Prepared for: City of Calgary - Water Resources

Confederation Park Regional Drainage Study

Final Report

Associated Engineering

GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Executive Summary

Introduction

In 2013, 1744228 Alberta Ltd. (the Landowner) acquired the former Highland Park Golf Course (HPGC) lands. Maple Projects Inc. and Amble Ventures Ltd. (the Developers) plan to develop the former HPGC lands into a mixed-use, commercial and residential development known as the Highland Park Development (HPD). The City of Calgary (The City) has approved the Land Use and Outline Plan for the proposed development subject to conditions, including but not limited to, the findings of a regional drainage study.

- In 2017, The City commissioned Associated Engineering (AE) to undertake the Confederation Park Regional Drainage Study (The Study) which includes the former HPGC lands.
- On May 31, 2018, AE issued the Draft Final Report for The Study. This report expands on the Draft report with discussions regarding dam safety and new information from AEP.

The Master Drainage Plan (MDP) component of The Study is focused on Confederation Creek, the Lower Confederation Trunk and the Confederation Valley. The analysis will inform The City of regional drainage patterns and the effects of the HPD on the drainage system. Within this study, options have been developed to mitigate regional drainage issues.

This report summarizes the MDP component of The Study.

Study Area

The Confederation Creek Catchment encompasses approximately 2,700 ha in northwest Calgary. It is roughly bounded by Nose Hill Park to the north, Shaganappi Trail NW to the west, 24th Avenue NW to the south, and Edmonton Trail to the east.

Confederation Creek now conveys the combined major and minor system flow from the CP15/16 Outfalls within the Confederation Park Golf Course through Confederation Park to the D33 Inlet. Downstream of the D33 Inlet, minor and major system flows are respectively conveyed to Nose Creek via the Lower Confederation Trunk and the Confederation Valley.

Confederation Creek is interrupted by roadway embankments at 14th Street NW and 10th Street NW. Both embankments have culverts and pedestrian walkways (which function as elevated culverts). During high intensity storm events, the embankments retain water upstream within the Confederation Park Golf Course and Confederation Park.

The Confederation Valley conveys major system flow when the capacity of the Lower Confederation Trunk is exceeded. Major system flow ponds within the Queen's Park Cemetery, the 40th Avenue NW and 4th Street NW intersection, and upstream of the Centre Street N embankment within the former HPGC lands.

Crown Owned Land

In 2017, The City submitted an inquiry to Alberta Environment and Parks (AEP) to gain clarity on the potential for a Public Lands claim along the historic reaches of Confederation Creek. In November of 2017, The City received an email from AEP stating that "*this water feature is indeed Crown owned under Section 3 of the Public Lands Act*". In October of 2018, The City of Calgary received a letter from AEP indicating a reversal of the Crown claim in the Confederation Creek Catchment.

Highland Park Development

Drainage within the Confederation Creek Catchment will be affected by the proposed HPD. The development includes up to 4 m of fill material to accommodate at-grade intersections of the proposed Highland Drive NW with Centre Street N and 40th Avenue NW. The fill material would remove 97,000 m^3 of Confederation Valley's depression storage west of Centre Street N.

Drainage Modelling

AE built a stormwater model to understand the hydrologic and hydraulic regime of the study area. The modelled results indicate the following drainage issues:

- The size of the existing culverts along Confederation Creek causes the temporary impoundment of stormwater runoff upstream of 14th Street NW and 10th Street NW. Stormwater runoff is also impounded upstream of 30th Avenue NW and Centre Street N.
- Major overland system flow occurs between 30th Avenue NW and the N25 Outfall during high intensity rainfall events. Centre Street N currently impedes overland flow and creates a large depression in the former HPGC lands.
- Flows to Nose Creek will increase if the HPD proceeds as proposed in the Land Use and Outline Plan. This is because 97,000 m^3 of existing storage upstream of Centre Street N will be filled in as part of the HPD's grading requirements causing runoff to overtop Centre Street N more frequently.
- Climate change and densification are predicted to increase the magnitude of the peak flows and runoff volumes during rainfall events. The increased runoff will compound the existing issues.

Preliminary Findings

Overland Flow

There are public safety risks associated with overland flow along the Confederation Valley. These risks will become more severe if development is permitted within the valley as proposed because more people may be exposed to the presence of deep, fast moving water through the valley. The expected overland flow upstream of the HPD would exceed the municipal and provincial safe overland flow criteria without upstream drainage improvements or safe management of overland flow within the HPD. The overland flow criteria serve as an indicator for the potential risk of people being swept away by the force of deep, fast moving water.

Removal of the depression storage could allow overland flows to overtop Centre Street N more frequently. These flows could also damage the future Green Line LRT and inundate the proposed tunnel at McKnight Boulevard NW. Major system flow which overtops Centre Street N could also cause damage within Greenview Park and the community of Greenview.

Dam Safety

The existing embankments along Confederation Creek were not constructed for the purpose of storing water. The embankments were constructed to convey vehicular traffic across the Confederation Valley. Therefore, the existing embankments are not expected to be classified as dams according to provincial regulation.

Despite the roadway embankments not being classified as dams, there is a public safety risk associated with the upstream storage depths and volumes. These risks include slope stability risks and drowning risks. In 2016, Thurber Engineering Ltd. determined that a slope on the upstream face of the 14th Street NW embankment was marginally stable.

Nose Creek

Nose Creek has been modified with the urbanization of Calgary, as have the areas contributing runoff to the creek. The creek has been straightened and now receives more unattenuated and untreated urban runoff than it did previously. As a result, the water quality in Nose Creek has deteriorated, while the bed and banks of the creek have been subjected to excessive scour and erosion.

In 2007, the Nose Creek Watershed Partnership (NCWP) issued the *"Nose Creek Watershed Water Management Plan"*. The plan provides a framework and recommendations for sustainable development within the watershed including rate, volume and quality targets. In 2018, the NCWP updated the *"Nose Creek Watershed Water Management Plan"*. "*The update was necessary to reflect advancements in knowledge, changes in provincial and municipal policies, and to address new challenges in land and water resource management.*" (Nose Creek Watershed Partnership, 2018).

Further increase in the magnitude of the peak flow rate and volume will likely negatively affect Nose Creek and adjacent properties. Based on currently available information, it is unlikely that Nose Creek can accommodate additional flows without major capacity upgrades along the entire creek down to its confluence with the Bow River. The capacity upgrades would not align with the Nose Creek Watershed Management Plan. In addition, due to the anticipated provincial and federal scrutiny, extensive environmental provisions may be required to minimize impacts on fish habitat and riparian areas.

Climate Change and Densification

Research indicates that the climate is changing, which is expected to reflect more extreme weather conditions. "*Climate change will likely result in long-term changes in temperature and precipitation, as well as increased frequency and severity of weather events such as droughts, floods, forest fires, and severe storms.*" (Alberta Government, 2019)

Climate change direction has been set by The Federal and Provincial governments, which Municipalities must adhere to. The City has dedicated a team to facilitating city, citizen, and business actions to mitigate and adapt to the impacts of climate change. This team is taking multiple steps to accomplish this including developing a *Climate Resilience Plan* endorsed by City Council in mid-2018.

The City's *Climate Resilience Plan* includes an "a*daptation plan identifying actions to reduce the impacts from the changing climate*" (City of Calgary, 2017). Adaptation strategies include building resilience into proposed stormwater infrastructure to manage higher intensity rainfall.

In alignment with The City's approach, The City directed AE to consider the effects of climate change in this Study to determine the impact it will have on existing infrastructure, and to propose improvements to manage the anticipated effects of climate change.

Study Objectives

Upon review of the preliminary findings, The City instructed AE to develop stormwater management options which met the following objectives:

- Reduce the magnitude of overland flooding in Queen's Park Cemetery, at the intersection of 4th Street NW and 40th Avenue NW, and within the former HPGC lands.
- Maximize the amount of developable land within the former HPGC lands.
- Reduce the likelihood of overland flows crossing the future Green Line LRT.
- Reduce the risks associated with dam safety.

The City considers the former HPGC lands as undeveloped land and considers the HPD to be a greenfield development. Considering this and The City's desire to adapt to climate change with resilient infrastructure, The City directed AE to develop options that account for the anticipated effects of climate change for the 1:100-year, 4-hour, storm event. Given the on-going residential and commercial re-development, The City also requested that AE consider an increase in impervious area while developing options.

The City also instructed AE to develop options which maintained the Scenario 1 (1:100-year, existing condition) peak flow rate to Nose Creek recognizing that Nose Creek and the surrounding infrastructure could be negatively affected by receiving additional flow.

Options

AE developed six different options:

- **Option 1A** – No Improvements – Without the HPD.
- **Option 1B** – No Improvements – With the HPD.
- **Option 2** – West Storage and Conveyance to Nose Creek – With the HPD.
- **Option 3** – West Storage and Diversion to the Bow River – With the HPD.
- **Option 4 Ultimate** – West Storage and Centre Street N Storage – Without the HPD.
- **Option 4 Interim** – Existing Risk Mitigation – Without the HPD.

The HPD as referenced in this report refers to the HPD as identified in the current, approved Land Use and Outline Plan.

AE and The City considered several other storage facilities during the development of these options. These storage facilities were comprised of smaller scale storage sites. Some of these suggested alternative storage facilities may be able to be incorporated into the overall option if they are proven to be effective and cost beneficial as detailed design is initiated.

Option 1A – No Improvements – Without the HPD

Option 1A does not include any of the improvement projects and assumes that the former HPGC lands remain as green space.

Option 1B – No Improvements – With the HPD

Option 1B does not include any of the improvement projects proposed; however, in contrast to Option 1A, Option 1B assumes that the HPD will be developed as per the proposed Land Use and Outline Plan. Recognizing that the former HPGC lands are privately owned, Option 1B would limit The City's flexibility to manage stormwater runoff within the Confederation Creek Catchment.

Municipal and provincial overland flow criteria would be exceeded within the HPD without safe management of overland flow within the HPD. These criteria were developed to prevent people from being swept away by the force of deep, fast moving water, and to provide safe access for emergency vehicles during rainfall events.

Option 2 – West Storage and Conveyance to Nose Creek

Option 2 consists of intentional storage upstream of: 14th Street NW, 10th Street NW and 30th Avenue NW; and conveyance improvements that reduce the magnitude of the overland flow in the Confederation Valley. Intentionally storing stormwater upstream of these road embankments would result in them being classified as dams under the Water Act regulation. The storage in the west half of the catchment would attenuate peak flows to reduce the size of downstream conveyance improvements. The conveyance improvements in the east half of the catchment would reduce the magnitude of the overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk. The assumption is that the HPD would be developed as part of Option 2.

Option 2 Summary:

- 310,000 m^3 of dam storage upstream of 14th Street NW.
- 295,000 m^3 of dam storage upstream of 10th Street NW.
- 80,000 m^3 of dam storage upstream of 30th Avenue NW.
- 3,250 m of conveyance upgrades along the Lower Confederation Trunk.
- Centre Street N piped major system.
- 1:100-year peak flows to Nose Creek could increase from 31.8 m^3/s for existing conditions to 82.7 m^3/s during future conditions.

Option 3 – West Storage and Diversion to the Bow River

Option 3 consists of intentional storage upstream of: 14th Street NW, 10th Street NW and 30th Avenue NW; conveyance improvements, and a flow diversion to the Bow River. Together, these improvement projects reduce the magnitude of the overland flow in the Confederation Valley and prevent an increase in peak flow to Nose Creek. The intentional west catchment storage upstream of 14th Street NW, 10th Street NW and 30th Avenue NW would require classifying the embankments as dams and would attenuate peak flows to reduce the sizes of downstream conveyance improvements. The conveyance improvements in the east half of the catchment would reduce the magnitude of the overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk upstream of the diversion. The Bow River diversion would prevent an increase in the peak flow rate to Nose Creek by directing a significant amount of flow directly to the Bow River. It was assumed that the HPD would be developed as part of Option 3.

Option 3 Summary:

- 310,000 m^3 of dam storage upstream of 14th Street NW.
- 295,000 m^3 of dam storage upstream of 10th Street NW.
- 80,000 m^3 of dam storage upstream of 30th Avenue NW.
- 2,560 m of conveyance upgrades along the Lower Confederation Trunk.
- Centre Street N piped major system.
- The diversion tunnel would be between 4 m and 5 m in diameter and would be at least 4.5 km in length.

Option 4 Ultimate – West Storage and Centre Street N Storage

Option 4 Ultimate consists of intentional storage upstream of: 14th Street NW, 10th Street NW and 30th Avenue NW; conveyance improvements, and intentional storage upstream of Centre Street N within the former HPGC lands (which are privately owned at this time). Together these improvement projects reduce the magnitude of the overland flow in the Confederation Valley and prevent an increase in the peak flow rate to Nose Creek. The intentional storage in the west catchment and upstream of Centre Street N would require classifying the embankments as dams under the Water Act regulation.

The storage in the west half of the catchment would attenuate peak flows to reduce the size of downstream conveyance improvements. The conveyance improvements in the east half of the catchment would reduce the magnitude of overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk upstream of the former HPGC lands. The storage upstream of Centre Street N would prevent an increase in the peak flow rate to Nose Creek by attenuating flows. Based on collaboration with the developer's consultant it was determined that intentionally storing stormwater upstream of Centre Street N would substantially reduce the development potential of the parcel. As such, for Option 4, the assumption is that the HPD would not be developed as indicated in the proposed Land Use and Outline Plan, but Option 4 does not preclude all development on these lands.

Option 4 Ultimate Summary:

- 310,000 m^3 of dam storage upstream of 14th Street NW.
- 295,000 m^3 of dam storage upstream of 10th Street NW.
- 80,000 m^3 of dam storage upstream of 30th Avenue NW.
- 2,350 m of conveyance upgrades along the Lower Confederation Trunk.
- 180,000 m^3 of storage upstream of Centre Street N within the former HPGC lands.

The HPGC lands and parcel east of Centre Street N are privately owned. A significant portion of the HPGC lands would be required for Option 4 Ultimate. If necessary, the required land extents would be delineated in a future study.

Option 4 Interim – Existing Risk Mitigation

Option 4 Interim consists of small-scale improvement projects to mitigate some of the existing risk within the Confederation Creek Catchment assuming that the HPGC lands remain as greenspace until a new Land Use and Outline Plan is proposed by the landowner.

Option 4 Interim would allow The City to mitigate some of the existing risk while studies and data collection are undertaken to inform and optimize the final configuration of Option 4 Ultimate.

Option 4 Interim Summary:

- Ponding level monitoring upstream of 14th Street NW, 10th Street NW, 30th Avenue NW and Centre Street N.
- Periodic geotechnical inspection of 14th Street NW, 10th Street NW, 30th Avenue NW and Centre Street N.
- Geotechnical Improvements at 14th Street NW.
- Major system conveyance through Greenview Park.
- All interim improvements noted above are within public property.

Option Evaluation

Table E-1 below identifies which objectives are met within each option.

Table E-1
Objective Summary

Objectives	Option 1A	Option 1B	Option 2	Option 3	Option 4 Ultimate	Option 4 Interim
Reduce the magnitude of overland flooding in Queen's Park Cemetery, at the intersection of 4th Street NW and 40th Avenue NW, and within the former HPGC lands.	No	No	Yes	Yes	Yes	No
Maximize the amount of developable land within the former HPGC lands.	None	Full	Moderate	Moderate	Minimal	None
Reduce the likelihood of overland flows crossing the future Green Line LRT.	No	No	Yes	Yes	Yes	No
Maintain Current Peak Flow Rate to Nose Creek.	No	No	No	Yes	Yes	No
Address Impacts of Climate Change and Densification.	No	No	Yes	Yes	Yes	No
Reduce the risks associated with dam safety.	Yes	Yes	No	No	No	Yes

Cost Estimates

Class 5 cost estimates are presented within **Table E-2**. Class 5 cost estimates have an expected variance of -50 % to +100 % according to The City's "*Estimation and Contingency Standard*" (City of Calgary, 2012).

Table E-2
Class 5 Cost Estimates

Option	Estimated Cost*	Inclusions	Exclusions
Option 2	$110,000,000 Cost Estimate Range $55,000,000– $220,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW	• Contingency • Centre Street N Piped Major System Crossing • Substantial Nose Creek Improvements to Receive Increased Flows
Option 3	$370,000,000 Cost Estimate Range $185,000,000– $740,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW • Bow River Diversion Tunnel	• Contingency • Centre Street N Piped Major System Crossing
Option 4 Ultimate	$130,000,000** Cost Estimate Range $65,000,000- $260,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW • Dam Safety Retrofits at Centre Street N • HPGC Lands Channel and Storage Facility	• Contingency • Land Acquisition
Option 4 Interim	$10,000,000** Cost Estimate Range $5,000,000– $20,000,000	• Engineering Fees • Monitoring & Inspection of Roadway Embankments • Local Stabilization of 14th Street NW • Greenview Park Conveyance Channel	• Contingency

*The Class 5 cost estimates are presented as a value and a range. The value presented does not include contingency. The range presented is -50 % to +100 % of the cost estimate and is based on the expected variance of the Class 5 cost estimates. The range has been rounded up to the nearest $1,000,000.
** The costs of Option 4 Interim are not included in Option 4 Ultimate.

The cost estimates also exclude the following items:

- Future Studies
- Permits
- Approvals
- Environmental Requirements and Compensation
- Operation and Maintenance Costs
- Taxes.

Summary

In 2017, AE was commissioned to undertake the Confederation Park Regional Drainage Study to inform The City of regional drainage patterns within the Confederation Creek Catchment.

The Confederation Creek Catchment is affected by regional drainage issues which stem from existing development. AE's drainage modelling suggests that: runoff is impounded within the Confederation Valley upstream of roadway embankments; major overland system flow occurs within the Confederation Valley; flows to Nose Creek will increase with increased re-development in the catchment area; and climate change and densification will compound these issues.

These drainage issues create risks within the Confederation Creek Catchment. These risks include:

- Public safety risks associated with deep fast-moving water;
- Dam safety risks associated with water retention in the Confederation Valley;
- Risk of property damage due to flooding; and
- Environmental risks associated with erosion damage to Nose Creek.

If future development and climate change are not planned for and managed, these drainage risks could be further compounded. In an attempt to mitigate these risks, AE and The City developed five regional options. It should be noted that the proposed HPD was a key consideration for each option due to its impacts on regional drainage and potential stormwater management strategies.

Option 1A and Option 1B (No Improvements – Without/With the HPD) would result in unacceptable levels of risk. These risks would be associated with dam safety, high flows through the proposed HPD and Nose Creek's lack of ability to receive additional flow. The City is not investigating Option 1A or 1B any further.

Option 2 (West Storage and Conveyance to Nose Creek) would increase peak flow rates to Nose Creek beyond those in existing conditions. Given Nose Creek's lack of ability to receive the additional flow required to accommodate Option 2, The City is not investigating Option 2 any further.

Option 3 (West Storage and Diversion to the Bow River) would result in the removal of 97,000 m^3 of stormwater attenuation in the catchment to accommodate the HPD. The estimated cost of managing this removal of storage is prohibitively expensive ($370,000,000). The City also anticipates that a feasibility study to assess the viability of the Bow River Diversion Tunnel could take between 1 and 2 years to complete. Therefore, The City is not investigating Option 3 any further.

Option 4 Ultimate (West Storage and Centre Street N Storage) would achieve most of The City's objectives; however, the HPGC lands and parcel east of Centre Street N are privately owned. As such, for Option 4, the assumption is that the HPD would not be developed as indicated in the proposed Land Use and Outline Plan, but Option 4 does not preclude all development on these lands.

Option 4 Interim (Existing Risk Mitigation) would allow The City to mitigate some of the existing risk while further studies and data collection are undertaken to inform and optimize the final configuration of Option 4 Ultimate.

Conclusions

AE recommends that The City take a two-stage approach to stormwater management in the Confederation Creek Catchment (Option 4 Interim & Option 4 Ultimate).

- Option 4 Interim (Stage 1) would allow The City to mitigate some of the existing risks while:
  - The City addresses the need for land within the HPGC lands for Option 4 Ultimate.
  - The City undertakes a regional study of Nose Creek.
  - The City further assesses the potential effects of climate change on rainfall.
  - The City undertakes geotechnical inspection of the roadway embankments.
  - The City considers optimization of Option 4 Ultimate
- Option 4 Ultimate (Stage 2) would allow The City to meet its ultimate objectives.

The City's next steps include:

- Finalizing the reporting for the Community Drainage Improvement component of this Study.
- Continued discussion with the landowner on a revised plan for the HPGC lands to accommodate Option 4 Ultimate.
- A regional study of Nose Creek which confirms the creek's existing hydraulics and identifies the potential for regional improvements which may enable optimization of Option 4.

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1 Introduction

The Confederation Creek Catchment collects runoff from 2,700 ha of northwest Calgary. Runoff within the catchment discharges into Nose Creek, approximately 6 kilometres upstream of the confluence with the Bow River.

Development in Calgary has changed drainage within the Confederation Creek Catchment. Historically, the catchment was drained by small tributary creeks which originated within Nose Hill Park and discharged into Confederation Creek. Residential development has removed many of these natural tributary creeks and replaced them with an engineered drainage system. Roadway embankments now cross Confederation Creek at various locations, while the creek's lower reaches have been replaced with underground storm infrastructure for conveyance of low intensity rainfall events.

Drainage within the catchment is affected by the maximum stormwater rate that can be safely discharged to Nose Creek. This target will become more challenging to meet as drainage in the catchment will be affected by an anticipated increase in rainfall severity associated with climate change, based on current climate change predictions.

Future development will also affect drainage within the catchment. On-going densification will increase the amount of impervious area resulting in higher peak flows and runoff volumes during rainfall events.

In 2013, 1744228 Alberta Ltd. (the "Landowner") acquired the former Highland Park Golf Course (HPGC) lands. Maple Projects Inc. and Amble Ventures Ltd. (the Developers) plan to develop the former HPGC lands into a mixed-use, commercial and residential development known as the Highland Park Development (HPD). The City of Calgary (The City) has approved the Land Use and Outline Plan for the proposed development subject to conditions, including but not limited to, the findings of a regional drainage study.

- In 2017, The City commissioned Associated Engineering (AE) to undertake the Confederation Park Regional Drainage Study (The Study) which includes the former HPGC lands.
- On May 31, 2018, AE issued the Draft Final Report for The Study. This report expands on the Draft report with discussions regarding dam safety and new information from AEP.

There are two components to The Study:

Master Drainage Planning

The Master Drainage Plan (MDP) component of The Study is focused on Confederation Creek, the Lower Confederation Trunk, and the Confederation Valley. The analysis will inform The City of regional drainage patterns and the effects of the HPD on the drainage system. Within this study, options have been developed to mitigate regional drainage issues. This report summarizes the MDP component of The Study.

Community Drainage Improvements

The Community Drainage Improvements (CDI) component of The Study will focus on mitigating local drainage problems. Reporting on the CDI component of The Study will be completed early in 2019.

2 Study Area

2.1 OVERVIEW

The Confederation Creek Catchment encompasses approximately 2,700 ha in northwest Calgary as shown in **Figure 2-1**[1]. It is roughly bounded by Nose Hill Park to the north, Shaganappi Trail NW to the west, 24th Avenue NW to the south, and Edmonton Trail NE to the east. The Upper Confederation Trunk, Confederation Creek and Lower Confederation Trunk convey the minor system stormwater runoff to Nose Creek. The Confederation Valley conveys major system stormwater runoff to Nose Creek when the capacity of the minor system is exceeded. Runoff discharges into Nose Creek at the N25 Outfall, approximately 6 kilometers upstream of the confluence with the Bow River. **Figure 2-2** details Confederation Creek and Confederation Valley.

2.2 PRE-DEVELOPMENT CONDITION

Historically, Confederation Creek was known as the North Hill Coulee. The coulee and its tributaries originated within Nose Hill Park and conveyed runoff to Nose Creek. The relatively steep grades resulted in erosional down cutting and the creation of the coulee. The coulee stopped abruptly as it transitioned into the historic flood plain of Nose Creek. The meandering channel of Nose Creek then conveyed runoff to the Bow River.

AMEC Foster Wheeler Environmental & Infrastructure (AMEC) and Tannas Conservation Services Ltd. (Tannas) prepared a draft report in 2017 entitled "*Ephemeral and Intermittent Watercourse Mapping, Classification and Setbacks within The City of Calgary*" (AMEC Foster Wheeler Environment & Infrastructure, 2017). Their work digitized the coulee and its tributary watercourses from aerial photos taken between 1924 and 2015.

AMEC and Tannas identified three historical creeks that converged on the former HPGC lands:

- Confederation Creek.
- Creek A – Tributary creek roughly aligned with McKnight Boulevard NW.
- Creek B – Tributary creek roughly between Trafford Drive NW and Thorneycroft Drive NW.

These creeks have been modified by development between 1950 and 1970; this is particularly true for the tributary creeks which have almost been completely removed. However, major system flow continues to follow the alignment of the former creeks during high intensity rainfall events.

[1] All Figures have been included within **Appendix A**.

2.3 EXISTING CONDITION

2.3.1 Dual Drainage System

Drainage within the Confederation Creek Catchment has changed with the development of Calgary. As part of development practice, many of the former watercourses have been replaced with an engineered dual drainage system. This engineered dual drainage system comprises of a minor and a major system described as follows:

> "*The minor system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events*."
>
> *"The major system conveys runoff from the extreme (high intensity, less frequent) rainstorm events that are in excess of what the minor system can handle*." (City of Calgary, 2011)

The minor system is typically described as being composed of underground storm sewer system infrastructure which includes storm pipes, manholes and catchbasins. The purpose of the minor system is to provide conveyance for stormwater runoff for low intensity[2] rainfall events. The major system is composed of the overland drainage system including gutters, swales and roadways. The purpose of the major system is to convey stormwater runoff which exceeds the capacity of the minor system.

Minor System

The Upper and Lower Confederation Trunks convey the runoff delivered by the minor system located in the upland areas of the Confederation Creek Catchment. The Upper Confederation Trunk conveys runoff from Crowchild Trail to Confederation Creek at the CP15/16 Outfalls within the Confederation Park Golf Course. The Lower Confederation Trunk conveys water between the D33 Inlet in Confederation Park, and the N25 Outfall at Nose Creek.

The Upper Confederation Trunk was originally installed in the early 1960s and later twinned in 1997. The Lower Confederation Trunk was installed in the late 1960s and early 1970s.

Major System

In 1965, the Centennial Ravine Park Society was established to advocate for a park to be built within the North Hill Coulee. Construction of Confederation Park was completed for Canada's centennial year in 1967. Since this time, the drainage course through the park has been referred to as Confederation Creek.

Confederation Creek now conveys the combined major and minor system flow from the CP15/16 Outfalls within the Confederation Park Golf Course through Confederation Park to the D33 Inlet. Along the way, the creek also receives stormwater runoff from 15 smaller outfalls. The creek is interrupted by roadway embankments at 14th Street NW and 10th Street NW. Both embankments have culverts and pedestrian walkways (which function as elevated culverts). During high intensity storm events, the existing embankments retain water upstream within the Confederation Park Golf Course and Confederation Park.

[2] Prior to the 1950s, the minor system was typically designed for a 1:2-year rainfall event. However, since the 1950s, minor systems have been designed for a 1:5-year rainfall event.

Downstream of the D33 Inlet, the Confederation Valley conveys major system flow to the N25 Outfall at Nose Creek when the capacity of the Lower Confederation Trunk is exceeded. During high intensity rainfall events, major system flow ponds within the Queen's Park Cemetery, the 40th Avenue NW and 4th Street NW intersection, and upstream of the Centre Street N embankment.

The Centre Street N embankment obstructs the Confederation Valley. Stormwater accumulates upstream of the embankment in a depression within the former HPGC lands and is slowly released into the Lower Confederation Trunk. The large capacity depression prevents spill over Centre Street N during low intensity storm events.

There is no defined major system downstream of Centre Street N. Overland flow takes the path of least resistance and travels in an easterly direction, generally towards the back lane north of Greenview Park. Major system flows eventually arrive at Nose Creek in the vicinity of the N25 Outfall.

2.3.2 Public Lands

Section 3, subsection 1 of the Public Lands Act states that:

> "*The title to the beds and shores of all permanent and naturally occurring bodies of water, and all naturally occurring rivers, streams, watercourses, and lakes is vested in the Crown*". (Province of Alberta, 2018).

In 2017, on behalf of The City, AE developed a memorandum titled the "*Confederation Creek Crown Claimability Assessment*" (Associated Engineering, 2017). This memorandum included a review of historical information pertaining to the presence of a naturally occurring[3] watercourse. AE used aerial photography from 1924 and 2015 to compare Confederation Creek during pre-development and existing conditions.

In 2017, The City submitted an inquiry to Alberta Environment and Parks (AEP) including the aforementioned memorandum. The purpose of the inquiry was to gain clarity on the potential for a Public Lands claim along the historic reaches of Confederation Creek. In November of 2017, The City received an email from AEP stating the following:

> "*In response to your inquiry regarding Crown ownership of the water course that runs through sections 28, 29, 33 and 34 of Twp24-R01-W5M; air photos dated Oct/1924 and Aug/1949 are the earliest photographic records available that provide a view of this water course in a somewhat undisturbed state. On these photos, a clearly distinct and continuous channel with numerous bridges can be observed. As such, this email serves to advise the interested parties that this water feature is indeed Crown owned under Section 3 of the Public Lands Act."*
>
> *Note: The above assessment of the water bodies ownership should not be taken to mean that authority has been granted under the provincial Water Act to alter, infill, or drain a water body. Please contact your local Environment Office for additional information regarding approval requirements.*" (AEP Water Boundaries, 2017).

[3] For this assessment, "naturally occurring" is defined to be from geomorphic origin and not a man-made landscape feature. This definition was adopted from the "*Guide for Assessing Permanence of Wetland Basin"* (Alberta Government, 2016).

In October of 2018, The City of Calgary received a letter from AEP indicating a reversal of the Crown claim in the Confederation Creek Catchment. The letter stated the following:

> *"Upon further investigation, while preparing a response to a follow-up email, it was discovered that a previous Water Boundary file dated April/2005 had examined Confederation Creek for a Licence of Occupation application. Due to the observed alterations in the watercourse since the early 1960's, resulting in some portions of the watercourse being heavily ditched or re-directed underground in concrete storm pipes, the permanence of the bed and shore was deemed inconclusive and therefore the decision in 2005 was not to claim Crown ownership of the watercourse's bed and shore. The Water Boundary Unit always attempts to maintain consistency in our determinations and as such, our current position is that our most recent assessment dated November/2017 is nullified by the prior April/2005 decision regarding claimability of the bed and shore of Confederation Creek under Section 3 of the Public Lands Act."* (Alberta Environment and Parks, 2018).

Correspondence with AEP has been included within **Appendix B**.

2.3.3 Wetlands and Stormwater Management Facilities

In 2014, HAB-TECH Environmental Ltd. (HAB-TECH) conducted a Level 1 Biophysical Impact Assessment (BIA) for the former HPGC lands. The assessment identified two small Class II wetlands[4] in the area which *"are fed by small ephemeral/temporal water channels which originate from the lower portion of the slope*" (HAB-TECH Environmental Ltd, 2014).

There are stormwater management ponds within the Confederation Park Golf Course and Confederation Park. The ponds function as water quality enhancement facilities and do not provide significant stormwater attenuation. The "*Confederation Park Pond Assessment*" (CH2M Hill, 2015) indicates that these facilities are undersized and cannot manage the sediment volume they receive.

2.3.4 Nose Creek

With the urbanization of Calgary, Nose Creek has been modified, as have the areas contributing runoff to the creek. Over time the creek has been straightened and now receives more unattenuated and untreated urban runoff than it did in the pre-development condition. As a result, the water quality in Nose Creek has deteriorated, while the bed and banks of the creek have been subjected to excessive scour and erosion.

Nose Creek Watershed Partnership

In 1998, The Nose Creek Watershed Partnership (NCWP) was formed in response to decreasing water quality in the creek. Today, the NCWP is a stewardship group of municipalities and environmental agencies which includes The City. Its goal is "*To protect the riparian areas and improve water quality in the Nose Creek watershed*" (Nose Creek Watershed Partnership, 2018).

[4] The Alberta Wetland Policy requires compensation for Class II – V wetlands if they are permanently impacted. Under the Municipal Government Act, The City can retain Class III – V wetlands as Environmental Reserve.

In 2007, the NCWP issued the *"Nose Creek Watershed Water Management Plan"*. The plan provides a framework and recommendations for sustainable development within the watershed including rate, volume, and quality targets.

In 2018, the NCWP updated the "*Nose Creek Watershed Water Management Plan*". "*The update was necessary to reflect advancements in knowledge, changes in provincial and municipal policies, and to address new challenges in land and water resource management.*"

Flood Frequency

In 2000, Alberta Environment updated the flood frequency analysis for Nose Creek. "*Peak flow estimates were based on a frequency analysis of 23 years of data from the Water Survey of Canada Station 05BH003.*" (Golder Associates Ltd., 2005). The lack of historical data results in uncertainties regarding the peak flow in Nose Creek. In 2000, AEP estimated the 1:100-year peak flow to be:

- 93.9 m^3/s at the confluence of Nose Creek and the Bow River
- 33.4 m^3/s at the confluence of West Nose Creek and Nose Creek.

The methodology adopted by AEP to estimate the 1:100-year peak flow rate suggests that the more significant contribution from the urban areas may not have been accounted for. In 2003, Westhoff Engineering Resources, Inc. (Westhoff) wrote a report entitled "*West Nose Creek - Stream Corridor Assessment - Phase 2*" (Westhoff Engineering Resources, Inc., 2003). This report compared the 1:100-year flows from the pre-development condition, 2002 condition, and future build-out condition within the West Nose Creek Watershed. This analysis suggested that 1:100-year peak flows (in 2002) at West Nose Creek's confluence with Nose Creek could be between 34.9 m^3/s and 38.4 m^3/s. Westhoff's analysis also suggested that, in future build-out conditions[5], the 1:100-year peak flow rate at the confluence could increase to between 39.4 m^3/s and 43.0 m^3/s which are 18-29% higher than AEP's estimates.

Westhoff's analysis suggests that AEP's analysis underestimated peak flows. The West Nose Creek Watershed is still not at full build-out conditions suggesting that peak flows are expected to increase further. Extrapolating this observation to Nose Creek suggests that the peak flow rates in Nose Creek may be substantially higher than what was estimated by AEP. This is attributed to higher contributions from urban areas in Calgary, Rocky View County, and Airdrie.

Flood Mapping

In 2005, Golder Associates (Golder) prepared a hydrologic and hydraulic analysis of Nose Creek using AEP's peak flow estimates from 2000. The report indicates that "*Calibration with historical highwater marks was not possible for either Nose Creek or West Nose Creek due to the lack of reliable historical information.*" (Golder Associates Ltd., 2005). Lack of calibration results in uncertainties associated with the water depths and inundation extents on Nose Creek.

[5] As envisioned in 2003, excluding development beyond Calgary's city limits at the time.

Discussion

The lack of historical flow and level data within the Nose Creek watershed have introduced uncertainties within the flood frequency analysis and flood mapping. Westhoff's analysis further questions the peak flows developed by AEP and suggests that peak flows could be higher than anticipated on Nose Creek. The existing scour and erosion on the creek also suggests that further increase in peak flows could cause additional damage. Therefore, discharging additional flow to Nose Creek could have negative impacts to the creek and adjacent properties. Without further study of Nose Creek, it is unclear whether Nose Creek has the ability to receive additional flow.

2.4 FUTURE CONDITION

Stormwater drainage within the Confederation Creek Catchment is expected to be affected by climate change and densification (including the HPD and the future Green Line LRT).

2.4.1 Climate Change

Research indicates that the climate is changing which is expected to reflect more extreme weather conditions. "*Climate change will likely result in long-term changes in temperature and precipitation, as well as increased frequency and severity of weather events such as droughts, floods, forest fires, and severe storms.*" (Alberta Government, 2019). Higher intensity rainfall due to climate change will gradually reduce the existing level of service (LOS) of the stormwater system.

Climate change direction has been set by the Federal and Provincial governments which municipalities must adhere to. The City has dedicated a team to facilitating city, citizen, and business actions to mitigate and adapt to the impacts of climate change. This team is taking multiple steps to accomplish this including developing a Climate Resilience Plan endorsed by City Council in mid-2018.

The City's Climate Resilience Plan includes an "*Adaptation plan identifying actions to reduce the impacts from the changing climate.*" (City of Calgary, 2017). Adaptation strategies include building resilience into proposed stormwater infrastructure to manage higher intensity rainfall.

In alignment with The City's approach, The City directed AE to consider the effects of climate change in this Study to: determine the impact it will have on existing infrastructure; and to propose improvements to manage the anticipated effects of climate change.

2.4.2 Densification

In various part of Calgary, older houses are being removed and replaced with larger houses, infilled with multiple lots or multi-family residential development. Commercial business is also expanding in these neighborhoods to accommodate population growth. These developments are referred to as densification and influence stormwater management by increasing the amount of impervious area.

On September 28, 2009, City Council approved the Municipal Development Plan and Calgary Transportation Plan that were created through the PlanIT Calgary process which included extensive public consultation. The municipal planning process reflected in these documents includes population growth predictions to 2076. These 2076 growth projections are used within this Study to estimate the corresponding increase in impervious area.

2.4.3 Highland Park Development

The HPGC was privately owned and operated between 1965 and 2012. The former golf course lies within the Confederation Valley between 40th Avenue NW and Centre Street N[6]. In 2013, 1744228 Alberta Ltd. (the "Landowner") acquired the former Highland Park Golf Course (HPGC) lands. Maple Projects Inc. and Amble Ventures Ltd. (the Developers) plan to develop the parcel. The proposed HPD includes high density, mixed-use, residential, and commercial multi-level buildings.

The proposed HPD[7] includes up to 4 m of fill material to accommodate at-grade intersections of the proposed future Highland Drive NW with Centre Street N and 40th Avenue NW. The fill material would remove 97,000 m^3 of depression storage west of Centre Street N and impact the Class II wetlands in the former HPGC lands.

The proposed HPD includes a stormwater storage facility for regional drainage. Preliminary discussions with the Developer's engineers at ISL Engineering and Land Services (ISL) indicate that this storage facility is envisioned to have between 5,000 m^3 and 27,000 m^3 of capacity.

The proposed HPD is assumed to include on-site stormwater storage facilities such that the development can meet runoff rate, volume, and quality targets mandated by The City.

2.4.4 Green Line LRT

The Green Line is a proposed Light Rail Transit (LRT) line that will add 46 kilometres of track to the existing 59 km LRT system. The Green Line is currently being designed and is expected to open in phases beginning in 2024. Once the full alignment is built, the Green Line will connect communities between 160th Avenue N and Seton to downtown Calgary.

The Green Line is envisioned to run north-south along Centre Street N through the proposed HPD and to pass underneath McKnight Boulevard NW in a tunnel north of the proposed HPD. The tunnel will begin very close to the Confederation Valley.

[6] The proposed HPD also included a parcel east of Centre Street N. At the time of writing it is unclear whether this parcel remains as part of the proposed HPD as it is presently for sale on Colliers International.
[7] Drawing 25839 (dated March 28, 2017) from the HPD drawing set was provided to AE by ISL during a meeting on September 18, 2017.

2.5 DAM SAFETY

Dam safety in Alberta is regulated by the Provincial Government and is the responsibility of the owner of the dams in question. "*Alberta Environment and Parks (AEP) provides regulatory oversight to ensure dam owners take active responsibility for the integrity and safe operations of their dams through the Alberta Water Act and Part 6 of the Water (Ministerial) Regulation – Dam and Canal Safety*."[8]

2.5.1 Dam Definition

On October 11, 2018, AE and The City met with representatives from AEP's Dam Safety group to discuss dam safety within the Confederation Creek Catchment[9]. AEP indicated that intent to store water was the most important criteria within the definition of a dam.

On December 12, 2018, The Alberta government updated the "*Water (Ministerial) Regulation*" changing the definition of a dam. The previous provisions for minimum depth and volume were removed. The new definition is as follows:

> *(h) "dam means a barrier that is designed and is or is to be constructed for the purpose of retaining, storing or diverting water, including water containing another substance, fluid waste or flowable tailings within the meaning of section 26(1)(e), and includes all other works associated with such a barrier."*

2.5.2 Existing Embankments

The existing embankments along Confederation Creek were not constructed for the purpose of storing water. The embankments were constructed to convey vehicular traffic across the coulee. Therefore, based on feedback from AEP, the existing embankments are not expected to be classified as dams according to provincial regulation.

Despite the roadway embankments at 14th Street NW, 10th Street NW and Centre Street N not being classified as dams, there is a public safety risk associated with the upstream storage depths and volumes. These risks include slope stability risks and drowning risks. Slope stability and geotechnical risk of water retention at these structures has been documented as follows:

- Thurber Engineering Ltd. (Thurber), part of the consulting team for this study, indicated that although a dam breach scenario is unlikely, the embankments could experience local slope failures and scour if flows were to overtop the embankments (Thurber Engineering Ltd., 2017).
- Thurber Engineering Ltd. determined that a slope on the upstream face of the 14th Street NW embankment was marginally stable and recommended that the slope be flattened (Thurber Engineering Ltd., 2016).

Refer to **Section 5.2.5** for details on risk mitigation measures.

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[8] Retrieved from AB Environment and Parks, (September 12th, 2017), http://aep.alberta.ca/water/programs-and-services/dam-safety/default.aspx)

[9] Meeting minutes have been included within **Appendix B**.

3 Model Build

3.1 OVERVIEW

AE built a detailed stormwater model to understand the hydrologic and hydraulic regime of The Study area. The model was built within the PCSWMM modelling software using The City's GIS database, and has a one dimensional minor and major system.

Details regarding the model build are included within **Appendix C**. Figures regarding the model build are included within **Appendix A**.

4 Modelling Results

4.1 OVERVIEW

AE selected the four scenarios within **Table 4-1** to illustrate the impacts of: climate change and densification; and the proposed HPD on regional drainage patterns.

Table 4-1
Model Scenarios

Condition	Development	
	Without the HPD	With the HPD
Existing	Scenario 1	Scenario 3
Future	Scenario 2	Scenario 4

Existing Condition

The existing condition considers the study area, land usage, and hydrology as of 2017. This condition does not consider climate change or densification.

Future Condition

The future condition considers the study area under anticipated conditions representative of 2076. These conditions include more intense rainfall events associated with climate change, and higher imperviousness associated with densification.

Without the HPD

The condition without the HPD assumes that the former HPGC lands remain undeveloped as they are presently. This condition assumes that the depression storage west of Centre Street N is available for stormwater attenuation, recognizing that the former HPGC lands are privately owned.

With the HPD

The condition with the HPD assumes that the former HPGC lands are developed as indicated within the proposed Land Use and Outline Plan (ISL Engineering & Land Services, Tetra Tech, Brown & Associates Planning Group, n.d.) and reflect the preliminary drawings provided to AE by ISL during a meeting on September 18, 2017. AE considered the following:

- Removal of the depression storage west of Centre Street N.
- Construction of Highland Drive NW, including at-grade intersections at 40th Avenue NW and Centre Street N.
- Catchment areas within the development with 75 % imperviousness.
- On-site stormwater management facilities to attenuate local drainage to a minor system unit area release rate of 35 L/s/ha as per direction from The City.

4.2 RESULTS

The stormwater model was analysed to assess the differences between the four scenarios. The analysis was focused on Confederation Creek, the Lower Confederation Trunk, and the Confederation Valley. The results for each scenario are presented in the following sections.

4.2.1 Scenario 1 Results

Ponding along Confederation Creek and Confederation Valley

There is considerable ponding expected along Confederation Creek. The ponding is due to the difference between the magnitude of the upstream flows and the capacity of the culverts and minor system. **Table 4-2** illustrates the difference in cross-sectional area from upstream to downstream within Confederation Park.

Table 4-2
Confederation Creek Capacity Limitations

Location	Size (mm)	Cross Sectional Area (m^2)
Upper Confederation Trunk	1600 x 3050 Duct 1800 x 2400 Double Duct	13.52
14th Street NW Culvert	2700 x 2700 Duct	7.29
10th Street NW Culvert	1500 Diameter	1.77
Lower Confederation Trunk	1650 x 1800 Double Duct	5.94

There is extensive ponding within the former HPGC lands upstream of Centre Street N. The ponding occurs because the roadway embankment blocks the Confederation Valley. During high intensity rainfall events, overland flows cannot enter the Lower Confederation Trunk because the trunk is already flowing at capacity and there is inadequate inlet capacity to the trunk.

Table 4-3 summarizes the estimated ponded water depths and volumes upstream of the roadway embankments, as well as the spillover rates for in Scenario 1 for various storm events.

Table 4-3
Scenario 1 – Maximum Ponded Depths, Volumes, and Spillover Rates

Road	Parameter	Return Period					
		2	5	10	25	50	100
14th Street NW	Depth (m)	2.4	3.2	3.6	3.9	4	4.2
	Volume (m^3)	2,600	12,600	20,900	29,800	37,000	44,700
	Spill (m^3/s)	0	0	0	0	0	0
10th Street NW	Depth (m)	4.2	5.6	6	6.4	6.7	6.9
	Volume (m^3)	29,200	81,800	107,400	134,100	150,800	166,900
	Spill (m^3/s)	0	0	0	0	0	0
30th Avenue NW	Depth (m)	1.9	3.3	4.1	4.8	5	5.1
	Volume (m^3)	800	8,000	27,000	52,500	59,100	62,800
	Spill (m^3/s)	0	0	0	4.8	10.0	13.3
Centre Street N	Depth (m)	0.7	1.6	2.2	4.5	5.1	5.3
	Volume (m^3)	1,100	10,400	22,000	87,400	113,400	124,600
	Spill (m^3/s)	0	0	0	0	7.2	15.4

Overland flow that overtops the embankments can potentially damage the roadways and erode the downstream slope of the roadway embankments. Overland flow that overtops Centre Street N could also flow over of the future Green Line LRT and inundate the proposed LRT tunnel at McKnight Boulevard NW.

Lower Confederation Trunk

During existing conditions, it is estimated that the Lower Confederation Trunk can convey the runoff generated by a 1:2-year storm before surcharging to the surface. Higher intensity storms surcharge the trunk to surface within Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, the former HPGC lands, and within Greenview Park.

Overland Flow

During existing conditions, Confederation Creek is predicted to spill overtop of 30th Avenue NW beginning at the 1:25-year return period event. This flow spills overland through the Confederation Valley impacting Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, and the former HPGC lands. Major system flows at key locations are summarized within **Table 4-4**.

Table 4-4
Scenario 1 – Maximum Major System Flows (m^3/s)

Location	Description	2	5	10	25	50	100
30th Avenue NW		0	0	0	4.8	10.0	13.3
4th Street NW		0.1	0.5	1.5	7.1	13.3	17.7
40th Avenue NW	Entering HPGC	0	0.1	0.8	6.7	13.0	17.3
Centre Street N	Exiting HPGC	0	0	0	0	7.2	15.4

Hydrograph Pattern

The configuration of the Confederation Creek Catchment and the degree of upstream attenuation creates a dual peak within the hydrographs downstream of the 4th Street NW and 40th Avenue NW intersection. The two separate peaks are attributed to the attenuated release of volume from the roadway embankments in the west, and the unattenuated peak flows from communities directly north and northwest of the former HPGC lands. The two peaks are delayed by approximately 3 hours.

4.2.2 Scenario 2 Results

Ponding along Confederation Creek and Confederation Valley

Table 4-5 summarizes the estimated ponded water depths and volumes upstream of the roadway embankments, as well as the spillover rates for Scenario 2 for various storm events.

Table 4-5
Scenario 2 – Maximum Ponded Depths, Volumes and Spillover Rates

Road	Parameter	Return Period					
		2	5	10	25	50	100
14th Street NW	Depth (m)	3	3.7	4	4.3	4.6	4.9
	Volume (m^3)	8,300	25,100	35,000	49,400	68,100	93,700
	Spill (m^3/s)	0	0	0	0	0	0
10th Street NW	Depth (m)	5.2	6.2	6.6	6.9	7.2	7.5
	Volume (m^3)	63,800	118,600	143,200	171,900	200,100	224,000
	Spill (m^3/s)	0	0	0	0	0	0
30th Avenue NW	Depth (m)	2.8	4.5	4.9	5.1	5.2	5.3
	Volume (m^3)	3,700	38,400	56,200	63,400	67,800	71,100
	Spill (m^3/s)	0	0	7.6	13.8	18.0	21.1
Centre Street N	Depth (m)	1.5	3.1	4.9	5.4	5.5	5.6
	Volume (m^3)	7,900	44,200	106,100	126,300	132,800	136,900
	Spill (m^3/s)	0	0	3.0	16.8	22.4	26.0

Lower Confederation Trunk

During future conditions, it is estimated that the Lower Confederation Trunk will surcharge to surface during storm events less than the 1:2-year return period.

Overland Flow

During future conditions, Confederation Creek is predicted to spill overtop of 30th Avenue NW beginning at the 1:10-year return period event. This flow spills overland through the Confederation Valley impacting Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, and the former HPGC lands. Major system flows at key locations are summarized within **Table 4-6**.

Table 4-6
Scenario 2 – Maximum Major System Flows (m^3/s)

Location	Description	2	5	10	25	50	100
30th Avenue NW		0	0	7.6	13.8	18.0	21.1
4th Street NW		0.3	2.9	10.2	18.2	22.9	26.3
40th Avenue NW	Entering HPGC	0	2.5	9.8	17.8	22.6	25.9
Centre Street N	Exiting HPGC	0	0	3.0	16.8	22.4	26.0

Differences Between Scenario 1 and 2

Comparing the results of the Scenario 1 and 2 models illustrates the anticipated impacts of climate change and densification without the HPD. Major and minor system flows increase throughout the study area resulting in increased depths and volumes upstream of the roadway embankments. The frequency and magnitude of overtopping of the roadway embankments increase.

The magnitude of overland spill over Centre Street N is higher in Scenario 2 than in Scenario 1. The 1:100-year peak flow reaching Centre Street N is estimated to increase from 15.4 m^3/s to 26.0 m^3/s. This equates to a 10.6 m^3/s increase in peak flow. The frequency of overtopping is also expected to increase from the 1:50-year return period to the 1:10-year return period.

The peak flow discharge to Nose Creek is higher in Scenario 2 than in Scenario 1. The 1:100-year peak flow rate is estimated to increase from 31.8 m^3/s to 43.9 m^3/s. This equates to a 12.1 m^3/s increase in peak flow rate. **Figure 4-1** shows the 1:100-year hydrographs from Scenarios 1 and 2 at the N25 Outfall.

4.2.3 Scenario 3 Results

Ponding along Confederation Creek and Confederation Valley

Table 4-7 summarizes the estimated maximum ponded water depths and volumes upstream of the roadway embankments, as well as the spillover rates for Scenario 3 for various storm events.

Table 4-7
Scenario 3 – Maximum Ponded Depths, Volumes and Spillover Rates

Road	Parameter	Return Period					
		2	5	10	25	50	100
14th Street NW	Depth (m)	2.4	3.2	3.6	3.9	4	4.2
	Volume (m^3)	2,600	12,600	20,900	29,800	37,000	44,700
	Spill (m^3/s)	0	0	0	0	0	0
10th Street NW	Depth (m)	4.2	5.6	6	6.4	6.7	6.9
	Volume (m^3)	29,200	81,800	107,400	134,100	150,800	166,900
	Spill (m^3/s)	0	0	0	0	0	0
30th Avenue NW	Depth (m)	2	3.4	4.2	4.9	5	5.1
	Volume (m^3)	1,100	10,200	29,800	53,800	59,700	63,300
	Spill (m^3/s)	0	0	0	5.7	10.5	13.8
Centre Street N	Depth (m)	N/A	N/A	N/A	N/A	N/A	N/A
	Volume (m^3)	N/A	N/A	N/A	N/A	N/A	N/A
	Spill (m^3/s)	0	0.7	2.6	8.3	14.2	18.3

Lower Confederation Trunk

During existing conditions, it is estimated that the Lower Confederation Trunk can convey the runoff generated by a 1:2-year storm before surcharging to surface. Higher intensity storms surcharge the trunk to surface within Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, and within Greenview Park.

Overland Flow

During future conditions, Confederation Creek is predicted to spill overtop of 30th Avenue NW beginning at the 1:25-year return period event. This flow spills overland through the Confederation Valley impacting Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, and the former HPGC lands. Major system flows at key locations are summarized within **Table 4-8**.

Table 4-8
Scenario 3 – Maximum Major System Flows (m^3/s)

Location	Description	2	5	10	25	50	100
30th Avenue NW		0	0	0	5.7	10.5	13.8
4th Street NW		0.1	1.4	2.7	9.0	15.1	18.8
40th Avenue NW	Entering HPD	0	0.5	2.5	8.6	14.6	18.6
Centre Street N	Exiting HPD	0	0.7	2.6	8.3	14.2	18.3

AE estimates that flows on the proposed Highland Drive NW in excess of 4.5 m^3/s and 1.6 m^3/s will violate AEP's Flow-Velocity-Depth (QVD) requirements and The City's dry lane criteria respectively. These criteria were designed to minimize the risk of people being swept away by the force of deep, fast moving water and to provide safe access for emergency vehicles during rainfall events. As estimated in the table above, the 1:100-year flows significantly exceed AEP's QVD requirements and The City's dry lane criteria resulting in an increased risk of unsafe conditions unless the flow is safely managed within the HPD. This estimate was based on:

- Modified roadway cross sections from the "*Highland Village Green Outline Plan and Land Use Re-designation*" (ISL Engineering and Land Services, 2017).
- A longitudinal slope of 1.5 % taken from Drawing 25839 in the HPD drawing set, dated March 28, 2017.
- AE's assumptions regarding Manning's Roughness Coefficient (0.015), roadway cross fall (2%), boulevard cross fall (2%) and slopes beyond the right of way (10H:1V).
- Alberta Environment's permissible depths for submerged objects from Table 3-1 of the "*Stormwater Management Guidelines for the Province of Alberta*" (Alberta Environment, 1999).
- The City's dry lane criteria for collector roads from Section 3.4.3, Subsection ii of the "*Stormwater Management and Design Manual*" (City of Calgary, 2011).

Differences Between Scenario 1 and 3

Comparing the results of the Scenario 1 and 3 models illustrates the impacts of the HPD. The HPD proposes to infill the Confederation Valley removing 97,000 m^3 of storage upstream of Centre Street N. Removal of this storage increases the frequency and magnitude of overtopping at Centre Street N.

The magnitude of overland spill over Centre Street N is higher in Scenario 3 than in Scenario 1. The 1:100-year peak flow rate crossing Centre Street N is estimated to increase from 15.4 m^3/s to 18.3 m^3/s. This equates to a 2.9 m^3/s increase in peak flow. The removal of the depression storage affects higher frequency storm events more significantly than the 1:100-year storm event. The frequency of overtopping is also expected to increase from a 1:50-year return period to a 1:5-year return period.

The peak flow discharge to Nose Creek is higher in Scenario 3 than in Scenario 1. The 1:100-year peak flow is estimated to increase from 31.8 m^3/s to 43.2 m^3/s. This equates to an 11.4 m^3/s increase in peak flow rate. The increase in peak flow is shifted to the earlier parts of the storm which indicates a faster time to peak. The faster time to peak is due to the removal of the depression storage west of Centre Street N. **Figure 4-2** shows the 1:100-year hydrographs from Scenario 1 and 3 at the N25 Outfall.

4.2.4 Scenario 4 Results

Ponding along Confederation Creek and Confederation Valley

Table 4-9 summarizes the estimated maximum ponded water depths and volumes upstream of the roadway embankments, as well as the spillover rates for Scenario 4 for various storm events.

Table 4-9
Scenario 4 – Maximum Ponded Depths, Volumes and Spillover Rates

Road	Parameter	Return Period					
		2	5	10	25	50	100
14th Street NW	Depth (m)	3	3.7	4.0	4.3	4.6	4.9
	Volume (m^3)	8,300	25,000	35,000	49,400	68,100	93,800
	Spill (m^3/s)	0	0	0	0	0	0
10th Street NW	Depth (m)	5.2	6.2	6.7	6.9	7.2	7.5
	Volume (m^3)	64,100	118,700	143,400	172,200	200,400	224,300
	Spill (m^3/s)	0	0	0	0	0	0
30th Avenue NW	Depth (m)	3	4.6	5.0	5.1	5.2	5.3
	Volume (m^3)	5,200	41,900	57,100	63,800	68,300	71,500
	Spill (m^3/s)	0	0	8.4	14.2	18.4	21.5
Centre Street N	Depth (m)	N/A	N/A	N/A	N/A	N/A	N/A
	Volume (m^3)	N/A	N/A	N/A	N/A	N/A	N/A
	Spill (m^3/s)	0.4	4.0	11.2	18.7	23.7	29.5

Lower Confederation Trunk

During future conditions, it is estimated that the Lower Confederation Trunk will surcharge to surface during storm events less than the 1:2-year return period.

Overland Flow

During future conditions, Confederation Creek is predicted to spill overtop of 30th Avenue NW beginning at the 1:10-year return period event. This flow spills overland through the Confederation Valley impacting the

Queen's Park Cemetery, the 4th Street NW and 40th Avenue NW intersection, and the former HPGC lands. Major system flows at key locations are summarized within **Table 4-10**.

Table 4-10
Scenario 4 – Maximum Major System Flows (m^3/s)

Location	Description	2	5	10	25	50	100
30th Avenue NW		0	0	8.4	14.2	18.4	21.5
4th Street NW		0.7	3.7	12.1	19.4	24.1	28.0
40th Avenue NW	Entering HPD	0.3	3.7	11.6	19.0	23.9	27.6
Centre Street N	Exiting HPD	0.4	4.0	11.2	18.7	23.7	29.5

AE estimates that flows on the proposed Highland Drive NW in excess of 4.5 m^3/s and 1.6 m^3/s will violate AEP's QVD requirements and The City's dry lane criteria respectively. These criteria were designed to minimize the risk of people being swept away by the force of moving water and to provide access for emergency vehicles during rainfall events. As estimated in the table above, the 1:100-year flows significantly exceed AEP's QVD requirements and The City's dry lane criteria. AE's assumptions regarding the HPD are documented within **Section 4.2.3**.

Differences Between Scenario 3 and 4

AE analyzed the changes anticipated due to future conditions combined with the HPD by comparing the results between Scenarios 3 and 4. Major and minor system flows increase throughout the study area resulting in increased depths and volumes upstream of the roadway embankments. The frequency and magnitude of overtopping of the roadway embankments increase.

The magnitude of overland spill over Centre Street N is higher in Scenario 4 than in Scenario 3. The 1:100-year peak flow is estimated to increase from 18.3 m^3/s to 29.5 m^3/s. This equates to an 11.2 m^3/s increase in peak flow. The frequency of overtopping is also expected to increase from the 1:5-year return period to the 1:2-year return period.

The peak flow discharge to Nose Creek is higher in Scenario 4 than in Scenario 3. The 1:100-year return period peak flow is estimated to increase from 43.2 m^3/s to 65.7 m^3/s. This equates to a 22.5 m^3/s increase in peak flow rate. This is illustrated within **Figure 4-3** which shows the 1:100-year hydrographs from Scenario 3 and 4 at the N25 Outfall.

4.3 SUMMARY

The modelled results indicate several drainage issues within the Confederation Creek Catchment:

- The size of the existing culverts along Confederation Creek causes the temporary impoundment of stormwater runoff upstream of 14th Street NW and 10th Street NW. Stormwater runoff is also impounded upstream of 30th Avenue NW and Centre Street N.
- Major overland system flow occurs between 30th Avenue NW and the N25 Outfall during high intensity rainfall events. Centre Street N currently impedes overland flow and creates a large depression in the former HPGC lands.
- Flows to Nose Creek will increase if the HPD proceeds as proposed in the Land Use and Outline Plan. This is because 97,000 m^3 of existing storage upstream of Centre Street N will be filled in as part of the HPD's grading requirements causing runoff to overtop Centre Street N more frequently.
- Climate change and densification are predicted to increase the magnitude of the peak flows and runoff volumes during rainfall events. The increased runoff will compound the existing issues.

Table 4-11 and **4-12** summarize the estimated overtopping frequency and 1:100-year major system flow respectively.

Table 4-11
Embankment Overtopping Frequency (Years)

Road	Scenario 1	Scenario 2	Scenario 3	Scenario 4
14th Street NW	>1:100	>1:100	>1:100	>1:100
10th Street NW	>1:100	>1:100	>1:100	>1:100
30th Avenue NW	1:25	1:10	1:25	1:10
Centre Street N	1:50	1:10	1:5	1:2

Table 4-12
1:100-Year Major System Flow (m^3/s)

Location	Description	Scenario 1	Scenario 2	Scenario 3	Scenario 4
30th Avenue NW		13.3	21.1	13.8	21.5
4th Street NW		17.7	26.3	18.8	28.0
40th Avenue NW	Entering HPD	17.3	25.9	18.6	27.6
Centre Street N	Exiting HPD	15.4	26.0	18.3	29.5

5 Stormwater Management Options

5.1 DESIGN CRITERIA

Objectives

The City instructed AE to develop options which met the following objectives:

- Reduce the magnitude of overland flooding in Queen's Park Cemetery, at the intersection of 4th Street NW and 40th Avenue NW, and within the former HPGC lands.
- Maximize the amount of developable land within the former HPGC lands.
- Reduce the likelihood of overland flows crossing the future Green Line LRT.
- Reduce the risks associated with dam safety.

Approaches

There are three different approaches that can be used to achieve the objectives noted above:

- Increasing the minor system capacity through conveyance improvements.
- Diverting flows to the Bow River.
- Attenuating peak flows in the catchment using storage.

Level of Service & Climate Change

The City considers the former HPGC lands as undeveloped land and considers the HPD to be a greenfield development. Therefore, The City has selected a LOS equal to the 1:100-year, 4-hour storm event.

The City's *Climate Resilience Plan* will include direction to provide climate change adaptation where possible by building resilience into proposed stormwater infrastructure to manage higher intensity rainfall (City of Calgary, 2017). Therefore, The City directed AE to consider the effects of climate change on existing infrastructure and propose improvements to manage these effects within this Study.

Densification

Given the on-going residential and commercial re-development, The City also requested that AE consider an increase in impervious area while developing options. Refer to **Section 2.4.2** for details.

Nose Creek

There are uncertainties associated with the provincial flood frequency analysis and flood mapping on Nose Creek. Current information suggests that discharging additional flow could have negative impacts to the creek and adjacent properties. Therefore, The City instructed AE to develop options which maintained the Scenario 1 (1:100-year, existing condition) peak flow rate to Nose Creek.

5.2 OPTIONS

AE developed six different options:

- **Option 1A** – No Improvements – Without the HPD.
- **Option 1B** – No Improvements – With the HPD.
- **Option 2** – West Storage and Conveyance to Nose Creek – With the HPD.
- **Option 3** – West Storage and Diversion to the Bow River – With the HPD.
- **Option 4 Ultimate** – West Storage and Centre Street N Storage – Without the HPD.
- **Option 4 Interim** – Existing Risk Mitigation – Without the HPD.

The HPD as referenced in this report refers to the HPD as identified in the current, approved Land Use and Outline Plan.

The six options are described in more detail in this section. Each option consists of individual improvement projects which have been described in **Section 7**. These options are subsequently compared in **Section 8**.

AE and The City considered several other storage options during the development of these options. These storage options were comprised of smaller scale storage facilities. Some of these facilities were proposed by the developer's engineer, ISL. Water Resources and AE assessed the proposed storage areas and concluded that they would only reduce the required storage at the Centre Street N location by a maximum of approximately 15%. The findings were presented to ISL and they acknowledged the results.

Some of these suggested alternative storage locations may be able to be incorporated into the overall option if they are proven to be effective and cost beneficial as detailed design is initiated.

5.2.1 Option 1A – No Improvements – Without the HPD

Option 1A does not include any improvement projects and assumes that the former HPGC lands remain as green space.

Objectives

Option 1A does not address the existing risks associated with the impounded depths and volumes upstream of the roadway embankments. However, it does not increase dam safety risk because Option 1A does not intentionally increase storage upstream of 14th Street NW, 10th Street NW, 30th Avenue NW and Centre Street N.

Hydraulics

Option 1A was modelled as part of Scenarios 1 and 2 for existing and future conditions, respectively. Ponded depths and volumes upstream of the roadway embankments are presented in **Section 4.2.1** and **Section 4.2.2**.

Benefits

AE identified the following benefits associated with Option 1A:

- Capital spending on large scale stormwater improvement projects is not required for Option 1A.
- The existing embankments will not be classified as dams if there are no improvements made to intentionally store water.

Risks

AE identified the following risks associated with Option 1A:

- Centre Street N is predicted to overtop during the 1:50-year storm event for existing conditions and the 1:10-year storm event for future conditions. This flow could damage the future Green Line LRT, inundate the proposed tunnel at McKnight Boulevard NW, and cause property damage within the community of Greenview.
- Despite the roadway embankments not being classified as dams, there is a public safety risk associated with the upstream storage depths and volumes.
- There is an increased risk of damage within Nose Creek as the magnitude and volume of runoff is expected to increase in the future condition. The 1:100-year peak flow rate to Nose Creek is estimated to increase from 31.8 m^3/s for existing conditions to 43.9 m^3/s for future conditions.
- Allowing an increase in the magnitude of runoff to Nose Creek could affect The City's reputation as a member of the Nose Creek Watershed Partnership.
- It is anticipated that climate change impacts and densification will increase the amount of runoff and increase the probability and severity of the risks described above.

5.2.2 Option 1B – No Improvements – With the HPD

Option 1B does not include any improvement projects; however, in contrast to Option 1A, Option 1B assumes that the HPD will be developed as per the proposed Land Use and Outline Plan.

Objectives

Option 1B would increase the existing risks associated with the impounded depths and volumes upstream of the roadway embankments because more people would be living in the Confederation Valley. Option 1B would achieve The City's objectives of maximizing the amount of developable land. However, it would limit future options to manage stormwater runoff within the Confederation Creek Catchment. Option 1B would not achieve The City's other objectives of: reducing flooding, reducing the likelihood of flows overtopping the Green Line LRT, reducing the risks associated with dam safety, considering climate change, considering densification, and maintaining existing 1:100-year peak flows to Nose Creek.

Hydraulics

Option 1B was modelled as part of Scenarios 3 and 4 for existing and future conditions, respectively. Ponded depths and volumes upstream of the roadway embankments are presented in **Section 4.2.3** and **Section 4.2.4**.

Benefits

AE anticipates the following benefits associated with Option 1B:

- Capital spending on large scale stormwater improvement projects is not required for Option 1B.
- The existing embankments will not be classified as dams if there are no improvements made to intentionally store water.

Risks

AE anticipates the following risks associated with Option 1B:

- The Scenario 4 modelling estimates that the 1:100-year peak flow exiting the HPD could be 29.5 m^3/s. Flows of this magnitude on Highland Drive NW would greatly exceed municipal and provincial overland flow criteria. The overland flow criteria serve as an indicator for the potential risk of people being swept away by the force of deep, fast moving water. These flows could pose significant safety risks to the HPD if they were not safely managed within the development.
- Recognizing that the former HPGC lands are privately owned, Option 1B would limit The City's flexibility to manage stormwater runoff within the Confederation Creek Catchment.
- With the HPD in-place, Centre Street N is predicted to overtop during the 1:5-year storm event for existing conditions and the 1:2-year storm event for future conditions. This flow could damage the future Green Line LRT, inundate the proposed tunnel at McKnight Boulevard NW, and cause property damage within the community of Greenview.
- Removing the storage upstream of Centre Street N is predicted to cause Centre Street N to overtop more frequently. These overtopping flows could damage Greenview Park and create public safety risks.
- Despite the roadway embankments not being classified as dams, there is a public safety risk associated with the upstream storage depths and volumes.
- There is an increased risk of damage within Nose Creek as the magnitude and volume of runoff are expected to increase due to the removal of the depression storage west of Centre Street N and the impacts of future conditions. AE estimates that the 1:100-year peak flow rate to Nose Creek would increase from 31.8 m^3/s to 43.2 m^3/s with the removal of the depression storage for existing conditions, and subsequently from 43.2 m^3/s to 65.7 m^3/s for future conditions.
- Allowing an increase in the magnitude of runoff to Nose Creek could affect The City's reputation as a member of the Nose Creek Watershed Partnership.
- It is anticipated that climate change impacts and densification will increase the amount of runoff and increase the probability and severity of the risks described above.

5.2.3 Option 2 – West Storage and Conveyance to Nose Creek

Option 2 consists of intentionally storing stormwater upstream of 14th Street NW, 10th Street NW and 30th Avenue NW combined with conveyance improvements that reduce the magnitude of the overland flow in the Confederation Valley. Intentionally storing stormwater upstream of these road embankments would result in them being classified as dams under the Water Act regulation.

The storage in the west half of the catchment would attenuate peak flows to reduce the size of downstream conveyance improvements. The conveyance improvements in the east half of the catchment would reduce the magnitude of overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk. The assumption is that the HPD would be developed as part of Option 2. The improvement projects are summarized in **Table 5-1** and shown within **Figure 5-2**.

Table 5-1
Option 2 Summary

West Half Improvement Projects	East Half Improvement Projects
• Increase storage upstream of 14th Street NW, 10th Street NW and 30th Avenue NW. Increasing storage would likely lead to these structures being classified as dams.	• Conveyance Improvements on the Lower Confederation Trunk between 30th Avenue NW and Nose Creek. • Increased capture capacity in Queen's Park Cemetery and the 4th Street NW and 40th Avenue NW intersection. • Piped major system crossing at Centre Street N.

Objectives

Option 2 would achieve The City's objectives of reducing the magnitude of overland flooding and reducing the likelihood of overland flows crossing the Green Line. This option may also achieve the objective of maximizing developable land provided The Developers can incorporate the piped major system crossing at Centre Street N into their proposed plan. These objectives would be achieved while considering climate change and densification.

Option 2 would not achieve The City's objective of maintaining the magnitude of the existing peak flow rate to Nose Creek for either existing or future conditions. Option 2 would increase the dam safety risk and would not achieve The City's objective of reducing dam safety risk.

Benefits

AE identified the following benefits associated with Option 2:

- 1:100-year major system flows would be significantly reduced throughout the Confederation Valley. Option 2 is predicted to prevent 1:100-year, major system flows from overtopping 30th Avenue NW, and from entering the proposed HPD from 40th Avenue NW. Reduced overland flow throughout the Confederation Valley would decrease safety risks and flood damages.
- Traffic interruptions due to ponding water at the 4th Street NW and 40th Avenue NW intersection would decrease.
- Reduced overland flow through the Queen's Park Cemetery would reduce the frequency and severity of flooding at the cemetery.

Risks

AE anticipates the following risks associated with Option 2:

- AE's modelling of Option 2 suggests that the 1:100-year peak flow exiting the HPD could be 14.6 m^3/s. These flows originate from the north and northwest and are not reduced by the upstream improvement projects. Flows of this magnitude on Highland Drive NW would still exceed municipal and provincial overland flow criteria. The overland flow criteria serve as an indicator for the potential risk of people being swept away by the force of deep, fast moving water. These flows could pose risks to the HPD if they are not safely managed within the development.
- Ponded depths and volumes upstream of the roadway embankments exceed those for more conventional storage ponds. There are risks associated with these depths and volumes, and a risk of damage to the Confederation Park Golf Course and Confederation Park.
- Dam storage within the Confederation Valley would increase the risk of a dam breach. The likelihood of this risk would be reduced through dam safety improvements at the embankments; however, the consequences of the breach would be significant.
- There is an increased risk of damage to Nose Creek as the peak flow rate is expected to increase due the capacity increases on the Lower Confederation Trunk. AE estimates that the 1:100-year peak flow rate to Nose Creek would increase from 31.8 m^3/s for existing conditions to 82.7 m^3/s for future conditions as part of Option 2. Current information suggests that discharging additional flow could have negative impacts to the creek and adjacent properties.
- Allowing an increase in the magnitude of runoff to Nose Creek could affect The City's reputation as a member of the Nose Creek Watershed Partnership.
- It is anticipated that climate change impacts and densification will increase the amount of runoff and increase the probability and severity of the risks described above.

Additional Considerations

The following should also be considered:

- The impacts of increasing the peak flow rate and runoff volume to Nose Creek would have to be assessed as part of a regional Nose Creek study to identify whether improvements to Nose Creek to receive additional flow are feasible.

5.2.4 Option 3 – West Storage and Diversion to Bow River

Option 3 consists of intentional storage, conveyance system improvements, and a flow diversion to the Bow River. Together, these improvement projects reduce the magnitude of the overland flow in the Confederation Valley and prevent an increase in peak flow to Nose Creek. The intentional west catchment storage upstream of 14th Street NW, 10th Street NW and 30th Avenue NW would result in the embankments being classified as dams and would attenuate peak flows to reduce the sizes of downstream conveyance improvements.

The conveyance improvements in the east half of the catchment would reduce the magnitude of the overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk upstream of the diversion. The Bow River diversion would prevent an increase in the peak flow rate to Nose Creek by directing a significant amount of flow directly to the Bow River. AE estimates that the diverted peak flow to the Bow River could be within the range of 50-60 m^3/s. It was assumed that the HPD would be developed as part of Option 3. The improvement projects are summarized in **Table 5-2** and shown in **Figure 5-3**.

Table 5-2
Option 3 Summary

West Half Improvement Projects	East Half Improvement Projects
• Increase storage upstream of 14th Street NW, 10th Street NW and 30th Avenue NW. Increasing storage would likely lead to these structures being classified as dams.	• Conveyance Improvements on the Lower Confederation Trunk between 30th Avenue NW and Centre Street N. • Increased capture capacity in Queen's Park Cemetery and the 4th Street NW and 40th Avenue NW intersection. • Piped major system crossing at Centre Street N. • 4 m to 5 m diameter Bow River Diversion Tunnel.

Objectives

Option 3 would achieve The City's objectives of reducing the magnitude of overland flooding and reducing the likelihood of overland flows crossing the future Green Line. This option may also achieve the objective of maximizing developable land provided The Developers can incorporate the piped major system crossing at Centre Street N with their proposed plan. This option would enable maintaining the exiting peak flow rate discharge to Nose Creek. These objectives would be achieved while considering climate change and densification.

Option 3 would increase the dam safety risk and would not achieve The City's objective of reducing dam safety risk.

Benefits

AE anticipates the following benefits associated with Option 3:

- 1:100-year major system flows would be significantly reduced throughout the Confederation Valley. Option 3 is predicted to prevent 1:100-year, major system flows from overtopping 30th Avenue NW, and from entering the proposed HPD at 40th Avenue NW. Reduced overland flow throughout the Confederation Valley would decrease safety risks and flood damages.
- The runoff volume discharged to Nose Creek would be reduced.
- Traffic interruptions due to ponding water at the 4th Street NW and 40th Avenue NW intersection would decrease.
- Reduced overland flow through the Queen's Park Cemetery would reduce the frequency and severity of flooding at the cemetery.

Risks

AE identified the following risks associated with Option 3:

- AE's modelling of Option 3 suggests that the 1:100-year peak flow exiting the HPD could be 14.6 m^3/s. These flows originate from the north and northwest and are not reduced by the upstream improvement projects. Flows of this magnitude on Highland Drive NW would still exceed municipal and provincial overland flow criteria. The overland flow criteria serve as an indicator for the potential risk of people being swept away by the force of deep, fast moving water. These flows could pose risks to the HPD if they are not safely managed within the development.
- Ponded depths and volumes upstream of the roadway embankments exceed those for more conventional storage ponds. There are risks associated with these depths and volumes and a risk of damage to the Confederation Park Golf Course and Confederation Park.
- Dam storage within the Confederation Valley would increase the risk of a dam breach. The likelihood of this risk would be reduced through design elements; however, the consequences of the breach would remain significant.
- It is possible that climate change impacts and densification will increase peak rainfall runoff and increase the probability and severity of these risks.
- The feasibility of installing a 4 m to 5 m diameter Bow River Diversion Tunnel has not been confirmed. There are various constructability risks associated with this installation including an alignment which minimizes conflicts, tunnelling equipment failure requiring rescue, vibration effects on nearby infrastructure, and risks associated with managing groundwater and traffic.
- The hydraulics of the 4 m to 5 m diameter Bow River Diversion Tunnel have not been confirmed. There are various risks associated with conveying flows of this magnitude including air entrainment, thrusts, impact resistance and debris passage.
- A feasibility study would be required to assess the viability of the Bow River Diversion Tunnel. The City estimates that this study could take between 1 and 2 years, and further delay the proposed HPD.

5.2.5 Option 4 Ultimate – West Storage and Centre Street N Storage

Option 4 Ultimate consists of intentional storage in the west, conveyance improvements, and intentional storage upstream of Centre Street N within the former HPGC lands (which are privately owned at this time). Together these improvement projects reduce the magnitude of the overland flow in the Confederation Valley and prevent an increase in the peak flow rate to Nose Creek. The intentional storage in the west catchment and upstream of Centre Street N would result in the embankments being classified as dams under the Water Act regulation.

The storage in the west half of the catchment would attenuate peak flows to reduce the size of downstream conveyance improvements. The conveyance improvements in the east half of the catchment would reduce the magnitude of overland flow by lowering the hydraulic grade line in the Lower Confederation Trunk upstream of the former HPGC lands. The storage upstream of Centre Street N would prevent an increase in the peak flow rate to Nose Creek by attenuating flows.

Based on collaboration with the developer's consultant it was determined that intentionally storing stormwater upstream of Centre Street N would substantially reduce the development potential of the parcel. As such, for Option 4, the assumption is that the HPD would not be developed as indicated in the proposed Land Use and Outline Plan, but Option 4 does not preclude all development on these lands.

The improvement projects are summarized in **Table 5-3** and shown within **Figure 5-4**.

Table 5-3
Option 4 Ultimate Summary

West Half Improvement Projects	East Half Improvement Projects
• Increase storage upstream of 14th Street NW, 10th Street NW and 30th Avenue NW. Increasing storage would likely lead to these structures being classified as dams.	• Increase Storage Upstream of Centre Street N. • Conveyance Improvements on the Lower Confederation Trunk between 30th Avenue NW and the former HPGC lands. • Increased capture capacity in Queen's Park Cemetery and the 4th Street NW and 40th Avenue NW intersection.

Objectives

Option 4 Ultimate would achieve The City's objectives of reducing the magnitude of overland flooding and reducing the likelihood of overland flows crossing the future Green Line. These objectives would be achieved while considering: climate change and densification; and maintaining the magnitude of the existing peak flow rate to Nose Creek.

Option 4 Ultimate would not achieve The City's objective of maximizing developable land. Based on feedback from the HPD's consulting team, the land required for stormwater management upstream of Centre Street N would drastically reduce the development potential of the former HPGC lands. The HPD could not proceed as per the current approved Land Use and Outline Plan. Option 4 Ultimate would also increase the dam safety risk and would not achieve The City's objective of reducing dam safety risk.

Benefits

AE anticipates the following benefits associated with Option 4 Ultimate:

- 1:100-year major system flows would be significantly reduced throughout the Confederation Valley. Option 4 Ultimate is predicted to prevent 1:100-year, major system flows from overtopping 30th Avenue NW, and from entering the former HPGC lands at 40th Avenue NW. Reduced overland flow throughout the Confederation Valley would decrease safety risks and flood damages.
- Traffic interruptions due to ponding water at the 4th Street NW and 40th Avenue NW intersection would decrease.
- Reduction of overland flow through the Queen's Park Cemetery would reduce the frequency and severity of flooding at the cemetery.

Risks

AE anticipates the following risks associated with Option 4 Ultimate:

- Ponded depths and volumes upstream of the roadway embankments exceed those for more conventional storage ponds. There are risks associated with these depths and volumes, and a risk of damage to the Confederation Park Golf Course, Confederation Park and the former HPGC lands.
- Dam storage within the Confederation Valley would increase the risk of a dam breach. The likelihood of this risk would be reduced through design elements; however, the consequences of the breach would remain significant.
- There is an increased risk of damage to Nose Creek as existing peak flow rates would be sustained for longer durations than in current conditions.

Additional Considerations

The following should also be considered:

- The City's next steps include continued discussion with the landowner on a revised plan for the HPGC lands to accommodate Option 4 Ultimate.

5.2.6 Option 4 Interim - Existing Risk Mitigation

Option 4 Interim consists of small-scale projects to mitigate some of the existing risk within the Confederation Creek Catchment assuming that the HPGC lands remain as greenspace until a new Land Use and Outline Plan is proposed by the landowner. These projects would be done in the interim while:

- The City explores land acquisition options for the former HPGC lands.
- The City assesses regional Nose Creek stormwater management strategies.
- The City further assesses the potential effects of climate change on rainfall.
- The City undertakes geotechnical inspection of the roadway embankments.

The improvement projects are:

- Collect information for further decision making.
- Undertake periodic geotechnical inspection of the roadway embankments biannually and after significant rainfall events.
- Undertake slope stabilization at 14th Street NW.
- Provide major system conveyance through Greenview Park.
- Refine and optimize Option 4 Ultimate based on findings of Option 4 (Interim).

The improvement projects are shown within **Figure 5-5**.

Level Monitoring & Inspection

AE recommends that monitoring equipment be installed at 14th Street NW, 10th Street NW and 30th Avenue NW. This equipment would capture the rapid change in water levels upstream of the embankments during high intensity rainfall events. This information could be used to help inform decisions and could be used to calibrate the hydraulic model. AE also recommends that radar rainfall information be collected for the study area.

AE recommends that The City undertake periodic geotechnical inspections of the stability and integrity of the roadway embankments at 14th Street NW, 10th Street NW, 30th Avenue NW and Centre Street N. These inspections should accompany analysis of the monitoring data and be used to evaluate improvement projects to mitigate slope instabilities if necessary.

14 Street Slope Stabilization

AE recommends that the slope on the upstream face of 14th Street NW be flattened as per Thurber's work which was completed as part of a separate study (Thurber Engineering Ltd., 2016).

Greenview Park Major System Conveyance

AE recommends that major system (overland) conveyance be improved in Greenview Park as it transitions from Confederation Valley into the Nose Creek floodplain. The existing park has virtually no major system conveyance capacity and surcharging flows from the Lower Confederation Trunk are believed to have caused property damage in the area.

This improvement project would consist of a wide, shallow channel, constructed above the Lower Confederation Trunk, from Confederation Valley to Edmonton Trail NE. At Edmonton Trail NE flows could either: be piped under the roadway within an upgraded minor system; or be conveyed via a daylighted channel and pass under the roadway via a bridge or large culvert. This option would require:

- Protection of the existing utilities.
- Relocation of the existing playground and workout equipment.
- A detailed landscape design.
- Tree removal and replacement.

AE recommends that the Lower Confederation Trunk be inspected during design of the channel to confirm the condition of the trunk and its ability to withstand construction loads. The Lower Confederation Trunk could also be replaced with a new trunk or daylighted channel as proposed within **Section 7.2** if required.

6 Dam Safety

6.1 OVERVIEW

Improvement projects to intentionally store runoff upstream of the roadway embankments at 14th Street NW, 10th Street NW, 30th Avenue NW and Centre Street N would require converting them into dams according to provincial regulation (Refer to Section 2.5). The requirements associated with these dams are based on their dam classification. Dams are classified based on the estimated social, environmental, historical and economic impacts during a modelled dam breach.

AE undertook a quantitative analysis to determine the social impacts (potential for loss of life) and a qualitative analysis to determine the environmental, cultural and economic impacts. The following sections detail the quantitative analysis to determine the potential for loss of life during a dam breach event.

Scenarios

AE analyzed the following options to assess the dam classifications of the proposed storage locations:

- Option 2 – West Storage and Conveyance to Nose Creek.
- Option 4 Ultimate – West Storage and Centre Street N Storage.

These options were selected to illustrate the difference in Population at Risk (PAR) with and without the proposed HPD. Options 1A/B were not considered because the roadway embankments are not currently considered dams. Option 3 was not considered because it is functionally equivalent to Option 2 for dam breach analysis.

Methodology

The United States Bureau of Reclamation (USBR) has a methodology to calculate the loss of life during a dam failure (US Bureau of Reclamation, 2015). AE adopted this methodology for loss of life estimation and modified it to consider the Canadian Dam Association's (CDA) recommendations regarding incremental losses (Canadian Dam Association, 2013). AE's workflow was as follows:

1. Conduct a 2-dimensional breach analysis to determine the inundation extents and maximum depth-velocity product considering scenarios where the dams fail and where they do not fail.
2. Estimate the PAR within the inundation extents.
3. Determine the loss of life for both scenarios based on the USBR's empirical curves.
4. Calculate the difference in estimated loss of life between the two scenarios to determine the incremental loss of life due to dam failure.

Dam breach analysis assumes a worst-case scenario where dam failures are simulated, regardless of implemented measures to prevent failure. It was assumed that the failure of 14th Street N would create a wave significant enough to cause failure of 10th Street NW and that the resultant wave would be significant enough to fail Centre Street N. The dam at 30th Avenue NW was deemed insignificant relative to the other three dams based on the difference in elevation between the crest and the downstream toe. These assumptions were made to gauge the worst-case scenario.

6.2 2D BREACH ANALYSIS

6.2.1 Model Development

AE assessed the dam breach analysis using the MIKE software package developed by Danish Hydraulic Institute (DHI). This software can integrate one dimensional (1D), two dimensional (2D) and three dimensional (3D) modules to model a complex range of flood related issues.

For this project, AE combined the MIKE 21 Flexible Mesh (FM), MIKE 11 and MIKE URBAN models into a single, dynamically coupled model system for the dam breach analysis using MIKE FLOOD. A detailed description of the model setup is provided below.

MIKE 21 FM Model Development

The MIKE 21 FM model was used to simulate flows within Confederation Creek and Confederation Valley. AE used The City's LIDAR data to create a flexible (unstructured/triangular) and quadrangular (structured/rectangular) mesh within MIKE 21 FM. The mesh is a set of finite elements used for computational analysis. The creek topography and majority of the floodplain was represented using the flexible mesh while sections of the roads and the proposed breach locations were represented using the quadrangular mesh.

AE performed a mesh optimization during the 2D model development. Mesh optimization is a process that involves iteration of the mesh configuration within a domain to provide the best geometric representation with limited computational effort. AE also performed a sensitivity analyses on key parameters noted below.

- Time steps and simulation period
- Solution techniques for the shallow water equation
- Flooding and drying depths
- Eddy viscosities
- Roughness coefficients
- Mesh sizes
- Downstream boundary conditions.

The following summarizes the optimized mesh configuration:

- Within Confederation Valley, a maximum triangular mesh size of 15 m was used.
- Within Confederation Creek, a maximum triangular mesh size of 10 m was used.
- At the roadway crossings, a 2.5 m quadrangular mesh was used.
- In the vicinity of James Fowler High School, a 2.5 m quadrangular mesh was used.
- Outside the Confederation Valley and Confederation Creek, a maximum triangular mesh size of 100 m was used.

MIKE 11 and MIKE URBAN Model Development

The MIKE 11 model was used to simulate flows through the culvert and the pedestrian walkways at the roadway crossings. AE selected MIKE 11 to better represent the hydraulics of these structures. Mike Urban was used to model the Lower Confederation Trunk. AE converted and simplified the PCSWMM model which was used within the Draft Report. This simplification isolated the dam breach analysis from the surrounding catchments.

Coupled Model

As stated earlier the MIKE 21 FM, MIKE 11 and MIKE URBAN models were integrated into a single, dynamically coupled model system to assess the breach analysis. The MIKE 11 model was coupled to MIKE 21 FM at the inverts of the structures using a standard link function. The manholes within the MIKE URBAN model were coupled to MIKE 21 FM using the urban link function. The result is an integrated model capable of passing flows between the minor and major systems.

Hydrology

The CDA guidelines specify that dams with an extreme classification must be designed to withstand the Probable Maximum Precipitation (PMP). To simulate the worst-case scenario, AE used the PMP within the dam breach analysis.

- Hydrographs applied to MIKE 21 represent overland flows and were applied at several locations along Confederation Creek and Confederation Valley.
- Hydrographs applied to MIKE URBAN represent minor system flows and were applied at the downstream stub of each lateral.

6.2.2 Dam Failure

AE analyzed a dam failure at each of the roadway crossings within MIKE 21. The dams were simulated to fail when the upstream water depths were at a maximum. Breach parameters derived from "Embankment Dam Breach Parameters Revisited" (Froehlich, 1995) have been shown in **Table 6-1**.

Table 6-1
Breach Parameters

Breach Parameter	Option 2			Option 4 Ultimate		
	14th Street NW	10th Street NW	Centre Street N	14th Street NW	10th Street NW	Centre Street N
Top Width (m)	34.3	38.6	N/A	34.3	38.6	46.2
Base Width (m)	17.3	20.4	N/A	17.3	20.4	20.4
Depth (m)	6.1	6.5	N/A	6.1	6.5	9.2
Formation Time (min)	36	41	N/A	36	41	33

6.2.3 Depth Velocity Product - Figures

The results of the dam breach analysis have been shown within the figures indicated within **Table 6-2**.

Table 6-2
Maximum Depth-Velocity Product – Figures

Option	No Dam Failure	Dam Failure
Option 2	Figure 6-1	Figure 6-2
Option 4 Ultimate	Figure 6-3	Figure 6-4

6.3 POPULATION AT RISK

The Population at Risk (PAR) includes residential and employment populations within the inundation extents of a breach event. The PAR is separated into day and night PAR to estimate fatalities at different breach timings. The PAR can also be modified under different scenarios to reflect emergency response procedures under different warning times.

6.3.1 Census Data

AE used The City's 2017 census data to estimate the number of people living within each building. AE equally distributed the total residential population from each census tract onto the individual buildings. The night PAR was assumed to be the full residential population, while the day PAR was assumed to be half the residential population. AE adjusted the census data at the locations within **Table 6-3**.

Table 6-3
Population at Risk Adjustments

Location	Day PAR	Night PAR	Source
James Fowler High School	850	0	Wikipedia
JE Harris House	120 (98 Units)	120 (98 Units)	Alberta Seniors Housing Directory
4th Street NW & 40th Avenue NW Commercial	42	14	AE Assumption
Highland Village Green (Proposed Development)	2070 (2070 Units)	4140 (2070 Units)	"*Highland Village Green Design Guidelines*" (City of Calgary, 2016)

AE made the following assumptions while determining the PAR:

- It was assumed that the entire population of a building would be included within the PAR.
- It was assumed that there would be no people outside during a dam failure event.
- AE did not account for people within vehicles as part of the loss of life calculations.

6.3.2 Emergency Response Procedures

An effective emergency response plan can significantly reduce the PAR during a dam failure event. This is evident within the empirical fatality curves proposed by the USBR. However, an emergency response plan requires advance notice and warning time to be effective.

AE consulted with The City regarding emergency response procedures. It was agreed that it would be extremely difficult, to evacuate the inundation area because of the lack of warning time and advanced notice of a dam breach in a developed area. Therefore, the PAR was not modified to reflect an evacuation. This decision was based on the following factors:

- The proposed dams would be subject to rapid changes in depth which would reduce warning time.
- In many of the USBR's referenced historical failures, the PAR is significantly (>10kms) downstream of the dam. The longer the distance to the downstream PAR, the more warning time would be available. Given that there are residences less than 300 m downstream of Centre Street N, it was assumed that there would be no time to warn the downstream PAR after a dam failure.
- Environment and Climate Change Canada issues public alerts for high intensity rainfall events with up to two hours of notice. It would be extremely difficult to initiate an emergency response plan without greater advance notice.

6.4 LOSS OF LIFE ANALYSIS

The United States Bureau of Reclamation (USBR) has recently compiled information from sixty historical, international dam failures and developed empirical curves to estimate the loss of life during a dam failure. The USBR has four different fatality curves for the warning and no warning scenarios. These curves are shown below and correspond to: the upper and lower overall limit; and the upper and lower suggested limit (US Bureau of Reclamation, 2015).

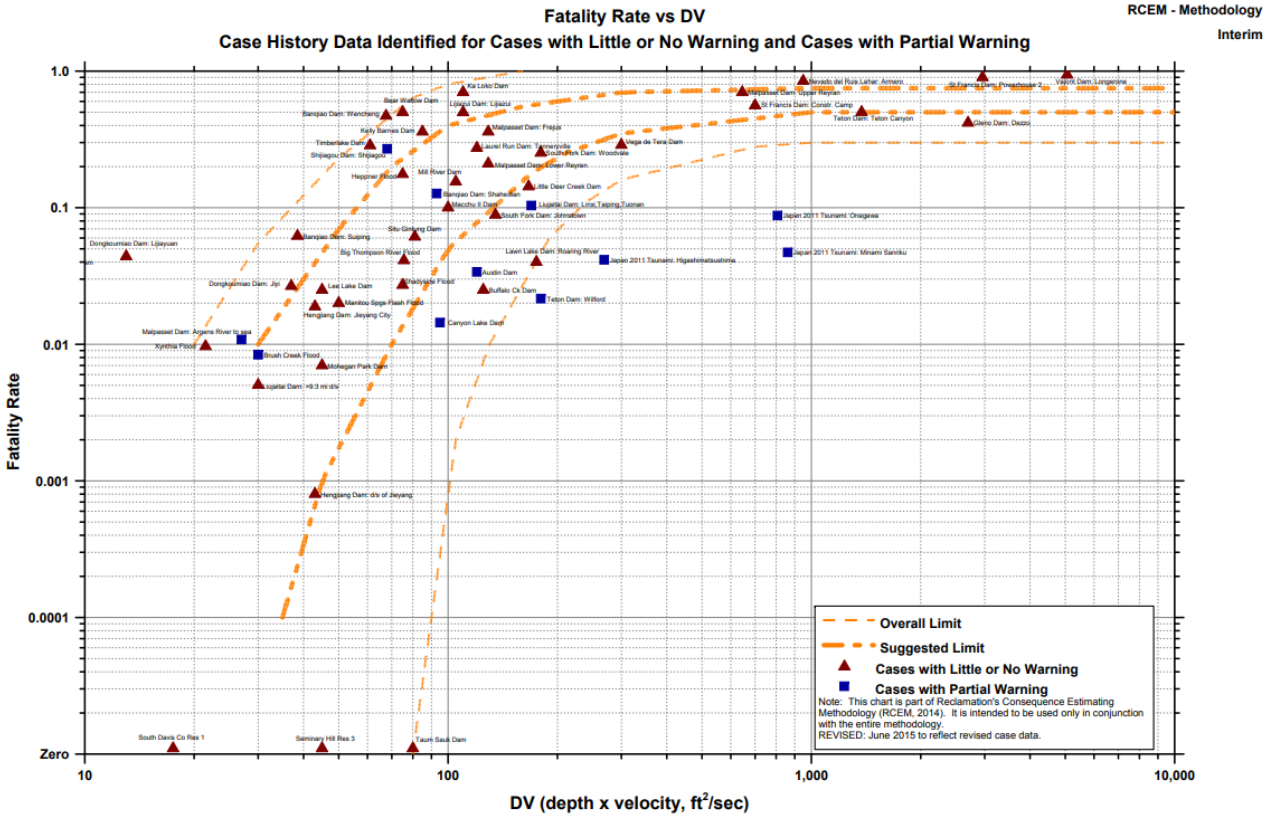

Figure 6-5
Fatality Rate vs DV

AE consulted with The City regarding selection of a curve. It was agreed that AE would develop estimates for the loss of life based upon: the low suggested limit; the high suggested limit; and a medium scenario which is an average of the two. However, AE and The City agreed that the high suggested limit was likely the most representative for this study due to the lack of warning time and the urban setting that forms the Confederation Creek Catchment.

6.4.1 Option 2 Results

Refer to **Table 6-4** for the results of the loss of life analysis for Option 2.

Table 6-4
Option 2 – Estimated Loss of Life Results

Breach Scenario	USBR Curves	Day		Night	
		No Warning	Warning	No Warning	Warning
No Breach Scenario	Low	0	0	0	0
	Medium	1	0	3	0
	High	17	2	28	3
Breach Scenario	Low	13	0	23	0
	Medium	85	1	143	2
	High	297	8	492	13
Difference	Low	13	0	23	0
	Medium	84	1	140	2
	High	280	6	464	10

Based on the preceding discussion, AE believes that the most applicable loss of life scenario is the high, no warning scenario. The estimated potential loss of life for Option 2 is within the range of 280-464.

6.4.2 Option 4 Ultimate Results

Refer to **Table 6-5** for the results of the loss of life analysis for Option 4 Ultimate.

Table 6-5
Option 4 Ultimate – Loss of Life Results

Breach Scenario	USBR Curves	Day		Night	
		No Warning	Warning	No Warning	Warning
No Breach Scenario	Low	0	0	0	0
	Medium	0	0	0	0
	High	2	0	2	0
Breach Scenario	Low	2	0	2	0
	Medium	18	0	11	0
	High	69	2	41	1
Difference	Low	2	0	2	0
	Medium	18	0	11	0
	High	67	2	39	1

Based on the preceding discussion, AE believes that the most applicable loss of life scenario is the high, no warning scenario. The estimated potential loss of life for Option 4 is within the range of 39-67.

6.4.3 Incremental Losses

AE undertook a quantitative analysis to determine the social impacts (loss of life) and a qualitative analysis to determine the environmental, historical and economic impacts. The results of this analysis have been summarized within **Table 6-6**.

Table 6-6
Incremental Losses

Scenario	Loss of Life	Environmental & Cultural Values	Infrastructure & Economics
Option 2	Estimated 280-464 fatalities	AE anticipates significant damage to Confederation Creek, Queen's Park Cemetery, the former HPGC Lands and Greenview Park.	AE anticipates damage to 14th Street NW, 10th Street NW, 30th Avenue N, Centre Street N and Edmonton Trail.
Option 4 Ultimate	Estimated 39-67 fatalities		

6.5 DAM CLASSIFICATION

6.5.1 CDA Dam Classification

Dams are classified based upon the risks expressed as incremental "losses" in the event of a dam failure. The CDA defines these incremental losses as the "*total damage from an event with dam failure, minus the damage that would have resulted from the same event had the dam not failed*." Once the Provincial Government classifies a dam, they work with the dam owner to determine the required safety measures. **Table 6-7** is from the "*Dam Safety Guidelines 2007 (2013 Edition)"* (Canadian Dam Association, 2013).

Table 6-7
Dam Classification

Dam Class	Population at Risk [Note 1]	Incremental Losses		
		Loss of Life [Note 2]	Environmental & Cultural Values	Infrastructure & Economics
Low	None	0	- Minimal short-term loss. - No long-term loss.	Low economic losses; area contains limited infrastructure or services.
Significant	Temporary Only	Unspecified	- No significant loss or deterioration of fish or wildlife habitat. - Loss of marginal habitat only. - Restoration or compensation in kind highly possible.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes.
High	Permanent	10 or fewer	- Significant loss or deterioration of important fish or wildlife habitat. - Restoration or compensation in kind highly possible.	High economic losses affecting infrastructure, public transportation, and commercial facilities.
Very High	Permanent	100 or fewer	- Significant loss or deterioration of critical fish or wildlife habitat. - Restoration or compensation in kind possible, but impractical.	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100	- Major loss of critical fish or wildlife habitat. - Restoration or compensation in kind impossible.	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances).

Note 1. Definitions for population at risk:

None – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary – People are only temporarily in the dam-breach inundation zones (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent – The population at risk is ordinarily located in the dam-breach inundation zones (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

Note 2. Implications for loss of life:

Unspecified – The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

6.5.2 Discussion

Comparing the incremental losses of dam failure (**Table 6-6**) to the CDA's dam classifications (**Table 6-7**) suggests that:

- The dams proposed within Option 2 would be classified as Extreme.
- The dams proposed within Option 4 Ultimate would be classified as Very High.

The difference in classification is attributed to the proposed HPD increasing the population at risk. The development proposes 2,070 units within the Confederation Valley. This additional population would significantly increase the risks associated with dam safety.

The difference in classification means that the proposed dams would have to be designed to a higher standard when considering the proposed HPD. Higher classification dams require more rigorous monitoring, operation, maintenance, inspection and design requirements. These higher requirements will translate into higher up-front capital costs and higher costs associated with long term operation and maintenance.

Other Considerations

- The dam breach analysis was explicitly conducted to estimate the dam classification and to identify risks and dam safety implications associated with the options presented within The Study.
- The City requires a risk mitigation strategy which is out of the scope of The Study.
- The dam breach analysis represents a worst-case scenario which is required for regulatory requirements.
- Beyond this study's limits, AE anticipates that a dam breach could cause significant damage to Nose Creek and may affect 16th Avenue NW, Deerfoot Trail, the CP Tracks and Memorial Drive.
- The impounded depths and volumes during high intensity storm events may pose dam safety risk.

7 MDP Improvement Projects

Table 7-1 illustrates the individual improvement projects required for each option.

Table 7-1
Improvement Projects by Option

Improvement Project	Option 1A / 1B	Option 2	Option 3	Option 4 Ultimate	Option 4 Interim
Western Storage	No Improvements	Yes	Yes	Yes	No
Lower Confederation Trunk Capacity Increases	No Improvements	Yes (3,250 m)	Yes (2,560 m)	Yes (2,350 m)	No
Bow River Diversion Tunnel	No Improvements	No	Yes	No	No
Centre Street N Storage	No Improvements	No	No	Yes	No
Centre Street N Piped Major System Crossing	No Improvements	Yes	Yes	No	No
Option 4 Interim Improvement Projects	No Improvements	No	No	No	Yes (Refer to **Section 5.2.5**)

7.1 WESTERN STORAGE

Options 2, 3 and 4 Ultimate include storage at 14th Street NW, 10th Street NW, and 30th Avenue NW. The purpose of these improvements is to increase the depth and volume of ponded runoff upstream of the roadway embankments. According to provincial regulation, these facilities would qualify as dams because the improvement project changes the function of the roadway embankment to intentionally store water. AE estimated the dam classifications within Section 6 and presented them within **Table 7-2** below.

Table 7-2
Western Dam Classifications

	Option 2	Option 3	Option 4 Ultimate
14th Street NW	Extreme	Extreme	Very High
10th Street NW	Extreme	Extreme	Very High
30th Avenue NW	Extreme	Extreme	Very High

The difference between the Extreme and Very High dam classifications in Options 2/3 and 4 Ultimate is solely attributed to the presence of the HPD in Options 2 and 3. The proposed HPD increases the PAR and potential loss of life during a breach event. As a result, the improvement project's capital costs, on-going operational and maintenance costs will be higher for Options 2 and 3 relative to Option 4 Ultimate.

The maximum depths, footprints and storage volumes for the western improvement projects are shown in **Table 7-3**. It is expected that the required storage will be optimized within the bounds of the maximum storage values. Even with optimization of the improvement project, these storage volumes are expected to be significant.

Table 7-3
Western Storage Improvements – 1:100-year – Hydraulic Details[10]

Location	Max Storage (m^3)	Max Depth (m)	Max Footprint (ha)
14th Street NW	310,000	6.4	19.5
10th Street NW	295,000	8.2	11.3
30th Avenue NW	80,000	5.1	4.9

Dam Storage Concept

The proposed dams at 14th Street NW, 10th Street NW and 30th Avenue NW are required to function safely[11] during the Design Flood Event (DFE). The DFE increases with the classification of the dam.

- Dams with a Very High classification (i.e., Option 4) are required to safely pass a DFE that is 2/3 between the 1000-year return period flood and the probable maximum flood.
- Dams with an Extreme classification (i.e., Options 2 and 3) are required to safely pass a DFE that is equal to the probable maximum flood.

The proposed dams at 14th Street NW and 10th Street NW will require the following key components. The magnitude of these components will increase based on the DFE / dam classification.

- A seepage mitigation system to prevent seepage into and through the shell. In concept, the seepage mitigation system will be composed of an impermeable layer backed with a layer of granular material to reduce pore water pressures and facilitate safe drainage to the dam's foundation. The extents of the seepage mitigation system have been assumed pending further geotechnical analysis.
- An embankment foundation seepage cut-off to prevent seepage underneath the foundation of the proposed dam. The seepage cut-off could consist of a pile or sheet wall. The depths and extents of the proposed cut-off have been assumed pending further geotechnical analysis.

[10] The storages, depths and inundation footprints are subject to change.
[11] Damage to the key components may occur, provided that such damage does not impede the safe operation of the dam or increase the risk of a dam failure.

- An inlet control structure for controlling and conveying stormwater flows through the dam. The inlet control structure will require various appurtenances such as a trash rack and a remotely actuated gate system.
- A spillway on the downstream face of the dams to convey overtopping flows safely over the proposed dam. AE evaluated a spillway composed of large steps; however, there are many different alternatives.
- A floodwall near the downstream crest of the dams to confine overtopping flows to the spillway.
- A tailwater pool / energy dissipation system at the bottom of the spillway to: mitigate scour at the downstream toe of the dam; and to control discharge back to Confederation Park.

The proposed dams at 14th Street NW and 10th Street NW will also require:

- Relocation of existing utilities within the embankments which conflict with the key components of the proposed dams.
- Removal and replacement of the pedestrian underpasses and culverts due to conflicts with the proposed spillways.
- Retrofitting the pedestrian underpasses with a remotely actuated gate system which can control flows through the structure.

The proposed dam at 30th Avenue NW will require:

- Raising the 30th Avenue NW roadway embankment to impound flows during the 1:100-year return period flood without flooding the roadway.
- A floodwall near the downstream crest of the dam to confine overtopping flows to the spillway.
- Construction of a paved parking lot on the downstream side of the 30th Avenue NW roadway to mitigate against erosion and scour of the embankment during a spillway event. The parking lot will act as a spillway. The parking lot requires specific extents and grading to meet hydraulic conditions. An earth fill berm is required along the sides of the proposed spillway parking lot to confine flows.

The dam storage improvement concepts assume:

- That the dam concepts are feasible from a geotechnical perspective. The geotechnical conditions at and upstream of the proposed dams could significantly affect the dam requirements. However, geotechnical analysis sufficient for determination of dam requirements has not been conducted. An in-depth geotechnical stability assessment will have to be conducted to assess the impacts of storing water upstream of the western dams. This assessment will need to consider the slope stability of the embankments and valley walls when the detention facility is full, as well as a during the rapid reduction in water levels following the storm events.
- That the existing stormwater conveyance through the embankment can be retained and incorporated safely into the dam storage concept with limited structural and backfill improvements at the upstream and downstream ends.
- That the existing utilities within the embankment, which do not conflict with the proposed dam improvements, can be maintained in-place during and after construction.

Other Considerations

- The dam concept assumes that spillway flows will cross over the roadway at each dam location prior to discharging through the spillway. This will necessitate cleanup of the areas around the dams after storm events. Cleanup could include removal of sediment, trash and/or other debris which accumulate within the inundated areas. It may also include restoration of areas which receive damage due to erosion.
- The inundation areas upstream of the western dams will affect the Confederation Park Golf Course and Confederation Park. Consideration will have to be made for flood resistant landscaping, debris mobilization, erosion and sediment management and other impacts of standing water.
- The inundation areas upstream of the western dams are unconventional in that they do not adhere to typical design parameters[12] for conventional stormwater attenuation facilities. The design of these facilities should consider public safety measures including evacuation procedures, extreme weather forecasting and early warning systems.
- The inundation areas upstream of 14th Street NW, 10th Street NW and 30th Avenue NW make use of the existing topography upstream of the embankments and do not require grade changes upstream.
- The operational philosophy of multiple dams could be optimized during future design phases which will alter the depths and inundation extents determined within This Study.
- Optimization of storage could reveal that additional capacity is required. This additional capacity could be achieved by raising the height of the dams or by other means. Additional capacity may also be required for freeboard, wave runup, spillways or for operational purposes.
- An in-depth geotechnical stability assessment will have to be conducted to assess the impacts of storing water upstream of the western dams. This assessment will need to consider the slope stability of the embankments and valley walls when the detention facility is full, as well as a during the rapid reduction in water levels following the storm events.
- The cost estimate assumes that an upstream liner can be constructed within the existing roadway embankment to meet the geotechnical requirements. If this assumption is not valid, it may result in loss of storage volumes or an increase in the construction cost.
- Construction activities will result in temporary closure of the roadways. Traffic management associated with these closures should be assessed in future phases of design.
- There are numerous deep and shallow utilities within the roadway embankments which may require relocation to facilitate dam construction. Refer to **Table 7-4**.

Table 7-4
Utilities within Embankments

14th Street NW	10th Street NW	30th Avenue NW
1 x 250 mm Sanitary 1 x 600 mm Water 3 x Gas Main (2'', 2'' 12'') 3 x Storm CBs & Leads Overhead Power Power / Communication	1 x 375 mm Storm 1 x 750 mm Sanitary 1 x 300 mm Water 2 x Storm CBs & Leads Power	1 x 750 mm Sanitary 1 x 150 mm Water 1 x Storm CB & Lead Power

[12] i.e.,. Maximum depth, sideslopes, configuration and access requirements stated within The City's "*Stormwater Management and Design Manual*" (City of Calgary, 2011).

7.2 LOWER CONFEDERATION TRUNK CAPACITY INCREASES

Options 2, 3, and 4 Ultimate include capacity increases on the Lower Confederation Trunk. The purpose of capacity increases on the Lower Confederation Trunk is to lower the hydraulic grade line through the 4th Street NW and 40th Avenue NW intersection, and reduce the magnitude of the overland flow entering the former HPGC lands. Capacity increases on the Lower Confederation Trunk would also include minor system improvements within the intersection of 4th Street NW and 40th Avenue NW. The extent of the upgrades to the Lower Confederation Trunk varies for the respective options. Refer to **Table 7-5** for the sizes and extents in each option.

Table 7-5
Lower Confederation Trunk Capacity Increases by Option

Option	Extent	Size	Figure
Option 2	Outfall D33 to Outfall N25	520 m of 1.8 m x 2.4 m Duct 410 m of 2.4 m x 2.4 m Duct 1340 m of 2.4 m x 3.0 m Duct 980 m of 2.4 m x 2.4 m Double Duct	Figure 5-2
Option 3	Outfall D33 to West End of Greenview Park	520 m of 1.8 m x 2.4 m Duct 410 m of 2.4 m x 2.4 m Duct 1000 m of 2.4 m x 3.0 m Duct 630 m of 2.4 m x 2.4 m Double Duct	Figure 5-3
Option 4 Ultimate	Outfall D33 to Outfall N25	520 m of 1.8 m x 2.4 m Duct 410 m of 2.4 m x 2.4 m Duct 420 m of 2.4 m x 3.0 m Duct 1000 m of 1.5 m diameter Pipe	Figure 5-4
Option 4 Interim	N/A	N/A	Figure 5-5

Option 2 and 3 Considerations

- The proposed capacity increases on the Lower Confederation Trunk should be done in conjunction with any development within the former HPGC lands.
- A structural analysis may have to be undertaken on the Lower Confederation Trunk in the former HPGC lands to determine whether it could withstand any additional fill material.

Option 4 Ultimate Considerations

- The City's next steps include continued discussion with the landowner on a revised plan for the HPGC lands to accommodate Option 4 Ultimate.

Alternative for Conveyance East of Centre Street N

For Options 2, 3 and 4 Ultimate, the conveyance improvements east of Centre Street N could be achieved with a daylighted channel[13] through Greenview Park instead of increasing the capacity of the Lower Confederation Trunk. This option would provide the required conveyance to Nose Creek and provide an overland escape route for flows in excess of the intended level of service. This daylighted channel would require:

- Reconstruction of all of Greenview Park.
- Conveyance underneath Edmonton Trail NE through a large culvert or conversion of Edmonton Trail NE to a bridge.
- Appropriate erosion protection.
- Relocation of 750 mm and 300 mm sanitary mains west of Edmonton Trail NE to a location west of the existing location.
- Relocation of a 200 mm watermain.

7.3 BOW RIVER DIVERSION TUNNEL (OPTION 3)

Option 3 includes construction of a 4.0 m to 5.0 m diameter diversion tunnel to convey flows 4.5 kms south to the Bow River. This tunnel would eliminate an increase in the magnitude of the peak flow rate to Nose Creek. The improvement project would be comprised of a large diversion structure east of Centre Street N, a deep drop shaft, a large diameter tunnel system and a new outfall to the Bow River in the vicinity of the Centre Street Bridge.

Option 3 Considerations

- The alignment of the tunnel should be refined if the tunnel's feasibility is confirmed. Consideration should be made to identifying an outfall location on the Bow River and the geotechnical stability of the area. Consideration should also be made to the locations of intermediate shafts and construction areas required for tunneling.
- The design of the tunnel system would require management of siphoned flows, icing, dewatering, air entrainment, impact resistance within the shafts, hydraulic jumps, energy dissipation at the outfall, and thrust resistance.
- The construction of the tunnel and shaft system would require significant measures including vibration dampening, noise reduction, traffic accommodation, and substantial construction areas.
- The proposed outfall should include considerations for river morphology, scour protection, in-stream dredging and backwater prevention.
- The proposed outfall would require approvals in accordance with the Fisheries Act, Navigation Protection Act, Water Act, Public Lands Act, and Historical Resources Act. Given the magnitude of the flows to be redirected, the anticipated size of the structure and extents of instream activities, AE anticipates that these approvals may require substantial mitigation measures or offsetting requirements during construction.

[13] Note that this daylighted channel is different than the wide shallow channel proposed within Option 4 Interim.

- Relocation of utilities around the working shafts and the tunnel would likely be required during construction. AE anticipates that the working shafts and tunnel could conflict with storm, sanitary and water mains, as well as numerous shallow utilities.
- Overall, this option would be extremely difficult to design and construct. The construction will require specialist contractors with proven experience with large diameter tunnelling.

7.4 CENTRE STREET N STORAGE (OPTION 4 ULTIMATE)

Option 4 Ultimate includes storage within the former HPGC lands. The purpose of the storage facility is to attenuate flows such that the magnitude of the discharge peak flow rate is not increased over the current rates. The existing Lower Confederation Trunk would be removed between 40th Avenue NW and Centre Street N. The trunk would be replaced with a constructed channel that transitions into the proposed storage area within the northeastern areas of the former HPGC lands. According to provincial regulation, this facility would classify as a dam because the improvement project changes the function of the roadway embankment. AE estimated the dam classification to be Very High as described within **Section 6**.

Hydraulic details regarding the HPGC lands storage facility are shown in **Table 7-6**.

Table 7-6
Centre Street N – Hydraulic Details

Location	Max Storage (m^3)	Max Depth (m)	Max Footprint (ha)
Centre Street N	180,000	8.9	7.1

Dam Storage Concept

The proposed dam at Centre Street N will require the following key components:

- A seepage mitigation system to prevent seepage into and through the shell. In concept, the seepage mitigation system will be composed of an impermeable layer backed with a layer of granular material to reduce pore water pressures and facilitate safe drainage to the dam's foundation. The extents of the seepage mitigation system have been assumed pending further geotechnical analysis.
- An embankment foundation seepage cut-off to prevent seepage underneath the foundation of the proposed dam. The seepage cut-off could consist of a pile or sheet wall. The depths and extents of the proposed cut-off have been assumed pending further geotechnical analysis.
- An inlet control structure for controlling and conveying stormwater flows through the dam. The inlet control structure will require various appurtenances such as a trash rack and a remotely actuated gate system. The existing storm duct will have to be removed and relocated to avoid conflicts with the proposed spillway.
- A spillway on the downstream face of the dam to convey overtopping flows safely over the proposed dam. AE evaluated a stepped spillway composed of large steps; however, there are many different alternatives.
- A floodwall near the downstream crest of the dams to confine overtopping flows to the spillway.

- A tailwater pool/energy dissipation system at the bottom of the spillway to: mitigate scour at the downstream toe of the dam; and to control discharge back to the daylighted channel within Greenview Park.
- Relocation of existing utilities within the embankments which conflict with the key components of the proposed dams.

The dam storage improvement concepts assume:

- That the dam concepts are feasible from a geotechnical perspective. The geotechnical conditions at and upstream of the proposed dam could significantly affect the dam's requirements. However, geotechnical analysis sufficient for determination of the dam requirements has not been conducted. An in-depth geotechnical stability assessment will have to be conducted to assess the impacts of storing water upstream of the western dams. This assessment will need to consider the slope stability of the embankments and valley walls when the detention facility is full, as well as a during the rapid reduction in water levels following the storm events.
- That the existing utilities within the embankment, which do not conflict with the proposed dam improvements, can be maintained in place. This includes the existing 750 mm sanitary trunk immediately south of Laycock Drive NW.

Option 4 Ultimate Considerations

- The City's next steps include continued discussion with the landowner on a revised plan for the HPGC lands to accommodate Option 4 Ultimate.
- The inundation area upstream of the dam will influence the former HPGC Lands. Consideration will have to be made for flood resistant landscaping, debris mobilization, erosion and sediment management and other impacts of standing water.
- The inundation area upstream of the dam is unconventional in that it does not adhere to typical design parameters[14] for conventional stormwater attenuation facilities. The design of this facility should consider public safety measures including evacuation procedures, extreme weather forecasting and early warning systems.
- The current concept assumes that spillway flows will cross over Centre Street and the Green Line LRT tracks prior to discharging through the downstream spillway. Depending on the severity of the spill event, it may require maintenance and repair of the LRT tracks and cleanup of the areas around the dam. Cleanup could include removal of sediment, trash and/or other debris which accumulate within the inundated areas. It may also include restoration of areas which receive damage due to erosion.
- The cost estimate assumes that an upstream liner can be constructed within the existing roadway embankment to meet the geotechnical requirements. If this assumption is not valid, it may result in loss of storage volumes or an increase in the construction cost.
- Significant excavation would be required upstream of Centre Street N to achieve the volume of storage required.

[14] i.e., Maximum depth, sideslopes, configuration and access requirements stated within The City's "*Stormwater Management and Design Manual*" (City of Calgary, 2011)

- Outfalls would be required for the 10 existing laterals discharging into the proposed channel. Each of these outfalls will require a headwall and erosion protection. The three largest outfalls are 1200 mm, 1050 mm, and 1050 mm in diameter.
- Erosion protection would be required along the channel and within the storage area.
- Wetland compensation would be required for removal of the two existing wetlands.
- There is an existing 750 mm sanitary trunk in a 30 m right-of-way which runs along the west and north sides of the former HPGC lands. The channel should be designed such that it does not negatively affect the sanitary trunk.
- Many of the existing trees within the former HPGC lands would have to be removed to accommodate the new channel and storage area.
- The existing springs in the toe of the slope indicate a high groundwater table. Excavation to accommodate the channel and storage area may require significant dewatering.
- Construction activities will result in temporary closure of the roadways. Traffic management associated with these closures should be assessed in future phases of design.
- There are numerous deep and shallow utilities within Centre Street N which may require relocation. Refer to **Table 7-7**. Costs associated with the relocation will likely be significant, but have been excluded at this time given the uncertain nature of the associated works.

Table 7-7
Utilities within Centre Street N

Centre Street N
1 x 1500 mm Storm 1 x 300 mm Storm 1 x 750 mm Sanitary 1 x 250 mm Sanitary 1 x 250 mm Water 1 x Gas Main (8'') 2 x Storm CB and Leads Power Communication

7.5 CENTRE STREET N PIPED MAJOR SYSTEM CROSSING

Options 2 and 3 require a piped major system crossing at Centre Street N. The purpose is to convey major system flows underneath the future Green Line LRT. The design flow rate will be determined by The City. The HPD as it is shown within the proposed Land Use and Outline Plan may need to be altered to accommodate the piped major system crossing. In concept, AE anticipates that the piped major system crossing would have the following features:

- A minimum design capacity capable of conveying the 1:100-year storm.
- A provision to divert water off the road into a large capacity inlet to the Lower Confederation Trunk.

As these improvements would be incorporated with the HPD, details regarding this improvement are not discussed in this report and are not accounted for in the cost estimates of the options identified in The Study.

8 Summary

8.1 OPTION SUMMARY

AE compared the options by:

- Option Summary as shown in **Table 8-1.**
- Objective Summary as shown in **Table 8-2.**
- Risks as shown in **Table 8-3.**
- Main Benefits (excluding costs) as shown in **Table 8-4.**

These tables are on the following pages.

Intentionally blank.

Table 8-1
Option Summary[15]

Project	Option 2	Option 3	Option 4 Ultimate	Option 4 Interim
Western Storage	• 310,000 m^3 of dam storage upstream of 14th Street NW • 295,000 m^3 of dam storage upstream of 10th Street NW • 80,000 m^3 of dam storage upstream of 30th Avenue NW	• 310,000 m^3 of dam storage upstream of 14th Street NW • 295,000 m^3 of dam storage upstream of 10th Street NW • 80,000 m^3 of dam storage upstream of 30th Avenue NW	• 310,000 m^3 of dam storage upstream of 14th Street NW • 295,000 m^3 of dam storage upstream of 10th Street NW • 80,000 m^3 of dam storage upstream of 30th Avenue NW	
Lower Confederation Trunk Capacity Increases	• 520 m of 1.8 m x 2.4 m Duct • 410 m of 2.4 m x 2.4 m Duct • 1340 m of 2.4 m x 3.0 m Duct • 980 m of 2.4 m x 2.4 m Double Duct	• 520 m of 1.8 m x 2.4 m Duct • 410 m of 2.4 m x 2.4 m Duct • 1000 m of 2.4 m x 3.0 m Duct • 630 m of 2.4 m x 2.4 m Double Duct	• 520 m of 1.8 m x 2.4 m Duct • 410 m of 2.4 m x 2.4 m Duct • 420 m of 2.4 m x 3.0 m Duct • 1,000 m of 1.5 m diameter Pipe	
Bow River Diversion Tunnel		• 4.5 kms of 4.0 m to 5.0 m diameter diversion tunnel		
Centre Street N Storage			• 180,000 m^3 of dam storage within the former HPGC Lands • Land acquisition within the former HPGC lands	•
Centre Street N Piped Major System Crossing	Yes	Yes	No	No

Table 8-2
Objective Summary

Objectives	Option 1A	Option 1B	Option 2	Option 3	Option 4 Ultimate	Option 4 Interim
Reduce the magnitude of overland flooding in Queen's Park Cemetery, at the intersection of 4th Street NW and 40th Avenue NW, and within the former HPGC lands.	No	No	Yes	Yes	Yes	No
Maximize the amount of developable land within the former HPGC lands.	None	Full	Moderate	Moderate	Minimal	Minimal
Reduce the likelihood of overland flows crossing the future Green Line LRT.	No	No	Yes	Yes	Yes	No
Maintain Current Peak Flow Rate to Nose Creek	No	No	No	Yes	Yes	No
Address Impacts of Climate Change and Densification	No	No	Yes	Yes	Yes	No
Reduce the risks associated with dam safety	Yes	Yes	No	No	No	Yes

Table 8-3
Risks of Options

Option	Discussion
Option 1A	• Risk of overland flow, overtopping Centre Street N during the 1:10-year storm, damaging the future Green Line LRT, and causing property damage within the community of Greenview. • Despite not being classified as dams, the existing roadway embankments pose a risk to public safety because of the impounded depths and volumes of runoff. • Increased risk to Nose Creek when flows increase from 31.8 m^3/s to 43.9 m^3/s due to the effects of climate change and densification.
Option 1B	• Risk of overland flow, overtopping Centre Street N during the 1:2-year storm, damaging the future Green Line LRT, and causing property damage within the community of Greenview. • Despite not being classified as dams, the existing roadway embankments pose a risk to public safety because of the impounded depths and volumes of runoff. • Increased risk to Nose Creek when flows increase from 31.8 m^3/s to 65.7 m^3/s due to the effects of: climate change and densification; and the HPD. • Public safety risk associated with an estimated overland peak flow rate of 29.5 m^3/s through the HPD.
Option 2	• Public safety, environmental and economic risks associated with the storage depths and volumes upstream of the roadway embankments. • Increased risk to Nose Creek when flows increase from 31.8 m^3/s to 82.7 m^3/s due to the effects of climate change and densification and the HPD. • Public safety risk associated with an estimated overland peak flow rate of 14.6 m^3/s through the HPD.
Option 3	• Public safety, environmental and economic risks associated with the storage depths and volumes upstream of the roadway embankments. • Public safety risk associated with an estimated overland peak flow rate of 14.6 m^3/s through the HPD. • Constructability risks associated with the feasibility of the Bow River Diversion Tunnel.
Option 4 Ultimate	• Public safety risk associated with the storage depths and volumes upstream of the roadway embankments. • Increased risk to Nose Creek due to the peak flow rate of 31.8 m^3/s being sustained for longer durations than existing conditions.
Option 4 Interim	• Until a decision regarding an ultimate improvement project is made, Option 4 Interim carries many of the same risks associated with Option 1A. However, the geotechnical risk associated with 14th Street NW and the overland flow risk associated with Greenview Park will be mitigated.

Table 8-4
Benefits of Options

Option	Discussion
Option 1A	The main benefits of Option 1A are not incurring: the increases in peak flow to Nose Creek and the increases in public safety hazards associated with the proposed HPD.
Option 1B	The main benefit is higher density development near the future Green Line LRT.
Option 2	The main benefits are higher density development near the future Green Line LRT and reduced overland flow in the Confederation Valley.
Option 3	The main benefits are higher density development near the future Green Line LRT, reduced overland flow in the Confederation Valley, and maintaining the existing peak flow rate to Nose Creek.
Option 4 Ultimate	The main benefits are reduced overland flow in the Confederation Valley and maintaining the existing peak flow rate to Nose Creek.
Option 4 Interim	Until a decision regarding an ultimate improvement project is made, Option 4 Interim carries many of the same risks associated with Option 1A. However, the geotechnical risk associated with 14th Street NW and the overland flow risk associated with Greenview Park will be mitigated. Option 4 Interim also allows for further analysis of Nose Creek and the anticipated impacts of climate change. This additional information will enable The City to optimize the proposed improvement projects.

[15] Note that Options 1A and 1B do not have improvement projects and are not included within **Table 7-1**.

8.2 COST ESTIMATES

Class 5 cost estimates are presented in **Table 8-5**. Class 5 cost estimates have an expected variance of -50 % to +100 % according to The City's "*Estimation and Contingency Standard*" (City of Calgary, 2012).

Table 8-5
Class 5 Cost Estimates

Option	Estimated Cost*	Inclusions	Exclusions
Option 2	$110,000,000 Cost Estimate Range $55,000,000– $220,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW	• Contingency • Centre Street N Piped Major System Crossing • Substantial Nose Creek Improvements to Receive Increased Flows
Option 3	$370,000,000 Cost Estimate Range $185,000,000– $740,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW • Bow River Diversion Tunnel	• Contingency • Centre Street N Piped Major System Crossing
Option 4 Ultimate	$130,000,000** Cost Estimate Range $65,000,000- $260,000,000	• Engineering Fees • Lower Confederation Trunk Capacity Increases • Dam Safety Retrofits at 14th Street NW, 10th Street NW and 30th Avenue NW • Dam Safety Retrofits at Centre Street N • HPGC Lands Channel and Storage Facility	• Contingency • Land Acquisition
Option 4 Interim	$10,000,000** Cost Estimate Range $5,000,000– $20,000,000	• Engineering Fees • Monitoring & Inspection of Roadway Embankments • Local Stabilization of 14th Street NW • Greenview Park Conveyance Channel	• Contingency

*The Class 5 cost estimates are presented as a value and a range. The value presented does not include contingency. The range presented is -50 % to +100 % of the cost estimate and is based on the expected variance of the Class 5 cost estimates. The range has been rounded up to the nearest $1,000,000.
** The costs of Option 4 Interim are not included in Option 4 Ultimate.

The cost estimates also exclude the following items:

- Future Studies
- Permits
- Approvals
- Environmental Requirements and Compensation
- Operation and Maintenance Costs
- Taxes.

The cost estimates associated with the construction of the Centre Street N piped major system crossing were excluded because details of the required infrastructure could vary significantly depending on the proposed on-site stormwater management facilities within the HPD development.

8.3 NOSE CREEK STUDY

There are uncertainties associated with the flood frequency analysis and flood mapping on Nose Creek. The impacts of increasing peak flow rates and runoff volumes from the Confederation Creek Catchment to Nose Creek are similarly uncertain. Therefore, in accordance with the recommendations in the Nose Creek Watershed Management Plan, The City instructed AE to develop solutions that would restrict the magnitude of the peak flow rate to Nose Creek to present day values, given that increases in the peak flow rate and volume will likely negatively affect Nose Creek and adjacent properties.

It is unlikely that Nose Creek is able to accommodate additional flows without major capacity upgrades along the entire creek down to its confluence with the Bow River. These capacity upgrades would not align with the Nose Creek Watershed Management Plan. In addition, due to the anticipated provincial and federal scrutiny, extensive environmental provisions may be required to minimize impacts on fish habitat and riparian areas. Even significant improvements to Nose Creek are unlikely to enable Option 2 to proceed as proposed. However, modifications to Nose Creek may enable optimization of Option 4.

AE therefore recommends that, in collaboration with the Nose Creek Watershed Partnership, The City develop a plan for Nose Creek which includes the following:

- Confirmation of the creek's hydrology, hydraulics, morphology, fish habitat, and water quality.
- Development of options to mitigate existing flooding.
- Assessment of the creek's ability to manage the anticipated impacts of climate change and densification in its contributing areas.
- Development of regional strategies to manage the anticipated impacts of climate change and densification within Nose Creek's tributary catchments.

At this time, in collaboration with the Nose Creek Watershed Partnership, The City is developing a timeline to initiate this study.

8.4 STAKEHOLDER INVOLVEMENT

There are numerous stakeholders who have interests in the Confederation Creek and Nose Creek Catchments. AE recommends that stakeholder engagement continue throughout the planning, design and construction process. These stakeholders include, but are not limited to:

- City Council
- The Developers
- Various City of Calgary Stakeholders
- Alberta Environment and Parks
- Department of Fisheries and Oceans
- Nose Creek Watershed Partnership
- The Green Line Project Team
- Confederation Park Golf Course
- Queen's Park Cemetery
- Affected Community Associations
- Affected members of the public within the Confederation Creek Catchment Area
- Special Interest Groups (e.g., Friends of Confederation Creek)

8.5 SUMMARY

In 2017, AE was commissioned to undertake the Confederation Park Regional Drainage Study to inform The City of regional drainage patterns within the Confederation Creek Catchment.

The Confederation Creek Catchment is affected by regional drainage issues which stem from existing development. AE's drainage modelling suggests that: runoff is impounded within the Confederation Valley upstream of roadway embankments; major overland system flow occurs within the Confederation Valley; flows to Nose Creek will increase with increased re-development in the catchment area; and climate change and densification will compound these issues.

These drainage issues create risks within the Confederation Creek Catchment. These risks include:

- Public safety risks associated with deep fast-moving water;
- Dam safety risks associated with water retention in the Confederation Valley;
- Risk of property damage due to flooding; and
- Environmental risks associated with erosion damage to Nose Creek.

If future development and climate change are not planned for and managed, these drainage risks could be further compounded. In an attempt to mitigate these risks, AE and The City developed five regional options. It should be noted that the proposed HPD was a key consideration for each option due to its impacts on regional drainage and potential stormwater management strategies.

Option 1A and Option 1B (No Improvements – Without/With the HPD) would result in unacceptable levels of risk. These risks would be associated with dam safety, high flows through the proposed HPD and Nose Creek's lack of ability to receive additional flow. The City is not investigating Option 1A or 1B any further.

Option 2 (West Storage and Conveyance to Nose Creek) would increase peak flow rates to Nose Creek beyond those in existing conditions. Given Nose Creek's lack of ability to receive the additional flow required to accommodate Option 2, The City is not investigating Option 2 any further.

Option 3 (West Storage and Diversion to the Bow River) would result in the removal of 97,000 m^3 of stormwater attenuation in the catchment to accommodate the HPD. The estimated cost of managing this removal of storage is prohibitively expensive ($370,000,000). The City also anticipates that a feasibility study to assess the viability of the Bow River Diversion Tunnel could take between 1 and 2 years to complete. Therefore, The City is not investigating Option 3 any further.

Option 4 Ultimate (West Storage and Centre Street N Storage) would achieve most of The City's objectives; however, the HPGC lands and parcel east of Centre Street N are privately owned. As such, for Option 4, the assumption is that the HPD would not be developed as indicated in the proposed Land Use and Outline Plan, but Option 4 does not preclude all development on these lands.

Option 4 Interim (Existing Risk Mitigation) would allow The City to mitigate some of the existing risk while further studies and data collection are undertaken to inform and optimize the final configuration of Option 4 Ultimate.

8.6 CONCLUSIONS

AE recommends that The City take a two-stage approach to stormwater management in the Confederation Creek Catchment (Option 4 Interim & Option 4 Ultimate).

- Option 4 Interim (Stage 1) would allow The City to mitigate some of the existing risks while:
  - The City addresses the need for land within the HPGC lands for Option 4 Ultimate.
  - The City undertakes a regional study of Nose Creek.
  - The City further assesses the potential effects of climate change on rainfall.
  - The City undertakes geotechnical inspection of the roadway embankments.
  - The City considers optimization of Option 4 Ultimate
- Option 4 Ultimate (Stage 2) would allow The City to meet its ultimate objectives.

The City's next steps include:

- Finalizing the reporting for the Community Drainage Improvement component of this Study.
- Continued discussion with the landowner on a revised plan for the HPGC lands to accommodate Option 4 Ultimate.
- A regional study of Nose Creek which confirms the creek's existing hydraulics and identifies the potential for regional improvements which may enable optimization of Option 4.

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Certification Page

This report presents AE's findings regarding the Confederation Park Regional Drainage Study.

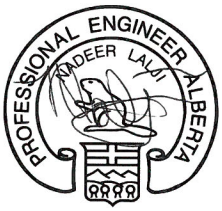
Respectfully submitted,

Prepared by:

2019-03-06

Andrew Rushworth, P.Eng.

Reviewed by:



2019-03-06

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ASSOCIATED ENGINEERING

QUALITY MANAGEMENT SIGN-OFF

Signature: _____ 2019-Mar-07

APEGA Permit to Practice P 3979