2022-07-07

Public

Kiley Marchuk
Planning & Development Services
Strathcona County
2001 Sherwood Drive
Sherwood Park, AB T8A 3W7

Dear Ms. Marchuk,

Please find enclosed the unsigned final submission of the Astotin Creek Resiliency Study: Resiliency Action Plan. As per discussions between Strathcona County and WSP, in addition to the previously provided signed and sealed report, we are also providing this document as an unsigned final version to enable the County to reduce the file size to meet requirements for sharing this report on the County's website.

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Yours sincerely,

Joshua Maxwell, M.Sc., P.Eng. PMP.
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Encl. Astotin Creek Resiliency Study: Resiliency Action Plan

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ASTOTIN CREEK RESILIENCY STUDY

Resiliency Action Plan

June 2022

STRATHCONA COUNTY

WSP

Territorial Acknowledgment

Strathcona County honours the past, present and future First Peoples of this land. We acknowledge that this land has embraced and nourished the Cree, Métis, Blackfoot, amongst many others, for generations. We recognize Strathcona County is within Treaty Six Territory and the homeland of the Métis Nation of Alberta, Region Two and Four.

Strathcona County has an inherent responsibility to foster healthier relationships with Indigenous Partners. We will strive to respond to the Calls to Action as outlined by the Truth and Reconciliation Commission.

Strathcona County is close in proximity to Enoch Cree Nation (maskêkosihk), Ermineskin Cree Nation (neyaskweyahk), Louis Bull Tribe (kisipatinahk), Michel First Nation, Montana First Nation (akamihk), Papaschase First Nation, Samson Cree Nation (nipisikopahk), and Saddle Lake Cree Nation (onihcikiskwapiwinihk).

Furthermore, the geographic boundaries of Strathcona County includes parts of Regions Two and Four of the Métis Nation of Alberta, and are near the Elizabeth Métis Settlement, Fishing Lake Métis Settlement, Buffalo Lake Métis Settlement, and Kikino Métis Settlement.

We recognize the importance of allying with First Peoples and taking steps to foster a healthier relationship. As such, we will demonstate ***manacitôwin****, the Cree word meaning respect for each other.*

Signatures & Authorizations

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Disclaimer

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Table of Contents

Introduction 7

1.1 Importance of Resilience for Astotin Creek 11
1.2 Project Approach and Objectives 13

State of the Watershed 16

2.1 Land-use and development 17
2.2 Existing Watershed Health and Biophysical Context 21
2.2.1 Soils 21
2.2.2 Vegetation 22
2.2.3 Wildlife 24
2.2.4 Fish and Aquatic Habitat 26
2.3 Watershed and Flood Analysis 28
2.4 Stormwater Management 31
2.5 Climate Change in the Watershed 33
2.6 Historical and Indigenous Cultural Resources 35

Community and Indigenous Engagement 37

3.1 Public and Indigenous Engagement Program 38
3.2 What We Heard 39

Recommended Actions 41

4.1 Visions for Astotin Creek Resilience 43
4.2 Vision 1: Healthy Ecosystem 45
4.3 Vision 2: Integrated Watershed Management 62
4.4 Vision 3: Resilient Infrastructure 71
4.5 Vision 4: Proactive Management 84
4.6 Vision 5: Flood and Drought Preparedness 91
4.7 Vision 6: Educated, Engaged, and Empowered Public 102

Implementation 111

5.1 Action Prioritization 112
5.1.1 Action Prioritization Methodology 112
5.1.2 Action Prioritization Results 114
5.2 Implementation Considerations 116
5.3 Funding Opportunities 119
5.3.1 Federal Funding Programs 119
5.3.2 Provincial Funding Program 123
5.3.3 Non-government Funding Programs 127

Acknowledgments 131

References 132

Appendices

A Undersized Crossings
B Action Prioritization Matrix
C Project Recognition

INTRODUCTION

1

The Astotin Creek Resiliency Study is focused on building resilience within the Astotin Creek watershed. Resilience for Astotin Creek refers to the **creek withstanding and recovering from drought and flood** without the creek losing its ability to function or suffering damage **that cannot be recovered from naturally without intervention.**

The Astotin Creek Resiliency Study began with environmental and engineering assessments to understand the current state of the watershed. Results from these studies were included in the State of the Watershed and the Drainage Master Plan. The experiences and concerns of residents and other regional stakeholders have also been important components of this study. Stakeholder and Indigenous engagement occurred throughout this study and outcomes from the engagement sessions are included in the What We Heard and Did Engagement Summary Report. The Resiliency Action Plan is the final report for the Astotin Creek Resiliency Study. The Resiliency Action Plan builds on the findings from the State of the Watershed, Drainage Master Plan, and stakeholder engagement programs and includes recommended actions to improve resilience to flooding and drought. The Resiliency Action Plan includes some key takeaways and findings from previous assessments, but methodology and detailed findings are to be found in the State of the Watershed, Drainage Master Plan, and What We Heard and Did Engagement Summary Report.

There is no one-size-fits all solution for building resilience across the watershed. Instead, a combination of different actions is required to build resilience. As such, the Resiliency Action Plan is intended to provide a “tool-box” of actions that Strathcona County can use. Some actions may only be applicable in certain sections of the watershed, while other actions may be applicable at a watershed scale. Details on the applicability of actions are included within each action description. Although the County will be primarily responsible for implementation of the Resiliency Action Plan, collaboration between the County, residents, and regional stakeholders will be crucial for successful implementation. Additionally, there are some actions which have been included which can be implemented by residents, with support from the County.

The Resiliency Action Plan will begin with project context, approach, and objectives (Section 1). This will be followed by a summary of key findings from the State of the Watershed and the Drainage Master Plan (Section 2), and by key findings and outcomes from the stakeholder and Indigenous engagement programs (Section 3). A series of actions to build resilience in the watershed will be presented (Section 4), followed by considerations for implementation of the Resiliency Action Plan (Section 5).

1.1 IMPORTANCE OF RESILIENCE FOR ASTOTIN CREEK

The Astotin Creek watershed lies in the northern part of Strathcona County, in an area supporting agricultural, industrial, and rural residential land use. The watershed is within the northern end of the Beaver Hills Biosphere Reserve and forms an important link between the North Saskatchewan River valley and Elk Island National Park. This watershed is a part of a regionally significant natural area and provides important ecological goods and services, including ecological connectivity, water quality and availability. Activities undertaken along Astotin Creek can influence local and downstream conditions and so taking a holistic, watershed-scale approach to building resilience is required to ensure that actions provide intended benefits.

The current land-use and development that has occurred in the watershed provide important context for this Resiliency Action Plan. The watershed has experienced past agricultural and industrial development, clearing of riparian habitat along the creek in some areas and removal of wetlands. Both riparian vegetation and wetlands play an important role in creek health and moderation of run-off conditions. These changes to the landscape have increased flood and drought risk and reduced the overall resilience of the watershed.

Several recent flooding events (Figure 1-1) have brought considerations of water management to the forefront for Astotin Creek. The creek has flooded three times in the past decade, affecting agricultural lands, roads, and private residences. The County has responded to flood events with emergency mitigation measures such as road closures, pumping and monitoring flood conditions to protect roads, private homes, and property. These events and their associated impacts on property, infrastructure, biodiversity, water quality and quantity have prompted Strathcona County to conduct the Astotin Creek Resiliency Study. This Resiliency Action Plan will provide the County with actions to reduce flood and drought risk to ultimately reduce the costs and impacts associated with drought and flood. It is important to acknowledge that even if actions are taken to reduce risk, flood and drought risk cannot be fully eliminated. Therefore, this Resiliency Action Plan also includes actions to increase preparedness for these events.

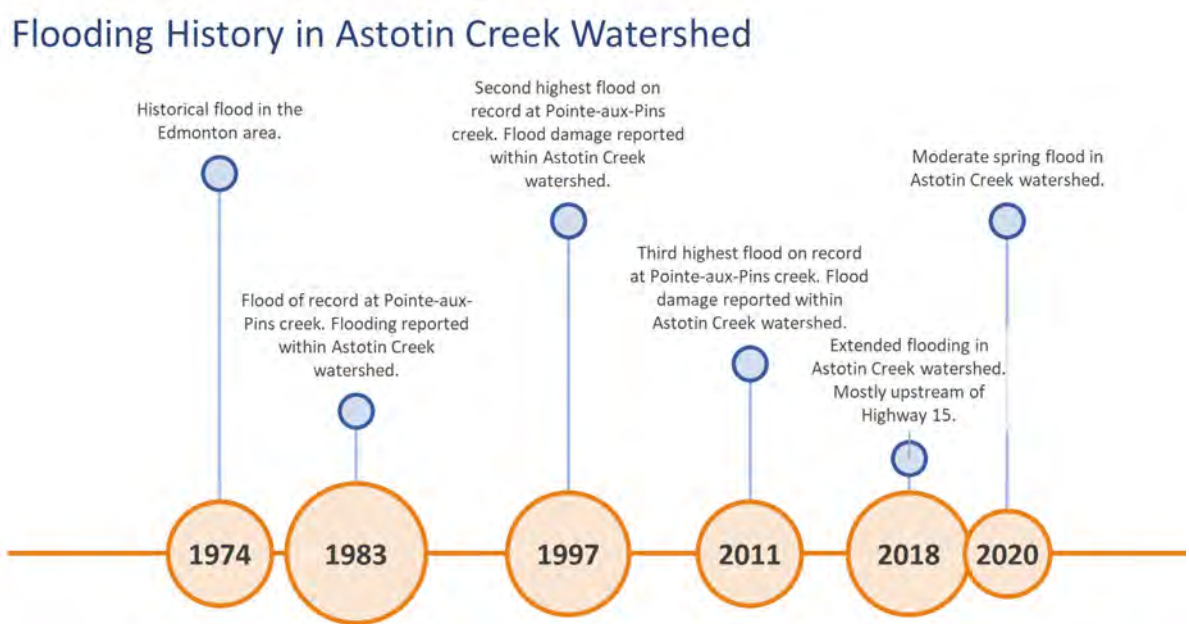


Figure 1-1 Recent flooding history in Astotin Creek watershed. Historical floods recorded at the Pointe-aux-Pins Creek hydrometric station correspond to the historical floods experienced within the Astotin Creek watershed

Taking action to increase flood and drought resilience is important to reduce the risk of infrastructure damage and the associated costs and risks to public health and safety. The April 2018 flood response provides an example of the level of effort required by the County to respond to a flood event. The response required extensive deployment of County Transportation and Agricultural Services (TAS) equipment and resources to protect landowner and County property. By Tuesday April 24, 2018, the County had received reports of more than 515 culvert issues across the County, with nearly 427 resolved as of Tuesday morning (Proulx, 2018). Response efforts included:

- 2,500 sandbags laid out by Strathcona County;
- 650 tons of sand used for home protection;
- 450 feet of rapid deploy water worms, plus 26 active pumps; and
- 36 daytime TAS staff working on solutions and mitigation, and 18 nighttime workers

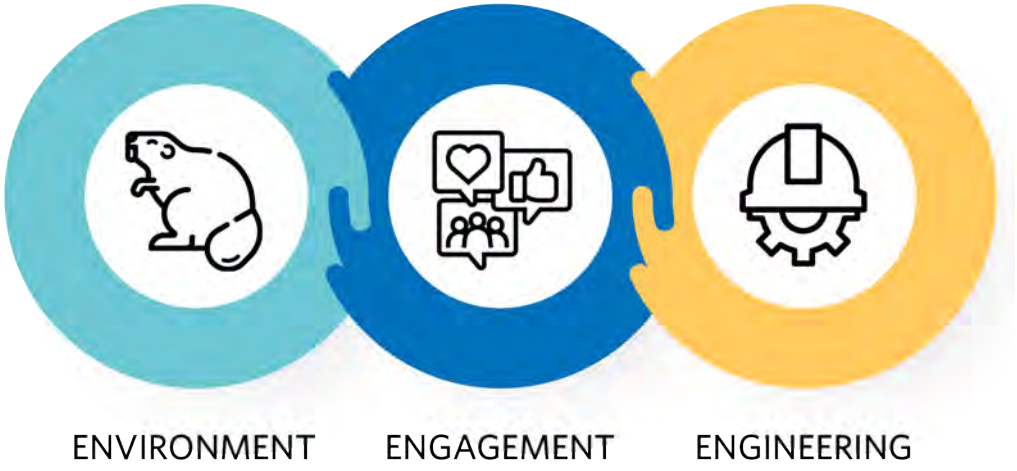
> **"...research is showing that investments in adaptation and risk mitigation measures can help ensure Canadian communities are resilient to threats caused by a changing climate, including risks to our public infrastructure. Some studies have shown a return on investment around 6:1, meaning that for every dollar invested in mitigation measures, $6 is saved in future damages."**
>
> - *Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level, Federation of Canadian Municipalities & Insurance Bureau of Canada (2020).*

1.2 PROJECT APPROACH AND OBJECTIVES

The Astotin Creek Resiliency Study has four main objectives:

- Advance flood, drought, and water quality resiliency in priority areas within the Astotin Creek watershed to enhance the community and improve the environment;
- Restore and enhance ecological connectivity, function, and water quality in critical areas of the Astotin Creek watershed;
- Increase knowledge, awareness, and participation by industrial landowners, private landowners, agricultural producers, and citizens in activities that restore and sustain the function of the Astotin Creek watershed; and
- Enhance community capacity to restore and maintain critical features of the Astotin Creek watershed for future generations.

Resilience planning requires an interdisciplinary and cooperative approach that assesses the watershed from an environmental and engineering perspective. To be effective, resilience initiatives require the support of all stakeholders, and a good understanding of the opportunities and constraints for management. To reflect this interdisciplinary and holistic approach, the Astotin Creek Resiliency Study has been guided by "three E's": environment, engagement, and engineering. This study established an understanding of the watershed though a combination of environmental and engineering assessments, and stakeholder engagement as described below:



- The State of the Watershed includes the findings from a series of environmental assessments to understand the current ecological condition of the watershed. This includes soil, vegetation, wildlife, and aquatic ecosystem assessments. Findings from these studies provide information on biodiversity and habitat condition of terrestrial and aquatic ecosystems in the watershed.

- The State of the Watershed and Drainage Master Plan include findings from engineering analysis, which describe the historical and current hydrological conditions of the creek. This includes creek flood risk, past trends, and anticipated future conditions in light of climate change projections.

- The Drainage Master Plan investigated stormwater management guidelines and infrastructure requirements to manage current and potential future levels of development.

- A stakeholder, public, and Indigenous engagement program sought input on existing conditions, issues, challenges, and opportunities within the watershed. The engagement program also solicited feedback on recommended actions from the public, Indigenous groups, and other stakeholders. Details on the engagement program are included in the What We Heard and What We Did Engagement Summary.

The recommendations in this Resiliency Action Plan respond to the findings of the **environmental** and **engineering** assessments, as well as input shared by the community during **engagement** sessions and public surveys.

To meet the objectives of the Astotin Creek Resiliency Study, opportunities for nature-based solutions have been identified wherever possible. Nature-based solutions are "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUNC, 2019). Nature-based solutions consider the value of ecological goods and services (EGS) currently provided by Astotin Creek and seek to enhance these benefits.

Nature-based solutions not only provide co-benefits to human well-being and biodiversity, but also typically present a low-carbon alternative to traditional engineering options. Seeking to implement low-carbon solutions for flood and drought mitigation is important, as climate change is projected to exacerbate current flood and drought conditions in the future. Since nature-based solutions can reduce greenhouse gas emissions, these types of solutions help to mitigate climate change while simultaneously supporting climate adaptation.

Figure 1-2 Ecological Resiliency and Benefits through Nature-based Solutions (UCN, 2019)

STATE OF THE WATERSHED

2

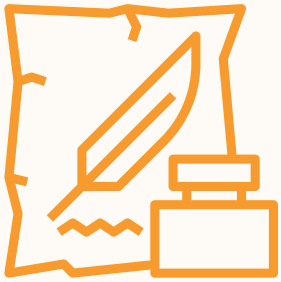
The following sections **outline key findings and considerations** from the ecological and engineering assessments completed as a part of the State of the Watershed and Drainage Master Plan. These assessments included a review of relevant policies for land-use and development, ecological assessments (soil, vegetation, wildlife, aquatic ecosystem), watershed and flood analysis, stormwater management, climate change impacts, and historical and cultural resources. Additional details on methodology and detailed results of these assessments are found in the State of the Watershed and the Drainage Master Plan.

2.1 LAND-USE AND DEVELOPMENT

The Astotin Creek watershed includes a mix of developed and natural environments, including federal and provincial protected areas. Three assessment reaches were identified within the Astotin Creek watershed for this study (Upper, Middle, and Lower Assessment Reaches), in addition to the headwaters in Elk Island National Park. The assessment reaches differ considerably in their level of development, ecological and hydrological condition, and management concerns. (Figure 2-1)

Strathcona County has developed a Municipal Development Plan (MDP) and associated Land Use Bylaw (LUB) to manage land development. The MDP outlines a broad development vision across the County, with policy areas outlining permitted types and densities of development. The three MDP policy areas (Beaver Hills Policy Area, Agricultural Large Holdings Policy Area, Heartland Policy Area) within the Astotin Creek watershed, roughly match the three assessment reaches (Figure 2-1).

The LUB provides more specific guidance for future development. Land use districts mapped within the County designate specific land uses, and the bylaw outlines permitted density, setbacks, access, and building specifications. It is important to note that past development allowed within each area has also created expectations of 'status quo' development approaches. This plan must engage affected landowners by explaining both the rationale for adaptive changes to development approach and anticipated benefits.



Each section of the watershed has unique character and historical patterns of land use to be considered through the Resiliency Action Plan. Recommended actions include notes on applicability to specific land-uses and/or watershed assessment reaches. For example, as there have been considerable impacts from development in the Middle Assessment Reach, certain actions target this reach to improve resilience.

Upper Assessment Reach (Rural residential)

The upper assessment reach includes forested lands with rural residential and some agricultural land use (e.g., grazing). Development has been low-density, and upland habitats have experienced little disturbance or clearing.

The Upper Assessment Reach lies within the **Beaver Hills Policy Area**, created to conserve natural areas adjacent Elk Island National Park to buffer the park from more intensive land use, as part of the Beaver Hills Biosphere. Agricultural activities and low-density development can occur, including rural residential areas.

Headwaters (Natural area)

The Astotin headwaters lie within Elk Island National Park, a large federal protected

area with abundant natural habitat, biodiversity, and a Core Area of the Beaver Hills Biosphere. The Park and Biosphere both play an important role in sustaining the ecological function and benefit of the Upper Astotin Watershed, and through the creek's hydrogeological and habitat connections, its downstream reaches as well.

Middle Assessment Reach (Agricultural)

Land in the middle assessment reach has been extensively cleared for agricultural crop and pasture use. Native habitat has been retained where development was not practical, or where landowners have chosen not to clear the land. Small patches of forest remain in some upland locations and along the creek where it provides vegetated buffers of variable width along the creek edge. Wetlands have been influenced by agricultural practices (e.g., seasonal cultivation) or draining, although there are some larger wetlands, including a large reservoir (the Josephburg Reservoir), created by a weir on Astotin Creek.

The Middle Assessment Reach lies within the **Agriculture Large Holdings Policy Area**, created to help maintain the long-standing, larger scale farming operations in this area, and limit potential subdivision. Land use is intended to remain focused on agriculture.

Lower Assessment Reach (Industrial Heartland)

The lower assessment reach is largely naturally vegetated, with extensive forests and wetlands that extend beyond the watershed. Two provincial Natural Areas lie within this part of the watershed. The Lower Assessment Reach also lies within the Industrial Heartland, an area designated by the County for large petrochemical industrial developments. Petrochemical sites and facilities have been long established within this area, with supporting railway and road networks. The Lower Assessment Reach lies within the **Heartland Policy Area**. It was created to focus petrochemical industry development in an area with access to road, rail, and pipeline infrastructure. Although some agricultural land remains in the area, permitted future development includes commercial land use and new industrial projects.

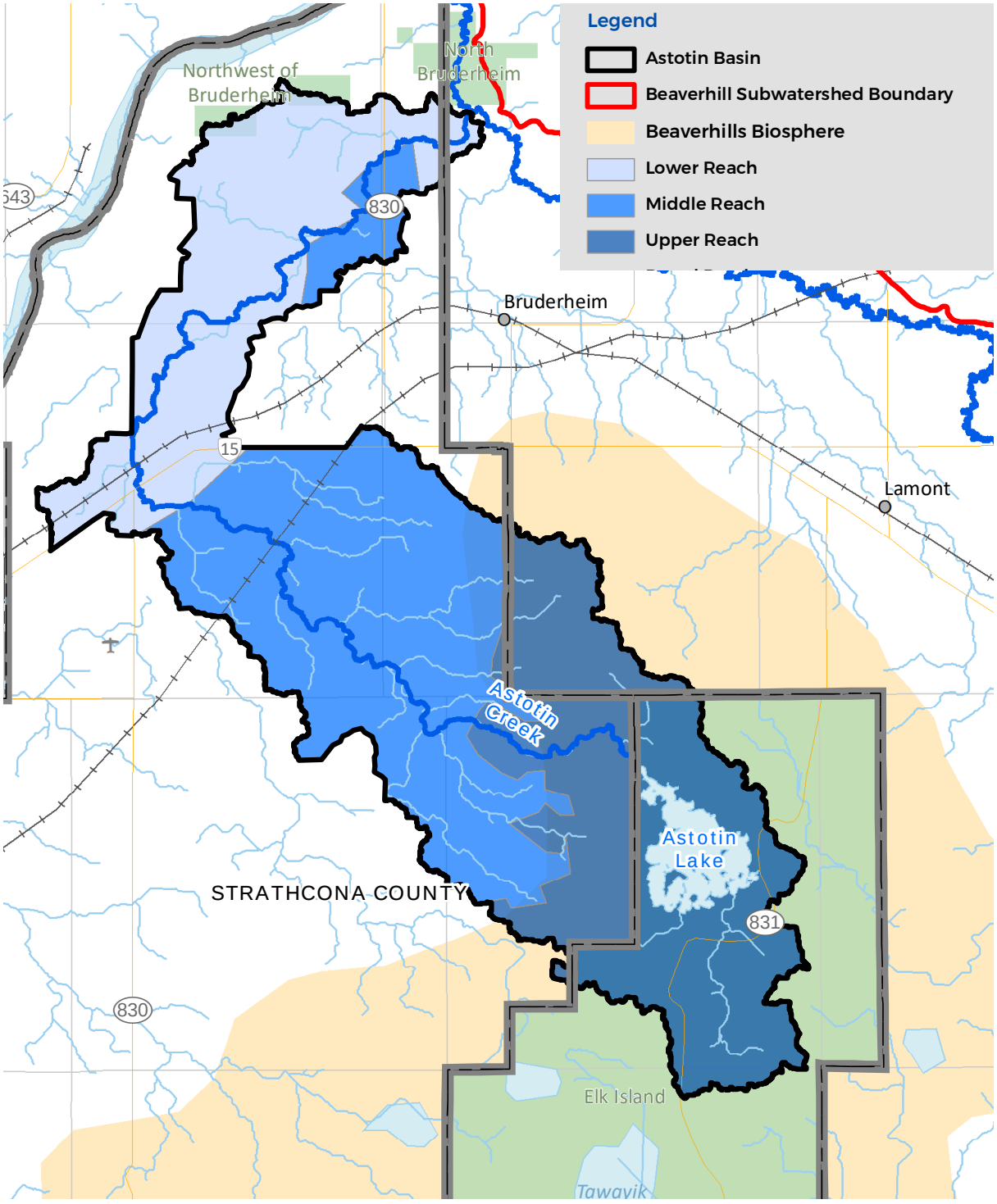


Figure 2-1 Astotin Watershed - Assessment Reaches

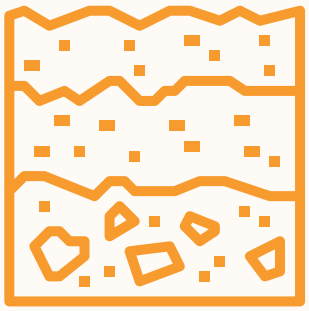
2.2 EXISTING WATERSHED HEALTH AND BIOPHYSICAL CONTEXT

2.2.1 SOILS

The soil characteristics of each part of the Astotin Creek watershed have supported development of both its natural and human landscape. In order to understand soil characteristics throughout the watershed, previous soil mapping and studies were reviewed. The outcome of the soil assessment provided information on the types of soils, soil texture, and the resulting agricultural capability of the soils found throughout the watershed.

Key Findings:

- The **Upper Assessment Reach** has soils and terrain less suitable for agricultural use. Soils include a mixture of poorly drained soils, mainly of medium-texture (clay, clay-loam), developed on knob and kettle terrain of varied relief (Alberta Agriculture and Forestry, 2020).
- Soils in the **Middle Assessment Reach** have high agricultural capability. Terrain is undulating, with low relief and good soil texture and drainage, amenable for cereal agriculture.
- The soils of the **Lower Assessment Reach** area are varied, with a mixture of terrain and soils of higher agricultural suitability and unique terrain associated with sandy soils.
- Soil texture provides a good indication of erosion risk. Coarse to fine sandy and fine silty soils are highly erodible to wind and water erosion, while medium textured clays are less so. Soil mapping shows medium texture soils across much of the Astotin Creek watershed, with areas of fine textured soils adjacent to Elk Island National Park, and across most of the Industrial Heartland area within the Astotin Creek watershed. Coarse textured (sandy) soils extend from Fort Saskatchewan to the County boundary, along the northern edge of the Astotin Creek watershed. Small pockets of sandy soils also occur throughout the watershed, as well as localized deposits along the creek and its tributaries.



Soil characteristics provide insight to areas of higher erosion risk, which in turn can contribute to potential for sediment release to aquatic habitats. Erosion and sediment control is addressed in the Resiliency Action Plan. Soil characteristics also indicate where ecological restoration may be challenging (e.g., sandy soils) and will need to be considered when implementing actions related to ecological restoration.

2.2.2 VEGETATION

The three assessment reaches within the Astotin Creek watershed each support different vegetation communities, including native and non-native/agricultural communities. The vegetation assessment aimed to describe these communities in terms of the dominant species found in each plant community, presence of species of management concern, and types of wetlands. The biodiversity of each area was also characterized using both field survey data of species observed in different habitat types, and iNaturalist citizen science information.

Key Findings:

- Astotin Creek ranges from 5 m to 15 m wide across its channel and lies within a shallow valley with varied levels of natural and human influence on riparian habitat. The riparian buffer zone, which supports various ecological functions (e.g., water quality protection, ecological connectivity), is wider and more contiguous in the Upper and Lower Assessment Reaches. The Middle Assessment Reach has long gaps in both the 30 m and 100 m buffer zone, which has been cleared for agricultural and other human use.

- The **Upper Assessment Reach** consists of large, well connected natural habitats (riparian and uplands) with some rural, residential, and agricultural development. A few agricultural fields and pastures are present within the Upper Assessment Reach, but generally this reach is relatively undeveloped with large tracks of deciduous forest. Occasional conifer and mixedwood-dominated stands are interspersed within the deciduous stands. Large, isolated wetlands and wetland complexes are also present within the Upper Assessment Reach.

- The **Middle Assessment Reach** is dominated by agricultural development with limited native vegetation and low ecological connectivity. Cropland extends up to the riparian fringe of the creek in a large portion of the Middle Assessment Reach, which limits the native vegetation present within the riparian zone. Several small woodlands and wetlands were scattered throughout the reach. The deciduous stands were relatively small and isolated and were heavily influenced by clearing and agricultural activities in the area.

- The **Lower Assessment Reach** has some larger patches of natural habitats with moderate connectivity interspersed within cleared/industrial developed lands. This Reach is located within the northern portion of the Astotin Creek watershed where vegetation is generally characterized by jack pine mixedwood forests on sandy soils with willow-sedge wetland complexes (Spencer, 2005). Burnt areas from past fires were noted north of Range Road 560 and Astotin Creek during the field assessment. Pastures in this reach have been seeded with common agronomic species.

- One rare plant, long-leaved bluets (Houstonia longifolia), was identified at eleven locations in the Upper Assessment Reach. Observed populations in these locations ranged from 1 to over 200 individuals.

- Wetland mapping for the area found marsh, swamp, and open-water wetland classes across the Astotin Creek watershed area. Marsh wetlands were the most dominant wetland class across the area, with more areal extent in the Middle and Lower Assessment Reaches. Swamps were also found across the watershed but were more extensive in the Lower Assessment Reach. Some of these swamps may be coniferous swamp, or potentially peatlands. Shallow open water ponds comprised a larger area in the Lower Assessment Reach, then the Upper Assessment Reach.

A healthy riparian buffer enhances water quality, increases flood and drought resilience, and supports other ecological functions such as regional travel by wildlife and propagation of plant species. Similarly, wetlands provide multiple benefits including flood and drought resilience. Restoration and conservation of riparian areas and wetlands have been included as actions.

2.2.3 WILDLIFE

The Astotin Creek watershed lies between two areas of regionally important wildlife habitat: The Beaver Hills Moraine, and the North Saskatchewan River valley. Riparian buffers provide valuable habitat for wildlife and are critical for supporting biodiversity. Habitat along the creek and its tributaries can support movement by large mammals, such as deer and moose, as well as sustaining a variety of medium and smaller species including amphibians, mice, breeding birds, waterfowl, hawks, owls, and even carnivores like weasels and coyotes.

Semi-aquatic mammals are also common in creek and wetland habitat areas in the watershed. This includes beavers, whose dam-building can create flooding concerns, but also help sustain vegetation, wildlife and even soil moisture conditions. An understanding of ecologically important habitats and species diversity in the Astotin Creek watershed is essential to sustaining its resiliency.

The wildlife assessment included a review of previous studies to build an understanding of habitat areas, trends in habitat condition, and wildlife known to use the watershed. There was a field program to inventory wildlife in the watershed. The field program included amphibian surveys, breeding bird surveys, and remote camera surveys focused on small aquatic mammals and large mammals. An eDNA assessment was also completed to identify the presence of

four riparian carnivores based on testing at wildlife camera sites. A citizen science initiative supported the wildlife assessment which allowed citizens to share wildlife observations via the iNaturalist and NatureLynx apps.

Key Findings:

- Citizen scientist findings (using the iNaturalist nature app) returned over 3300 observations of 231 different species within the original Astotin Creek watershed area including 4 amphibian, 5 arthropod, 89 bird, 116 insect, and 17 mammal species.
- Most species observations were in the **Upper Assessment Reach**. Since the Upper Assessment Reach overlaps with Elk Island National Park, higher species observations may be linked to the rich biodiversity in the park as well as more active citizen scientists in the park area.

Actively maintaining vegetative diversity will help support diverse wildlife populations. This begins with restoring forest connectivity and riparian vegetation where land use activities have extended to the creek edge.

Management strategies can also be used to support wildlife habitat management. This includes evaluating the current protected areas within the Astotin Creek watershed, managing agricultural and industrial land use through County collaboration with private landowners, and restricting incompatible land use that leads to environmental degradation of sensitive areas.

- Results from the breeding bird, amphibian, and remote camera surveys as well as incidental observations collected during the field program provided an indication of species richness in each area of the watershed. **The Upper Assessment Reach** and **Lower Assessment Reach** were comparable at 40 species and 43 species, respectively. The **Middle Assessment Reach** had slightly lower species richness at 37 species.

- The eDNA results identified American mink at all three camera survey sites, and Northern bog lemming at the Upper and Lower Assessment Reach camera sites. American water shrew had relatively strong analysis signals at the Upper Assessment Reach site, although results for this species should be interpreted cautiously. River otter were not detected at any of the three sites.

2.2.4 FISH AND AQUATIC HABITAT

Astotin Creek and its tributaries have the potential to sustain various aquatic species. The creek and riparian wetland areas can support water birds, semi-aquatic mammals, and the aquatic invertebrate populations that, in turn, sustain them. The creek and tributaries receive waters from overland run-off, and thus can be affected by potential pollutants from human and natural sources. As a result, water quality is a key determinant of habitat quality, in addition to physical characteristics of the creek and adjacent riparian habitat. A fish habitat assessment was completed for Astotin Creek from the Astotin Creek headwaters to the downstream boundary of Strathcona County by a Qualified Aquatic Environmental Specialist, where land access was permitted. Surface water samples were also collected at five sampling points to characterize water quality relative to federal and provincial standards.

Key Findings:

- A total of six fish species have been historically documented within Astotin Creek. Most are small minnow species that are tolerant of low oxygen levels (particularly stickleback) and able to survive in shallower waters (Nelson and Paetz, 1992).

- Assessed aquatic habitat was of moderate quality for fish spawning and rearing. Habitat was assessed as moderate to good quality for migration, although it was noted that man-made weirs and perched culverts, as well

as beaver dams, may be a physical barrier for fish migration. Habitat was assessed as poor to moderate for overwintering due to the shallow depth of Astotin Creek.

- Beaver activity was evident throughout the sections of Astotin Creek accessed for fish habitat assessment. A total of 17 active dams were identified in the **Upper Assessment Reach**, 14 in the **Middle Assessment Reach**, and 6 in the **Lower Assessment Reach**.

- Water quality exceedances noted in the field samples included:

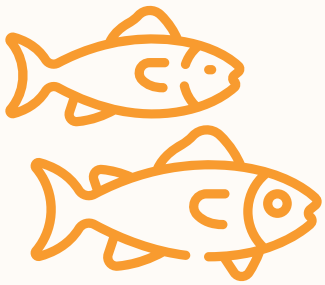
    - Fluoride exceeded the Protection for Aquatic Life (PFAL) guideline at all sampled sites but was below the criteria for agricultural land use. It is likely due to background soil conditions.

    - Total dissolved solids were just above agricultural criteria levels at one **Lower Assessment Reach** location, in a large, ponded area created by beaver damming activities.

    - E. coli was above criteria for agricultural use at two locations: slight exceedance downstream of a small subdivision area in the **Upper Assessment Reach** and double the criteria level at a site in the **Lower Assessment Reach**. This was within pasture lands leased for cattle grazing, but not currently stocked with cattle.

    - Manganese was above both the PFAL and Agriculture criteria at three locations: at the Elk Island boundary, one location in the **Middle Assessment Reach**, and in the **Lower Assessment Reach** at the downstream County boundary. Exceedances are likely linked to background conditions.

    - Slight exceedances of trace metals, including arsenic, cobalt, manganese, iron, mercury, and selenium were detected across many of the sites, but again, likely linked to background conditions rather than contamination concerns.



Aquatic health, and resiliency is determined in large part by the condition of the lands adjacent to water. An effective riparian zone is influenced by many factors including the size, topography, and geology of the watershed, which in turn affect the rate of runoff and the type of contaminants that could be introduced (ESRD, 2012). For fish bearing watercourses, a minimum 30 m riparian buffer should be maintained to help protect water quality.

2.3 WATERSHED AND FLOOD ANALYSIS

The Astotin Creek watershed lies in an area with varied terrain. This terrain has supported the development of Astotin Creek and its tributary streams, as well as wetlands and larger waterbodies, including Astotin Lake, at the creek headwaters in Elk Island National Park. The resulting hydrological network carries flows from across the watershed to the North Saskatchewan River - a relatively short direct distance but a much longer and convoluted path along the creek. The section of Astotin Creek within the County's boundaries is about 50 km long, not including its tributaries. Groundwater connections in this area are also interesting, with extensive recharge zones. Water management in this area thus must consider both surface flows and connections to underlying aquifers.

Astotin Creek flows northwest from Elk Island National Park towards Highway 15, after which the creek turns toward the northeast and eventually discharges into Beaverhill Creek, about 5 km upstream of its junction with the North Saskatchewan River. The Astotin Creek watershed at the junction with Beaverhill

Creek was delineated using topographic data, which identified a total drainage area of 184 km^2. Field survey of the creek mainstem (where access allowed) assessed bridge, culvert, and channel conditions.

The recent flooding events experienced within the Astotin Creek watershed were generated by meteorological events that overwhelmed Astotin Creek's flow capacity. A good understanding of the local hydrology is therefore required to understand the flood dynamic of the region. To build this understanding, a hydrological analysis was completed that included review of regional climate and streamflow data[1] to understand the driving mechanism behind the flood events experienced in the region. A flood frequency analysis, run-off model, and hydraulic modeling were also completed to better understand flood risk in the watershed.

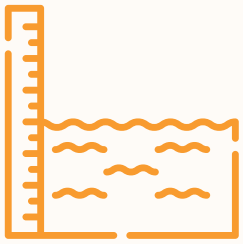
Key Findings:

- Flood inundation maps were produced for the 100 year, 50 year, and 20 year flood events (included in the Drainage Master Plan, Appendix D). This modeling identified flood-sensitive areas along the study reach. Vulnerable areas generally consisted of overtopped roads, flooded agricultural lands, and residential lands. Flooding in these areas could generally be attributed to low-elevation floodplains and undersized crossings. The model results also suggest that part of Astotin Creek flow would leave its watershed during large flood events, spilling over into the adjacent Ross Creek watershed southwest of Highway 15. However, flood propagations outside of Astotin Creek watershed were not modeled and the entire flood flow was conveyed through Astotin Creek in the hydraulic model, leading to more conservative (wider) flood extents downstream of these outflow locations.

- The floodway for the 100-year flood was delineated where possible, and flood hazard maps were produced (included in the Drainage Master Plan, Appendix H). The simulated water velocities were also reviewed to identify reaches that are more vulnerable to erosion. Higher velocities can be expected in steeper and deeper creek sections, which are mostly located in the Middle Assessment Reach of the creek.

[1] Streamflow data was not available for Astotin Creek. The Pointe-Aux-Pins Creek station is located about 20 km southwest of the Astotin Creek watershed and has similar characteristics to the Astotin Creek watershed, such as size, land use, and topography. Therefore, the Pointe-Aux Pins station is considered the most representative of Astotin Creek drainage characteristics and was used as a proxy to derive the main hydrological characteristics of Astotin Creek.

- A climate change analysis was completed to create inundation maps for a 100-year flood that incorporated a 40% increase in flow due to projected climate change impacts for a far-future high global emissions scenario[2] (included in the Drainage Master Plan, Appendix I).



Flood inundation maps and flood hazard maps have identified key areas to target in the Resiliency Action Plan. These areas are noted as a part of the recommended actions. Due to the variation within the watershed, there is no one-size-fits-all solution for resilience. Actions will include nature-based solutions, engineering solutions, and management actions, which can be used in combination throughout the watershed.

[2] RCP 8.5 was used in the climate change analysis. Far-future refers to a 2080 time horizon.

2.4 STORMWATER MANAGEMENT

The existing drainage system in the watershed consists primarily of drainage ways, roadside ditches, culvert crossings, privately owned and operated wet pond stormwater management facilities (SWMF), wetlands, dugouts, and depressions. The Drainage Master Plan completed as a part of this study identified issues and constraints with the current drainage system, developed a drainage servicing concept for the watershed, and identified stormwater design criteria for future development.

Key Findings:

- The number of culvert crossings (excluding private access road crossings) in the watershed is estimated to be over 100. Survey data indicated that culvert crossing pipe diameters ranged between 400 mm and 5,000 mm, including those along the creek channel. Outside of the creek channel, there are two bridge-size structures (culvert diameters greater than 1500 mm).

- Drainage patterns throughout much of the watershed generally appear to follow pre-development or natural patterns, except where modified due to the development of the transportation network. Alterations to the natural drainage patterns consist mainly of the placement of hydraulic structures across roadways (i.e., bridges or culverts) as well as straightening or realignment of portions of the creek itself and drainageways along roads.

- Drainageways are located mostly within private property, which may impede proper maintenance work and protection from alterations. Private crossings are present in some existing drainageways within private property.

- Stormwater from the agricultural lands runs off into drainageways of the creek. Stormwater from the industrial development sites is collected in privately owned and operated SWMFs for quantity control and quality enhancement. Some of the existing industrial developments retain stormwater that may not be returned to the creek. Other industrial developments release stormwater at a controlled rate into the creek only after water quality testing has been completed and approved for discharge to the creek's system. Most SWMFs include either control structures, valves, or pump stations designed to release stormwater at a maximum unit peak historical discharge rate of 4.1 L/s/ha.

- Future developments in the watershed are expected to be primarily focused on the Alberta Industrial Heartland (AIH) and comprise industrial-type developments. Based on the analysis completed, it is recommended the County adopt a 1.9 l/s/ha unit area release rate (UARR) for the watershed. While this value is lower than the current UARR (4.1 l/s/ha), it is not expected to restrict future developments. Design criteria for developments in the watershed are recommended to follow the municipal and provincial guidelines and regulations.

- A proposed drainage servicing plan was provided for the AIH lands in the watershed. The proposed system comprises a network of overland conveyance channels (i.e., ditches) and private SWMFs. Applicable stormwater best management practices for the watershed were also provided. Challenges for current and future drainage servicing in the watershed were identified and must be mitigated using best management practices.

Understanding and addressing both current and future drainage needs are important factors for flood resilience. Recommendations seek to address drainage issues identified through a variety of actions including nature-based solutions, engineering solutions, and management practices. Collaboration with landowners is crucial for maintaining and improving the drainage system in the watershed.

2.5 Climate Change in the Watershed

Increased greenhouse gas emissions are causing a long-term rise in global temperatures, which is causing changes in weather around the world. Effects of climate change are particularly notable in Canada, where warming is approximately twice the global average. This is caused by several feedback cycles such as the melting of snow and ice in high latitudes and land warming faster than oceans (Bush and Lemmen, 2019). In coming years, communities across the country will face increasing impacts that affect people, buildings and infrastructure, natural systems, and the economy.

To understand how climate change may impact flood and drought risk in the Astotin Creek watershed, an exposure assessment was completed to identify climate variables that may impact Astotin Creek. Projected changes in climate variables that relate directly to flooding (e.g., extreme precipitation) were assessed as well as those that have a more indirect influence (e.g., wildfire). Climate variables related to drought (e.g., precipitation and drought index) were also considered.

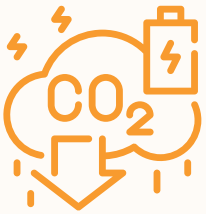
To enhance the resilience of the Astotin Creek watershed to climate change impacts, it is important to account for future climate projections in the development of flood resilience measures. For all recommended actions, including infrastructure solutions, nature-based solutions, and land-use decisions, changing climate conditions should be considered. For example, when replacing culverts, they should be sized with future precipitation projections in mind, so that they are not overwhelmed as rainfall increases throughout the century. Resulting solutions will reduce risk both in the near-term and further into the future.

Key Findings:

- An increase in mean annual precipitation is projected, which can contribute to increased creek flows and may increase the likelihood of other events causing flooding (e.g., freshet, extreme precipitation).
- Summer precipitation and maximum 5-day precipitation are projected to increase in the future. This may contribute to more frequent and severe summer flood events.
- Spring flood due to freshet is impacted by the size of snowpack and the speed at which it melts. Multiple climate parameters influence snowpack and snowmelt, and some counteracting climate trends make this hazard difficult to project. Winter and spring precipitation are projected to increase. However, snow formation could be inhibited by increases in mean winter temperature, and so snowpack size is projected to decrease over time. Mean temperatures for the spring months are projected to increase, which could result in more extreme freshet events. Spring precipitation is also expected to increase, which could also intensify freshet episodes.
- Mean annual temperature, maximum summer temperature, and minimum winter temperature are all projected to increase. The region is projected to experience more than double the number of annual heat waves[3] in the long term. The length of heat waves is also expected to increase.
- While Astotin Creek has not historically been exposed to large forest fires, an increase in summer temperatures and dry, windy days could increase future occurrences. Land cover changes caused by more frequent wildfires could increase the potential for flooding.
- The number of dry days where rainfall is less than 1 mm is projected to remain stable over the century. However, the Palmer Drought Severity Index (PDSI) shows an increase in relative dryness over time. Droughts, while affecting water availability, can also have implications for the water quality in water bodies such as Astotin Creek. Drought can make the area more susceptible to intense flooding if the ground becomes hard, preventing infiltration of intense precipitation and increasing surface run off and potential for erosion and pollutant release to the creek.
- Other climate variables have the potential to impact the water quality of Astotin Creek. For example, rising water temperatures may impact habitats

[3] Heat waves are a period of three-days or more when temperatures exceed 30˚C.

and biodiversity through mechanisms such as the growth of harmful algal blooms. Additionally, water quality may be impacted by increased runoff during intense storms, increased sediment in runoff following a wildfire event, or increased runoff due to drought conditions.



Low-carbon resilience approaches will be prioritized where possible. A variety of actions will be required to reduce the risk of flooding from Astotin Creek in the face of changing climate conditions. However, it is important to be aware that some measures have the potential to increase greenhouse gas emissions that are driving climate change (e.g., concrete-intensive solutions), exacerbating flood risk over time. For this reason, nature-based solutions will be emphasized to further climate change mitigation and adaptation goals at the same time.

2.6 Historical and Indigenous Cultural Resources

The Astotin Creek watershed and surrounding region have seen a dramatic shift in land use over the past two centuries. This shift has brought about competing interests in the land, from Indigenous land users to a growing settler population, and later to industrial and agricultural development pressures. Balancing the needs of the people of Strathcona County, the environment, and industry continues to be a challenge today.

First Nations peoples have hunted, trapped, fished, conducted ceremony, and lived in the Astotin Creek watershed and surrounding area for thousands of years. The area's rich resources, including waterbodies, forests, open prairies, and hills provided food, shelter, and materials for ceremony (Matters and Hood 2016). The animals and plants that still make the ecosystem what it is today, such as elk, deer, moose, waterfowl, berries, and wild vegetables, provided food for the many groups that passed through the region.

The name of the moraine lands along the southern border of the watershed, amiskwaciy (Cree), or Beaver Hills, recognized the abundance of this fur-bearing mammal and its importance for Indigenous livelihood. The water systems in the watershed provided fresh drinking water, and the forests provided wood for shelter, fire, and poles used for ceremony (Matters and Hood 2016). While the landscape has changed, as has access to the land for hunting, gathering, and cultural use, Indigenous people still hold strong ties to the land today (Matters and Hood 2016), and an understanding of its ecology based in generations of past use. Those perspectives can help develop a better understanding of landscape change and resilience (e.g., gained from past periods of climate change).

The inclusion of Indigenous knowledge and perspectives in the implementation of the Resiliency Action Plan will help to enhance the narrative about the Astotin Creek watershed and surrounding area and can help to better understand land use and conservation opportunities in the region.

While many people who now live in the Astotin Creek watershed have a strong understanding of the complexities of the landscape and a strong connection to it, Indigenous land users and knowledge holders have a unique perspective on the region, and a deep connection to the land and water, developed over thousands of years. The meaningful inclusion of their voices will contribute to the long-term resiliency of the watershed through broadened perspectives on ecological health.

COMMUNITY AND INDIGENOUS ENGAGEMENT

3

3.1 Public and Indigenous Engagement Program

Strathcona County is committed to meaningful engagement with its residents, businesses, and neighbours. Accordingly, for this project, both public and Indigenous engagement were used to gain insights on the experiences, concerns, and management ideas for the watershed. COVID restrictions did not allow for in-person events, but outreach was possible through various existing engagement tools established by the County's Communications Team, including its SCOOP survey and eNewsletters to subscribing residents. Mail-outs with contact information and website links were sent to residents, and in August 2021, the County hosted a virtual Open House to provide early results of the environmental and engineering assessments. In November 2021, the County hosted a second set of virtual Open Houses to share information about the Resiliency Action Plan. A survey was also sent out to solicit feedback on the initial study findings, and later on the Resiliency Action Plan.

In October 2021, the County invited 31 Indigenous communities and organizations to discuss the project via one-on-one virtual meetings. Five Indigenous groups requested a meeting, during which the project was introduced and a path forward for communication was established if desired by the Indigenous group. The County is continuing these conversations with the goal of knowledge sharing and furthering relationships with its Indigenous neighbours. All participating Indigenous groups indicated they would like updates about the progress of the Resiliency Action Plan and an invitation to participate in future activities pertaining to Astotin Creek, particularly outreach or education activities and restoration activities. Overall, participating groups wanted to build stronger relationships with the County and develop pathways for ongoing communications. This feedback is represented in Vision 6, Action 4: Indigenous Relations.

3.2 What We Heard

Resulting from the first outreach initiatives in summer 2021, residents and industry identified several key areas of interest or concern: flooding, development, and the role of beavers in the ecosystem and County. These comments were used to inform the Vision Statements in the Resiliency Action Plan and are listed below.

- **Flooding:** Flooding was identified as an ongoing issue, with flood frequency seen to be increasing. Flooding was noted to be a natural process. Stakeholders noted that flooding has been seen to impact accessibility, impact agricultural lands, and noted challenges with managing flood waters.

- **Development:** Development (industrial, residential, and agricultural) has been seen to impact the creek. The condition of dams, weirs, and culverts was noted to be of concern. Concerns were also raised about the width and condition of riparian areas

- **Beavers:** Beavers were noted to be a part of nature within the watershed. Both positive and negative impacts were noted in relation to beavers. Concerns were raised related to beaver impacts and control (e.g., impacts to cattle) as well as concerns related to flooding. Positive impacts were related to water quality for cattle as for well water.

Following the development of draft Vision Statements and examples of supporting actions, another series of public engagement activities (mailouts, online survey, and virtual public engagement sessions) provided residents and stakeholders with the opportunity to provide their insight into the direction of the plan. Again, three key themes emerged from the comments received: development and infrastructure, flooding, and costs and responsibilities. These themes varied slightly from those received in the first set of engagement activities and are summarized below.

Development and infrastructure (increased and decreased development):

- Development should not be restricted beyond current bylaws (increased development)

- The Creek should be returned to a natural state and development should be restricted (decreased development)

- Connectivity of riparian areas and water flow should be maintained from the Creek source (Elk Island National Park) to the North Saskatchewan (decreased development)

Flooding:

- Flooding impacts landowners negatively and needs to be addressed
- Debris should be removed from the Creek to increase flow. Programs should include ongoing debris management.
- Engineered solutions (culvert replacement, diverting, channeling) are effective ways of dealing with flooding
- A natural creek and riparian area will flood less

Costs and responsibilities:

- Costs for resiliency actions should not be borne by landowners
- Collaboration with adjacent municipalities and parks is required
- Compensation and land buy-back programs should be cautiously explored

Overall, participants found support for the proposed Vision Statements, though participants placed higher value on different Vision Statements.

RECOMMENDED ACTIONS

4

Findings from the State of the Watershed, Drainage Master Plan, and what we heard during the stakeholder engagement sessions contributed to a series of **recommended actions to increase resilience in Astotin Creek**.

The full set of recommended actions has been developed as a **"tool-box" that provides Strathcona County with several different types of actions to address issues** throughout the watershed. This approach considers the diversity of landscapes and land uses that exist throughout the watershed. Some recommendations will apply across the watershed, while others are intended for specific geographic locations and/or only apply to certain land uses.

The applicability of each recommended action is included as a part of the action description.

4.1 Visions for Astotin Creek Resilience

As shown in the figure below, six visions were developed to represent different outcomes that will contribute to resilience in the Astotin Creek watershed.

Figure 4-1 Visions for Astotin Creek Resilience

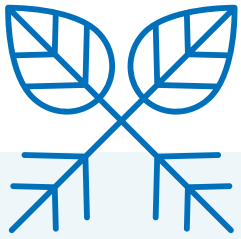
The following table provides a summary of the visions and supporting actions. Sections 4.2 – 4.7 provide additional details on each vision and the associated supporting actions.

Table 4-1 Summary of Recommended Actions

Vision	Vision Statement	Supporting Actions
Vision 1: Healthy Ecosystem	Astotin Creek has a healthy watershed with rich vegetation and aquatic habitat, which supports biodiversity, maintains water quality, and provides flood and drought resilience.	V1.1 Conserve/restore vegetated buffer V1.2 Conserve/restore natural water retention features V1.3 Implement erosion and sediment control measures V1.4 Implement co-existence with wildlife strategies V1.5 Ensure aquatic connectivity V1.6 Prevent livestock from accessing creek

Vision	Vision Statement	Supporting Actions
 **Vision 2: Integrated Watershed Management**	Responsible land management within Astotin Creek watershed reduces flood and drought risk and protects ecosystems.	V2.1 Conserve and restore wetlands V2.2 Develop land buyback and/or compensation programs V2.3 Maintain ecological function in Upper Assessment Reach V2.4 Protect and enhance drainageways
 **Vision 3: Resilient Infrastructure**	Infrastructure in the Astotin Creek watershed is designed to reduce flood risk and enable adaption to climate change.	V3.1 Replace undersized infrastructure V3.2 Elevate roads along with crossing upgrades V3.3 Update the allowable stormwater discharge rate for new developments V3.4 Incorporate flood construction level requirements in the LUB V3.5 Include climate change considerations in infrastructure and development standards/policy
 **Vision 4: Proactive Management**	Strathcona County's programs and operations reduce flood risk in the Astotin Creek watershed.	V4.1 Implement a debris management program V4.2 Expand asset management program V4.3 Proactive creek inspections and monitoring V4.4 Landowner education and partnership for private property clean up
 **Vision 5: Flood and Drought Preparedness**	Strathcona County will invest in response planning to ensure staff and residents can deal with flood and drought events.	V5.1 Develop flood response plan and training V5.2 Develop flood forecast, monitoring, and warning system V5.3 Develop a drought mitigation plan V5.4 Increase public understanding of flood prevention and drought mitigation, property protection and emergency response V5.5 Incentivize property level flood protection V5.6 Investigate availability of flood insurance for landowners
 **Vision 6: Educated, Engaged, and Empowered Public**	Strathcona County residents will have a shared understanding of flood and drought risks and feel empowered to participate in actions to manage risks.	V6.1 Implement public outreach programs V6.2 Implement pilot programs to showcase nature-based solutions V6.3 Implement citizen science initiatives V6.4 Indigenous relations

4.2 Vision 1: Healthy Ecosystem



Healthy Ecosystem Vision Statement:

Astotin Creek has a healthy watershed with rich vegetation and aquatic habitat, which supports biodiversity, maintains water quality, and provides flood and drought resilience

Vision 1 is focused on building a healthy ecosystem in Astotin Creek. This vision recognizes the interconnectedness between the environment and human well-being. Actions supporting this vision include nature-based solutions which enhance water quality and provide flood and drought resilience.

Strathcona County recognizes the connections between a healthy ecosystem and the health and wellbeing of its residents. Strathcona County's MDP and the recently adopted Environmental Framework (2021) promote cooperative efforts to conserve and enhance the quality of air, water, land, and natural systems found in the region. This vision is directly aligned with Strathcona County's environmental objectives.

The following actions have been identified to support the vision of a healthy ecosystem for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V1.1 Conserve and restore vegetated buffer**
- **V1.2 Conserve and restore natural water retention features**
- **V1.3 Implement erosion and sediment control measures**
- **V1.4 Implement co-existence with wildlife strategies**
- **V1.5 Ensure aquatic connectivity**
- **V1.6 Prevent livestock from accessing creek**

V1.1 CONSERVE AND RESTORE VEGETATED BUFFER

Description of Action

The actions required to provide a vegetated buffer along Astotin Creek will vary depending on the current condition and width of the riparian buffer, as well as existing land use/land ownership. The County recognizes the need for cooperative effort with landowners, engaged through access to existing programs and funding, and new County programs. Identifying and targeting priority areas in need of restoration will help protect the watershed as a whole. Working with landowners to maintain riparian buffers will ensure those benefits are sustained. Focus initial restoration efforts on water quality protection, riparian wildlife habitat enhancement, maintenance of habitat connectivity and implementation of a minimum 30 m riparian buffer from top of bank. These recommendations are consistent with provincial guideline documents, such as Stepping Back from the Water - A Beneficial Management Practices Guide For New Development Near Water Bodies in Alberta's Settled Region (ESRD, 2012), which offers a foundation of broader practice to support restoration efforts. The 30 m setback is also consistent with the land use planning process.

Specific actions could include the following steps:

- Re-establish vegetation along Astotin Creek where native vegetation buffers are less than 30 m as a first priority, ideally to a 100 m buffer to protect both water quality and biodiversity (e.g., by aiding wildlife movement).

- Promote existing ecological restoration outreach and funding programs such as the Alternative Land Use Services (ALUS), Cows and Fish, or the Green Acreages (Land Stewardship Centre) Programs to build on existing tools and funding that can help private landowners restore and maintain riparian vegetation buffers.

- Work with landowners to implement alternative land use practices that will maintain native vegetation buffers along wetland and riparian areas (e.g., rotational grazing programs, off-stream watering stations, weed management). These could be offered through County workshops, or in

partnership with existing programs such as ALUS, Cows and Fish or the Land Stewardship Centre.

- Limit removal of intact riparian native vegetation in the Upper and Lower Assessment Reaches to maintain connectivity between Elk Island National Park, the two Natural Areas and the North Saskatchewan River Valley (e.g., through County development policy or bylaws). Focus at a minimum on the creek buffers and consider opportunistic conservation of 'stepping-stone' habitats where extensive, larger habitat patches exist near the creek (e.g., through conservation easements).

- Identify and implement conservation measures required to protect known rare plant populations within the watershed, and particularly where present on County lands (e.g., the long-leaved bluets (*Houstonia longifolia*) identified in a County owned, former sand pit area). These populations can serve as sources for natural propagation, particularly if ecological connectivity is maintained.

Benefits

The riparian area serves multiple purposes for Astotin Creek including bank and shoreline stability, improved water quality, provision of habitat, as well as providing a buffer for flood resilience. Vegetation can anchor soils adjacent to stream, preventing erosion of banks during flood and severe storm events. Vegetation buffers can also filter out sediments that may be carried in overland surface flows into the creek. Such measures are particularly important in sandy areas, which are more susceptible to erosion. Vegetated riparian areas can also buffer drought effects, by reducing evapotranspiration effects. The vegetation, particularly if left ungrazed in early spring (i.e., with rotational grazing), prevents evaporative loss from the underlying soils.

Applicability

This action applies to the entire watershed, but particularly to the Middle Assessment Reach where riparian vegetation has been removed up to the creek edge (both along the mainstem and smaller tributary areas) and riparian intactness was much lower than in the rest of the watershed.

Cost

Restoration costs would mainly address seed and seedling plants, and costs of County outreach support. Similar programs have been used by rural municipalities in the past, providing seedlings to land owners who sign-up with a description of their restoration plans. Costs would be relatively low, depending on uptake. Various funding options can be made available, either through County-wide programs such as the ALUS program, or through site-specific funding offered through organizations such as the Land Stewardship Centre's Green Acreages program. The new federal initiative to reforest lands in partnership with municipalities (2 Billion Trees Program) offers another potential funding source.

The ALUS program relies on local advisory committees formed from interested agricultural producers and landholders, which offers advantages for promotion and support for program delivery, as well as locally relevant advice on restoration methods and funding. Additionally, the County could partner with non-profits such as Cows and Fish or Agroforestry & Woodlot Extension Society (AWES) to support outreach initiatives for management of riparian areas. Their programs are tailored specifically to agricultural landowners and emphasize benefits relevant to sustainable agricultural activities.

"Cows and Fish is non-profit society striving to foster a better understanding of how improvements in grazing and other management of riparian areas can enhance landscape health and productivity, for the benefit of landowners, agricultural producers, communities and others who use and value riparian areas."

"Since its creation in 1992, Cows and Fish has delivered presentations, field days and workshops to over 92,200 people across Alberta and Canada."

— (Cows and Fish, 2021).

V1.2 CONSERVE AND RESTORE NATURAL WATER RETENTION FEATURES

Description of Action

Flood attenuation can be provided by the natural capacity of wetlands and adjacent flood fringe lands to capture and slowly release water back to the creek system. These same features can also provide drought resilience by storing water, particularly if riparian vegetation is left intact. Potential conservation and restoration areas include wetlands and flood fringe zones along the main Astotin channel, but also tributary drainages that comprise the headwaters of the creek. They, and other wetlands throughout the watershed, will hold back flood waters in very wet years, attenuating flood events, but also sustaining soil moisture in the adjacent lands through shallow groundwater flows. In drought years, these areas can sustain soil moisture and open water longer, particularly if vegetation cover is maintained within and immediately adjacent to wetlands and the creek. Riparian vegetation helps to reduce evaporative loss, holding soil moisture longer than cleared lands.

Specific actions to help conserve and restore natural water retention features, including headwater drainage channels and wetlands both adjacent the creek and tributaries, and in the uplands include the following:

- Conserve and enhance wetlands in off-channel (in adjacent uplands) and near channel (within the riparian buffer) habitats to hold water during high precipitation years and dampen flooding intensity. This can include avoiding cultivation through smaller, more temporary wetlands near the creek edge or in the flood fringe zone or maintaining larger permanent wetlands in upland and riparian areas. The County's existing Wetland Conservation Directive generally covers wetland loss and could be expanded to address cultivation and drainage of wetlands in agricultural areas.

- Implement wetland restoration through use of provincial funding associated with the County's Wetland Replacement Program. Working with interested landowners, identify potential restoration sites within the Middle Assessment Reach in particular, where wetland loss has been most dramatic.

- Through existing programs such as Cows and Fish, or the ALUS program, promote alternative land management strategies in agricultural areas to help maintain healthy vegetation cover adjacent to riparian areas. Healthy, dense vegetation cover can help prevent evaporative loss to sustain soil moisture during drier periods; native cover species are also more resistant to drought than most introduced species.

Benefits

Retention of wetlands and flood fringe zones adjacent to the creek channel can provide additional flood storage, and mitigate peak flood flows, as well as enhancing aquatic habitat and species diversity. In drought years, healthy vegetation in these areas can reduce evaporative loss, helping to sustain open water and soil moisture for agricultural and ecological benefits.

Applicability

Wetland conservation in upland and flood fringe areas can be applied throughout the watershed, while restoration efforts should focus on the Middle Assessment Reach, where land clearing has been most extensive. Areas where the riparian buffer has been cleared, or where riparian wetlands have been cultivated in dry years would provide more immediate and tangible demonstration of flood attenuation, and ecological benefits, and could serve as demonstration or pilot project areas. These areas would also have less impact on agricultural operations, and thus better potential uptake by landowners. Restoration and replacement of upland wetlands would have similar effect, and could also be pursued with willing landowners, but the lack of direct connection to the creek obscures the relationship to reduced run-off, and flood flows. To build program support, pilot projects along riparian areas may have more impact.

Cost

Delivery of public awareness programs could be completed in conjunction with partnering organizations, or alternatively through County staff outreach activities. Restoration efforts should focus on the Middle Assessment Reach, both through opportunistic, site-specific wetland restoration efforts (e.g., through delivery of provincial wetland restoration projects, funded by provincial wetland compensation), and through outreach programming to shift land management practices.

ALUS is an agriculturally focused program that promotes sustainable land management, working in cooperation with local landowners and producers. "ALUS partnerships help build vibrant communities by implementing the program through a Partnership Advisory Committee (PAC) made up of local farmers, community stakeholders and other NGOs. This allows each community program to address specific local environmental challenges and work collaboratively towards implementing sustainable solutions. ALUS provides financial and technical support for the implementation of these projects and annual payments to its participants to ensure the ongoing stewardship of each of their ALUS projects" (ALUS, 2021).

V1.3 IMPLEMENT EROSION AND SEDIMENT CONTROL MEASURES

Description of Action

Uncontrolled stream erosion can lead to undesirable bank migration impacting private and public lands. Stream erosion typically occurs at fast-moving water sections where the bank and riverbed are unprotected. Excessive erosion can impact water quality and aquatic species by increasing the water turbidity. The eroded material is transported downstream and deposited in the creek's flatter and slower flow sections, where the sediment transport capacity is reduced. Excessive sedimentation can also have undesirable effects by elevating the creek bed elevation, which increases water levels upstream of these deposition zones. The hydraulic simulation results suggested that the Middle Assessment Reach is more prone to erosion, given the higher water velocities along the steeper creek slopes. However, the prevalence of beaver dams in this section of the creek reduces the water velocities and the bank erosion potential. Several mitigation measures can be implemented to address site-specific erosion problems, such as:

- Bank hardening (riprap)
- Bio-engineering stabilization (wattles, brush mattress, branch packing, live crib wall)
- Floodplain restoration

Bank hardening measures generally consist of placing unerodable materials, such as stones (riprap), along the eroded section of a stream. Riprap can be placed longitudinally along the bank or transversely (spurs bendways) to direct stream flow away from the eroded banks. Bio-engineering stabilization methods use vegetation to restore the bank and improve its erosion potential.

Riparian enhancement and site-specific bank stabilizations will also help address the increased sediment inputs from the lack of a riparian buffer. Consider unique soils in ecological restoration. Sandy areas that occur in pockets across the watershed will have faster water infiltration rates than areas of fine to medium texture. Ecological restoration in these areas will require different planting

mix and methods, including selection of drought resistant species. Selecting revegetation species and planting methods appropriate to local soil drainage, flooding patterns, and moisture conditions (including drought-resistance) will help ensure good vegetation catch and sustainable growth. Native species are often better adapted to regional flood and drought cycles than non-native species and will be a better choice for restoration.

Benefits

Implementation of sediment control measures improves bank and stream stability and limits bank migration, improving water quality. Bio-engineering stabilization methods can also restore floodplain riparian areas and improve habitat diversity. Erosion control measures also reduce sediment transport, limiting excessive sedimentation and potential stream obstruction.

Applicability

Erosion and sediment control measures should be implemented where excessive erosion has been noted (e.g., adjacent undersized culverts or bridges). Regular inspection programs, including the debris clean-up along the creek can help identify candidate sites. Bio-engineering stabilization should be prioritized in sections of the creek where bank migration does not pose a significant risk to landowners and public infrastructure. Bank hardening techniques should be used at high-risk location where roads and infrastructure are located close to the creek. A mix of bioengineering and bank hardening techniques can also be implemented to provide robust and green stabilization upgrades.

Cost:

Cost of erosion and sediment control measures can range from $1000 to $5000 per linear meter depending on the type of control measure.

V1.4 IMPLEMENT CO-EXISTENCE WITH WILDLIFE STRATEGIES

Description of Action

The proximity of Elk Island National Park and the North Saskatchewan River valley at either end of the Astotin Creek watershed helps to sustain watershed and regional biodiversity, which means watershed residents will encounter a greater variety of wildlife than in more developed areas. While some species are appreciated, others, such as beaver and large carnivores, are often considered nuisance or risk species. Others are not typically noticed, yet play significant ecological roles (e.g., pollinators). Collectively, biodiversity provides important ecological and human benefits that are sometimes overlooked, but expensive to replace through engineered solutions. Co-existence strategies can help ensure these species, and their benefits are sustained. Such strategies rely firstly on a shared understanding of benefits, as well as means to minimize negative effects, or in some cases, compensate landowners for adverse impacts.

Learning to Live with Beavers

Beaver have been extirpated in Britain for centuries, and are only now being reintroduced as part of watershed restoration. Often such programs use outreach to build program support, and pro-actively address potential human-beaver conflicts.

Auster et al. (2021) assessed one such program, providing recommendations to reduce conflict and promote co-existence:

- **Proactive engagement or a fast response for potential issues;**
- **Appropriate lines of communication;**
- **Shared decision-making;**
- **Foster a sense of the role of humans in beaver conflicts;**
- **Address need for certainty through proactive planning.**

Co-existence strategies to address the negative impacts, or sustain the benefits of wildlife species include the following:

- Develop public outreach programs to raise awareness of the presence of wildlife and the benefits of co-existence. Species such as beaver and large carnivores that were extirpated from many areas during early settlement have either re-established in this area (e.g., beaver) or are returning due to loss of habitat in other areas (large carnivores). For some landowners, these species may be 'new' relative to memories of earlier generations on the land, and yet they are filling important ecological roles pre-dating settlement of this area. Removal of species well adapted to this landscape, like beaver, will be costly, since recolonization from adjacent habitat will be on-going and long-term. Co-existence will be less expensive and provide other ecological benefits, like sediment capture, water storage and support of higher biodiversity.

- Consider innovative tools to foster co-existence with beavers. Although beaver activities along Astotin Creek are thought to cause flooding and other damage that create human-wildlife conflicts, they can also provide a variety of ecological benefits. Alternative management techniques such as 'beaver deceivers', pond levellers and similar devices can control flood damage while still allowing beaver to remain on the landscape. Promoting such solutions for co-existence through outreach has been successful in other jurisdictions (Auster, et al., 2021), and is consistent with the objectives of the Environmental Framework.

- Working with affected landowners, develop new, innovative methods such as compensation for land flooded by beaver, to help sustain beaver ponds in strategic locations (e.g., within high priority habitat units, or as 'stepping stones' along the creek to maintain ecological connectivity), or areas where recolonization by beaver is likely (e.g., near Elk Island National Park, or in the Industrial Heartland). The ALUS program and federal initiatives for climate adaptation may offer means to fund compensation.

- Track wildlife-human conflict (e.g., with beaver and large carnivores) particularly in areas adjacent to Elk Island National Park and the North Saskatchewan River. Consider implementation of programs such as 'Bear Aware' to avoid creating attractants (e.g., garbage, compost piles) or to promote deterrent measures and alternatives to avoid beaver impacts

on private lands (e.g., beaver deceivers, pond levellers, exclusion fencing), and emphasize the ecological and human benefits of beavers. Additional innovative programs could be developed with affected landowners proactively to address emerging concerns, through community advisory groups established through other programs (e.g., through the ALUS program, which involves landowners in ecological restoration planning).

Benefits

The benefits of beavers include helping to maintain water on the landscape during drought, as well as moderating floods and erosion effects by holding back water and sediment behind dams. Higher soil moisture resulting around beaver ponds also offers a natural protection from wildfire (Fairfax and Whittle, 2020). Other benefits include improvements to water quality by retention and breakdown of nutrients and capture of naturally occurring contaminants (e.g., metals) in less hazardous forms within pond sediments. Ecological benefits include promoting biodiversity, from aquatic invertebrates and amphibian species through to waterfowl and ungulates. These species in turn can help control pest species (e.g., insects), and support other services such as pollination. Large carnivores can help regulate populations of other wildlife species (e.g., ground squirrels, deer, and beaver), as well as providing aesthetic wildlife viewing opportunities for residents and visitors to the area.

Applicability

Co-existence programs would apply across the watershed, but particularly in areas near Elk Island National Park and the North Saskatchewan River. Such areas may support more abundant populations of perceived nuisance species, and adjacent landowners may have more frequent issues.

Cost

Outreach could be supported through County staff, or in partnership with groups such as Cows and Fish and the Miistakis Institute (e.g., for beaver management alternatives). Alberta Parks and Elk Island National Park have all implemented alternative beaver management programs and have also developed large carnivore awareness and prevention programs. These agencies are affiliated with the Beaver Hills Biosphere, which could help facilitate collaborative program delivery in the watershed. The Beaver Hills Biosphere is currently undertaking a project focused on coexisting with wildlife. Future outcomes from this project could help to inform strategies for co-existence with wildlife. Finally, pond levelers and exclusion fencing are relatively inexpensive to install ($1000 to $2000/ site for materials) and require limited maintenance (see the Miistakis Institute information **here**).

Beavers and Climate Resilience

A recent study in Washington State evaluated the capacity of beaver re-introductions to buffer drought effects of climate change (Dittbrenner, 2019).

Reintroductions in the Skykomish area, in the Cascade Mountains found surface water storage increased by 243 m3 /100 m of stream in year one, and stored and additional 2.4 times more groundwater. Downstream water temperatures were 2.3 C cooler in summer, which helped reduce evaporative loss.

With climate projections of reduced snowfall in this area, beavers were estimated to increase summer water availability by 20% - a considerable ecological and human benefit.

V1.5 ENSURE AQUATIC CONNECTIVITY

Description of Action

The State of the Watershed highlighted the need for aquatic connectivity to prevent flood conditions through adequately sized and debris-free culverts. Aquatic connectivity can also provide ecological benefits by facilitating access to habitat for aquatic and semi-aquatic species and maintaining diverse aquatic habitats. This in turn provides human benefits such as reducing nutrients in downstream systems, pollination, and insect controls. Some judgement is required for implementation of these actions: not all debris is necessarily a barrier. Trees and logs carried downstream along the channel can provide ponded and riffle habitat and hiding cover for aquatic and semi-aquatic wildlife, as well as shading to reduce evaporative loss. Even beaver dams allow a small trickle of flow, and travel overtop or through the impoundment by aquatic, semi-aquatic, and terrestrial species. Natural creek flows have a mixture of ponded (flat) and flowing (riffle and run) habitat, each of which supports different plant and wildlife species. Riparian vegetation buffers can also indirectly support connectivity by reducing evaporative loss and thus, sustaining flow.

Connectivity can be maintained by both engineering and nature-based solutions and would best be implemented in cooperation with landowners along the creek. Recommended actions for the creek and its tributaries include the following:

- Removal of physical barriers to improve aquatic connectivity. Examples of barriers include perched culverts (outlet suspended above water), debris jams at culverts and bridges, high weirs, and fencing across the creek that can capture debris. Aim for removal of barriers that will obstruct both animal movement and water flow, on both the mainstem of the creek and its tributaries.

- Replace undersized culvert and bridge crossings. Undersized crossing structures constrain flows, which can result in upstream flooding. Smaller crossings also increase the velocity of flow through them, which can prevent upstream access for some species (e.g., frogs, minnows) and create stream erosion issues downstream.

- Develop a community awareness program with information on the types of obstructions that pose a risk, human and natural barriers to flow, and characteristics and benefits of a healthy and connected aquatic system.

- Monitor debris accumulation at culvert and bridge crossings, particularly after large storm or flood events. Monitoring could be done by residents through a citizen science program coordinated by the County. This approach would provide proactive monitoring support and help raise local awareness of the types of barriers they could control on their own lands (e.g., fencing, undersized culverts).

Benefits

Improved aquatic connectivity will reduce flooding, but also help to sustain biodiversity and increase resilience throughout the creek, in terms of habitat and species. Diverse aquatic communities will play a role in controlling water quality, as well as supporting other services supported by the riparian edge (e.g., habitat for pollinators and insectivorous birds). Aquatic vegetation, riparian vegetation, and other micro-organisms in the water (e.g., bacteria) both take up nutrients carried in creek water, helping to 'clean' water of inputs (e.g., fertilizer, manure) contributed from overland flows.

Applicability

Aquatic connectivity actions apply across the watershed. One perched culvert was identified during field surveys at 54511 RR 204 crossing (south of Hwy 15). Undersized crossings are listed in Vision 3.

Cost

Programming to support a citizen science or public information campaign could be supported by the County, or in collaboration with Cows and Fish or ALUS programming. Debris removal and culvert or bridge replacement would mainly be funded through County programs.

V1.6 PREVENT LIVESTOCK FROM ACCESSING CREEK

Description of Action

While streams, wetlands and other waterbodies have long been used to provide water for livestock, open access can have detrimental effects on water quality and quantity, as well as habitat conditions. Manure and 'potholing' around the riparian edges created as cattle access water can introduce nutrients and sediment, as well as pathogens (e.g., bacteria like E. coli). Grazing often occurs around the riparian edge too, since soil moisture promotes lush grass growth, but ironically, overgrazing can cause drought conditions in later summer, due to evaporative loss. Maintaining off-stream watering stations can alleviate these problems, as can riparian edge fencing to restrict grazing at certain points of the year. Cost-benefit studies of alternative water sources have found cattle do better as well – cattle weight gain has been found to be higher with a watering system, rather than dug-outs or stream access (Canfax, 2018). The improved water quality enhances palatability, and better cattle hydration. A rotational grazing pattern in riparian areas helps ensure good vegetation cover over the spring and summer months, which helps sustain year-round stream flow and good grazing conditions later in summer.

Specific actions related to livestock access management include the following:

- Install an off-stream watering station (e.g., solar-powered pump/trough system) that provides better access for livestock to water. Ideally, a watering station would be combined with fencing along the riparian edge to restrict access to the stream and grazing lands near the creek, as part of a rotational grazing system.

- Allow areas that have experienced past grazing to recover through vegetation growth for an appropriate period, then implement rotational grazing in these areas.

- Combine access management with restoration of riparian vegetation (planting of native grasses or shrub stakes) to help restore riparian vegetation cover. This will help reduce evaporative loss from the creek and sustain stream flows through drier periods.

- Develop a community awareness program to build understanding of livestock impacts on riparian areas and provide information on livestock management options to reduce impacts.

Benefits

Reducing inputs of nutrients, sediment and other contaminants will improve water quality in the creek for participating landowners, and downstream users. Improved water quality will also improve aquatic and riparian habitat conditions, supporting other ecological services and human use.

Applicability

These actions would apply on any lands currently used for livestock grazing, including leased lands.

Cost

Costs include solar-powered watering systems and fencing materials, which can be supported through the ALUS system (should the County chose to adopt it), or the Green Acreages Program. Units can range from $9,565 for a solar powered pumping system, to $13,274 for a windmill system, plus costs for pipe (Canfax, 2018) . Federal and provincial watershed protection grants have periodically sponsored such activities, and the County could also apply for grant funding on behalf of interested residents.

4.3 Vision 2: Integrated Watershed Management

Integrated Watershed Management Statement:

Responsible land management within Astotin Creek watershed reduces flood and drought risk and protects ecosystems.

Land use and development are important considerations for resilience. Flood and drought resilience needs to be considered on a watershed scale to ensure that actions taken in one area of the watershed do not have negative upstream or downstream impacts. Providing areas for water storage and protecting ecosystems are both important to build resilience to flooding and drought.

Policy and programs related to land-use and development are tools that can be used to guide future development, as well as create opportunities for restoration to enhance resilience.

The following actions have been identified to support the vision of integrated watershed management for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V2.1 Conserve and restore wetlands**
- **V2.2 Develop land buyback and/or compensation programs**
- **V2.3 Maintain ecological function in Upper Assessment Reach**
- **V2.4 Protect and enhance drainageways**

V 2.1 CONSERVE AND RESTORE WETLANDS

Description of Action

Wetlands, both within the creek flood fringe and in the uplands across the watershed play an important role in flood risk by holding back surface flows after snowmelt and storm events. They also help to sustain soil moisture in these same areas, through infiltration into the adjacent soils in shallow groundwater flow. Wetland vegetation takes up nutrients entering the wetland through surface flows, improving water quality before release through shallow groundwater flow. Retaining intact wetlands is critical to supporting these benefits, including temporary and seasonal wetlands that flood mostly in spring or rain events, as well as open water ponds. Creating a shared understanding of the diverse types of wetlands, and their ecological benefits will help support conservation and habitat enhancement efforts. Lastly, the County's role in the provincial Wetland Replacement Program could help replace or enhance existing wetland habitat.

Actions to support wetland conservation in the watershed include:

- Encourage retention of wetlands, particularly in the flood fringe zone (e.g., in development proposals).
- Limit new development within the Upper Assessment Reach to maintain wetland habitat, ideally with a minimum 30 m wide buffer. Policy updates to stress avoidance of wetland loss could strengthen existing policy tools (e.g., including development incentives for proposals that avoid and protect wetlands or requiring local replacement, rather than compensation payment, by developers).
- Seek locations for wetland restoration in collaboration with interested private landowners to identify sites proactively for inclusion into the Wetland Replacement Program.

- Encourage land management practices that can help maintain and sustain wetlands (e.g., avoid cultivation within the 30 m buffer, or within temporary and seasonal wetlands). Working with conservation partners to deliver outreach programs can build on existing materials, experience and delivery approaches for agricultural and rural residential programming (e.g., Land Stewardship Centre, Cows and Fish, Miistakis Institute).

Benefits

Wetlands can help take up flood flows and help sustain water availability through drought conditions, as well as providing water quality improvements, and enhancing habitat and biodiversity.

Applicability

Wetland conservation can be done across the watershed. Wetland restoration efforts should focus on the Middle Assessment Reach, where loss has been higher, and specifically on the riparian flood fringe, which would affect crop cultivation less.

Cost

Delivery of public awareness programs could be done in conjunction with partnering organizations, or alternatively through County staff outreach activities. Wetland restoration activity is funded by provincial wetland compensation.

V2.2 DEVELOP LAND BUY-BACK AND/OR COMPENSATION PROGRAMS

Description of Action

Certain jurisdictions in Alberta have recently resorted to deliberate overland flooding to temporarily divert and/or store flood water to reduce peak flows and flood risk downstream of these locations. This sometimes leads to temporary flooding of agricultural and recreational lands, which can adversely impact landowners. Temporary storage of flood water on large agricultural areas can significantly reduce flood flows and flood risk downstream. This flood management approach typically includes a Flood and Compensate model, providing payment for economic losses due to flooding.

The recent floods on Astotin Creek revealed that several agricultural lands are located within the floodplain and are at risk of flooding. While this is detrimental to certain landowners, overland flooding can have a beneficial effect on downstream flood risk by temporarily storing a large amount of water and reducing downstream flood flows. Any attempt to contain the creek flow at these locations, through dikes and channelization work, would reduce floodplain storage and potentially increase flood risk downstream. Such measures also require on-going maintenance, adding to overall cost. A potential flood management approach would be to tolerate overland flooding, to reduce downstream flood risk, and compensate the impacted landowners for their agricultural losses. For example, significant overland flooding was noted during the 2018 flood between Range Road 212 and Highway 15 in the Middle Assessment Reach. A Flood and Compensate program would compensate the landowners for crop loss based on the total area of impacted land, negotiated between the County and the landowners using current market rates. It should be noted that all-risk crop insurance is also available to farmers in every province through The Crop Insurance Act, enacted in 1959. Historically, the Canada-Alberta Excess Moisture Initiative II (CAEMI II) provided $30 per eligible acre to producers with land too wet to seed as of June 20, or for land already seeded which lost crop due to flooding. Although this program is not in place anymore, the Agricultural Financial Services Corporation (AFSC) now provides a suite of crop insurance programs which offer protection against crop losses from designated perils, such as flooding and drought.

Land buyback is another alternative, which gives owners the option to move away from flood areas and reduces the amount of physical property potentially impacted by flood events. Strategic acquisitions of natural and undeveloped parcels can also be done to preserve the floodplain from future developments. This approach was recently implemented in Sainte-Marie-de-Beauce, in Quebec, where over 200 properties located within the Chaudière Rivière floodplain were purchased and demolished in 2020.

Benefits

Floodplain protection through a land buyback or compensation program conserves the floodplain integrity and allows for flood storage and peak flow attenuation. Land buybacks also decrease the extent of potentially impacted homes and physical infrastructure and future flood recovery costs.

Applicability

Land buybacks and compensation programs can be implemented over the entire floodplain, with a focus on the Middle Reach.

Cost

Land acquisition costs are highly variable but are estimated at about $100,000 per hectare of land. Crop compensation costs vary with market values. Current cereal crop value is about $1000 per hectare.

V2.3 MAINTAIN ECOLOGICAL FUNCTION IN UPPER ASSESSMENT REACH

Description of Action

The Upper Assessment Reach has largely retained native forest and grassland cover, due to constraints imposed by morainal terrain. As a result, surface flows are well filtered through vegetated areas, evaporative loss is lower and flood attenuation is provided by wetland storage. This part of the watershed thus supports downstream flows in both quality and quantity, and in both wet and dry years. Conserving these naturally vegetated areas as much as possible will help moderate the severity of floods and drought on downstream areas.

Policy and conservation tools will help to maintain ecological function in the Upper Assessment Reach area:

- Review and update land use planning policies to ensure specific references to conservation priorities such as wetlands, riparian buffers, floodplains and creek tributaries are protected, as a minimum consideration for future development proposals. Smaller tributaries and temporary or seasonal flood duration wetlands, in particular, are not necessarily linked to conservation requirements in agricultural use nor residential development policies.

- Promote riparian land management practices through County outreach activities, or in collaboration with environmental organizations already active in this area of practice (e.g., the Land Stewardship Centre, Cows and Fish, Miistakis Institute).

- Work with local landowners to establish conservation easements along the length of the 100 m riparian buffer lands through the Upper Assessment Reach area to help protect the headwaters and water supply for downstream areas and provide flood attenuation.

- Protect parcels with high environmental value (e.g., known species at risk, wetlands) through conservation land purchase, as opportunities arise.

Benefits

Maintaining ecological function of the lands in the Upper Assessment Reach will help protect water quality, sustain downstream flows (especially in drought), and buffer flood and storm events through wetland and flood fringe storage. Such protective measures will also help sustain ecological connections with Elk Island National Park and within the rest of the Beaver Hills Biosphere, as well as associated ecological benefits.

Applicability

Applies to new development in the Upper Assessment Reach, which are addressed in part under the Beaver Hills Policy Area requirements in the MDP. The Policy Area currently places limitations and obligations on agricultural, residential and commercial landowners. Some are specific, such as development of an Environmental Farm Plan to promote responsible human – environment interactions and limitations on structures or land use, while others more generally require consideration of environmental impacts. More explicit protections for land management around wetland and riparian lands could be added to the MDP and LUB to protect riparian buffers (for example) or limit forest clearing for operational (as opposed to structural development) land improvements.

Cost

Updates to MDP and LUB can be done through regular administration and Council approval processes. Conservation easements or land purchase could be held by the County, or other environmental organizations active in this area (e.g., Ducks Unlimited, the Edmonton Area Land Trust, Nature Conservancy of Canada). Land costs in this area will dictate purchase costs (currently about $100,000 per hectare). The Land Stewardship Centre, Cows and Fish, and the Miistakis Institute have prepared various educational materials that provide advice on riparian management that could be distributed through the County as part of outreach programs (e.g., Stepping Back From Water).

V2.4 PROTECT AND ENHANCE DRAINAGEWAYS

Description of Action

Runoff in the watershed is conveyed to Astotin Creek through overland flow collected in drainageways that are primarily located within private property. In the Middle Assessment Reach, such areas have been cultivated through, removing all vegetation buffers and the benefits they provide (e.g., reducing evaporative loss and enhancing filtration). In the Upper and Lower Assessment Reaches, vegetated buffer areas may remain, but they can be at risk to future development. To protect these lands from alteration and aid in restoration, the County could pursue easement or drainage right-of-way acquisition along key drainageways. Another alternative is to develop conservation buffer zones for key drainageways through modifications to existing land use policy (e.g., within the LUB), as a strategy to promote riparian health throughout the watershed.

Benefits

Implementation of this vision would aid in conserving or restoring vegetated buffer zones. More practically, an easement would allow the County access to complete maintenance activities such as removal of sediment, debris, and trash, and repair of hydraulic structures along key drainageways. This vision also offers some degree of protection from alterations to drainageways that help sustain flows or provide flood attenuation (e.g., through riparian wetlands or flood fringe lands).

Applicability

This vision is primarily applicable to the agricultural lands in the Middle Assessment Reach immediately south of Highway 15.

Cost

Easement or right-of-way acquisition costs are highly variable. An estimated range would be $15,000 or $25,000 per hectare of land. Land use policies that protect a buffer on tributary drainageways would have no land purchase costs, but would require public outreach to secure buy-in.

Quebec Magpie River 'rights of the river'.

In February 2021, Quebec broke new legal ground by establishing 'rights of a river'. Two parallel resolutions, one by the Innu Council of Ekuanitshit, the other by the regional government of Minganie grant the river nine rights — including the right to live, exist and flow; the right to respect for its natural cycles; and the right to take legal action. This action mirrors other international examples ranging from New Zealand to India, that seek to establish the same protections against harm currently granted to people and corporations.

Hessey, 2021

4.4 Vision 3: Resilient Infrastructure

Resilient Infrastructure Vision Statement:

Infrastructure in the Astotin Creek watershed is designed to reduce flood risk and enable adaption to climate change

Infrastructure plays a critical role in maintaining quality of life in Strathcona County. To ensure infrastructure continues to function as designed and serve the community, it is crucial that County infrastructure is resilient. Actions supporting this vision seek to identify and address issues with existing infrastructure as well as guiding resilient design for new infrastructure. When designing and developing new infrastructure, flood risk and climate change are both important considerations. As climate change is anticipated to impact flooding in the future, infrastructure should be designed with future climate in mind to build long-term resilience.

The following actions have been identified to support the vision of resilient infrastructure for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V3.1 Replace undersized infrastructure**
- **V3.2 Elevate roads along with crossing upgrades**
- **V3.3 Update the allowable stormwater discharge rate for new developments**
- **V3.4 Incorporate flood construction level requirements in the LUB**
- **V3.5 Include climate change considerations in infrastructure and development standards/policy**

V 3.1 REPLACE UNDERSIZED INFRASTRUCTURE

Description of Action

The hydraulic modeling simulations for the creek revealed that several crossings (bridges/culverts) are undersized for large flood events, thereby increasing upstream water levels and leading to wider flood inundation zones. This was expected, given that most crossings on small local roads are generally designed for smaller flood events than the 100-year flood in Alberta. Hydraulic design of crossings in Alberta are generally based on the basin potential and channel capacity analyses, combined with a reduction factor provided in Alberta Transportation's Hydrotechnical Design Guidelines for Stream Crossings (AT, 2006). For low volume local roads, these hydrotechnical calculations typically lead to a smaller design flow than the 100-year flood. Given that the watershed area increases further downstream along the creek, the design flow and hydraulic opening of the crossings should increase as well. However, this is not the case for Astotin Creek. A wide range of hydraulic openings was measured at crossings along Astotin Creek, moving from Elk Island National Park to Lower Assessment Reach, as shown on Figure 4-2.

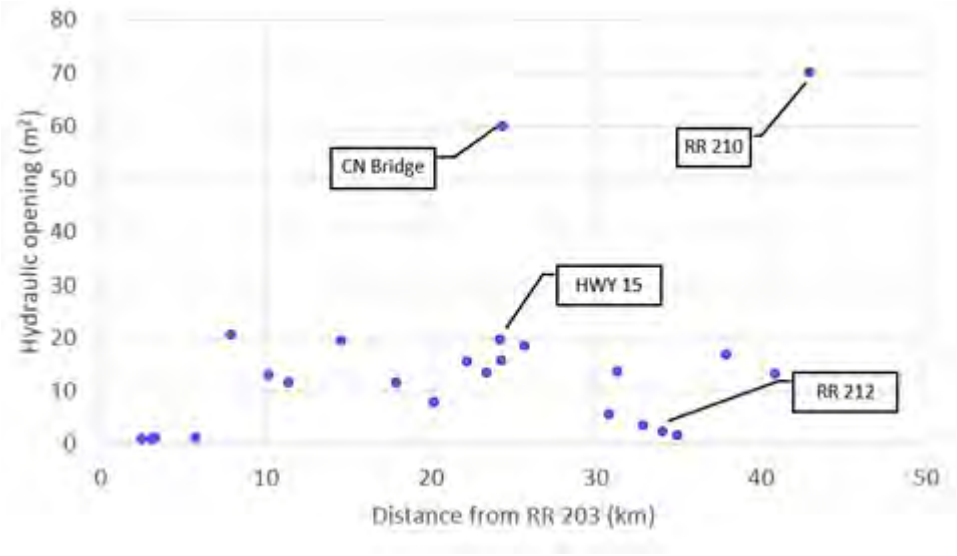


Figure 4-2 Hydraulic opening of surveyed crossings along Astotin Creek

Some of the smallest culverts along Astotin Creek were found in the lower section of the creek, about 35 km downstream of Astotin Lake, despite draining a larger watershed area than upstream crossings. For example, RR 212, shown on Figure 4-3 (a), comprises three culverts with diameters of 920 mm, 1200 mm, and 780 mm respectively, for a combined hydraulic opening of 2.3 m^2. In comparison, the CN bridge, shown on Figure 4-3 (b) and located about 10 km upstream of RR 212, has a hydraulic opening of 60 m^2, which is about 25x bigger than the crossings at RR 212. The CN bridge and the RR 210 bridge have the two highest hydraulic opening along the study reach, whereas the other crossings generally have a hydraulic opening of 20 m^2 or less. The culverts at Highway 15 have a hydraulic opening of about 20 m^2.

Figure 4-3 a) Culverts at RR 212 b) CN bridge, downstream of Highway 15

When replacing existing structures, bridges and open bottom culverts (arch culverts) should be favored over culverts as they can provide a greater discharge capacity and provide better hydraulic connectivity for aquatic species. Several crossings located on private lands were also identified along Astotin Creek, but their dimensions could not be surveyed due to access restrictions. Some of these crossings are located just downstream of residential and agricultural lands and could promote overland flooding if they are not adequately designed. Although upgrading crossings on private lands falls outside of Strathcona County's jurisdiction, landowners should be made aware of potential consequences of installing undersized creek crossings and encouraged to consult with the County when installing or changing crossings along Astotin Creek. Such an outreach program could be incorporated into existing agricultural extension programs offered under the County's Agriculture Master Plan.

Benefits

Replacing existing crossings with larger structures would bring the following benefits:

- Reduced blockage risk
- Increased discharge capacity, reducing upstream water levels and flood risk
- Reduced erosion and scour downstream
- Reduced likelihood of road overtopping
- Improved stream connectivity and fish passage

Applicability

Although upgrading all Astotin Creek crossings by bridges that can accommodate the 100-year flood is not economically practical, it is recommended to upgrade specific crossings located in flood-prone areas. Based on the hydraulic simulations, the following crossings, also shown on maps in Appendix A, were found to be undersized and promoting overland flooding. Replacement should be considered first at these sites:

- RR 204 (SW33-54-20-4)
- RR 205 (SW32-54-20-4)
- RR 210 (NW31-54-21-4)
- RR 210 (NW6-55-20-4)
- RR 212 (SW2-56-21-4)
- TR 550 (NW32-54-21-4)
- TR 552 (NW-11-55-21-4
- TR 560 (NE33-55-21-4)
- TR 560 (NE34-55-21-4)

Replacements of the culverts at TR560 (NE33-55-21-4 and NW34-55-21-4) should be prioritized as it considerably impacts upstream flood levels, which could promote overland flooding in the Industrial Heartland. The other crossings identified in Appendix A and listed above also increase upstream flood risk for landowners, but their length of influence upstream is more limited, given the

steeper longitudinal slope of the creek. The bridge at RR 210 directly impacts the flood levels for the landowner of SW6-55-20-4 and should be prioritized. Site-specific hydrotechnical studies should be conducted at each site to determine the most appropriate crossing size and opening when considering local topography, constructability, aquatic connectivity, and flood risk. As further detailed in the following vision (V3.2), raising roads that currently can get overtopped during large flood could increase the flow being conveyed through culverts and bridges. Future road upgrades should be taken into account when completing site-specific hydrotechnical study for crossing upgrades.

Although closed-bottom culverts are generally cheaper and easier to install, clear span and open bottom structures (bridges) offers many advantages over culverts, such as:

- Greater discharge capacity due to greater hydraulic opening.
- More resistance to erosion during large flood events if the abutments are well armored.
- A natural stream channel in continuity with the natural stream.
- Improved aquatic connectivity by reducing water velocities compared to culverts which improves fish passage.

Certain types of open-bottom culvert types can offer similar advantages to bridges such as arch culvert as well as embedded closed-bottom structures. The choice and design of crossing structures on a fish-bearing stream are determined by a number of factors, including sensitivity of fish habitat, cost, fluvial geomorphology and topography. A site-specific approach should be implemented when determining which structure type should be used to replace existing crossings.

Cost

Cost for crossings upgrades depends on the size and type of the new structures. Recent work completed by Strathcona County suggest that replacement cost of existing crossings can range from $50,000 to $1,000,000 per project.

V3.2 ELEVATE ROADS ALONG WITH CROSSING UPGRADES

Description of Action

Road overtopping was reported at several locations within Astotin Creek watershed during the 2018 flood. The hydraulic model confirmed that several local roads would be overtopped during large flood events. Road overtopping can be attributed to undersized crossings and low points along the road. For instance, RR 213 was overtopped over a significant length during the 2018 flood. The hydraulic model showed overtopping at the same location, which correspond to a low point of the road according to the LiDAR elevation data, as shown on Figure 4-4. Raising the road elevation at such sites would prevent road overtopping and improve transportation connectivity during large flood events.

The hydraulic model also suggests that the overtopped section of the road convey a significant portion of Astotin Creek flow for large flood events. For the 20-year flood, the modeled flow overtopping RR 213 accounted for nearly 40% of the total Astotin Creek flow and 60% was conveyed through the bridge. Raising RR 213 above flood levels would increase the flow to be conveyed by the bridge, which would lead to higher water levels upstream of RR 213 compared to current conditions.

In other words, raising roads without increasing the crossing's discharge capacity could increase flood risk upstream of the upgraded roads. The existing bridge/culvert discharge capacity should be considered when raising a road susceptible of overtopping along Astotin Creek.

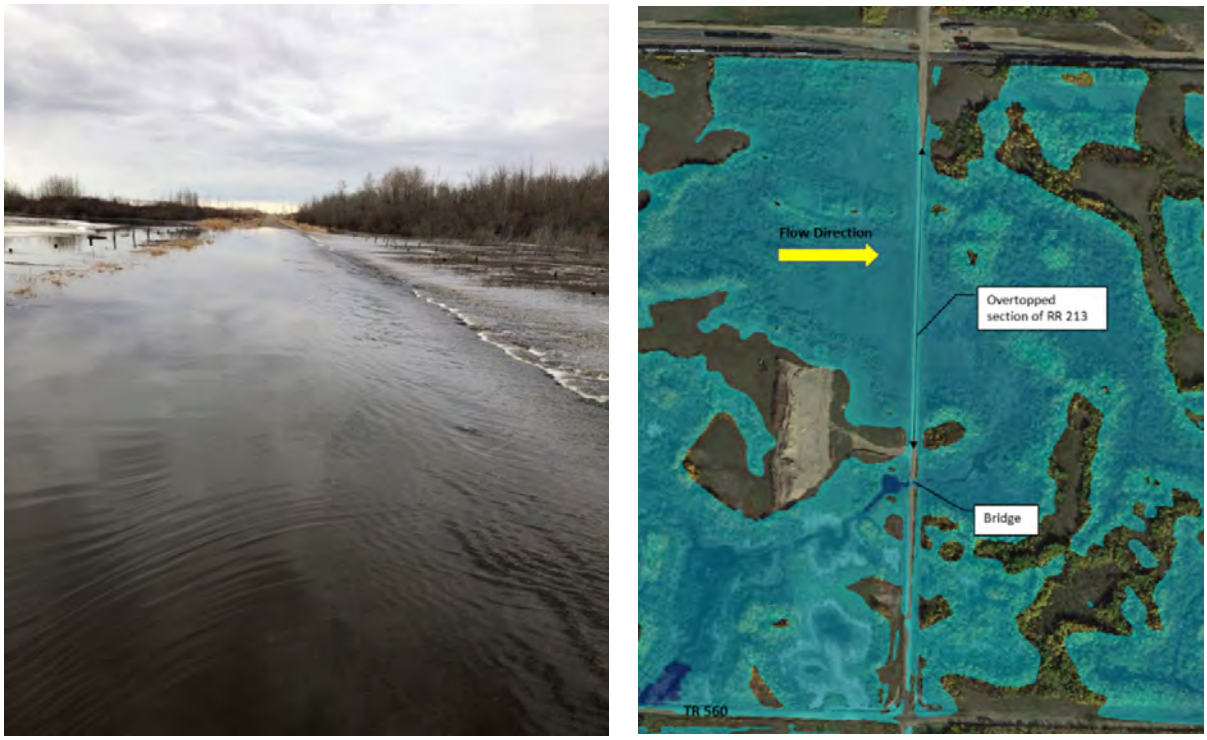


Figure 4-4 (LEFT) RR 212 overtopped during the 2018 flood event (b) Hydraulic modeling results of the 20-year flood.

Benefits

Raising roads above flood levels improves connectivity and emergency response during flood events. It also reduces the flood-related damages to infrastructure and improves post-flood recovery. Raising the roads at low points would, however, increase the flow through the crossings, which could increase upstream flood levels if the crossing is undersized. It is important to consider the crossing's current discharge capacity when raising roads at risk of overtopping to avoid unintended flooding impacts. Combining road raising with an upgraded crossing could be required at some locations where the current culvert or bridge is undersized.

Applicability

The hydraulic model identified the following roads, also shown on maps in Appendix A, as being potentially overtopped during large flood events:

- 54511 RR204 (SW33-54-20-4)
- RR 204 (SW33-54-20-4)
- RR 205 (SW32-54-20-4)
- RR 210 (SW31-54-20-4)
- RR 210 (SW6-55-20-4)
- RR 211 (SE11-56-21-4)
- RR 212 (Multiple locations)
- RR 213 (Multiple locations)
- RR 214 (Multiple locations)
- TR 550 (NW36-54-21-4)
- TR 552 (NW11-55-21-4)
- TR 553 (upstream of HWY 15)
- TR 560 (Multiple locations)
- TR 562 (NE12-56-21-4)
- TR 554 (NW21-55-21-4)

Upgrading some of the crossings identified in V3.1 would reduce the frequency and magnitude of overtopping at the roads listed above and roads upgrades might not be required if the new crossings are sufficiently large. Potential road upgrade works should therefore be analyzed in combination with crossings upgrades to determine if roads should be raised above their current elevation.

Cost

Cost for road upgrades depends on the length and the depth of fill required to reach the desired crest elevation. Recent work completed by Strathcona County suggest that cost of road upgrades can range from $500 to $1,000 per linear meter of road upgrades.

V3.3 UPDATE THE ALLOWABLE STORMWATER DISCHARGE RATE FOR NEW DEVELOPMENTS

Description of Action

Hydrologic analysis of the Astotin Creek watershed indicated that the pre-development unit area release rate (UARR) is 1.9 l/s/ha for the 100-year flood event. Future developments in the County's Industrial Heartland within the Lower Assessment Reach where there is greater potential for intense development should adopt the pre-development UARR for the design of stormwater management best practices. The UARR is applicable to the Upper and Middle Assessment Reaches as well.

Benefits

The intent of adopting the pre-development UARR is to maintain or replicate natural hydrological conditions after development has occurred, by requiring peak flow attenuation. This in turn minimizes the impact to downstream water and land resources. More specifically, adoption of the pre-development UARR protects Astotin Creek by:

- Mitigating large peak runoff rates, which can in turn impact the downstream water and land resources.
- Mitigating creek streambed and bank erosion.
- Mitigating the delivery of pollutants to the creek.

Furthermore, hydraulic assessment of the creek channel and instream hydraulic structures (culverts and bridges) indicated that capacity is limited. The pre-development UARR can help address capacity issues and thus allow for smaller hydraulic structures.

Applicability

This vision applies to all areas of the watershed that will undergo development. Currently, the County's planning documents indicate that future developments requiring stormwater management are anticipated to occur in the Industrial Heartland area within the watershed.

Cost

Costs associated with this action are anticipated to be minimal and internal to the County.

V 3.4 INCORPORATE FLOOD CONSTRUCTION LEVEL REQUIREMENTS IN THE LUB

Description of Action

Raising finished floor levels within a development is an effective way of avoiding damage to the interior of buildings (i.e., furniture and fittings) in times of flood. A Minimum Building Elevation (MBE) effectively mitigates flood risk damage to new buildings and allows for people to recover more quickly after a flood event. Modifying ground levels to raise the land above the design flood level is a very effective way of reducing flood risk to a particular site, in combination with other measures such as emergency response planning. Figure 4-5 shows how raising a building can reduce physical property damage.

Figure 4-5 MBE effect on physical property damage

Although new developments in the flood fringe might be acceptable (e.g., if development in the flood fringe does not increase upstream flood levels by more than 0.3 m) the first floor of new developments (including the building's electrical and mechanical equipment) must be constructed at or above the design flood level. The flood fringe corresponds to the portion of the flood hazard area outside of the floodway, where flood water is generally shallower and flows more slowly, as shown in Figure 4-6.

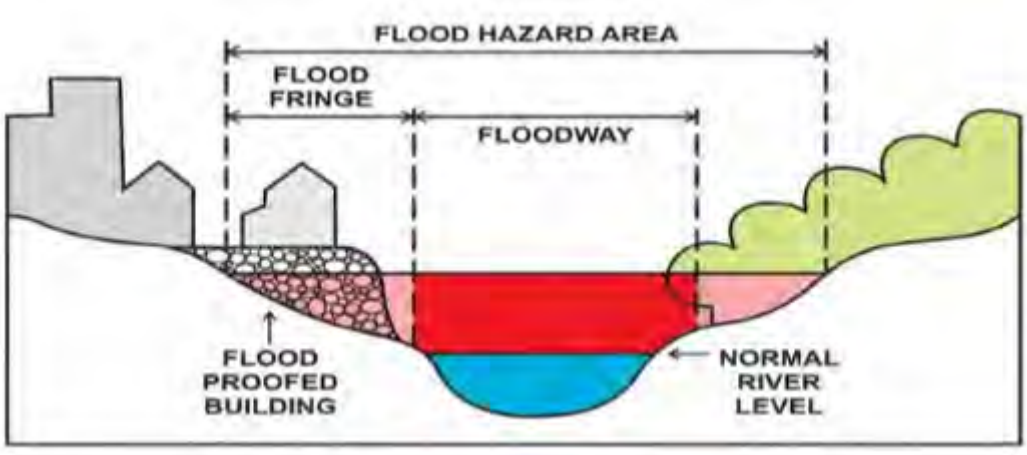


Figure 4-6 Illustration of the floodway and flood fringe.

If new developments are to be allowed within the flood fringe, Strathcona County's LUB could be updated to require a minimum building elevation for new developments along Astotin Creek. Geotechnical evaluations already required for subdivision development, for example, could incorporate recommendations for flood proofing for development in the flood fringe. The minimum building elevations are site-specific and should include sufficient freeboard (0.6 m is recommended) above the legislated flood level. Existing structures in good condition can sometimes be elevated on extended foundation walls or on compacted fill to raise the level of the first floor above the MBE. Raising existing buildings above flood construction levels is, however, an expensive endeavor and actions proposed in other visions may be more economically effective.

Benefits

Flood construction levels greatly minimize the flood damage for future developments within the floodplain. They ensure that living spaces and areas used for the storage of goods are kept above flood levels.

Applicability

Flood construction levels would be applicable to any new development within the Astotin Creek floodplain.

Cost

There is minimal cost to implement policy changes. There is an increase in construction cost to build homes above MBE, however, these additional costs are expected to be largely compensated by reduced flood damages.

V3.5 INCLUDE CLIMATE CHANGE CONSIDERATIONS IN INFRASTRUCTURE AND DEVELOPMENT STANDARDS/POLICY

Description of Action

To build infrastructure resilience to climate change, climate change considerations can be integrated into standards and policy related to infrastructure design and land development. This includes the addition of language to consider climate change when developing design criteria for new infrastructure. For example, when designing stormwater infrastructure, future rainfall projections should be considered in infrastructure sizing. At a minimum, climate projections should align with the infrastructure's design life. For infrastructure with a design life of 50 years or more, climate projections for the 2080 time-horizon should be considered.

It is also important to consider climate change for development within the floodplain. The 1:100-year flood plain is typically considered for future development and is referenced in the LUB and the provincial Municipal Government Act Subdivision Regulation. While this restriction has been long-standing in municipal land use policy, adaptations to consider climate change have not. Consistent application of these policies, and incorporation of steps to consider climate change risks will ensure that development within the floodplain incorporates appropriate adaptation measures for flooding.

Climate change science is an evolving discipline and ongoing monitoring of climate science and trends is important to understand and respond to climate risks. Climate risk assessment and response planning should be an ongoing exercise for the County and requirements for infrastructure and development should be adjusted as required over time to address climate risk.

Benefits

Infrastructure designed to withstand climate change will not only provide required services today but will continue to provide reliable services and safe operations in the future. Climate resilient infrastructure design contributes to overall community resilience and helps to manage and mitigate climate change risks. Taking action to integrate climate resilience during infrastructure planning and design prevents the need for early replacement or retrofits to adapt to a changing climate.

Applicability

This recommended action applies to all County policies, standards, and regulations that govern infrastructure design and development. This includes, but is not limited to, the LUB, stormwater design guidelines, and culvert design requirements.

Cost

There is minimal cost to implement policy changes. Costs to design to future climate may increase, however, investing in infrastructure resilience is anticipated to have long-term cost benefits by preventing future damages.

4.5 Vision 4: Proactive Management

Proactive Management Vision Statement:

Strathcona County's programs and operations reduce flood risk in the Astotin Creek watershed.

This vision is focused on actions that the County and landowners can take on a regular basis to reduce flood risk in Astotin Creek. Programs and operations that focus on the early identification of issues will allow for timely action to remedy these issues before they become significant. Although it is intended that the County take a lead on the actions within this vision, as private land extends to the Astotin Creek edge throughout the watershed, partnership and collaboration with landowners will be important for the successful implementation of recommended actions. Landowners can be directly involved in supporting this vision through initiatives on their land as described within the supporting actions.

The following actions have been identified to support the vision of proactive management for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V4.1 Implement a debris management program**
- **V4.2 Expand asset management program**
- **V4.3 Proactive creek inspections and monitoring**
- **V4.4 Landowner education and partnership for private property clean up**

V4.1 IMPLEMENT A DEBRIS MANAGEMENT PROGRAM

Description of Action

During a site visit completed in June 2021 by WSP, some natural and anthropogenic features were recognized that might reduce the carrying capacity of the creek and cause ponding issues at several locations. Some examples of these features are illustrated on Figure 4-7 and listed below:

- Beaver dams under or downstream of crossing structures
- Woody debris along the creek and especially at the upstream end of small culverts
- Piles of woody debris along the creek (naturally washed out or manually removed from the channel and stacked in the floodplain)
- Human made obstacles (e.g., fences crossing the creek) .

A debris management program (e.g., annual debris removal) should be developed to keep the channel clear, especially at bridge and culvert crossings. The debris management program can include removing beaver dams located close to crossings and flood risk areas, wood jams, dead trees and shrubs, and silt accumulation at the entrance of crossings. Debris accumulation is highly dynamic and evolves rapidly year over year. The debris management program should therefore be complemented by proactive site inspections, as described in Vision 4.3.

Benefits

Regular debris removal and channel clearing helps to improve the creek's flow conveyance capacity, reduce the risk of local flooding and erosion, and maintain the creek's natural beauty.

Applicability

Debris removal is mainly applicable to the upstream parts of the creek with natural conditions (e.g., the Upper Assessment Reach). However, annual investigation and cleaning is recommended around all the crossings and wherever overland flooding has been noted. Only major debris blockage, as shown on Figure 4-7, should be cleared along the creek. Small accumulations of woody debris should be left undisturbed as they generally do not cause conveyance problems and provide other habitat and stabilization roles.

Cost

Under most circumstances, debris removal expenses are relatively low and are limited to the cost of labour unless heavy machinery is needed.

Figure 4-7 Examples of excessive debris accumulation and manmade barriers noted along Astotin Creek

V4.2 EXPAND ASSET MANAGEMENT PROGRAM

Description of Action

Municipalities are increasingly tasked with tracking maintenance and replacement costs of infrastructure, including culverts and bridges. Many have turned to asset management systems that can track infrastructure specifications and age, as well as maintenance and performance issues, to assist in capital and operational budgeting. In some cases, such information has clarified or supported assumptions regarding long-term performance, informing future planning expectations, as well as budgeting. An asset management program that tracks culverts and bridges, plus other associated infrastructure (road repairs, alternative beaver management installations) can help with future planning and budgeting. Strathcona County currently manages select assets through the Bridge and Bridge Culvert Replacement Program which includes bridge culverts with a diameter of 1.5m or greater. Pedestrian bridges are not included in the current program. It is recommended that Strathcona County expand on this existing program to include all drainage infrastructure in the watershed.

Recommended actions for an expanded asset management program include:

- Creating an inventory of current assets, with age, condition, and replacement costs (if known). This initial inventory provides the starting point for future tracking, and ideally is linked to locations through a GIS spatial layer. The Bridge and Bridge Culvert Replacement Program does include a GIS layer, however, at this time asset information is not linked to location.

- Tracking on-going maintenance costs and timelines over the lifespan of the infrastructure. This information will inform future replacement timing, and operational budgeting. The Bridge and Bridge Culvert Replacement Program already tracks and records costs, and so this process could be replicated in an expanded asset management program.

- Completing regular inspections and include a complaint tracking log tied to each asset for use in monitoring maintenance issues, repairs, and other condition updates. The system, once established as a baseline can

be used to forecast annual maintenance, replacement, or upgrading costs. The Bridge and Bridge Culvert Replacement Program already includes inspections by certified bridge inspectors following Alberta Transportation's Bridge Inspection Manual. Inspections inform replacement planning and prioritization of work based on condition and available budget. Additionally, the current program is building a deterioration model and confirming expected service life of assets based on experience and data verification. The systems in place for the Bridge and Bridge Culvert Replacement Program can be built upon in an expanded asset management program, with tailored inspection requirements for different types of assets.

Benefits

By tracking the installation costs and specifications, condition, maintenance, and repair of all drainage infrastructure in the watershed, future maintenance and replacement can be better forecast, based on actual performance records. For innovative solutions such as beaver pond levelers, data can be compared to traditional management costs to 'prove the concept'.

Applicability

Ideally, an asset management program would include all drainage infrastructure in the watershed (i.e., all culverts and bridges), plus any stormwater or other control infrastructure, including alternative beaver management installations. Tracking would exclude the two bridge-sized culvert structures owned and managed by Alberta Transportation.

Cost

An asset management program can be developed using existing County personnel and GIS systems. Some additional funding may be required (e.g., to cover cost of inspections and/or additional time required to set up an expanded asset management program), but may be eligible for grant funding. Costs associated with inspections and condition ratings for some assets are already included in County budgets through the Bridge and Bridge Culvert Replacement Program.

V4.3 PROACTIVE CREEK INSPECTIONS AND MONITORING

Description of Action

Action 4.1 highlighted the importance of maintaining adequate flow conveyance at flood-prone locations. To avoid excessive debris accumulation, Astotin Creek should be inspected annually. Annual inspections would also help identify other undesirable concerns such as:

- Bank and channel erosion;
- Damages and blockages at bridges and culverts; and
- New beaver dams in flood-prone areas (e.g., at culvert and bridge sites).

Results of the annual inspection should feed into the debris management program (V4.1) to schedule clean-up. The annual inspection report should also identify concerns that should be addressed such as bank repairs or bridge and culvert maintenance or replacements. Annual inspections should be carried out following the spring freshet or any major storm events to identify potential issues arising from increased flow.

Benefits

Proactive creek inspections would provide valuable information regarding the creek's integrity and would help identify areas of concern that should be addressed. It would also provide a clearer picture of the creek's current condition and help budget required capital work.

Applicability

Recognizing that inspecting the entirety of Astotin Creek would be time consuming, focus the inspection activities at the bridge and culvert crossings and at the flood-prone areas identified in Appendix H of the Drainage Master Plan. Recruiting resident support for a volunteer survey on private lands could provide information on debris accumulation in these areas.

Cost

Costs associated with this action are anticipated to be minimal and internal to the County.

V4.4 LANDOWNER EDUCATION AND PARTNERSHIP FOR PRIVATE PROPERTY CLEAN UP

Description of Action

Several culvert crossings and sections of the creek are located on private lands and are not readily accessible to the County's staff. A community approach to the Astotin Creek cleanup could be implemented by the County. Astotin Creek residents could be encouraged to 'adopt a reach' of Astotin Creek where they would help monitor, clean and maintain the creek on their lands. This could either be carried out through individual, continuous activity or through annual creek cleanup events organized by the County. Landowner education would be required to highlight the impact of debris blockage on flood risk, and the types of blockage that need to be removed. The debris management program could be shared openly to any landowner motivated to take part into the cleanup effort. Note that timing of the clean-up activity should avoid times where impacts to wildlife might occur (e.g., during spring bird breeding season, fall beaver and amphibian hibernation periods), particularly if water draw-down may result.

Benefits

Partnerships with landowners would foster collaboration and promote individual involvement in the flood mitigation effort. This would also promote 'ecological literacy' and help develop a shared understanding of a healthy creek environment.

Applicability

This action applies to the entire watershed and would be relevant to landowners adjacent to Astotin Creek. Creek clean-up events could also include other County residents who would like to get involved in activities to improve flood resilience for the community.

Cost

Costs associated with this action are anticipated to be minimal and internal to the County.

4.6 Vision 5: Flood and Drought Preparedness

Flood and Drought Preparedness Vision Statement:

Strathcona County will invest in response planning to ensure staff and residents can deal with flood and drought events.

Although the Resiliency Action Plan seeks to reduce flood and drought risk, it is also important to prepare for flood and drought as risk cannot be fully eliminated. Supporting actions within this vision seek to build an understanding of how to respond to flood and drought events. These measures aim to ensure health and safety, while protecting infrastructure and reducing damage.

The following actions have been identified to support the vision of flood and drought preparedness for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V5.1 Develop flood response plan and training**
- **V5.2 Develop flood forecast, monitoring and warning system**
- **V5.3 Develop a drought mitigation plan**
- **V5.4 Increase public understanding of flood prevention and drought mitigation, property protection, and emergency response**
- **V5.5 Incentivize property level flood protection**
- **V5.6 Investigate availability of flood insurance for landowner**

V 5.1 DEVELOP FLOOD RESPONSE PLAN AND TRAINING

Description of Action

Although flood events are somewhat unpredictable in nature, emergency response procedures should be clearly defined, and operating staff well trained to manage a flood emergency in an organized and coordinated manner. The flood response procedures should be outlined in a specific plan that documents the actions that operations staff are to follow in the event of a flood. The plan should include the key emergency response roles and responsibilities, in order of priority. The response plan should also include the following:

- Flood response levels based on streamflow and meteorological data;
- Notification procedures, including contact information for key emergency roles;
- Notification chart of all residents living within the flood inundation zone;
- A list of preventive and remedial actions;
- Flood inundation maps; and
- Location and availability of equipment, emergency power sources, contractors and stockpiled materials that are critical to the emergency response.

The flood response plan is not a one-off activity, but rather a living document that needs to be revisited and reassessed as the community grows and changes. The plan also needs to be practiced through mock flood events and examined for effectiveness after a flood event.

Benefits

A flood response plan will enable a swift, effective, and efficient response, which can limit flood damage and accelerate recovery.

Applicability

This action is applicable for the entire Astotin Creek watershed.

Cost

The cost to develop a flood response plan is estimated to be about $50,000 and annual training is estimated at about $5,000.

V5.2 DEVELOP FLOOD FORECAST, MONITORING AND WARNING SYSTEM

Description of Action

Data on flood flows and levels are essential to understanding when and where extreme river flows and levels might occur and to inform flood risk management measures. Similarly, recording details of flood events is extremely useful to build knowledge of flood risk throughout the community and to understand flooding patterns. This can also help to calibrate the computer models used to predict potential future flooding. The ongoing collection of flood-related data is a measure that will help to continually improve preparation for, and response to flooding.

It is possible to forecast floods using weather predictions, observed rainfall, observed snowpack, and predicted temperature. River levels and flows then can be predicted using hydrological models. Flood forecasting involves significant uncertainty, as it entails simulation of very complex systems in real-time with limited data which may result in false alarms. Alternatively, streamflow can be monitored in real-time to determine rate of water level rise and potential upcoming flooding. Streamflow monitoring combined with flood thresholds can be used to develop flood alert levels.

Some flood monitoring strategies follow a three-level approach, as shown in Table 4-2. Each warning level explains the level of risk and demonstrates the actions that need to be undertaken. A flow value is typically associated with each alert level, which is triggered when the flows measured at monitoring stations exceed these thresholds. These flood thresholds should be clearly defined in the Flood Response Plan described in V5.1.

Table 4-2 Example of flood alert levels

	**Flood alert – Prepare** Check flood warnings/updates regularly. Ensure vulnerable people are aware and prepare their vital possessions and prescriptions.
	**Flood warning – Act** Prepare for a potential flood, contact vulnerable people, move valuables to safe zone, watch flood alerts for potential evacuation.
	**Severe flood warning - Evacuate** Evacuate to safe area.

Benefits

Having a flood forecast and warning system in place helps people to act appropriately and mitigate risk. Knowing that a flood event is impending allows people in the community to prepare for the flood, for example, by moving people, furniture, and valuables away from the incoming floodwater. Streamflow monitoring would also provide valuable streamflow data at Astotin Creek that can be used to refine the hydrological and hydrotechnical analyses completed as part of this study. Citizen participation in monitoring rainfall and stream flow, in addition to County run stations, can help engage residents in flood preparedness, and provide a broader network of monitoring stations.

Applicability

The flood forecast, monitoring and warning system would apply to the whole Astotin Creek watershed and its residents. Flow monitoring stations should be installed at locations where the creek is well confined to ensure that the station captures the entirety of the flow. Figure 4-8 shows a potential location for hydrometric station installation, in quarter-section SW12-55-21-4, where Astotin Creek is well confined and streamflow monitoring would be possible. Any other locations where Astotin Creek is well confined and where overland flooding is limited would be suitable sites to install a hydrometric station.

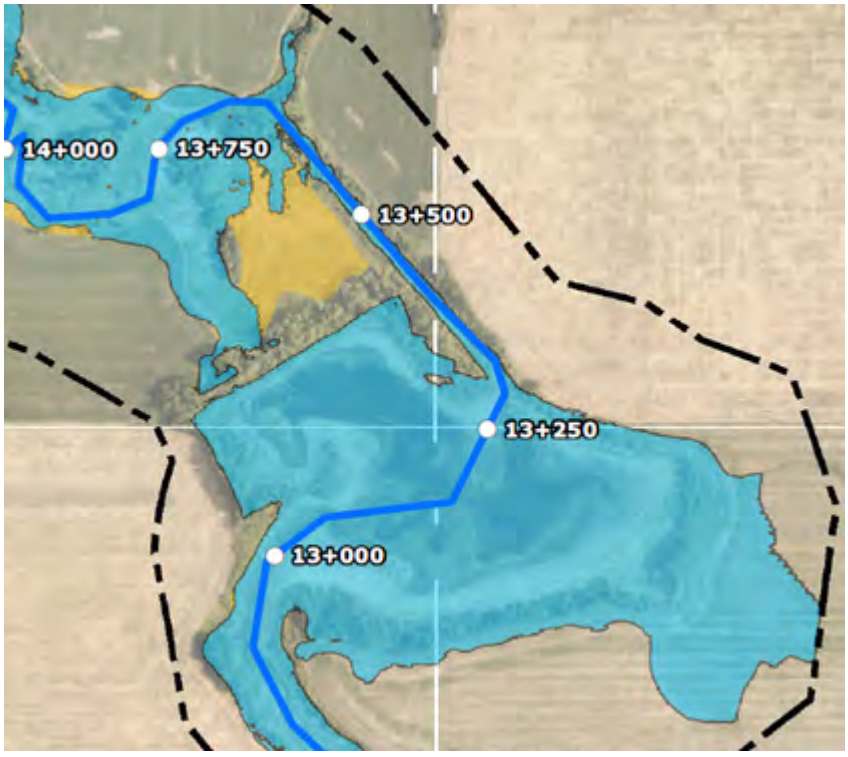


Figure 4-8 Potential hydrometric location

Cost

$25,000 to $50,000 per streamflow monitoring station, depending on the sophistication level of the installed instruments. Rain gauges and simpler stream gauges could be provided to residents at low cost and data acquisition could be supported through County resources (e.g., online or phone reporting).

V5.3 DEVELOP A DROUGHT MITIGATION PLAN

Description of Action

As noted by the National Drought Mitigation Centre (2021), drought planning should seek to:

- Identify water-dependent functions of the community;
- Prioritize water-dependent functions; and
- Determine steps to adapt those functions if water supplies begin to drop.

Undertaking an exercise to understand the impacts of drought on the Astotin Creek watershed is the first step to building drought resilience. Looking at water needs for residential, industrial, and agricultural water users will help to build this understanding. It is also important to consider fire risk and ecosystem impacts from drought. Establishing the priority of water uses, and the steps that will be taken to reduce water use and/or seek alternate sources of water are both important components of drought preparedness. A drought response plan should be developed for the Astotin Creek watershed that includes the prioritization of water uses and adaption plans.

The American Planning Association has developed guidance on Planning and Drought that provides additional aspects of drought planning. Important components of drought planning include monitoring and early warning, vulnerability assessment, and mitigation actions. Many drought plans also incorporate a phased response, which outline different actions to be taken as drought conditions intensify. The importance of community engagement to support drought planning is also noted. (Schwab, 2013)

Benefits

Understanding the impacts of drought for the watershed and developing response and mitigation plans will help to County and residents to adapt in the event of a drought.

Applicability

Drought preparedness will apply to the entire watershed.

Cost

Internal costs for staff time and resources.

V5.4 INCREASE PUBLIC UNDERSTANDING OF FLOOD PREVENTION AND DROUGHT MITIGATION, PROPERTY PROTECTION, AND EMERGENCY RESPONSE

Description of Action

Flood and drought risk management is a shared responsibility between the County and private landowners. The public needs to understand how to prevent flooding through their activities in the watershed, protect their property in the event of flood and drought and how to behave in an emergency situation. Effective risk communication and associated action requires that all participants have a common understanding of risk, understand their role in risk management, and feel empowered to act. The Partners for Action's Community Guide to Effective Flood Risk Communication (MacKinnon et al., 2018) recommends a series of steps to develop a risk communication plan:

1. Understand the community's perception of risk via two-way communication and consultation.

2. Create localized communications that include community-specific values, stories, and tangible examples of risk.

3. Link local stories, actions, and examples to a broader strategy, goals, or messaging, such as nation-wide impacts of climate change, or national/regional flood and drought mitigation strategies.

4. Communicate the responsibilities (and limitations) of public authorities relative to individual response, using the context and communication

pathways established in the previous steps.

5. Monitor the effectiveness of the communication plan and identify areas for improvement and update the process as necessary.

Benefits

Prepared residents are better able to participate in the County's emergency response processes and will be safer and better able to respond to an emergency event. Informed residents can actively participate in preventative actions to reduce flood and drought risk, working with County administration.

Applicability

Communicating risk response and preparedness will apply to the entire watershed.

Cost

There is little to no capital cost to establishing a public outreach campaign, but staff time and resources will be required.

V5.5 INCENTIVIZE PROPERTY LEVEL FLOOD PROTECTION

Description of Action:

Property level flood protection (PLFP) is any measure that helps a property owner reduce flood damage without adversely affecting neighboring properties. Some examples are grading property away from the house, removing expensive items from the basement, installing weeping tiles, elevating electrical/HVAC equipment above flood levels, installing a sump pump, using water-resistant material, and building dykes to protect vulnerable infrastructure. Figure 4-9 provides various PLFP and their adoption rates in Canada, according to a 2016 survey (Thislethwaite et al. 2018). Note some of these PLFP are more efficient against sewer backups than overland flooding.

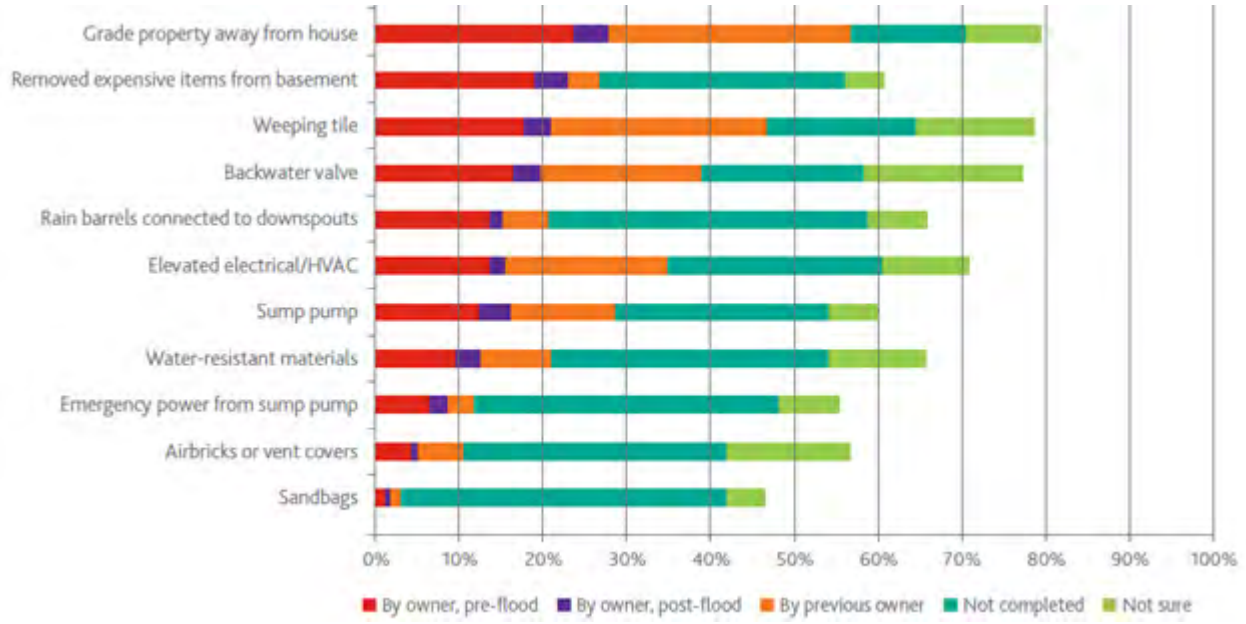


Figure 4-9 Various property level flood protection measures and their adoption rate in Canada (Thislethwaite et al. 2018)

Local governments can promote PLFP uptake through various economic and bylaw interventions. For example, Toronto's Basement Flooding Protection Subsidy Program offers up to $3,400 per property for installing a backflow prevention valve or sump to protect against flood. Similar incentives could be implemented by the County to promote PLFP uptakes by residents located within the Astotin Creek floodplain.

Benefits

Implementing property level flood protection measures reduces the impact of floods on people and their property and allows for a faster flood recovery.

Applicability

The property level flood protection measures are applicable to all the owners with a property in a floodplain, especially those with a residential house in or close to the floodplain.

Cost

PLFP cost can range from minimal for removing expensive items from basement to costly, such as floodproofing a property with water resistance materials. PLFP cost are generally covered by landowners but as mentioned previously, local governments can also implement economic incentives to favor PLFP uptake. Federal and provincial climate resiliency grants may also support such incentives, providing a potential funding source.

V5.6 INVESTIGATE AVAILABILITY OF FLOOD INSURANCE FOR LANDOWNERS

Description of Action

Flood coverage is one of the most complicated aspects of home insurance in Canada and few insurers were offering overland flooding coverage until recently. But as of 2019, about 80% of Canadians had access to some form of overland flood insurance. Most insurers now offer optional overland flood coverage, which covers losses from damage to home, condo or personal property. But despite more accessible flood coverage, market penetration for overland flood insurance was still below 40% as of 2018 and coverage in high-risk areas was either unaffordable or not readily available. A National Working Group on Financial Risk of Flooding, co-chaired by Public Safety Canada and the Insurance Bureau of Canada (IBC), has been recently implemented to develop a new insurance model in Canada that would promote affordability, inclusivity, and efficiency. The shift towards a risk financing approach rather than a public disaster recovery approach is still relatively new and rapidly evolving. As overland flood insurance becomes more available and accessible to landowners, Astotin Creek owners located within the floodplain should consider acquiring optional overland flood coverage to mitigate the financial impact of a flood event.

As mentioned in Action V2.2, all-risk crop insurance is also available to farmers in every province through The Crop Insurance Act, enacted in 1959. More specific to Alberta, the Agricultural Financial Services Corporation (AFSC) provides a suite of crop insurance programs which offer protection against crop losses from designated perils, such as flooding and drought. Lands that are subject to repeated flooding or where excess moisture is a recurring problem may not be insurable, at the discretion of the AFSC.

Benefits

Provides landowners with financial support following a flood and spreads the risk among policy holders. Personal flood insurance also decreases reliance on governments to support financial reparation following a flood event.

Applicability

Applicable to any landowners located within the Astotin Creek floodplain. Insurance coverage availability should be confirmed with insurance brokers. As new policies become more available, the option can be included in County flood preparedness information for residents. County GIS mapping provides means to identify relevant landowners, including those immediately adjacent the creek.

Cost

Applicable to any landowners located within the Astotin Creek floodplain. Insurance coverage availability should be confirmed with insurance brokers. As new policies become more available, the option can be included in County flood preparedness information for residents. County GIS mapping provides means to identify relevant landowners, including those immediately adjacent the creek.

4.7 Vision 6: Educated, Engaged and Empowered Public

Educated, Engaged, and Empowered Public Vision Statement:

Strathcona County residents will have a shared understanding of flood and drought risks and feel empowered to participate in actions to manage risks.

Flood and drought resilience will require both County action and involvement from residents throughout Strathcona County. It is important that residents understand risks related to flood and drought as well as opportunities to contribute to risk reduction efforts. This vision supports the realization of the other five visions in the Resiliency Action Plan as public support and involvement will be crucial for the success of numerous supporting actions.

The following actions have been identified to support the vision of an educated, engaged, and empowered public for Astotin Creek. Details on each supporting action are provided in the following sections.

- **V6.1 Implement public outreach programs**
- **V6.2 Implement pilot programs to showcase nature-based solutions**
- **V6.3 Implement citizen science initiatives**
- **V6.4 Indigenous Relations**

V6.1 IMPLEMENT PUBLIC OUTREACH PROGRAMS

Description of Action

Several of the previous visions included public outreach programs to inform and empower residents to participate in flood and drought preparedness and risk reduction. Examples include support to ecological restoration actions for a healthy ecosystem, information on natural creek systems to support debris removal in the creek, and information on wetland conservation. Emergency preparedness is another area where public involvement will be critical. In some cases, outreach will provide additional context to develop shared understandings of an issue, in others, outreach will provide information, ideas and resources to allow landowners to undertake projects to support creek resiliency and protect their own property from flooding and drought impacts. Partnering with existing organizations who have these materials and delivery mechanisms already established may be helpful (e.g., working with Cows and Fish, the Miistakis Institute, and the Land Stewardship Centre to deliver workshops or provide information). Some outreach would be better coordinated through the County, to provide local context and more direct insight into management decision processes. In all cases, outreach should aim to engage, inform, and empower residents and stakeholders, and provide the County with feedback on local interests and capacity to adopt recommended management plans.

Benefits

Flood and drought resiliency is necessarily a collaborative process involving landowners and municipal administrators. Moving toward shared understanding of issues and the applicability of management solutions will ensure implementation of cost-effective and timely solutions, and allow for active participation of residents and other stakeholders. Strathcona County has an existing public engagement policy and various tools for public outreach (website, newsletter, surveys, community engagement events, etc.). The County can use these existing means to communicate flood and drought risk and response, following the recommended pathways for risk communication outlined in Action V5.3.

Proximity to Astotin Creek and the primary use of private land will impact the relative risk of a residential property to flood and drought and will influence the responsibilities and applicable behaviours of the resident. Communications (outreach events, communications, etc.) may be tailored to different land users and owners, with a focus on personal property protection for those likely to be directly impacted by flood or drought. Targeted outreach events with invitations to directly affected landowners and residents can help to address specific risk communication and actions regarding flood and drought protection, such as property-level flood protection. Targeted events may include stakeholder engagement sessions or targeted mail-outs.

General community awareness of how the County is assessing and addressing flood and drought risk, and what individuals can do to mitigate personal and community risk, will support overall community awareness of flood, drought, and associated climate change-related risk. Establishing a baseline understanding of community awareness of flood and drought, through the surveys completed during this project, will help inform appropriate public outreach activities based on gaps in awareness.

An aware public is better able to understand and support County decisions around flood and drought risk management. Informed landowners are better able to take proactive measures to protect their property from flood and drought and will have an improved understanding of the roles and responsibilities of the County relative to their own. Actively engaged residents can help the County to identify risks and practical and relevant adaptive strategies to manage those risks.

Applicability

Applicable to all County residents, with targeted activities for landowners and residents directly impacted by flood and drought.

Public outreach programs recommended in this plan address all areas of the watershed, and a variety of topics, from ecosystem restoration and function to hydrology and engineering solutions and emergency preparedness. Specific public outreach activities which have been identified throughout the Action Plan are highlighted in the following table.

Table 4-3 Actions with Public Outreach Component

Associated Action(s)	Public Outreach Objectives
V1.1, V1.2, V2.1, & V2.3	Build understanding of the benefits of a vegetated buffer and natural water retention features; provide landowners with information on alternative land use practices to promote healthy riparian area
V1.2 & V2.1	Build understanding of wetland conservation and restoration benefits. Work with interested landowners to identify potential wetland restoration sites.
V1.4	Raise awareness of the presence of wildlife and benefits of co-existence.
V1.5	Build understanding of the benefits of aquatic connectivity and the types of obstructions which pose a risk to creek flow and connectivity.
V1.6	Build understanding of livestock impacts on riparian areas and provide information on livestock management options to reduce impacts.
V4.4	Build understanding of how debris can impact the watershed and promote ongoing debris management practices.
V5.4	Build public understanding of flood and drought risks, flood prevention measures, property protection measures, and emergency response.

Cost

Various grant programs are available to support public outreach activities and could support County staffing and additional resources for program delivery, with or in cooperation with relevant non-governmental organizations (e.g., Cows and Fish, ALUS).

There is little to no capital cost to establishing a public outreach campaign, but staff time and resources will be required.

V 6.2 IMPLEMENT PILOT PROGRAMS TO SHOWCASE NATURE-BASED SOLUTIONS

Description of Action

For many members of the public, engineering solutions are a broadly recognized, traditional solution to flooding concerns. However, in the context of limitations to government funding, climate change, and a need for adaptation to flood and drought risk, nature-based solutions are of increasing interest. Residents and other stakeholders may not be familiar with such solutions, or the expectations of community involvement in their application, and introducing several changes at once may be overwhelming. Pilot projects conducted with willing landowners can provide 'proof of concept' as well as local champions that can explain the benefits and observed outcomes of the project. For this reason, choice of project is also critical: building up from a series of achievable projects with less risk of failure will foster more trust. Potential pilot projects that could be implemented with interested landowners include the following:

- Restoration of a section of riparian flood fringe or wetland area (e.g., by eliminating mowing, or by planting native species in previously cultivated areas).
- Installation of an off-stream livestock watering station and fencing a section of riparian pasture to regulate livestock access to the creek.
- Installation of beaver pond levelers to manage pond extent (e.g., in the Upper or Lower Assessment Reach).

Each pilot project would require some level of monitoring, ideally involving the participating landowner, or other interested groups (e.g., school classes, 4H clubs), and creating realistic expectations of the period for observing positive effects. Monitoring results can be reported back to the community through County communications, or through media coverage to share the results, generate community interest, and ultimately promote adoption of resiliency strategies.

Benefits

Pilot projects with high probability of success can demonstrate tangible positive results resulting from changes in practice. Early success with such initiatives is key to building community trust and maintaining the support of the sponsoring landowner.

Applicability

Pilot projects could be developed anywhere in the watershed, but to have maximum effect, should reflect the priorities for action, and if possible, an area best representing the management concern.

Cost

Pilot project costs will vary based on their complexity. A beaver pond leveler installation can range from $1000 to $2000 for materials, while an ecological restoration project using native plant seeds or seedling could be more expensive, depending on planting requirements and plant availability. A variety of funding programs provide support for such projects (e.g., Green Acreages, provincial watershed protection grants), and could be secured by the County or the landowner (e.g., for an industry partner).

V 6.3 IMPLEMENT CITIZEN SCIENCE INITIATIVES

Description of Action

Public engagement can be encouraged through outreach, but also through active participation in some part of flood and drought management. Various examples of potential citizen science programs have been suggested for the visions in previous sections. The launch of the iNaturalist and NatureLynx Astotin projects as part of the State of the Watershed assessment has started this process, by encouraging citizen scientists and residents to record their observations during their home, work, and recreational activities. Future initiatives could include community-based monitoring of debris in the mainstem

creek and tributaries or encouraging reporting observations of 'nuisance' wildlife encounters. Other examples that could help raise awareness of creek hydrology and flood risk among local residents could include volunteer monitoring of stream gauges at set locations along the creek, or even reporting local rainfall events to the County.

Some initial costs include supplies (e.g., free rain gauges offered to landowners, or installation of simple stream gauges at strategic locations on private lands) and training. Data management and quality controls will also be important, to provide checks of the accuracy of reporting by residents. For example, County monitored stream gauges can be used to confirm readings from residents, and rainfall recordings from Environment Canada monitoring stations in Elk Island National Park provide a reference against residents' data.

Benefits

Public participation in data collection programs is of increasing interest because it involves stakeholders more directly in the management process. Participants have the satisfaction of contributing to the solution, but also, a better understanding of the constraints and challenges involved in management.

Applicability

Citizen science programs could be implemented anywhere in the watershed, and could be targeted to specific audiences (e.g., agricultural landowners, industrial land managers), or to a broad public audience. There may be an opportunity to partner with organizations such as the Beaver Hills Biosphere or Friends of Elk Island Society to implement citizen science programs.

Cost

The cost of many citizen science projects can be quite low, involving a means of recording or reporting observations, and training in proper technique.

People Power – Citizen Science as an Outreach Tool

Citizen science brings volunteers and scientists together to gather data to answer environmental problems. Often, these projects also build shared understandings of change, risk and need for action.

Examples include outreach that engages volunteers to record plants and animals, like the iNaturalist program used in this study. Other examples include collecting rainfall data, observing spring flowering timing, or annual surveys for specific species, like owls and amphibians. Such studies can raise awareness of issues and help motivate support and, more importantly, action.

V 6.4 INDIGENOUS RELATIONS

Description of Action

Indigenous peoples have inhabited the Astotin Creek watershed and surrounding areas for over 10,000 years and today, First Nation and Metis peoples continue to have a strong connection to the land (MacDonald, 2009; Matters and Hood, 2016). Exploring these connections with Indigenous peoples can help foster a greater understanding of the ecological and land use history in the region and help to build a shared understanding of the watershed. Pilot projects, co-developed with interested Indigenous groups can be used to explore these connections and demonstrate a path forward. Indigenous groups who participated in the engagement program all identified an interest in building stronger relationships with the County and participating in future activities in the Astotin Creek area. The County is committed to continuing to foster these relationships during the implementation of the Resiliency Action Plan.

The Beaver Hills Biosphere is undertaking projects that explore Indigenous history and connection to the land, and the County can potentially collaborate on these initiatives or contribute to the learning network and overall objectives.

Benefits

Collaborating with Indigenous communities will help move the County towards a path of reconciliation and will help build better relationships with Indigenous peoples with connection to this land. Additionally, the County will have more information to help inform decision-making.

Applicability

Indigenous Relations may be incorporated into a number of actions, particularly those related to nature-based solutions. Broader engagement and collaboration with Indigenous groups would be undertaken by relevant County staff and learnings can be shared widely where appropriate. Although programs or projects that require individual landowner collaboration will apply directly to landowners, Indigenous Relations may provide additional perspectives to these initiatives which could enhance learning for County residents and staff.

Cost

Costs of programs, projects, and collaborations will vary but seeking funding partnerships with Indigenous communities can help offset capital costs.

The Treaty Land Sharing Network fosters communication between landowners and Indigenous land users in Treaty 4 and Treaty 6 Territories. Volunteer landowners in the network receive signs to indicate that their lands are open for Indigenous peoples to access for traditional activities and for exercising treaty rights. (Treaty Land Sharing Network, n.d.)