Mitigating Calgary, Alberta's Vulnerability to Flooding:
Strategies to Reduce Negative Impacts to the Built Environment

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Introduction

Floods are a regular part of river and floodplain life. This change event has several possible benefits, such as spreading nutrients across fertile agricultural lands. However, when a city is located within a floodplain, some of these potential environmental benefits can become liabilities for the built environment. A flood resilient city is one that can adapt to, and mitigate against, frequent flooding to a point where normal life can continue before, during, and after a flood event.

Flooding within the City of Calgary, Alberta is a long-term problem that has negatively impacted the built environment. This paper strives to recommend approaches that will enable the city to become more flood resilient. This task will be accomplished by asking and answering a series of six questions:
1) What values or assets do you want to protect or enhance? 2) What are the apparent risks or opportunities for enhancement? 3) What is the range of risk-reduction or opportunity-enhancement strategies available? 4) How well does each strategy reduce the risk or enhance the resource? 5) What other risks or benefits does each strategy introduce? 6) Are the costs imposed by each strategy too high?

Ultimately, the paper recommends the increased use of natural landscaping, low impact development (LID), dry flood proofing around essential buildings, and the diversion of floodwaters around the downtown core through a multifunction flood diversion channel. This strategy could be implemented in three phases and would primarily help mitigate impacts to the built environment from the smaller, more frequent floods. In addition, this strategy could also be utilized to reduce some of the vulnerabilities from the more severe, less frequent flood events that Calgary, and many other cities, face.

Characterizing the Change Event

To better answer the six questions listed in the introduction, it is important to first understand the change event impacting Calgary. In the summer of 2013, a severe flood swept through Calgary and became known as the worst natural disaster to ever hit the city.[1] The floodwaters reached the tenth row of the city’s hockey rink (approximately 15 feet), killed three people, washed out streets, damaged homes and businesses, and forced the entire downtown to evacuate.[2] Floods of this magnitude are rare in Calgary, with the last occurring in 1932.[3] However, smaller scale floods occur frequently, and minor floods occur almost every year in different regions of the city. These floods can inflict significant damage on homes and businesses,[4] and will be the central focus of this paper’s mitigation recommendations.

1. What values or assets do you want to protect or enhance?

Calgary is situated in southern Alberta between the foothills of the Canadian Rockies to the west, and the Canadian Prairies to the east. This paper concentrates on protecting the built capital within the downtown core of the city. An area of roughly 750 acres, bounded by 14 Street Southwest to the west, CPR mainline tracks south of 9 Ave SW to the south, the Elbow River to the east, and the Bow River to the north.[5]

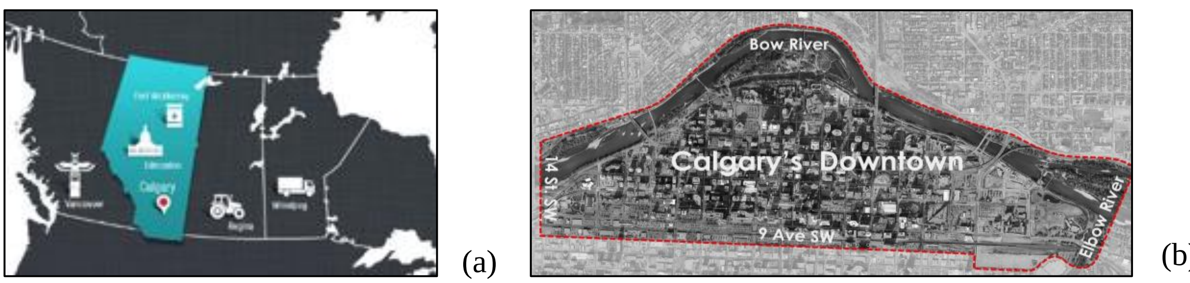


Figure 1. a) Location of Calgary within Alberta [6]; b) Study Area

2. What are the apparent risks or opportunities for enhancement?

The Bow River originates from the Bow Glacier in the Canadian Rockies, flows southeast into Calgary and ends in the South Saskatchewan River. The Elbow River begins in the Canadian Rockies Elbow Lake, flows northeast into Calgary, and merges into the Bow River. The confluence of the two rivers is situated at the northeast corner of downtown Calgary, where there is a high concentration of built capital and dense human populations. The confluence of the river exposes downtown to several vulnerabilities.

According to the 2011 Census, the residential population of the study area is 16,281.[7] In addition, there are over 140,000 people who work in the 3,500 businesses, 1,000 retail stores, and 173 commercial office buildings.[8] When the downtown floods, these individuals must be evacuated, businesses must close, and facilities suffer damage from the floodwater. In 2013, downtown Calgary had approximately 3,000 buildings flooded, which negatively affected over 4,000 businesses. The city's transportation and parks were also shut down,[9] and initial damage estimates to the city's infrastructure were $445 million.[10]

In regards to Calgary's capability to respond to flooding, its current flood management plan focuses primarily on flood recovery and flood preparation. After the 2013 flood event, Calgary identified over 200 flood-related infrastructure recovery projects in parks, public pathways, and buildings located along the river.[11] To better support both the recovery of residents and property owners, the local and provincial governments have also begun several public flooding support programs that include a "property tax relief program" that encourages flood preparation.[12] This paper's recommendations capitalize on this program and incentivize natural landscaping and LID on a private, individual scale. Additionally, the city utilizes flooding simulations and provides flooding maps to the public to help forecast and make the public aware of potential future floods.[13] This system could be used to disseminate information and warnings prior to a flood event. The goal of this paper is to propose strategies that fit within this established framework.[14]

3. What is the range of risk-reduction or opportunity-enhancement strategies available?

There are a wide range of risk-reduction strategies that are available to Calgary and other cities in similar situations. First, Calgary could invest its time, energy, and money into levee creation. This has not been a selected option in the past, although this structural option to control the frequency of flooding is available.[15] Other mitigation strategies that have been implemented in other cities include relocation, elevating buildings, and accommodating floods by removing assets from the first floor of buildings.

The preferred alternative is to utilize vegetation and LID to reduce the severity of flooding through tree trenches, rain gardens, bioswales, green roofs, infiltration trenches, and porous pavement. The paper also recommends diverting floodwater from the Bow River around the study area to the Elbow River downstream through a flood diversion channel. Finally, dry floodproofing essential buildings are advocated as a last line of defense against floods that overwhelm the capacities of LID and the channel.

The study area scale considers the entire downtown as one unit, and attempts to protect as much of it as possible (Figure 2). This strategy would need to be managed by the city, as they can afford to see the big picture. A block scale considers which of the individual LID approaches enumerated above could be

Figure 2. Illustration of how a study area scale approach could ideally look.

implemented around particular buildings or blocks (Figure 3). The local government may need to kick-start this strategy using public property for pilot projects, such as installing green roofs on government buildings, or resurfacing municipal parking lots with porous pavement. Utilizing the property tax relief program or new ordinances to incentivize private individuals, may also be necessary. It would also be a task of the local government to retrofit the railway below 9th Ave into a diversion channel to help infrastructure survive severe floods.

Figure 3. a) Aerial view of potential block; b) Potential parking lot; c) Potential tree trench in ROW

The final phase of the strategy would include scaling the approach up to include the entire city, and focusing on upstream and downstream water retention. Increasing upstream water retention could drastically reduce the Bow River discharges, and thus the flooding potential for Calgary. Increasing downstream water retention would help mitigate any potential negative downstream effects from diverting Bow River overflow to the Elbow River through the channel (Figure 4).

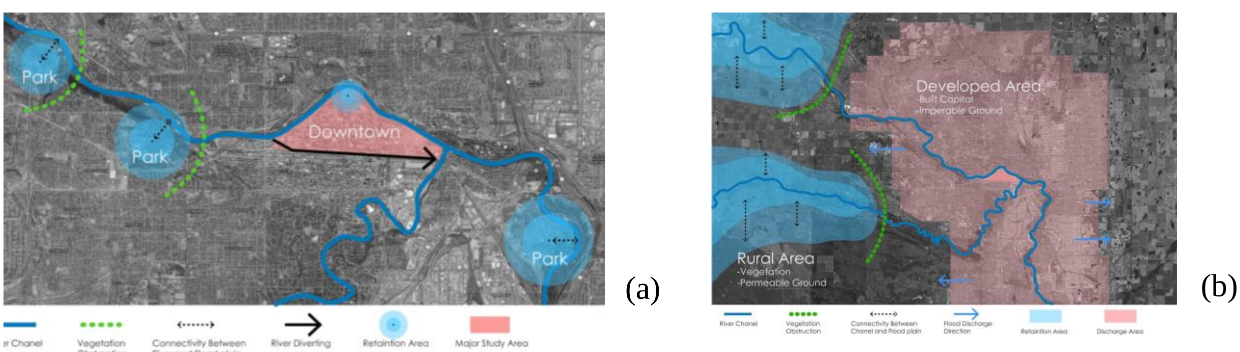


Figure 4. a) Scaling up within the surrounding downtown area; b) Strategy scaled up for the entire city

4. How well does each strategy reduce the risk or enhance the resource?

While most residents would like full structural protection from floods, this is not always possible or financially feasible. Though levees can reduce the frequency of flooding, they cannot prevent high severity floods from breaching the walls. Additionally, levees are expensive, averaging between $4,000 and $19,000 per linear foot.[16] Elevating structures are more affordable and feasible for smaller buildings, but this approach would not be appropriate for the study area as it consists of dense, high rise buildings.

Constructing vegetated buffers around the rivers and LID projects throughout the study area could significantly reduce flood vulnerabilities to the study area's built capital. These approaches would address aspects of both flooding frequency and severity by attempting to mimic more "natural" hydrological cycles within the urban environment. Studies have shown that natural riparian buffers, riparian forests, and wetlands surrounding surface water bodies work to absorb potential floodwater as it flows into urban areas. It works by allowing the water to spread out further horizontally in space to give the soil and vegetation a chance to absorb or slow the water before it reaches, and can negatively impact, the built capital. LID can still be utilized to reduce flood severity even if it is located at further distances away from the rivers. Vegetation, no matter its location, utilizes several thousand gallons of water and this works to reduce the amount of water that can impact buildings.[17] Rain gardens, biowsales, infiltration basins, and tree trenches along the right-of-way of streets can capture and store potential floodwater.

These systems work to slow, reduce, and direct floodwaters away from the built capital. Buffers and LID projects can also work to filter contaminants before the floodwater flows back into the river, provide soil stability to prevent erosion and sedimentation that could increase the chances of floods, and absorb some energy from floods.[18] The riparian buffer could be enhanced along the Elbow and Bow Rivers, although this may not be feasible due to private land ownership in the area.[19] LID is possible through incentives.

5. What other risks or benefits does each strategy introduce?

While a levee can reduce the frequency of flooding, it can also increase the severity of the floods that do come. Further, a levee high enough to protect against a 100 or 500 year flood event may become so high that the residents can no longer enjoy the recreation and aesthetic benefits of living along a river. To elevate every downtown building several feet may be structurally unfeasible, and expensive. Such actions could also significantly limit street level interaction between buildings and downtown pedestrians, a crucial connection for the prosperity of downtown businesses.

In addition to acting as a "sponge" for potential flood and stormwater runoff, LID provide other benefits such as filtering out contaminants from surface run-off, aesthetic beauty, habitat for non-human species, sequestering greenhouse gases, and slowing car traffic.[20] However, as with any other flood protection strategies, relying on only one can be risky. There is a limit to soil's capacity to store water, and once soil is saturated, the LID projects can become overwhelmed. Therefore, this paper also recommends dry floodproofing essential buildings and allowing the railway to be used as a diversion channel during extreme flood events. LID can be effective for mitigating the impacts of frequent, minor flooding, although dry floodproofing and a floodwater corridor are necessary to increase the capacity of the city to mitigate against the risks of more severe and rare floods.

6. Are the costs imposed by each strategy too high?

The economic and social costs associated with constructing levees and elevating buildings are very high. Additionally, public opinion does not currently exist to force the government to make such drastic decisions. The costs to implement LID projects, dry floodproofing, and to convert the railway corridor to a dual-purpose rail and floodwater channel could also be expensive. Installing LID projects over one residential block in the city of Seattle, for instance, cost approximately $850,000. Therefore, the paper recommends that implementation of the above strategies be phased to spread out costs.

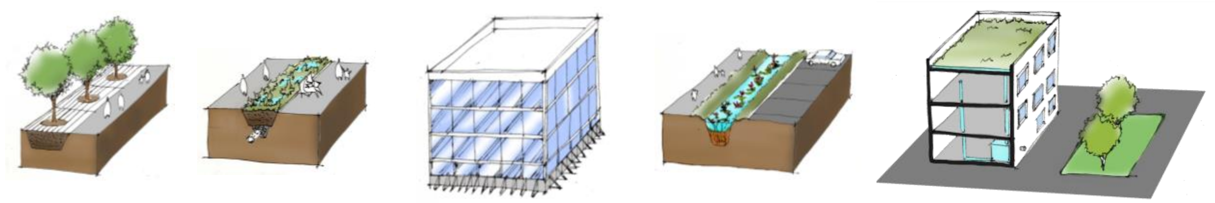
Mitigating Flood Related Risks to the Study Area

Phase 1 → Focus on the downtown-scale within government owned properties:

- Enhance riparian buffers along the rivers by planting more vegetation to increase density. Enlarge total buffer width, where possible, through land acquisition or conservation easements.
- Divert floodwater from the Bow River at 14th Street SW through the 9th Ave SW railway into the Elbow River during major flood events. Floodgates will be constructed at the mouth of the railway to reduce the flow of water that could pass through the study area's built capital during severe floods.

Before the gates are opened, an early warning system must alert train workers and parking lot users to evacuate the area. The railway corridor should be lowered to keep the diverted floodwaters within the channel, with the help of constructed berms along the corridor. The current infrastructure, including the rail track, should be retrofitted to ensure that the materials will not contaminate the natural capital downstream. Installing vegetated surfaces between the tracks and the parking lots, and porous pavement within the parking lots can reduce total floodwater, and help filter out harmful pollutants before the diverted water is released into the Elbow River.

- Create a network of natural landscaping /LID projects within the public right-of-way, including tree trenches, rain gardens, and bioswales. The narrower sidewalks should utilize tree trenches, while the wider ones should utilize rain gardens and bioswales.
- Resurface municipal parking lots using permeable pavement to allow for water infiltration and storage. Use bioswales along the parking lot peripheries and parking spaces medians.
- Construct green roofs on top government-owned buildings, and dry floodproof the first floor.



(a) (b) (c) (d) (e)

Figure 5. a) Tree trenches on the individual scale; b) Infiltration trench and rain garden within a sidewalk; c) Dry floodproofed building; d) Bioswale lining parking lot; e) Green roof

Phase 2 → Encourage implementation of block/building-scale strategies on privately-owned properties:

- Encourage/incentivize property owners to construct green roofs, resurface private parking lots, construct bioswales, and plant natural landscaping along any private sidewalks, in the form of tree trenches and rain gardens.
- Encourage/incentivize property owners to take secondary protective measures during major flood events using dry floodproofing strategies, such as temporary flood walls.

Phase 3 → Expand strategy to rest of the city and increase water retention up and downstream of city:

- Scale up implementation of LID and natural landscaping throughout the city.
- Create open space upstream to allow for more water storage.

Conclusion

This paper has made the above recommendations to help mitigate the city's flood vulnerabilities. This approach attempts to emulate a more natural hydrological system that circulates water through the city's open space, soils, and rivers instead of through the built capital. As explained above, this strategy is cost-effective, feasible, and within the city's current framework of flood reduction strategies.

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