CALGARY'S FLOOD RESILIENT FUTURE

Report from the Expert Management Panel on River Flood Mitigation

June 2014

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FOREWORD

In June 2013, Calgary and southern Alberta experienced the region's most severe floods since the early 1900s. Water levels and flows increased far beyond what was experienced during the last major flood in 2005. Large areas were inundated to depths never before seen; power supplies to large sections of downtown and residential areas were shut off; roads and light rail transit lines became impassable. Normal activities in the city stopped or changed significantly for the majority of Calgarians.

As the waters receded, an amazed populace took in the degree of the devastation. Homes, cars and valuables were damaged or destroyed. Offices, restaurants and shops were closed. Travel was difficult or halted in many areas. Extensive resources were mobilized by The City and the Province and an army of volunteers sprang up to deal with the immediate aftermath, trying to restore some semblance of normalcy. There are many for whom this event was devastating, both emotionally and financially, and who still struggle with the lingering impacts nearly a year later.

As the recovery process proceeded, Calgarians asked many questions, such as: How can we prevent this from happening again? What could we have done differently? When will it happen again? Is this normal or caused by a changing climate? How can I protect myself from future flooding?

The City of Calgary determined that a broad investigation of flood mitigation issues and responses was required. The City also decided that the investigation should be carried out by an arms-length body of experts who would bring to bear the most current knowledge available on these issues and who would extensively involve the public in their work. The River Flood Mitigation Program was established on those terms.

In order to lead the effort and to provide strategic direction, The City formed an Expert Management Panel as part of the mitigation program. The Panel gathered the input of many scientific and engineering experts, wide ranging public input and support from a number of City staff; from that, the Panel developed this report.

The report presents recommendations for making Calgary more resilient and prepared for future events. While the focus is on Calgary-specific measures, implementing the recommendations does not negatively impact communities outside of Calgary. To ensure there was coordination of these larger considerations and of the major investments being contemplated, Program staff have worked closely with the Province's Flood Recovery Task Force and other agencies and stakeholders.

Mitigating flood risks will not be achieved through a one-time report and set of recommendations. This report points to a way forward and contains only a few detailed actions. It outlines opportunities and also identifies where there is little to be gained – channeling future resources into appropriate areas. Much work will flow from this report and will have to be carried out by The City over time, often with provincial cooperation to achieve the desired outcomes.

History shows that following through on recommended changes in the time after a disaster is always a challenge. Memories fade, other priorities arise and the will is lost to do the things that need doing. We encourage all parties to keep the financial and human costs of this event in mind and to maintain the determination to make Calgary more able to withstand, what will inevitably be, the next flood.

I want to note here my personal thanks for everyone's valuable advice and commitment to the mission. One could not have expected more.

Wolf Keller
Chair of the Expert Management Panel
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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Although the 2013 flood was the largest in recent memory, historical records indicate that Calgary experienced floods of similar magnitude in 1879, 1897 and 1932. The impacts of these earlier floods were less severe because Calgary was not as densely developed at the time. There will always be a risk of flooding within the floodplain and a flood larger than the 2013 flood will likely occur in Calgary's future. While future floods cannot be prevented, action can be taken to better ensure public safety and minimize flood damage. Urban centres around the world are challenged by the need to improve resiliency to extreme floods; best practices from a number of these cities can help inform Calgary's ongoing resiliency efforts.

Without effective flood response measures during the 2013 flood and, flood-resiliency efforts that followed the 2005 flood, damage to Calgary in 2013 would have been even more devastating. Despite protective measures, the city experienced major flooding, required extensive evacuation, saw its downtown core rendered inaccessible for days and had significant flood damage to both private and public property. Damage estimates range into the billions of dollars.

Following the flood of 2013 The City of Calgary has been repairing damage, restoring services and making sure it is better prepared for the next extreme flood. The City established the River Flood Mitigation Program to recommend ways of managing future river flood risks in Calgary. Dialogue with Calgarians was a priority and included numerous community open houses and meetings with groups representing flood-affected communities. Close coordination with the Province allowed work plans and recommendations to be aligned. To guide the program, The City formed an independent Expert Management Panel who identified six theme areas to guide the development of recommendations.

This report presents recommendations from the Panel in six action areas that emerged across the six themes. The Panel also identified actions that it does not recommend The City undertake. In addition to the recommendations, the Panel identified major findings from each of the six themes investigated.

MAJOR FINDINGS FROM THE SIX THEMES

Managing flood risk

- Living in a floodplain has inherent risks, which can be managed, but they can never be eliminated. As seen in the flood of 2013, the level of flood risk in Calgary is unacceptably high and it is time to invest in better managing that risk.
- Increasing the level of flood protection would result in less damage, disruption and risk to human life when flood occurs. Investing in greater flood protection will be expensive and may be disruptive.
- In some cases it is more practical to move development away from the water than to move water away from development. Relocating people, homes and businesses is inherently a painful process for a community, but it needs to be considered as part of an overall plan.
- Informing and communicating with Calgarians about flood risk requires relatively little investment and can provide a large benefit for individuals and communities.

Watershed management

- The 2013 floodwaters were mostly generated in the mountains and foothills and the Bow and Elbow Rivers rapidly carried them to Calgary and beyond. Land-use within the Bow Watershed has only a small influence on this type of extreme flood.
- An integrated approach to watershed management is important to buffer smaller floods and so water supply, water quality and natural habitats are not compromised.

Event forecasting

- After the 2013 flood, Calgarians in flood affected zones expressed that they wanted earlier notification of future floods to better prepare themselves. Because of Calgary's proximity to the mountains where river floods originate, warning of actual floodwaters approaching can only be given in hours, not days.
- The 2013 flood demonstrated high uncertainty in forecasting due to the nature of Alberta's watersheds and weather patterns. Earlier warning can be given to citizens but it will inevitably give false alarms as weather systems shift unpredictably.

Storage, diversion and protection

- Existing dams and reservoirs in the Bow and Elbow watersheds have limited flood reduction potential and are managed to balance a number of watershed objectives. The existing storage on the Bow and Elbow Rivers was used to buffer the 2013 flood. If not for these reservoirs, the flood would have been much more severe in Calgary.
- There are opportunities for additional floodwater control. Modified operation of the TransAlta dams on the Bow River, three potential large-scale civil works on the Elbow River, and opportunities for new permanent flood barriers are subjects of further study by The City and the Province. An integrated analysis is needed to identify the best combination of flood mitigation measures on each river.
- The City has emergency plans for constructing temporary barriers in the event of floods of various magnitudes. Temporary flood barriers are not feasible in some areas because they would be required along lengthy stretches of private riverside property.

Infrastructure and property resiliency

- Many communities in Calgary were built before there were criteria for locating development outside of the floodway or designing properties for flood-resilience. As a result, much private development in the floodplain is inadequately built to withstand floods.
- Policy and planning changes can be used to build flood resiliency into City-owned and managed public infrastructure over time. Building resiliency into utility and communication infrastructure involves working in partnership with the private sector and may require significant investments.
- Many of the recovery projects undertaken by The City to repair damaged infrastructure after the floods of 2005 and 2013 have included measures to improve resiliency.

Changing climate

- Changes in the global climate system are expected to bring more frequent and intense weather events around the world, including to the Canadian prairies. The probability of experiencing extreme floods in the future could be greater than in the past.
- Flood mitigation work should be done with a view to several possible climate scenarios including drought. Design standards and mitigation measures should be versatile as part of a comprehensive approach to climate adaptation.

Building resilience to flooding requires action across many disciplines and organizations. The Panel worked particularly closely with several other initiatives critical to Calgary's flood resiliency to ensure efforts were coordinated: The City of Calgary Flood Recovery Task Force, the Calgary Emergency Management Agency and the Alberta Flood Recovery Task Force.

This report is one step of many towards greater resiliency to floods and other disruptive events in Calgary. The suite of recommended actions presents an approach that requires collaboration with the Province of Alberta and other stakeholders, and sets a direction towards Calgary's flood resilient future.

ACTION AREAS AND RECOMMENDATIONS

As potential flood mitigation measures were explored across the six themes, key recommendations emerged and were divided into six action areas based on common goals. The Expert Management Panel recommends that The City of Calgary undertake the following suite of actions as part of a multi-faceted approach to continue making Calgary more resilient to future river floods.

Immediate actions should be undertaken and completed as soon as possible.

Mid-term actions should be completed within The City's Action Plan 2015-2018.

Long-term actions should be initiated within Action Plan 2015-2018.

Ongoing actions are existing initiatives that should receive additional attention.

Through its investigation of potential flood mitigation measures, the Panel concluded that some options should not be considered further. The Panel **does not** recommend the following:

· Dredging the Glenmore Reservoir, the Bow or the Elbow Rivers, because of high costs, negative impacts, and a negligible effect on flood mitigation.

ACTION AREAS AND RECOMMENDATIONS	TIMEFRAME	PAGE
ACTION AREA 1: DEVELOP OPTIONS FOR PROTECTING COMMUNITIES, INFRASTRUCTURE AND PRIVATE PROPERTY TO A HIGHER FLOOD LEVEL.		
a. Perform a social, economic and environmental analysis to evaluate the need for a minimum flood protection level above the 1:100 flood currently used for land-use planning and structural protection across Calgary.	MID-TERM	19
b. Create graduated flood protection level requirements for City infrastructure.	MID-TERM	47
c. Expand the review of the Land Use Bylaw and other development regulations to update flood resiliency requirements for private property in flood risk areas.	MID-TERM	50
d. Strengthen partnerships with utility providers to improve resiliency of their infrastructure and operations, with first priority to energy supply and communication networks.	ONGOING	49
ACTION AREA 2: SUPPORT CALGARIANS IN MANAGING THEIR FLOOD RISK THROUGH IMPROVED NOTIFICATION, FORECASTING AND PREPAREDNESS.		
a. Pursue a common river forecasting platform with Alberta Environment and Sustainable Resource Development (AESRD) and TransAlta for faster and more accurate information and alerts about future flood events.	MID-TERM	32
b. In partnership with AESRD and TransAlta, expand the network of river and weather monitoring stations upstream of Calgary and protect stations from damage during flooding.	MID-TERM	31
c. Incorporate lessons learned from the 2013 flood to enhance communication channels to keep Calgarians informed of conditions that may lead to high river levels.	IMMEDIATE	34
d. Expand the flood risk communication strategy and provide information and tools that empower Calgarians to make informed choices and better manage their personal flood risk.	ONGOING	24
e. Develop programs that support building-owners to implement flood resiliency measures.	MID-TERM	51
ACTION AREA 3: AS PART OF AN INTEGRATED CITY AND PROVINCIAL PROGRAM, PERFORM SOCIAL, ECONOMIC AND ENVIRONMENTAL ASSESSMENTS OF CAPITAL WORKS OPTIONS TO INCREASE STORAGE, DIVERT WATER AND INCREASE PROTECTION.		
a. In partnership with the Province, compare the three major capital works options for mitigating floods on the Elbow River and identify the optimal investment plan: i. A diversion from the Elbow River to the Bow River, in accordance with the conclusions of the feasibility studies underway. ii. The Springbank off-stream diversion and storage site. iii. The McLean Creek dry dam.	MID-TERM	42
b. Increase the operating water storage capacity of the Glenmore Reservoir on the Elbow River through modifications to the Glenmore Dam.	MID-TERM	40

- Moving **all** development out of the floodplain, as Calgary is strongly established in some floodplain areas. Removal of buildings in strategically selected locations may be warranted where the risk is unacceptably high or the buildings prevent the construction of flood barriers that would protect the broader community.
- Investing in watershed stewardship actions in the context of a river flood mitigation strategy, because these actions would have minimal benefit in preventing alpine flood events. Watershed management is, however, recognized as critical for achieving other environmental objectives.
- Building permanent or temporary flood barriers directly along the shore of the Elbow River residential areas because of challenges with private property. Where critical stretches of riverside land are available and identified as appropriate for flood protection, flood barriers should be considered.
- Diverting floodwaters from the Bow River through the Western Irrigation District canal system at Harvie Passage, because the canal system would likely be damaged and does not provide the opportunity to divert significant flood volumes.
- Focusing climate adaptation planning exclusively on flood potential. Instead, a comprehensive approach allows many possible climate scenarios to be addressed, including the possibility of more severe droughts.

ACTION AREAS AND RECOMMENDATIONS	TIMEFRAME	PAGE
c. Continue to cooperate with TransAlta and the Province to increase flood storage on the Bow River through existing TransAlta facilities.	ONGOING	38
d. Construct additional or higher flood barriers in key locations throughout the city and update temporary flood barrier plans to protect against higher flood levels.	MID-TERM	44
ACTION AREA 4: MANAGE CALGARY'S FLOODPLAIN TO REDUCE IMPACT FROM RIVER FLOODS OVER THE LONG-TERM.		
a. Review The City's existing land-use planning documents and develop amendments, new guidelines or policies that will minimize development in the floodplain over time.	MID-TERM	22
b. Prepare a time-phased plan to modify structures that constrain river flow during flood events, such as pathways and bridges.	LONG-TERM	44
c. In partnership with the Province, develop a time-phased plan to remove buildings from areas with high flood risk, while minimizing the disruption to affected communities.	LONG-TERM	22
ACTION AREA 5: IMPROVE UNDERSTANDING OF FLOOD RISKS, PRESENT AND FUTURE.		
a. Publish up-to-date, graduated flood maps for public information.	ONGOING	21
b. Urge the Province to regularly review and update official flood hazard maps.	IMMEDIATE	21
c. Maintain a comprehensive flood risk database integrated with existing geographic information systems (GIS).	ONGOING	47
d. Develop a suite of watershed-scale climate models to capture various weather event scenarios, with input from regional partners, post secondary institutions and other levels of government.	MID-TERM	54
e. Collaborate with academic and other partners to develop computer models that identify groundwater movement in Calgary in relation to flood conditions.	MID-TERM	28
ACTION AREA 6: ESTABLISH A VISION AND FRAMEWORK FOR ONGOING FLOOD RESILIENCY ACTIVITIES FOR THE CITY.		
a. Establish a permanent team within The City to oversee flood preparedness and resilience.	MID-TERM	55
b. Connect with the provincial body overseeing flood protection and loss reduction and support the Province's continuing analysis of flood mitigation options and implementation of appropriate measures throughout the Bow and Elbow watersheds.	IMMEDIATE	56
c. Evaluate social, economic and environmental impacts of flood mitigation options.	MID-TERM	56
d. Develop a comprehensive climate adaptation plan and implementation tools to reduce The City's infrastructure and operational vulnerabilities.	MID-TERM	53
e. Host a national flood risk management workshop to share best practices and develop an ongoing networking group.	IMMEDIATE	56
f. Provide an annual update to City Council on progress related to the recommendations from the Expert Management Panel on River Flood Mitigation.	IMMEDIATE	55

INTRODUCTION

Resilience is the capacity to endure and recover from disruptive events. Resilience requires appropriate action before, during and after an event to minimize negative effects. A more resilient city suffers less impact when disasters occur and recovers more quickly.

The flood of June 2013 was the largest flood in Calgary since 1932. Extraordinary rainfall in the Rocky Mountains and foothills over several days led to high water levels in and around the city.

Across Alberta, the flood resulted in the loss of five lives and as much as $6 billion in financial losses and damage to property. Those who were evacuated and whose homes were flooded were faced with trauma, loss, and the challenge of rebuilding or the permanent loss of their home. Flooding disrupted businesses and damaged critical infrastructure. It also led to power outages across some parts of Calgary.

Increased population growth and urbanization result in a greater impact to people and economies when these extreme weather events occur.[i] Natural catastrophes are also becoming more common around the world, driven in part by changes in weather patterns. Cities need to invest in preparing for more frequent and severe natural events to protect their citizens, their infrastructure and their finances.


THE CALGARY DAILY HERALD 5 O'CLOCK EDITION

HUNDREDS OF CITY HOMES MENACED BY RIVERS

Baldwin Gov't Votes to Hand In Resignation

Ghost River Dam Menaced by Floods

Worst Floods Since '02 Ravage Calgary And South Districts

Two Streams Pouring Flood Waters Over Big Sections of the City

Swollen Highwood Flowing Through High River Streets

It has been about 80 years since the last extreme flood struck Calgary.

THE 2013 FLOOD

An extreme weather event - a successful civic response - Heavy rains on melting snowpack in the Rocky Mountains combined with steep, rocky terrain caused rapid and intense flooding in several southern-Alberta watersheds in June 2013. As the waters rushed down the rivers in the steep alpine region and through the foothills towards Calgary, The City issued a flood warning, activated the Municipal Emergency Plan, declared a state of local emergency and gave an evacuation notice for communities at risk.

To protect the city from impending floodwaters, The City had lowered the water level in the Glenmore reservoir to the limit at which drinking water could still be supplied by the treatment plant, maximizing the volume of floodwaters that were captured by the reservoir. Temporary flood barriers were constructed at many critical locations throughout the city. TransAlta also responded quickly and was able to reduce the flood level in the Bow River through operations at its six upstream reservoirs. Throughout all of this, The City was able to maintain drinking water quality for Calgarians. Without these flood response measures, damage to Calgary would have been much more devastating.

Despite these protective measures, there was major flooding over the banks of the lower Elbow River, and the Bow River over-topped its banks in several locations. Calgary efficiently carried out its emergency response plan, including approximately 80,000 evacuations. The time for warning is short given the close proximity of the mountains, where river floods originate. Extensive emergency response was required across 32 communities in Calgary and the downtown was inaccessible for days.

Significant flood damage was caused to both private and public property by overland flooding, rising groundwater, storm water back-up and sewer back-up. The impact to individuals from the trauma of emergency evacuations and the damage to private property was immense. Recovery continues to be costly for both public and private property.

How often have floods like 2013 happened? - Although the 2013 flood was the largest in recent memory, it was within the range of natural variability for the Bow River. Historical records indicate that Calgary experienced floods of similar magnitude in 1879, 1897 and 1902 on the Bow River. Other large floods occurred in 1929 and 1932 on both the Elbow and the Bow Rivers. No floods of the magnitude of the 2013 event have occurred since 1932 (Figure 1).

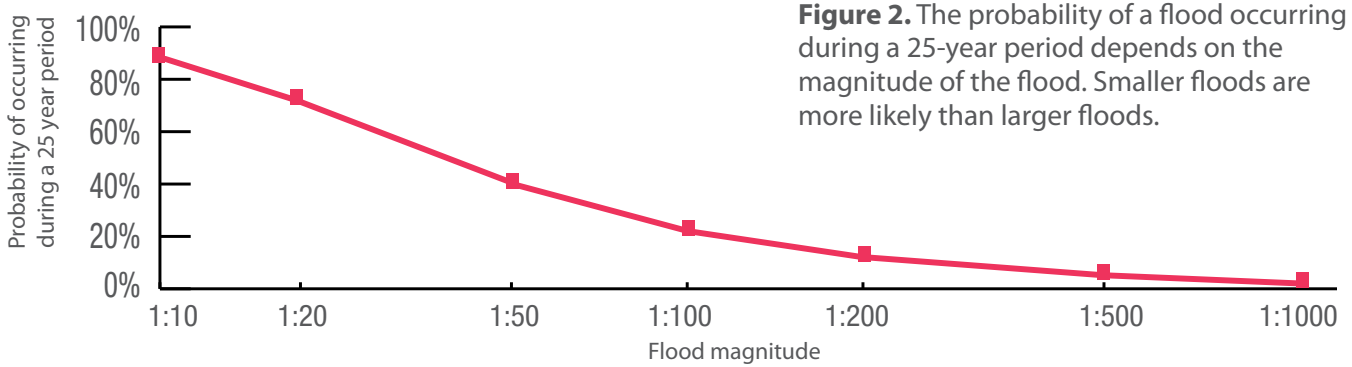


Figure 2. The probability of a flood occurring during a 25-year period depends on the magnitude of the flood. Smaller floods are more likely than larger floods.

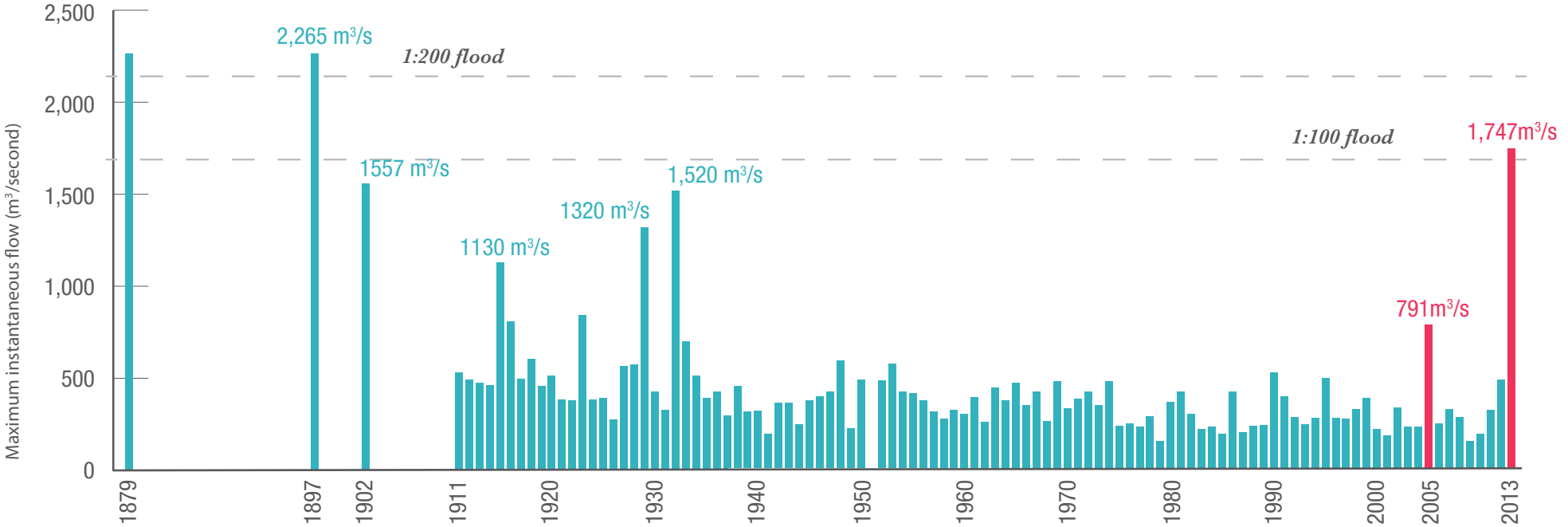


Figure 1. Maximum flow in the Bow River at Calgary between 1879-2013.

What is a 1:100 flood?

A 1:100 (or 100-year) flood is a flood event that has a one per cent chance of happening in any given year. This does not mean that after a 1:100 flood occurs it will not happen again for another 100 years; a similarly sized flood has a one per cent chance of happening again the following year and every year after that. Likewise, a 1:10 flood has a 10 per cent chance of happening and a 1:200 flood has a 0.5 per cent chance of happening in any given year.

During the lifetime of a 25-year mortgage, there is a 22 per cent chance of a 1:100 flood occurring (Figure 2).

The 2013 flood was approximately a 1:100 flood on the Bow River and downstream of the Glenmore Dam on the Elbow River. It was approximately a 1:500 flood upstream of the Glenmore Dam; the difference was the short-term flood storage in the Glenmore Reservoir. In comparison, the 2005 flood was approximately a 1:10 flood on the Bow and a 1:20 flood on the Elbow downstream of the Glenmore Dam.

THE COSTS OF THE 2013 FLOOD

The emotional and health costs of the 2013 flood were borne by over 100,000 Calgarians directly impacted. The financial costs continued to be shared by individuals, private companies, insurers, The City of Calgary, the Government of Alberta and the Government of Canada, and through them by taxpayers.

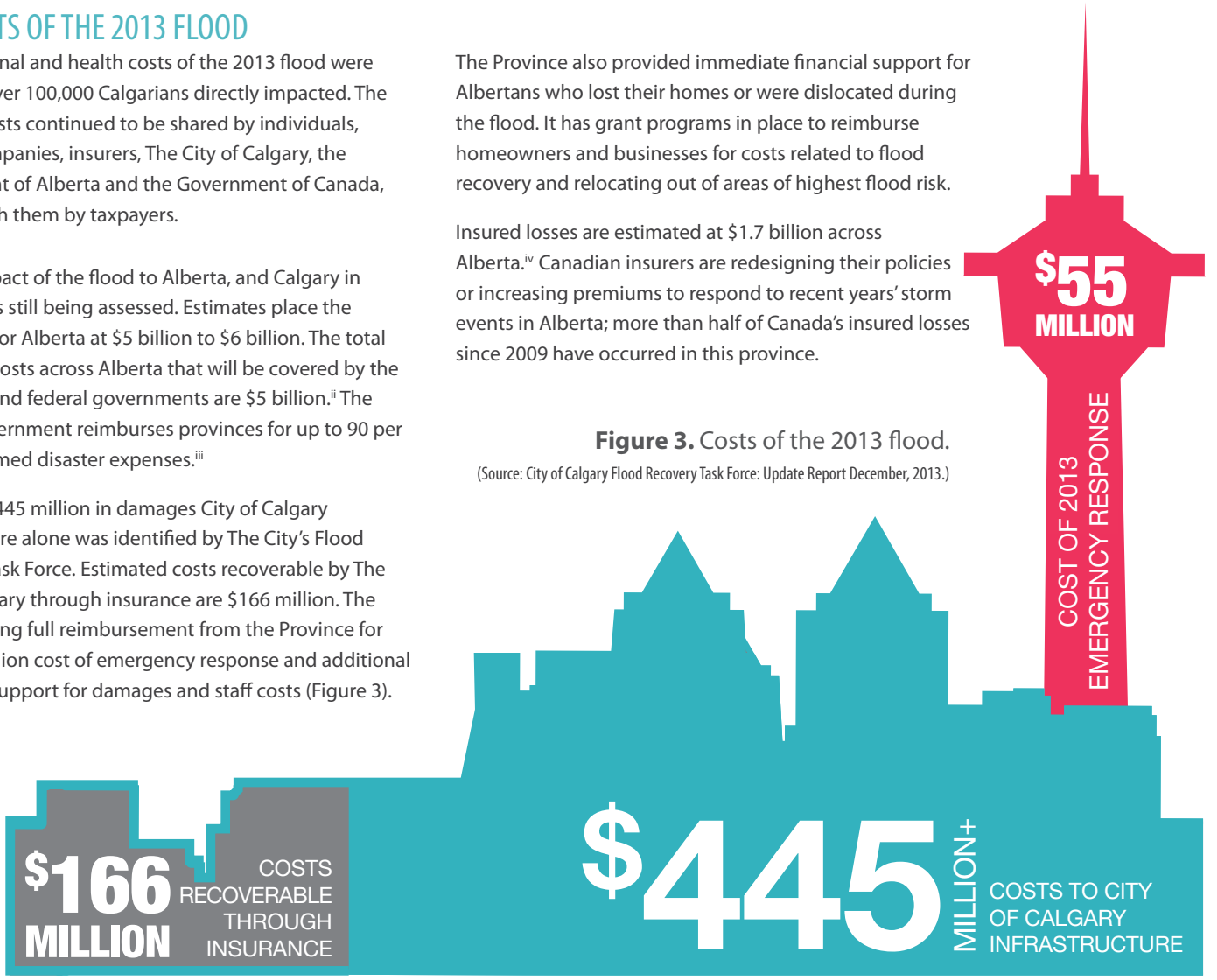
The full impact of the flood to Alberta, and Calgary in particular, is still being assessed. Estimates place the total costs for Alberta at $5 billion to $6 billion. The total estimated costs across Alberta that will be covered by the provincial and federal governments are $5 billion.[ii] The federal government reimburses provinces for up to 90 per cent of claimed disaster expenses.[iii]

A total of $445 million in damages City of Calgary infrastructure alone was identified by The City's Flood Recovery Task Force. Estimated costs recoverable by The City of Calgary through insurance are $166 million. The City is seeking full reimbursement from the Province for the $55 million cost of emergency response and additional provincial support for damages and staff costs (Figure 3).

The Province also provided immediate financial support for Albertans who lost their homes or were dislocated during the flood. It has grant programs in place to reimburse homeowners and businesses for costs related to flood recovery and relocating out of areas of highest flood risk.

Insured losses are estimated at $1.7 billion across Alberta.[iv] Canadian insurers are redesigning their policies or increasing premiums to respond to recent years' storm events in Alberta; more than half of Canada's insured losses since 2009 have occurred in this province.

Figure 3. Costs of the 2013 flood.
(Source: City of Calgary Flood Recovery Task Force: Update Report December, 2013.)



RIVER FLOOD MITIGATION PROGRAM

The City of Calgary established the River Flood Mitigation Program to investigate and initiate ways of mitigating future river flood risks. To guide the program, The City created the Expert Management Panel: a five-member panel of nationally and internationally recognized experts.

The Panel identified six theme areas that would guide the investigation:

- Managing flood risk
- Watershed management
- Event forecasting
- Storage, diversion and protection
- Infrastructure and property resiliency
- Changing climate

Dividing the work along the lines of the six themes allowed for a focused approach on each area of specialized knowledge. To provide subject-matter expertise, specialists in relevant areas were invited to generate and assess options for each theme. Many expressions of interest were received and a final selection resulted in 36 experts working on the six themes.

City staff managed the program and supported the Expert Management Panel and technical committees by providing information needed for assessing options and summarizing and presenting the results of discussions and technical input. In addition, they engaged extensively with Calgarians and contacted communities around the world to understand shared experiences and innovative approaches to dealing with similar challenges.

Building resilience to flooding requires action across many disciplines and organizations. From forecasting and monitoring weather, to engineering design standards and emergency preparedness, there are many planning processes and activities that are all critical for improving flood resilience. Many organizations and initiatives across Canada are improving flood resiliency. The Panel worked particularly closely with several other initiatives that are especially critical to Calgary's flood resiliency:

The City of Calgary Flood Recovery Task Force - This task force was created following the 2013 flood and includes representatives from across The City. This team has been essential in identifying and resourcing immediate flood recovery activities and supporting the development of recovery, mitigation and resilience recommendations for The City's 2015-2018 business planning and budgeting cycle. The task force is focused on five priority areas: people, housing and property, infrastructure, services and funding.

Calgary Emergency Management Agency (CEMA) - CEMA works with City departments and the community to increase Calgary's capacity to be prepared for and recover more quickly from a disaster. During the 2013 flood, CEMA worked with the Water Emergency Operation Centre, emergency responders, other City departments and outside agencies to provide a coordinated multi-service and multi-jurisdictional response.

Alberta Flood Recovery Task Force - This task force coordinates the provincial intermediate and long-term recovery efforts, including supporting community recovery efforts through funding and information and ensuring effective flood hazard mitigation to protect against potential future damage.

The Panel also heard from Calgarians

Early in the program, the Panel invited Calgarians to share their ideas and comments to cast a wide net for possible actions and to try to understand the questions that needed to be addressed in the final report. Over 200 written submissions were received from citizens in over 70 communities. Dialogue with communities has been a priority and has included numerous community open houses and meetings with groups representing flood-affected communities.

Public input provided insight into how the 2013 flood affected people in the city and ideas for preparing better for the next flood event. Quotes from Calgarians appear throughout this report.

Calgary is more flood resilient today than in 2013

Since the flood of 2013 The City of Calgary has been actively repairing damage, restoring services and making sure The City is better prepared for the next extreme flood. Learning from the effects of the 2013 flood, activities undertaken by The City include making infrastructure more flood resilient as it is rebuilt, reviewing legislation that governs flood protection for private property and stockpiling additional supplies for emergency flood response. The City is also working closely with utility providers to improve the resilience of power supply and communication systems.

PRINCIPLES FOR FLOOD RESILIENCE

Future floods cannot be prevented, but The City can take action to protect public safety and minimize the damage that floods cause. The focus of the Panel's work has been to develop recommendations to The City of Calgary on how to continue improving resilience to extreme river floods. The development of recommendations was guided by the following four principles:

1. **Building resiliency:** Addressing vulnerabilities and taking proactive measures to safeguard infrastructure, minimize social, environmental and economic impacts, and protect public and private property

2. **Long-term vision:** Considering what Calgary should look like in the future and recognizing it will take time to achieve goals. Flood risks can be managed over time by using and building on existing initiatives.

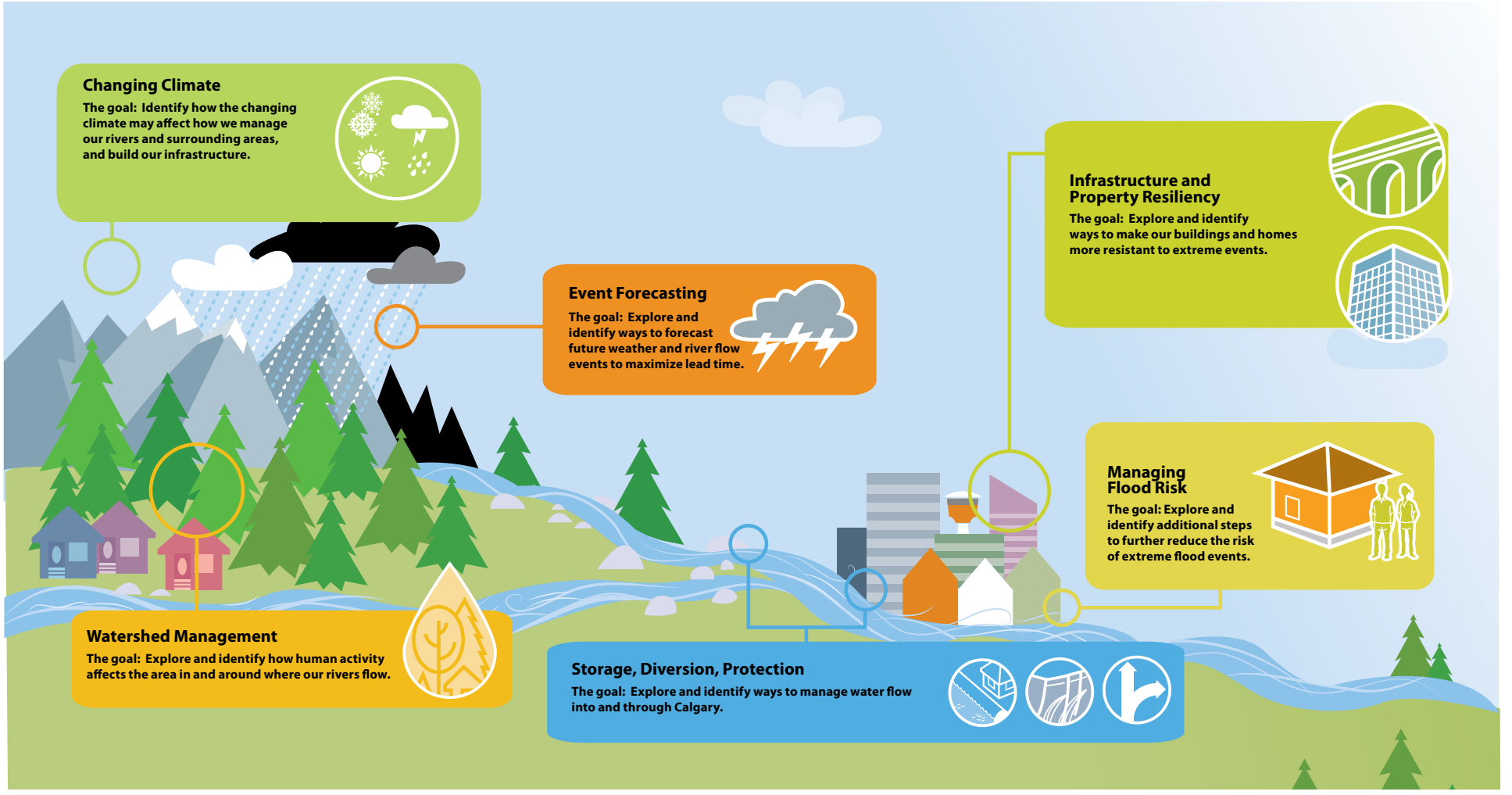
3. **Watershed approach:** Looking at the Bow River Watershed for flood mitigation opportunities, and the implications of these opportunities for drought and potential upstream and downstream impacts. Measures must consider watershed-scale, city-scale and community-scale mitigation opportunities. Flood protection actions should not jeopardize the wealth that the rivers provide in the process. Safeguarding drinking water, natural habitats and recreational opportunities are also important priorities for all decisions affecting the river valleys

4. **Working with the river:** Enhancing value throughout the city by protecting and conserving natural systems, protecting water resources and riparian areas and integrating non-infrastructural, ecosystem-based approaches. Approaches should seek to accommodate the natural hydrology of the region, including the consequences of drought.

Figure 4. The City of Calgary has undertaken many actions since the 2013 flood to improve resiliency.

RIVER FLOOD MITIGATION THEMES

Figure 5. The Expert Management Panel on River Flood Mitigation established six themes to focus on.



MANAGING FLOOD RISK

Over the past century Calgarians have collectively chosen to develop a portion of Calgary in the floodplain. Living in a floodplain has inherent risks, as the flood of 2013 made obvious. These risks can be managed, but they can never be eliminated. Following the flood of 2013, there has been a strong sense that the flood risk in Calgary may be unacceptably high.

To effectively manage flood risk, the probability and impact of flood events must first be understood. The better risk is quantified, the more informed risk management decisions can be. There are four general strategies for managing any kind of risk, including floods:

Avoid risk: Calgarians can choose to live, work and play in areas with higher risk or areas with lower risk. New development can be located away from high risk areas and existing development can be moved out of high risk areas. Relocating development is costly and disruptive.

Reduce risk: Many actions can reduce risk so it becomes more tolerable. Reducing risk may entail implementing flood resiliency measures for buildings, erecting flood barriers, constructing large scale infrastructure such as dams or diversions and emergency preparedness.

Transfer risk: Some financial risk can be transferred to other parties, for a cost. The City of Calgary has transferred some of its risk to insurance companies and some of the risk is shared with the provincial and federal governments. Homeowners in Canada have limited options for insuring against floods.

Accept risk: Risk that is not avoided, reduced or transferred is necessarily accepted by everyone who locates in areas with flood risk. This may be termed "tolerable risk"; it is not welcomed, but it is tolerated. The amount of flood risk tolerated affects how heavily impacted Calgary will be when floods occur.

Within each of these strategies there are actions that have already been taken by The City of Calgary and opportunities for The City, individuals and businesses to further manage flood risk (Table 1).

	GOVERNMENT		INDIVIDUALS & BUSINESSES
UNDERSTAND RISK	• Identify likelihood of floods and potential impacts		• Understand likelihood of floods and potential impacts
MANAGE RISK	AVOID	• Move and keep development out of flood risk areas	• Locate outside of flood risk areas
	REDUCE	• Construct and maintain flood defences • Set flood protection requirements for development • Undertake flood forecasting • Prepare for flood response	• Design and build property for flood resilience • Understand flood risks • Prepare for to respond effectively to flood warnings
	TRANSFER	• Insure public infrastructure	• Insure private property (limited options in Canada)
	ACCEPT	• Accept residual risk of development in flood risk areas • Prepare for recovery	• Accept residual risk of locating in a flood risk area

Table 1. Actions that governments, individuals and businesses can take to understand and manage flood risk.

Understanding and managing flood risk is a continuous process. It is prudent for municipalities, businesses and individuals to consider the amount of flood risk they tolerate, and whether it is appropriate to avoid, reduce or transfer more of that risk. This section discusses a number of ways The City of Calgary can further manage flood risk:

- Increase Calgary's flood protection level.
- Reduce development in flood risk areas.
- Support Calgarians to manage their personal flood risk.

Flood protection levels

Winnipeg is protected to the highest flood level of any city within Canada; the Red River Floodway diversion system provides protection up to a 1:700 flood. Manitoba uses the 1:100 flood level for flood protection across the province and is considering increasing this to a 1:200 flood.[v] The protection of Winnipeg to a higher level was based on a cost-benefit analysis , and the local geography allowed for a practical capital project in the form of the Red River Floodway.

British Columbia recently increased its flood protection level from a 1:100 flood to 1:200 flood for new flood protection works, but it does not require existing flood protection to be raised to meet this new standard. Calgary and Alberta use a 1:100 flood level for protection planning and Alberta has guidelines for locating new critical structures such as schools and hospitals where they will be protected to as high as a 1:1000 flood level.[vi] Ontario uses the 1:100 flood or the largest flood on record, whichever is largest.[vii]

The flat geography of The Netherlands, much of which is below sea level, means that if dikes were breached, results would be catastrophic. The Dutch build dikes to protect against river flooding to a 1:1250 flood level; this protection level was set qualitatively and then reviewed according to cost-benefit and risk of loss of life analyses. Given the extensive engagement and analysis required for this assessment, the Netherlands has determined that every 50 years is an appropriate period of time to review flood protection levels.

CALGARY'S FLOOD PROTECTION LEVEL

Much of Calgary's flood management is based on the 1:100 flood, but this is not universally applied across the city. Some parts of Calgary have a flood protection level lower than the 1:100 flood and a few isolated areas have a flood protection level higher than the 1:100 flood. The *Storage, Diversion and Protection* section of this report discusses the protection level provided by flood barriers and why it varies across Calgary.

- Permanent and temporary flood barriers in Calgary are primarily designed to protect against floods as high as the 1:100 flood, plus a margin of safety where possible. However, not all parts of the city's floodplain are protected to this level, leaving some areas vulnerable to more frequent flood events. In several locations, flood barriers have been built to above a 1:100 flood level to provide additional protection.
- The official provincial flood hazard maps show areas that may be impacted by a 1:100 flood. These maps are the basis for flood-related land-use planning and bylaws, governing where development is allowed to occur and according to which requirements.
- Private property has to meet specific flood protection requirements under The City's Land Use Bylaw if it is built within the flood fringe as indicated by the official 1:100 flood hazard maps.

In this way, Calgary tolerates more flood risk than some cities and provinces in Canada and abroad that have chosen to invest in protecting to a higher flood level than the 1:100 flood.

Figure 6. Plan view showing flood hazard areas where red is the floodway, blue is the normal river channel and pink is the flood fringe.

Source: Government of Alberta, 2013 (http://environment.alberta.ca/01655.html)

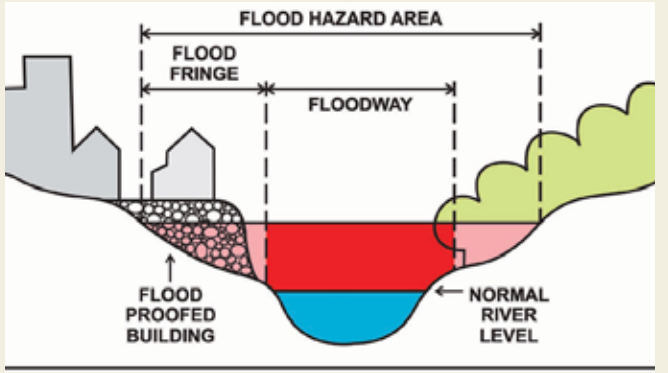


Figure 7. Cross sectional view of flood hazard areas. Development within the flood fringe is permissible providing it is flood resilient. Development in the floodway is not permitted.

Floodway, flood fringe and overland flow: flood hazard maps

Flood hazard maps are official provincial maps that define the areas likely to be affected by surface water during a 1:100 flood. The flood hazard area is divided into floodway and flood fringe zones (Figure 6 and Figure 7).

The floodway is the portion of the flood hazard area where floodwaters are the deepest and most destructive. Floodwater in the flood fringe is generally shallower and flows more slowly than in the floodway. Within Calgary a special type of flood fringe area has been defined: overland flow areas. Overland flow areas are parts of the flood fringe where water is assumed to flow along the ground at very shallow depths and slow velocities, often along roads or across fields.

Flood hazard maps for Calgary were passed into legislation by the Government of Alberta in 1983. These official maps were updated in 1996 following additional modeling work. The Province has updated the criteria for defining the floodway since the Calgary maps were prepared in 1983. The updated definition for the floodway includes any area that experiences floodwaters deeper than one metre or flowing faster than one metre per second. Flood hazard maps throughout the rest of Alberta use this broader definition of floodway, but the Calgary floodway has not been re-mapped according to the new criteria.

Increasing Calgary's flood protection level

The level of flood protection that is appropriate for a specific city, or a specific neighbourhood, is a financial, environmental and social consideration. Investing to achieve a higher flood protection level would result in less damage, disruption, and risk to human life when floods occur. A higher flood protection level would also reduce demands on emergency response service during floods and speed up recovery after floods.

However, achieving higher flood protection involves substantial trade-offs that would affect some parties negatively. It could require greater investment in flood barriers, stricter land-use planning, additional requirements and limitations for development in flood risk areas and large capital works, among other actions. Many of these measures are expensive and disruptive and some would also have aesthetic and environmental impacts.

Given that flood risk changes with time, as do social values and the physical environment, the appropriate level of flood protection should be reassessed periodically. After the 2013 flood, The City of Calgary should consider whether protection above the 1:100 flood level is warranted across all or some parts of Calgary.

"When The City grants approvals to build on or adjacent to the current [1:100] floodway line, The City is asking for trouble. The [1:100] flood is a statistical prediction that does not include the really large floods that could happen in the near or distant future." – Public input

Recommendation: Perform a social, economic and environmental analysis to evaluate the need for a minimum flood protection level above the 1:100 flood currently used for land-use planning and structural protection across Calgary.

"Assess the appropriate level of [flood protection], i.e., 1:100 or 1: 200 or 1:500, etc. Other jurisdictions have adopted substantially higher levels of [flood protection] given the resulting damage and rehabilitation costs of the system being swamped by flood flows." - Public input

Overland flow area operating as designed in Erlton neighbourhood

MANAGING DEVELOPMENT IN THE FLOODPLAIN

Calgary, like many other communities in Canada and around the world, has historically developed within the floodplain. As a consequence, portions of the city are inherently vulnerable to flood impacts from extreme events. The downtown core and several communities within the city are built in low-lying areas that are prone to surface flooding, high groundwater levels and sewer back-up during river floods. Since 1985, limited new development has been permitted in the floodway and flood resilience requirements guide new development in the flood fringe. At times these limitations are relaxed for development.

The amount of development in the floodplain has a significant impact on Calgary's vulnerability to flood events. Development along riverbanks also limits the protection that can be provided to entire neighbourhoods as land is unavailable for The City to construct either permanent or temporary flood barriers in these locations.

IMPROVING MANAGEMENT OF FLOODPLAIN DEVELOPMENT

The City can improve management of floodplain development by:

- Urging the Government of Alberta to update official flood hazard maps.
- Publishing up-to-date, graduated flood maps.
- Reviewing land-use planning policies and documents.
- Relocating selected development out of high risk areas.

Flood hazard maps - The official flood hazard maps prepared by the province show approximately 5,300 buildings in flood hazard areas within Calgary. Of these, only approximately 83 are fully or partially in the floodway. However, the river flood risk is greater than indicated by the maps. Experience from 2013 and the most recent modeling by The City of Calgary and the Province have shown:

- The 1:100 floodway could be significantly larger in some places than shown in the official flood hazard maps.
- The official flood hazard maps do not show the areas that would be affected by a flood larger than a 1:100 event.
- The official flood hazard maps do not show areas that are likely to be affected by groundwater or sewer back-up flooding as a result of river flood events.

The greatest damage to public and private property from the 2013 flood was sustained within the official flood hazard areas, but The City estimates that about 20 per cent of the buildings damaged were outside of official flood hazard areas. This suggests that the current flood hazard maps are inadequate to communicate the extent of river flood risks in Calgary.

Flood maps need to be regularly assessed to ensure they reflect changing river morphology, development and climate and the latest technology for flood forecasting and modeling. The expanded criteria for defining the floodway, as used across the rest of the province, should be considered in an update to Calgary's flood hazard maps. Provincial legislative approval is needed to issue official flood hazard maps. This should be done regularly enough to reflect any significant changes to the best understanding of flood risk, so the municipal development approval process can be supported with up-to-date information.

Recommendation: Urge the Province to regularly review and update official flood hazard maps.

Graduated flood maps - A new model to generate flood maps in Calgary was completed in 2012 in partnership with the Province and is now being updated to reflect changes to the rivers from the 2013 flood. The maps generated by this model were accurate in predicting the extent of the 2013 flood and they are currently used to inform City of Calgary projects such as erosion control along riverbanks, bridges, flood barriers and emergency response plans. These flood maps provide information on flood events from as small as a 1:5 flood to as large as a 1:1000 flood. In May 2014, The City released maps up to a 1:100 flood on its website.

The maps do not, however, include information on the extent of groundwater flooding, which impacted many residences and businesses outside of the areas affected by surface water in 2013. Flood risk mapping should be expanded to include information about groundwater risks once these are further investigated, as discussed in the *Watershed Management* section of this report.

The City should generate user-friendly flood maps that show risk from larger flood events and groundwater and stormwater. Sharing the best available information will:

- Support Calgarians in understanding and managing their flood risk.
- Allow insurers to assess flood risk while designing insurance policies.
- Provide the possibility for graduated flood resilience requirements for private development.
- Inform discussions about the need for Calgary to consider higher levels of flood protection.

Recommendation: Publish up-to-date, graduated flood maps for public information.

"Looking at the flood maps, it seems odd that the buildings across the street from us are in the floodway and we are in the flood fringe when there is very little (if any) elevation change between the two sides of the block." – Public input

"Do not allow construction in high flood risk areas. If areas are already occupied, The City should buy properties and assist in the relocation of occupants. Return areas to a natural state and designate as parks. The parkland can also act as a buffer for flood waters. Yes it is a very expensive and disruptive suggestion, but is it more expensive and disruptive than a major flood event?" – Public input

Land-use planning policies and documents

Resilience planning must be incorporated into long-term civic planning, such as zoning considerations and new infrastructure location and design. To ensure resilience considerations continue beyond the 2013 flood recovery program, they should be included in key City policy and planning documents.

Recommendation: Review The City's existing land-use planning documents and develop amendments, new guidelines or policies that will minimize development in the floodplain over time.

Relocating out of the floodplain - In Alberta, as in many places throughout the world, there are increasing examples of communities relocating development away from flood risk areas. Moving development away from rivers allows rivers to flood without damaging property or risking lives and preserves the ecological functions of riparian areas along riversides. In many cases it is more practical to move development away from the water, than to move water away from development.

In the fall of 2013, Alberta introduced legislation to prohibit future development in the floodway and initiated a relocation program for homes in the floodway, which has been extended until August 2014. As of April 2014, approximately 11 homes within Calgary have been purchased by the Province under this program. The houses are being removed from these properties and future development will never be allowed in these locations.

The purchased properties are scattered along the Elbow River, creating a speckled empty-lot effect throughout these neighbourhoods and raising challenges for maintenance and community integrity. Individual lots also provide very limited potential for The City to provide additional flood protection to the broader neighbourhood. Strategically selected, longer stretches of riverside land would be needed for permanent or temporary flood barriers. The City will likely take ownership, or at least maintenance, of these properties from the Province within several years.

It is a momentous decision for people to choose to relocate from their homes, and relocating people, homes and businesses is inherently a painful process for a community. The City should ensure that any further relocation is planned through close collaboration with affected communities and that property-owners are granted sufficient time to consider their options. Relocating development must also be planned with consideration of other flood mitigation measures that The City and the Province will undertake, which may reduce flood risk in some parts of Calgary.

The City should investigate whether removing buildings from flood-risk areas is warranted, and, if so, prepare a time-phased plan to support flood risk communities that will experience development relocation. This should include identification of areas that may be targeted for relocation, such as specific riverside areas that have the highest risk or restrict opportunities for flood protection for the broader neighbourhood. Relocation may include residential, commercial and public buildings.

If additional relocation is considered, it should be coordinated with the Province as a possible expansion of their current relocation program. This may be particularly applicable to properties that are not identified as being in the floodway under the official flood hazard maps, but are within the floodway according to more current flood maps. Residents in this expanded risk area may be unaware of their personal risk and need a reasonable opportunity to face this reality and its consequences.

Recommendation: In partnership with the Province, develop a time-phased plan to remove buildings from areas with high flood risk, while minimizing the disruption to affected communities.

"Neighbourhoods like mine are dying. Dying because many people cannot financially or emotionally afford to rebuild. Had a buyout offer been presented to me I would have taken it. We cannot afford to move. Our equity was in our home. So we rebuild. Where else can we go?" – Public input

Leaving the floodplain

In Alberta, the communities of Fort MacLeod, Medicine Hat, High River and Edmonton have all relocated development away from specific areas with high flood risk.

Houses in flood risk areas may be raised above flood levels rather than removed. Across the United States, homes that are substantially damaged by a flood are required to be raised above the flood safety level, as mapped by the Federal Emergency Management Agency (FEMA). Homes in designated flood zones that are not raised above this level have significantly higher rates for mandatory flood insurance.[viii] *Some states are providing grants to help homeowners raise houses that were damaged by Hurricane Sandy.*[ix]

Managing the floodplain for flood control

The Miami Conservancy District in Ohio manages more than 4,500 acres of protected floodplain land, in cooperation with municipal governments and local park districts and funded by the Ohio Greenspace Preservation Grant Program.[x]

Over 5,000 acres of land around the main river through Curitiba, Brazil, were purchased to create a large public park for flood control following a destructive flood in 1995. The population was resettled out of this new parkland, a secondary channel was constructed through the park to help carry flood flows and the park now serves as a buffer between the flood-prone river and the city.[xi]

MANAGING PERSONAL FLOOD RISK

Calgarians potentially affected by floods must determine the amount of flood risk that they are willing to tolerate. Calgarians can manage their flood risk through actions that include:

- Knowing the flood risk in their neighbourhood and staying informed during flood season.
- Protecting property against flood damage:
  - Designing and building private property to meet and exceed The City's requirements for flood protection if they are located in the flood fringe.
  - Undertaking flood protection measures such as installing backflow prevention devices even if they are outside of the official flood hazard area and particularly if they have been impacted by a previous flood.
- Insuring private property against flood damage to the extent that insurance is available.
- Preparing personal emergency and evacuation plans for themselves and their family.
- Choosing to locate outside of the floodplain.

"People and businesses along the banks, especially the Elbow, must take action for themselves. Let's keep in mind that this is mother nature and people living in the floodplain must take that into account."
– Public input

The extent of the 2013 flood came as a shock to most Calgarians. Evacuations covered large areas of the city and many people were surprised to find that their properties were flooded. The buildings that were most heavily damaged by surface flooding were properties constructed prior to regulations that offer additional flood protection through location restrictions and design requirements. However, flooding was widespread through the city's floodplain and included locations beyond the official flood hazard areas.

The costs to repair private property damage have been carried by individuals, insurance companies, the Province and the Federal Government. Property owners in the official flood fringe who received funding from Alberta's 2013 Disaster Recovery Program will not be eligible for future flood-relief funds unless they rebuild to meet flood mitigation requirements.

Properties in the floodway that are rebuilt with provincial funds are ineligible for any future flood relief regardless of the property's flood resiliency.[xii] Although the Province considered putting a notice on the land-titles of properties in the official flood hazard area that were damaged during the 2013 flood, it has chosen to examine other options to communicate with prospective property-buyers about flood risk.

There will always be a risk of flooding within the floodplain and a flood larger than the 2013 flood will likely occur at some point in Calgary's future. There are limits to the protection that can be provided by The City through large-scale flood diversions and barriers, as well as flood protection measures for homes and buildings. Protective measures could give Calgarians a false sense of security, reducing the likelihood that they will evacuate during future floods or otherwise manage their flood risk. It is critical that The City continue to inform Calgarians about the risk of flood and the importance of understanding and managing personal flood risk.

"Manage expectations with the general public of how well flood mitigation measures will or will not work in future floods." – Public input

Insurance is a common mechanism used by homeowners and businesses to manage the risk of loss and damage from most hazards. Flood insurance is available for businesses in Canada, and insurance for homeowners for sewer back-up is widely available. Following the 2013 flood, payouts from insurance companies to property owners provided essential funds to support recovery. However, insurance against overland flooding (water that enters from the surface, typically through doors or windows) is not presently available for most homeowners in Canada.

Overland flood insurance is available to homeowners in many other countries, including the United States, United Kingdom, Germany and France. Canadian insurance companies have stated that flood risks are too high to be insurable in some places and municipalities like Calgary will have to reduce risk to make overland flood insurance feasible.[xiii] The insurance industry and the Government of Canada have begun discussing introducing residential overland flood insurance. In 2014 at least one insurance provider started to offer limited private property insurance for overland flood in Calgary.[xiv] Where uncertainty about the probability of flooding exists, insurance premiums will likely be unaffordable for many Calgarians.

Supporting Calgarians to better manage their personal flood risk - The City can provide additional information, tools and programs that will support Calgarians in assessing and managing their personal flood risk. As it may be many years until the next major flood event, The City must maintain awareness of flood risks. Educating and communicating with Calgarians requires relatively little investment and provides a large benefit for individuals and communities. The City already provides flood-related information to Calgarians through multiple departments and channels. This information should be reviewed as part of a comprehensive flood risk communication program.

"Establish a 'monument to the flood.' People's memories are too short and complacency about the river will soon be prevalent again." - Public input

Information and tools that would support Calgarians to manage their personal flood risk include:

- Interactive maps that easily communicate the flood risk for specific properties.
- Information on the flood protection level provided by flood barriers for specific neighbourhoods.
- A checklist for measures to make homes and buildings more resilient to floods.
- Information on how to prepare for evacuation and infrastructure outages.
- Flood education built into a school education program.
- Flood resiliency measures and products showcased through public events, such as a public exposition.

Some property-owners may prefer to not have such flood risk information made widely available because it may affect property values. While The City does not wish to adversely affect the economic circumstances of individual Calgarians, The City has a responsibility to full disclosure to prospective buyers. Precedents for situations involving disclosure about asbestos and other hidden real estate risks are well established.

Recommendation: Expand the flood risk communication strategy and provide information and tools that empower Calgarians to make informed choices and better manage their personal flood risk.

Communicating flood risk

In the United Kingdom a flood report that details the specific flood risks to a home is a standard element of property purchasing. The report outlines the degree of flood risk from various types of flood events and gives the home an overall flood risk rating. It also provides descriptions and estimated costs of measures that could make the home more resilient to flooding.

A similar program exists in Toronto, initiated with the real estate industry to ensure prospective owners are made aware of the existing flood risks.

"Provide education and assistance on flood proofing measures: Do I have a backflow preventer? Do I need one? How much would it cost? What about sump pumps?" – Public input

WATERSHED MANAGEMENT

A watershed or drainage basin is an area of land that slopes toward and drains to the same place. Upstream of Calgary, the Bow River Watershed (which includes the Elbow River, Nose Creek, Fish Creek and Pine Creek tributaries) comprises about 10,000 km^2 of land. The Elbow River sub-watershed makes up 1,200 km^2 of this area.[xv] Much of the upper watershed is steep mountain or foothills that cause rainfall to rapidly runoff (Figure 8).

Calgary is the only large city in Canada that is located at the confluence of two mountain rivers that are subject to rapid development of flood conditions. The waterways flow from the mountains through the foothills towards Calgary, passing through various ecosystems and landscapes before reaching the city. The watershed provides habitat for a variety of plants and animals, and supports irrigation, hydro-power, industrial uses and recreational opportunities. The Bow and Elbow Rivers also provide the critical supply of drinking water to Calgary, as well as other communities along the rivers.

Flows in the Bow and Elbow Rivers change seasonally. Peak run-off typically occurs in June when both mountain snowmelt and rainfall occur at the headwaters in the Rocky Mountains. Snowmelt is a smaller fraction of the runoff and is an important contributor to summer flows needed for water supply to municipal, industrial and agricultural users. Flows decline over the late summer, fall and winter; during that time groundwater from aquifers becomes an important source for river flow. The amount of storage, such as reservoirs, lakes and wetlands in the watershed is not large enough to completely buffer the wide range of precipitation experienced in the watershed. The result is that the watershed is prone to both flood and drought, with drought being a more frequent occurrence. (Figure 9).

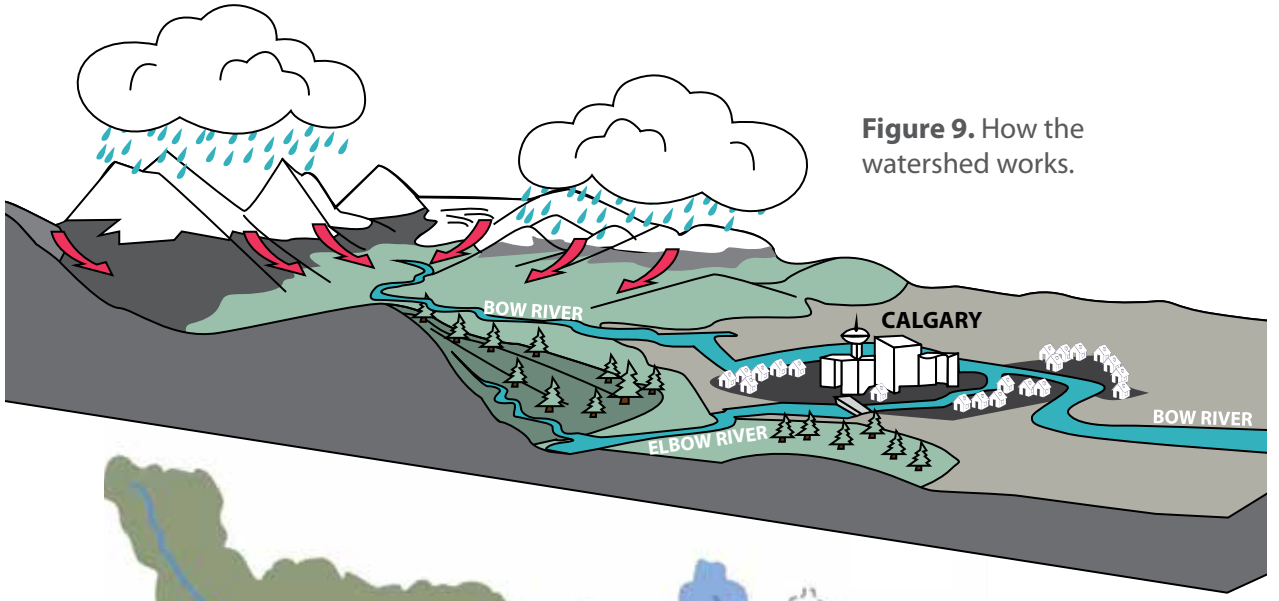


Figure 9. How the watershed works.

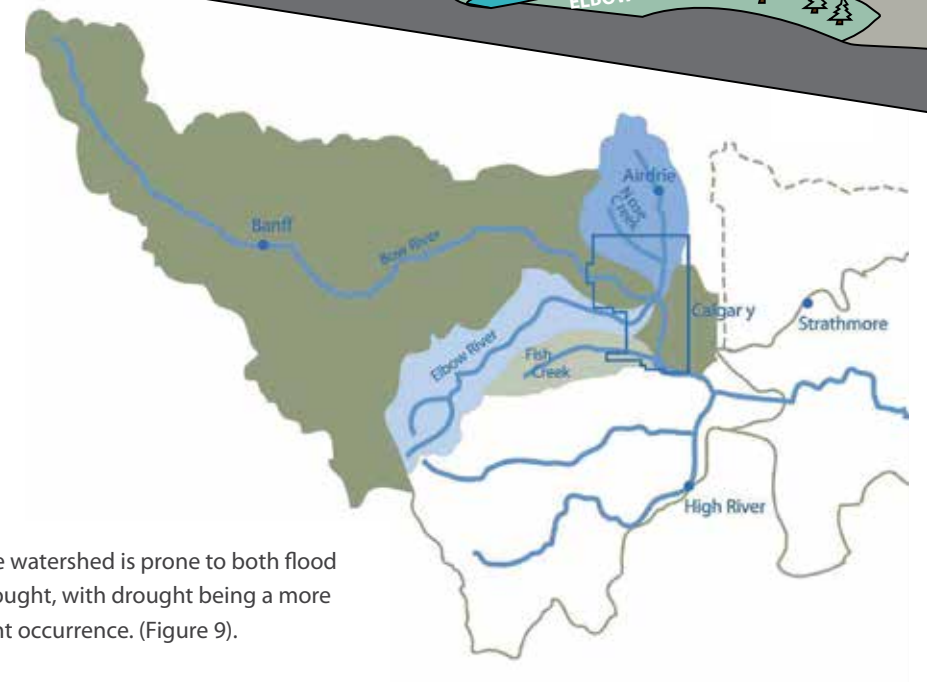
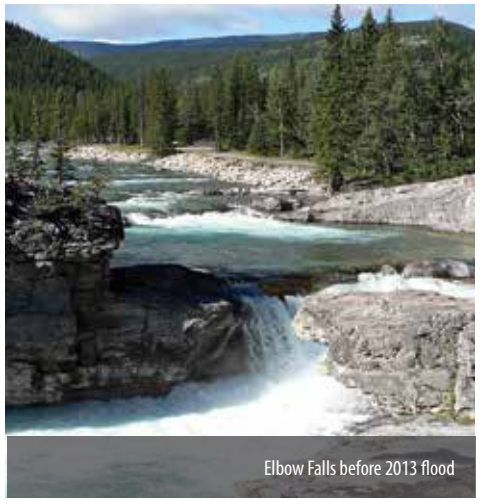
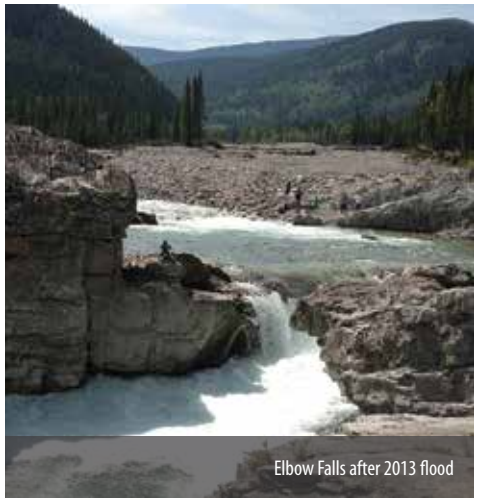


Figure 8. Regional watersheds.



Elbow Falls before 2013 flood



Elbow Falls after 2013 flood

The watershed during the 2013 flood - *The mountains, foothills and the city of Calgary experienced heavy, intense rainfall in the days leading up to June 20, 2013. The rain was centred in the mountains and foothills, where it also melted a large accumulated snowpack, adding to the volume of water rushing down the rivers from the steep upper alpine region.*

Since the flow was generated mostly in mountains and foothills, the Bow and Elbow Rivers on the prairies acted like a pipeline rapidly transmitting high flows from the upper watershed, to Calgary and beyond. Factors such as urban development, patterns of agricultural and resource use, commercial and recreational activity have small influences on this type of flood.

WATERSHED HEALTH

The mountain zones of the Bow River Watershed are largely protected areas, including Banff National Park, Peter Lougheed and the Elbow-Sheep Wildland Provincial Parks, and Kananaskis Country. In these parklands, the forest zones are relatively unaltered from their natural condition, although there are some roads and other corridors that alter runoff. Since the upper watershed is generally intact, there would be limited benefit in changes in land use to restore the condition of the upper watersheds where much of the runoff originated in the 2013 flood.

Because most of the river flow is generated in the upper watershed where there is little development, current land uses within the lower parts of the watershed do not substantially contribute to severe flood potential. In contrast, the watershed does play a role in mitigating the type of flood seen in 2005, where long steady rainfall in the lower reaches saturates the ground and eventually causes rivers to overflow. Nevertheless, residential, recreational, industrial and other land-use pressures continue to grow in the watersheds and these pressures may impact water quality. It is important to manage the watersheds so they can buffer small floods and so water supply, water quality, habitat and environmental protection are not compromised.

"We have allowed development to encroach closer and closer to the banks of ALL our rivers, lakes, reservoirs and streams. We ignore the importance of Riparian areas, those 'buffer zones' between the banks of water bodies and human habitat."
– Public input

Logging in the watersheds - *Logging occurs in about one to two per cent of the Bow River Watershed. Forest soils are capable of reducing runoff, but generally this is true only for small-scale rainfall events which are not responsible for severe flooding. Forests and land cover have only a limited influence on large-scale floods*[xvi] *such as the one southern Alberta experienced in 2013. Water quality can certainly suffer because of increased erosion as a result of logging.*

REGIONAL WATERSHED MANAGEMENT

Regional partnerships are key to implementing integrated watershed management planning. Flood, drought and other issues are more challenging to address if efforts are implemented in isolated parts of a watershed, without considering upstream and downstream users. Dedicating adequate resources to these partnerships ensures that projects and programs are carried through and that The City of Calgary's interests are represented. The City has an influential role as one of many stakeholders in protecting the watershed, but has direct control only over the urban watershed within Calgary's boundaries.

Calgary's creeks and rivers are a defining feature of Calgary's character and the banks and areas beside these rivers are an integral part of a healthy watershed. They provide a variety of benefits for Calgarians and keeping these riparian areas healthy allows them to naturally moderate impacts such as flooding and drought.

The land adjacent to Calgary's rivers has been developed since the city's inception. The areas of highest flood risk in Calgary were the first to develop, altering many of Calgary's natural riparian zones.

Keeping the land next to the rivers healthy is important to flood risk management. Riparian zones can help store and slow down water during small scale floods. They can help mitigate the risk of damage due to smaller scale flooding, and reduce the need for flood and erosion control structures and post-flood repairs to bridges, outfalls or buildings. Riparian buffers allow natural changes to watercourses and mitigate damage from small-scale flooding.[xvii]

A post 2013 flood assessment was performed by The City to determine the flood effects on riparian areas. The study found that many sites impacted by human uses were not as resilient as natural riparian zones. In the year following the flood, The City has repaired six critical erosion sites along Calgary's rivers and plans to address an additional 27 vulnerable sites by 2015. However, those sites that had been assessed as healthy in the past survived very well in the flood.

The City's Environmental Reserve Setback Policy, Riparian Strategy, Wetlands Policy, Land Use Bylaw, Municipal Development Plan and Stormwater Management Strategy help to ensure Calgary's rivers and watershed remain functional and that riparian areas continue to enhance the urban setting as Calgary continues to grow. These initiatives help protect river habitat and wetlands, control erosion, maintain water quality and mitigate small-scale flooding. The Panel strongly endorses these policies and The City's participation in regional watershed plans.

"The panel should also address winter groundwater flooding in Downtown West, Hillhurst and Sunnyside. Damage due to winter groundwater flooding has already cost property owners hundreds of thousands of dollars." - Public input

UNDERSTANDING THE INFLUENCE OF GROUNDWATER ON FLOODING

Neighbourhoods in Calgary's low-lying areas are built over aquifers that are linked to the rivers. An aquifer is an underground layer made of permeable material such as sand or gravel that allows water to move through it, and much of Calgary's geology in the river valleys is high permeability materials.

When the river level is high, water can move rapidly from the rivers to the aquifers, increasing groundwater levels. When the river level is low, water in the aquifers can move into the rivers. During the 2013 flood, many homes and businesses experienced flooding from groundwater and many of the costs of the flood were due to groundwater inundation.

Additional groundwater monitoring in key locations throughout the city would help inform understanding of the influence of groundwater flows during flooding and how groundwater is impacted by urban development. Installing new groundwater monitoring equipment and developing computer models would allow for a better understanding of the relationship between groundwater, surface water and flood waters. This information should be used with other modeling to improve communication between regulators and to inform the public of groundwater risks.

Recommendation: Collaborate with academic and other partners to develop computer models that identify groundwater movement in Calgary in relation to flood conditions.

EVENT FORECASTING

Flood alerts, forecasts and warnings are important components of flood preparedness. Flood forecasting uses weather and river data to foresee the timing and severity of high river level conditions, so measures can be taken to ensure public safety, protect critical infrastructure, keep water treatment operational and limit impact to the environment. Near the Rocky Mountains, the weather is sometimes unpredictable and can change rapidly.

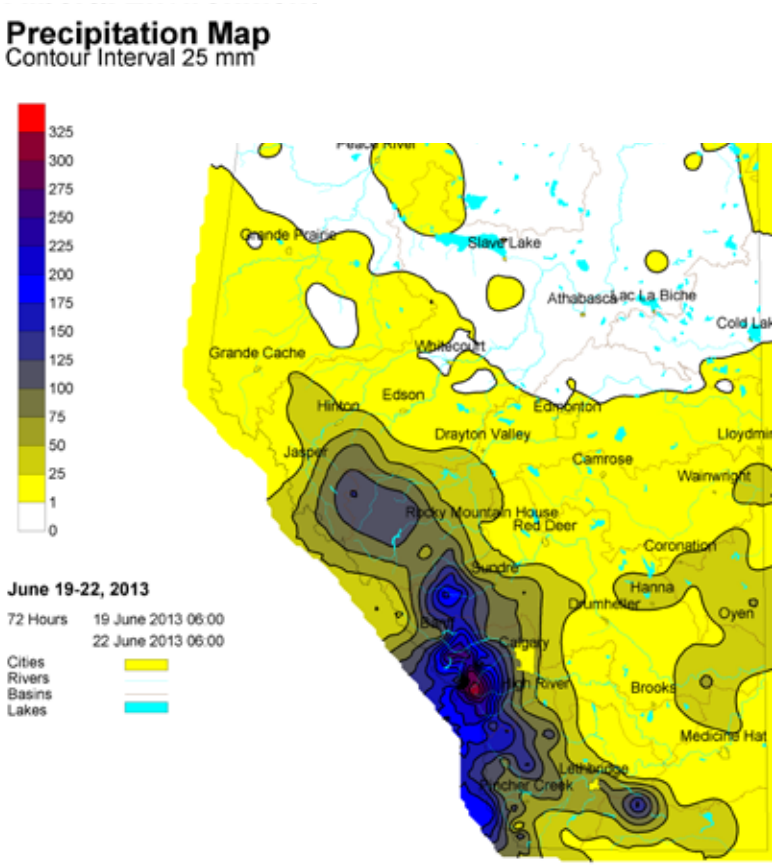
City staff and other forecasters watch for or predict key factors for potential flooding scenarios: river and reservoir levels, mountain snow conditions, precipitation and temperature patterns and soil saturation. There is much uncertainty involved in this process. The timing and severity of flooding is influenced by the intensity, duration, distribution and type of precipitation over the watershed. Direction of storm movement is a key factor in determining if and how flooding may occur.

The City of Calgary's role - *Monitoring river and weather conditions occurs year-round by a small team at The City of Calgary working with the Alberta River Forecast Centre, and takes on special importance from May to July when it focuses on flood potential. Computer models are used to predict river conditions in the watershed so that operational decisions can be made. City staff with expertise in hydrology interpret the models along with river and weather conditions. They coordinate information with the Province and TransAlta, and share it with Water Resources' Business Continuity and Emergency Management to coordinate any required action such as pathway closures and temporary barrier construction. The information is also shared with the Calgary Emergency Management Agency that uses it to make notification decisions and take other actions based on flood threat levels. Such information allowed The City to call the State of Emergency in 2013 as early as it did.*

Forecasting the 2013 flood - *The flood in June 2013 demonstrated how rapidly weather and runoff can change and how fast conditions in mountain areas can become dangerous. The event also highlighted the uncertainty in predicting how much and where rain will fall and the impacts that has on flooding. Weather forecasts had predicted 100 mm of rain – when over 300 mm fell in the Rocky Mountains and foothills. To complicate matters, several of the monitoring gauges that forecasters rely on were destroyed during the flood and observers had to physically go out and determine what was happening.*

During the public engagement process, the Panel heard that Calgarians wanted earlier warning and more time to better protect their property and prepare for evacuation. Calgarians did not realize how severe the flood was going to be and people want to have a better understanding of rapidly changing situations in the future. The reality for Calgary is that flood peak flows can reach the city within hours of when they are generated in the mountains. This leaves a relatively short time to warn and evacuate people from hazard areas regardless of monitoring and predictive models. This reality heightens the importance of advance planning and preparation.

Forecasting an event does little to prevent that event from happening. This is where flood mitigation strategies come into play.



IMPROVING PROVINCIAL AND FEDERAL FORECASTING

The City receives weather forecasting information from the Government of Alberta, Environment Canada, the U.S National Weather Service and other sources.

The Government of Alberta is undertaking a number of studies to improve flood forecasting and communications: documenting lessons learned from 2013; identifying best practices in forecasting performance measures; assessing the performance of weather models on past events; documenting the 2013 event; and determining lead time for emergency action in areas vulnerable to rapid flooding. These studies should be complete by July 2014. The new Alberta Rivers App for smartphones provides advisories and information about Alberta's lakes and rivers directly from the Alberta River Forecasting Centre.

Environment Canada is taking action to improve communication with provincial officials when a severe event is on the horizon and plans to have a national flood forecasting system running within two years. The system will combine Environment Canada's new river flow model with a prediction system to help provide earlier and more accurate warnings of disasters.

Calgarians will ultimately benefit from improvements made at the provincial and federal level and The City should ensure alignment with and uptake of any new forecasting tools and processes.

Figure 10. Alberta Environment and Sustainable Resource Development Precipitation Map (total precipitation in mm).

"Flood mitigation needs excellent information, like [...] accurate flow rates. Not something that stopped measuring water flow."– Public input

REBUILDING AND IMPROVING MONITORING CAPABILITY

The City of Calgary works closely with Alberta Environment and Sustainable Resource Development (AESRD) River Forecast Centre, Environment Canada and TransAlta to collect and share forecasting information. Alberta's River Forecast Centre has access to over 400 river and 600 weather stations throughout the province. These stations monitor real-time water levels, stream flows, precipitation, snowpack, temperature, wind and other data from strategic points throughout the watershed. Much of the information is available to the public online but translation of these data into flood risk predictions is not something that average citizens are likely to be able to perform. The City and TransAlta also operate stations within the watershed for their own operational needs.

The Bow River Watershed covers an area of 10,000 km^2 and weather and river conditions can vary drastically from one part of the watershed to another. This makes monitoring conditions throughout the watershed crucial to fully understand what is happening during a rainfall event, and expanding the coverage of the monitoring network would be beneficial. Several new stations have been installed since the flood of 2013, and additional upstream locations on the Bow and Elbow Rivers should be considered for new stations.

Enhanced monitoring is being explored by The City, including links to Geographical Information Systems, soil moisture, photos and runoff in the upper watershed. Specialized technology would allow better real-time forecasting to inform decisions leading up to and during extreme events. There is also an opportunity to improve the transmission of data between agencies to increase forecasting accuracy.

The flood in 2013 destroyed a number of hydrological monitoring stations and caused others to malfunction. Although most stations continued to function, this raised the issue of protecting existing and future additional stations from flood damage. Some monitoring stations have been made flood resistant during recovery efforts and several additional locations that require flood protection have been identified.

Recommendation: In partnership with Alberta Environment and Sustainable Resource Development and TransAlta, expand the network of river and weather monitoring stations upstream of Calgary and protect stations from damage during flooding.

SHARING INFORMATION FOR FASTER AND MORE ACCURATE FORECASTS

Because forecasting information is collected by several agencies, communication during emergencies is crucial to response time. Although professionals from The City, Alberta River Forecast Centre and TransAlta were in constant communication during the 2013 flood, strengthening communal knowledge can lead to better forecasting and faster warnings to the public.

A common platform for computer modeling would allow forecast data to be compared, providing increased accuracy on weather and river conditions. A platform that allows multiple models may use ensemble (group of simulations) forecasts to better understand uncertainties in predictions. Recognizing that modeling technology is constantly evolving, an adaptive approach is necessary.

The City should support research being conducted by the Province on forecasting best practices and weather forecast effectiveness. The City should also pursue additional research in all aspects of hydrological information, including research to improve scaling down regional information to the local level and examining specialized tools with a local focus.

Recommendation: Pursue a common river forecasting platform with Alberta Environment and Sustainable Resource Development and TransAlta for faster and more accurate information and alerts about future flood events.

"As a victim of both the 2005 and 2013 floods, I think it is imperative The City develop a protocol through media, social media, etc., to notify residents of impending flood conditions. In both floods we received 3 hours notice or less which is entirely unacceptable." -Public input

ENHANCING FLOOD COMMUNICATION AND AWARENESS

After the 2013 flood, Calgarians in flood affected zones overwhelmingly expressed that they wanted earlier notification in the future to prepare themselves and their properties in the event of an evacuation. Because there is a high degree of uncertainty in forecasting and short lead time available because of the nature of the watershed and weather patterns, giving earlier warning will inevitably lead to some false alarms. The City must balance the need to predict flood risk as early as possible with the possibility of message fatigue if too many false alarms are called in an effort to maximize early warning capability. Ongoing dialogue with Calgarians about living with flood risk is important to raise awareness and encourage them to prepare each flood season. This issue is discussed in more detail in the *Managing Flood Risk* section of this report.

The City follows an internal communication process and emergency management plan where forecasters share new information as soon as possible with emergency managers and the Calgary Emergency Management Agency (CEMA), whose responsibility it is to communicate notifications and warnings to the public. The City and CEMA are currently reviewing tools and processes used to communicate with the public leading up to and during an event. In addition, The City is exploring improved tools to communicate in advance of actual flood warnings. Consistency between federal, provincial and municipal messages to the public is important to incorporate to avoid mixed messages that may cause confusion.

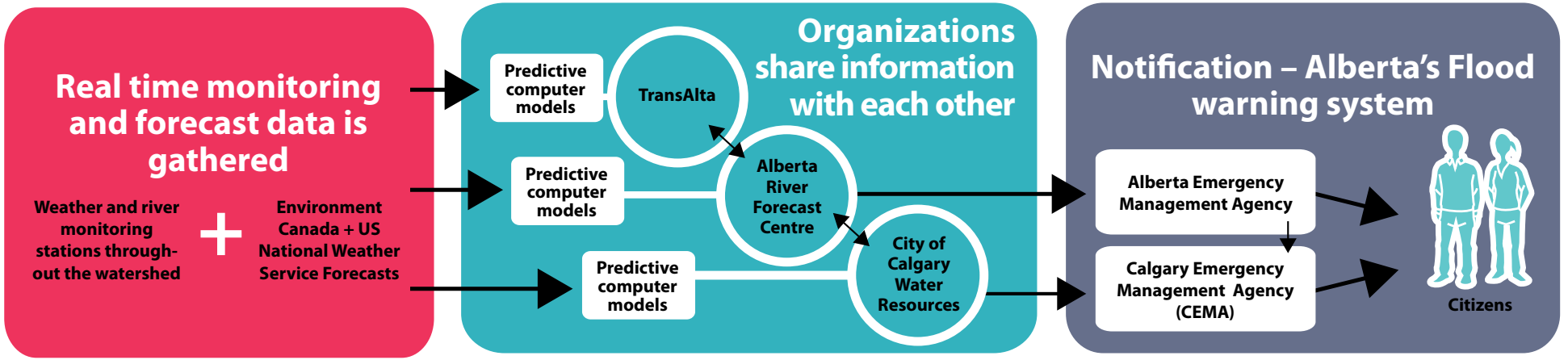


Figure 11. How organizations work together to communicate flood risk.

Frequent public updates are necessary as an event develops and should make use of social media, web pages and other electronic media. Visually communicating risks can be shown through a wide range of means including interactive maps, informative graphics, charts, flood warning lines on bridges and photos of key bridges or landmarks overlaid with projected water levels.

Recommendation: Incorporate lessons learned from the 2013 flood to enhance communication channels to keep Calgarians informed of conditions that may lead to high river levels.

Source: UK Environment Agency, 2014.

The UK's flood alert system

To give people real-time flood warnings, the United Kingdom's Environment Agency produces an interactive web-based flood alert map for England and Wales. Alerts are live 24/7 and are updated every 15 minutes with information about flood risks in any chosen area. At the street-level, a graduated system of alerts informs people what actions they need to take to protect themselves. Citizens can sign up for flood warnings by phone, text or email. The agency also provides online tools including a three day flood risk forecast, river and sea levels, a telephone hotline and advice on what to do before, during and after a flood.[xvii]

Flood messaging in Toronto

The Toronto and Region Conservation Agency (TRCA) updated its flood message terminology in 2012 to make messaging consistent with information from other agencies such as Environment Canada and the Weather Network. The terminology includes four stages: Normal, Water Conditions Statement (early warning of high flows, runoff, rain, unstable banks, etc.) Flood Watch and Flood Warning. The TRCA also uses social media, a 24-hour hotline and an extensive website to inform the public about flood preparedness.[xix]

The City can learn from these examples and others in developing more communication tools to share forecasting information with Calgarians.

STORAGE, DIVERSION AND PROTECTION

Rivers are dynamic systems with water levels and riverbeds changing over time. Floods and droughts are natural, unavoidable occurrences. Throughout Alberta and the world, structures such as dams, canals and flood barriers are constructed to manage the flow of rivers. Water control structures may be designed to:

- Store water to manage high flows and low flows, reducing the peak of flood events and storing water so it is available during low flow seasons.
- Divert water to desired locations for water supply or away from critical locations for flood protection.
- Protect locations from flooding by hardening river channels or creating flood barriers.

Until 1910, no major water control structures existed along the Bow or Elbow Rivers. The Bow River is now affected by 11 dams and six reservoirs upstream of Calgary. The only infrastructure on the Elbow is the Glenmore Dam and Reservoir in Calgary. These water control structures are operated under provincial licenses with consideration of the rights of upstream and downstream water users. They have limited flood reduction potential, but are managed to balance a number of objectives, including water supply, irrigation, power supply, water quality, habitat protection, erosion potential, recreation, and drought and flood control. The existing structures that manage the flow of water upstream of Calgary and within the city are listed in Table 2 and their locations are shown in Figure 12.

EXISTING STRUCTURES UPSTREAM OF CALGARY AND WITHIN THE CITY		PRIMARY FUNCTIONS	MANAGING ORGANIZATIONS
BOW RIVER	**UPSTREAM STORAGE** • Six reservoirs controlled by hydroelectric dams (Lake Minnewanka, Spray Lakes, Barrier Lake, Upper Kananaskis Lake, Lower Kananaskis Lake and Ghost Lake)	• Hydro-electric production	• TransAlta
	DIVERSION • Western Headworks Canal from Harvie Passage	• Irrigation supply	• Province Of Alberta
	PROTECTION • Permanent flood barriers in specific locations within the city • Temporary flood barriers erected during flood events	• Flood protection • Flood protection	• Province Of Alberta, City Of Calgary • City Of Calgary
ELBOW RIVER	**IN-CITY STORAGE** • Glenmore Reservoir controlled by Glenmore Dam	• Water supply	• City Of Calgary
	PROTECTION • Permanent flood barriers in specific locations within the city • Temporary flood barriers erected during flood events	• Flood protection • Flood protection	• City Of Calgary • City Of Calgary

Table 2. Existing structures that manage water upstream and within Calgary.

While existing facilities provided some flood mitigation, significant damage still resulted from the 2013 flood. Possibilities for additional floodwater control are listed in Table 3, along with the organizations that would be able to lead each activity. The locations of several options are also shown in Figure 12.

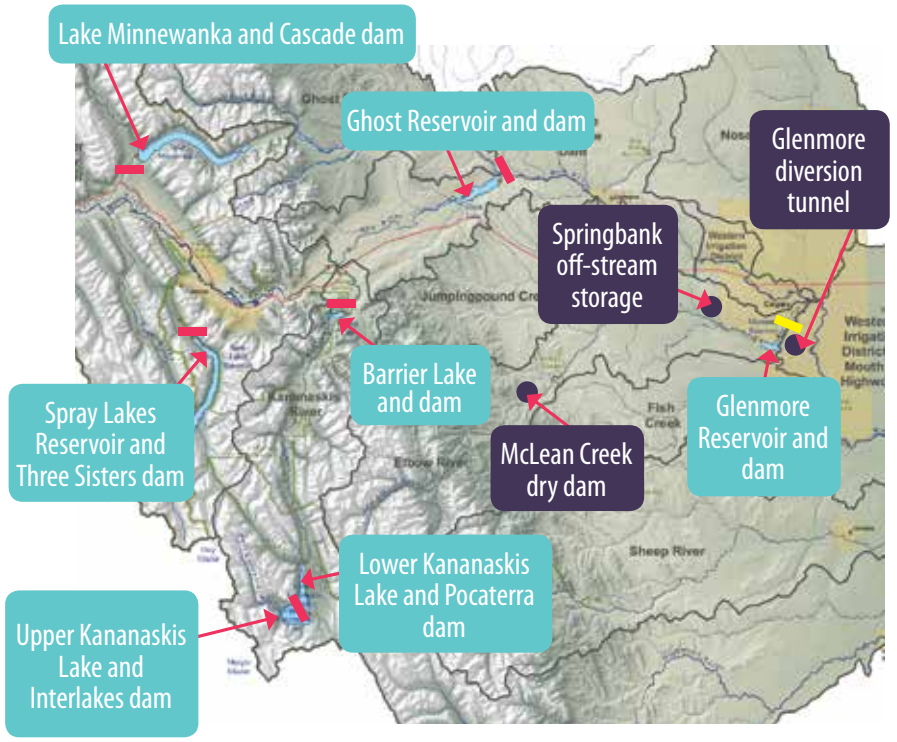


Figure 12. Water management structures in the Bow and Elbow Rivers upstream of Calgary.

OPTIONS FOR ADDITIONAL FLOODWATER CONTROL UPSTREAM OF CALGARY AND WITHIN THE CITY		LEAD ORGANIZATION
BOW RIVER	**UPSTREAM STORAGE**	
	• Operate TransAlta dams for additional flood mitigation	• TransAlta and Province of Alberta
	• Increase capacity of TransAlta reservoirs	• TransAlta and Province of Alberta
	• Store floodwaters in farmland, Crown Land, or wetlands	• Province of Alberta
	PROTECTION WITHIN CALGARY	
	• Construct or increase protection level of flood barriers	• City of Calgary
	• Design infrastructure so it does not obstruct river flooding	• City of Calgary
ELBOW RIVER	**STORAGE**	
	• Increase capacity of the Glenmore Reservoir	• City of Calgary
	• Build a dry dam in the headwaters at McLean Creek	• Province of Alberta
	• Store floodwaters in an off-stream storage site near Springbank	• Province of Alberta
	DIVERSION IN AND AROUND CALGARY	
	• Construct a flood bypass from the Elbow River to the Bow River	• The City of Calgary with the Province of Alberta
	PROTECTION WITHIN CALGARY	
	• Construct or increase protection level of flood barriers	• City of Calgary
	• Design infrastructure so it does not obstruct river flooding	• City of Calgary

Table 3. Options under investigation for water control upstream and within Calgary.

Dredging

Dredging the Glenmore Reservoir and the river channels to create more room for floodwaters was proposed following the 2013 flood.

Glenmore Reservoir

The City commissioned an independent report on the merits of dredging the Glenmore Reservoir. The report concluded that the increased capacity that could be gained by dredging would be small and provide a maximum two per cent reduction in moderate flood events (1:50) and less for larger events. Dredging the reservoir would also:

- Disturb sediment that can impact the quality of Calgary's drinking water.
- Require transport and disposal of dredged material.
- Have to be undertaken regularly as benefits are temporary.

Bow and Elbow Rivers

The river channels naturally change over time as the rivers deposit and move gravel during different flow conditions. During the 2013 flood the rivers carved out larger channels by moving gravel and eroding riverbanks. Some of that extra channel capacity will decrease gradually over time as the river deposits gravel under normal flow conditions. Areas where gravel accumulated during the flood will be monitored by The City to ensure vegetation growth does not cause new flood debris hazards. Dredging the rivers would have a negligible effect on channel capacity during floods as gravel will naturally deposit in dredged areas. Dredging the river channels would also damage aquatic habitat. The Bow and Elbow Rivers are fish-bearing rivers, protected from disturbance under the federal Fisheries Act.

Given the costs, negligible benefits and negative impacts of dredging, this option was not considered further.

Structural protection such as dams, diversions and barriers can significantly reduce the amount of water that inundates developed areas under flood conditions, as shown during the 2013 flood. However, no amount of structural protection eliminates risk in a floodplain. Physical flood protection measures inherently have limitations and additional risks associated with operations or failures. They may also provide a false sense of protection.

Although any of the options in Table 3 would reduce flood impacts, they are only advisable if further study shows that they would provide an overall benefit. Evaluating the merits of water control structures requires examining the positive and negative effects they may have on people, property, and the broader watershed during droughts, normal conditions and floods. Maintenance and long-term operational costs of physical flood protection measures must also be considered. Identifying the most effective combination of measures in the watershed is important.

Working with the Province of Alberta on upstream options - The options presented in Table 3 are at various stages of study by the Province and The City of Calgary. The Province initiated the Bow Basin Flood Mitigation and Watershed Management Project[xx] to identify and assess options for flood mitigation throughout the Bow Watershed. One of the most promising options on the Bow River in the near-term is modifying the operation of the TransAlta facilities during flood events. From the identification and analysis of many capital-works options on the Elbow River, the provincial Flood Recovery Task Force has selected the following three flood mitigation options for further consideration:

1. A dry dam on McLean Creek that would temporarily hold water and help control flow rates under flood conditions.
2. A diversion and water storage site near Springbank.
3. A diversion tunnel from the Glenmore Reservoir to the Bow River.

The Panel is supportive of flood mitigation options that are appropriate for broader watershed management as well as for buffering floods. The proposed Springbank water storage site and the dry dam would both provide additional water storage capacity upstream of Calgary, while the diversion tunnel can only manage flood waters.[xxi]

A watershed-based approach to large-scale flood mitigation works is important. The Province must continue to work with The City and other stakeholders to evaluate and implement options for upstream mitigation on the Elbow and Bow Rivers.

STORAGE

Water may be stored so it is available for later use or to slow the release of floodwaters. Water storage can be as small as a garden rain barrel or as large as a reservoir. In many parts of Calgary, urban stormwater is stored in retention ponds to slow its movement towards the river, reducing flooding and encouraging water to infiltrate into the groundwater. The same principles apply to storing and slowing floodwaters in the watersheds upstream of Calgary.

Most water storage upstream of Calgary is in large reservoirs controlled by dams. Reservoirs temporarily store floodwaters, releasing the water at slower rates than it arrives in the reservoir. This reduces peak flows and flooding downstream, and allows more time for evacuation and emergency preparation. The existing storage on the Bow and Elbow Rivers was used to buffer the 2013 flood. If not for these reservoirs, the flood would have been much more severe in Calgary.

Bow River storage - TransAlta operates dams that control water in six reservoirs upstream of Calgary (Lake Minnewanka, Spray Lake, Upper Kananaskis Lake, Lower Kananaskis Lake, Barrier Lake and Ghost Lake). These dams are designed for hydroelectric power generation and provide secondary benefits for security of municipal and irrigation water supply, recreation and, to a limited extent, flood mitigation.

TransAlta estimates that the floodwater stored in these reservoirs reduced the peak flood on the Bow River by 15 to 20 percent in Calgary during the 2013 flood. This kept flood levels in Calgary at approximately equivalent to the 1:100 flood levels. Unfortunately, this flood level still caused significant riverbank erosion through the city and some overland flooding.

The most promising option for additional flood storage on the Bow River, as identified by the Bow Basin Flood Mitigation and Watershed Management Project, is through modifications to the operation of the existing TransAlta system during floods. TransAlta and the Government of Alberta are discussing operational changes and possible reservoir expansions to mitigate future floods while maintaining water supplies for electricity generation and municipal, agricultural and industrial uses. Other options for storing water upstream of Calgary, either in wetlands or off-stream areas such as farmland or Crown Land, should also being explored further by the Province.

Recommendation: Continue to cooperate with TransAlta and the Province to increase flood storage on the Bow River through existing TransAlta facilities.

Elbow River storage - The Elbow River was dammed in 1932 to create the Glenmore Reservoir. The Glenmore Reservoir and dam are operated by The City of Calgary; they are used primarily for drinking water supply, and secondarily for flood mitigation and recreation. The dam operational protocol includes lowering the water level in the reservoir as a precautionary measure during the May to July flood season. When a flood is forecast, the water in the reservoir may be brought down to the lowest level that still allows the treatment plant to produce potable water, maximizing the volume of floodwaters that can be captured to reduce peak flow downstream on the Elbow River. The amount of floodwater the reservoir can store is limited by the size of the reservoir and the need to ensure the availability and quality of drinking water supply for the city.

Floodwater storage during the 2013 flood

Leading up to the 2013 flood The City lowered the level of the Glenmore reservoir by approximately 3.5 metres. This created room to capture the initial, very high peak flood flow.

The peak flow into the reservoir was approximately a 1:500 flood, while the flow out of the reservoir was approximately a 1:100 flood (See Figure 13).

As a result, there was extensive flooding in the neighbourhoods along the Elbow River and a large portion of the downtown core.

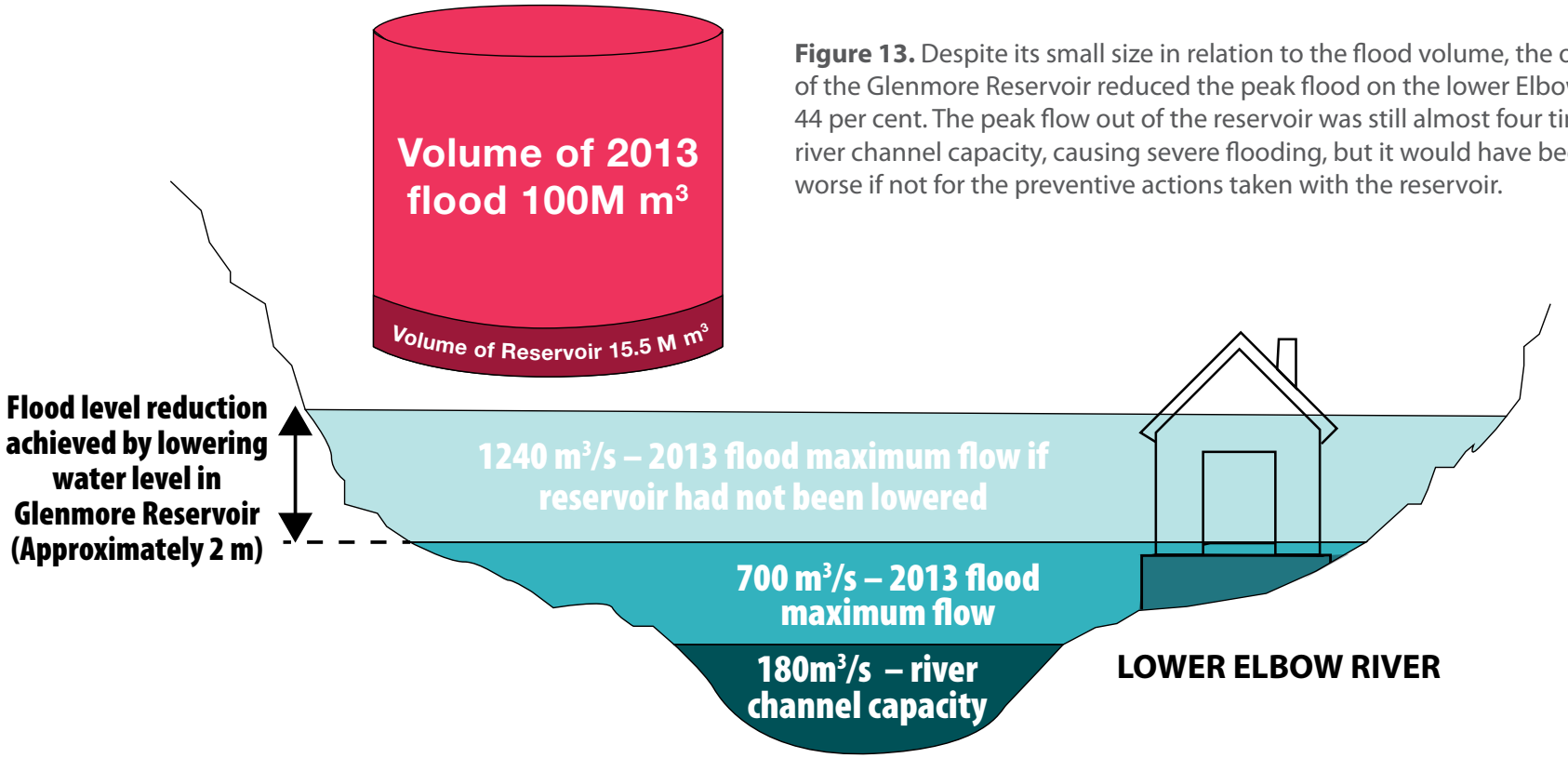


Figure 13. Despite its small size in relation to the flood volume, the operation of the Glenmore Reservoir reduced the peak flood on the lower Elbow River by 44 per cent. The peak flow out of the reservoir was still almost four times the river channel capacity, causing severe flooding, but it would have been much worse if not for the preventive actions taken with the reservoir.

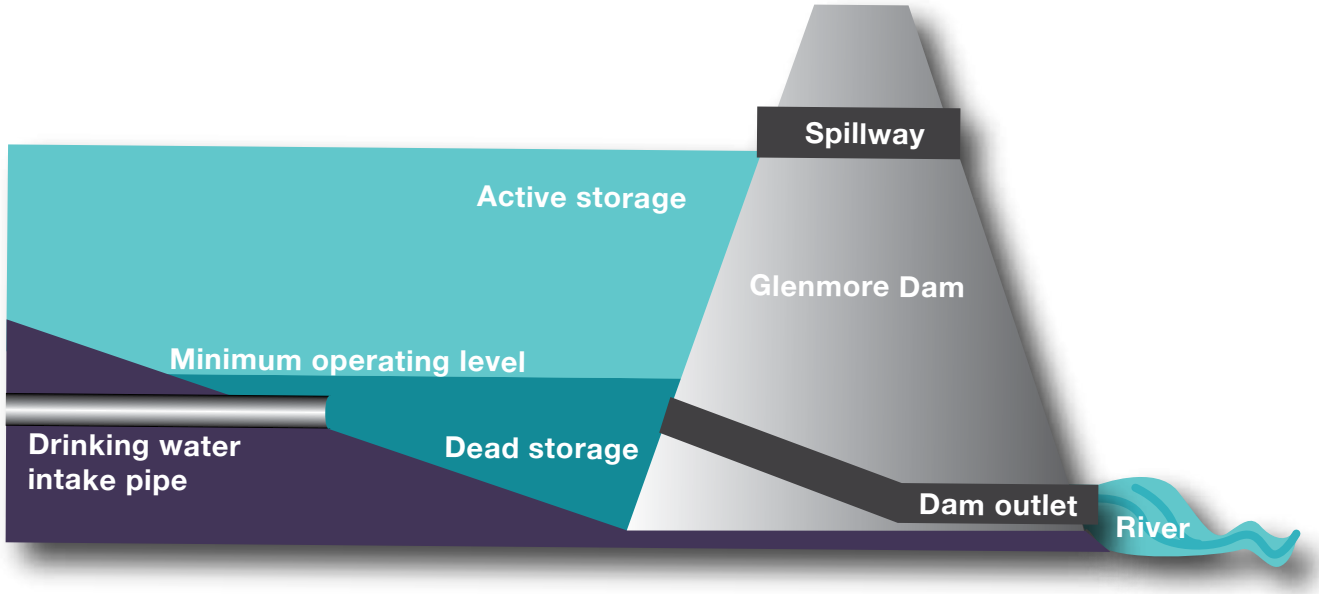


Figure 14. The water level in the Glenmore Reservoir has to stay above the drinking water intake to maintain water supply for Calgary. Water below that level is "dead storage" as it cannot be released. Dredging the deepest part of the reservoir only adds to the "dead storage" volume and does not provide any additional flood mitigation capacity.

The available storage in Glenmore Reservoir greatly reduced flooding downstream of the dam. Additional storage capacity in the Elbow River Watershed would increase the amount of floodwaters that could be stored for short durations during future floods. Approximately 100 million cubic metres of storage would be needed in the watershed to completely buffer a flood the size of the 2013 event within Calgary. This is equivalent to approximately five more Glenmore Reservoirs, an option that is not plausible within Calgary.

While increasing the capacity of the Glenmore Reservoir cannot provide enough additional storage to buffer the 2013 flood on its own, it could be one of a combination of projects to effectively mitigate floods on the Elbow River and would provide additional water supply storage for Calgary. Increasing the reservoir volume would raise water levels in the reservoir, increase the footprint of the reservoir, and affect surrounding infrastructure and development. The potential to increase storage in the Glenmore Reservoir through raising the height of the dam by small or large increments is being investigated by consultants retained by The City.

"Anything to expand the capacity of the Glenmore Reservoir should be pursued." – Public input

Recommendation: Increase the operating water storage capacity of the Glenmore Reservoir on the Elbow River through modifications to the Glenmore Dam.

"Begin the process of building the 58th SW tunnel for water diversion immediately. It is proven technology and, whatever it costs, it is a fraction of the damage, loss of business, and social impacts of weather events like the recent one."
– Public input

DIVERSION

Flood waters can be diverted from their natural course to split through multiple channels, reducing the water flowing through the natural channel. The only water diversion within Calgary is the Western Irrigation District (WID) canal system which diverts water from the Bow River for irrigation supply downstream. Water is diverted by the weir at Harvie Passage in Calgary through the Western Headworks Canal to Chestermere Lake, then to a canal system to farmland and water storage sites.

The WID canal system was not designed to carry floodwaters and its capacity is only one to two per cent of the 2013 flood flow. The canal system does not provide the opportunity to divert significant flood volumes. The Harvie Passage weir was damaged during the flood and will be rebuilt in 2015. A redesign should also address safety issues for recreational users identified before the flood. No practical options have been identified to divert floodwaters from the Bow River.

Diverting floodwaters on the Elbow River

Since the Glenmore Dam was completed in 1932, floods have overtopped the dam and caused significant local flooding downstream twice, in 2005 and 2013. The Government of Alberta's Flood Mitigation Advisory Panel recommended investigating the construction of a large tunnel to divert floodwaters from the Elbow River at Glenmore Reservoir to the Bow River. This would protect communities downstream of the reservoir and parts of downtown Calgary. The Province commissioned a preliminary report that outlined the concept of a five kilometre long tunnel beneath either 58 Avenue South or Heritage Drive. The preliminary cost estimate was $200 to $290 million. A consultant for The City was retained to conduct a more detailed feasibility study for the diversion tunnel, reporting the following:

- A tunnel diameter of 9 meters would be capable of preventing flooding on the lower Elbow River during a 1:100 flood event, equal to the actual 2013 flood.
- The estimated cost of construction is $457 million.
- The optimal route of the diversion is under Heritage Drive because the intake design is simpler and the bedrock conditions are more consistent for tunnelling than beneath 58 Avenue South.

The consultant report also details the geotechnical conditions, entry and exit hydraulics, energy dissipation at the outlet into the Bow River, potential impacts on downstream flows, and social, environmental and economic costs and benefits.

Another possibility examined by the Panel for an Elbow River diversion is an open channel or tunnel to Fish Creek, diverting water either from the Glenmore Reservoir or the Elbow River before it enters Calgary. The Fish Creek valley within the city has high escarpments providing the possibility of constructing a dry dam that would temporarily contain diverted floodwaters, controlling outflow to the Bow River. This option would provide additional water storage which is not possible with the diversion tunnel directly to the Bow River. This route would, however, be a longer diversion than the direct tunnel from Glenmore Reservoir to the Bow River, and would heavily impact Fish Creek. An investigation of the merits and disadvantages of this diversion option is being undertaken by The City.

The two diversion alignments studied

A diversion from the Elbow to the Bow River needs to be evaluated alongside the other two large-scale capital-works projects being considered by the Province on the Elbow River: the off-stream diversion and storage site at Springbank and at the dry dam at McLean Creek. Given that these two projects are presently estimated to cost under $200 million each, the diversion to the Bow River is the most expensive option. The selection of capital works projects to undertake should consider, also which works will be most appropriate for broader watershed management, including both flood mitigation and drought response. A combination of civil works, new flood barriers and removing buildings from the floodway could be complementary parts of an overall plan.

An integrated analysis will be needed to identify the best combination of flood mitigation measures on the Elbow River. The analysis must consider initial capital cost, total cost of ownership, reliability, environmental impacts, stakeholder interests and land accessibility. Large diversion projects inherently present many risks that must also be included in a full evaluation. Examples include:

- Agreements with federal, provincial and First Nation governments.
- Disruption to local communities during construction.
- Potential relocation of existing infrastructure.
- Potential impacts on downstream communities and downstream infrastructure.
- Potential delays and extra costs from regulatory requirements, procurement processes and financing approvals.
- Construction and tunneling risks, including geotechnical variability, equipment failure and weather.

Recommendation: In partnership with the Province, compare the three major capital works options for mitigating floods on the Elbow River and identify the optimal investment plan:

i. A diversion from the Elbow River to the Bow River in accordance with the conclusions of the feasibility studies.

ii. The Springbank off-stream diversion and storage site.

iii. The McLean Creek dry dam.


source: sayangwak.wordpress.com

Large-scale water diversions

The Kuala Lumpur Stormwater Management and Road Tunnel "SMART" is a 9.7 km tunnel that carries water during flash floods and serves as a roadway when not carrying flood waters. The tunnel protects the centre of Kuala Lumpur from river floods by diversion from one river to another.[xxii]

The Waller Creek Flood Control Tunnel Project is a 1.6 kilometre, eight metre diameter stormwater bypass tunnel protecting much of downtown Austin, Texas. Currently under construction, the estimated cost is approximately $150 million.[xxiii]

The Niagara Tunnel is 12.7 metres wide, 10.2 kilometres long and cost approximately $1.5 billion. It was completed in 2013 and diverts water from the Niagara River to a hydroelectric plant for power generation.[xxiv]

The Red River Floodway was expanded, starting in 2005, and now protects Winnipeg against a 1:700 flood. The expansion cost of $665 million and was shared by Canada and Manitoba. It is estimated that this channel has prevented over $40 billion in damages since it was first built in 1968.[xxv]

"Natural streams do a better job of containing rising water levels. I'm afraid that all our ideas are about building more dams and concrete diversion channels." – Public input

PROTECTION

Permanent and temporary barriers provide some protection from floods in Calgary. In 2013 they prevented and limited flooding in many parts of Calgary and yet they were overtopped within several communities.

Permanent barriers - Permanent flood barriers have been constructed along stretches of the Bow River through Calgary and isolated reaches of the lower Elbow River. Most flood barriers in the city were originally designed to protect against flooding caused by ice jams. Since the TransAlta facilities were constructed during the early and mid 1900s and began regulating water flow in the Bow, ice flooding risk has been greatly reduced and spring floods are the more common river flood events in Calgary with the exception of a few select reaches.

The City designs flood protection barriers in general to a 1:100 flood level plus an additional 0.5 metres of elevation to account for uncertainty in predicting actual flows. For each site where a barrier is constructed or raised, The City undertakes a social, environmental and economic assessment to identify the appropriate height. The highest level of protection constructed within the city is designed to a 1:100 flood level plus 1.0 metres. Riverbanks that were damaged during the 2013 flood are being repaired with additional height (to 1:100 flood plus 0.5 metres) where possible.

Communities behind flood barriers live with the risk that the barrier could be overtopped in a flood larger than the barrier designed, because flooding could occur through groundwater upwelling or storm water back-up during large river floods. Riverside neighbourhoods that are being redeveloped, such as Quarry Park and East Village, have been required to raise the ground with fill to reduce the need for river flood barriers for protection.

Areas where private property stretches to the riverside, primarily along the lower Elbow River, are generally not protected by permanent flood barriers. Often the density of development in these locations makes barrier construction problematic. Some residents have built their own retaining walls or landscaping features to mitigate flood risk to their personal property. These require a permit and oversight from The City to ensure they are structurally sound and will not adversely affect neighbouring properties.

Temporary barriers - The City has detailed emergency plans for the location and construction methods of temporary flood barriers in the event of floods of various magnitudes up to a 1:100 flood. The first priority for temporary barrier construction is protecting public safety and second is protecting critical infrastructure. These are followed by protecting private property and the environment. Temporary flood barriers are not feasible in some areas along the lower Elbow River, because they would be required along lengthy stretches and private riverside property is inaccessible for rapid barrier construction. The City continues to study where additional temporary barriers would be useful, and the most appropriate construction materials and methods for these barriers.

Improving flood protection - Calgary's flood protection can be increased through increasing the level of protection from flood barriers, and modifying structures that constrain floodwaters.

A cost-benefit analysis is currently being performed to assess the feasibility of increasing the protection level provided by permanent barriers across the city. The results of this analysis may identify areas that economically should be protected to higher standards. The recommended assessment of flood protection levels across Calgary (see *Managing Flood Risk* section) may also identify areas that should be protected to a level higher than the 1:100 flood.

Recommendation: Construct additional or higher flood barriers in key locations throughout the city and update temporary flood barrier plans to protect against higher flood levels.

At points along the Bow and Elbow Rivers the river channel is constricted by structures such as bike paths and bridges. Floodwaters are forced around or above these structures, resulting in higher floodwater levels locally. Several pedestrian bridges over the Elbow River in Calgary are being redesigned so they do not constrict the river channel and allow more space for the river to flood.

Recommendation: Prepare a time-phased plan to modify structures that constrain river flow during flood events, such as pathways and bridges.

Examples of temporary flood barriers

There are many types of temporary flood barriers appropriate for different locations and flood scenarios.

Earthen barriers made with sandbags and tubes that may be filled with water, mud slurry or concrete are common around much of the world and used by The City of Calgary as needed.

Modular barriers with waterproof board or steel pieces that can slot into place are also used by some municipalities and property-owners in other cities, notably in towns in the United Kingdom where flooding is a regular threat.

Hydraulically actuated flood walls that can be raised during flood events are used by towns in Germany, the UK and Japan to protect short river reaches, such as roadways between riverside buildings.

The City of Calgary uses water-filled tubes as temporary flood barriers

INFRASTRUCTURE AND PROPERTY RESILIENCY

Infrastructure is necessary to provide essential and non-essential services and can be categorized as either public or private. The City's role is distinct with regards to building resiliency into public and private infrastructure. Policy and planning changes can be used to build resiliency into City-owned and managed public infrastructure. Building resiliency into utility and communication infrastructure involves working in partnership with the private sector.

Public infrastructure *is owned and operated by provincial or municipal government and includes hospitals, schools, municipal buildings, police and fire stations, roads, bridges, light rail transit (LRT) water and wastewater systems.*

Private infrastructure *is owned and/or operated by private companies and includes communication and energy networks.*

Private property *includes houses, condominiums, businesses, commercial buildings and private industrial areas.*

PUBLIC INFRASTRUCTURE

The Province has recently created flood risk management guidelines for locating new facilities that are funded by Alberta Infrastructure.[xxvi] The guidelines categorize facilities based on their function, identifying those that should be located on sites that are less vulnerable to flooding. The guidelines outline three flood protection levels:

I. 1:1000 flood for "lifeline facilities" that are critical for saving and avoiding loss of human life during emergencies, endanger human life or the environment if compromised and that house irreplaceable items. These include hospitals, hazardous waste disposal sites, museums and communication centres.

II. 1:500 flood for other facilities critical for maintaining and restoring public order. These include courthouses, schools, correctional facilities, airports and seniors residences.

III. 1:100 for all other facilities.

While the 1:100 flood hazard mapping informs the development of public infrastructure in Calgary there are no standards or guidelines for infrastructure that do not fall under the provincial guidelines. While public development is avoided in the floodway some exceptions related to certain land uses are made, such as the RiverWalk promenade and pathway along the Bow River downtown.

Following the 2005 flood, Calgary initiated numerous projects to improve the flood-resiliency of specific City infrastructure. New operating guidelines at the Glenmore Reservoir increased the volume of floodwater that the reservoir was able to store. Investments in water treatment following an assessment conducted in partnership with the Public Infrastructure Engineering Vulnerability Committee (PIEVC) of Engineers Canada[xxvii] allowed The City to continue providing high quality drinking water throughout the 2013 flood. A flood wall recently built in Inglewood significantly reduced the impact of flood for that community. The impacts of the 2013 flood would have been much worse if it were not for the initiation of flood-resiliency efforts that followed the 2005 flood.

Impacts to public infrastructure during the 2013 flood - Despite additional flood resiliency initiatives taken by The City since 2005, considerable public infrastructure in the floodplain suffered damage in 2013, requiring extensive repairs and impairing vital services to Calgarians. Specific impacts included:

- Approximately $445 million in damage to public infrastructure.
- Twenty bridges closed, 50 bus routes canceled or detoured and 16 LRT stations closed.
- Thirty parks flooded.
- The Bonnybrook Wastewater Treatment Plant was completely inundated with floodwaters and discharged untreated wastewater to the Bow River.
- Disruption to City services while the Municipal Building was inaccessible.
- Extensive damage to St. Mary's, Rideau Park and Elbow Park schools.

Many of the recovery projects to fix damaged infrastructure have included capital measures not just to restore facilities but also to improve their resiliency so the impacts of a future event are lessened. For example:

- Riverbanks are being engineered to better withstand the effects of erosion.
- Several pedestrian bridges over the Elbow River are being rebuilt to be more resilient to future floods.
- Mechanical systems have been relocated above areas susceptible to flooding in restored parks facilities.
- Utility lines damaged from erosion have been relocated below anticipated depths of flood erosion.

The Centre Street bridge was washed out by Bow River flood in 1910.

Additional resiliency plans include flood protection measures for Bonnybrook Wastewater Treatment Plant, and riverbank stabilization and community drainage projects for Sunnyside Community.

The City is supporting civic partners, including the Calgary Zoo, Calgary Stampede, Talisman Centre and the Telus Convention Centre, to undertake projects to protect their facilities and operations from future floods. The Calgary Zoo is considering a flood barrier designed to protect to a 1:100 flood level, and to manage both overland and groundwater flooding. Over the last 15 years, the Calgary Stampede has been planning and constructing flood barriers to protect portions of their site and facilities. Additional barriers and systems are now under construction.

Both the Calgary Zoo and Stampede have been using flood mapping information over the last few decades to ensure that new facilities are more resilient to impacts of high water events. Federal, provincial and municipal processes are in place to ensure that for any flood protection concepts, the implications on the aquatic or riparian environment, water quality, water levels or erosion potential are addressed.

Improving the resilience of public infrastructure

For public infrastructure that does not fall under provincial flood protection guidelines The City may consider identifying graduated levels of tolerable flood risk depending on the function of specific types of infrastructure. The City should also review how the 1:100 flood level is used throughout City planning and operations and consider whether there should be firm design standards in place for any specific situations, rather than the 1:100 flood guideline. At minimum, The City should ensure that public development sets a good example for private development by meeting stringent flood protection standards in the flood fringe and avoiding building new structures in the floodway.

Recommendation: Create graduated flood protection level requirements for City infrastructure.

Improving the resiliency of infrastructure and property can be a costly and time-intensive undertaking. It is important that flood-resiliency projects are selected based on best available information. The City has a geographic information system (GIS) that includes layers of information that support analysis of flood risks, flood barrier planning and emergency preparation planning. Information related to flood risk in the existing GIS databases includes:

- Flood hazard maps for various magnitudes of flood events.
- Critical information specifics, such as value of assets and replacement schedules.
- Elevation of roads with respect to 1:100 flood levels.
- Critical transportation routes for access and egress throughout the city.
- Hospitals, schools, long-term-care facilities and other facilities that house vulnerable populations.
- Numbers of residential units in specific buildings and neighbourhoods.

This database should be expanded to include information on flood extent, causes of flooding and damages sustained during the 2013 flood. It can then be used to create a priority action list for future flood resiliency investments, such as critical infrastructure that deserves focused risk assessments. The GIS tool and priority action list should be integrated into flood resiliency planning, as per recommendations in the *Implementation* and the *Managing Flood Risk* section of this report.

Part of improving the resilience of public infrastructure may include implementing the PIEVC Protocol to assess climate vulnerability and recommend modifications to City systems as was done to improve the resilience of The City's water supply system. The PIEVC protocol helps municipalities identify and plan for climate-driven risks to infrastructure. Further assessments should be conducted for different infrastructure types including the wastewater treatment plant that flooded in 2013.

Recommendation: Maintain a comprehensive flood risk database integrated with existing geographic information systems (GIS).

ENMAX substation #32 surrounded by floodwaters.

PRIVATE INFRASTRUCTURE

ENMAX is the electrical distribution utility serving Calgary. ENMAX uses The City's flood inundation mapping in their infrastructure design considerations and flood mitigation plans. They review, revise and exercise their flood preparedness plan on an annual basis. They also have mutual assistance agreements in place with their counterparts to respond to emergency events. During the 2013 flood this led to ENMAX receiving help from EPCOR in Edmonton.

Impacts to private infrastructure during the 2013 flood - To protect public safety and to prevent significant damage, the Calgary Emergency Management Agency (CEMA) coordinated staged shut-offs of electricity and gas in advance of floodwaters reaching areas during the flood. Power outages extended into areas not affected by surface flooding because of the limited capability of the electrical distribution network to isolate outages. Larger areas needed to be evacuated than were actually impacted by the floodwater due to these power outages. Power outages and fuel shortages in the city resulted in the shut-down of sump pumps and back-up generators contributing to flooding in buildings that were not directly impacted by surface flooding.

Approximately 35,000 ENMAX customers were without power for varying periods of time. ENMAX substation #32, which provides critical power supply to the new hospital in south Calgary, had 300 mm of flooding and was threatened by severe bank erosion. Access to the substation was cut off. Four river crossing lines from this substation were lost during the flood. CEMA arranged for the Canadian Forces and emergency response volunteers to help with riverbank stabilization at the substation.

Improving the resilience of private infrastructure - Many of the recovery projects to repair damaged infrastructure have included measures to improve resiliency. For example, redundancy has been built into power supply and communication networks for critical operations. Additional resiliency plans include specific projects for improving the resilience of ENMAX's power supply network, such as hardening substations and other electrical infrastructure that was threatened in 2013.

The critical nature of energy supply in the case of emergencies necessitates working closely with utility providers to continue to improve resilience.

"I believe it is important to manage how/if electricity is cut off in affected areas. Our building did not directly flood, however the parkade experienced backup (more than an entire level was flooded). The reason for the flooding was that the sump pumps were not functioning because the power was shut off." – Public input

Opportunities to improve the resilience of Calgary's energy supply include:

- Making existing infrastructure more robust against floods.
- Adding a more modular electrical supply system that allows electricity to be cut-off at the level of specific neighbourhoods.
- Installing smart meters in flood-prone areas so that disconnections and reconnections can be done remotely at the household level.
- Enhancing the capability to effect more localized disconnections and re-connections of electricity supply downtown.
- Improving the resilience of the Downtown District Energy Centre.
- Providing ENMAX and City staff with enhanced information system tools to improve the speed at which re-connections can be made.
- Enhancing ENMAX's ability to share geospatial data with CEMA on the status of power re-connection.

With respect to all of the above-mentioned opportunities, ENMAX has applied to the Government of Alberta Flood Mitigation Secretariat for implementation funding.

Opportunities to improve resilience in the communication sector include:

- Making existing infrastructure more robust against floods.
- Expanding CEMA's membership to include additional communication providers to build resiliency throughout the sector.

Recommendation: Strengthen partnerships with utility providers to improve resiliency of their infrastructure and operations, with first priority to energy supply and communication networks.

PRIVATE PROPERTY

Many communities in Calgary were established before there were criteria for locating development outside of the floodway or designing properties in the floodplain for flood-resilience. As a result, much private development in the floodplain is vulnerably located and inadequately built to withstand floods and allow for a quick, cost-effective recovery.

In 1985 The City updated the Land Use Bylaw, forbidding new development in the floodway and putting requirements in place for development in the flood fringe. The City is working to remove grandfathering language from the Land Use Bylaw so all existing development will have to meet flood protection standards when re-developments are planned. Outside of the official flood hazard areas there are no requirements for flood protection of private property.

The City's Land Use Bylaw - *Development in the floodway and flood fringe is governed by the Land Use Bylaw. No new structures are permitted in the floodway but existing homes can be replaced using the same footprint as grandfathered properties that were in place prior to 1985. Flood fringe development specifies set back distances from the floodway and edge of rivers and creeks.*

"Unless otherwise referenced in subsection (2), all buildings constructed in the flood fringe after September 9, 1985 must be designed in the following manner:

(a) to prevent structural damage by floodwaters

(b) the first floor of all buildings must be constructed at or above the designated flood level

(c) all electrical and mechanical equipment within a building shall be located at or above the designated flood level"

Impacts to private property during the 2013 flood -

During the 2013 flood, properties were flooded both within and outside of the official flood hazard areas causing extensive damage. Flooding was caused by surface water, groundwater and backflow through sanitary sewers and storm sewers. Buildings constructed prior to 1985 and covered by the grandfathering clause of the Land Use Bylaw sustained the most extensive damage.

Much of the damage to commercial buildings and condominiums resulted from the flooding of underground structures containing critical building systems, such as electrical vaults, elevator shafts and parking garages. In many cases simple flood protection measures could have avoided significant losses.

In addition to direct property damage, the flooding of private property resulted in broader losses, such as lost work time, financial stress and emotional trauma. Some Calgarians were out of their building for months as a result of damage. Businesses lost weeks if not months of productivity because their offices or shops were shut.

Erlton flood resilient development - *Part of the Erlton neighbourhood was designed to sustain minimal damage during flood events up to the 1:100 flood. Buildings were constructed with elevated main floors. While the streets and garages in this development were inundated with water, repairs were much less expensive than in developments not designed for flood resilience.*

Improving the resilience of private property

In many cases there are basic resilience measures that could drastically reduce impacts of future floods, such as raising electrical equipment above the 1:100 flood level.

It may be appropriate to require flood protection in areas outside of the official flood hazard area that sustained damage from the 2013 flood or can otherwise be identified as being in a flood risk area. The City should consider implementing stricter design standards for private property in the flood hazard area or graduated flood protection requirements according to graduated flood maps.

Recommendation: Expand the review of the Land Use Bylaw and other development regulations to update flood resiliency requirements for private property in flood risk areas.

"While volunteering to help clean up flood affected homes, of the 10 houses I worked on, 9 had only basement flood damage. Only 1 house had some water damage to the main floor as well as the basement. If that ratio is a truism, if we had no basements in the flood fringe, we would have 90% less damage." – Public input

Green Calgary in partnership with Green Communities Canada offers home visits to help homeowners identify ways to reduce damage from storm water and floodwaters on their properties. The City should initiate additional programs that would further support building-owners to implement flood resiliency measures, such as:

- An incentive program that provides home improvement grants and loans for flood resilience products.
- Collaborating with the insurance industry and emergency management agencies to create a home flood resilience audit program, similar to a home energy audit program.
- Workshops or seminars in collaboration with the insurance industry that support community and business organizations to identify risk management strategies.

"Placing utilities [in office and apartment high rises] above ground level would considerably reduce the time to re-occupation, even if the parking is unusable. City Building code should be updated accordingly, and where possible, applied retroactively." – Public input

Recommendation: Develop programs that support building-owners to implement flood resiliency measures.

CHANGING CLIMATE

After Alberta's 2013 floods, many asked the question: was climate change to blame? The answer is not simple. Extreme weather events in the region like the 2013 flood are rare and there are insufficient historical data on which to base predictions in their frequency or intensity.[xxix] Regardless of the inevitable uncertainty about climate change, we know that extreme weather events have happened in the past and we can be sure they will happen again in the future. We cannot know exactly when future extreme weather will occur.

The Intergovernmental Panel on Climate Change's latest Assessment Report concludes that the global climate system is warming, with increases in average air and ocean temperatures, melting of snow and ice, and rising global average sea level.[xxx] In Canada, an average temperature increase of 1.3°C has been observed between 1950 and 2000. But what does this mean at the local level?

The Canadian prairies have one of the world's most variable climates. Changes in the global climate system are expected to bring more frequent and intense weather events to the prairie region. The climate and weather is expected to become more unpredictable with more frequent droughts and flooding from intense rainfalls and rapid snow melt.[xxxi]

The Water Survey of Canada uses historical river flow data to calculate the size of the 1:100 flood.

Each year, more data are collected and can be used to refine the estimate of the size of the 1:100 flood.

As the climate is changing, large floods could become more common.

This means that the size of the 1:100 flood may be larger in the future than it is today.

ADAPTING TO A CHANGING CLIMATE

Increasingly unpredictable weather and climate patterns in Calgary may impact The City's ability to make well-informed decisions regarding service delivery and infrastructure. Flood mitigation work must be done with a view to several possible scenarios to manage this uncertainty – applying adaptability to design standards and mitigation measures as part of a comprehensive approach to climate adaptation. The City must consider the potential for droughts and other climatic conditions and severe localized weather events (such as hail, thunderstorms, and high winds) in its planning. Drought events can be more costly than flood events when broader impacts are measured, for example, agricultural losses. Robust and flexible adaptation options are needed. The challenge is to put in place design standards for infrastructure that will be built to last 50 to 100 years. What will that infrastructure have to withstand and how might operations need to change?

Recommendation: Develop a comprehensive climate adaptation plan and implementation tools to reduce The City's infrastructure and operational vulnerabilities.

City of Calgary water treatment system vulnerability - *In partnership with Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC), in 2011 The City of Calgary assessed the potential vulnerability of its water supply infrastructure to climate change. The vulnerabilities seen as the highest priorities were those associated with extreme events such as flooding and drought. Operation and management plans are in place to reduce risk of some negative climate-infrastructure impacts. It is likely the climate changes will be gradual so adaptation can be incorporated into The City's long-range plans.*

Resiliency of flood control dams in Toronto

A 2010 vulnerability study examined current and future climate change impacts on two Toronto flood control dams and reservoirs. The assessment, taken up to the 2050 time horizon, examined the impacts of rainfall on performance of the dams to determine if any engineering solutions were needed. The report found that the current infrastructure is resilient to anticipated severe weather events allowing the city to prioritize infrastructure maintenance.[xxxii]

Examining infrastructure vulnerability to flood and other extreme weather should be part of a comprehensive climate adaptation plan for The City. As part of the plan, The City must evaluate the highest infrastructure vulnerabilities to climate change impacts and then prioritize interventions to improve resilience and incorporate these into existing asset replacement plans. Flood mitigation in public and private infrastructure is discussed in detail in the *Infrastructure and Property Resiliency* section.

THE LOCAL CLIMATE

Calgary has a prairie type climate, influenced by the city's proximity to the Rocky Mountains making the weather quite variable and unpredictable. The climate is typically sunny and dry, with cold winters and most of Calgary's precipitation occurring in the form of rainfall in late spring and early summer.

The understanding of variability in Calgary's future climate and weather patterns has focused mostly on annual averages and long-term changes. Understanding the types and frequencies of extreme events expected as a result of climate change at the local level requires researching weather and flooding events and how they are connected. Translating regional predictions into more local conditions is not yet well developed.

The impacts of climate change on spring flooding in the Elbow River Watershed were examined in 2007; results showed that annual average temperatures were increasing. The eastern portion of the watershed showed significant decreases in annual snowfall, while the western portion near the foothills showed increases in snowfall. Modeling showed that spring time flooding from expected increases in precipitation may nearly double flood peaks in the future.[xxxiii] However, it is important to note that even though trends in average snowfall and accumulated snow or snowpack conditions are decreasing, the trends in extreme snow conditions can be different.

The South Saskatchewan River Basin Adaptation to Climate Variability Project commissioned an evaluation of potential climate change impacts in the Bow River Basin.[xxxiv] As part of the project The City was involved in developing the Bow River Operational Model (BROM), which examined how changes in climate could impact flows and functions of the Bow River. This approach and others should be used to give the best simulations for the Bow Watershed.

Watershed-scale climate modeling provides information for The City and regional stakeholders in managing the uncertainties in projected changes in flood magnitudes and seasonality, expected changes in extreme precipitation and impacts on other water management issues such as drought. A better understanding of historical events and future scenarios can inform flood risk assessments, flood hazard maps, structural and land-use design standards, as well as contribute to flood and drought mitigation measures. This gives decision makers a tool to address vulnerabilities and direct resources where needs are highest. If The City pursues local climate models, other orders of government should be consulted.

"Calgary is a world class city and the downtown areas need protecting. The city cannot afford to have its business centre flooded again and it would be short sighted not to proceed with this preventative work. The floods will become more frequent in the coming years due to climate change." – Public input

Recommendation: Develop a suite of watershed-scale climate models to capture various weather event scenarios, with input from regional partners, academic institutions and other levels of government.

Climate resiliency models for cities - *In British Columbia, the Pacific Climate Impacts Consortium developed regional scenarios for the Georgia Basin on climate variables such as: annual heating and cooling days, hydrological models and the length of time between events of a certain size or magnitude. Researchers used eight regional climate models to project changes in extremes. The information was used by the City of Vancouver to inform its climate change adaptation strategy.*[xxxv]

IMPLEMENTATION

The result of the Panel's investigation is a wide-ranging report that brings forward the most effective recommendations possible based on broad engagement and the best information that could be gathered in the months available. The timeframe did not allow the Panel to undertake new research, extensive design or modeling or detailed evaluation of alternatives. This work remains to be done and will be turned over to City Administration. To guide this work, The City should develop a vision and principles to direct flood risk management in the city and report annually on activities undertaken to improve resiliency and how well they are working.

Recommendation: Establish a permanent team within The City to oversee flood preparedness and resilience.

Recommendation: Provide an annual update to City Council on progress related to the recommendations from the Expert Management Panel on River Flood Mitigation.

The Expert Management Panel reviewed all recommendations qualitatively, considering potential economic, environmental and social impacts. The City should further assess flood mitigation options for their relative life-cycle costs and benefits to select options that best serve the public good and make efficient use of public funds.

Capital project options are at various stages of study by The City and the Province. More study would better quantify the impacts and should consider regional water management objectives. The City must consider combinations of measures yielding optimum results, as some measures are complementary, and some measures, if implemented, may reduce the need for others. Implementation decisions should be based on a thorough assessment across all mitigation options.

Recommendation: Evaluate social, economic and environmental impacts of flood mitigation options.

What The City does may influence what the Province is considering upstream of Calgary and vice versa. Many of the structural opportunities for reducing floodwaters in Calgary are upstream of the city; investigating or pursuing these options requires coordination with the Province, TransAlta, First Nations and private property owners.

Recommendation: Connect with the provincial body overseeing flood protection and loss reduction and support the Province's continuing analysis of flood mitigation options and implementation of appropriate measures throughout the Bow and Elbow watersheds.

The City can learn from other communities' efforts to improve their resiliency to flood events, and share lessons learned on what worked well during the 2013 flood and where improvements are being made or could be made. There are numerous events related to floods hosted by organizations such as cities, professional organizations and non-governmental organizations, but there is no regular event that brings together professionals from across Canada with a focus on municipal flood resiliency. This presents an opportunity for Calgary to initiate a regular national dialogue on these issues.

Recommendation: Host a national flood risk management workshop to share best practices and develop an ongoing networking group.

NEXT STEPS

This report is one step of many towards resiliency to floods and other disruptive events in Calgary. Implementing these recommendations requires a collaborative and coordinated approach between The City, the Province and other parties. The way forward will require investment – municipal, provincial, and federal. The pace of these investments must be balanced against the risk and reward achieved from each action.

Some of the recommendations in this report are contingent on the implementation of others and decisions on these may cause priorities to change. Even with dedicated efforts, flood resilience is not something that can be achieved overnight. Resilience requires continually learning and adapting as situations change. The city will grow, the watershed and climate will change, and flood risks will evolve. Calgary's flood mitigation strategy must evolve as well.

"I hope that our leaders will not shy away from making long-term solutions possible because they fear the short-term reactions of citizens." - Public input

GLOSSARY

1:100 or 100 year flood – A flood whose magnitude has a one per cent chance of occurring in any year. It is also sometimes referred to as the one per cent flood, since the probability that it will be exceeded in any given year is one per cent.

Aquifer – A subsurface formation that is permeable enough to store or conduct groundwater to wells and springs. An aquifer can be adjacent to and hydraulically connected to water bodies such as rivers and lakes.

Basin – The drainage area of a stream, river or lake. Also known as a watershed.

Climate adaptation – Anticipating the effects of climate change and taking appropriate action to prevent or minimize the damage they may cause.

Climate scenario – A simplified representation of the future climate, typically constructed for use as input to climate change impact models.

Dry dam – A dam constructed for the purpose of flood control, allowing water to flow past under normal conditions, and temporarily holding back floodwaters, releasing them over a period of time.

Ecosystem approach – A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in a way that is balanced and equitable to future generations. It requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning.

Ensemble forecasts – A group of model simulations used for weather or climate projections. Variation of the results across the ensemble gives an estimate of uncertainty. Multi-model ensembles with simulations by several models include the impact of model differences.

Flood barrier – A permanent earthen embankment or wall, or a temporary wall constructed of sand bags or other materials, erected to provide protection from floods.

Flood fringe – The portion of the flood hazard area outside of the floodway. Water in the flood fringe is generally shallower and flows more slowly than in the floodway.

Flood hazard area – The area that is affected by a 1:100 flood, as indicated by official provincial flood hazard maps. The flood hazard area is typically divided into floodway and flood fringe zones and may also include areas of overland flow.

Flood hazard map – An official map published by the Government of Alberta that indicates the areas likely to be affected by surface water during a 1:100 flood event.

Floodplain – The area of land adjacent to a river that stretches to the base of the enclosing valley walls and experiences flooding during periods of high river flow.

Flood protection level – Flood magnitude (e.g. 1:100 flood) that infrastructure such as flood barriers are designed to withstand.

Floodway – The portion of the flood hazard area where flows are deepest, fastest and most destructive. The floodway typically includes the main channel of a stream and a portion of the adjacent area.

Hydrology – The scientific study of the properties, distribution and circulation of water on and below the earth's surface and in the atmosphere.

Model – A physical or mathematical representation of a process that can be used to predict some aspect of the process.

Overland flooding – Flooding of a property by water that enters the property from the surface, typically through doors or windows.

Overland flow area – Part of the official flood hazard area and typically considered special areas of the flood fringe.

Peak flow – The highest rate of water moving through a river during a specific event or period of time. The water level in the river is highest during peak flow. Also known as maximum flow.

Reservoir – A storage place for water created by construction of a dam in a river valley, and from which the water may be withdrawn for such purposes as irrigation, power generation or water supply.

Resilience – The ability of a social or ecological system to absorb disturbances while retaining the same ways of functioning and the capacity to adapt to stress and change.

Riparian zone or riparian area – Transition zones between the water and land. Riparian zones play an important role in protecting the river; they prevent excessive erosion, act as natural floodplains, provide river bank stabilization and also offer aesthetic, economic and recreational benefits.

Risk – The likelihood that an event will occur that causes harm.

Watershed – An area of land where waters flowing from different rivers, streams, lakes and wetlands, is conveyed to the same outlet. Other terms that are used to describe a watershed are drainage basin, catchment basin, catchment area, and river basin. Large watersheds may contain several smaller sub-watersheds that drain to the same outlet.

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