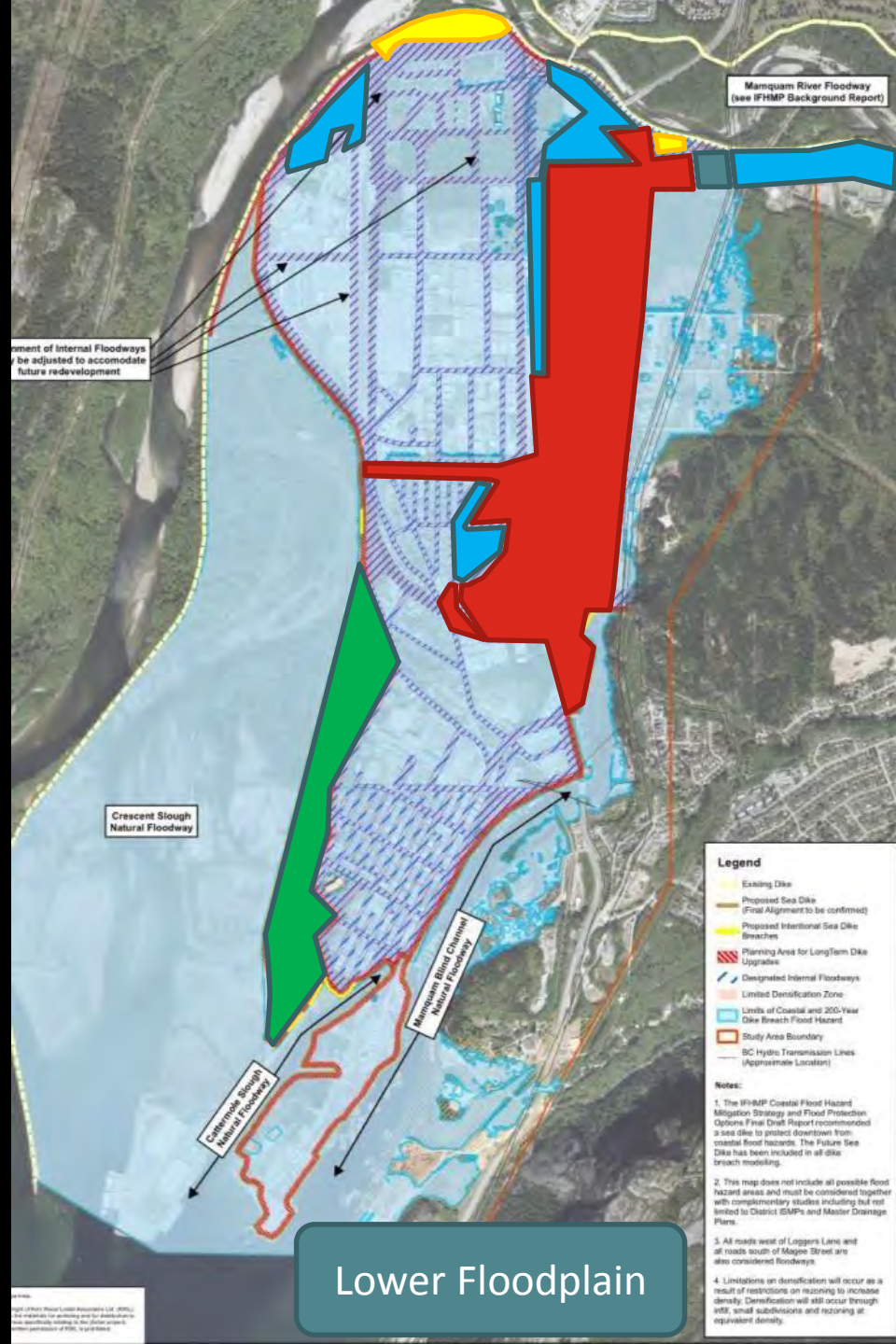
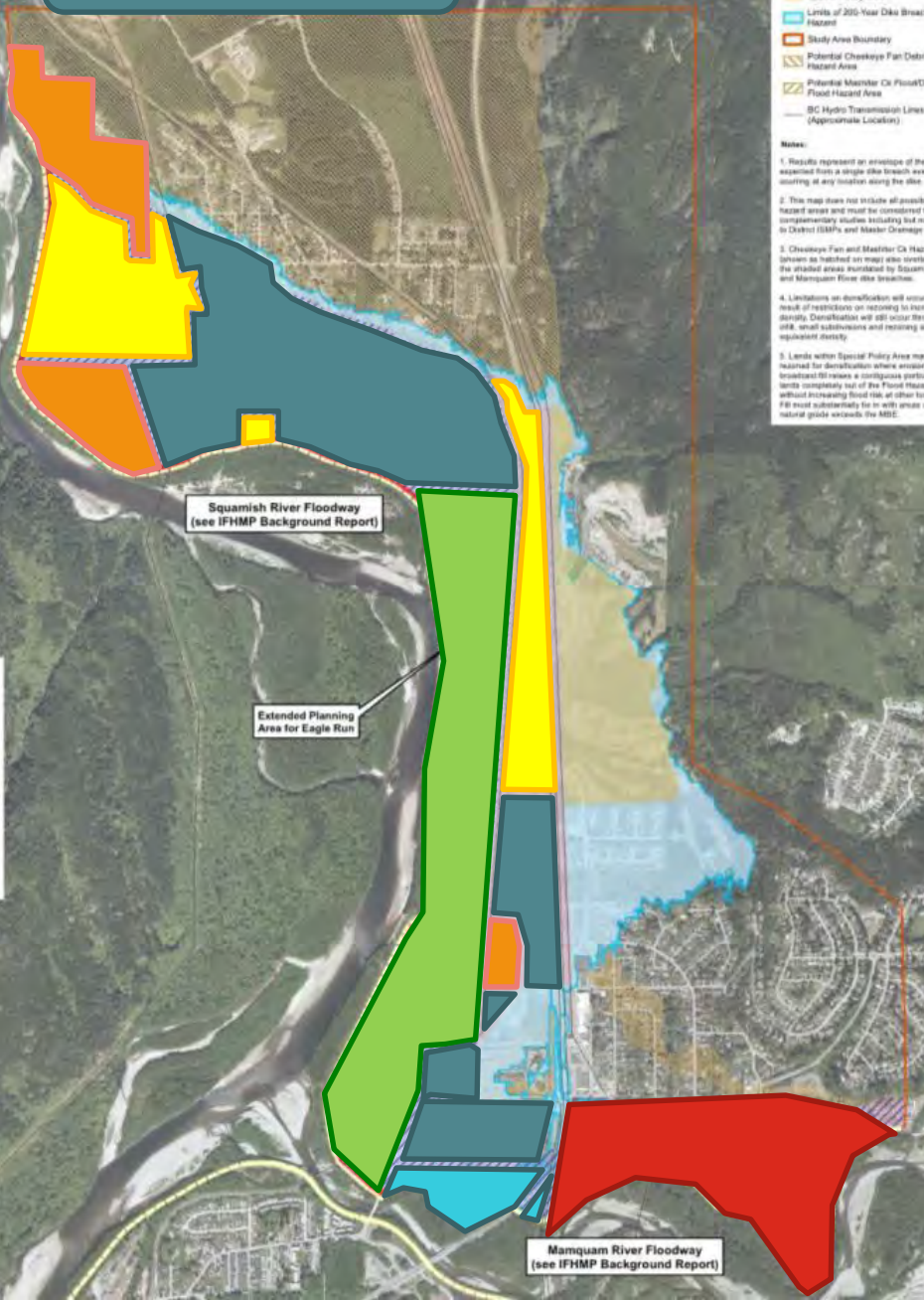


## Preventing future flood damage

- Going forward, will require municipalities not approve future development in floodways
- Will involve legislative changes that will be made in the fall.
- Current legislation says municipalities "should not" approve future developments.
- Changes will include "must not" approve future developments.
- Many municipalities already have requirements in place for this
- Work supported by flood hazard mapping by the provincial government

13

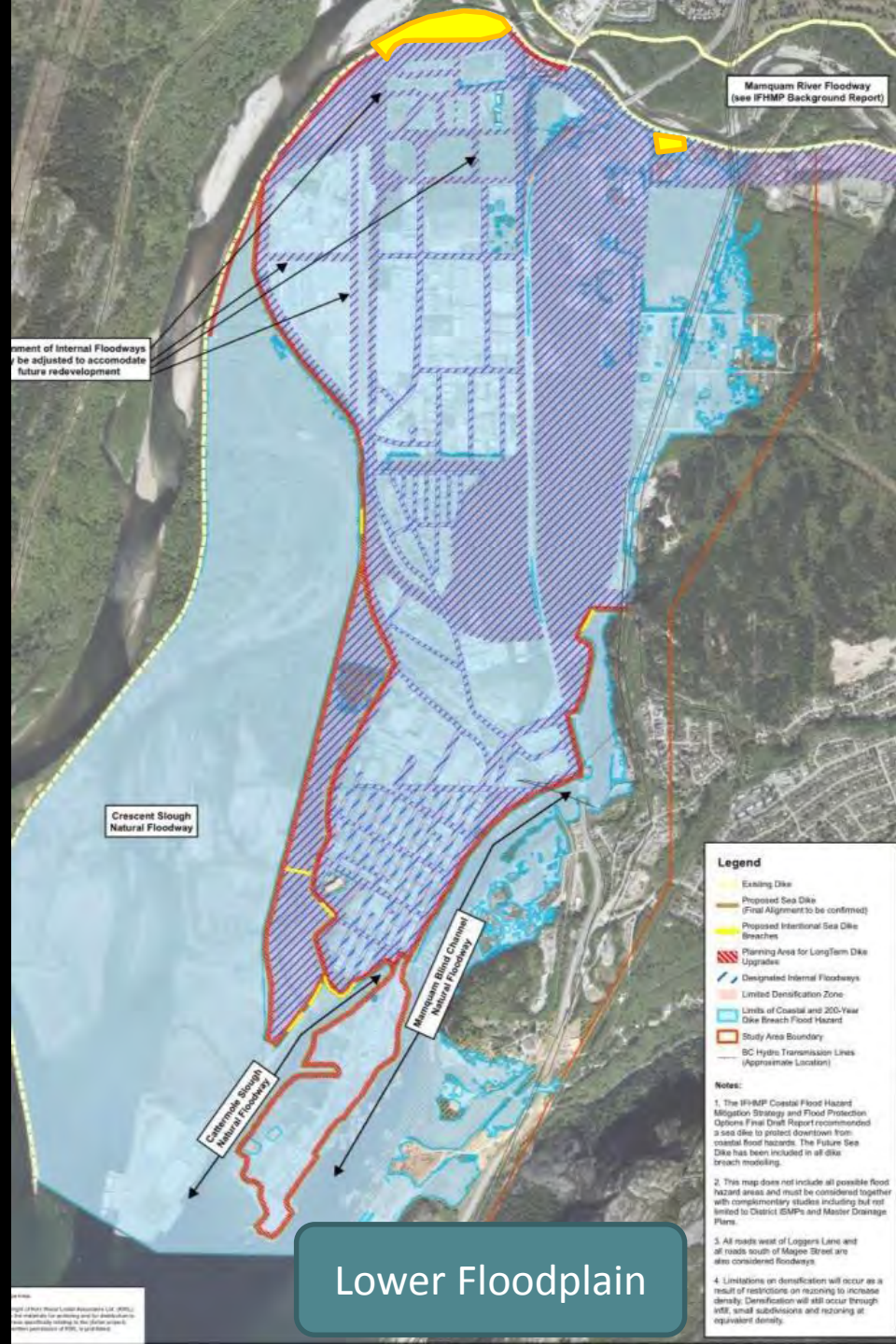
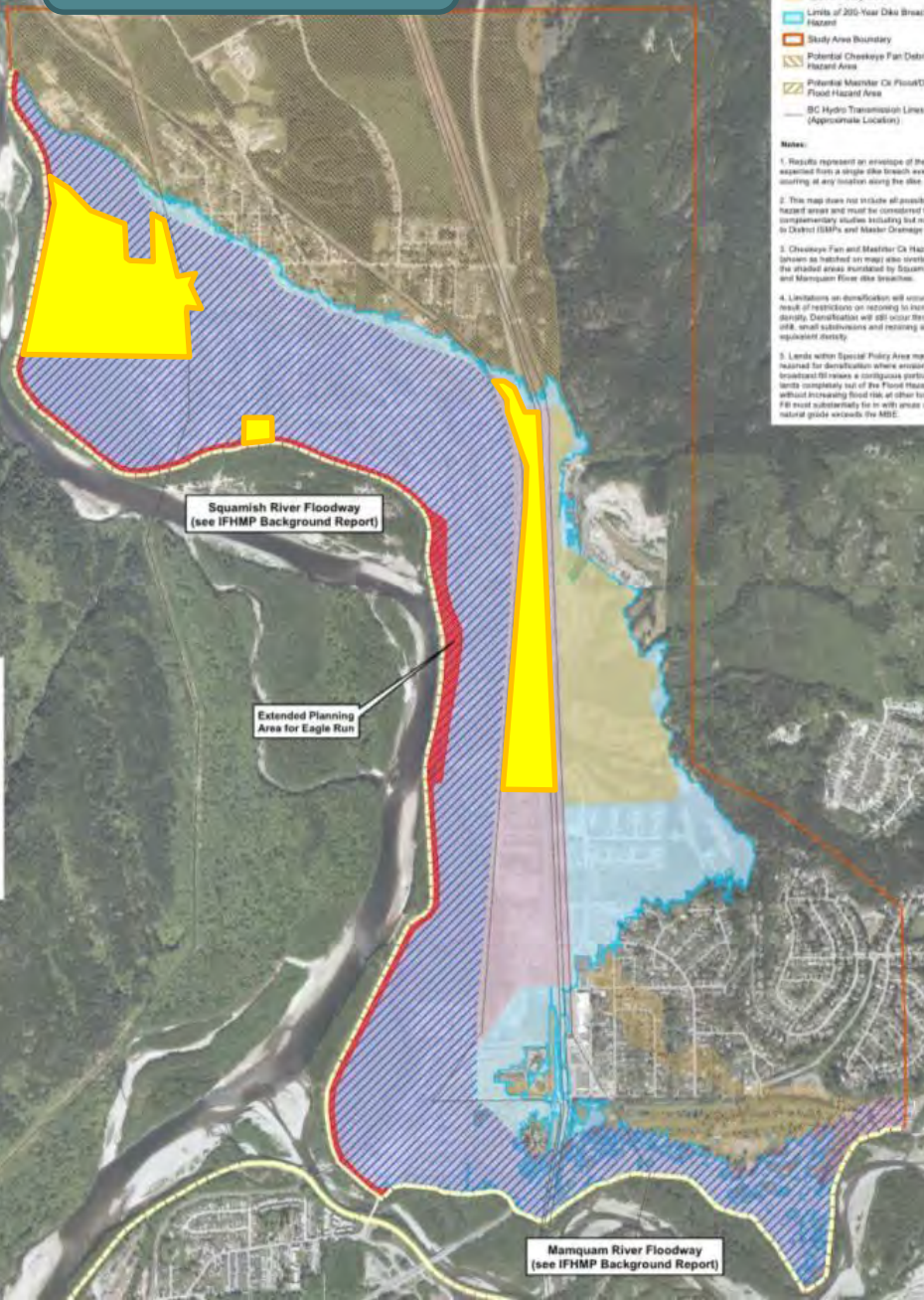
# Upper Floodplain



# Lower Floodplain



# Upper Floodplain



# Lower Floodplain

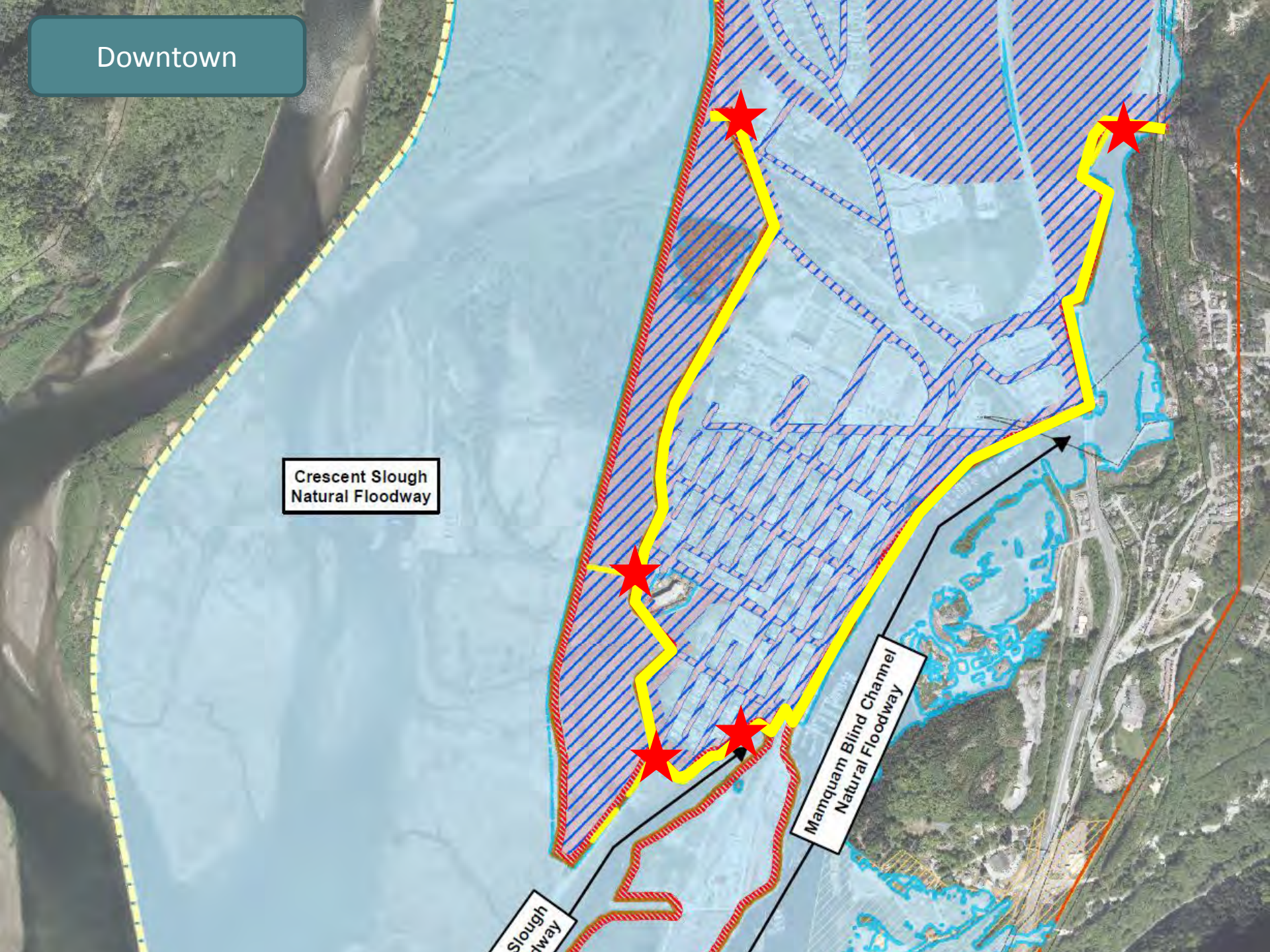


Downtown

Crescent Slough  
Natural Floodway

Mamquam Blind Channel  
Natural Floodway

Slough  
Floodway



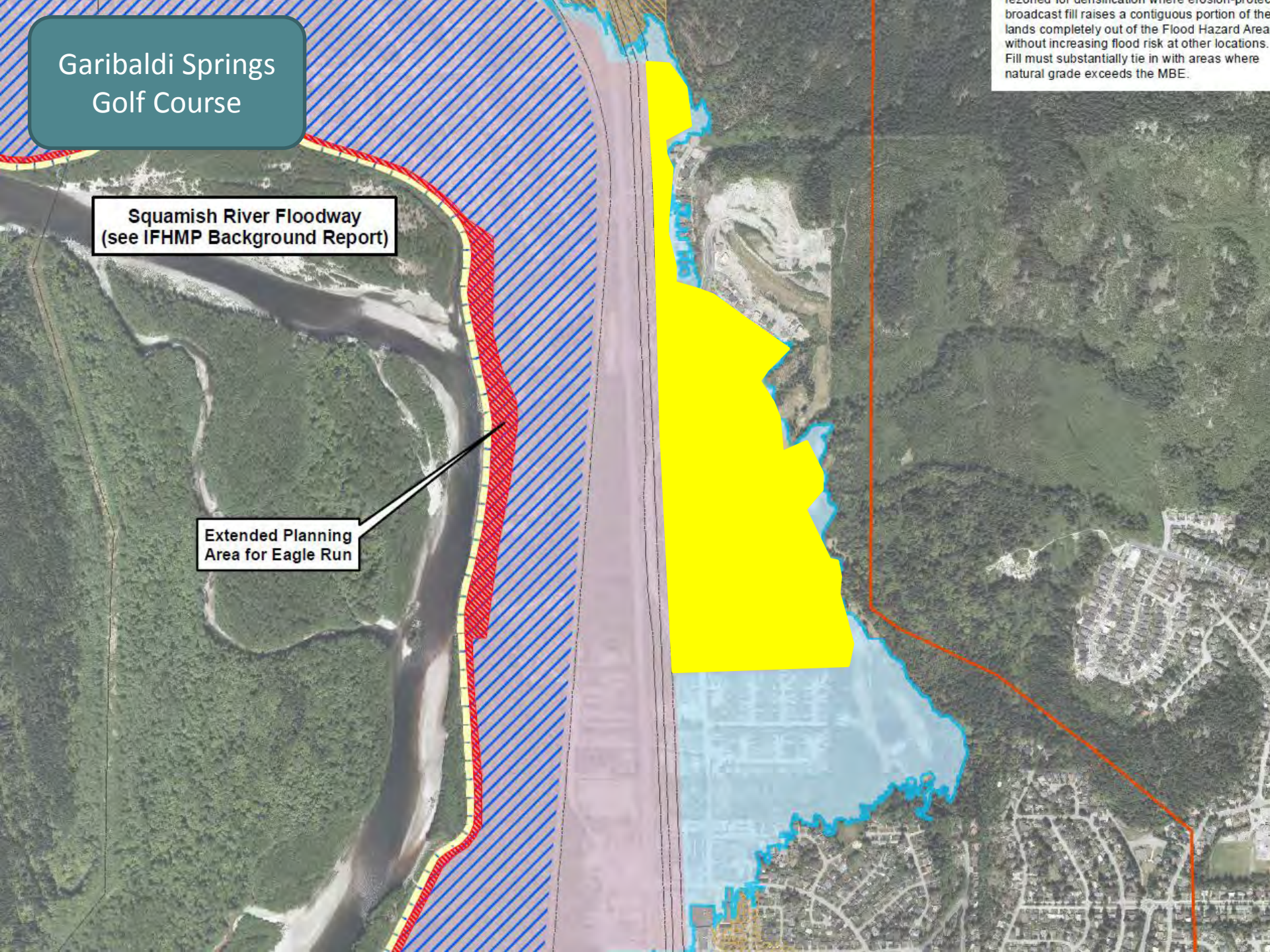


# Garibaldi Springs Golf Course

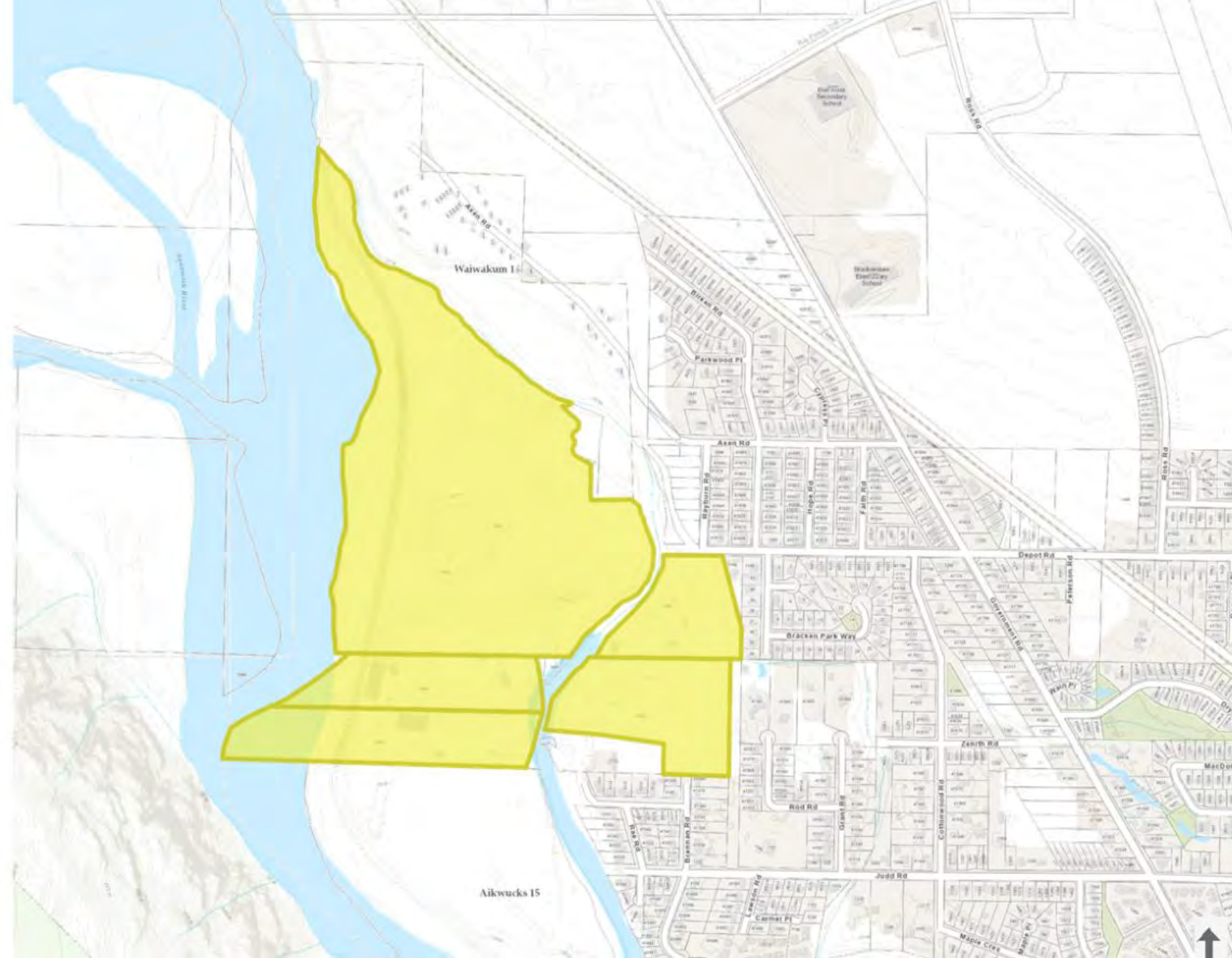
**Squamish River Floodway**  
(see IFHMP Background Report)

**Extended Planning  
Area for Eagle Run**

referred to densification where erosion protection  
broadcast fill raises a contiguous portion of the  
lands completely out of the Flood Hazard Area  
without increasing flood risk at other locations.  
Fill must substantially tie in with areas where  
natural grade exceeds the MBE.





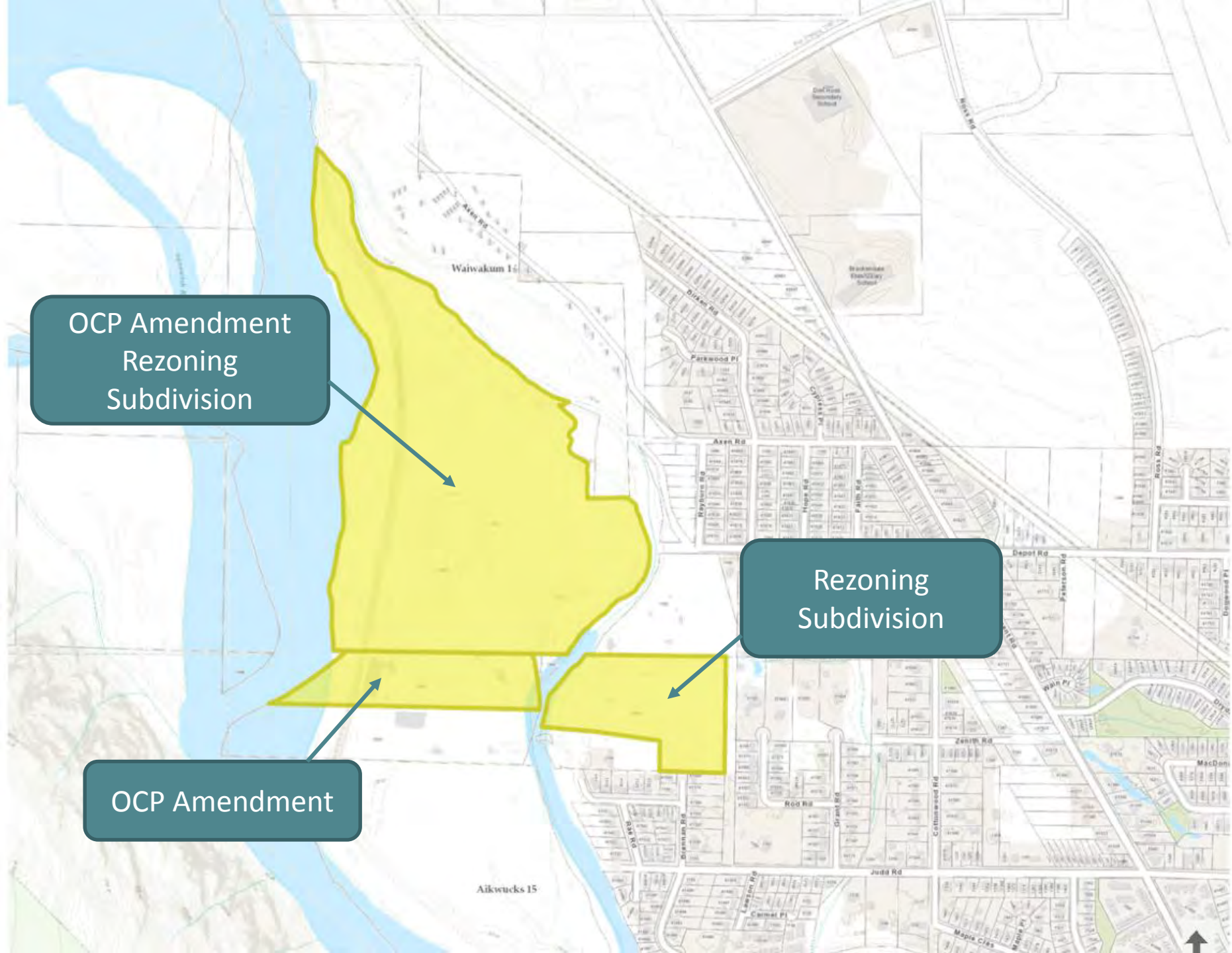




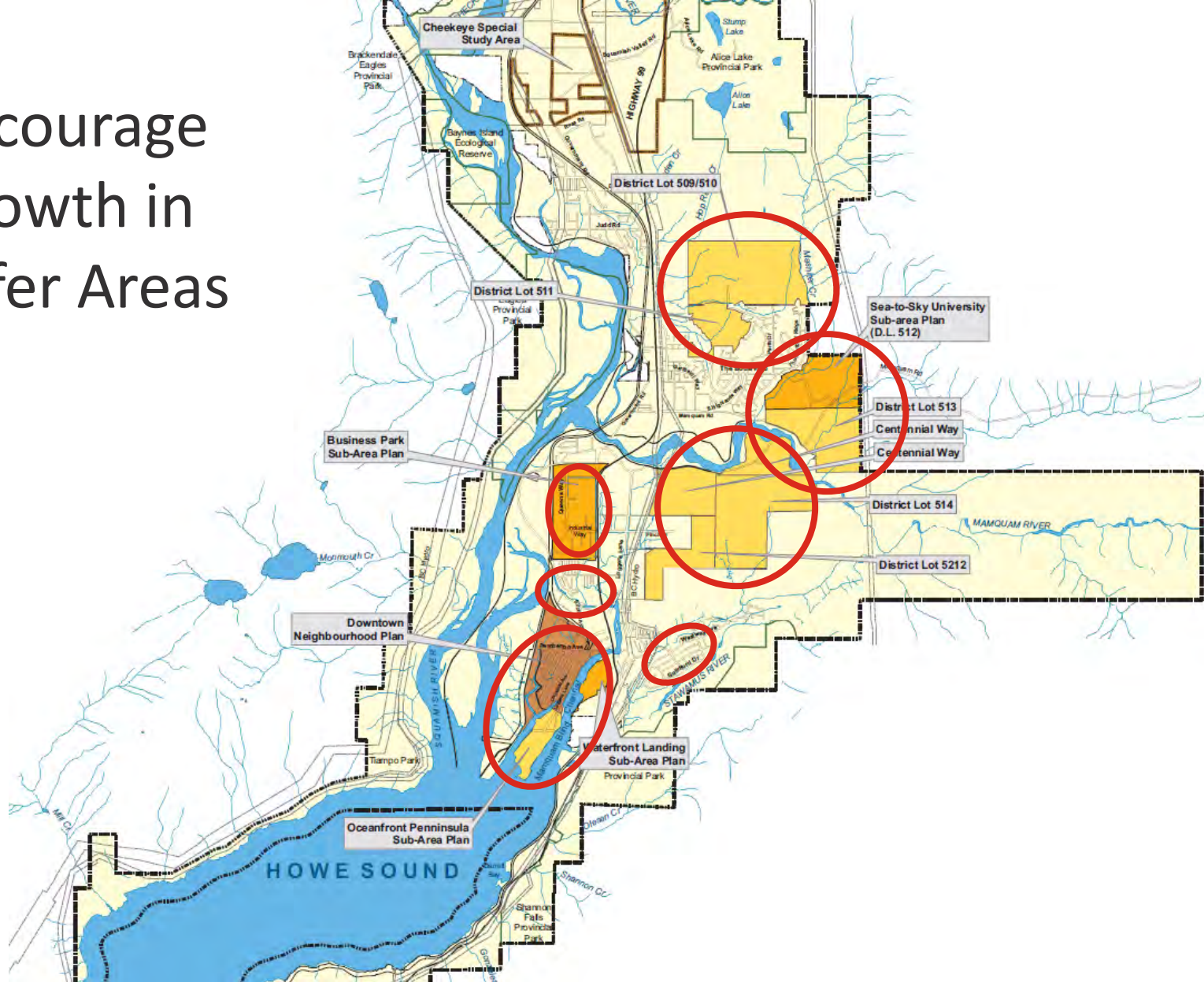
OCP Amendment  
Rezoning  
Subdivision

Rezoning  
Subdivision

OCP Amendment

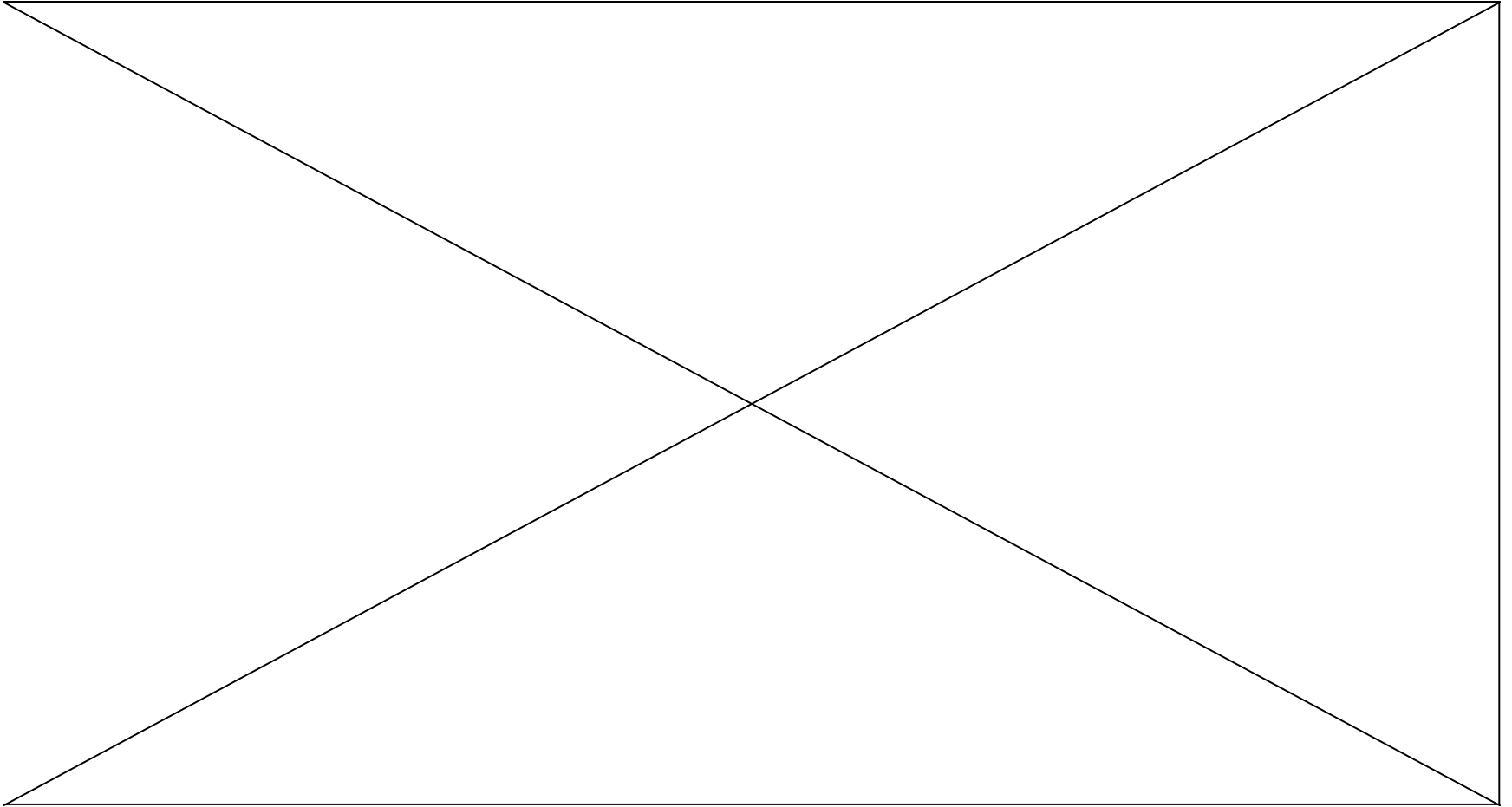


# Encourage Growth in Safer Areas

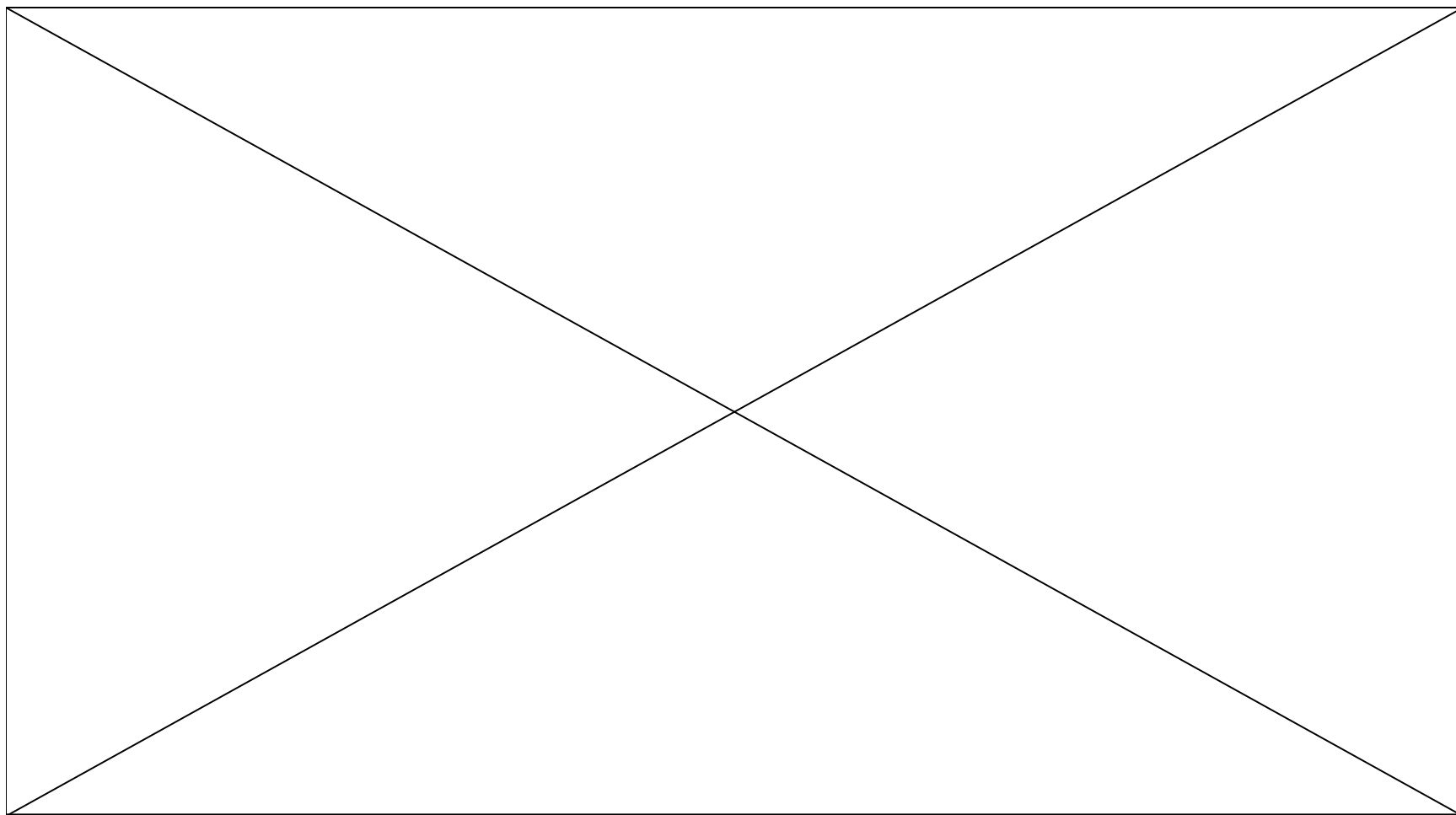




# Joso, Japan 2015



# Squamish 2003





# IFHMP Next Steps

Now

- Complete engagement process
- Finalize plan
- Council endorsement of mitigation plan
- Prepare final IFHMP
  - Draft floodplain bylaw
  - Further consultation
- Finalize IFHMP, 1<sup>st</sup> Reading draft bylaw
- Incorporate into OCP

Aug  
2016

An aerial photograph of a coastal town nestled between a large body of water and a range of mountains. A prominent, steep, rocky mountain peak is visible on the left. The town is situated along the shoreline, with a road and some industrial or commercial areas. The water is calm, and the mountains in the background are covered in forest and some have snow-capped peaks.

# Guiding Principles

- Reduce flood risk
- Identify development opportunities
- Make sustainable decisions
- Design achievable solutions



# Questions/Discussion