Flood Mitigation Options Assessment Summary

A City of Calgary Summary

Full report prepared by IBI Group and Golder Associates

December 15, 2017

Introduction

Calgary was built at the confluence of two mountain rivers, making it vulnerable to river flooding. The downtown economic core, the beltline areas and other communities are at risk of being flooded by the Bow and Elbow rivers every year. These vital areas include government buildings, social and health services, historic communities, commercial and industrial areas, major tourist attractions and recreation facilities (Figure 1).

The 2013 floods in Southern Alberta were one of Canada's most costly natural disasters, resulting in loss of life as well as significant property damage, personal impact and social and economic disruption. The 2013 flood event emphasized the need to address flood risk in Calgary, protect public safety and reduce future social, environmental, and economic flood damages to our city. This imperative drove the recommendation for The City to gain a better understanding of Calgary's flood risk and the changing dynamics of the floodplain, and develop evidence-based strategies to reduce flood risk.

The Flood Mitigations Options Assessment, completed for The City by IBI Group and Golder Associates Ltd. in 2017, is an important step towards achieving these goals. The study undertook four key steps:

1. Develop a detailed computer model to calculate the risk of flood damages within the city (Damage Model).
2. Assess the risk of flood damages under a number of scenarios with potential mitigation options in place (Scenario Analysis).
3. Compare mitigation scenarios using a framework that considers cost, benefit and social-environmental sustainability (Sustainability Assessment).
4. Provide recommendations for reducing potential river flood damages though structural and non-structural measures (Recommendations).

The purpose of this document is to provide an overview of key findings from the study.

"Flood Mitigation remains a top priority for The City of Calgary."
(Utilities and Corporate ServicesCommittee, April 2017)

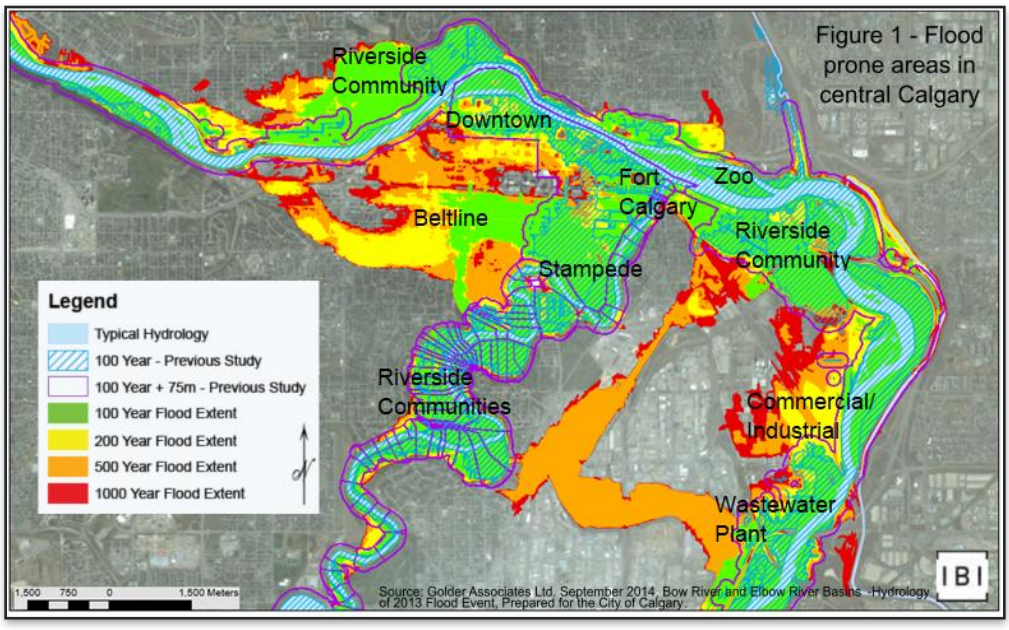
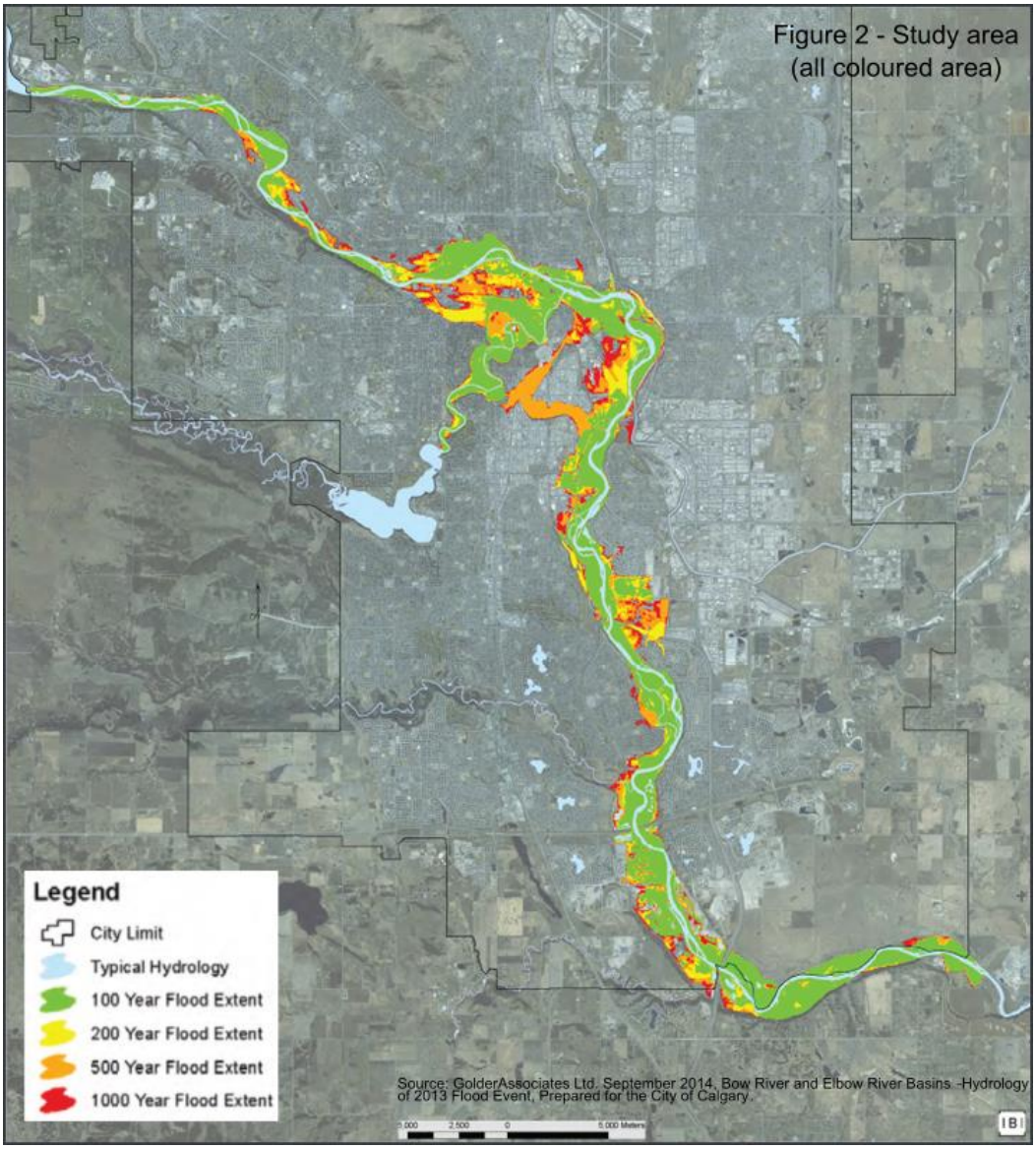


Figure 1 - Flood prone areas in central Calgary

The Flood Damage Model

Understanding the impacts of flooding is a crucial part of mitigating against the hazard. One way to understand the impacts is to create a flood damage model. In general, a flood damage model calculates the depth of flood water at every property for various sized flood events. It then calculates the estimated damage based on the flood depth, current land use and infrastructure on that property. Where possible, The City's model also calculates a financial value for environmental and social impacts of flooding, which provides a more holistic evaluation of flood impacts.

The City's flood damage model is an updated version of a model previously created by IBI Group and Golder Associates for the Province of Alberta (AEP, 2014). The area considered in this study (Figure 2) encompasses all of the flood prone areas within the city limits on the Bow and Elbow Rivers, up to a 1:1000 year flood.



A 1:100 year flood has a 1% chance of occurring in a given year, and a flow rate of 2820 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:200 year flood has a 0.5% chance of occurring in a given year, and a flow rate of 3520 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:500 year flood has a 0.25% chance of occurring in a given year, and a flow rate of 4600 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:1000 year flood has a 0.1% chance of occurring in a given year, and a flow rate of 5600 m^3/s on the Bow River downstream of the Elbow confluence.

Scenario Analysis

The study used the flood damage model to assess the flood risk in Calgary with and without mitigation. Without mitigation measures, such as those put in place since 2013, the average cost of flooding in Calgary would be nearly $170 Million per year. This value is the cost of damages from all floods that could happen (large and small), averaged out as annual payments. This amount is called the “average annual damages” (AAD).

With the existing mitigation in Calgary, including the projects currently under construction in 2017 (e.g., the flood barrier in West Eau Claire/downtown and upgraded gates on Glenmore Dam), the average annual damages have been reduced by 30% to $115 Million per year. This significant reduction in flood risk has been a notable achievement for our city, with support from citizens and The Province.

The remaining risk of $115 Million per year is still high. The study also explored a number of mitigation scenarios to further reduce potential flood damages. Each scenario is a plausible combination of options that can prevent flooding in communities, or remove buildings and people from harm’s way. The process for selecting mitigation scenarios for consideration involved an initial screening of options, taking into account local feasibility, functional reliability, financial efficiency, and environmental and social impact.

The resulting options considered for mitigation scenarios included:

- Watershed-level structural flood mitigation measures – new reservoirs and refined operations of existing reservoirs upstream of Calgary on the Bow and Elbow Rivers.
- Community-level structural mitigation – new flood barriers within Calgary, and
- Property-level and land use policy-based mitigation measures.

The results of this analysis include calculation of a cost-benefit ratio for each scenario, and the “residual” average annual damages that large floods could still cause, even with the proposed mitigation measures in place. The following table shows the results of the analysis. A full description of each of scenario is provided in the full report.

The technical information used for each measure, such as size, location and conceptual cost, was based on other technical studies, such as The City’s Permanent Flood Barrier Protection Assessment (2017), and The Province’s Bow River Working Group (report submitted in 2017), of which The City has been an active member. A protection level to the 1:200 year flood (which has a 0.5% chance of occuring in any year) was selected for the assessment, to evaluate the feasibility of protecting beyond the current provincial standard and to address future climate uncertainty.

The City’s ongoing improvements to forecasting and emergency response were included in all scenarios.

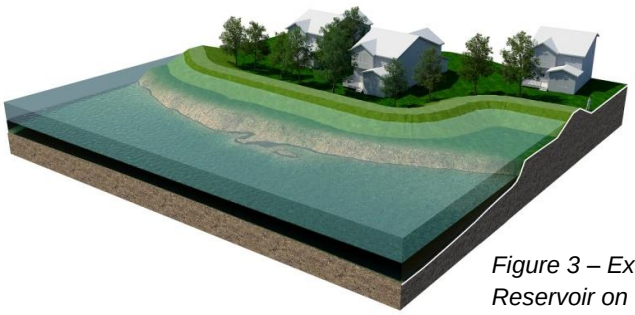


Figure 3 – Existing Glenmore Reservoir on the Elbow River (left) and conceptual flood barrier in a residential community (right).

Summary of Scenario Analysis

All scenarios include the flood protection provided by:

- Glenmore Dam, including the upgraded gates.
- TransAlta agreement with The Province to operate reservoirs in the Bow River system for flood mitigation.
- Existing and under-design barriers as of 2016 (e.g., Stampede, Zoo, West Eau Claire, Heritage Drive & Glendeer Circle, Centre Street Bridge, Bonnybrook, Deane House).
- Existing stormwater outfall gates and stormwater management plans.
- Existing flood forecasting and emergency response plans (including temporary flood barriers).

Scenario	**Capital Cost**	**Benefit-Cost Ratio***	**Residual Average Annual Damages (AAD) – per year**
Existing (Baseline) – does not include the TransAlta operational agreement	N/A	N/A	$115 million
1**) Springbank Off-Stream Reservoir** (SR1) on the Elbow River	$510 million	3.22	$45.2 million
2) **Springbank Off-Stream Reservoir** (SR1) on the Elbow River and a new **reservoir on the Bow River**	$1.41 billion	1.35	$31.8 million
3) **Elbow River barriers** below the Glenmore Dam and a **Bow River reservoir**. Total length of the barriers is estimated at 14.6 km.	$1.80 billion	1.06	$44.7 million
3a) **Scenario 3 plus groundwater controls** included with the barriers.	$1.96 billion	1.08	$38.2 million
4) **Springbank Off-Stream Reservoir** (SR1) **and Bow River barriers** (no upstream reservoir on the Bow). Total length of the barriers is estimated at 30 km.	$900 million	2.53	$34.6 million
4a) **Scenario 4 plus groundwater controls** included with the barriers.	$1.13 billion	2.09	$28.8 million
5) **Elbow River barriers** below the Glenmore Dam and **Bow River barriers** (no upstream reservoirs). Total length of barriers is estimated at 44 km.	$1.32 billion	1.69	$45.6 million
5a) **Scenario 5 plus groundwater controls** for barriers.	$1.75 billion	1.55	$31.9 million
6) **Buyouts** of all residential properties in the 1:200 year floodway (980 properties)	$1.81 billion	0.47	$88.8 million
7) **Upstream reservoirs on the Bow and Elbow Rivers with 1:25 barriers** for Downtown, Sunnyside and Bowness on the Bow River. Total length of the barriers is estimated at 4.5 km.	$1.45 billion	1.33	$31.5 million
7a) **Scenario 7 without reservoir on the Bow.**	$547 million	3.07	$43 million

Scenario	Capital Cost	Benefit-Cost Ratio*	Residual Average Annual Damages (AAD) – per year
8) **Scenario 7 plus groundwater control** for Sunnyside and a 1:200 level barrier for the downtown core.	$1.47 billion	1.32	$31 million
8a) **Scenario 8 without upstream reservoir on the Bow.**	$569 million	3.02	$43 million
9) **Scenario 8a with higher barriers** (1:100 for Bowness/Sunnyside and 1:200 for Inglewood/Downtown).	$658 million	2.84	$38.6 million

**Note: The benefit-cost ratio does not reflect the benefit/cost of individual measures, but of all the measures included in the scenario working together. The benefit-cost ratio is all benefits over the life of the project (100 years was used in the analysis) divided by all costs over the life of the project (100 years).*

Benefit-cost ration (B/C Ratio) = Benefits / Costs. If the B/C Ratio is greater than 1, the scenario is cost-beneficial. If benefits equal costs, the B/C Ratio = 1, and the project will "break even". If benefits are less than the costs, the B/C Ratio is less than 1.

Sustainability Assessment

In addition to technical analysis using the flood damage model, a sustainability assessment was conducted for each mitigation scenario.

Mitigation scenarios were evaluated through technical analysis, sustainability assessment and public engagement.

Each flood mitigation scenario was evaluated in the areas of social well-being, environmental protection, economic well-being and ease of implementation (Figure 4). Each theme area was equally weighted. The criteria within each area, their assigned individual weightings, and the scores for each mitigation scenario were determined based on:

- Feedback from public engagement.
- Subject matter expertise from across *several City departments.*
- *IBI Group and Golder's expertise.*
- *The City's Triple Bottom Line Policy, Sustainability Direction, Sustainability Appraisal Tool* and watershed goals, and
- Best practices in sustainability analyses.

Significant community and stakeholder engagement work was undertaken to inform the study (e.g. development of the sustainability criteria, scenario evaluation) and the direction of The City's future mitigation work. Public engagement activites included:

- Community Advisory Group (flood-affected and non-flood-affected citizens who met throughout the duration of the project).
- Telephone survey (randomized third-party) on values around the river, flooding, mitigation and development, and
- Public booths, workshops and open houses (11 events city-wide).

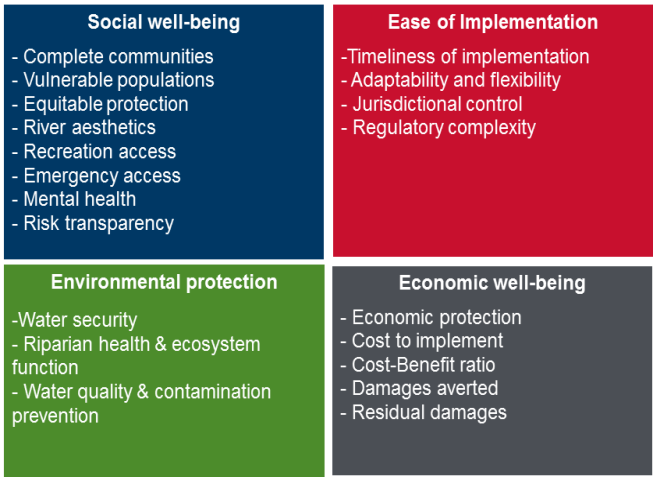


Figure 4 – Flood mitigation scenario sustainability assessment criteria

At the end of the study, The City also reconvened with the Expert Management Panel on River Flood Mitigation, established after the 2013 flood, to gather their perspectives on how the assessment's recommended approach aligned with the Panel's original vision and recommendations.

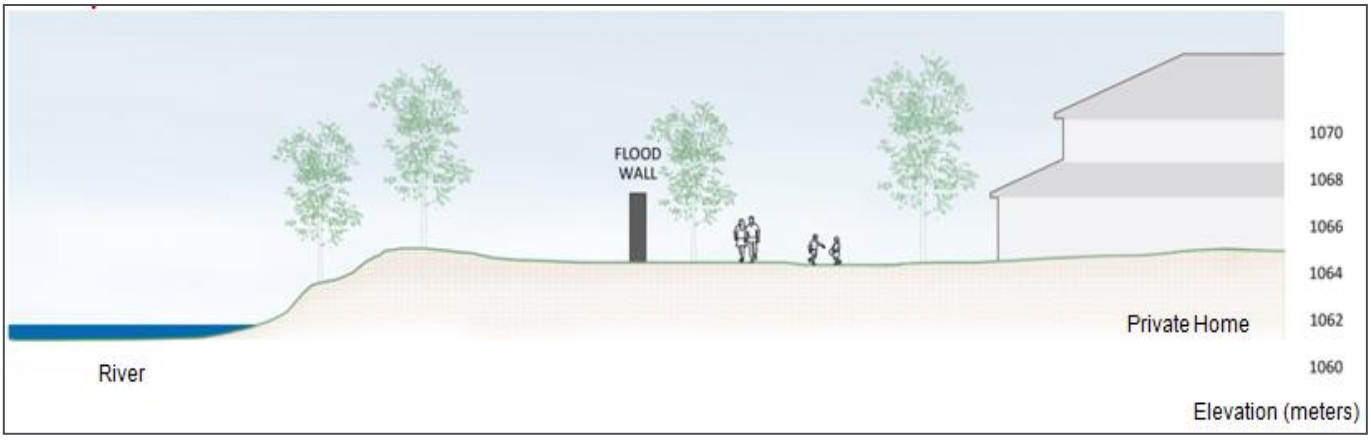


Figure 5 – Social and environmental impacts of 1:200 year flood barriers (illustrated here) were evaluated.

Results and Recommendations

The assessment provided a multi-faceted and robust evaluation of the opportunities and challenges associated with each potential mitigation scenario. Under the Sustainability Assessment, upstream mitigation (reservoirs) scored highest due to:

- Potential climate adaptability and water security benefits.
- Geographical extent and equitability of protection along the entire river downstream of the reservoir, and
- Lower level of community disruptions compared to large barriers.

The study identified that because community-level flood barrier projects are within The City's jurisdiction, they can be constructed more quickly than watershed-scale projects such as reservoirs, which is a benefit.

The study also highlighted the drawbacks of each mitigation measure. Every mitigation measure is designed to protect against a certain sized flood, and can be overtopped by rare larger events. Dams and reservoirs cause significant environmental impacts, take years to plan and construct, and have a small chance of catastrophic dam failure, although this is mitigated through rigourous dam safety legislation in Alberta. Barriers (such as illustrated in Figure 5) lack any protection benefits for events larger than the design flood, are aestheticly and environmentally intrusive; may not protect against groundwater flooding, and cannot provide opportunities for drought management, energy generation, or recreation.

To address the deficiencies of each individual measure, and to provide adaptability for future climate uncertainty, multiple or redundant defences can be used to create a layered approach for increased resiliency. Scenarios that included upstream reservoirs and complementary low-height barriers scored higher than fortification of the rivers by barriers alone or upstream reservoirs alone. This aligns with concepts of integrated watershed management and integrated flood risk management, which aim to manage the watershed as a holistic system and create climate adaptable resilience.

The mitigation scenario including upstream reservoirs on the Bow and the Elbow, small barriers at specific locations along the Bow (to achieve equivalent level of protection) and complementary non-structural measures had among the lowest residual average annual damages, and a robust #1 ranking for sustainability.

Scenario 1
The study results showed that the Springbank Reservoir (SR1) on the Elbow River removes a significant portion of flood risk, as does the current 5-year agreement between the Government of Alberta and TransAlta to operate the Ghost Reservoir on the Bow River for flood mitigation. Together, these measures reduce the city-wide flood risk by another 30%. This scenario has a very high benefit-cost ratio of 3.2. It does, however, leave a high residual risk ($45.2 Million per year), largely on the Bow River, as the level of protection provided in this scenario is not as high on the Bow as the Elbow.

Scenario 2
To further reduce risk on the Bow, the potential mitigation benefits from an additional (new) reservoir on the Bow River was modelled upstream of Calgary. This change increases the capital cost significantly, but lowers the residual annual average flood damages to $31.8 Million per year.

Scenarios 3, 3a, 4, 4a, 5 and 5a
These scenarios investigated mitigating flooding using barriers on each river without having an upstream reservoir to provide additional mitigation. Residual average annual flood damages were between $28.8 and 45.6 Million per year. The costs, however, were similar or higher than building reservoirs. This is due to the amount of private land that would have to be aquired along the river to accommodate barriers large enough to mitigate against flooding because upstream reservoirs are not in place. Scenarios involving large flood barriers scored low on the sustainability analysis, however, largely due to the social and environmental impacts of constructing large permanent barriers, in a few cases up to 6m high, along the rivers.

Scenario 6
Buyouts of properties in a hypothetical floodway based on a 200-year flood were assessed as a mitigation solution. The results showed this measure is one of the most costly, even though it did not provided mitigation to all properties at risk of flood damage. While the study acknowledged flood damages would be completely eliminated for the bought-out properties, the high cost of purchasing the properties made it the only scenario that was not cost-beneficial. Further discussion on property buy-out is included in the following section.

Scenarios 7, 7a, 8, 8a and 9
After reviewing public input and the results of the first six scenarios, Scenarios 7, 7a, 8, 8a and 9 were developed to assess combinations of reservoirs and barriers on the Bow River. Because a new reservoir on the Bow River would likely still not provide enough flood water storage to mitigate a 2013-sized flood event, and because of the long timeframe to explore and build such a reservoir, complementary barriers were modelled along the Bow. These barriers were modelled in locations where extra measures are required in addition to a reservoir, to achieve equivalent levels of protection to that committed to on the Elbow River.

While the addition of these barriers increase the cost of these scenarios, it also increases benefits correspondingly, and increases the equitability of protection for all at-risk Calgary communities. These scenarios were ranked the highest out of all of the options.

Non-Structural Options

In addition to structural mitigation measures such as reservoirs and flood barriers, the study also evaluated potential non-structural measures that can reduce future flood damages in Calgary. It identified feasible measures and generalized costs and benefits. The measures identified form a basis for The City's ongoing work exploring policy and land use based flood resiliency measures.

Contingency Measures

These measures include forecasting and warning systems, keeping citizens educated and updated, emergency response planning and enhanced connections and partnerships. These methods are highlighted as being essential, flexible and low-cost.

Land Use Regulations

The study acknowledges that while not developing in a floodplain eliminates flood damages, historic development patterns have led to a complex relationship between cities and floodplains, and the social and economic value of development in floodplains is significant.

The study identified basement damages as a significant risk, even with current or stricter building flood proofing regulations. Over time, basement damages could be reduced by implementing regulations that eliminate development of below grade space, prohibiting habitable space (such as bedrooms or suites) in basements, and requiring sump pumps and sewer backflow preventers in all flood prone areas.

Further investigation of the costs and benefits associated with specific potential land use regulation changes is recommended.

Property Level Mitigation/Floodproofing

Property level mitigation is described by the researchers as being cost-effective and keeps flood readiness front of mind for citizens. The emphasized options include incentives for sump pumps and backflow preventer valves. Other options include higher elevation of main floors, basement removal or finishing basements with materials that are easy to clean after floods, and property-level flood protection such as berms and flood gates for commercial and larger buildings.

Exploration of property level mitigation is recommended in combination with structural measures, and can significantly reduce private property damage from groundwater, sewer back-up and overland flooding. Public engagement demonstrated an interest from Calgarians for more public education on reducing flood risk and financial incentives for private property owners to flood proof homes and other buildings. The Assessment recommended that The City explore the development of an incentive program for property level measures with a supporting education program.

Flood Insurance

The study suggests that flood insurance should not be relied on to achieve acceptable levels of protection. The costs and levels of risk involved suggest that premiums for unmitigated homes are not viable for most property owners. Insurance is a tool to redistribute the financial risk of flooding, not prevent flood damages.

What about buying out properties at risk?

Property ownership and development within Calgary's floodplain is diverse, spanning many land uses and demographics. The cost of buying out all properties at flood risk in Calgary and converting them to parkland is extrodinarily high (over $2 Billion) – far more costly than any other mitigation option assessed.

Not all properties have to be bought out to reduce future flood damages. Buying out select properties, however, leaves many other properties still in need of protection. The fincanical and social implications of buying properties must be considered very carefully.

There are also ways to alter how Calgary develops that can decrease flood risk – for example, restricting land uses that would be at most risk during a flood, and protecting high-value riparian areas. The City is exploring or already implementing such options.

Currently in Calgary, no new development is allowed in the floodway, and development in the flood fringe must be flood-proofed. The City continues to investigate the costs and benefits of removing or further restricting development in Calgary's floodplain.

What's Next: The City's River Flood Mitigation Strategy

Based on the results of this study and other work undertaken since 2013, The City recommended an informed flood resiliency and mitigation strategy, which was approved by Council in April 2017. Subsequently, an implementation plan was approved by Council in June 2017 that outlined a combination of watershed and community level mitigation that allows flexibility and adaptability in managing flood risk.

The recommended scenario is Scenario 8, which has the lowest residual average annual flood damages, and provides the most timely and equitable protection to communities at risk of flooding from the Bow and Elbow Rivers.

Recommended Scenario: #8

- Upstream reservoirs on the Bow River (upstream of Calgary) and Elbow River (SR1).
- Low-height barriers for Sunnyside, Bowness and Pearce Estates on the Bow River.
- 1:200 barrier for the downtown core.

While The City of Calgary can implement some mitigation measures within its jurisdiction, it is essential that upstream mitigation is built to provide the level of protection needed for Calgary. The City will continue to support and advocate for upstream mitigation on both the Elbow and Bow Rivers.

As approved by Council, work is already underway to fund, design and construct barriers to complement a potential new reservoir on the Bow River that would achieve equitable protection for all at-risk communities across the city.

The City has implemented several lessons-learned from the 2013 flood, and continues to improve forecasting, emergency response, citizen education and communication, and preparedness for citizens, businesses and city departments.

Other non-structural solutions, such as policy, regulations, education, incentives and selective property buyouts are being explored to complement structural measures and provide further flood resiliency for Calgary.

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Government of Alberta. Springbank Off-stream Reservoir. http://www.transportation.alberta.ca/sr1.htm

The full Flood Mitigation Options Assessment report can be requested by contacting 311.

For more information on flooding in Calgary, resiliency and mitigation,
please visit www.calgary.ca/floodinfo or contact 311.