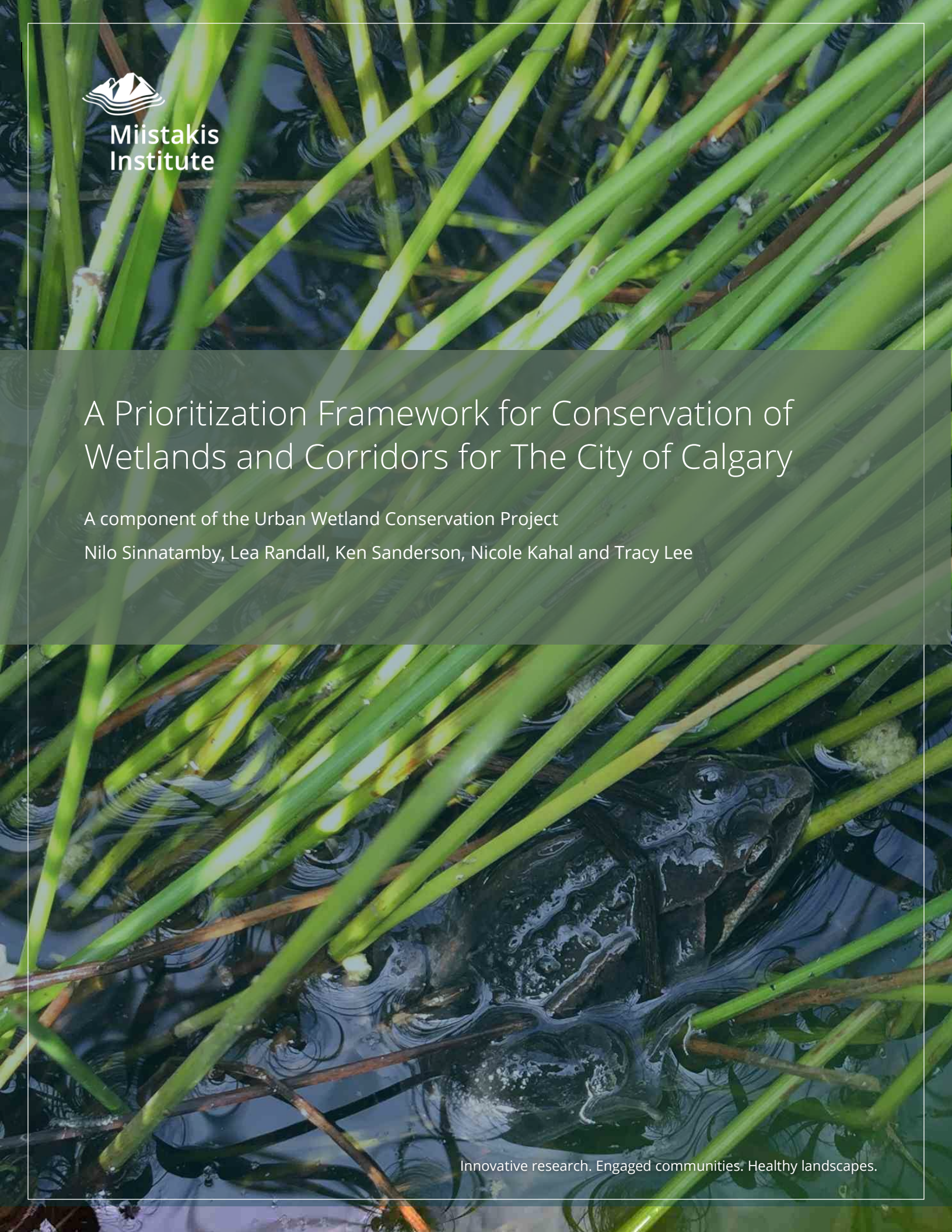

Miistakis Institute

A Prioritization Framework for Conservation of Wetlands and Corridors for The City of Calgary

A component of the Urban Wetland Conservation Project

Nilo Sinnatamby, Lea Randall, Ken Sanderson, Nicole Kahal and Tracy Lee

Innovative research. Engaged communities. Healthy landscapes.

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December 2023

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Executive Summary

Wetlands are essential for the well-being of Calgarians since they provide vital ecosystem services like clean water, protection from flood and drought, and habitat for a diversity of plant and animal species. With over 2700 wetlands within the city of Calgary, operational decision making on which wetlands to prioritize for conservation is a challenge. We developed a series of prioritization frameworks to guide decision making and site selection for in-depth field assessments.

Framework 1 prioritizes wetlands for protection/management or restoration based on the Aquatic Condition Index score for wetland ecological function, whether the wetland was identified as a core wetland and/or a keystone wetland for amphibians, and whether it is within The City's defined Ecological Network. This prioritization framework resulted in four protect/manage priority bins, and four restore priority bins. Most of the top priority wetlands for protection/management were located at the extreme edges of the city, whereas two clusters of top priority wetlands for restoration were identified in the southeast and near the Town of Chestermere. We present wetland protection strategies, and restoration principles and strategies to guide actions that can be taken to improve wetland conservation in the city of Calgary.

Frameworks 2 and 3 provide guidance to help prioritize wetland corridors for conservation based on management goals to support the amphibian network in Calgary. Framework 2 prioritizes corridors based on amphibian movement pathways to conserve areas where amphibian movement is likely occurring. Most of these pathways with a high probability of amphibian movement were located at the north and east sides of the city, whereas a small proportion of isolated pathways were in the inner city and on the west side of the city. Framework 3 prioritizes corridors based on The City of Calgary's Ecological Network, which focuses on areas of terrestrial importance where amphibian networks were largely missing because remaining wetlands are isolated. Most of the areas identified in this framework were located along the rivers in the inner city or toward the west side of the city. We present corridor conservation strategies, which include both protection and restoration measures.

We provided additional recommendations, such as feasibility considerations, that can be used to narrow down the number of wetlands selected for in-depth field assessments, guidelines on when the framework should be revised or reassessed, and a recommendation for education and outreach alongside conservation actions.

The City of Calgary has a strong tradition of environmental stewardship and was the first municipality in Canada with a wetland conservation plan. Wetland and corridor prioritization frameworks are a positive next step that will maximize the efficient use of resources to conserve these valuable resources.

Introduction

"We need to carefully consider how to best develop Calgary, how to conserve and manage functional natural areas, how to bring nature into what we build and how to work with Calgarians and experts to address these questions to meet the needs of citizens."

-Our BiodiverCity. Calgary's 10-year biodiversity strategic plan, 2015

Wetlands are essential for the well-being of Calgarians since they provide vital ecosystem services like clean water, protection from flood and drought, and habitat for a diversity of plant and animal species. The importance of wetlands as natural assets will only grow in importance as the effects of climate change become more pressing and severe. Despite their importance and past efforts to protect them through policy, wetlands still face threats from land-use decisions that alter or remove wetlands to make room for human development. In Alberta, approximately 60-70% of wetlands have disappeared since settlement in populated areas; in Calgary, that number is even higher, estimated at nearly 90% in 2004 (City of Calgary, 2004). Since municipalities are responsible for making land-use decisions, there is a pressing need for policies, management strategies and decision-making tools to ensure protection or restoration of key wetlands.

Urban Wetland Conservation Project

The Urban Wetland Conservation project aimed to support The City of Calgary's biodiversity goals. The project was made up of four components including a field-based rapid assessment method for urban wetlands, a modelled index based on landscape scale indicators, a prioritization framework to guide protection and restoration decision making for wetlands and corridors, and a beneficial management practices guide to promote wetland biodiversity (Figure 1).

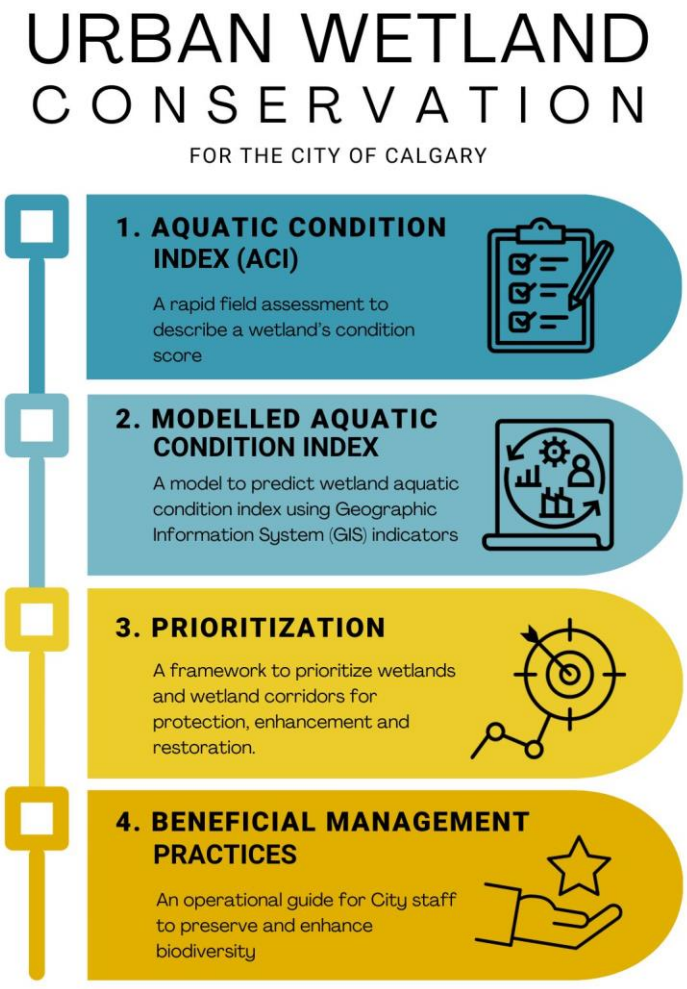

Figure 1. Illustration of the four components of the Urban Wetland Conservation project

Objective

The objective of the prioritization component (Figure 1, component 3) was to develop a framework for The City of Calgary to prioritize wetlands and corridors for conservation to support The City's biodiversity goals. In this report, conservation can mean protection, management or restoration and specific definitions can be found in Figure 2. This report presents the framework developed by the Miistakis Institute with input from the project advisory committee. We present the methods used to develop and apply the framework to all wetlands within the city's limits, including City-managed wetlands and those on private land. We present and discuss the resulting priorities and protection and restoration strategies to support the framework.

There are over 2700 wetlands within the city of Calgary with varying functions (i.e., ranging from retained natural to constructed stormwater ponds) (Nwaishi et al., 2023). This number of wetlands presents logistical challenges in making operational decisions to prioritize wetlands for protection or restoration within human and economic resource constraints. To assist in prioritizing wetlands for more in-depth field assessments, we built a prioritization framework based on existing spatial datasets developed with The City of Calgary.

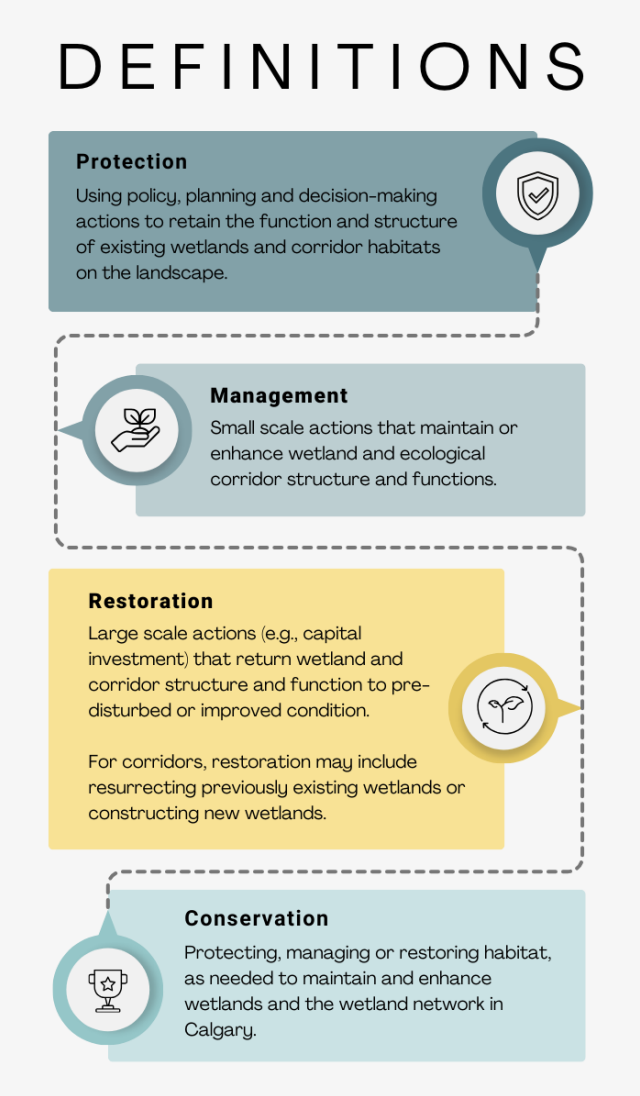

Figure 2. Definitions for conservation, protection, management, and restoration

The prioritization framework focuses on wetland and corridor conservation to promote biodiversity in the city using amphibians as a proxy for biodiversity. The term conservation, here, refers to protecting, effectively managing or restoring habitat, as needed. Wetland restoration refers to returning a degraded wetland to a pre-existing or desired condition. Amphibians are a great taxon to reflect biodiversity within the urban environment because they are highly sensitive to environmental change and use a variety of habitats in both aquatic and terrestrial ecosystems. Furthermore, their relatively small dispersal ranges are likely to serve as a good minimum connectivity distance for a larger suite of organisms.

Methods

Study Area

Calgary, Alberta, is one of Canada's largest cities, with a population of over 1.2 million. Calgary has a heavily developed core surrounded by residential neighbourhoods that continue to spread, currently covering 848 km^2. As a result of this expansion, it is estimated that Calgary has lost 90% of its wetlands since European settlement began in the 18^{th} century (City of Calgary, 2004). Most remaining wetlands in Calgary's urbanized areas contribute in some form to stormwater management, which depending on the management practice may have implications for biodiversity. A current estimate indicates approximately 2,720 wetlands remain within the city limits (Figure 3), with the majority occurring in non-urbanized areas. Wetlands predominately occur in the north, east, and south of the city where densification has not yet occurred, alongside major roads within the transportation network, or within urban parks.

Components of Wetland Prioritization Framework

Below, we present the spatial datasets that were used and a description of how the components were arranged in the **wetland prioritization framework**, which focuses on protecting and restoring individual wetlands. The description of components and how those components were arranged in a **corridor prioritization framework**, which prioritizes conservation of corridors to support amphibian connectivity, follows.

The **full wetland dataset** in Calgary is made up of over 2700 wetlands (Figure 3); these include City-managed wetlands and those on private land. The wetland inventory used in the prioritization component was provided by Calgary's Parks and Open Spaces Department and was merged with The City's storm pond asset management inventory. The dataset was the same as the one used in the modelled ACI component where duplicates and inventory types recorded as reservoirs, dry ponds, historic wetlands, and community lakes were removed (Lee et al., 2023).

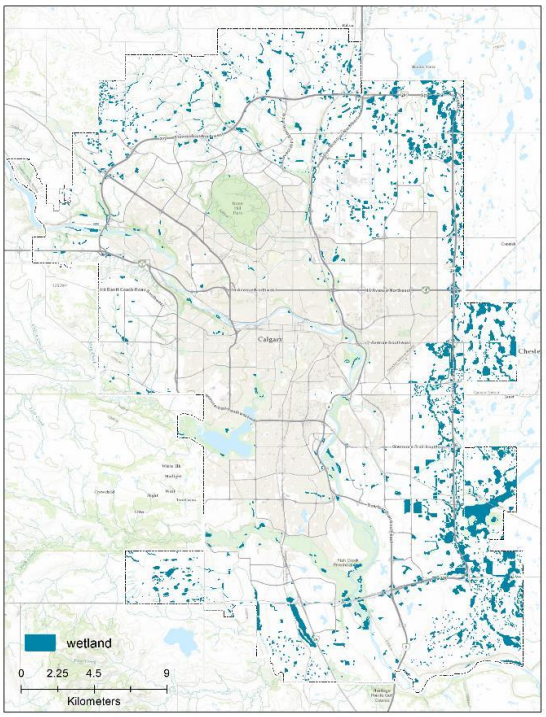

Figure 3. Wetland inventory (dark blue), in Calgary, Alberta with natural areas (green) and roads (light grey).

The **Modelled-Aquatic Condition Index** (Modelled ACI) was used to predict a condition score for each wetland in Calgary (Figure 4) (Lee et al., 2023). The score is made up of three components: hydrological, water quality and ecological. For the prioritization framework, we used the ecology function alone because of the biodiversity focus of the project.

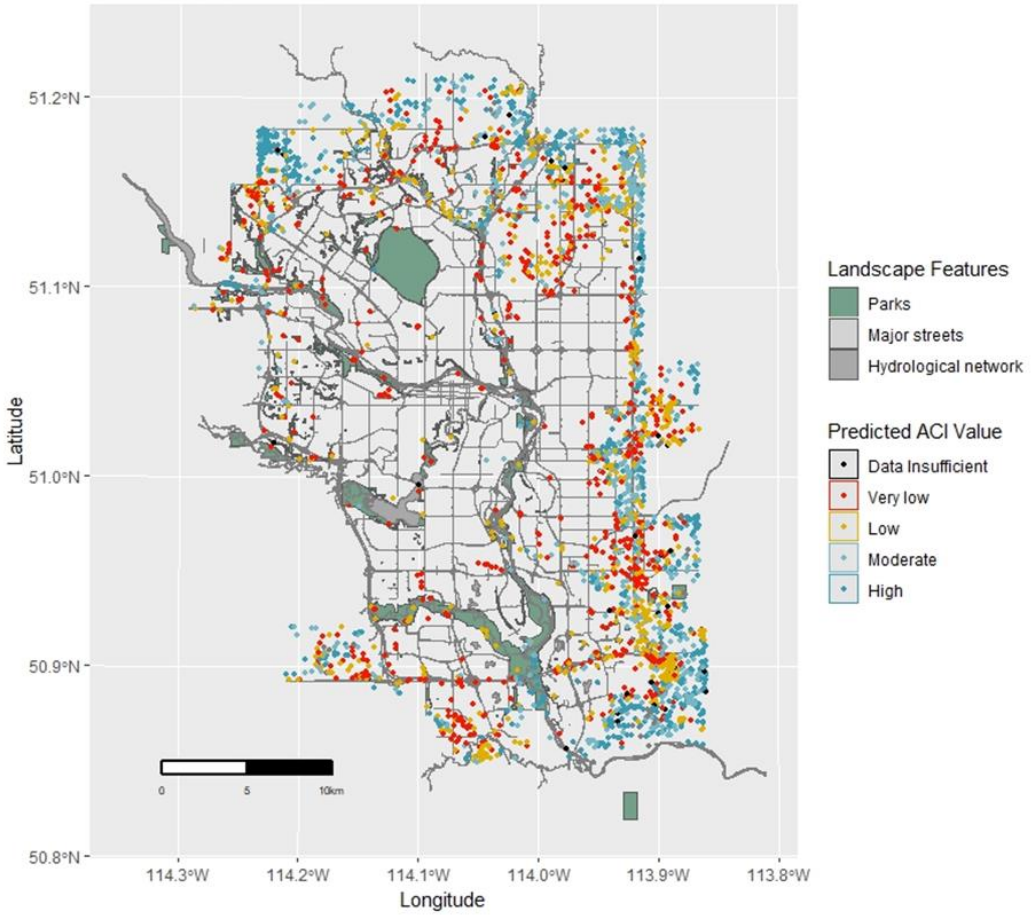

Figure 4. A map of the City of Calgary spatially illustrating the ecology-modelled Aquatic Condition Index divided into four quantiles.

Amphibian core wetlands are those identified to have high quality habitat for two or three of the amphibians found in Calgary, the wood frog, boreal chorus frog and tiger salamander (Figure 5). High quality habitat was derived from species-specific habitat suitability models that were stacked on top of one another. More information on how these were identified is described in Lee et al., (2020).

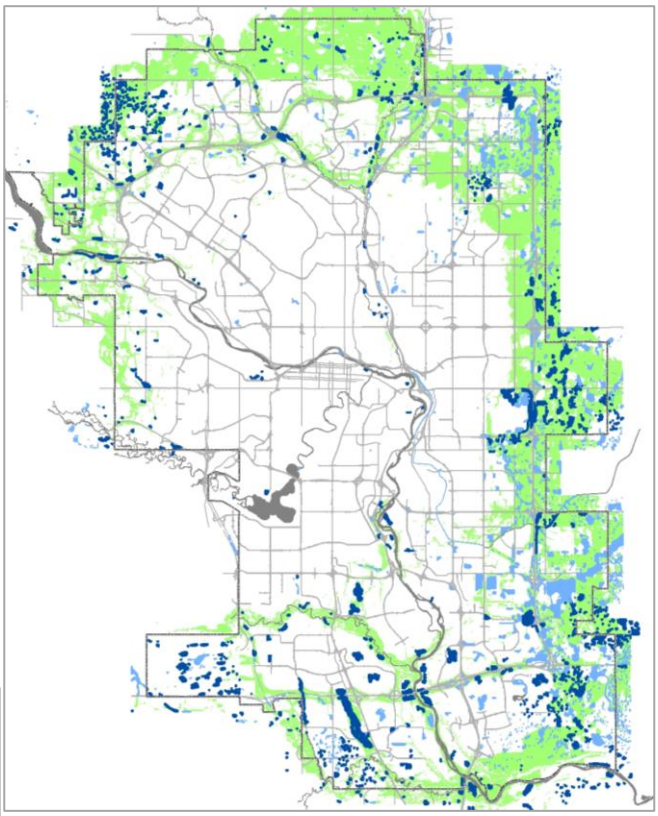

Figure 5. Map of the City of Calgary indicating core amphibian wetlands (dark blue), non-core wetlands (light blue) and core wetland corridor (light green). Map reproduced from Lee et al. 2020.

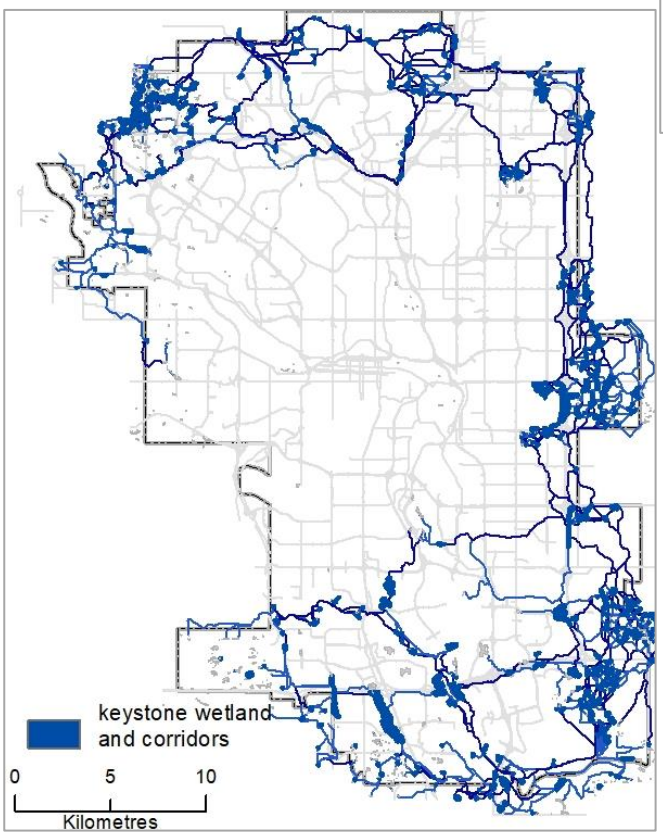

Figure 6. Map of the City of Calgary indicating keystone amphibian wetlands and keystone wetland corridors. Map reproduced from Lee et al. 2020.

Keystone wetlands are core wetlands that were identified as likely to play a significant role in supporting the overall wetland network in Calgary (Figure 6). If this subset of core wetlands is removed, this loss would have a disproportionately high impact on the amphibian population (Lee et al., 2020). Keystone wetlands were identified using a centrality analysis that calculated the cumulative current flow of a core wetland to all other core wetlands.

The **Ecological Network** is a network of natural areas and open spaces that The City of Calgary identified as necessary to maintain ecosystems and species in an urban landscape (Figure 7) (City of Calgary, 2020). The network comprises core habitat (natural areas greater than 30 ha), stepping stone habitat (natural areas between 5-29 acres) and natural and semi-natural open spaces that link those habitat types. The corridors are further divided into primary corridors, which connect Calgary to the broader region and are made up of linear riparian zones along Calgary's major waterways, and secondary corridors, which connect other Ecological Network features to the primary corridor through stepping stone habitats (City of Calgary, 2020). The Ecological Network was included in The City of Calgary's Municipal Development plan in 2020 to maintain biodiversity and landscape diversity but continues to be updated as the city builds out and more data becomes available.

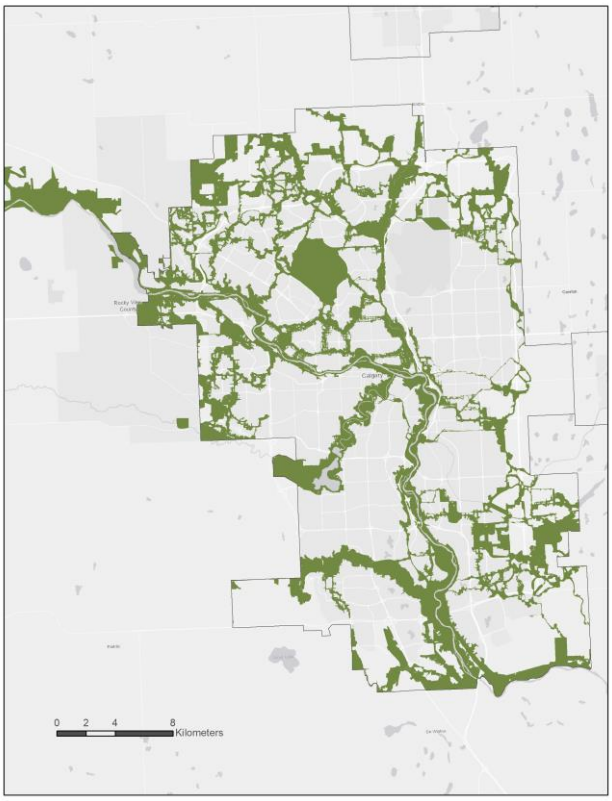

Figure 7. The City of Calgary's Ecological Network, revised from the Municipal Development Plan (2020).

Wetland Prioritization Framework

A wetland prioritization framework was developed through multiple discussions with the project advisory committee which began at a workshop in April 2023. The prioritization framework applies to wetlands that are currently included in the full wetland dataset. The data included in the four components described above were transformed into a simplified format (e.g., binary or quantile) in ArcGIS Pro, and exported for further processing in R. The prioritization framework illustrated in Figure 8 was programmed in R and the result of the first iteration was reviewed by some members of the committee. Field visits to three example wetlands (Bridlewood Wetland Complex, Auburn Bay, and Copperfield Vesta) were conducted to ground-truth prioritization results of wetland condition. This ground truthing exercise helped guide how the framework was revised, which led to a simplified process with a smaller number of resulting bins and a larger emphasis on the Modelled ACI score for the ecological function.

Figure 8 illustrates the final wetland prioritization framework:

- The first decision point of Framework 1 divides the full wetland dataset into two bins depending on whether the wetland had a high (top 50%) or low (bottom 50%) Modelled ACI score based on its ecological function.
- Left hand side of decision tree:
    - Wetlands in the top 50% of ecological modelled ACI scores resulted in priorities 1-4 for protect/manage.

    - The next decision point considered whether the wetland was an amphibian core wetland; if yes, this led to protect/manage 1 or 2 depending on whether the wetland was also classified as a keystone wetland (1) or not (2).
    - For wetlands that were not amphibian core wetlands, we determined if the wetland was within the Ecological Network (if so, this was categorized as a Protect/Manage 3 priority).
- Right hand side of decision tree:
    - The right hand side of the decision tree mirrors the left and results in restoration priorities 1 to 4.

Redhead (Aythya americana) chick at Bridlewood wetland complex. Photo by Tony LePieur.

Framework 1: Wetland Prioritization

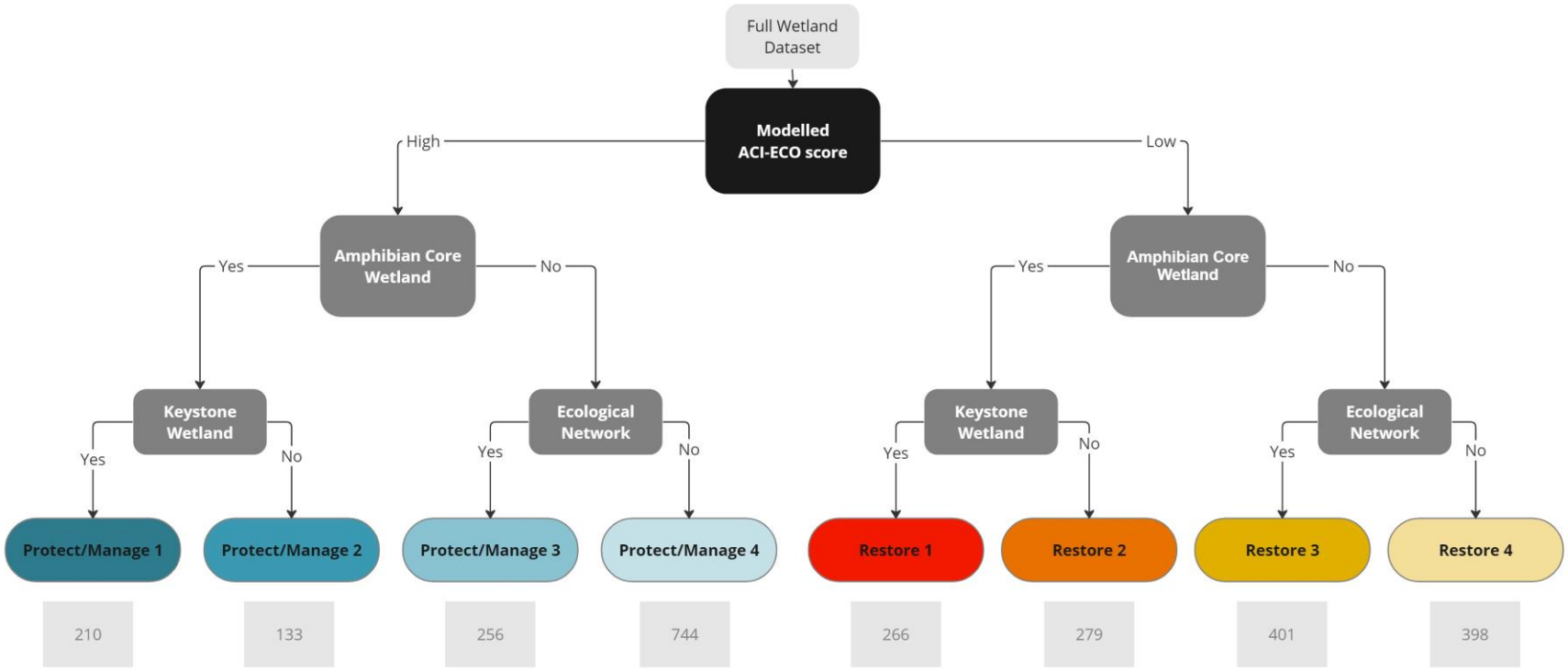

Figure 8. Framework 1: A decision tree illustrating the prioritization framework that results in priorities to protect or manage wetlands ranging 1 to 4, and priorities to restore between 1 and 4, where 1 is the highest priority and 4 is the lowest. The numbers in the grey bins reflect the number of wetlands that resulted from the prioritization framework.

Components of the Corridor Prioritization Frameworks

Amphibian Pathways were identified based on connectivity models for all three amphibian species found in Calgary (Figure 9). These corridors illustrate probable movement pathways for amphibians where high centrality, indicated by darker blue, reflects higher probability of movement, and lighter blue indicate lower probability of movement.

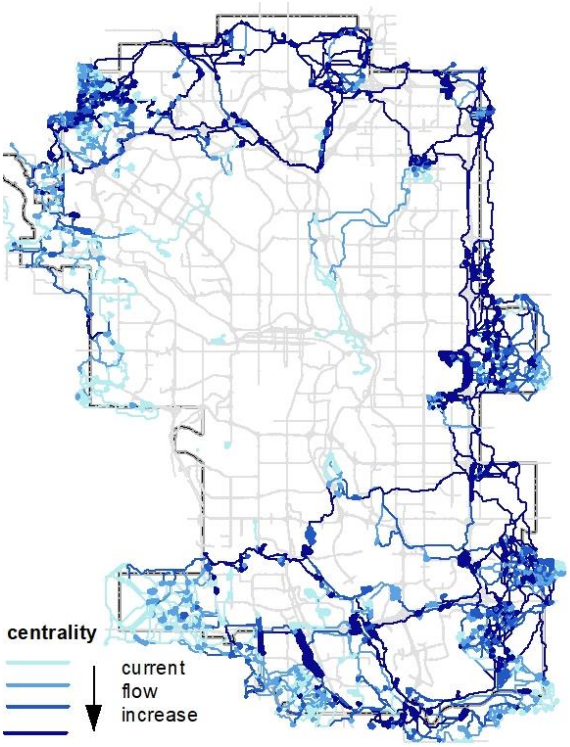

Figure 9. Amphibian pathways reflecting probable movement pathways identified through centrality models. Reproduced from Lee et al. 2020.

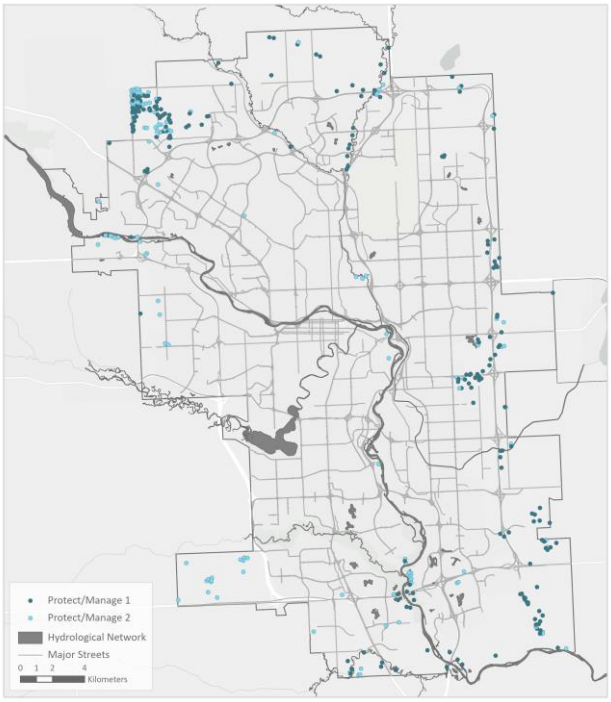

Figure 10. Top two categories for protection priority that resulted from the wetland prioritization framework.

High priority wetlands (prioritized for protection at levels 1 and 2) were identified using the wetland prioritization framework described above. The result of that process was included as an input into the corridor prioritization (Figure 10).

The **Ecological Network** was also used as an input in the corridor prioritization and is described above (Figure 7).

Proximity to **named rivers and streams** (e.g., Bow River, Elbow River, Fish Creek, Nose Creek, Pine Creek) was used as an additional input into the corridor prioritization framework.

Corridor Prioritization Frameworks

While we refer to the corridor frameworks as a prioritization, the results should be considered guidance to identify appropriate strategies for conservation as opposed to a hierarchical list of areas to conserve. In these frameworks, the strategies suited to the different end points (i.e., bins) were less clearly defined than those for protection/management or restoration. As such, we refer to conservation as the overarching goal in this section.

The Corridor Prioritization is made up of two separate frameworks that approach the central goal to conserve the wetland network in the city of Calgary from different ecological perspectives. Framework 2 focuses on retaining and strengthening existing wetland pathways identified using probable movement pathways of amphibians (Lee et al., 2020). Framework 3, on the other hand, focuses on The City of Calgary's Ecological Network, which was derived mainly using terrestrial habitat. Much of the inner city covered by the Ecological Network was not part of the amphibian-centered wetland network and likely reflects the lack of wetland connectivity in that area.

For Framework 2 (Figure 11), the amphibian pathway between two wetlands that resulted from centrality analysis was prioritized (Lee et al., 2020).

- The first decision point of the framework divides the amphibian pathways into the top or bottom 50% probability of movement.
- Left hand side of decision tree:
    - Amphibian movement pathways in the top 50% are considered under Conserve A1-A4.
    - Under this branch, we considered whether the pathway was near other pathways also in the top 50% based on density of pathways within a 1 km^2 hexagon grid.
    - For those pathways located in a high density of other top 50% pathways, we then looked at whether they were near a high density of wetlands that fell into the protect/manage 1 or 2 categories from Framework 1. Once again, high density was defined as the top 50% of densities calculated from a 1 km^2 area hexagon grid.
- Right hand side of decision tree:
    - Pathways in the bottom 50% probability of amphibian movement are considered under Conserve B1-B2.
    - We first looked at whether these pathways were near no other pathways or a low density of pathways; these were classified as Conserve B1.
    - For those pathways that were near other corridors, we then looked at if those surrounding corridors were also in the low 50% of movement probability; these were classified as Conserve B2.
    - If not, these were not assigned a priority.

For Framework 3 (Figure 12), we overlayed a 1 km^2 hexagon grid over the Ecological Network and considered each hexagon using the decision tree as follows:

- The first decision point assesses whether the hexagon contained a low density of wetlands of any priority outcome from Framework 1. Low density was defined as the bottom 50% of densities calculated.
- If yes, we considered whether the hexagon contained a named river or stream. This led to an outcome of Conserve C1.

- If so, these hexagons were given priority level 3 for restoration. If these hexagons were not near a river or stream, these were given priority level 4. The core and stepping stone areas including the Ecological Network modelling were clipped from the final result. This was done because these areas were largely provincial and city parks and already have a certain level of conservation action.

When using these frameworks to prioritize corridors for conservation, the specific framework and decision tree path that is selected should depend on the goal of the work. For example, if the goal is to protect and enhance the existing amphibian movement network, the left hand side of Framework 2 is most suitable. If the goal is to improve the existing amphibian network particularly in areas where the network exists but is vulnerable to alteration, the right hand side of Framework 2 is most suitable. Whereas, if the goal is to improve amphibian movement connectivity in the inner city, Framework 3 is most suitable.

Framework 2:
Corridor Prioritization - Amphibian Pathways

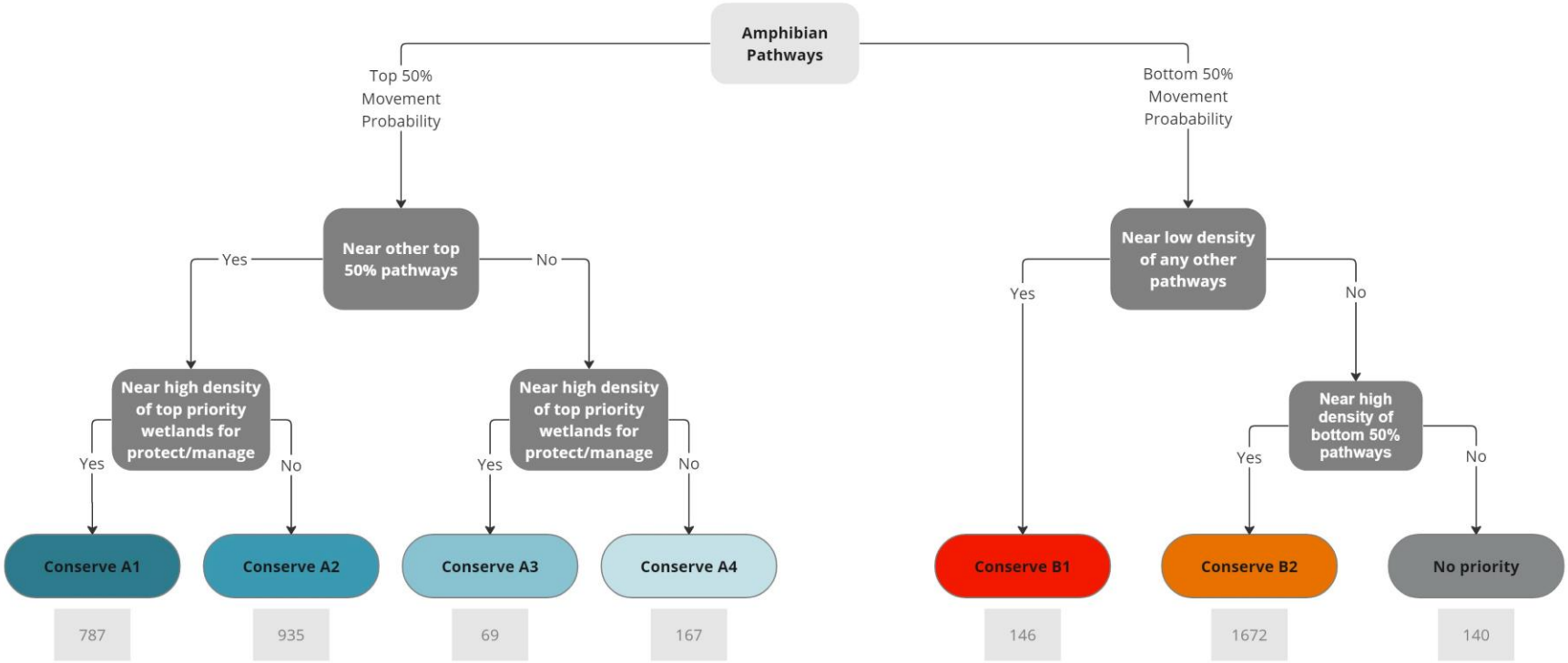

Figure 11. Framework 2: A decision tree illustrating the wetland corridor prioritization framework that results in bins of pathway segments to conserve the wetland corridor network in Calgary ranging from A1 to A4 and B1 to B2. The numbers in the grey boxes indicate the number of amphibian pathways that were categorized in each resulting bin.

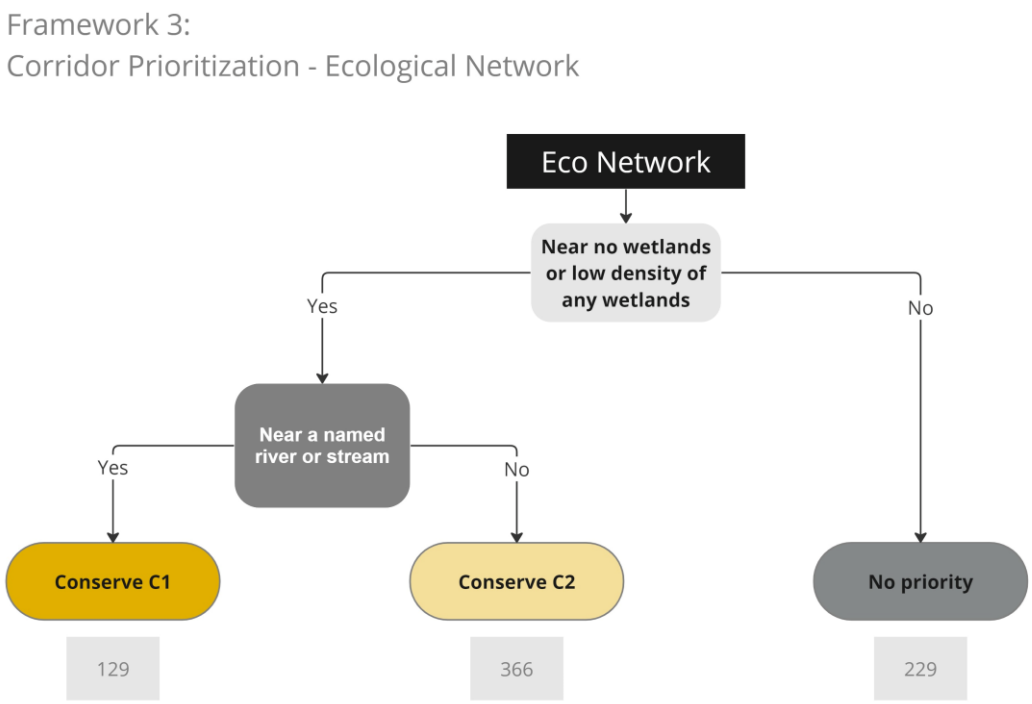

Figure 12. Framework 3: A decision tree illustrating the wetland corridor prioritization framework that results in two bins for conservation based on the Ecological Network. The numbers in the grey boxes indicate the number of hexagons that were categorized in each resulting bin.

Results

Wetland Prioritization

A total of 2720 wetlands were prioritized to either protect/manage (4 bins) or restore (4 bins) (Table 1). Thirty-three wetlands were not classified because they did not have ecological modelled-ACI scores assigned to them (Lee et al., 2023).

Table 1. Number of wetlands classified into each bin based on the wetland prioritization framework, Framework 1

Category	Number of Wetlands
Protect/Manage 1	210
Protect/Manage 2	133
Protect/Manage 3	256
Protect/Manage 4	744
Restore 1	266
Restore 2	279
Restore 3	401
Restore 4	398
Unclassified	33
Total	**2720**

Less than 13% of wetlands within the city of Calgary were in the top two priority categories to protect/manage (Table 1). These wetlands were mainly scattered around the periphery of the city, but a concentration of those wetlands was identified in the far northwest corner of the city (Figure 13). Other spatial concentrations of wetlands prioritized in the third and fourth categories for protection/management occurred in the northeast, east and southeast edges of the city, whereas the central south, and western edges of the city saw lower proportions of wetlands for protection/management.

Twenty percent of the wetlands within the city were classified in the top two priority categories for restoration (Figure 8). A cluster of restore priority 1 wetlands were identified in the southeast periphery of the city and another near the Town of Chestermere (Figure 13). An additional cluster of restore priority 2 wetlands were identified in the southwest of the city. While the density of wetlands was low in the inner city in general, those wetlands that were present were largely classified in low priority bins, whether for protection or restoration.

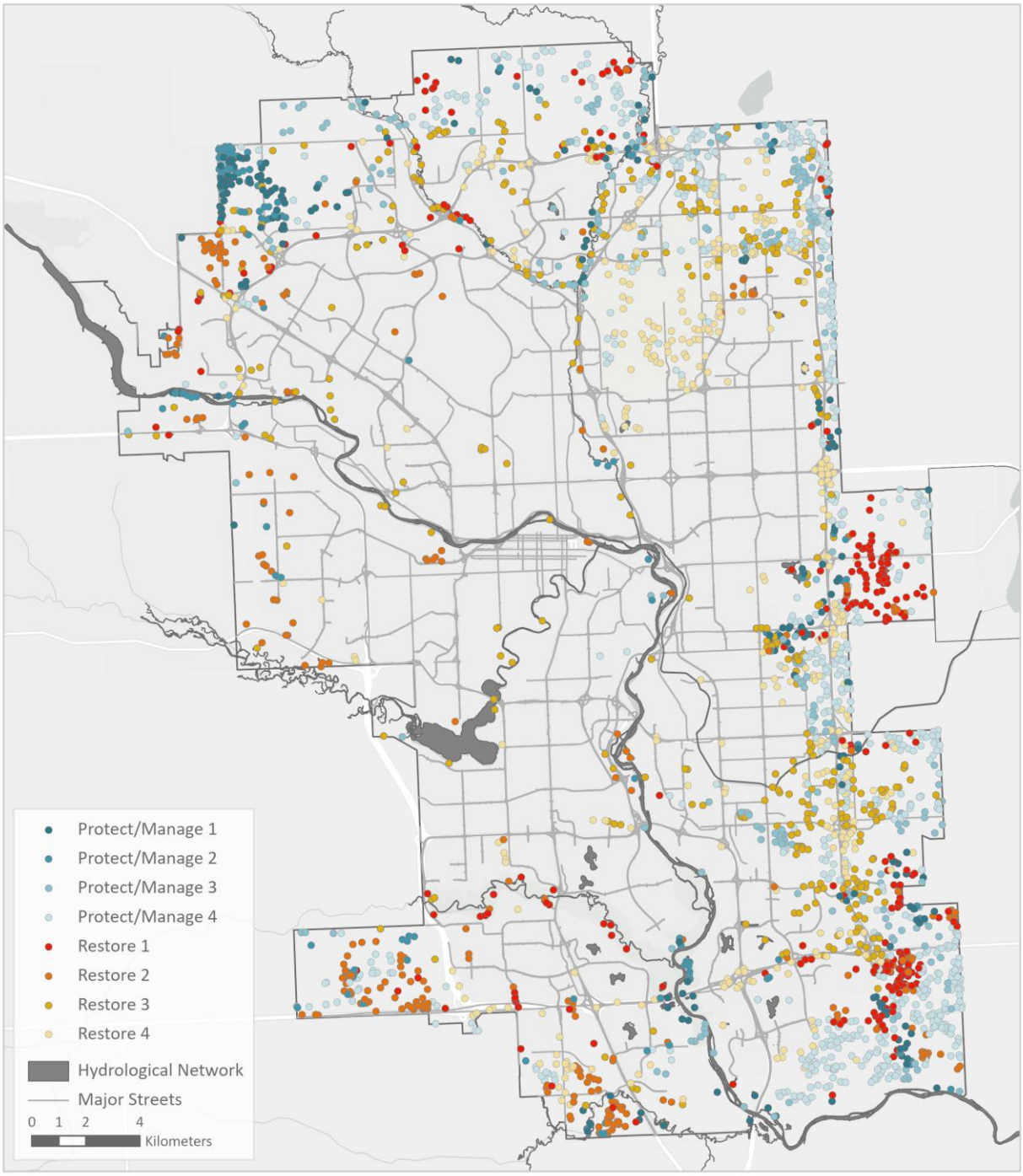

Figure 13. Prioritization results for wetland conservation for The City of Calgary based on the decision tree illustrated in Framework 1 (Figure 8).

Corridor Prioritization

Amphibian Corridor-focused Prioritization

We began with 3916 pathway segments that were identified using a centrality analysis which identified probable pathways of amphibian movement (Lee et al., 2020). Table 2 shows the number of those pathway segments that were categorized into each bin. No pathway segments were unclassified but 140 received no priority based on Framework 2 (Figure 11).

Most of the pathway segments were located on the periphery of the city and most of the segments categorized as Conserve A1- A4 were located on the north and east sides of the city (Figure 14).

The small proportion of pathway segments categorized as Conserve B1 was in the inner city and scattered around the western side of the city. Conserve B2 pathways were located mainly in the south and west of the city (Figure 14).

Table 2. Number of pathway segments categorized into each bin for wetland corridor conservation. These were based on pathways of probable amphibian movement identified by Lee et al., 2020.

Category	Number of Pathway Segments
Conserve A1	787
Conserve A2	935
Conserve A3	69
Conserve A4	167
Conserve B1	146
Conserve B2	1672
No Priority	140
Unclassified	None
Total	**3916**

Ecological Network-focused

We began with a total of 724 hexagon grid units that made up The City of Calgary's Ecological Network. Some of these grid units were partial hexagons as the shape of the Ecological Network was clipped from the hexagon grid that was laid over the City's footprint.

Of the 724 grid units, less than 18% were categorized as Conserve C1 group and just over 50% fell into the restore priority 4 group (Table 3, Figure 15). No grid cells were uncategorized and 32% had no priority based on Framework 3 (Figure 12).

Table 3. Number of grid units categorized into each bin for wetland corridor conservation resulting from Framework 3.

Category	Number of Grid Units
Conserve C1	129
Conserve C2	366
No Priority	229
Unclassified	None
Total	**724**

The grid cells categorized as Conserve C1 were mostly found along rivers within the inner city areas, whereas Conserve C2 were mainly located toward the western side of the city (Figure 15).

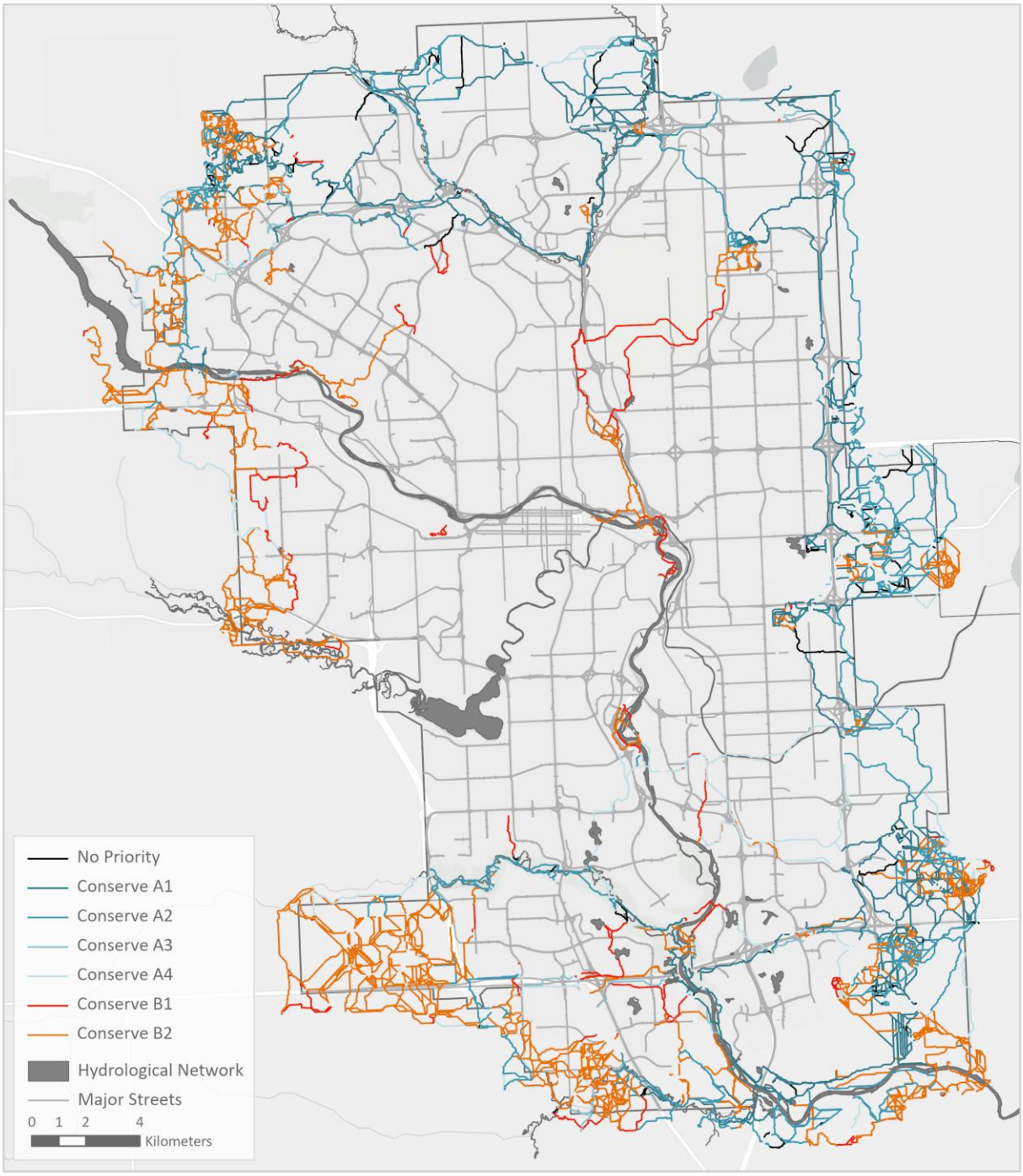

Figure 14. Prioritization results for wetland corridor conservation for The City of Calgary based on the decision tree illustrated in Framework 2 with a focus on amphibian corridors based on probability of amphibian movement Figure 11.

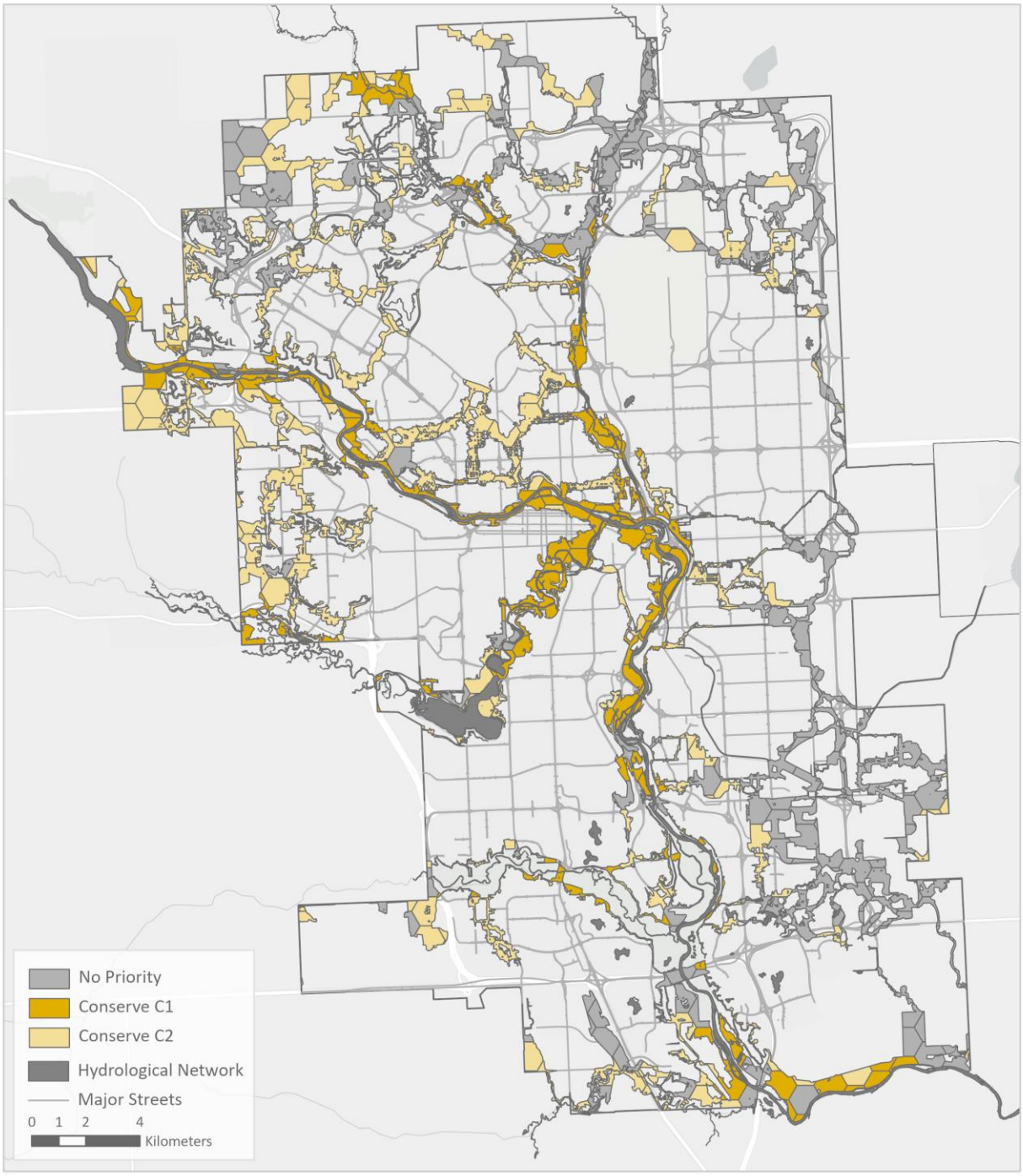

Figure 15. Prioritization results for wetland corridor conservation for The City of Calgary based on the decision tree illustrated in Framework 3 with a focus on The City's Ecological Network.

Discussion

Nature is important to Calgarians and wetlands are an essential part of our ecosystem, providing ecosystem services like clean water, protection from flood and drought, and habitat for a diversity of plant and animal species. This project developed a mechanism to help The City of Calgary prioritize its wetlands and corridors for conservation, including protection, management, and restoration. We designed three prioritization frameworks to support The City of Calgary when making decisions regarding where to focus resources to conserve wetlands and corridors. Conservation is defined here as protection or management actions to preserve the structure and function of these environments, or restoration to return these environments to a pre-disturbance or improved structure and function. Corridor prioritization was approached in two ways: 1. through the lens of probable amphibian movement pathways and 2. from the perspective of The City of Calgary's Ecological Network developed largely from terrestrial habitat and information.

Spatial Distribution of Conservation Priorities

Wetlands

Most of the remaining wetlands in the city are located at the periphery of the city, with most of the amphibian core wetlands located outside the Ring Road where urbanization is still limited. Wetlands within the Ring Road are primarily limited along intact riparian areas, green spaces along major roads, and city of Calgary natural areas and Fish Creek Provincial Park (Lee et al., 2020). Spatial distribution of the wetland prioritization results refines our previous knowledge of wetland distribution provided by Lee et al., (2020) by indicating that most of the wetlands prioritized for protection/management are located at the extreme edges of the city. A small cluster of the highest priority categories were identified in the far northwest where development is still relatively limited.

There were two areas with high concentrations of wetlands identified for restoration (Restore 1); these are located in the southeast of the city and also in an area nearest to the Town of Chestermere. Although there was not a high density of wetlands along Fish Creek, it is noteworthy that they were mainly categorized as Restore 1 or 2 priority.

Most of the inner city wetlands received a low priority score for both protection/management and restoration. This is likely related to their isolation that would result in a low keystone wetland score.

Corridors

Amphibian movement pathways also occur mainly at the periphery of city, in green spaces along major roads, or along intact riparian systems (e.g., Fish Creek, Nose Creek). The centrality analysis conducted by Lee et al., (2020) identified that there are limited movement opportunities between wetlands in the inner city neighbourhoods or in small natural areas within neighbourhoods. This was largely attributed to isolation of the few wetlands that remain in those areas and that distances between them and nearby wetlands exceed dispersal distances of amphibians (Lee et al., 2020). Our prioritization framework identified that most wetland pathways which were categorized as Conserve A1-A4 (pathways in the top 50% of movement probability), were located along the north and east edges of the city. These pathways likely reflect areas of the city where development is still limited, however along the eastern edge of the city, these may also reflect historical densities of wetlands in the region.

Only a small proportion of pathways were categorized as Conserve B1; these identified isolated pathways and were mainly located in the inner city or the west-most edge of town. Although these pathways had low probability of movement, they likely represent the only option for amphibian

movement in the areas where they were found. Because Conserve B1 pathways are isolated, there is a substantial risk that a stochastic event could lead to eradication of amphibians in some areas of the city, so these pathways should be prioritized for conservation to retain healthy amphibian populations throughout the city. The large proportion of pathways that were categorized as Conserve B2 (low movement probability pathways located near other similar pathways) were mainly located in the south and western edges of the city.

Most of the subsections of the Ecological Network that were categorized as Conserve C1 were distributed along rivers in inner city, whereas most that were categorized as Conserve C2 were located towards the west side of the city.

Wetland Conservation Strategies

Protection Strategies

We identified various strategies that can be used to protect wetlands by conducting a search for resources including government sources (municipal, provincial, state and federal – Canada and US). Wetland protection could include mechanisms that allow municipalities to bring new wetlands into The City's inventory allowing them to be effectively managed for biodiversity, or mechanisms to protect wetlands that are already within The City's inventory. In this section, we provide an overview of the various protection strategies that were identified in our resource review.

A **conservation easement** is a tool that may be useful to protect wetlands that are not currently within The City's inventory. A conservation easement is a voluntary agreement that permanently limits some land uses on a piece of land to protect its conservation value. A landowner enters a legal agreement with a qualified organization for all or part of their land. In 1996, a change in provincial legislature allowed Alberta municipalities to become qualified organizations in these agreements. More information about how municipalities can undertake conservation easements can be found in a report by Greenaway (2017) and more general information about conservation easements can be found here.

The City of Calgary may consider **land acquisitions** to target high priority wetlands for conservation. This may be possible through existing City processes for acquiring land through the Real Estate and Development Services department. However, The City may also explore public-private partnerships with Environmental Non-Governmental Organizations to acquire land for conservation.

The City may also consider voluntary programs to **incentivize private landowners** to employ conservation measures on wetlands on their property (Dooley, 2021).

Through the Municipal Government Act RSA 2000, c M-26, municipalities have management authority over water bodies including wetlands within their municipality in most instances. Municipalities can take measures to protect wetlands by identifying them as **environmental reserve** and implementing **setbacks**. Permitting and compliance for activities around wetlands are another way to protect existing City-managed wetlands from degradation.

Some natural areas containing wetlands may be eligible for designation as an **Other Effective Area-based Conservation Measures (OECM)**. An OECM is "a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values" (Convention on Biological Diversity, 2018). A report by the IUCN-WCPA's Task Force on OECMs (2019) included an example of OECM eligibility as "Urban or municipal parks managed primarily for public recreation but which are large enough and sufficiently natural to also effectively achieve the in-situ conservation of biodiversity (e.g. wild grassland, wetlands) and which are managed to maintain

these biodiversity value." However, small, semi-natural areas are unlikely to qualify. An OECM designation would bring requirements for monitoring and reporting to ensure long-term biodiversity outcomes (IUCN-WCPA Task Force on OECMs, 2019), but may provide a stronger basis for The City to ensure permanent protection.

Viewing and valuing wetlands as natural assets may provide a stronger basis for their protection, allowing the value of wetlands to be considered directly in more municipal policy and decision making, and allow for more adequate resourcing for protection, restoration and construction (City of Calgary, 2021b).

Management Strategies

All wetlands that were prioritized for protection should also be managed using beneficial management practices (BMPs) that were developed to promote urban wetland biodiversity (Figure 1) (Kinas et al., 2023). This collection of BMPs was developed for The City of Calgary to address operational activities that may have an impact on wetland biodiversity as identified by City staff. The document provides a list of general and timing-related BMPs as well as activity-specific BMPs. The document indicates whether the BMP is relevant to amphibians, birds or both and provides an operational priority rating that combines ecological importance and operational feasibility. A companion spreadsheet provides guidance on which BMPs should be considered for each operational activity.

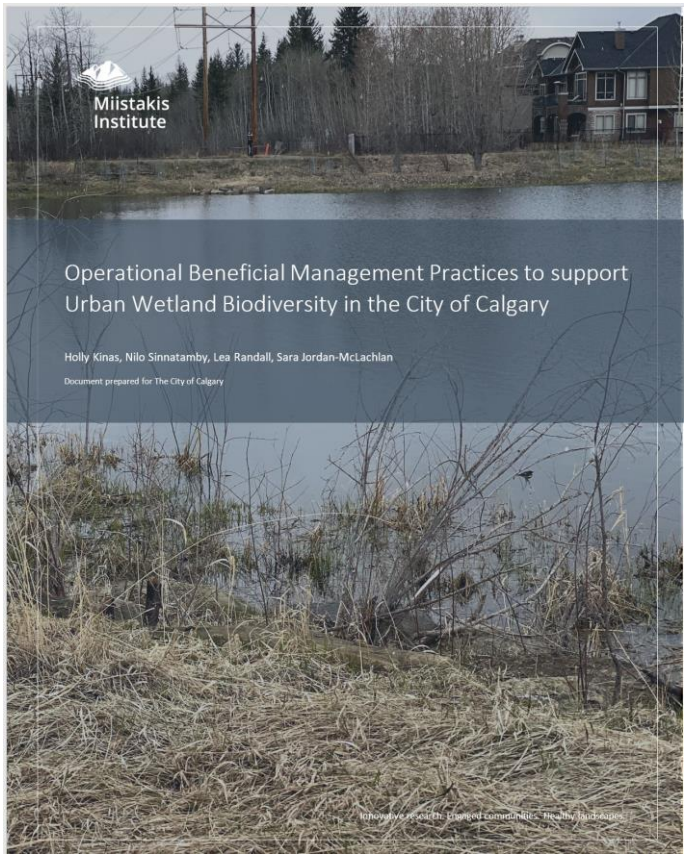

Figure 16. Beneficial Management Practices Guide developed for The City of Calgary

Restoration Principles and Strategies

Wetland restoration should aim to return a degraded wetland to a pre-existing condition or as close to that as possible. Determining specific pre-disturbance endpoints may not be feasible in all settings and in those cases a general aim should be a system with increased ecosystem services and resilience to stressors (reviewed in Burrow & Lance, 2022).

Principles

The following principles were largely informed by the Principles of Wetland Restoration developed by the Office of Wetlands, Oceans and Watersheds of the US Environmental Protection Agency (2000). The principles aim to promote effective restoration and were developed from lessons learned through a wide range of aquatic restoration projects.

- **Consider Feasibility**: Taking feasibility into account is particularly important in an urban environment and at the planning stage. It will help guide the development of goals for each

restoration project and should consider scientific, financial and social constraints (USEPA, 2000).

- **Identify Goals**: Develop clear, measurable goals for each restoration project (USEPA, 2000). The goals should align with feasibility and will guide how to measure success. They should also consider the natural potential of the watershed and aim to restore ecological integrity, specifically targeting natural structure and function. Although this prioritization scheme is aimed at promoting biodiversity, it may be helpful to consider the specific function of the wetland (i.e., hydrological, water quality or biodiversity, Creed et al., 2018; Lee et al., 2023).
- **Apply Adaptive Management**: Once clear goals are established, determine appropriate metrics that can be monitored to measure success (USEPA, 2000). Monitoring should be combined with an iterative process that allows restoration or management actions to change if success is not occurring as expected. A way to measure success could be to use a comparable reference site if one is available.
- **Use Self-Sustaining or Lower Cost Approaches:** These are approaches that will minimize the need for continuous operational intervention (USEPA, 2000). Below are different examples of these approaches.
    - Addressing ongoing causes of degradation will be more likely to result in success for any associated restoration action.
    - Using passive restoration such as allowing recovery time once the cause of degradation is addressed or taking advantage of hydrological events that may reconnect wetlands.
    - Applying beneficial management practices rather than large scale restoration actions.

Strategies

Wetland restoration involves a broad range of actions that aim to improve the natural structure and function of wetlands. Which strategies are employed will depend on the specific goal of the project and the feasibility constraints on the site. For tailoring restoration activities to support amphibian populations in Calgary, the habitat and dispersal needs and sensitivities of the three amphibian species found in Calgary should be considered; these are well described by Kinas et al., (2023). A detailed field assessment should be conducted to determine the appropriate restoration actions needed to address site-specific issues to support the habitat needs of those species. And the beneficial management practices outlined by Kinas et al., (2023) should be considered when conducting any restoration activities.

Wetland restoration strategies to promote amphibians can fall into the following broad categories:

- **Hydrological Restoration**: Most wetlands in Calgary perform some stormwater function and include water conveyance infrastructure that can be controlled to some degree. To promote amphibian populations, wetland hydrology should be managed to mimic natural hydrology such as hydroperiod (Pilliod & Wind, 2008). Ephemeral wetlands can be an important resource for amphibians but are often not maintained in an urban environment; this is a factor that can be addressed through hydrological restoration.
- **Soil Management:** Compacted soils or erosion could both be detrimental to amphibians depending on species and life stage. As an example, a restoration project aiming to improve burrowing habitat for tiger salamander or conduct vegetation plantings may include mitigation for compacted soils. This could include soil aeration or adding topsoil.

- **Water Quality Improvement**: Water quality is a serious concern in urban wetlands and stormwater ponds with implications for amphibian populations. Restorations to mitigate low water quality could include increased vegetation to promote uptake or filtering of contaminants, alterations in hydrological regime to promote flushing and/or creating sedimentation basins to control where contaminated inputs may settle.
- **Vegetation Management**: Restoration actions that promote native vegetation structure and composition resulting in a heterogeneous habitat should be considered (Pilliod & Wind, 2008). This may include removing non-native plants or plantings preferred native species species to avoid monotypic vegetation that can hinder amphibian movement. In addition to providing habitat, vegetation buffers can improve water quality by filtering water from contaminants and silt (Pilliod & Wind, 2008).
- **Management of Fish**: Both native and non-native fish can have negative impacts on amphibians. In Calgary, it was estimated that over 200 stormwater ponds contained goldfish or Prussian Carp (CBC News, 2023); carp can significantly alter aquatic ecosystems and goldfish have been known to consume tadpoles (Meyer et al., 1998). Non-native fish removals may be necessary to promote amphibian populations in Calgary. Most of the wetlands in Calgary perform some stormwater function and there is a tendency for wetlands that are retained on the landscape to hold water permanently as opposed to ephemerally. However, ephemeral wetlands can provide vital resources for amphibians and are also not suitable to support fish because of their temporary nature. As such, promoting hydrological management to keep ephemeral wetlands on the landscape should also be considered.

Corridor Conservation Strategies

The two approaches we used to identify corridors for conservation and the resulting outcomes from the prioritization frameworks may require different conservation strategies to address differences in their root characteristics/challenges. For example, the amphibian-focused framework (Framework 2, with framework outcomes A1-B2) relied on probable movement pathways identified through a modelling exercise that used a resistance layer based on GIS data and expert opinion (Lee et al., 2020). The outcome reflects areas that amphibians are already likely using. On the other hand, the Ecological Network-focused framework (Framework 3, with framework outcomes C1-C2) was based on terrestrial modelling and did not consider amphibians. Table 4 indicates which strategies are likely to be most suited to each framework outcome; the strategies are described below.

Table 4. Strategies for wetland corridor conservation – protection and restoration – to promote the amphibian network and amphibian populations in The City of Calgary. A1-A4 correlate with outcomes from the left-hand side of Framework 2, B1-B2 correlate with the right-hand size of Framework 2, and C1-C2 correlate with the outcomes from Framework 3. The dots indicate which strategies apply most to which Framework outcomes.

	Framework Outcomes							
Strategy	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**
Protection: Natural Assets	●	●	●	●	●	●	●	●
Protection: Ecological Network	●	●	●	●				
Barrier mitigation: Roads	●	●	●	●	●	●		
Barrier mitigation: Other impervious surfaces	●	●	●	●	●	●		
Barrier mitigation: Manicured turf	●	●	●	●				
Restore nearby wetlands		●		●	●	●	●	●
Resurrect drained or historical wetlands					●		●	●
Naturalize upland area surrounding stormponds	●	●	●	●			●	●
Buy-out programs							●	

Protection

Natural Assets

Naturalized spaces are also considered natural assets within the city of Calgary and like wetlands, being considered natural assets may provide a stronger argument for their protection particularly as The City of Calgary's natural asset valuation assessment tools evolve to accurately communicate the economic benefit to retaining, protecting and managing healthy urban wetlands (City of Calgary, 2021b).

Ecological Network

An additional strategy to protect amphibian pathways identified by Framework 2 may be to consider them in future refinements of The City's Ecological Network (City of Calgary, 2020).

Barrier Mitigation

Roads

Roads represent a large challenge to amphibian movement in the urban environment and was demonstrated as a significant barrier to movement between core wetlands by Lee et al., (2020). Movement challenges presented by roads can be mitigated through crossing structures such culverts (Beebee, 2013; Helldin & Petrovan, 2019; Smith et al., 2019). Lee et al., (2020) identified a need to prioritize sites for mitigation that would have the largest impact on the amphibian populations in Calgary. The prioritization frameworks presented here address that gap. The pathways we identified in this report could be further narrowed based on road size or traffic volumes to address issues around feasibility and cost. We would further recommend that The City of Calgary incorporate guidelines and policy adjustments to ensure mitigation for amphibians during new road development. Barriers created by the existing road network could be considered through integration of amphibian movement into transportation maintenance and upgrade projects for the existing road network.

Other Impervious Surfaces

Centrality analysis conducted by Lee et al., (2020) also identified likely barriers to movement (Figure 17). Many of the barriers identified using this method are roads, but some are likely other unidentified impervious surfaces or barriers like fences, retaining walls, parking areas and other engineered structures that challenge amphibian movement. Where barrier hotspots align with areas of importance highlighted by the prioritization framework, these areas should be assessed through field visits to determine what the barrier is and appropriate mitigation strategies.

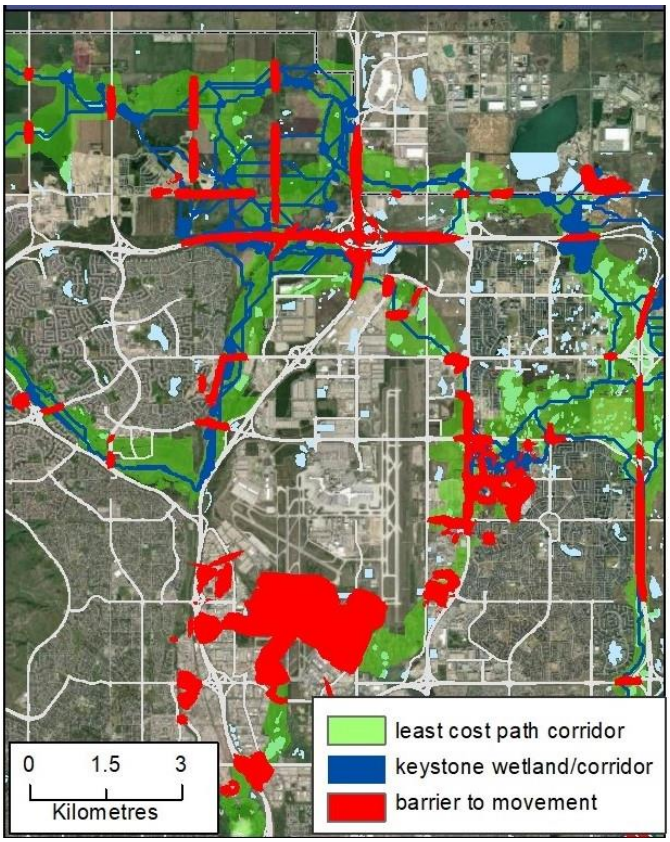

Figure 17. Barriers identified through centrality analysis conducted by Lee et al., (2020). Map illustrates barriers in a smaller area of Calgary near the airport.

Manicured Turf

Manicured turf was found to have a positive association with amphibian occupancy in Calgary (Lee et al., 2020), however, this may reflect a preference for these areas in comparison to more impervious surfaces. Lee et al., (2020) recommended naturalizing manicured spaces in the amphibian corridor to improve connectivity and usability by amphibians.

Restore Nearby Wetlands

For some framework outcomes, we identified existing amphibian pathways that were not located near a high density of wetlands that were ranked highly for protection. In this case, an effective strategy to enhance existing amphibian pathways would be to conduct site assessments at nearby wetlands to assess whether wetland restoration or application of beneficial management practices of a complex of wetlands could improve individual wetland condition and have beneficial impacts on the pathways.

Resurrect Drained Wetlands

The City of Calgary recently supported the development of four new wetland-focused spatial datasets for the Bow River Region. Figure 18 shows wetland inventory (blue polygons) and basins identified as potentially restorable around Calgary. The potentially restorable basins were thought to indicate drainage from the basin, that if addressed could restore the wetland. These new spatial layers provide additional resources that The City could employ to identify basins for restoration. The new wetland inventory may also contain new wetlands that are not yet part of The City's inventory but on City-owned land. More information about the datasets, how to download the data, and additional ideas on how they can be used can be found at www.bowregionwetlands.ca.

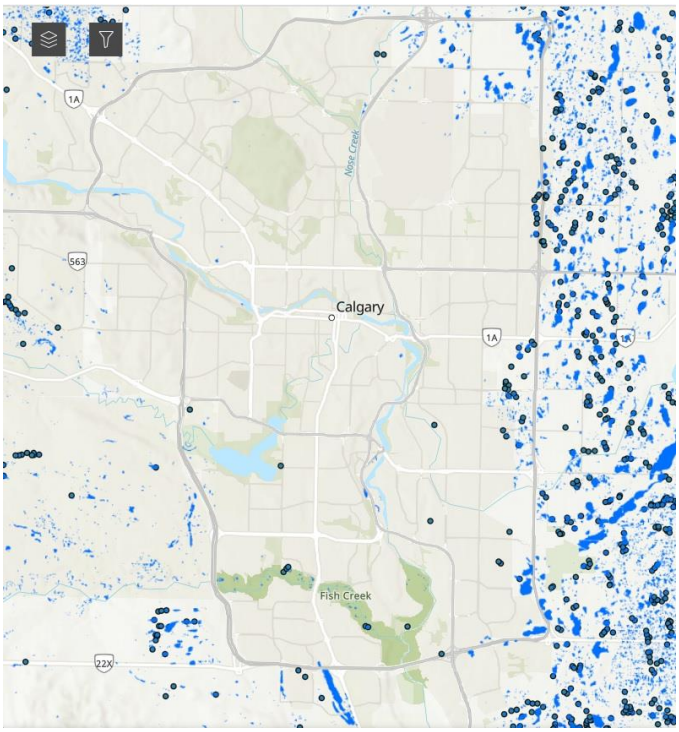

Figure 18. Wetland inventory (blue polygons) and potential restorable bins (blue points) in and around the City of Calgary. These data layers were developed as part of the Bow River regional wetland datasets project.

Naturalize upland area surrounding storm ponds

It may be challenging to find new land that can be used to resurrect or construct wetlands, particularly in the inner city. Naturalizing upland areas surrounding existing storm ponds may improve wetland conditions at these sites and improve connectivity between wetlands by extending usable areas. As well, naturalizing amphibian movement pathways along road rights-of-way, which were identified as opportunities for restoration, may strengthen existing pathways.

Buy-out Programs

Buy-out programs have been used in other jurisdictions in flood prone areas to reduce flood risk to infrastructure. Once the land is acquired, the site is returned to more natural conditions and the area is kept as an open space (Dooley, 2021).

Recommendations

Feasibility Refinement

The prioritization frameworks presented above are mainly based on ecological principles and spatial resources which are also based on ecological data with a focus on amphibians. Some of the resulting priority bins contain a large number of wetlands and it would be cost prohibitive to conduct field visits to each wetland to assess appropriate next steps. We recommend that The City narrow these priority bins further by applying additional feasibility filters. Field visits should be conducted on a smaller number of sites before protection, management or restoration actions are taken. Below are some feasibility filters that can be considered by the city:

City-owned land: City-owned land likely provides a simpler logistical process to implement any protection, management, or restoration actions. In addition to a simpler process for access, The City would already have additional information about the wetland such as historical information and stormwater function.

Parks and Open Spaces: These are areas that have already been earmarked for promoting biodiversity. As such, they likely have less conflict with other land uses.

Natural Area Parks: Within Parks and Open spaces, natural area parks have a specific mandate for promoting ecological function. As such, these areas likely have the least conflict with other land uses including stormwater function.

Periodically Update Prioritization

The prioritization frameworks presented in this report provide an ecological basis to prioritize wetlands and corridors for protection, management and restoration based on current knowledge. We recommend that the prioritization frameworks are revisited or rerun if new wetland or land use information is acquired. They can also be updated to reflect new goals identified by The City. Some examples of this include:

- Given that the wetland prioritization is strongly dependent on the ecological modelled ACI values, if that model is updated with new data for The City of Calgary, we recommend that the wetland prioritization is reanalyzed as well.
- The City of Calgary is currently developing a typology to define its various wetlands ranging from fully constructed stormwater ponds to less modified retained natural wetlands. Once the typology has been completed for all wetlands in Calgary, this will allow The City to prioritize conservation and strategies that align with the role of the wetland. For example, higher priority may be applied to existing retained wetlands, which are in a relatively undisturbed state.
- A key knowledge gap for amphibian conservation is an understanding of which wetlands have native fish populations vs. non-native fish populations or are fishless. If this information is acquired for the City's wetlands, the prioritization framework could be updated to prioritize protection of fishless wetlands, or fish removal at wetlands with non-native fish.

Education and Outreach

Although Calgarians have been clear that a city with healthy natural spaces is of utmost importance (City of Calgary, 2021a), wetland and corridor restorations and naturalization projects can be counterintuitive to how people would like to see natural spaces. Raising awareness of the important role that wetlands play in Calgary and the many ecosystem services they provide, as well as what a healthy natural space can look like will help build community support for these projects. Including communities and community education components in specific restoration projects will also build support and foster a stronger understanding of wetlands.

The City of Calgary has a strong tradition of environmental stewardship and was the first municipality in Canada with a wetland conservation plan (City of Calgary, 2004). Incorporating a mechanism to prioritize wetlands and corridors for conservation is a positive next step that will help to maximize the efficient use of resources to conserve these valuable assets.

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