Natural Asset Inventory & Valuation for the City of Leduc



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City of Leduc

Project #2513

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Executive Summary

Overview

Background

Municipalities are responsible for providing key public services to their residents. Many of these public services are delivered through engineered solutions like stormwater management facilities, floodways, and water treatment plants; infrastructure that is essential to creating a safe and healthy community. While engineered assets are vital to the provision of municipal services, municipalities also host assets that extend beyond traditional infrastructure such as forests, grasslands, and wetlands, that can be considered equally vital to the provision of key services. For example, wetlands store water, improve water quality, and moderate climate through carbon storage and sequestration. Vegetative cover can help control erosion, regulate temperatures, and support healthy insect populations that pollinate crops and wild flora.

Despite the significant contribution that ecosystems make to the health, well-being, and sustainability of communities, municipal asset management activities generally ignore the contributions of natural assets. As a result, natural assets are often lost and converted to other land uses, and the benefits of the ecosystem services provided from these assets are foregone. Recently, there has been a growing awareness that integrating natural assets into land use planning and managing these assets alongside engineered assets results in economic, environmental, and social benefits. A natural asset inventory that describes the spatial extent of municipal natural assets, the condition of the assets, the ecosystem services that they provide, and the economic value of those services is a key first step to incorporating natural assets into municipal asset management frameworks.

Study Purpose

The City of Leduc has a Municipal Development Plan (City of Leduc 2020a) with a vision that describes respect for the environment and accordingly, includes as a key strategy the need to balance municipal development with the preservation of the natural environment. Further, as part of the City's Environmental Plan (City of Leduc 2024), the City of Leduc aims to "be a community leader in environmental sustainability and stewardship" and identifies developing a natural asset inventory as a high priority action. As such, the City commissioned this study to map natural assets, quantify key ecosystem services produced by those assets, and identify benefits provided by those services to City residents, such that this information can be used to identify priority assets for conservation or protection, especially in the context of the planning and development of new subdivisions.
The City's natural asset inventory and valuation is a key first step to the City's broader natural asset management objectives that it is beginning to pursue.

Methodological Approach

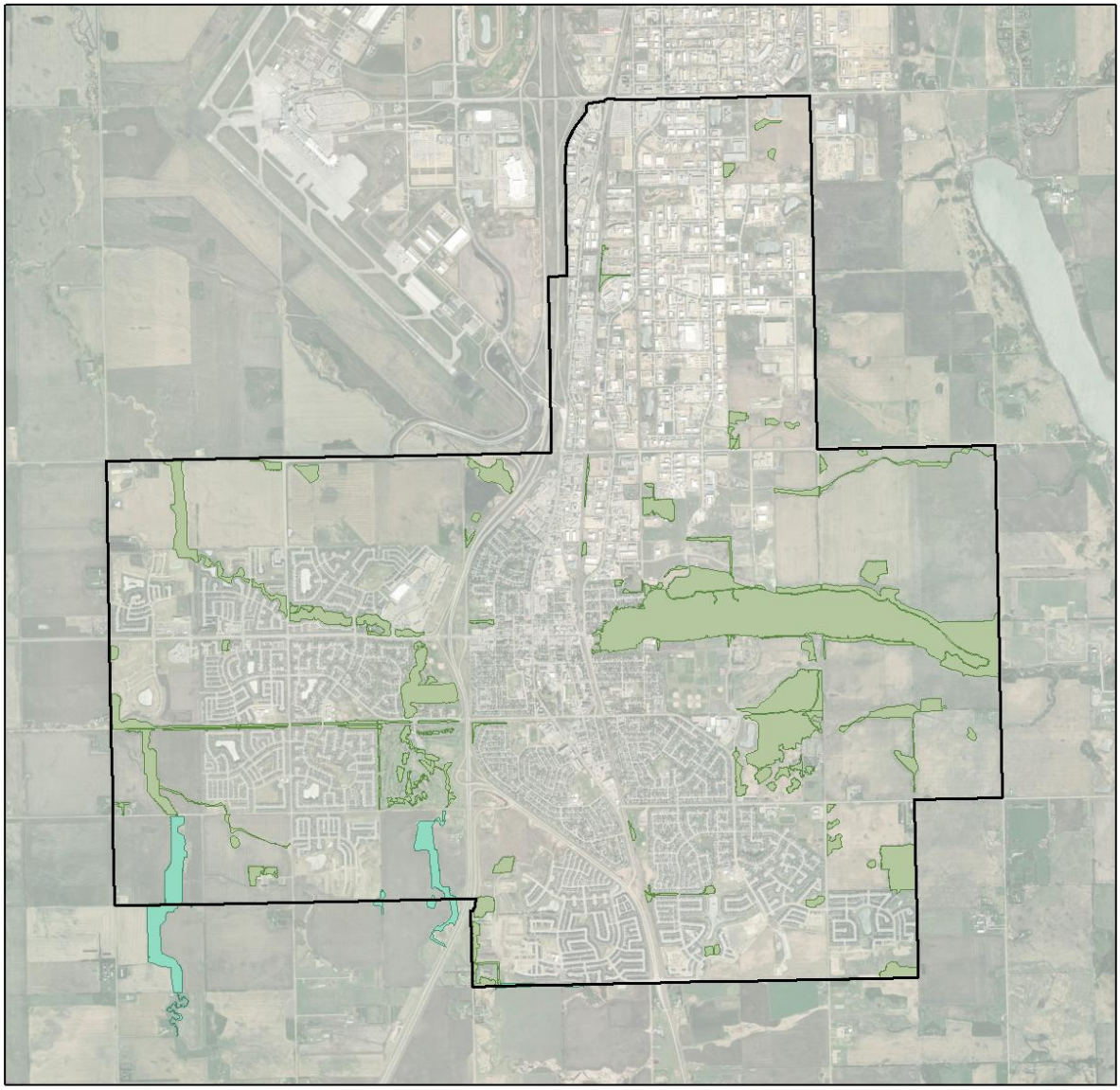
This project followed a stepwise approach to inventorying natural assets and assessing the value of ecosystem services associated with those assets. First, the purpose and focus of the assessment was defined through a workshop and ongoing consultation with City staff. Through this process, a list of priority ecosystem services was identified and included:

- water flow regulation,
- air quality regulation,
- atmospheric regulation,
- temperature regulation,
- wildfire regulation, and
- nature-based recreation.

Next, existing land cover products were extensively updated and processed to create the inventory of natural features. The study area was delineated as the area within the City's municipal boundary. Natural assets that extend across the City boundary and into Leduc County were included as well to account for transboundary assets. All mapping and assessment were applied within this study area extent. Then, the relative condition of natural assets was assessed in GIS using available spatial datasets. The delivery of ecosystem functions and services were then assessed using the modelling software InVEST, which provided relative scores for assets for the various ecosystem services of interest. Finally, monetary values for priority ecosystem services were calculated, where possible, and the natural asset inventory was attributed with this information.

Study Findings

A total of 104 unique natural assets were identified in the study area within the City and transboundary with Leduc County, covering 401 ha. Roughly 363 ha of the natural asset area is located within the City boundary, covering roughly 8% of the City. Assets range in size from 0.3 ha to 166 ha, with most ranging between 0.5 and 5.0 ha. There are 11 assets larger than 5 ha, which together account for 72% of the total natural asset area and represent large habitat patches that serve as core wildlife habitat at the local and regional scale. Woody cover was the predominant cover type within natural assets at 36%, although water cover was also substantial at 27%. Just over half (54%) of the natural assets have a relative condition score of Fair, with 9% considered Good, 36% rated as Poor, and 2% assigned a relative condition score of Critical.


Natural Assets
Jurisdiction
City of Leduc
Shared
N
0
0.5
1
2
3
KM
Natural Asset data created by Fiera Biological Consulting Ltd. Base Map data provided by Government of Alberta under the Open Government License and Esri, Maxar, Earthstar Geographics, and the GIS User Community.

The total estimated value of the ecosystem services that were evaluated in the City of Leduc is approximately **$361.8 million**.[1]

Nature-based recreation was the highest value service, with an estimated value of $347 million. This value reflects the importance of the City's natural assets for providing nature-based recreation opportunities to residents. Atmospheric regulation was the next highest valued service, with an estimated value of $13.5 million. This captures the value of carbon sequestration and the estimated avoided damages from various climate change impacts including, but not limited to, changes in net agricultural productivity, human health effects, property damage from increased flood risk, disruption of energy systems, and the value of ecosystem services (Government of Canada 2024). Finally, air quality regulation provided by natural assets was estimated to be worth roughly $1.3 million to City residents.

ESTIMATE OF ECOSYSTEM SERVICE VALUES IN THE CITY OF LEDUC

Ecosystem Service	Monetary Estimate ($2024)	Confidence in Estimate
Water Flow Regulation	*Partially Captured in Atmospheric Regulation*	--
Air Quality Regulation	$1.3 million	🔴
Atmospheric Regulation	$13.5 million	🟠
Temperature Regulation	*Partially Captured in Atmospheric Regulation*	--
Wildfire Regulation	*Discussed Qualitatively*	--
Nature-based Recreation	$347 million	🟠
Total Quantified Monetary Estimate	**$361.8 million**	

Notes:

🟢 Some assumptions or estimation was used to derive estimate, but the value is considered uncontroversial.

🟠 Some assumptions or estimation was used to derive estimate, which may be open to question. Accuracy of estimate is better than +/- 50%.

🔴 Estimates are in the right order of magnitude. Order of magnitude implies that for an estimate of 5 the real value is within the range of 0.5 to 50.

-- A value that is in the right order of magnitude cannot be estimated. This is due to the unquantifiable uncertainty in the science, valuation, or the relationship between them. What is understood can only be discussed qualitatively.

In terms of asset-specific economic value, only air quality regulation and atmospheric regulation estimates could be assigned to individual assets, and because trees and shrub cover drives value for these ecosystem services, the assets with the highest monetary values in the study area were generally associated with large natural assets that had extensive woody cover. Nature-based recreation values are assessed at a City-level and other ecosystem services evaluated in this work are discussed qualitatively. Telford Lake ranks as the highest valued asset, providing over $4.2 million in air quality and atmospheric regulation services. With respect to the City's $347 million in nature-based recreation value across all assets, it is likely that Telford Lake makes up a large proportion of this value as well, given the high-quality recreation opportunities that it affords. The woodland/wetland complexes near the Recreation Centre/Lions Campground and in Peace Park, a large woodland area just north of the Robinson neighbourhood, and a creek/riparian area extending along the City's southwest boundary are all in the top ten valued assets in the City.

[1] This value was calculated as a present value over a 50-year period at a 5% discount rate. All values are CAD $2024 unless otherwise stated.

For ecosystem services that were not valued in monetary terms, such as water flow regulation and temperature regulation, the estimated ecosystem service supply was used to highlight key assets. Telford Lake, the Leduc Reservoir, the woodland areas near the Recreation Centre/Lions Campground and north of the Robinson neighbourhood, as well as others, provide high or moderately high flood attenuation and cooling services to residents of the City.

Limitations & Uncertainties

Collecting primary data for ecosystem service valuation was outside the scope of this study. Instead, economic estimates from other studies were used to determine ecosystem service values, and these estimates may not be entirely representative of the ecosystem service values in the City. Furthermore, like market goods, the values of non-market ecosystem services are not necessarily static in nature. For example, as a natural asset becomes scarcer, the value of the asset will likely increase. Additionally, welfare estimates are known to change across income levels (those with higher incomes may be willing to pay more for natural assets than those with lower incomes). Given these limitations, the monetary values provided should be considered estimates only, with an acknowledgement that there are gaps in our knowledge of and ability to assess the monetary value of ecosystem services.

Next Steps

The City of Leduc has completed an important step in recognizing the value and benefits that natural assets provide to its citizens. The next steps involve defining policies, strategies, and plans that will ensure the successful integration of the natural asset inventory into a broader asset management system and the implementation of policies and plans that will ensure natural assets are considered in land development and management decisions.

List of Terms

Acronyms

CO_2e: Carbon dioxide equivalent

ECCC: Environment and Climate Change Canada

ES: Ecosystem Service(s)

POST: Parks, Open Spaces and Trails

PV: Present Value

SC-CO_2e: Social cost of CO_2 equivalent

SC-GHG: Social Cost of Greenhouse Gases

UHI: Urban Heat Island

WTP: Willingness to Pay

Glossary

Benefit Transfer (BT): a valuation approach that allows for the value of ecosystem services to be established through a review of published studies that contain estimates of values for comparable ecosystem services in similar jurisdictions.

CO_2e: carbon dioxide equivalent is a standard unit for measuring greenhouse gas emissions, allowing different gases to be compared based on their global warming potential. It allows for the conversion of all greenhouse gases into a single, comparable metric by expressing their impact as an equivalent amount of carbon dioxide.

Discounting: the process of calculating the present value of a future stream of costs or benefits.

Ecosystem function(s): intermediate between ecosystem processes and services; defined as the capacity of ecosystems to provide goods and services that satisfy human needs, directly and indirectly.

Ecosystem process(es): changes or reactions occurring in ecosystems; either physical, chemical, or biological; including decomposition, production, nutrient cycling and fluxes of nutrients and energy.

Ecosystem service(s): contributions of ecosystem structure and function—in combination with other inputs—to human well-being

Ecosystem service demand: the sum of all ecosystem goods and services currently consumed or used in a particular area over a given period.

Ecosystem service supply: the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given period.

Land cover: the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other cover types, that are mapped in a Geographic Information System (GIS). Land cover mapping is essential component of many land management practices, including ecosystem service mapping and assessment.

Natural asset: naturally-occurring habitats or ecosystems that contribute to the provision of one or more services required for the health, well-being, and long-term sustainability of a community and its residents. In this study, natural assets were defined as areas that were predominately covered by native vegetation (trees, shrubs, grasses, and forbs), as well as water bodies such as lakes, wetlands, streams, and rivers.

Present value: today's value of an expected future stream of costs or benefits.

Willingness To Pay (WTP): the maximum amount someone is willing to pay for the provision of a product or service.



1.0 Introduction

1.1. Background & Purpose

Municipalities are responsible for providing key public services to their residents. Many of these public services are delivered through engineered solutions like stormwater management facilities, floodways, and water treatment plants; infrastructure that is essential to creating a safe and healthy community. The efficient management of engineering infrastructure is critical for municipalities to ensure residents are well-served while also ensuring the community is in a healthy fiscal position year to year. Given that traditional municipal assets are market goods with clear monetary values, they are relatively easy to manage through asset management systems that allow for the financial assessment, monitoring, and replacement of assets.

While engineered assets are vital to the provision of municipal services, municipalities also host assets that extend beyond traditional infrastructure such as forests, grasslands, and wetlands that can be considered equally vital to the provision of key services. For example, wetlands store water, improve water quality, and moderate climate. Vegetative cover can help control erosion, regulate temperatures, and support healthy insect populations that pollinate crops and wild flora. Notably, many natural assets provide the same or similar services as engineered assets and can often do so at reduced cost because the capital and operating costs are often lower. Natural assets are also generally more resilient to the effects of climate change than engineered assets (Brown et al. 2019).

Whereas traditional engineered asserts are relatively straightforward to manage, natural assets are not. Ecosystem services that flow from natural assets are dynamic and highly dependent on the condition of the natural assets themselves. Further, despite providing large benefits to municipal residents, ecosystem services are difficult to monetize because they are not traded in traditional markets. As a result, very few municipalities have a comprehensive inventory of their natural assets, nor do they acknowledge or estimate the ecosystem services that flow from those assets, or the economic value of those services. The true cost of removing versus maintaining natural assets in terms of their value is therefore rarely factored into land development decisions, putting natural habitats at risk of being lost or converted in favour of other land uses. Recently, there has been a growing awareness that integrating natural assets into land use planning and managing these assets alongside engineered assets results in economic, environmental, and social benefits. As such, municipalities across Canada are beginning to acknowledge that accounting for and actively managing natural assets are critical components of municipal service delivery and will contribute more livable, resilient communities.

The City of Leduc (hereafter the City) has clearly acknowledged in several of their high-level planning documents, including their Municipal Development Plan (City of Leduc 2020a) and Environmental Plan (City of Leduc 2024), that natural assets are important to the well-being of their residents. To properly account for the benefits of natural assets, this study was initiated to identify and map natural areas within the City, and where possible, provide an estimate of the monetary value of key ecosystem services that flow from those assets. The inventory and valuation described in this report is a key first step to the City's broader natural asset management objectives that it is beginning to pursue. The inventory will serve as a foundation for this natural asset management work and future nature-related policy development in the City.

1.2. What are Natural Assets & Ecosystem Services?

A natural asset is a naturally occurring feature, habitat, or ecosystem that contributes to the provision of one or more services required for the health, well-being, and long-term sustainability of a community and its residents. A key component of this definition is the linkage between a natural asset and the provision of ecosystem services. The concept of natural capital and ecosystem services first began to emerge in the 1990s (e.g., Costanza and Daly 1992; Costanza et al. 1997), and over the last two decades the terms, definitions, and frameworks for classifying and assessing ecosystem services have changed and evolved. Early definitions described ecosystem services as the direct and indirect benefits or contributions to human well-being derived or obtained from natural habitats (Millennium Ecosystem Assessment 2005; TEEB 2010; de Groot et al. 2010). More recent definitions are more specific with respect to recognizing and describing how ecosystem structure and function contribute to human well-being (Burkhard et al. 2012; Burkhard & Maes 2017).

In terms of understanding what ecosystem services are, and how they relate to ecosystem function and benefits, the “cascade model” has become a commonly used heuristic for communicating the linkage between the biophysical structure and function of an ecosystem or natural asset, and how these produce services that directly or indirectly benefit society (Figure 1) (Potschin & Haines-Young 2017). Within this model, ecosystem services are at the interface between the environment (i.e., biophysical structure/process and ecological function) and people (i.e., social and economic systems). The “environment” is typically represented by a habitat or natural asset (e.g., wetland), and the ecosystem functions are the characteristics or properties of that habitat that are potentially useful to individuals or communities (e.g., water storage, filtration). In turn, ecosystem services are derived from ecosystem functions and represent the realized flow of services for which there is a demand (e.g., flood protection, water treatment) (de Groot et al. 2010; Maes et al. 2018; Potschin & Haines-Young 2017).

Importantly, an ecosystem service only has value if it creates a benefit that is experienced by an individual or a community; thus, clearly understanding the beneficiary of an ecosystem service is an important consideration in any assessment. In many cases, there is a desire or interest in quantifying the value of ecosystem benefits, and because people benefit from ecosystem goods and services across a range of different dimensions (Summers et al. 2012), valuation can be determined using monetary or non-monetary valuation approaches. The cascade model also acknowledges that the supply of ecosystem services can be impacted or regulated by external pressure or policy action, and that land management decisions can positively or negatively impact ecosystem structure and function, which in turn affect the amount and quality of the final service, as well as the benefits and values derived from that service.

Given the relationship between ecosystem function, ecosystem service supply, and benefit provision, a natural asset inventory and valuation exercise should track and measure indicators across the entire ecosystem service pathway (Figure 1). This is essential for understanding the supply and demand of services, and how human activities and land management interventions impact the quality and supply of these services.

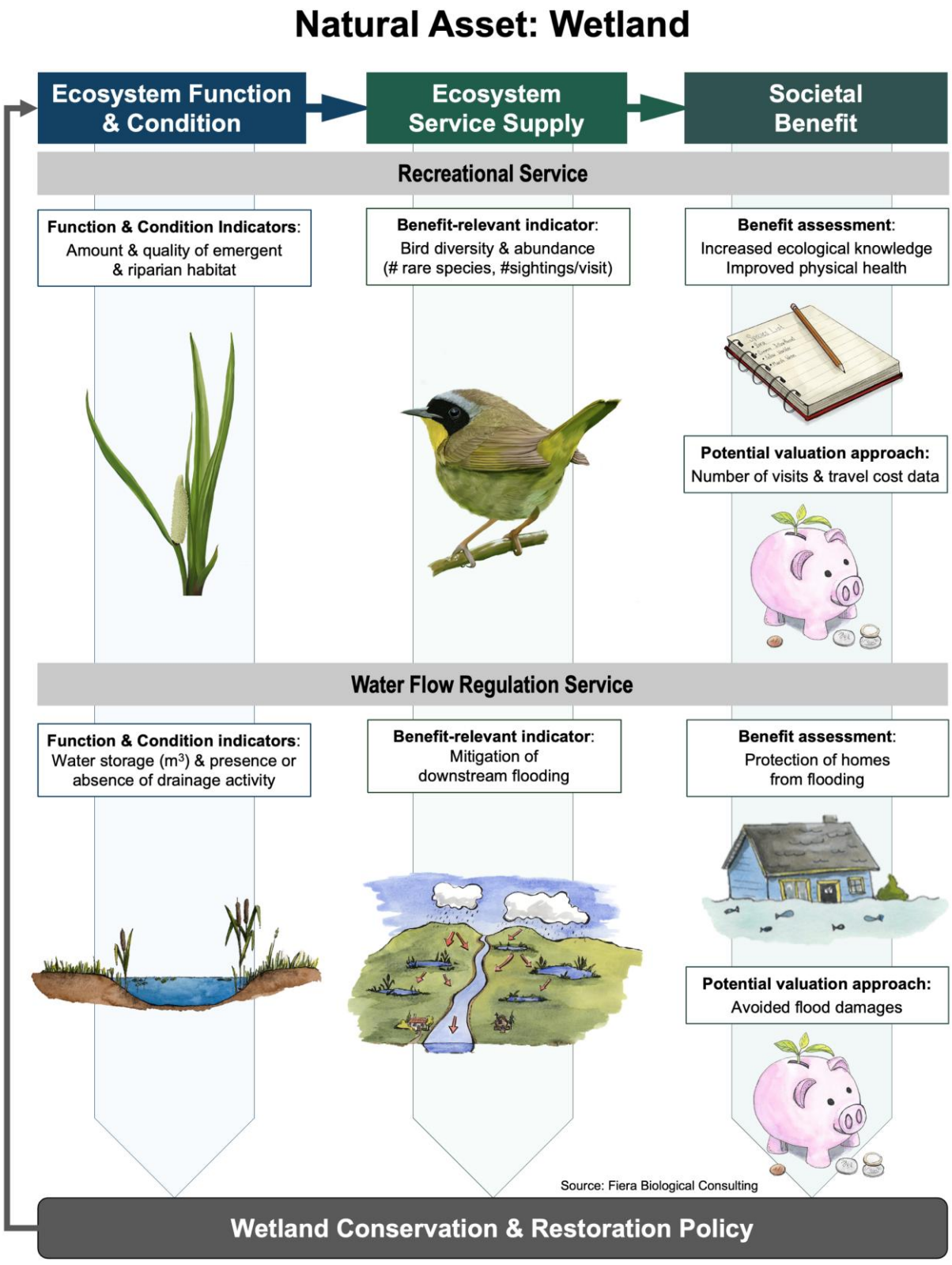


Figure 1. The ecosystem service pathway, illustrating the relationship between ecosystem function, ecosystem service supply, and societal benefit. In this example, different wetland functions give rise to multiple ecosystem services and benefits. The supply of the ecosystem services and benefits is influenced by land management practices, such as wetland drainage, which can be managed by municipalities through wetland conservation or restoration policies (adapted from Potchin and Haines-Young 2017).



2.0 Methodological Approach

2.1. Natural Asset Inventory & Assessment Framework

There are a number of different frameworks that describe how to inventory natural assets and undertake an ecosystem service assessment (e.g., Millennium Ecosystem Assessment 2003; Government of Alberta 2011; Everard & Waters 2013; Crossman et al. 2013; European Environment Agency 2016; Value of Nature to Canadians Study Taskforce 2017; Maes et al. 2018; Burkhard et al. 2018; von Haaren et al. 2019). Generally, these frameworks include the following major steps:

1) Define the purpose of the study and identify the natural asset(s) and/or ecosystem services that are the target of the assessment
2) Map the extent and location of target natural asset(s)
3) Assess the condition of the target natural asset(s)
4) Quantify ecosystem service supply associated with the target natural asset(s)
5) Assess the value and/or benefits of the ecosystem services

Once natural assets have been identified, mapped, and assessed the following steps are recommended:

6) Disseminate results and formulate a management and/or policy response
7) Monitor and assess outcomes

The scope of this study included steps one through five. These steps are the precursor to the development of a comprehensive asset management strategy that integrates the information generated by the study. The methods used in each of these steps is provided below. A detailed discussion of the potential next steps the City can take to create a comprehensive asset management system is provided in Section 5 of this report.

2.2. Defining the Purpose of this Natural Asset Assessment

Clearly defining the purpose of the assessment is an essential first step in any natural asset inventory, as this ensures that the information generated is both relevant and usable. To this end, the Study Team met with personnel from City of Leduc in the spring of 2025 to gather information and insights that were used to inform the focus of the inventory as well as the methods and approach that were used to map and value natural assets. At this half day workshop, the Study Team and City personnel with expertise in planning, environmental management, geospatial services, engineering, and City land management worked together to define *how* the City would use the inventory. Specifically, the City was asked to provide information on the types of land management and policy decisions they wanted to address with the inventory, as well as to provide information on how they envisioned operationalizing information from the inventory in their land use and land management decisions. Additionally, participants were asked to provide input into what type of assets and ecosystem services they considered to be highest priority for management within the City.

Information and feedback gathered during the workshop with the City as well as collaboration with City staff over the course of the project informed the approach and methods used in this study. This included the final list of ecosystem services that were the focus of the benefit and valuation assessment (Table 1). It is important to note that this is not a comprehensive list of the ecosystem services delivered by the natural assets in the City. Rather, this is the list ecosystem services that could be feasibly assessed as part of this study given the available resources and data.

Table 1. Key ecosystem services (ES) provided by natural assets in the City of Leduc that were assessed as part of this natural asset inventory and valuation study.

ES Category	Ecosystem Service	Example of Ecosystem Good/Benefit to End-Users
Regulation & Maintenance (Biotic)	Water Flow Regulation	Mitigation of damages because of reduced magnitude and frequency of flood/storm events
	Air Quality Regulation	Mitigation of damages because of reduce mortality/morbidity
	Atmospheric Regulation	Capture, removal, and storage of carbon in soil and vegetation resulting in avoided damage costs of carbon emissions
	Temperature Regulation	Increased thermal comfort for people, decreased heat stress for crops and other vegetation
	Wildfire Regulation	Mitigation of damages because of reduced severity of wildfire events
Cultural (Biotic)	Nature-based Recreation	Bird watching, cycling, walking and hiking, water-related activities (e.g., boating, fishing, etc.)

2.3. Mapping & Assessing Natural Assets

2.3.1. Study Area Extent

The study area was delineated as the area within the City's municipal boundary. Natural assets that extend across the City boundary and into Leduc County were included as well to account for transboundary assets. All mapping and assessment were applied within this study area extent.

2.3.2. Identification & Mapping of Natural Assets

Natural assets within the study area were identified and mapped using a multi-step process that leveraged existing datasets (Table 2) alongside manual editing. This resulted in a unique land cover map that was created specifically for use in this project. The steps that were used to create the natural asset inventory are described in detail below and are illustrated in Figure 2.

Table 2. Description of the spatial data used in the mapping and assessment of natural assets in City of Leduc.

Data Layer	Year	Source	Usage
City of Leduc Land Cover	2014	Fiera Biological 2016	Land cover for editing/asset creation
City of Leduc Natural Areas	2014	Fiera Biological 2016	Land cover for editing/asset creation
City of Leduc Orthophoto	2024	City of Leduc	Reference image for land cover editing
ESRI Basemaps	~2024	ESRI	Reference images for land cover editing
Google Earth Imagery	~2024	Google	Reference images for land cover editing

Step 1 – Detailed Land Cover Editing

An existing land cover layer (22 classes, ~10 m^2 minimum mapping unit) was used as the basis for the creation of the natural asset inventory (Table 3). Because the existing land cover was created using imagery from 2014, the land cover required substantial updating to ensure both natural and built features were current. The extent of the land cover included the City of Leduc plus an 800 m buffer to allow for the calculation of ecosystem service supply for transboundary assets. The land cover was manually edited using a 2024 City orthophoto, ArcGIS basemaps, and Google Earth imagery that were current to 2024. Editing tasks were focused on natural classes that were modified or no longer present (i.e., had been disturbed or removed between 2014 and 2024), along with correcting land cover class label errors (e.g., mix-up between tree and low cover). Additionally, two land cover classes (lowland graminoid and lowland woody) were added to account for wetland and riparian vegetation areas and features including these classes were edited accordingly. Time and budget constraints limited the amount of detailed editing that could be performed in areas dominated by residential and industrial development. In these areas, specific built features were not manually added (e.g., buildings and pathways); instead, larger areas were generally characterized by the type of development present (e.g., residential, industrial, construction).

Step 2 – Creation of Draft Natural Asset Inventory

Natural assets were created by combining adjacent (touching) natural cover types into a single feature. All natural classes (Grassland, Lowland Graminoid, Lowland Woody, Open Water, Shrub, Tree) from the land cover were selected and dissolved into separate polygons, resulting in over 11,000 individual natural asset boundaries ranging in size from <1 m^2 to 1,219,940 m^2. To remove fragments and very small assets, a minimum mapping unit (MMU) threshold was applied. Based on consultation with City of Leduc, the MMU for natural assets located within the study area was 3,000 m^2 (~0.3 ha). This resulted in a “draft” inventory that included 149 potential assets that were the focus of more detailed editing.

Step 3 – Final Natural Asset Selection and Cover Type Reattribution

The draft inventory included several managed assets (e.g., stormwater ponds). These managed assets were removed so that only natural features were included in the inventory. A final round of editing then occurred to finalize asset boundaries. Cover classes associated with assets were generalized into simplified natural asset cover types. Tree and Shrub classes were reclassified as “Woody” and Lowland Graminoid and Lowland Woody classes were reclassified as “Wetland”. Grassland and Open Water retained the same names resulting in four major natural asset cover types (Table 3). Assets were then attributed with an ID and jurisdiction. Assets contained entirely within the City boundary were assigned “City of Leduc” and assets that extended across the City boundary and into Leduc County were assigned “Shared”. The final set of natural assets totaled 104. The natural assets were then spatially joined back to the cover type polygons to allow for cover type summaries for each natural asset.

Table 3. Description of cover types associated with natural assets identified in the City of Leduc.

Asset Cover Type	General Description	Land Cover Classes	Land Cover Description
Woody	Areas dominated by woody vegetation primarily composed of native species.	Tree	Areas with >75% cover by coniferous or deciduous trees.
		Shrub	Areas dominated by woody vegetation typically <2 m tall.
Grassland	Areas dominated by non-woody vegetation primarily composed of native species. Can include areas being restored or naturalized.	Grassland	Areas dominated by naturally occurring or minimally managed grasses and/or forbs. Does not include lawns or lands currently used as pasture. May include areas being restored or naturalized.
Wetland	Areas dominated by shallow water and/or predominately native vegetation tolerant of moist soil conditions. Includes wetland restoration sites.	Lowland Graminoid	Depressional areas dominated by emergent or graminoid vegetation.
		Lowland Woody	Depressional areas dominated by deciduous tree or shrub cover.
Open Water	Areas dominated by persistent water.	Open Water	Lakes, open water areas in semi-permanent and permanent wetlands, and flowing water.

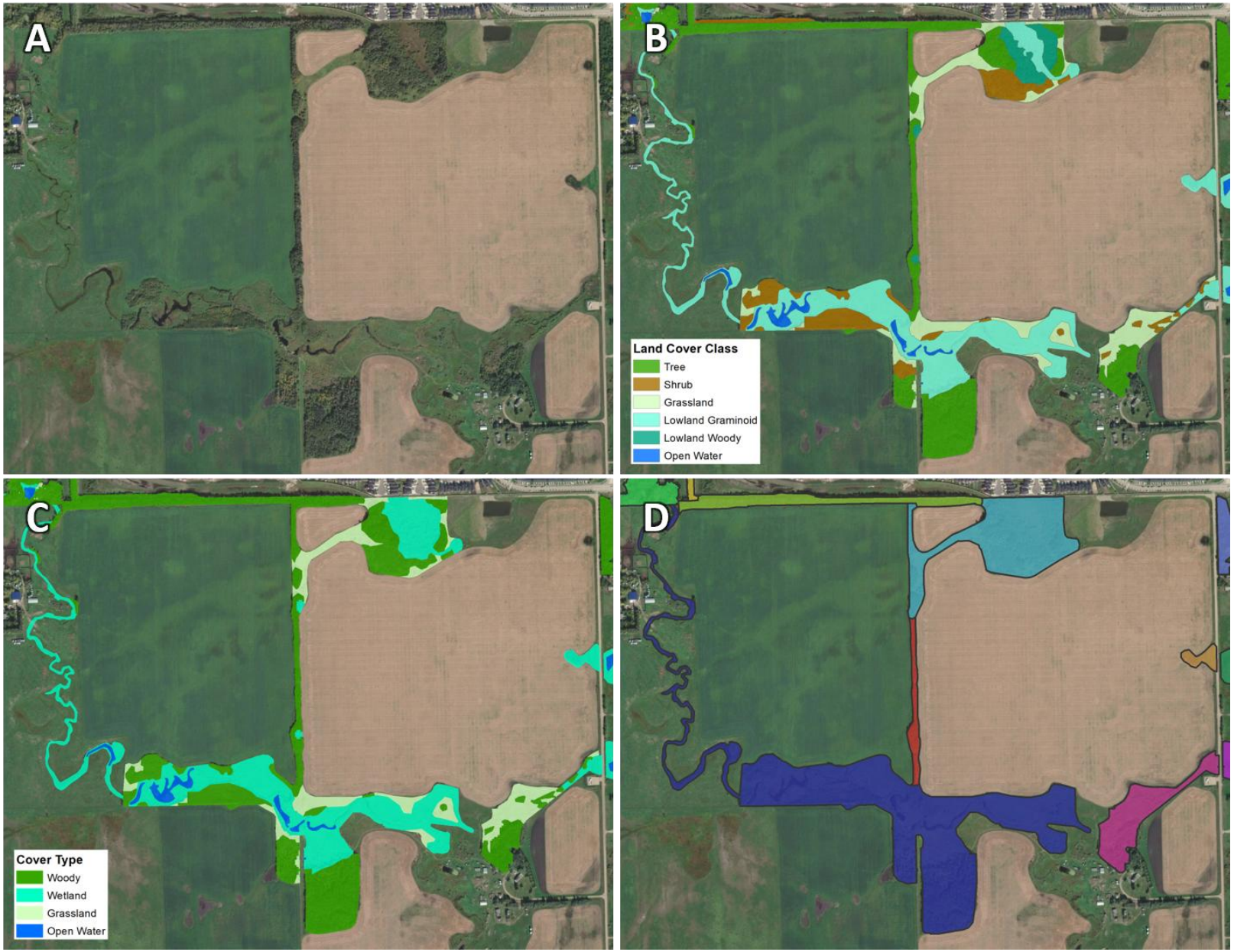


Figure 2. An example of how (A) natural cover in the City of Leduc was captured and mapped through the creation of a land cover layer (B) that was simplified into four main cover types (C), which were then used to identify and map individual natural assets (D).

2.3.3. Relative Condition Assessment

Natural assets and their underlying habitats generally need to be in good condition to provide ecosystem services, and drivers of change can have positive (e.g., restoration) and negative (e.g., land use pressure) impacts on condition (Maes et al. 2018; Vihervaara et al. 2019). As a result, pressure and condition are both linked to the supply of ecosystem services, as condition is likely to be good with correspondingly high function and supply of services if pressures are absent. Consequently, pressure can be used as a proxy for assessing condition in absence of information or data that allows for the direct measurement of habitat condition, quality, or biodiversity (European Environment Agency 2016). While direct measures of condition are often preferred, the existence of data that is of sufficient quantity or coverage is often lacking, and the collection of such data is typically cost-prohibitive (Maes et al. 2018; Vihervaara et al. 2019). As a result, indictors or proxies of condition are often used, and these can be measured indirectly or through modelling (European Environment Agency 2016; Maes et al. 2018).

Given that direct measures of condition from field data were not available for every asset identified in the City of Leduc inventory, a combination of indicators that evaluate surrounding land use pressures, as well as general indicators of habitat quality and biodiversity status were selected to describe the relative condition of each natural asset mapped in the inventory (Table 4). These indicators were selected because they account for a variety of ecological characteristics that are generally correlated with condition and there was suitable spatial data available to quantify the indicator using a desktop assessment.

For all indicators, raw score ranges were normalized and converted to a score between 0 (lowest score) and 100 (highest score). The approach used to score each metric is described in more detail in Table 4. To calculate a final condition score, metrics were aggregated, and the sum was divided by the total number of metrics. For assets that did not have a value for the Species Diversity metric (no observations recorded), this metric was not included in the final score tabulation so that these assets were not penalized for not having any recorded species observations. This gave a final score ranging between 0 and 100 percent, with higher scores representing assets predicted to be in better condition. To visualize the data, assets were binned into four condition categories using the following scoring cut-off values: Good (≥70), Fair (50-70), Poor (30-50), and Critical (≤30).

Notably, this analysis reflects a predicted condition score that utilizes desktop indicators. Most of the indicators used are measures of land use pressure, several of which are assessed at a larger scale than the asset itself. These scores provide important information about the asset and its potential condition, but cannot assess site-specific indicators of condition, such as vegetation structure and diversity, or the abundance of non-native species. These types of indicators must be evaluated in the field. As part of this study, a small number of natural assets were assessed in the field. These field condition scores can be used alongside the relative condition scores calculated using the desktop indicators to evaluate asset condition. The methods and results of the field assessment for the natural assets that were evaluated in the field are provided in Appendix A.

2.3.4. Additional Attributes

Three additional attributes were included to characterize natural assets to aid in future decision making. This included a development risk attribute that identifies risk of loss as identified through review of existing Area Structure Plans (ASPs) and Outline Plans (OLPs); a hydrological modification attribute to identify aquatic assets that contain wetlands that appear to be drained and are candidates for future restoration, and; an attribute that identifies assets that have an existing record of a Provincially and/or Federally listed species occurring within 50 m. The approach used to score each of these additional attributes is described in more detail in Table 6.

Table 4. Indicators and methods used to estimate relative condition scores for each natural asset in the City of Leduc.

Indicator	Description & Methods for Quantification	Data Used to Quantify Indicator
Intensity of Surrounding Land Use	Natural assets were buffered by 100 m and the proportional cover of each land use class was calculated. The proportional area of each land use class was then multiplied by the intensity value for each class (see Table 5), and a land use intensity value was calculated by summing the output values together. The area-weighted land use intensity values were then standardized to values between 0 and 100.	Natural Asset layer; Land Cover layer
Natural Asset Size	The total area of each asset was calculated, and the range of areas was normalized to values between 0 and 100. The Telford Lake asset was excluded from the normalization and manually set to 100 due to its exceedingly large size compared to other assets.	Natural Asset layer
Natural Asset Isolation	The shortest straight-line distance to the nearest natural asset was calculated as a measure of isolation. The nearest neighbour distances were normalized to values between 0 and 100.	Natural Asset layer
Natural Asset Neighbourhood	The number of natural patches ≥0.1 ha within a 500 m buffer of the asset was quantified as a metric of neighbourhood connectivity. The total count of natural area neighbours was normalized to values between 0 and 100.	Natural Asset layer; Land Cover layer
Vegetation Structural Diversity	The diversity in vegetation heights was calculated for each asset to quantify the heterogeneity of vegetation cover. Vegetation height classes were determined by subtracting the City DEM from the City DSM and classifying the values into six height categories (>1 m; 1-2 m; 2-5 m; 5-10 m; 10-25 m; >25 m). Areas of open water were excluded. Height class values were applied to assets and zonal statistics were used to calculate the standard deviation in height classes across each asset. This value was then multiplied by the number of different height classes present in the asset and output values were normalized to values between 0 and 100.	Natural Asset layer; City DEM; City DSM
Habitat Diversity	The number of different natural cover types within each asset was quantified. The total count of cover types was converted to a percentage of total possible types, with the maximum possible cover types equal to six.	Natural Asset layer; Land Cover layer
Relative Vegetation Vigour	The relative vigour/quality of vegetation was quantified using the mean NDVI value within the asset. Median summer NDVI was generated from Sentinel2 imagery in Google Earth Engine and zonal statistics were used to calculate mean NDVI value for each asset. The area associated with water was clipped out of assets prior to performing the calculation. The value for each asset was normalized by subtracting the mean NDVI value for the entire City from the asset's NDVI value and reclassed to values between 0 and 100. Assets with higher values are considered in better condition than those with lower values.	Natural Asset layer; Median Summer NDVI
Species Diversity	Data from the citizen science platforms eBird and iNaturalist were used to provide a measure of species diversity for natural assets. Total number of species reported within 50 m of each asset was tabulated, and for assets with observations a score between 70 and 100 was assigned, with lowest number of species assigned 70 and highest number of species assigned 100. For assets with no observations, no value was assigned, and the metric was not included in the final score tabulation.	Natural Asset layer; eBird data 2014-2025; iNaturalist data 2018-2025
Temperature Stress	Potential stress due to increased heat from surrounding landscape features was determined by quantifying the mean summer temperature within the asset and within a 100 m buffer around the asset using zonal statistics. This was based on an average summer temperature layer derived from Landsat time series data. Temperature stress was calculated by subtracting the mean asset temperature from the mean buffer temperature. This value was then corrected for buffer temperature relative to all asset buffers. Corrected temperature stress values were then normalized to values between 0 and 100.	Natural Asset layer; Landsat Average Summer Temperature layer

Table 5. Land cover classes and associated land use intensity values used to assess the intensity of surrounding land use indicator

Land Use Class	Intensity Value
Building, Commercial, Construction, Gravel Areas, Industrial, Mixed Use, Paved Area, Rail, Paved Road, Gravel Road, Residential, Sidewalk	100
Rail	80
Agriculture, Manicured	30
Paved Trail in Park	20
Gravel Trail in Park	10
Low Cover, Lowland Graminoid, Lowland Woody, Open Water, Shrub, Tree	1

Table 6. Indicators and the methods used to characterize additional attributes of natural assets in the City of Leduc.

Indicator	Description & Methods for Quantification	Data Used to Quantify Indicator
Development Risk	Maps from any existing ASP and OLP were georeferenced and cross-referenced to determine risk of loss. Assets were assigned a categorical development risk rating as follows: • Very High – Asset is identified for complete removal in and existing ASP or OLP • High – Asset will be reduced to less than 50% of its original size • Moderate – Asset will be reduced in size, fragmented, or modified, with at least 50% of the asset retained • Low – Asset is to be fully or almost completely (>95%) retained, or development related to the asset is already complete • Unknown – No ASP or OLP for the area was available, or the asset is outside of the City boundary	Natural Asset layer; City ASP and OLP
Hydrologically Modified	Airphotos and satellite imagery available in Google Earth was reviewed to identify streams or wetland habitats that appear to be hydrologically modified (e.g., drainage ditch, channel straightening). If modification was present the asset was attributed with “Yes”.	Natural Asset layer; Google Earth Imagery
Listed Species	The species diversity data from eBird and iNaturalist were cross-referenced with Provincial and Federal species status lists to identify observations of species that are Sensitive, May Be At Risk, At Risk, Of Special Concern, or Threatened. Total number of different listed species within 50 m of each asset was tabulated and was recorded as an attribute.	Natural Asset layer; eBird data 2014-2025; iNaturalist data 2018-2025

2.4. Quantifying Ecosystem Service Supply

For each of the primary ecosystem services, indicators linked to the production and/or consumption of the service were selected and quantified to allow for an assignment of monetary value. Notably, the supply of several of the priority ecosystem services could not be measured, either because the data for doing so were not readily available, or because of time and resource limitations. A description of how the supply of each service was quantified is provided below. For all measures, raw outputs were converted to relative scores since field validation of model outputs could not be completed. These relative scores are sufficient for comparing potential ecosystem service delivery among natural assets within the City.

Ecosystem service supply in the City of Leduc was assessed using a combination of different qualitative and quantitative approaches (Table 7). Water flow regulation and atmospheric regulation services were quantified using InVEST® (Natural Capital Project 2025), a free open-source software developed by Stanford University that has been used to model ecosystem services worldwide. A description of the methods used to assess each ecosystem service in City of Leduc is described in more detail below. Specifics related to the input datasets, values, and parameters used in each of the InVEST models is provided in the Appendix B.

Table 7. List of ecosystem services and associated methods that were used to quantify or describe the supply of services within the City of Leduc for this study.

ES Category	Ecosystem Service	Methods Used to Quantify ES Supply
Regulation & Maintenance (Biotic)	Water Flow Regulation	InVEST Urban Flood Risk Mitigation model
	Air Quality Regulation	Quantitative description
	Atmospheric Regulation	InVEST Carbon Storage model; Sequestration values based on literature review and landcover types
	Temperature Regulation	Landsat image analysis
	Wildfire Regulation	Not quantified (valuation discussed qualitatively)
Cultural (Biotic)	Nature-based Recreation	Qualitative description of nature-based recreational opportunities available in City of Leduc

2.4.1. Water Flow Regulation

The InVEST Urban Flood Risk Mitigation model estimates runoff reduction, which is the amount of runoff retained per pixel compared to a defined storm volume. This provides a measure of how natural features can mitigate flood hazards. The model is limited in that it uses a simple approach (curve numbers), which can introduce high uncertainties; however, the ranking between land cover types is typically well captured by this approach, which means that the effect of natural infrastructure in mitigating flood impacts is represented well qualitatively.

The model relies on land cover and soil data inputs, as well as several parameter values. A full list and description of data sources and parameter values used in this model is provided in Appendix B.

The model output includes a raster layer with per pixel estimates of runoff retention values measured in cubic meters (m^3). The total amount of runoff retained by each natural asset was calculated by summing the raster values within the boundary of each asset and an area weighted average was calculated by dividing the total retained runoff value by the asset area. The relative contribution of each natural asset to regulating water flow was determined by classifying assets on a scale between 1 and 10, where 1 indicates assets with the lowest runoff retention per unit area and 10 the highest runoff retention per unit area.

2.4.2. Air Quality Regulation

The i-Tree Canopy model (canopy.itreetools.org) was used to estimate air pollution removal by trees in the study area. This model uses Google aerial images to produce statistical estimates of tree cover in the study area and then applies a local standardized removal rate (e.g., kg/m^2 of tree cover) to estimate a total effect from trees (kg) (Nowak 2021). The model requires air pollution and weather data to generate estimates; however, no estimates are available in the model for Canada. Given this, Minnesota and North Dakota rates for urban areas were used to parameterize the model because these areas have climatic conditions comparable to the City of Leduc. Notably, the model provides estimates of the average pollution removal effect per unit of tree cover for the study area, including tress that are located outside of natural areas. Given this, estimates cannot be assigned specifically to natural assets and instead represent the overall air pollution removal per year by all trees in the City (Table 8).

Table 8. Air pollution estimates used by the i-Tree Canopy model. Values are in kg/km^2/yr

Pollutant	Description	Removal Value (kg/km^2/yr)
CO	Carbon Monoxide removed annually	54.810
NO_2	Nitrogen Dioxide removed annually	458.099
O_3	Ozone removed annually	3,730.355
SO_2	Sulfur Dioxide removed annually	57.539
PM2.5	Particulate Matter less than 2.5 microns removed annually	150.667
PM10	Particulate Matter between 2.5 and 10 microns removed annually	1,465.288

2.4.3. Atmospheric Regulation

The InVEST Carbon Storage model estimates the total amount of carbon stored within a given area based on estimates of the total amount of carbon present within four different carbon pools: aboveground biomass, belowground biomass, soil, and dead organic matter. This approach is limited in that it uses a simplified model of the carbon cycle that assumes carbon pools are static, and that each land cover type can be sufficiently represented by a single carbon pool value (i.e., it does not vary within the cover type).

The Carbon Storage model relies on land cover and soil data inputs, as well a carbon storage value (t/ha) for each land cover type and carbon pool. A full list and description of data sources and parameter values used in this model is provided in Appendix B.

Model outputs provide an estimate of the amount of carbon (in metric tonnes) stored in each pixel. For each natural asset, the total amount of carbon stored was calculated by summing the raster values within the boundary of each asset. An area weighted average was then calculated by dividing the total amount of carbon stored by the asset area. Open water area associated with the asset was not included in the area weighted average calculation. The relative contribution of each natural asset to carbon storage was determined by classifying assets on a scale between 1 and 10, where 1 indicates assets with the lowest amount of carbon stored per unit area and 10 the highest amount of carbon stored per unit area.

In addition to calculating the amount of carbon stored by each natural asset, the amount of carbon sequestered by each asset over a 50-year period was estimated. Carbon sequestration differs from carbon storage in that sequestration is the process by which atmospheric carbon dioxide is taken up by vegetation through photosynthesis and stored in another form that cannot be released (i.e., carbon storage). Carbon sequestration is an on-going process and differs from carbon storage in that once a natural asset is lost (i.e., a forest is cut down) the carbon sequestration service is no longer provided by that natural asset, but the carbon storage service may persist (e.g., if the trees are converted into lumber). For this reason, ecosystem service valuations typically use carbon sequestration, and not carbon storage, to estimate the value of atmospheric regulation services.

To allow for an estimate of the value of atmospheric regulation services provided by natural assets in the City of Leduc, carbon sequestration was estimated using values sourced from the literature (Table 9). For grasslands, Bork and Badiou (2017) cited a range of annual carbon sequestration rates for grasslands in

the Canadian Prairies (0.8 to 5.1 tonnes of CO_2e/ha/yr), and the value at the lower end of this range was selected to remain conservative. For wetlands, a recent study by Mistry (2025) suggests that wetlands in southern Ontario sequester carbon at an average rate of roughly 2.4 tonnes of CO_2e/ha/yr. For woody land cover, a recent study by Steenberg et al. (2023) suggests that tree cover in the subhumid and semiarid prairies sequester carbon at a rate of roughly 10.6 tonnes of CO_2e/ha/yr. Finally, in a study of northern lakes, Heathcote et al. (2015) estimated an average carbon burial rate (post-1900) of 0.139 t/ha/yr, which is equivalent to 0.5 tonnes of CO_2e/ha/yr.

It is important to emphasize the variation in carbon sequestration rates that are available in the published literature. The rates selected for this study represent, in our opinion, the most robust estimates to apply to natural assets in the City of Leduc at this time. However, research on carbon storage and sequestration is vast and constantly changing. As such, these estimates represent a snapshot in time and may be improved upon in the future as new work is published.

For each natural asset, a carbon sequestration score was derived. The annual carbon sequestration rates (Table 9) were multiplied by the area of each land cover type present, and the total was summed to derive an overall estimate of carbon sequestration over a 50-year time period. The relative contribution of each natural asset to carbon sequestration was determined by classifying assets on a scale between 1 and 10, where 1 indicates assets with the lowest amount of carbon sequestered over 50 years and 10 the highest amount of carbon sequestered over 50 years.

Table 9. Annual carbon sequestration rates by land cover class

Land cover class	Carbon Sequestration Rate (tonnes CO_2e/ha/year)	Source
Grassland	0.8	Bork and Badiou (2017)
Wetland	2.4	Mistry et al. (2025)
Woody	10.6	Steenberg et al. (2023)
Open Water	0.5	Heathcote et al. (2015)

2.4.4. Temperature Regulation

Landsat images from June through September for the years 2019 to 2024 were used to quantify median temperature values across a 30 m grid for the City. This temperature data was intersected with the natural asset boundaries to calculate an average temperature value for each asset. Assets were assigned a relative “cooling” score of 1 to 5 based on the range of temperatures across the City, where 1 indicates the lowest potential cooling effect and 5 indicates the greatest potential cooling effect.

2.4.5. Nature-based Recreation

There are a range of metrics that can be used to assess nature-based recreation; however, many of these require information related to visitation or use of natural areas, and these data are typically obtained through surveys of residents and recreational users. In 2023, the City completed a Recreation Facility Needs Assessment Update (City of Leduc 2023), which included the administration of a recreation user survey. Additional engagement is summarized in the City’s 2020 Parks, Open Space and Trails (POST) Master Plan Update (City of Leduc 2020b). The results of these surveys, along with a limited dataset on the City’s Multiway Trail System usage at Telford Lake, provide some insight on Leduc residents and their propensity to recreate within the City’s natural areas. A high-level summary of the nature-based recreation opportunities available in the City was also used to better understand the supply and value of nature-based recreation from Leduc’s natural assets.

2.5. Valuing Ecosystem Services

The final step in an ecosystem service assessment is the identification of the goods and benefits provided by an ecosystem service, and the associated value of those benefits that accrue to end-users (Burkhard & Maes 2017). The extent to which people derive benefits from ecosystem services defines the relationship between human well-being and an ecosystem, and the benefits or welfare gained by the end-users from the supply of an ecosystem service is considered the asset's value. As described previously, each ecosystem service identified for the City has an associated benefit to end-users (Table 1) and the specific group of end-users accruing benefits is variable. Indeed, many of the ecosystem services provided by natural assets in the City also benefit those who live outside of the City (e.g., climate regulation, nature-based recreation, etc.). While we endeavoured to focus the valuation of ecosystem services to City residents, depending on the valuation approach for individual ecosystem services, benefits to those living outside the City may also be captured in economic value estimates.

Estimates of economic values for ecosystem services provided by natural assets should consider the total economic value of the asset, which includes both use and non-use values (Figure 3):

- **Use values** include direct and indirect use values:
    - **Direct use** values reflect the value a person places on being able to actively use a particular natural asset. These include consumptive use values such as fishing or hunting, as well as non-consumptive use values like hiking or picnicking near a river.
    - **Indirect use** values reflect the value a person places on benefits derived from regulating services provided by natural assets like flood protection or climate regulation.
- **Non-use** or passive use values reflect the value a person places on an environmental asset that is not demonstrated through observable behaviour (Adamowicz et al. 1998). This includes the value of having the option to use the asset in the future (option value), the value for future generations to use the asset (bequest value), as well as the value of knowing that an environmental asset continues to exist, regardless of current or future use potential (existence value).

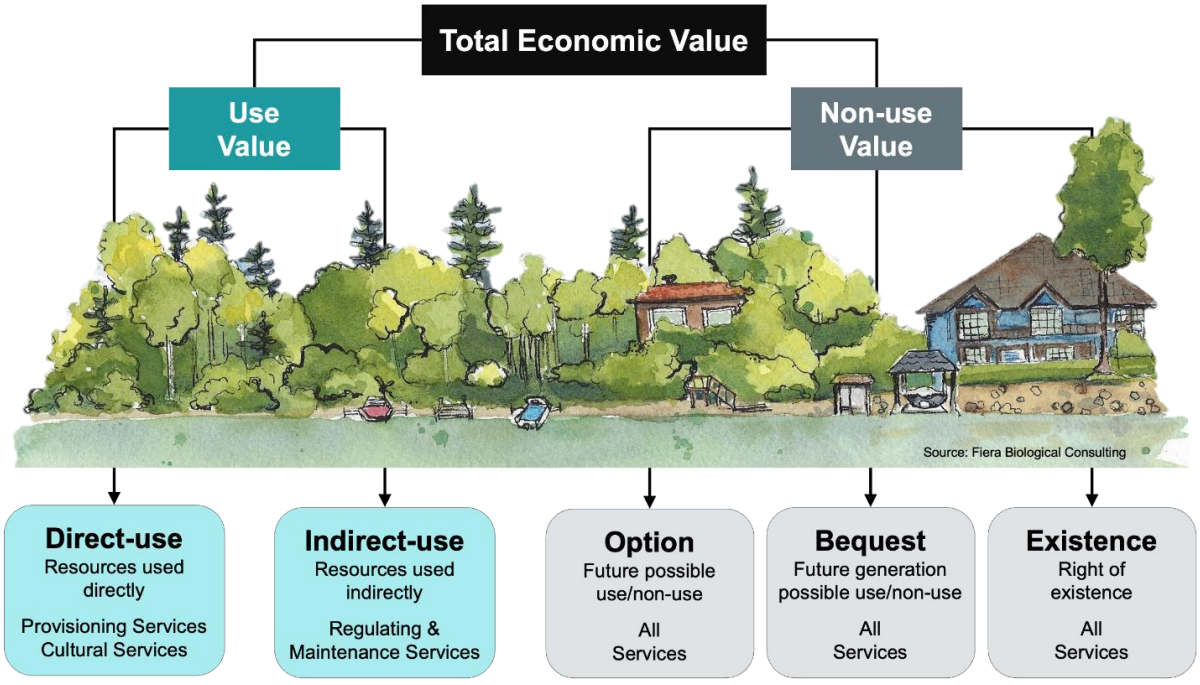


Figure 3. Use and Non-use values that make up the total economic value of an ecosystem.

2.5.1. Estimating Economic Value

Willingness To Pay (WTP)

Economic valuation attempts to measure the welfare derived from the use, consumption, or enjoyment of ecosystem services and is typically expressed in monetary units. For assets that are exchanged in conventional markets, valuation is simpler as we can more easily observe consumers' willingness to pay (WTP) for a market good using available market data (e.g., prices, demand curves). For goods that are not traded in markets (non-market assets) however, other valuation techniques are required. The economic literature outlines three generally accepted techniques to estimate end-users' WTP to determine their value:

- The **revealed preference (RP)** approach which, on a conceptual level, consists of examining transactions in a market to infer a value for an ecosystem good or service related to the transaction but not explicitly traded. For example, one can examine the costs that individuals are willing to incur (i.e., travel costs) to enjoy an activity (e.g., fishing) to provide insight into the value associated with the use of a particular ecosystem good (e.g., a lake). This approach works well for estimating use values.
- The **stated preference (SP)** approach involves designing surveys or experiments that explicitly asks what participants are willing to pay for a good or service that is not traded in a market. This approach is well-suited for estimating passive use values. For example, most Albertans have no use value for species such as woodland caribou; however, they may still have value in knowing that this species continues to exist (i.e., existence value). While this value cannot be measured through any observable behaviour, one could design a stated preference survey to ask participants what their WTP is for the continued existence of woodland caribou.
- The **benefit transfer (BT)** approach allows for the value of ecosystem services to be established through a review of published studies that contain estimates of values for comparable ecosystem services in similar jurisdictions. This approach is best suited for cases where primary data collection and analysis (i.e., revealed and stated preference approaches) are not practical or feasible. Published ecosystem service values are generally specific to a particular time and geography; therefore, the passage of time and difference in affected population need to be accounted for. The goal is to find values from studies with similar socio-economic conditions and cultural norms and practices. Where necessary, these values are adjusted to reflect inflation as well as differences in currency and purchasing power of key stakeholder groups.

It is important to note that the most robust form of environmental valuation is elicited through either revealed or stated preference techniques, as these methods allow for the estimation of welfare values to the end-users of natural assets. Benefit transfer allows individuals who cannot undertake primary data collection to use values estimated in comparable jurisdictions through either revealed or stated preference.

Market Proxies

It is not always feasible to acquire primary revealed or stated preference data, and these data are not always available in comparable jurisdictions to allow for the benefit transfer approach. As such, many have resorted to using other methods to estimate environmental values that are not considered to be true valuation approaches (Anderson et al. 2010). Market proxies, such as replacement costs of an asset or avoided damage costs associated with the degradation or destruction of an asset, are often used as an estimate of natural asset values. Conceptually, the use of replacement or avoided damage costs is predicated on the assumption that an asset is worth at least as much as expenditures made by individuals or institutions to replace it, or the damages that would occur if it were lost; however, there are several reasons why replacement and avoided damage costs may depart significantly from true WTP estimates.

For example, consider a naturally occurring wetland that is not providing substantial benefits to end-users in the community – perhaps it is in a remote location, is not used recreationally, and does not provide flood protection for any development. If that wetland were to be destroyed and replaced with a man-made wetland or alternative structure (e.g., stormwater management pond), there is no reason to believe that a linkage exists between the cost of replacement and the value of the initial asset to society. Conversely, a

natural wetland could reasonably have a much higher value than its replacement cost, particularly if the wetland provides ecosystem services that cannot be replaced with engineered infrastructure (e.g., habitat provision for species at risk).

In sum, these techniques do not necessarily represent WTP estimates of end-users since the end-users' WTP for ecosystem services may differ from the estimated avoided or replacement costs, making them an imperfect proxy for non-market values (Anderson et al. 2010). Having said this, market proxies like avoided cost estimates can, in some instances, provide reasonable estimates of environmental value, and are more readily available for natural assets in urban settings than WTP values through revealed or stated preference techniques. As such, market proxy estimates can still be of great use to the City for municipal decision-making purposes. Our goal here is simply to provide clarity around what estimation techniques are considered to reveal robust environmental values and what represent other market proxies.[2] Note that the benefit transfer approach can be used with market proxy value estimates as well.

2.5.2. Valuation Approach for this Study

Primary data collection for the economic valuation of ecosystem services in the form of revealed or stated preference approaches were cost-prohibitive for this study. As such, the benefit transfer method, as well as market proxy methods, were relied upon to estimate the economic value of ecosystem services in the City. Data and information sources used to undertake the valuation include:

- the Environmental Valuation and Reference Inventory (EVRI), a database of empirical studies on the economic value of environmental assets;
- academic literature; and
- engagement with the City regarding pathways through which ecosystem services and natural assets impact the City's end-point users.

For each of the estimated monetary values provided in this study, we also provide a general confidence level (low, medium, and high) based on several factors such as the valuation technique and the geographical similarity of the data.

[2] For the purposes of this study, we use the term 'value' and 'monetary estimate' interchangeably, so as not to create too much confusion.



3.0 Overview of Natural Assets

3.1. Natural Assets and Condition Assessment

In total, 104 unique natural assets were identified within the study area, covering 401 ha (Figure 4; Table 10). When considering only assets within the current City boundary, 99 assets were identified, covering roughly 8% (363 ha) of the City. Five natural assets (38 ha) are transboundary, meaning that they cross the City boundary and are shared between the City and County of Leduc.

Assets range between 0.3 ha and 166 ha in size (Table 10). The smallest natural assets are generally isolated tree stands within the built-up area of the City and wetlands in agricultural fields in the outlying parts of the City. Larger assets are spread across the City, with the largest being Telford Lake and the Leduc Reservoir, and the others being a mix of woody, wetland, and open water cover types.

Woody vegetation accounts for the greatest area (142 ha) and proportion (36%) of cover within natural assets in the study area (Figure 5). Open water makes up the second largest proportion (27%) of cover, while grassland makes up 21% and wetlands and riparian vegetation make up 16%.

Most natural assets (65%) are between 0.5 and 5.0 ha in size (Table 10). While natural assets >5.0 ha account for only 11% of the total number of assets, they make up 72% of the total area of assets.

Desktop condition scores for natural assets range between 23.3 and 84.7, with an average score of 53.7 (Table 10). Just over half (54%) of the natural assets have a relative condition score of Fair, with only 9% of assets having a relative condition score of Good. A further 36% of assets are rated as Poor, with an additional 2% of assets having a relative condition score of Critical (Table 11). Generally, larger assets have higher condition scores (Table 12; Figure 6), while assets with lower condition scores are smaller and are generally located within highly built-up areas and are surrounded by intensive human activity. Overall, there is general concordance between the desktop and field condition scores (see Appendix A for field scores); consequently, these desktop condition scores can be used as a general indicator of overall condition for assets that were not evaluated in the field.

A total of eight natural assets have hydrological modifications and 13 assets are associated with observations of sensitive species (Table 13; Figure 7). When considering Development Risk, 45 assets (43%) are classified as Very High or High Risk of loss, meaning that they are identified in existing planning documents for complete or nearly complete removal. An additional 8 assets (8%) are considered Moderate Risk (identified in planning documents for partial modification or alteration). Almost half of all natural assets in the study area (48) are in the Low Risk category, with an additional 3 assets (3%) being identified as Unknown Risk because they have not yet been identified in a planning document.

Table 10. Summary of size categories and condition scores assigned to natural assets in the project study area.

Asset Jurisdiction	Number of Assets	Size Category (ha)				Condition Score		
		0.3 to 0.5	0.5 to 1.0	1.0 to 5.0	> 5.0 ha	Minimum	Maximum	Average
City of Leduc	99	26	27	37	9	23.3	84.7	53.5
Shared	5	0	2	1	2	37.9	81.8	58.2
TOTAL	**104**	**26**	**29**	**38**	**11**	**23.3**	**84.7**	**53.7**

Table 11. Summary of condition scores assigned to natural assets in the study area.

Condition Score	Condition Category	Number (& proportion) of Assets	Area (& proportion) of Assets (ha)
70 - 100	Good	9 (9%)	251 (63%)
50 – 70	Fair	56 (54%)	114 (28%)
30 – 50	Poor	37 (36%)	35 (9%)
0 – 30	Critical	2 (2%)	1 (<1%)
	TOTAL	**104**	**401**

Table 12. Condition scores assigned to natural assets in the study area, summarized by size category.

Size Category	Condition Score		
	Minimum	Maximum	Average
> 5.0 ha	45.3	84.7	70.5
1.0 to 5.0 ha	32.9	71.9	56.5
0.5 to 1.0 ha	29.1	70.9	47.2
0.3 to 0.5 ha	23.3	68.8	49.9

Table 13. Summary of other attributes for natural assets in the study area.

Hydrologically Modified	Sensitive Species Observed	Development Risk				
		Very High	High	Moderate	Low	Unknown
8	13	39 (38%)	6 (6%)	8 (8%)	48 (46%)	3 (3%)

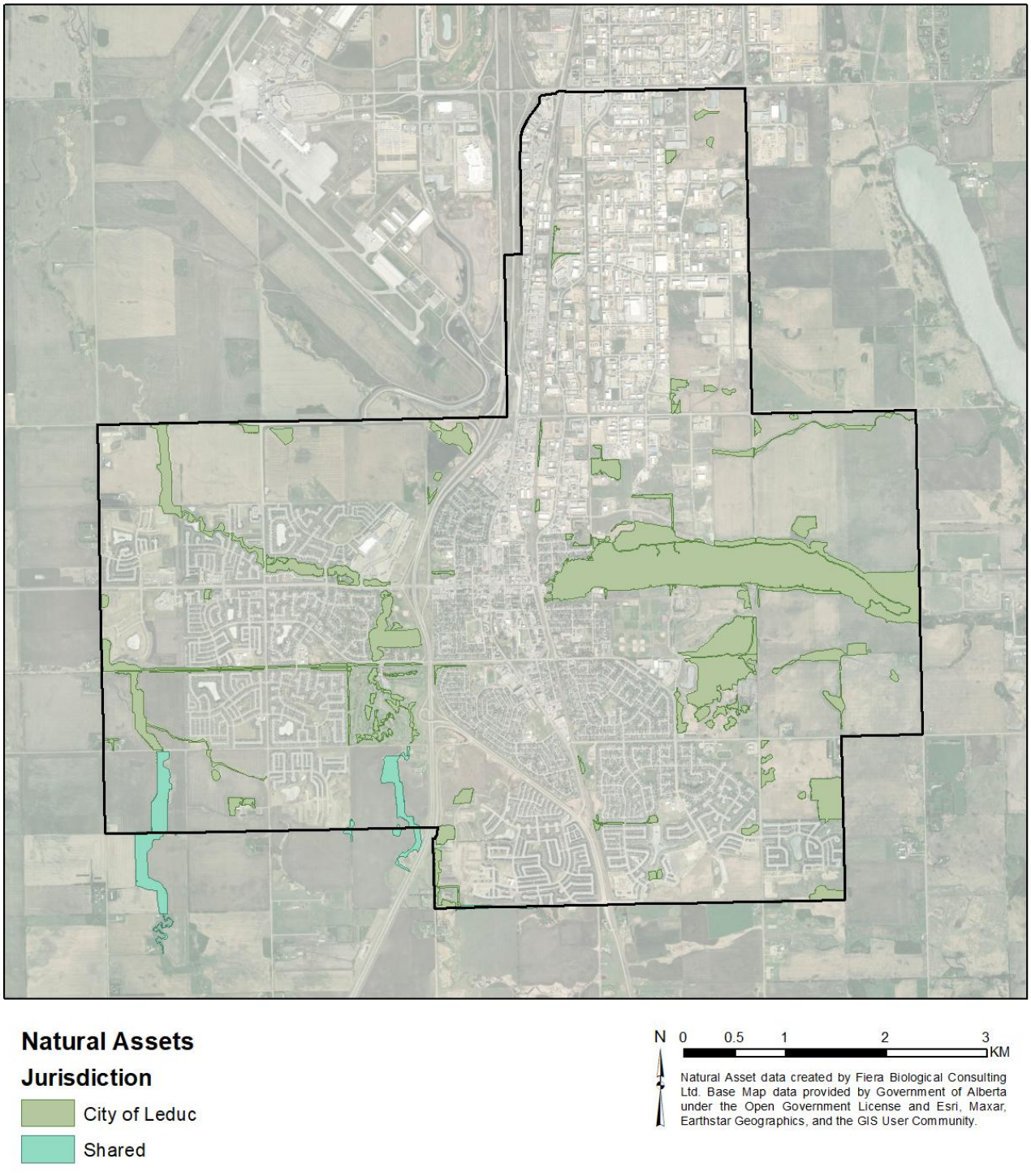


Figure 4. Natural assets identified in the project study area.

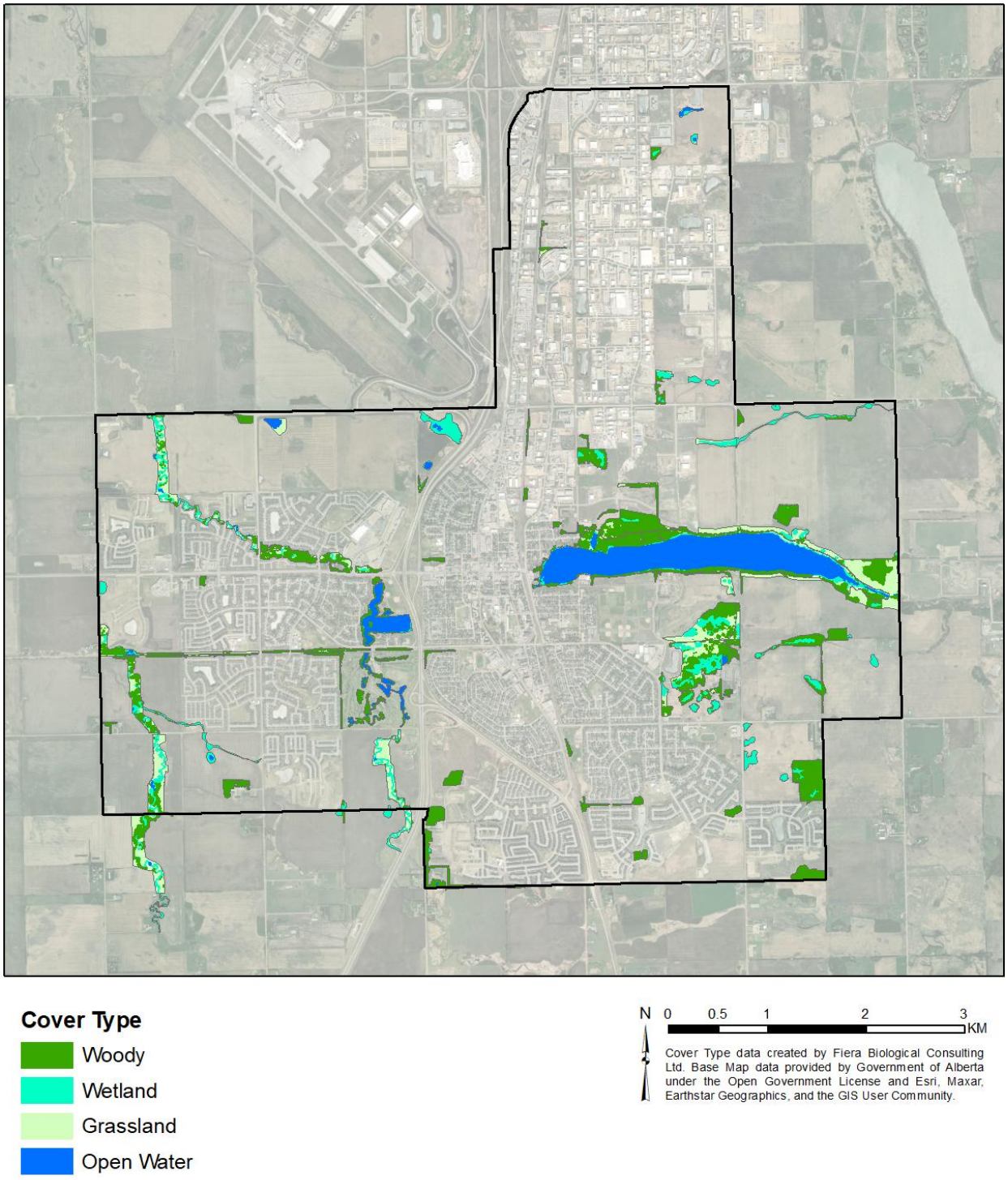


Figure 5. Major land cover types contained within the natural assets in the study area.

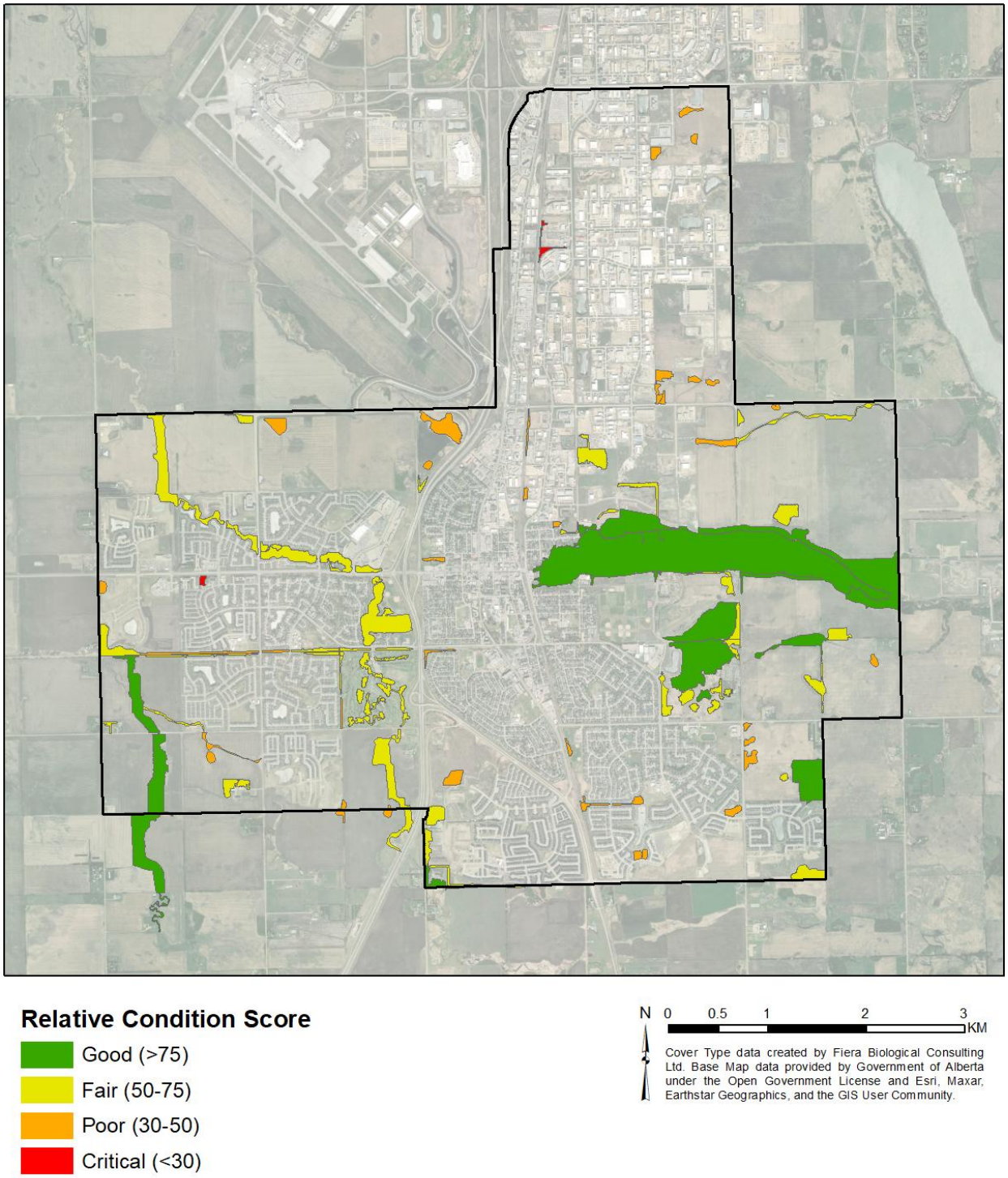


Figure 6. Relative condition scores for natural assets identified in the study area.

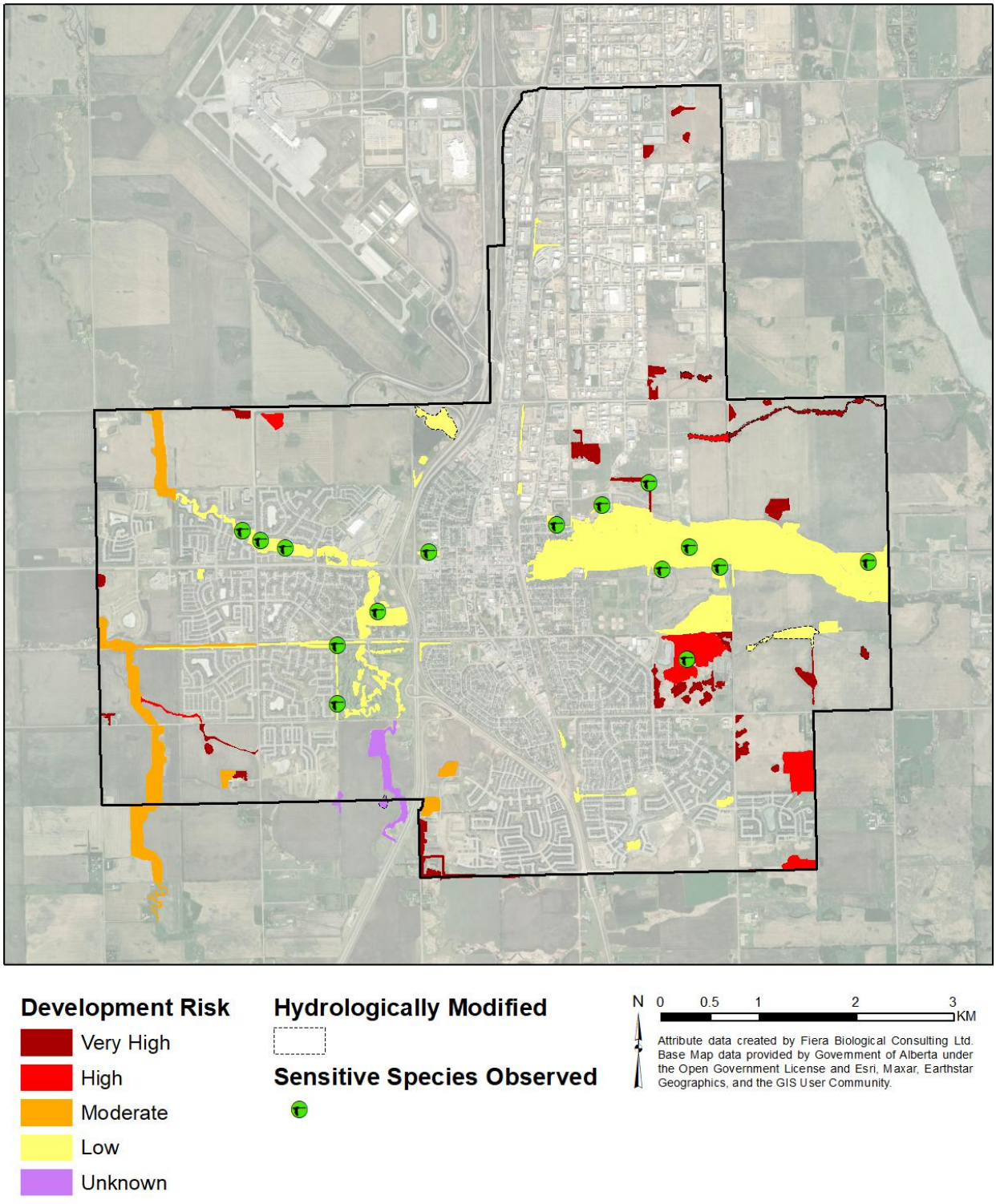


Figure 7. Other attributes characterizing natural assets in the study area.

3.2. Ecosystem Service Supply

Ecosystem service supply was assessed for all ecosystem services evaluated in this study except for wildfire regulation. Wildfire regulation is a complex ecosystem service with no standard approach for supply estimation. The economic value of this service and the benefits it may afford residents of the City is discussed qualitatively in Section 4.0 below.

3.2.1. Water Flow Regulation

The InVEST model predicts amount of runoff at the pixel level, which is then used to estimate relative runoff reduction by natural assets and their potential for regulating water flow. The relative retained runoff score for natural assets along with the predicted runoff amount is shown in Figure 8. Areas of high runoff are associated with built up areas, with soil type also playing a role in amount of potential runoff that is generated. Consequently, landscape position and land cover type both influence the potential for a natural asset to retain runoff, with natural assets that have a high proportion of wetland cover generally having high retained runoff scores. This includes wetlands within and outside the City boundary that are currently surrounded by agricultural lands.

3.2.2. Air Quality Regulation

The statistical estimates of tree cover in the study area that were generated by the i-Tree model were 3.87 (±0.74) km^2 or 5.52 (±1.05)% of the study area, which was consistent with the total tree cover mapped in the land cover data (including tree cover not included in the natural asset inventory).

Results of the model indicate that roughly 22,911 (±4,367 kg) of air pollutants are removed by trees in the study area each year (Table 14).

Table 14. Summary of air pollutants removed by total tree cover in the study area.

Pollutant	Amount (kg/yr)	± Standard Error (kg/yr)
CO	212	40
NO_2	1774	338
O_3	14,444	2,754
SO_2	223	42
$PM_{2.5}$	583	111
PM_{10}	5,674	1,082
TOTAL	**22,911**	**4,367**

3.2.3. Carbon Storage & Sequestration

The InVEST model predicts amount of carbon stored at the pixel level, which is then used to estimate relative carbon storage by natural assets and their potential for contributing to climate regulation. The InVEST model does not provide estimates of sequestration, so carbon sequestration was estimated using values sourced from the literature. The relative carbon storage score for natural assets along with the predicted carbon storage is shown in Figure 9. Areas of high carbon storage are associated with upland woody areas, especially forest stands. The relative carbon sequestration score based on an estimate over 50 years is shown in Figure 10. The largest assets tend to score high since they sequester more carbon over time. However, woody cover has the highest rate of carbon sequestration, and thus, assets with higher amounts of woody cover score also score higher for carbon sequestration.

3.2.4. Temperature Regulation

Median summer temperature during a 5-year period ranged from roughly 7°C to 25°C across the study area, with a mean temperature of 19°C (Figure 11). Cooler temperatures are associated with open water areas and areas where natural vegetation cover is more concentrated. Moderate temperatures are associated open agricultural areas, and the warmest temperatures are associated with residential and commercial areas, and some portions of the industrial park. When natural assets were ranked on their potential to moderate temperature and assigned a relative cooling score, open water areas scored the highest, and areas with a high proportion of woody cover (forest and woody wetlands) scored the next highest. Less of a cooling effect is associated with assets with predominantly graminoid or grassland cover, and the lowest cooling scores are associated with small, isolated, and linear (long and narrow) natural assets.

3.2.5. Nature-based Recreation

The City of Leduc hosts many nature-based recreation opportunities including, but not limited to (City of Leduc 2025):

- Telford Lake, a major recreation area in the City offering multi-use trails, birding, boating, and more.
- Fred Johns Park, one of the City's largest day-use parks offering multi-use trails, playgrounds, picnic areas, and access to the Leduc Reservoir for fishing.
- Over 85 km of multi-use pathways and trails across the City's Multiway Trail System.

While not all the City's outdoor recreation infrastructure are included in the natural asset inventory (for example, the entirety of the City's 85 km Multiway Trail System is not included in the inventory), large assets like Telford Lake and Fred Johns Park/the Leduc Reservoir are included.

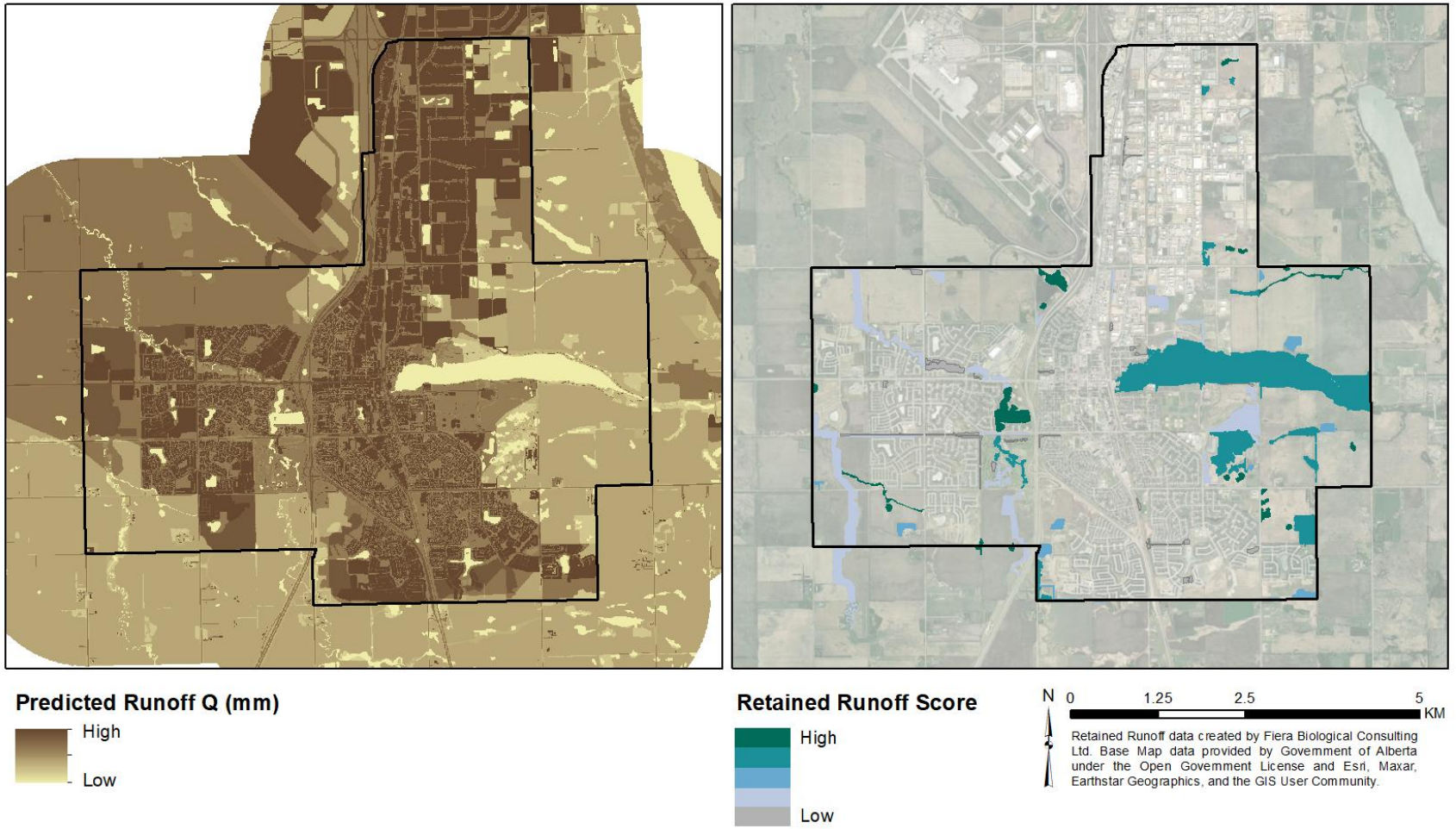


Figure 8. Predicted surface water runoff modelled using the InVEST Urban Flood Risk Mitigation model (left) and runoff retention score for natural assets (right). Assets with high retained runoff scores represent areas that are more likely to attenuate downstream flooding.

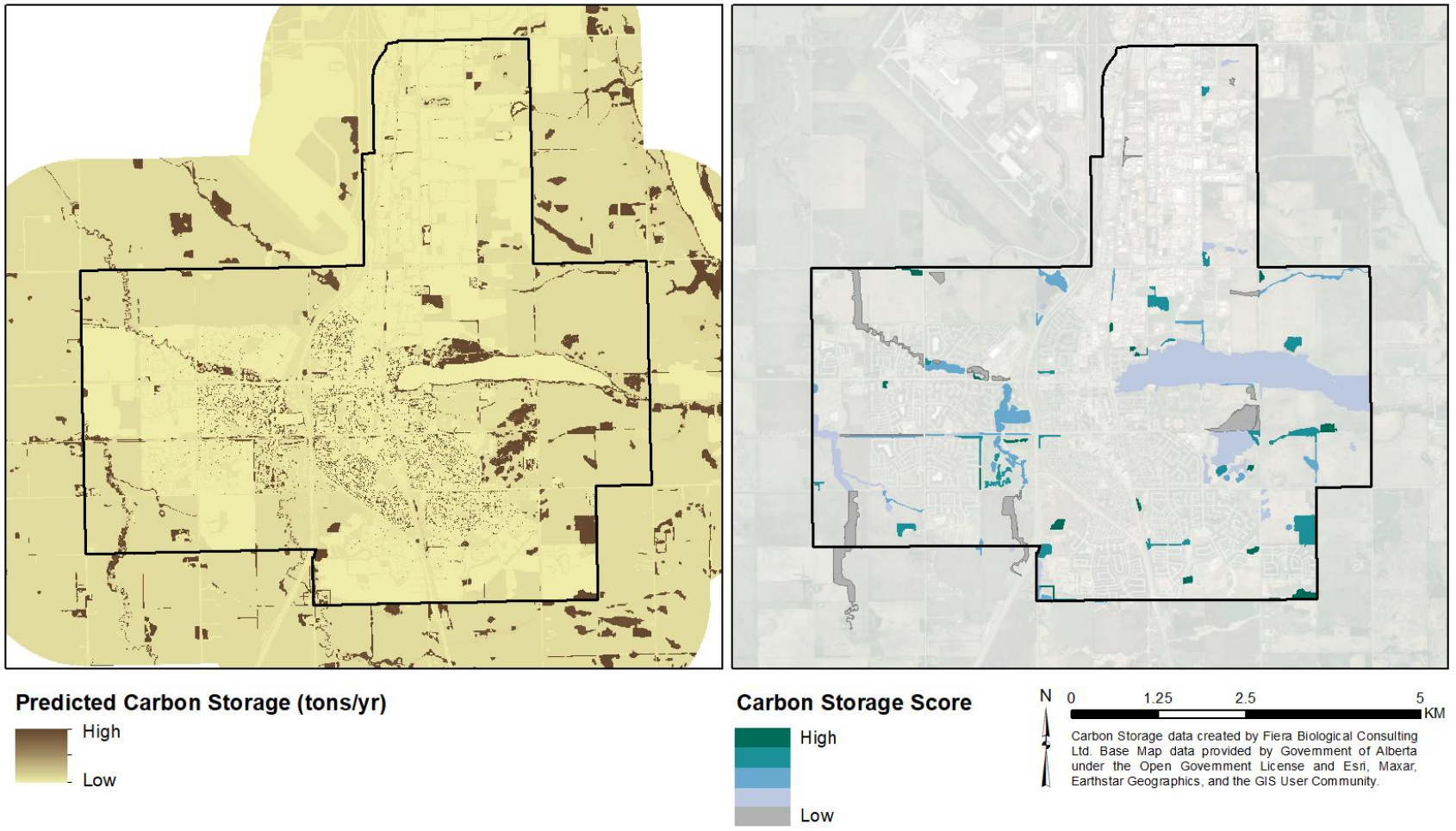


Figure 9. Predicted carbon storage (left) and corresponding carbon storage score (right) modelled using the InVEST Carbon Storage model. Assets with higher scores contribute more to atmospheric regulation with regards to carbon storage than those with lower scores.

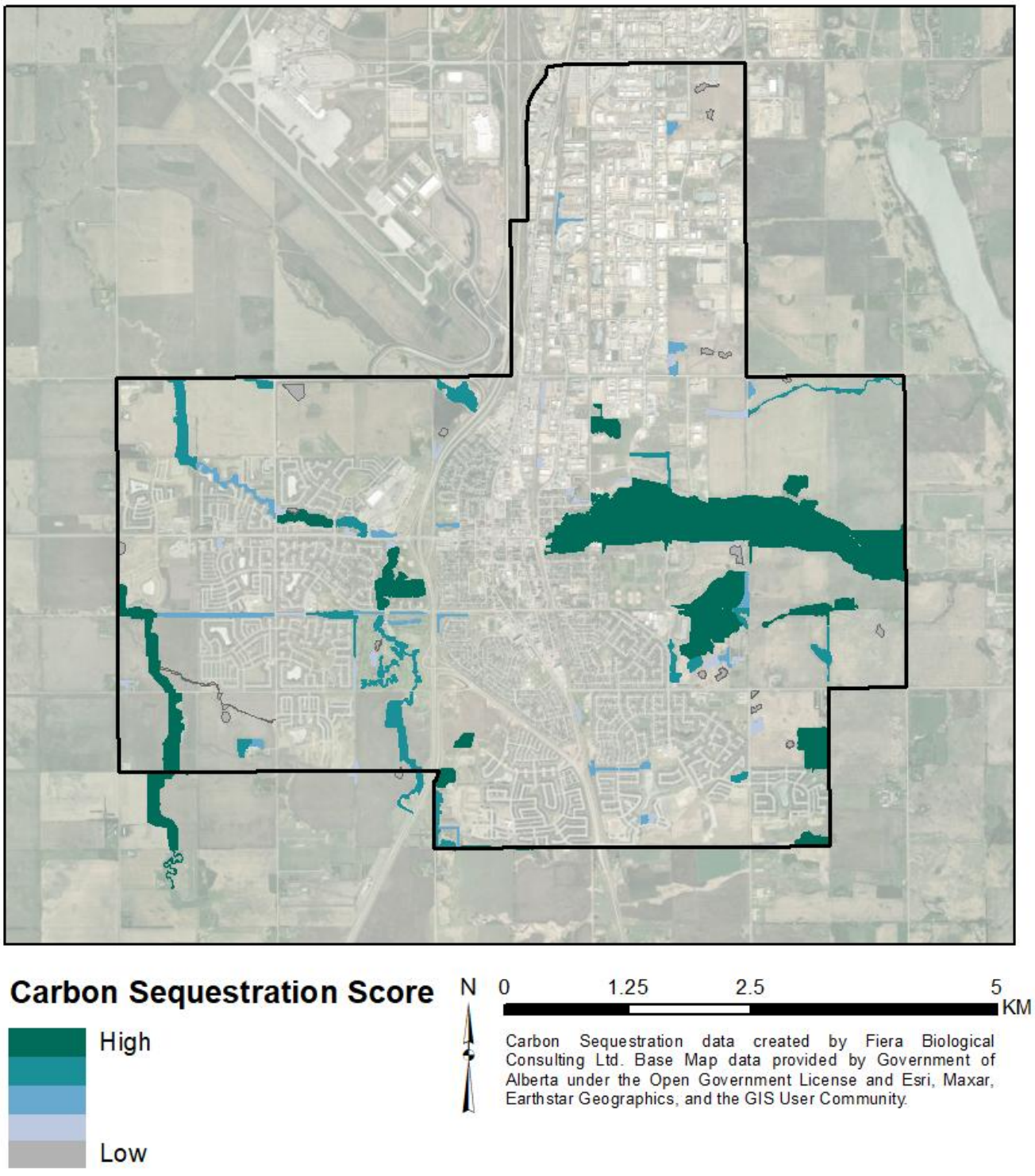


Figure 10. Carbon sequestration score estimated from carbon sequestration rates applied to land cover classes for natural assets. Scores are based on an overall estimate of carbon sequestration over a 50-year time period. Assets with higher scores contribute more to atmospheric regulation than those with lower scores.

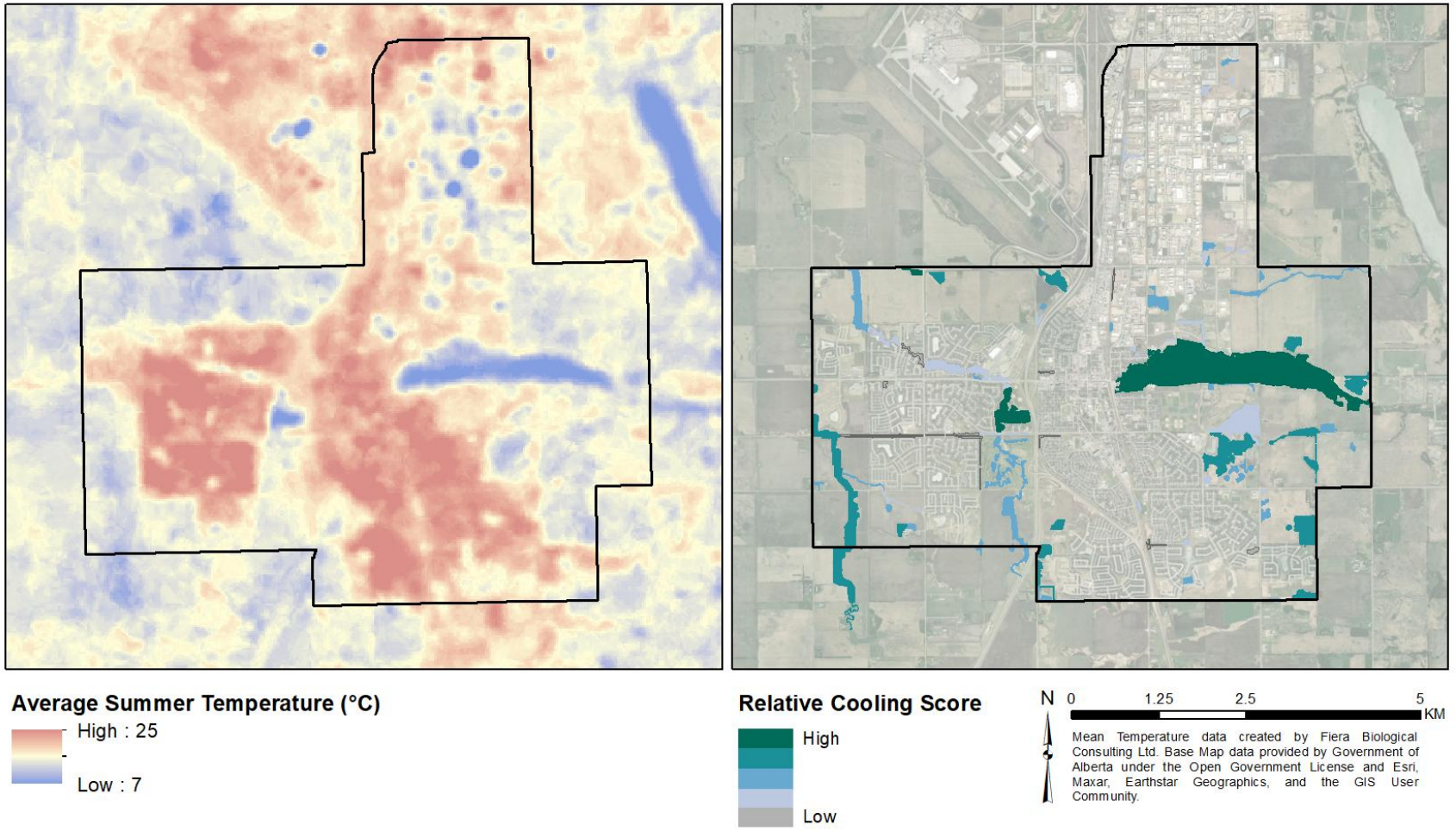


Figure 11. Average summer temperature calculated between 2019 and 2024 using Landsat imagery (left) and relative cooling score of natural assets (right). Assets with higher relative cooling scores have a higher cooling potential than assets with lower scores.



4.0 Ecosystem Service Valuation

The total estimated value of the ecosystem services evaluated in City of Leduc is **$361.8 million**[3] (Table 15).[4] This includes estimates for air quality regulation, atmospheric regulation, and nature-based recreation. Quantitative values specific to water flow regulation and temperature regulation services were not estimated individually; instead, these values are discussed in the context of carbon sequestration values as they relate to the social cost of carbon. Wildfire regulation was also evaluated qualitatively. A detailed overview of the valuation of each ecosystem service assessed in this study is provided in the sections that follow.

For ecosystem services that provide a stream of benefits into the future (e.g., annual benefit transfer values), a present value estimate was calculated assuming a 50-year period and a discount rate of 5%. For more information regarding how present values were calculated, see Appendix C.

It is important to note that the ecosystem service valuation for natural assets assumes that all assets are in good condition and the flow of services is not impaired due to reduced ecosystem function. For assets that are currently in poor or critical condition, the values estimated in this study may be inflated. Similarly, if assets that currently in good condition deteriorate over time, the value of the ecosystem services they provide could erode as well.

Table 15. Monetary estimates and confidence levels associated with the ecosystem services evaluated in this study.

Ecosystem Service	Monetary Estimate ($2024)	Confidence in Estimate
Water Flow Regulation	*Partially Captured in Atmospheric Regulation*	--
Air Quality Regulation	$1.3 million	🔴
Atmospheric Regulation	$13.5 million	🟠
Temperature Regulation	*Partially Captured in Atmospheric Regulation*	--
Wildfire Regulation	*Discussed Qualitatively*	--
Nature-based Recreation	$347 million	🟠
Total Quantified Monetary Estimate	**$361.8 million**	

Notes:

🟢 Some assumptions or estimation was used to derive estimate, but the value is considered uncontroversial.

🟠 Some assumptions or estimation was used to derive estimate, which may be open to question. Accuracy of estimate is better than +/- 50%.

🔴 Estimates are in the right order of magnitude. Order of magnitude implies that for an estimate of 5 the real value is within the range of 0.5 to 50.

-- A value that is in the right order of magnitude cannot be estimated. This is due to the unquantifiable uncertainty in the science, valuation, or the relationship between them. What is understood can only be discussed qualitatively.

[3] All values are CAD $2024 unless otherwise stated.
[4] Note that the ecosystem service valuation presented in this report does not play any role in the property assessment process undertaken by the City for taxation purposes.

4.1. Water Flow Regulation

When quantifying the value of water flow regulation (i.e., flood mitigation) provided by natural or man-made infrastructure, the most common approach is to estimate the value of flood damages that are avoided because of the presence of the infrastructure. Economists will estimate an annualized value of total potential damages (including both market and non-market damages) from a variety of flood events. Damages are typically estimated by first evaluating the spatial extent of flooding through hydrologic modelling. This information can then be used to create an Average Annual Damage (AAD) curve for flood events under consideration. Damages estimated in this type of analysis include:

- **Market Damages:**
    - **Direct Damages –** Including damages to residential, industrial, and institutional structures and contents, as well as infrastructure damages.
    - **Indirect Damages –** Including other market costs associated with flooding such as residential/commercial displacement, business disruption, traffic delays, cleanup, etc.
- **Intangible Damages**: Including non-market damages such as loss of ecosystem goods and services and mental health impacts associated with flood events.

For example, Moudrak et al. (2017) used hydrologic and hydraulic modelling that included an analysis of flood extents and flood depths for a range of precipitation events (2-year, 5-year, 10-year, 25-year, 50-year, and 100-year) for different regions in Ontario under various wetland loss scenarios. These flood extents were then analyzed in a GIS model to assess the number and types of buildings that would be inundated under each scenario, which then informed an estimate of the total value of annual flood damages with and without wetlands. A similar approach could be taken to estimate the flood mitigation value that natural assets provide to the City. For example, scenario modelling could include an evaluation of different rates of natural asset loss and/or restoration, as well as an examination of how the spatial configuration of natural asset loss or restoration may impact model outputs. However, detailed hydrologic modelling and economic valuation of market and non-market values are required (see Clare et al. 2021 for an example of how such as study could be conducted and the data sources required).

In the absence of detailed hydrologic and avoided flood damage data, the flood mitigation value of natural assets in the City cannot be robustly measured. However, the value of carbon sequestration provided by natural assets in the City described in Section 4.3 below provides key insights into the potential value associated with flood mitigation as it relates to climate change. Indeed, the social cost of greenhouse gas emissions published by Environment and Climate Change Canada (ECCC) includes estimated damages associated with various climate change-related impacts, including property damage from increased flood risk. As a result, the carbon sequestration value estimated for the City in Section 4.3 incorporates flood mitigation provided by natural assets due to climate change-related events.

4.2. Air Quality Regulation

The City of Leduc is located adjacent to and downwind from the Edmonton International Airport, and airports are among the largest sources of air pollution in North America. Combustion of jet fuel primarily releases CO_2 and water vapour; however, combustion also drives the formation of by-products, including nitrogen oxides, sulphur oxides, unburned hydrocarbons, and particulate soot (Masiol and Harrison 2014). Given the number of passenger and cargo flights that fly in and out of the airport each day, it can also be assumed that there is an increased amount of vehicular traffic that produces a large volume of emissions.

Ecosystems, particularly forest ecosystems, play an important role in removing air pollutants and regulation of air quality. Several studies have been conducted to estimate the economic value of air quality regulation provided by ecosystems. Some studies have relied on avoided cost estimates to determine how much it would cost to remove specific air pollutants in the absence of this ecosystem service. Horlings et al. (2020), for example, determined that forest areas in the Netherlands helped reduce health-related costs due to poor air quality by between €42 million and €86 million per year in 2015 ($76 to $155 million in CAD $2024). Other studies, such as Moon et al. (2021), have used stated

preference methods to estimate household WTP for pollutant reduction. In this case, the authors determined that households are WTP between KRW 197 and KRW 5,114 per tonne of air pollutants reduced each year, depending on the pollutant ($0.25 to $6.37 in CAD $2024).

Recently, Nolander and Lundmark (2024) conducted a meta-analysis of economic valuations of various ecosystem services. Based on 27 individual studies estimating air quality regulation values, the authors calculated an average value of USD 467 per ha per year (USD $2018) ($704 in CAD $2024). The authors also estimated a high standard deviation of USD 1,136 per ha per year (USD $2018) ($1,945 in CAD $2024), highlighting the variability in local valuation outcomes. Another recent study by L'Ecuyer-Sauvageau et al. (2021) sought to estimate the economic value of various ecosystem services in the Canadian Capital Region. The authors employed the iTree model to estimate the value of both rural and urban forest areas to air quality regulation. The underlying data within the iTree model are market proxy data that estimate the avoided costs of adverse health effects from air pollutants in the United States. The authors estimated that air quality regulation services are worth roughly $554/ha/year for urban forests and $10/ha/year for rural forests in the Canadian Capital Region.

To estimate the value of air quality regulation services from natural assets in Leduc, the Study Team relied on results of the iTree canopy model described in Section 2.4.2. The outputs of the model include estimated values per kg of removed pollutant in CAD $2024 (Table 8).

Table 16. Economic value of air pollutant removal by pollutant, by the i-Tree Canopy model.

Pollutant	Economic Value ($/ha/yr)
CO	$1.11
NO2	$3.34
O3	$138.77
SO2	$0.14
PM2.5	$209.22
PM10	$139.06
Total	**$491.64**

Because air quality regulation represents an annual service, the valuation of air quality regulation provided by natural assets in the City was estimated as the present value over a 50-year time period. In total, the present value of this benefit equals roughly $9,400 per hectare for woody areas.

Table 17. Air quality regulation valuation by land cover class, 50-year present value.

Land cover class	Air Quality Regulation Value ($/ha)
Woody	$9,400

In total, the estimated value of air quality regulation associated with natural assets in the City is **$1.3 million**.

A confidence rating of "low" has been assigned to the air quality monetary estimate. This estimate does not represent a WTP measure for climate regulation services by City stakeholders. Furthermore, while the iTree canopy model has been relied upon for the economic valuation of this ecosystem service in other published work (L'Ecuyer-Sauvageau et al. 2021) the underlying data within the model are not necessarily representative of the City (or Canadian) context. Nonetheless, this estimate still provides the City with a general idea of the value of air quality regulation from its natural assets.

4.3. Atmospheric Regulation

Natural assets in the City provide important climate regulation services by storing and sequestering carbon. Woody, grassland, wetland, and open water land covers all contribute to atmospheric regulation to some extent. For this study, the monetary value of atmospheric regulation provided by natural assets in the City is focused on carbon sequestration. Carbon storage, while an important ecosystem service, is difficult to monetize as the extent to which stored carbon could/would be lost through natural asset loss is highly uncertain. For example, development of a forested area that involves removal of timber does not necessarily result in a loss of stored carbon in the timber stock.

A frequently used method for estimating the monetary value of carbon sequestration from natural assets is by using ECCC's suggested Social Cost of Greenhouse Gas (SC-GHG) emissions (Government of Canada 2024). In the published SC-GHGs, ECCC provides an estimated value for the social cost of CO_2 equivalent (SC-CO_2e); this value captures the estimated damages from various climate change impacts including, but not limited to changes in net agricultural productivity, human health effects, property damage from increased flood risk, disruption of energy systems, and the value of ecosystem services (Government of Canada 2024). According to the cost schedule provided by ECCC, the SC-CO_2e in 2025 is an estimated $308 per tonne CO_2e in $2024. This value is expected to increase gradually over time as climate change damages become incrementally larger and economic wealth grows, rising to about $590 per tonne CO_2e by 2080.

The value of carbon sequestration provided by natural assets in the City was estimated as the present value over a 50-year time period. In total, the present value of this benefit ranges between roughly $3,800 per hectare for open water and $79,500 per hectare for woody areas.

Table 18. Carbon sequestration valuation by land cover class, 50-year present value.

Land cover class	Carbon Sequestration Value ($/ha)
Open Water	$3,800
Grassland	$6,300
Wetland	$18,100
Woody	$79,500

In total, the estimated value of carbon sequestration associated with natural assets in the City is **$13.5 million**.

A confidence rating of "medium" has been assigned to the carbon sequestration monetary estimate. While this estimate does not represent a WTP measure for climate regulation services by City stakeholders, the Study Team is confident in ECCC's updated SC-CO_2e estimate in the Canadian context, and thus believe this estimate provides the City with useful information regarding the value of this ecosystem service.

4.4. Temperature Regulation

Natural assets in the City can provide important cooling effects, particularly larger assets with open water and woody land cover. The Urban Heat Island (UHI) effect is known to have significant economic and health impacts, particularly in densely populated communities with limited natural areas. The UHI effect occurs when ambient temperatures in urban centres are higher than those in rural areas owing to limited vegetative cover in urban centres, as well as more dark surface area (e.g., roads, paved lots) that absorb the sun's rays and radiate head (Health Canada 2015). Negative impacts of the UHI effect include increased energy and electricity demands, increases in ozone, and increased heat stress contributing to higher mortality particularly amongst at-risk populations (Santamouris 2020).

There has been a plethora of research highlighting the importance of natural cover (particularly canopy cover) for mitigating the UHI effect (e.g., Rogers et al. 2018; Tapper et al. 2019; Whiteoak and Saiger 2019, Zhou et al. 2023). A recent Italian study by Morabito et al. (2021) found that a 10% increase in areas with hard surfaces and limited tree cover contributes to a 4°C increase in urban temperatures. Marando et al. (2022) studied microclimate regulation across 601 European cities and found that a 16% increase in tree cover can cool urban temperatures by 1°C. Work by Whiteoak and Saigar (2019) suggests that tangible economic benefits from reducing urban temperatures include savings associated with improvements in mortality, morbidity, work productivity, and energy/electricity use. These studies all suggest that maintaining urban canopy cover is important for regulating temperatures that create comfortable and safe living conditions for residents.

The benefits provided by natural urban areas are becoming increasingly more important in the face of climate change. Indeed, it can be argued that the biggest threat to heat regulation in the City (and other Canadian communities) is climate change. The value of atmospheric regulation provided by natural assets through carbon sequestration described in Section 4.3 can therefore provide key insights into the potential value associated with temperature regulation as it relates to climate change. The social cost of greenhouse gas emissions published by ECCC includes estimated damages associated with various climate change-related impacts, including human health effects from increasing temperature. As a result, the carbon sequestration value estimated for the City in Section 4.3 incorporates temperature regulation provided by natural assets due to climate change-related events.

4.5. Wildfire Regulation

The relationship between natural assets and wildfire is complex. While certain natural features can provide fire mitigation services (e.g., wetlands), mismanagement of lands and certain land cover types can alternatively increase the risk of wildfire.

Wildfires, like other natural disturbances such as drought and flood, are an important part of the natural cycle for many ecosystems. Indeed, wildfires can often stimulate new growth in forests by:

- releasing nutrients stored on the forest floor,
- opening canopy to more sunlight, and
- enabling certain tree species to reproduce (e.g., lodgepole and jack pine cones open with extreme heat) (NRCan 2025).

In grasslands, wildfire can also reduce buildup of dead vegetation and increase sunlight (Parks Canada n.d.). Furthermore, wildlife populations can benefit from wildfire, as regenerated vegetation acts as a food source for some animals (e.g., deer, moose, elk) (Parks Canada n.d.). Woodpecker populations have also been found to thrive post-wildfire, feeding on insects that colonize freshly burned trees (Parks Canada n.d.).

Although wildfires can be beneficial for some ecosystems by stimulating important regeneration activities, there are very real socio-economic costs to wildfires, particularly when inhabited areas are affected. Wildfires along with other natural disasters are also increasing in frequency and intensity, and the economic costs of these events are increasing as well. Botzen et al. (2019) have suggested that the reason for the increasing economic costs associated with natural disasters is likely two-fold: population and economic growth over time, and an increase in the frequency and intensity of weather and climate extremes (IPCC 2021).

Existing natural assets in communities like Leduc can play an important role in wildfire mitigation. Wet features on the landscape, including open water and wetlands, are particularly vital for wildfire prevention as these features act as natural fire breaks and can also provide refuge for wildlife (DUC 2023). Natural assets in the City like Telford Lake, the Leduc Reservoir, and other wetland assets are therefore important to retain.

4.6. Nature-based Recreation

The City hosts a variety of natural assets that support nature-based recreation opportunities, such as:

- birding,
- cycling,
- walking/hiking, and
- water-related activities (e.g., non-motorized boating, fishing, etc.).

The economic value of nature-based recreation in Alberta and Canada has been studied extensively (e.g., Boxall et al. 1996a, Boxall et al. 1996b, Haener and Adamowicz 2000). Recently, several studies have undertaken valuation modelling to produce welfare estimates of a variety of outdoor recreation activities in Alberta (e.g., Lloyd-Smith and Becker 2020; Lloyd-Smith 2021; Spence et al. 2023).

Indeed, the most recent and relevant study is Spence et al. (2023). In this study the authors rely on a large, comprehensive survey of Canadians focusing on their participation in a wide variety of nature-based activities. The survey included over 24,000 responses of those aged 18 and over and, using revealed preference data of respondent spending on nature-based activities, estimated the average annual welfare value per person, per activity (Table 19). To estimate the value of nature-based recreation in the City, the Study Team identified activities valued in Spence et al. (2023) that are available in the City (see Table 19). In total, these activities are estimated to provide benefits to residents of Leduc of roughly $2,935 per person per year.

Valuation of nature-based recreation in Leduc also requires an understanding of how many individuals in the City are participating in outdoor activities available within the City's natural assets. A variety of sources were consulted to provide information on activity levels in the City. These include:

- A recent user survey administered for the City's Recreation Facility Needs Assessment Update (City of Leduc 2023) that suggests of those surveyed, natural spaces like the City's Multiway Trail system and other natural areas are highly frequented by those engaging in outdoor activities (Figure 12).
- Data provided by the City describing Multiway Trail counts around Telford Lake that suggests high usage (Table 20).
- Engagement results from the development of the City's 2024 Environmental Plan (City of Leduc 2024) that highlights the importance of protecting and expanding natural areas for recreation purposes. Indeed, a key theme from this engagement was that natural areas are important to City residents for recreational purposes, particularly the Telford Lake area.
- The City's Parks, Open Spaces and Trails (POST) Master Plan Update (City of Leduc 2020b), resident engagement that revealed high-level participation rates for various POST assets in the City (Table 21).

Based on these sources, the City's natural spaces are clearly well-used for nature-based recreation.

Table 19. Average annual benefits per person per year for various nature-based activities.

Activity	Value[a] ($2024/person/year)
Birding[b]	$401
Camping	$86
Cycling[b]	$173
Fishing[b]	$240
Gardening	$555
Golfing[c]	$200
Hiking[b]	$1,097
Hunting birds	$37
Hunting large animals	$96
Hunting other	$27
Hunting waterfowl	$33
Recreational motor vehicles[b]	$457
Photography[b]	$293
Cross-country skiing[b]	$52
Downhill skiing	$61
Motorized boating	$284
Beach/non-motorized boating[b]	$222
All activities	$4,379
Activities available in City of Leduc[b]	**$2,935**

Notes:

[a] Spence et al. 2023 specifically estimate welfare values for various demographic sub-groups including “Indigenous”, “Immigrant”, and “Neither”. The welfare values presented in this table and used in the recreation valuation for the City are for the “Neither” sub-group, which included values that were predominantly in between the “Indigenous” and “Immigrant” sub-group values.

[b] Denotes activities assumed to be available through nature-based recreation within natural assets in the City.

[c] While there are golfing opportunities in the City, golf courses were not included in the natural asset inventory.

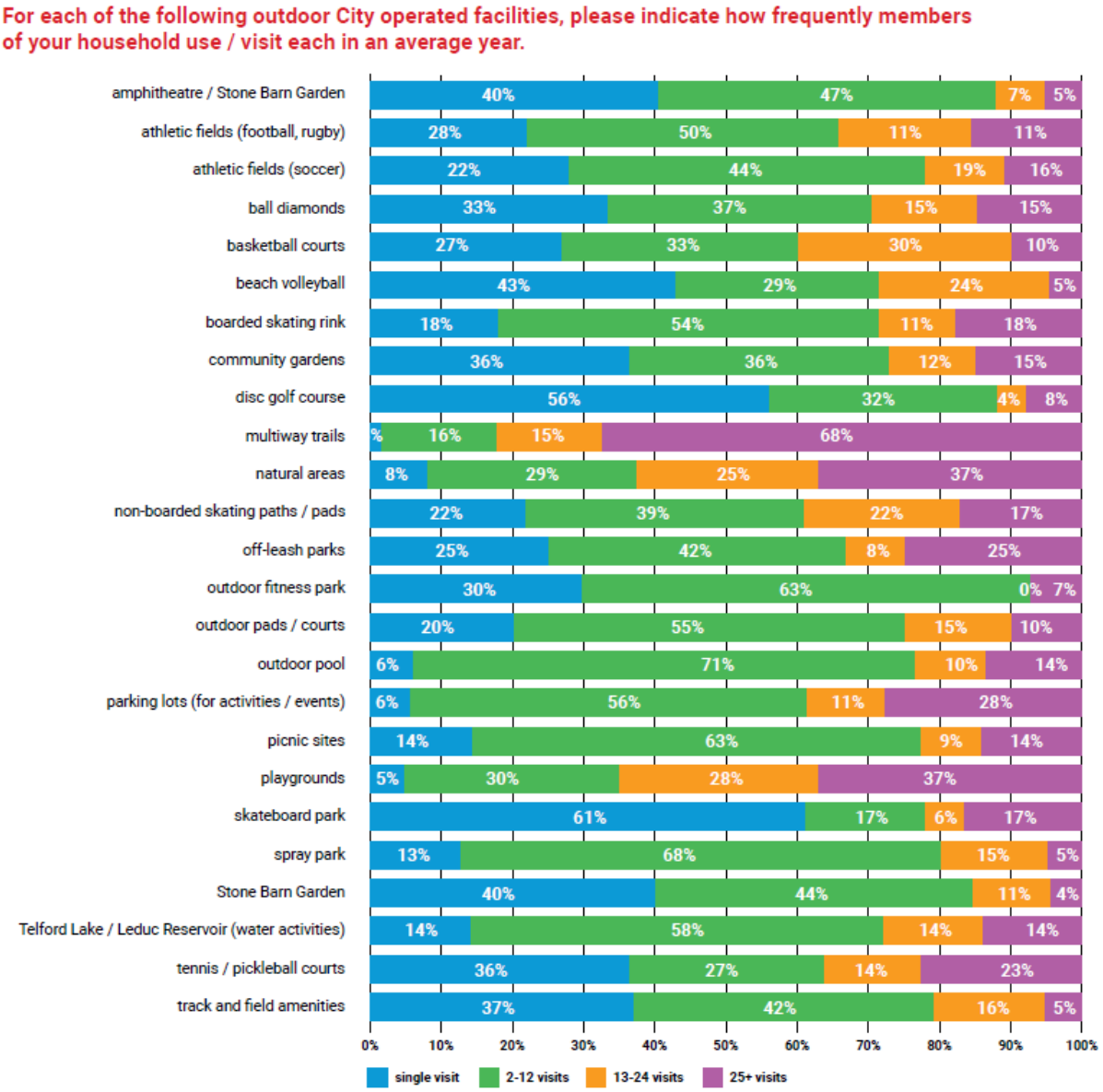


Figure 12. City of Leduc resident visitation rates, outdoor facilities.

Table 20. Telford Lake Multiway Trail Counts, 2019 – 2024

Year	Trail Count	Notes
2019	18,585	Installation year (partial count)
2020	86,469	Inflated values due to COVID-19 pandemic
2021	72,952	Inflated values due to COVID-19 pandemic
2022	57,329	-
2023	65,461	-
2024	53,212	-

Table 21. POST Amenity Resident Participation, 2020

POST Amenity	Participation Rate (%)
Multiway trails	97%
Playgrounds	66%
Telford Lake	63%
Outdoor rinks	34%
Outdoor pool	32%
Soccer fields	22%
Tennis courts	14%

The following assumptions are made with respect to nature-based recreation participation in the City:

- 80% of individuals residing in the City participate in outdoor activities. This assumption is based on the average participation of residents on the City's multiway trail system and Telford Lake as per the POST Master Plan Update (City of Leduc 2020b).
- City residents participate in roughly 20% of their annual nature-based recreation within natural assets in the City, acquiring ~$587 per person per year in value from nature-based recreation within the City.[5] Over a 50-year period, the present value of these benefits equals roughly $11,250 per person.

Note that the valuation of nature-based recreation from natural assets in Leduc is focused on City residents. In reality, some of the natural assets in the City provide value to residents of other neighbouring jurisdictions as well (e.g., Telford Lake).

Given that there were an estimated 38,543 residents in City of Leduc in 2024 (Statistics Canada 2025), we estimate the annual value of nature-based recreation in Leduc for City residents as being about **$347 million**. Note that this valuation is not divisible across individual natural assets. Non-market values for nature-based recreation are most often tied to households or individuals who participate in those activities. However, we can likely attribute much of the nature-based recreation value accruing to City of Leduc residents to its major recreation sites, including Telford Lake, the Leduc Reservoir, and the off-leash dog park.

It is important to note that while the City's major recreation sites are certainly valuable given the population they serve, the extent to which these assets will remain valuable as the City expands its over time is uncertain. The quality of the service may degrade as assets become popular/overused and therefore the usage and/or economic value may change. Maintaining these assets is important, but the City also needs to ensure an adequate number of natural assets are available for recreation activities, particularly as it continues to grow into the future.

A confidence rating of "medium" has been assigned to the nature-based recreation monetary estimate. While this estimate does represent a welfare measure for nature-based recreation, the published literature from which a benefit transfer value was estimated was not specific to the City context. Furthermore, robust information regarding recreation area usage from those within the City were sparse.

The confidence rating of the valuation for this ecosystem service could be increased to "high" with improved recreation usage tracking within the City. The City appears to already undertake surveys/data collection with respect to its recreation facilities and general visitation. Including questions that ascertain the extent to which residents participate in nature-based recreation activities (like those listed in Table 19) within the City versus outside of the City in a given year would be highly useful.

[5] Note that we acknowledge this assumption likely varies substantially depending on the activity. Twenty percent was selected as a conservative assumption.



5.0 Findings, Discussion & Recommendations

5.1. Summary of Findings

A total of 104 unique natural assets were identified in the study area within the City and transboundary with Leduc County, covering 401 ha. Roughly 363 ha of the natural asset area is located within the City boundary, covering roughly 8% of the City. Assets range in size from 0.3 ha to 166 ha, with most ranging between 0.5 and 5.0 ha. There are 11 assets larger than 5 ha, which together account for 72% of the total natural asset area and represent large habitat patches that serve as core wildlife habitat at the local and regional scale. Woody cover was the predominant cover type within natural assets at 36%, although water cover was also substantial at 27%. Just over half (54%) of the natural assets have a relative condition score of Fair, with 9% considered Good, 36% rated as Poor, and 2% assigned a relative condition score of Critical.

The total estimated value of the ecosystem services that were evaluated in the City of Leduc is approximately **$361.8 million**.[6]

Nature-based recreation was the highest value service, with an estimated value of $347 million. This value reflects the importance of the City's natural assets for providing nature-based recreation opportunities to residents. Atmospheric regulation was the next highest valued service, with an estimated value of $13.5 million. This captures the value of carbon sequestration and the estimated damages from various climate change impacts including, but not limited to, changes in net agricultural productivity, human health effects, property damage from increased flood risk, disruption of energy systems, and the value of ecosystem services (Government of Canada 2024). Finally, air quality regulation provided by natural assets was estimated to be worth roughly $1.3 million to City residents.

In terms of asset-specific economic value, only air quality regulation and atmospheric regulation estimates could be assigned to individual assets, and because trees and shrub cover drives value for these ecosystem services, the assets with the highest monetary values in the study area were generally associated with large natural assets that have extensive woody cover. Nature-based recreation values are assessed at a City-level and other ecosystem services evaluated in this study are discussed qualitatively. Telford Lake (Asset 37) ranks as the highest valued asset, providing over $4.2 million in air quality and atmospheric regulation services (Figure 13; Table 22). With respect to the City's $347 million in nature-based recreation value across all assets, it is likely that Telford Lake makes up a large proportion of this value as well, given the high-quality recreation opportunities that it affords. The woodland/wetland complexes near the Recreation Centre/Lions Campground (Asset 61 within the Fraser Area Structure Plan) and in Peace Park (Asset 40), a large woodland area just north of the Robinson neighbourhood (Asset 97), and a creek/riparian area extending along the City's southwest boundary (Assets 76 and 100) are all in the top ten valued assets in the City.

[6] This value was calculated as a present value over a 50-year period at a 5% discount rate. All values are CAD $2024 unless otherwise stated.

For ecosystem services that were not valued in monetary terms, such as water flow regulation and temperature regulation, the estimated ecosystem service supply was used to highlight key assets. Telford Lake (Asset 37), the Leduc Reservoir (Asset 51), the woodland areas near the Recreation Centre/Lions Campground (Asset 61) and north of the Robinson neighbourhood (Asset 97), as well as others, provide high or moderately high flood attenuation and cooling services to residents of the City (Figure 14).

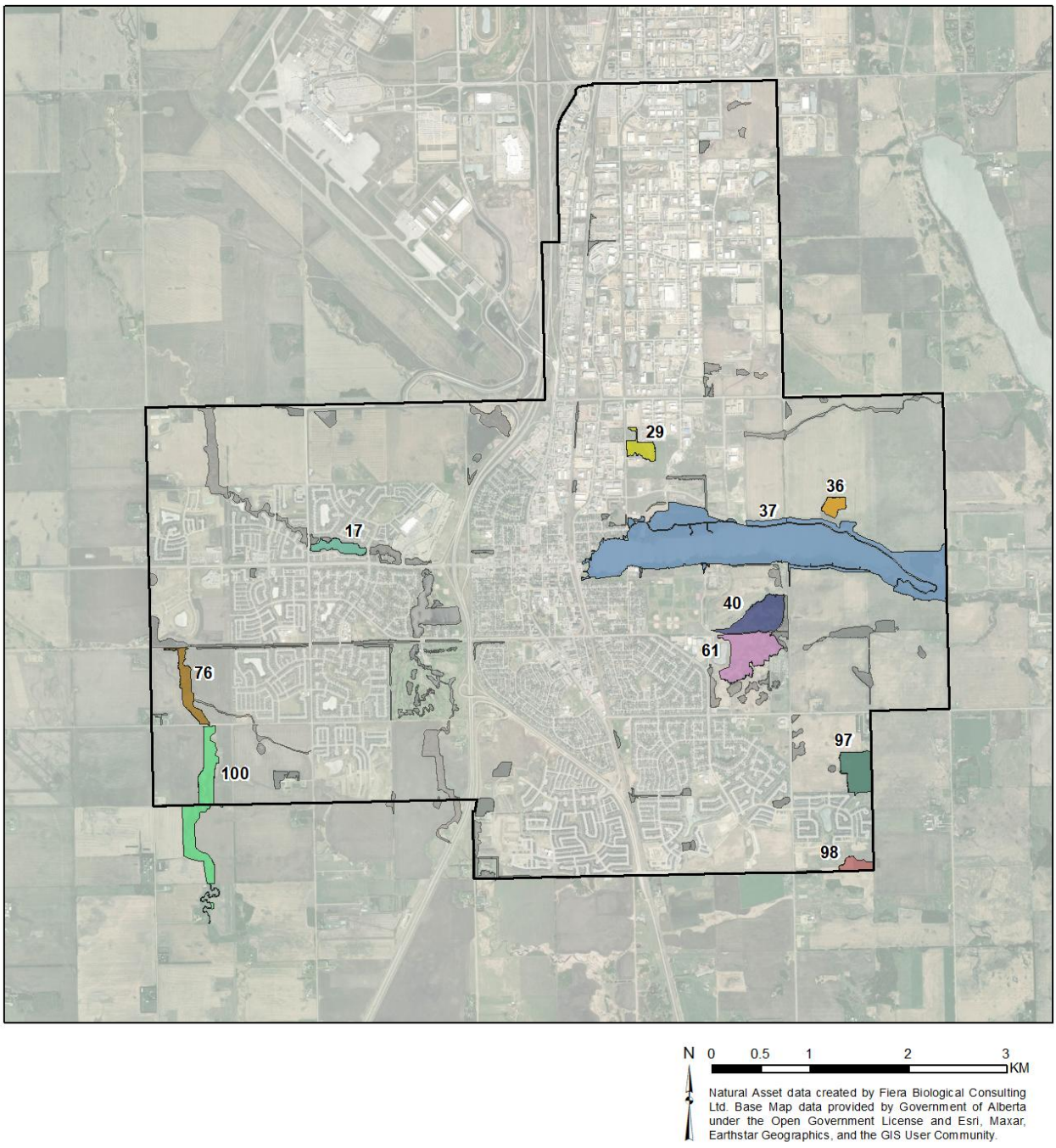


Figure 13. Top ten natural assets (coloured and labelled with ID numbers) by economic value. The other natural assets in the inventory are outlined in black.

Table 22. Top ten natural assets by economic value.

Asset ID	Economic Value[a]
37 (Telford Lake)	$4,205,000
97	$967,000
61 (within the Fraser ASP)	$774,000
100	$695,000
40	$542,000
76	$358,000
17	$345,000
29	$341,000
98	$335,000
36	$305,000

Notes:
[a] Asset-specific economic values include estimates for air quality regulation and atmospheric regulation. Nature-based recreation values are assessed at a City level, and other ecosystem services evaluated in this work are discussed qualitatively.

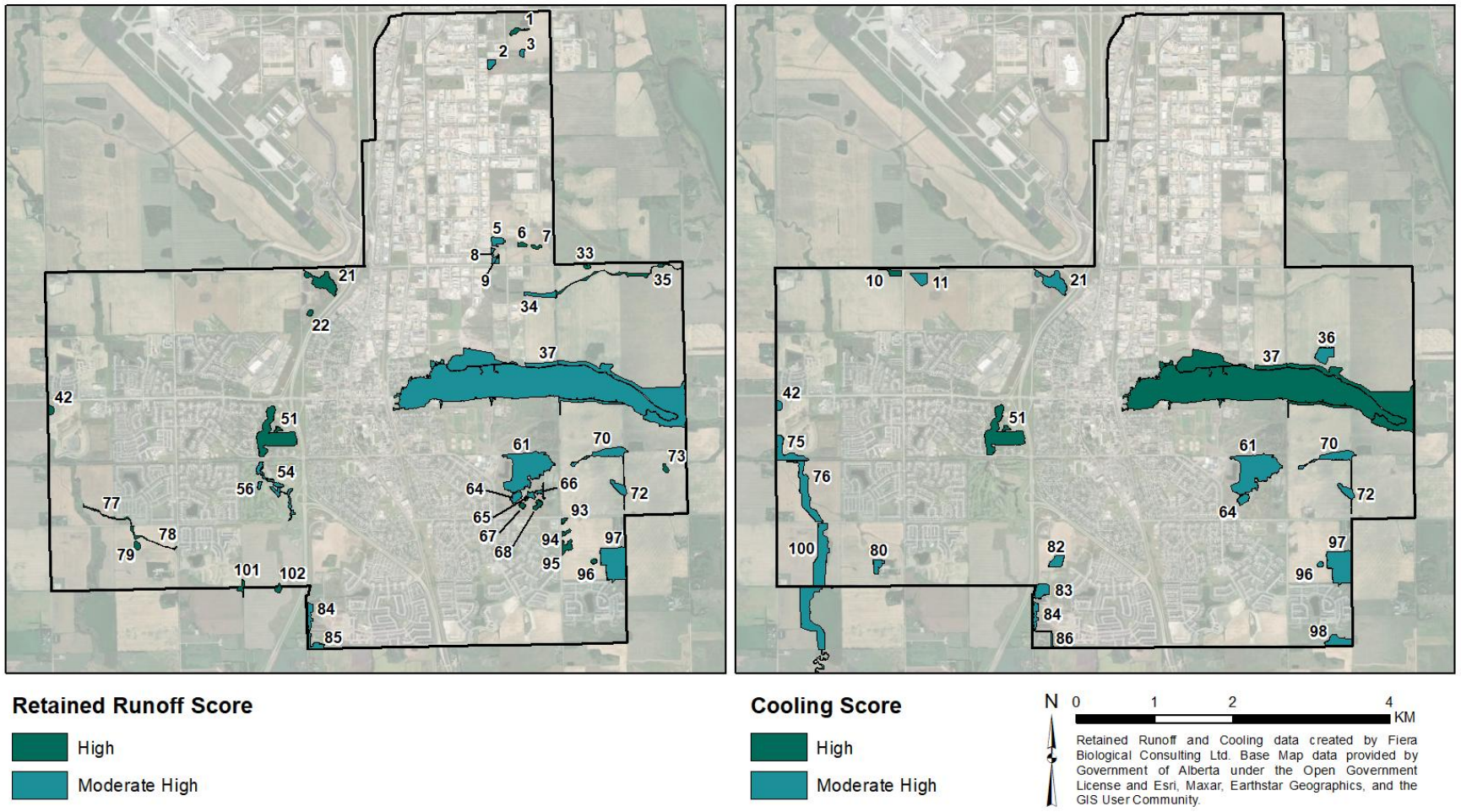


Figure 14. Natural assets that rank high or moderately high in terms of retained runoff and cooling scores.

5.2. Discussion

The City of Leduc's natural asset inventory and valuation is a critical ***first step*** to the City's full natural asset management project and goals to improving the management and preservation of key natural assets in the City. Municipalities actively manage traditional engineered or built assets like sidewalks, roadways, and stormwater facilities every day. Traditional asset management systems are designed to track assets over time, monitoring the monetary and physical state of these assets so that they can be appropriately used, maintained, and replaced. The inclusion of a natural asset inventory into existing municipal asset management frameworks is a developing field, but there is general agreement that including natural assets into municipal asset management activities allows for better integration of these assets into land use and development planning, infrastructure servicing, operations and maintenance, and budgeting and financial planning (Brown et al. 2019). Best practices on how to incorporate natural assets into traditional asset management systems, what information they are attributed with, and how that information should be leveraged have yet to be established.

The goal of any municipal asset management system is sustainable service delivery. Conceptually, there are three major steps in the process of integrating natural assets into an asset management strategy: Assess, Plan, and Implement (Brown et al. 2019; Figure 15). The City of Leduc has completed the first phase of work (assess) through the development of the natural asset inventory and valuation. With a solid understanding of the current state of natural assets in Leduc, the City can now begin the planning phase, whereby policies and strategies are defined to ensure natural assets are formally built into decision-making procedures and made part of the operational and political dialogue by which the City is held to account (Sunderland et al. 2023). The incorporation of information from the natural asset inventory into municipal policies and plans is key to ensuring that planning and development actions are undertaken in full consideration of natural assets and the benefits they provide to City residents.

The integration of natural assets into a municipal asset management strategy or municipal development plan should be done to ensure that *relevant* information about natural assets is included, such that this information can be incorporated in evaluations of trade-offs between service, costs, and risk (Brown et al. 2019). Natural assets and traditional, engineered assets are inherently different. As such, municipal asset management strategies should not treat them in the same way. For example, natural assets do not depreciate the way that engineered assets do, and in fact, many natural assets can appreciate over time. These types of differences between natural and engineered assets should be acknowledged for successful integration.

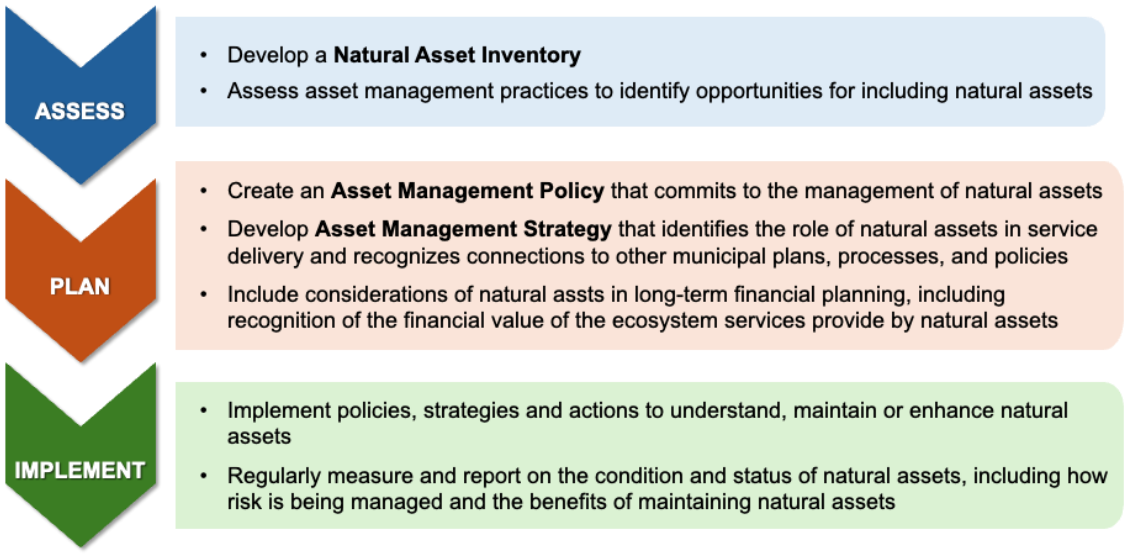


Figure 15. Major steps and actions required for successful integration of natural assets into an asset management system (adapted from Brown et al. 2019).

5.3. Recommendations

5.3.1. Planning and Implementation

A natural asset inventory and valuation on its own holds little weight if there are no adopted policies to guide developers and City administration in decision-making that explicitly considers the information presented in the inventory. A municipal natural asset inventory requires accompanying strategy and policy development and/or amendments to be effective. The natural asset inventory and estimated values provided in this report describe clear linkages between the City's existing natural assets, the ecosystem services that those assets provide, the benefits of those ecosystem services to City residents, and the realized value of those benefits (where possible). It is important that this data and information be incorporated into the City's guiding policies so that natural assets are not overlooked in land-use planning.

As a first step in the City's planning and implementation phases, clear objectives with respect to natural asset securement in the City can be defined. This includes clearly articulating a long-term vision for natural assets and how the information within the inventory will be used. This may be outlined in a formal asset management strategy, or other guiding documents the City relies on (e.g., Municipal Development Plan). For example:

- **Municipal Asset Management Strategy/Database:** The City could consider developing an asset management strategy that identifies what the priorities are with regards to including natural assets and their attributes in the City's overall approach to asset management. At the time of writing, the City does not have an overarching asset management strategy but is in the process of developing one. As such, the City has an excellent opportunity to explicitly incorporate natural assets into a City-wide asset management strategy and database as appropriate. This could include providing context regarding the specific role(s) of natural assets in the delivery of services and the connections to other municipal plans, processes, and policies.

  An asset management strategy could be developed to identify what the priorities are with regards to including natural assets and their attributes in the asset management system. This can include providing context regarding the specific role(s) of natural assets in the delivery of services, clarifying natural asset ownership and responsibility, and the connections between natural asset management to other municipal plans, processes, and policies. The strategy might also identify the benefits accruing to City residents provided by natural assets (Albert et al. 2019). Clearly communicating the benefits of natural assets can be particularly helpful in gaining support from and balancing the interests of diverse stakeholder groups. Finally, asset management plans and long-term financial plans can be implemented to document how natural assets are considered in the context of other assets. These plans can also identify and manage service delivery risks and the financial risks of not properly managing or considering natural assets.

- **Municipal Development Plan:** The City's Municipal Development Plan (MDP) (City of Leduc 2020a) describes in its vision respect for the environment and accordingly, includes as a key strategy the need to balance municipal development with the preservation of the natural environment. With the development of the natural asset inventory, the City should consider adopting clear language and guidance with respect to:
  - what its specific objectives are regarding its natural assets, and
  - how the data and information within the natural asset inventory should be considered when it comes to land-use planning decisions.

Ideally, the City would develop a specific objective with respect to its natural areas and use the data and information from the natural asset inventory to provide targets and guidance for achieving this objective, clearly describing and defining these criteria within the MDP and/or asset management framework. For example, if air quality is a local issue, then natural assets with a high proportion of woody cover and relatively high air quality regulation values could be prioritized for conservation. Alternatively, if the City is

concerned about flooding, prioritizing natural assets within the inventory that have high retained runoff scores for conservation may be desirable.

Other communities within the Edmonton region have begun adopting nature policies and incorporating 'nature positive' language into their guiding policy documents. For example, Parkland County completed a municipal natural asset inventory and valuation in Spring 2024. As part of its recent MDP update (Parkland County 2025a), the County implemented language that lays out specific guidelines related to "development policies to protect natural functions." Specifically, the County states that:

> *"Parkland County's natural systems have intrinsic value and provide functions that support the health and wellbeing of people and wildlife, like purifying water, pollinating crops, and providing habitat. The County has a responsibility to protect these functions so that they continue to support the region for generations to come. The County's High Priority Landscapes, Environmentally Significant Areas, and High Value Natural Features are the highest priority areas for protecting natural functions.*
>
> *Development can support this shared responsibility by being nature-positive. Nature-positive means activities and developments that, on balance, protect, conserve, and/or enhance the beneficial functions of the natural features within the County more than they impair, degrade, or nullify them. The best way for development to be nature-positive is to avoid the significant disruption of natural functions in the first place. This is the best option because is it very difficult to replicate the function of established, intact natural areas. When avoidance is not viable, the next best approach is to mitigate or reduce the impacts of a development. As a final option, when disturbance is unavoidable and mitigation is not viable, impacts to natural functions can be offset. Offsetting natural functions generally includes replacing or restoring part of the removed functions."*

The MDP goes on to describe nature positive development with targets/guidelines in keeping with the County's specific concerns (e.g., there is a strong focus on water-related assets and services). Additionally, as part of the planning and implementation work the County has developed and approved a Nature Policy Framework (Parkland County 2025b). The framework sets out a strategy, vision, and goals for conserving and restoring natural assets and includes a package of environmental policies that:

- provide guidance on how to move from identifying and mapping natural features towards actively working to conserve them and the beneficial services they provide,
- create alignment of goals, objectives, and strategies across the organization and amongst all departments
- Establishes system wide targets and goals for conservation,
- Enables innovative conservation approaches that contribute to the maintenance of natural features, functions, and associated beneficial ecosystem services.

The 'nature positive' language and guidelines set forth in the MDP ultimately provide the overarching expectations and support for specific targets and activities described within the policies of the Nature Policy Framework. With these policies in place, the County will be able to leverage the information and data from its natural asset inventory to track progress and achieve set outcomes. Setting clear objectives with respect to natural asset securement in the City and adopting policies that articulate these objectives is important, particularly when it comes to newly developed areas as the City grows into the future.

5.3.2. Future Growth

As the City grows over time, consideration should be given to any newly acquired natural assets. Expansion of the natural asset inventory and valuation may be necessary in the future, with new lands representing a 'clean slate' for the City when it comes to the conservation and preservation of natural assets. Indeed, many of the natural assets located within the City's existing boundary are at risk of loss

due to development plans that have already been approved (Figure 7). In the case of new growth, the City would have an opportunity to proactively implement new development policies and guidelines to achieve a higher rate of natural asset securement than what it has experienced historically.

In many instances, urban expansion results in natural assets that are currently located on private lands being captured within the boundary of a new community/neighbourhood. In these instances, land developers or the City of Leduc could engage with landowners to discuss mechanisms for the direct securement of high value natural assets in advance of formal planning and development processes, particularly for natural assets considered to be high-priority for retention. Securement tools could include, but are not limited to, mechanisms such as a conservation easement or direct purchase of lands that contain natural assets.

5.3.3. Consideration of Regional & Intermunicipal Assets

The scope of this inventory and valuation focused on the City's current boundaries (plus a small buffer); however, several of the natural assets identified in the inventory cross municipal boundaries and are components of a larger regional network of natural areas. With its new natural asset inventory, the City can collaborate with neighbouring municipalities to identify and manage key natural assets that deliver shared benefits to end users in multiple jurisdictions.

For example, Telford Lake is an important local and regional natural asset that provides significant ecosystem services, such as water flow regulation, water quality control, water provision, habitat provision, and nature-based recreation not only to residents of the City, but those across the Capital region. Further, the ecosystem services supplied by larger assets such as Deer Creek ultimately flow to end-users in multiple jurisdictions (e.g., Leduc County, Edmonton), and assets to the east of the City adjacent to Telford lake are part of an important wildlife corridor linked to Saunders Lake (Dragon et al. 2018). The City therefore has an obligation to carefully manage locally and regionally significant assets within its boundaries, as do neighbouring municipalities with shared or ecologically linked assets. Given this, regional planning and intermunicipal development plans are important tools for advancing the management of shared natural assets. Following the dissolution of the Edmonton Metropolitan Region Board (EMRB) in Spring 2025, coordination on natural asset management between individual municipalities is more important than ever. Leduc has an opportunity to reach out to neighbouring municipalities and use its natural asset inventory and ecosystem service assessment as both an example and a foundation for the identification and management of intermunicipal natural assets.



6.0 Study Gaps, Uncertainties & Limitations

6.1. Other Ecosystem Services of Interest

The natural asset inventory and valuation for the City focused on priority ecosystem services that were selected in collaboration with City staff. In reality, natural assets in the City provide a much broader range of ecosystems services than what was included in this assessment, including dozens of provisioning, regulation and maintenance, and cultural services that could not be assessed due to time, cost, and data limitations. While not an exhaustive list, Table 23 provides several additional examples of ecosystem services that are produced by natural assets in the City of Leduc. Despite not being included in this study, these services, in addition to many others, provide important benefits to City residents that were not captured in the monetary values estimated as part of this study.

Table 23. Additional examples of ecosystem services that were not included in this study but are provided by natural assets in the City of Leduc.

ES Category	Ecosystem Service	Example of Ecosystem Good/Benefit to End-Users
Provisioning (Biotic)	Harvestable volumes of wild plants and animals	Food from wild plants (e.g., berries, fruits, mushrooms, etc.) and animals (e.g., moose, deer, ducks, grouse, etc.) for subsistence
Provisioning (Abiotic)	Surface and groundwater for drinking	Safe and secure potable water for human consumption
	Surface and groundwater for non-drinking purposes	Non-potable water for use in agriculture (irrigation, animal rearing) or industrial processes
Regulation & Maintenance (Biotic)	Soil erosion regulation	Reduction of damage of sediment input to water courses
	Wind protection	Reduction in scale or frequency of damage from excessive winds
	Maintaining nursery populations and habitats	Sustainable populations of useful or iconic species
Cultural (Biotic)	Characteristics of living ecosystems that have existence value	Improved mental/moral well-being

6.2. Economic Valuation

Monetary values for the ecosystem services assessed in this study were based on benefit-transfer values for which the primary data were estimated using a variety of valuation techniques. As outlined in Table 24, monetary values for the ecosystem services quantified in this study were estimated using benefit transfer values from studies that relied on various valuation techniques. While these approaches can be used to estimate the benefits associated with natural assets and the ecosystem services they provide, the studies from which the benefit transfer values were derived each have their own set of uncertainties and caveats. Furthermore, like market goods, the values of non-market ecosystem services are not static and the non-market valuation literature is constantly changing and improving. As such, the value estimates presented in this work represent a snapshot in time and may be improved upon in the future as new work is published.

Table 24. Economic valuation approaches for ecosystem services evaluated in the City of Leduc.

ES Category	Ecosystem Service	Valuation Methods
Regulation & Maintenance (Biotic)	Water Flow Regulation	*Partially Captured in Atmospheric Regulation*
	Air Quality Regulation	Benefit Transfer – Market Proxy
	Atmospheric Regulation	Benefit Transfer – Market Proxy
	Temperature Regulation	*Partially Captured in Atmospheric Regulation*
	Wildfire Regulation	*n/a*
Cultural (Biotic)	Nature-based Recreation	Benefit Transfer – Revealed Preference (Travel-Cost)

Additionally, none of the studies relied upon are specific to the City of Leduc context. To this end, the City could benefit from undertaking additional revealed preference or stated preference work to acquire primary welfare data for their top assets or assets they believe to be at particular risk of loss or degradation. A potential revealed preference study that could support the City in acquiring primary natural asset valuation data would be a hedonic analysis of residential property values. Hedonic models of property values involve using real estate market data (i.e., housing prices) to isolate the various components of residential property prices including house characteristics (e.g., number of bedrooms, square footage, specific finishes), neighbourhood characteristics (e.g., school proximity, crime rates), and environmental characteristics (e.g., proximity to green space, desirable views). Using these data one can estimate the marginal WTP for environmental attributes and certain natural or semi-natural assets. Stated preference work is also an option for the City to acquire robust primary natural asset valuation data. While the theory behind stated preference surveys and WTP estimation is relatively simple, conducting these studies in practice presents many challenges. Stated preference surveys require careful and thoughtful design to avoid allowing respondents to introduce biases into the results including, but not limited to:

- Strategic bias, which occurs when respondents provide biased answers to influence a desired outcome.
- Information bias, which occurs when respondents must value attributes or assets with which they have limited experience or understanding.
- Hypothetical bias, which occurs when respondents feel there are no real-world outcomes associated with their responses, and thus, treat the survey casually instead of providing thoughtful responses.

These types of biases, and others that can occur in stated preference studies, can lead to substantially over- or under-estimated ecosystem values, leading to potentially costly municipal policy mistakes. As such, any future stated preference work conducted for the City should include expert survey design and implementation.

6.3. Study Limitations

While the natural asset inventory and the associated estimates of ecosystem service values for the City were developed following standard best practices, readers are asked to consider the following points as they interpret the results of this study:

- Natural assets were identified and mapped using air photographs and satellite imagery, the most recent of which was 2024. As a result, the location, size, and boundaries of the natural assets included in the inventory may not accurately reflect the status and/or presence of these features at present day. Further, the natural assets mapped in this assessment were not extensively field verified, and so the spatial accuracy of boundaries for some of the assets, and particularly for wetlands, may not accurately reflect the actual ecological boundaries. Because of this, area estimates for each asset likely have some degree of spatial error associated with them.
- Natural assets were assigned a condition score using metrics that could be assessed in a geographic information system (GIS). As a result, the condition scores are not reflective of characteristics that must be assessed in the field (e.g., presence of invasive or weedy species). Conditions scores are generally reflective of impacts that may be influencing the ecological function of an asset but should not be considered a definitive assessment on the current ecological state of these assets. A subset of assets was assessed in the field, the results of which are provided in Appendix A.
- Estimates of ecosystem service values assume that the underlying function of the natural asset has not been substantially impaired and the assets have sufficient function to deliver the ecosystem services that are being valued. Land development that causes change to ecosystem function can lead to a decrease in the supply and flow of some ecosystem services (e.g., water quality control) but may also lead to an increase in the supply of other ecosystem services (e.g., aesthetic or recreational value). The estimates of ecosystem service value presented in this study do not account for the influence of condition on the current supply of ecosystem services.
- Natural assets provide a wide range of ecosystem services, and not all services and associated values could be evaluated in this study. Because of this, the economic value calculated for some assets is likely underestimated.



7.0 Conclusion

The primary objective of this project was to create an inventory of natural assets for the City of Leduc and estimate the monetary value of priority ecosystem services that flow from these assets. This was done to provide a foundation for mapping and tracking the condition and status of natural assets over time, as well as to allow the City to better understand the economic and environmental trade-offs of land development.

A total of 104 natural assets covering 401 ha were identified and mapped as part of this study. This portfolio of natural assets represents a range of habitat types that support a diversity of wildlife and provide an important suite of ecosystem services.

Within the scope of this study, six priority ecosystem services were identified, including: water flow regulation, air quality regulation, atmospheric regulation, temperature regulation, wildfire regulation, and nature-based recreation. Ecosystem service value estimates were derived for three of the services, totalling approximately $361.8 million ($2024). This value was calculated as a present value over a 50-year period at a 5% discount rate.

This study provides the City of Leduc with information about the extent of natural assets and the value of a select number of ecosystem services that flow from these assets, which can be used to help inform land use management decisions consistent with existing City policies and bylaws.

7.1. Closure

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8.0 Literature Cited

Adamowicz, W., P. Boxall, M. Williams, and J. Louviere. 1998. Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation. American Journal of Agricultural Economics 80:64-75.

Albert, C., B. Schröter, D. Haase, M. Brillinger, J. Henze, et al. 2019. Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? Landscape and urban planning 182:12-21.

Al-Terra. 2025. Fraser Area Structure Plan. Prepared for Melcor Developments Ltd. Submitted to The City of Leduc, February 2025. Pp. 81.

Anderson, J., C. Gomez., G. McCarney, V. Adamowicz, N. Chalifour, et al. 2010. Natural Capital: Using Ecosystem Service Valuation and Market-Based Instruments as Tools for Sustainable Forest Management. A State of Knowledge Report. Sustainable Forest Management Network.

Bork, E. and P. Badiou. 2017. The Importance of Temperate Grasslands In The Global Carbon Cycle. Ducks Unlimited Canada Publication.

Botzen, W.J., O. Deschenes, and M. Sanders. 2019. The Economic Impacts of Natural Disasters: A Review of Models and Empirical Studies. Review of Environmental Economics and Policy 13(2):167-188.

Boxall, P., W. Adamowicz, J. Swait, M. Williams, and J. Louviere. 1996a. A comparison of stated preference methods for environmental valuation. Ecological Economics 18:243-253.

Boxall, P., B. McFarlane, and M. Gartrell. 1996b. An aggregated travel cost approach to valuing forest recreation at managed sites. The Forestry Chronicle 72(6):615-621.

Burkhard, B., R. de Groot, R. Costanza, R. Seppelt, S.E. Jørgensen, and M. Potschin. 2012. Solutions for sustaining natural capital and ecosystem services. Ecological Indicators 21:1–6.

Burkhard, B. and J. Maes. 2017. Mapping Ecosystem Services. Advanced Books 1:e12837.

Burkhard, B., F. Santos-Martin, S. Nedkov, and J. Maes. 2018. An operational framework for integrated Mapping and Assessment of Ecosystems and their Services (MAES). One Ecosystem 3:e22831.

Brown, G., B. Bedford, E. Machado, R. Brooke, K. Stephens, and T. Pringle. 2019. Integrating Natural Assets into Asset Management: A Sustainability Service Delivery Primer. Available at: https://www.assetmanagementbc.ca/wp-content/uploads/Integrating-Natural-Assets-into-Asset-Management.pdf

City of Leduc. 2020a. Municipal Development Plan. Bylaw 1057-2020.

- 2020b. Leduc POST (Parks, Open Space and Trails) Master Plan Update. Available at: https://www.leduc.ca/wp-content/uploads/2025/02/Leduc-Parks-Open-Space-Trails-Master-Plan.pdf
- 2023. Recreation Facility Needs Assessment Update. Available at: https://www.leduc.ca/wp-content/uploads/2025/07/Leduc-Recreation-Facility-Needs-Assessment.pdf
- 2024. City of Leduc Environmental Plan. Available at: https://www.leduc.ca/wp-content/uploads/2025/03/Leduc-Envrionmental-Plan.pdf

Clare, S., H. Campbell, H. Kinas, S. Koenig, T. Lee, et al. 2021. Contribution of Natural Infrastructure to Flood Mitigation in the Elbow River Watershed –Feasibility Study. Available at: www.rockies.ca/files/reports/FINAL_NI_Flood_Mitigation_Elbow.pdf

Costanza, R. and H.E. Daly. 1992. Natural Capital and Sustainable Development. Conservation Biology 6:37–46.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–260.

Crossman, N.D., B. Burkhard, S. Nedkov, L. Willemen, K. Petz, et al. 2013. A blueprint for mapping and modelling ecosystem services. Ecosystem Services 4:4–14.

de Groot, R.S., R. Alkemade, L. Braat, L. Hein, and L. Willemen. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7:260–272.

Dragon , B., H. Farooqui, S. Patel, N. Stelfox. 2018. Leduc Wildlife Corridor Study. Prepared for the City of Leduc, Leduc County, and Stantec Consulting Ltd.

Ducks Unlimited Canada (DUC). 2017. Boreal Wetlands and Climate Change. Available at: https://abnawmp.ca/wp-content/uploads/2020/09/Boreal-Science-Summary-Final_web.pdf

- 2023. Keeping water on the land: Wetlands offer excellent natural protection. Available at: https://www.ducks.ca/stories/conservator/wetlands-wildfire/

Edmonton Metropolitan Region Board (EMRB). 2025. The Region's Built and Natural Assets are Interconnected. Available: https://www.emrb.ca/growth-strategy/natural-assets/

Elgie, S., G.R. McCarney, and W.L. Adamowicz. 2011. Assessing the implications of a carbon market for boreal forest management 87(3):367-381.

European Environment Agency. 2016. Mapping and assessing the condition of Europe's ecosystems progress and challenges; EEA contribution to the implementation of the EU Biodiversity Strategy to 2020. Publications Office of the European Union, Luxembourg. Available from https://doi.org/10.2800/417530 (accessed January 3, 2020).

Everard, M. and R. Waters. 2013. Ecosystem Service Assessment: How to Do One in Practice. Version 1, October 13. Institution of Environmental Sciences, London. Available at: https://www.the-ies.org/sites/default/files/reports/ecosystem_services.pdf

Fiera Biological Consulting. 2020. Project Returns for Riparian Area Assessment of the Pembina River Watershed. Available at: https://geodiscover.alberta.ca/geoportal/rest/metadata/item/e6dc71d479c8433eae7d54ef78dd2425/html#identificationInfo

- 2021. Project returns for North Saskatchewan and Battle River Watersheds Land Cover Dataset. Available at: https://geodiscover.alberta.ca/geoportal/rest/metadata/item/5aa3bd3503334dd1b89beac469f08fbc/html

Government of Alberta. 2011. Ecosystem Services Approach Pilot on Wetlands: Operationalizing an Ecosystem Service Approach within the Government of Alberta - Steps and Lessons Learned. Page 69.

Government of Canada. 2024. Social cost of greenhouse gas emissions. Available: https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html

Goyette, J.O., A. Loiselle, P. Mendes, J. Cimon-Morin, S. Pellerin, M. Poulin, J. and Dupras. 2024. Above and belowground carbon stocks among organic soil wetland types, accounting for peat bathymetry. Science of The Total Environment 946:174177.

Haener, M. and W. Adamowicz. 2000. Regional forest resource accounting: a northern Alberta case study. Canadian Journal of Forest Research 30(2):264-273.

Health Canada. 2015. Reducing the Urban Heat Island Effect in Canadian Communities. Adaptation Bulletin Number 6.

Heathcote, A., N. Anderson, Y. Prairie, D. Engstrom, and P. del Giorgio. 2015. Large increases in carbon burial in northern lakes during the Anthropocene. Nature Communications 6:10016.

Horlings, E., S. Schenau, L. Hein, M. Lof, L. de Jongh, and M. Polder. 2019. Experimental monetary valuation of ecosystem services and assets in the Netherlands. Wageningen University & Research.

Intergovernmental Panel on Climate Change (IPCC). 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry, and Other Land Use. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

- 2021. Climate Change 2021: The Physical Science Basis, Technical Summary.

L'Ecuyer-Sauvageau, C., J. Dupras, J. He, J. Auclair, C. Kermagoret, and T. Poder. 2021. The economic value of Canada's National Capital Green Network. PLoS ONE 16(1):e0245045.

Lloyd-Smith, P. 2021. The Economic Benefits of Recreation in Canada. Canadian Journal of Economics 54(4):1684-1715.

Lloyd-Smith, P. and M. Becker. 2020. The Economic Value of Camping Using Administrative Data. Journal of Agricultural and Resource Economics 45(3):445-461.

Maes, J., A. Teller, M. Erhard, S. Conde, S. Vallecillo Rodriguez, et al. 2018. Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition in EU (page 75). JRC Publication. European Union, Luxembourg. Available at: https://linkinghub.elsevier.com/retrieve/pii/S2212041615300504.

Marando, F., H. Mehdi, G. Zulian, A. Udias, L. Mentaschi, et al. 2022. Urban heat island mitigation by green infrastructure in European Functional Urban Areas. Sustainable Cities and Society 77:103564.

Masiol, M. and R.M. Harrison. Aircraft engine exhaust emissions and other airport-related contributions to ambient air pollution: A review. Atmospheric Environment 95:409-455.

Millennium Ecosystem Assessment. 2003. Ecosystems and human well-being: a framework for assessment. Island Press, Washington, DC.

- 2005. Ecosystems and human well-being: synthesis. Island Press, Washington, DC.

Mistry, P., I.F. Creed, C.G. Trick, and D.A. Lobb. 2025. Reducing Uncertainties in Net Carbon Capture to Advance Wetlands as Natural Climate Solutions. Manuscript in preparation for submission to Environmental Research Letters.

Moon, H., S.H. Yoo, and S.Y. Huh. 2021. Monetary valuation of air quality improvement with the stated preference technique: A multi-pollutant perspective. Science of the Total Environment 793:148604.

Morabito, M., A. Crisci, G. Guerri, A. Messeri, L. Congedo, and M. Munago. 2021. Surface urban heat islands in Italian metropolitan cities: Tree cover and impervious surface influences. Science of the Total Environment 751:142334.

Moudrak, N., A.M. Hutter, and B. Feltmate. 2017. When the big storm hits: the role of wetlands to limit urban and rural flood damage. Prepared for the Ontario Ministry of Natural Resources and Forestry. Intact Centre on Climate Adaptation, University of Waterloo.

Natural Capital Project. 2025. InVEST 3.14.2 Stanford University, University of Minnesota, Chinese Academy of Sciences, The Nature Conservancy, World Wildlife Fund, Stockholm Resilience Centre and the Royal Swedish Academy of Sciences. Available at: https://naturalcapitalproject.stanford.edu/software/invest

Natural Resources Canada (NRCan). 2025. Why forests need fires, insects and diseases. Available at: https://natural-resources.canada.ca/forest-forestry/insects-disturbances/forests-need-fires-insects-diseases

Nolander, C. and R. Lundmark. 2024. A Review of Forest Ecosystem Services and Their Spatial Value Characteristics. Forests 15(919).

Nowak, D. 2021. Understanding i-Tree: 2021 Summary of Programs and Methods. USDA Forest Service General Technical Report NRS-200-2021.

Parkland County. 2025a. Parkland County Municipal Development Plan. Available at: https://yourparkland.ca/mdp

- 2025b. Nature Policy Framework. Available at: https://parkland.legistar.com/View.ashx?M=F&ID=14271536&GUID=7DF83B69-4995-4AE6-A007-59B1D44199D8

Parks Canada. n.d. The role of fire. Available at: https://parks.canada.ca/nature/science/conservation/feu-fire/role

Potschin, M. and R. Haines-Young. 2017. From Nature to Society (pages 39–45) in B. Burkhard and J. Maes, editors. Mapping Ecosystem Services. Pensoft Publishers, Sofia.

Rogers, C., A. Gallant, and N. Tapper. 2018. Is the urban heat island exacerbated during heatwaves in southern Australian cities? Theoretical and Applied Climatology 137:441-457.

Santamouris, M. 2020. Recent progress on urban overheating and hear island research. Integrated assessment of the energy, environmental, vulnerability and health impacts - Synergies with the global climate change. Energy and Buildings 207:109482.

Spence, D., C. Schuster-Wallace, and P. Lloyd-Smith. 2023. Disparities in economic values for nature-based activities in Canada. Ecological Economics 205:107724.

Statistics Canada. 2024. Table 18-10-0005-01 Consumer Price Index, annual average, not seasonally adjusted.

- 2025. Table 17-10-0155-01 Population estimates, July 1, by census subdivision, 2021 boundaries.

Steenberg, J., M. Ristow, P. Duinker, L. Lapointe-Elmrabti, J. MacDonald, et al. 2023. A national assessment of urban forest carbon storage and sequestration in Canada. Carbon Balance and Management 18(11)1-13.

Summers, J.K., L.M. Smith, J.L. Case, R.A. Linthurst. 2012. A Review of the Elements of Human Well-Being with an Emphasis on the Contribution of Ecosystem Services. AMBIO 41:327–340.

Sunderland, T., D. Marsh, J. Lusardi, C. Hudson, and R. Waters. 2023. Meeting decision support requirements through natural capital accounts: A case study in England's National Nature Reserves. Journal of Environmental Economics and Policy 12(1):1-18.

Tanguay, M., W. Adamowicz, and P. Boxall. 1995. An Economic Evaluation of Woodland Caribou Conservation Programs in Northwestern Saskatchewan. Project Report 95-01, Department of Rural Economy, University of Alberta.

Tapper, N., S. Lloyd, J. McArthur, K. Nice, and S. Jacobs. 2019. Estimating the economic benefits of Urban Heat Island Mitigation – Biophysical Aspects. Cooperative Research Centre for Water Sensitive Cities: IRP2-9-2019.

The Economics of Ecosystems and Biodiversity (TEEB). 2010. Mainstreaming the Economics of Nature: A synthesis of the Approach, Conclusions and Recommendations of TEEB. UNEP, Geneva.

Treasury Board of Canada Secretariat. 2022. Canada's Cost-Benefit Analysis Guide for Regulatory Proposals.

Value of Nature to Canadians Study Taskforce. 2017. Completing and Using Ecosystem Service Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts. Federal, Provincial, and Territorial Governments of Canada. Available at: http://www.deslibris.ca/ID/10088460 (accessed November 22, 2019).

Vihervaara, P., A. Viinikka, L. Brander, F. Santos-Martín, L. Poikolainen, and S. Nedkov. 2019. Methodological interlinkages for mapping ecosystem services – from data to analysis and decision-support. One Ecosystem 4:e26368.

von Haaren, C., A.A. Lovett, and C. Albert. 2019. Landscape Planning with Ecosystem Services: Theories and Methods for Application in Europe. Springer Dordrecht.

Whiteoak, K. and J. Saigar. 2019. Estimating the economic benefits of Urban Heat Island mitigation – Economic Analysis. Cooperative Research Centre for Water Sensitive Cities: IRP2-15-2019.

Zhou, W., Y. Wendong, Z. Zhang, W. Cao, and T. Wu. 2023. How can urban green spaces be planned to mitigate urban heat island effect under different climatic backgrounds? A threshold-based perspective. Science of the Total Environment 890:164422.

Appendix A: Field Condition Assessment

Overview

The condition of a limited number of assets was assessed in the field on July 3 and 4, 2025. The purpose of the field assessment was to estimate asset condition using a set of standard field metrics and collect information about variables that cannot be assessed using a desktop assessment (e.g., nativity, weediness). In total, fifteen natural assets located on municipal property were visited in the field, with most of the assessment effort towards assessing habitats surrounding Telford Lake. Given the very large size of Telford Lake and its adjoining upland areas and diversity of ecosystem types (e.g., lake, wetlands, forest, riparian areas), the Lake was split into 26 subareas, and each area was assessed and scored individually. The other 14 assets that were assessed were associated with Deer Creek, the Reservoir, and Peace Park. Assets and subareas assessed in the field are shown in Figure A-1.

Methods

Natural asset condition was characterized and assessed in the field using six different indicators that encompassed 39 different metrics. Indicators include native and non-native species cover, presence of habitat features (e.g., snags, coarse woody debris), and measures of anthropogenic use and impacts. Depending on the dominant cover present, specific forest and/or aquatic habitat conditions were also assessed. Forest habitats were assessed for intactness, vertical structure, succession stage and age, and aquatic habitats were assessed using measures of riparian cover and emergent vegetation. Additionally, a restoration potential category was assigned to each assessment area based on professional opinion.

Field data was organized in excel and categorical scores for the metrics were converted to numerical scores so they could be tabulated into an overall condition score. Scores were first derived for each metric, and then indicator category scores were calculated and combined into a final score (

Table A-1). Metrics that were not applicable for an assessed area were not included in the tabulation of the final score. For example, an area without forest habitat did not include forest habitat metrics as part of its condition score tabulation. The final condition score was a percent score out of 100. Condition scores were split into condition categories based on the distribution of scores and professional best judgement as follows:

- >80%: Very good condition
- 70 to 80%: Good condition
- 60 to 70%: Moderate condition
- 50 to 60%: Poor condition
- <50%: Very poor condition

Table A-1. Overview of the indicators and metrics used to score field condition.

Indicator Category	Metrics	Indicator Score Calculation
Native Cover	% tree cover; % shrub cover; % forb cover; % grass cover	Average of metrics
Non-native Cover	% cover of seven different non-native grasses and shrubs; weed occurrence; weed distribution	Weighted average of non-native cover species scores, weed occurrence, and weed distribution
Habitat Features	snag frequency; coarse woody debris frequency	Average of metrics
Human Impacts	Prevalence of seven different anthropogenic impacts; % area impacted by use	Weighted average of impact scores and area impacted by use
Forest Habitat	# of indicator species; overstory intactness; understory intactness; shrub intactness; forb/grass intactness; lichen/moss intactness	Average of metrics
Aquatic Habitat	% riparian disturbance; presence of adjacent riparian cover	Weighted average
	Overall Condition Score	Sum of Metric Category scores/ Total possible score

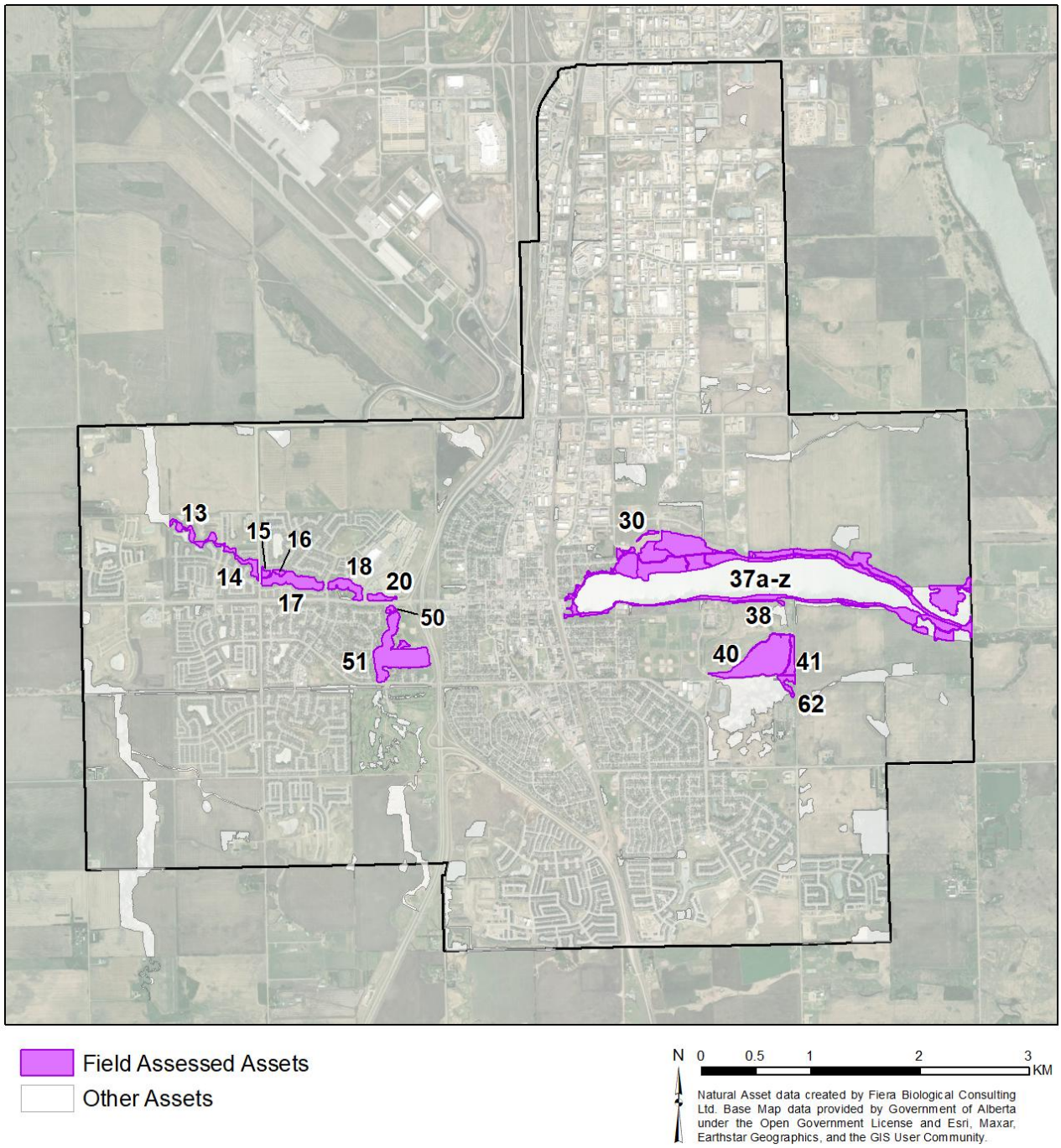


Figure A-1. Overview of natural assets that were assessed in the field.

Results

Field condition scores were calculated for 40 different assessment areas (Table A-2). Condition scores ranged from 33.3% to 90.4% with an average score of 65.4%. Field condition scores by general location are discussed in more detail below.

Telford Lake

Due to its large size, the Telford Lake natural asset was divided into 26 smaller areas for the field assessment. Condition scores ranged from 34.7% to 90.4% (Figure A-2; Table A-2). In general, the south shore tended to be in better condition than the north and eastern shores. The poorest condition areas of Telford Lake were concentrated along the western shoreline, in areas that abut residential development and where recreational activity is the most intense. These areas, 37x, 37y, and 37z, tended to have higher amounts of non-native and weedy cover and a high degree of human impact and use. Riparian zones associated with these areas also tended to be moderately to highly disturbed. Additionally, a small tree stand (37l) was scored very low condition. It was notably weedy with its forest structural layers absent or impacted. The highest condition areas included the southern shore of the lake (37v and 37w), the eastern parts of the upland forested area of North Telford Park (37c, 37g, and 37h), and a large tree stand at the east end of the lake next to Range Road 245 (37m) and a smaller tree stand to the south (37t). These areas all tended to have higher native cover, low to moderate weediness, less human impact and intact forest habitat. When aquatic or riparian habitat was present, it had little to no disturbance.

Two additional assets, 30 and 38, were assessed given their proximity to Telford Lake. Asset 30 was rated as Good Condition and Asset 38 was rated Very Poor condition. Asset 38 had high weed presence and was heavily impacted by human use.

Deer Creek

Seven natural assets associated with Deer Creek were assessed in the field (Figure A-3). Condition ranged from Good to Poor, with scores ranging from 53.1% to 74.3% (Table A-2). Asset 13, furthest west of the creek areas in the city was in the best condition of these assets, with generally high native cover, low weediness, and an intact riparian zone; however, this asset was highly disturbed and impacted by human use. Assets 14, 18, and 20 scored as Low condition. While these assets all had relatively intact riparian zones, they tended to be very weedy and impacted by human use. The three assets rated Moderate condition (15, 16, and 17) were also relatively weedy and impacted by human use, although the forest or riparian habitat associated with each individual asset tended to be intact.

Reservoir

Assets 50 and 51 are associated with the Reservoir (Figure A-3). Located at the north end of the reservoir at the outflow into Deer Creek, Asset 50 was scored as Moderate condition. This asset had intact riparian areas, and moderately intact forest habitat, but had higher levels of human impact and weediness. The reservoir itself (Asset 51), scored Very Poor for condition. Although the reservoir had fairly good presence of native species, weeds were prominent and the forest habitat and riparian areas were not intact and disturbed. A moderate amount of human use and impact further contributed to the reservoir's condition rating.

Peace Park

Three assets associated with the Peace Park area were assessed in the field, with assets 40 and 41 being assigned a score of Good Condition and Asset 62 assigned a score of Very Good (Figure A-4). These three assets had high amounts of native cover and only moderate weediness and had mostly intact forest and/or riparian habitat. These three assets were also noted as containing features such as snags and coarse woody debris, which serve as habitat for many types of wildlife.

Table A-2. Indicator and condition scores for locations assessed in the field in the City of Leduc.

Location	NA ID	Sub ID	Native Cover	Non-native Cover	Habitat Features	Human Impacts	Forest Habitat	Aquatic Habitat	Condition Score (/100)	Condition Category
Telford Lake	37	a	12.00	9.89	5.00	14.75	12.00	-	71.5	Good
	37	b	11.50	8.56	5.00	7.75	10.83	-	58.2	Poor
	37	c	13.25	11.44	13.50	12.42	15.00	12.75	87.1	Very Good
	37	d	10.50	8.56	8.50	13.25	7.67	-	64.6	Moderate
	37	e	10.75	3.94	5.00	9.17	7.67	15	57.3	Poor
	37	f	10.25	5.56	12.00	8.17	12.00	15	69.9	Moderate
	37	g	12.00	8.39	13.50	14.17	9.33	15	80.4	Very Good
	37	h	11.00	8.44	13.50	13.25	12.00	15	84.0	Very Good
	37	i	10.50	8.67	-	5.42	-	-	54.6	Poor
	37	j	11.50	10.56	-	6.25	-	-	62.9	Moderate
	37	k	12.50	8.44	-	6.25	-	12.75	66.6	Moderate
	37	l	6.75	3.89	8.50	9.50	4.50	-	44.2	Very Poor
	37	m	13.00	10.33	15.00	14.50	15.00	-	90.4	Very Good
	37	n	11.50	5.42	12.00	13.67	10.50	15	75.6	Good
	37	o	10.50	3.78	-	5.00	-	15	57.1	Poor
	37	p	11.50	5.94	8.50	10.42	8.83	15	66.9	Moderate
	37	q	10.25	4.11	-	6.00	-	15	58.9	Poor
	37	r	14.00	8.67	15.00	10.42	9.67	12.75	78.3	Good
	37	s	11.25	5.56	13.50	15.00	14.00	-	79.1	Good
	37	t	12.00	5.89	13.50	14.75	12.00	15	81.3	Very Good
	37	u	12.75	4.67	5.00	15.00	4.17	-	55.4	Poor
	37	v	13.25	7.72	12.00	13.25	15.00	15	84.7	Very Good
	37	w	12.25	10.28	13.50	13.25	12.50	15	85.3	Very Good
	37	x	9.25	4.17	8.50	8.43	4.17	3.75	42.5	Very Poor
	37	y	10.00	6.44	-	8.50	-	3.75	47.8	Very Poor
	37	z	5.00	4.56	0.00	5.07	6.83	9.75	34.7	Very Poor
Deer Creek	13		10.25	4.56	-	14.75	-	15	74.3	Good
	14		7.00	3.50	5.00	14.25	4.67	15	54.9	Poor
	15		8.75	6.11	5.00	14.17	11.50	-	60.7	Moderate
	16		8.75	6.11	5.00	14.17	11.50	-	60.7	Moderate
	17		9.50	4.44	13.50	14.25	5.33	15	68.9	Moderate
	18		7.00	4.33	8.50	14.50	3.33	13.13	56.4	Poor
	20		9.25	4.22	5.00	14.75	3.33	11.25	53.1	Poor
North of Telford	30		11.00	8.67	13.50	15.00	9.83	-	77.3	Good
South of Telford	38		9.50	4.44	0.00	13.50	2.50	0	33.3	Very Poor
Reservoir	50		7.75	6.56	5.00	11.92	8.17	15	60.4	Moderate
	51		11.00	6.28	5.00	8.17	3.83	6	44.8	Very Poor
Peace Park	40		13.00	10.33	12.00	9.33	12.50	11.25	76.0	Good
	41		12.00	8.22	12.00	13.00	9.00	-	72.3	Good
	62		12.00	7.78	15.00	13.25	15.00	-	84.0	Very Good

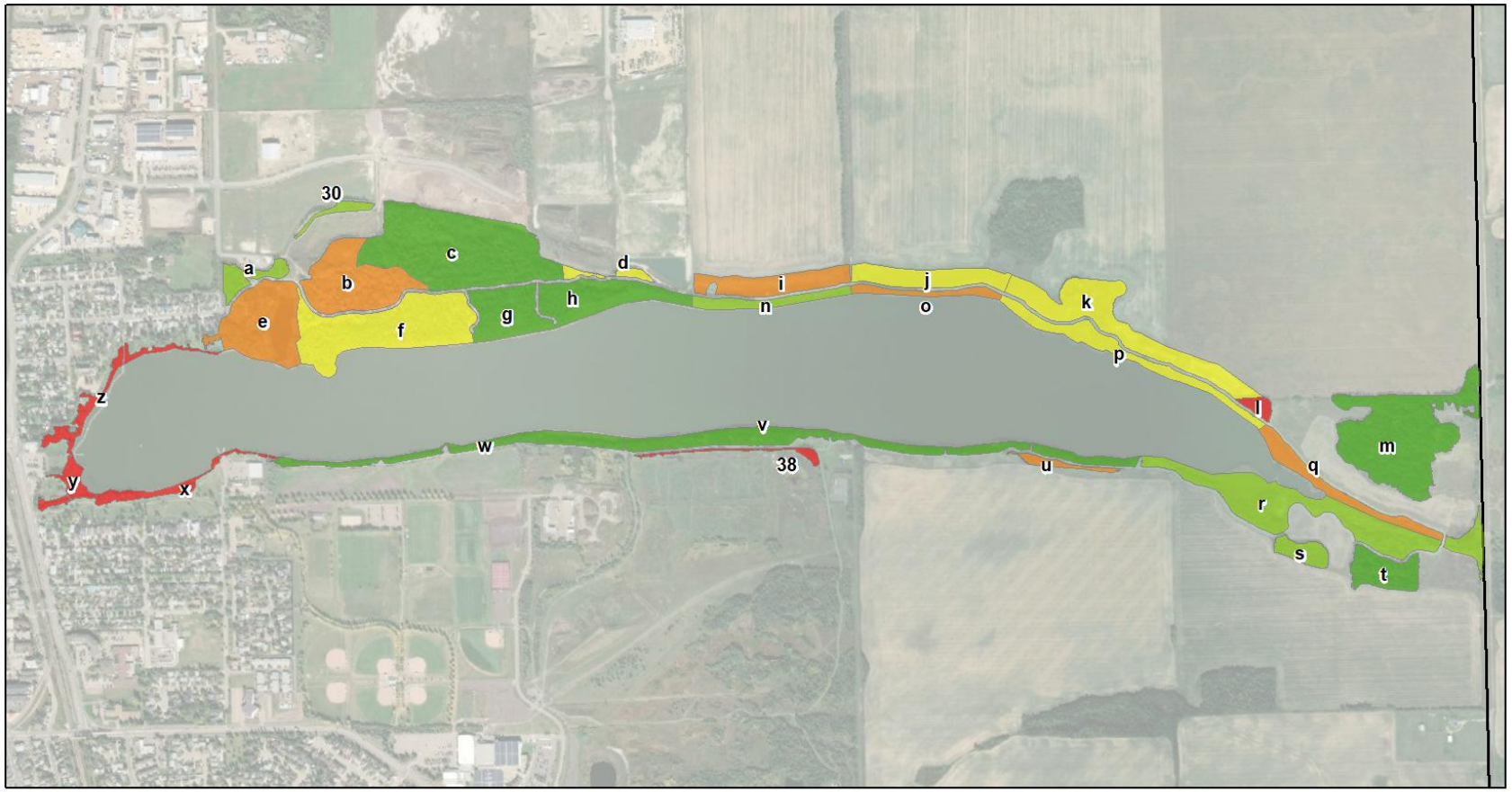


Figure A-2. Field condition scores for subareas assessed for Telford Lake (a-z) and Assets 30 and 38.

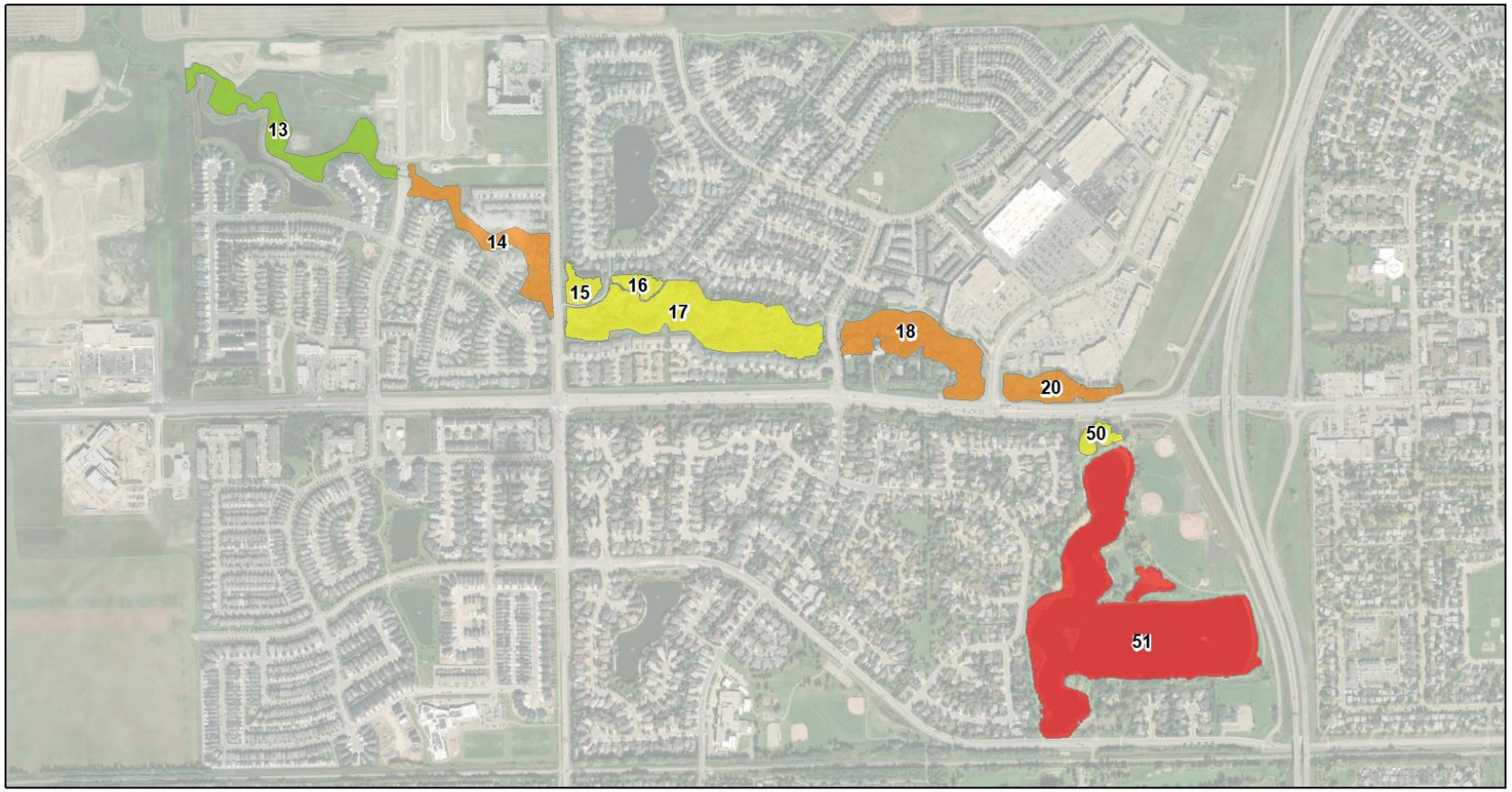


Figure A-3. Field condition scores for assets associated with Deer Creek (Assets 13-18 and 20) and the Reservoir (Assets 50 and 51).

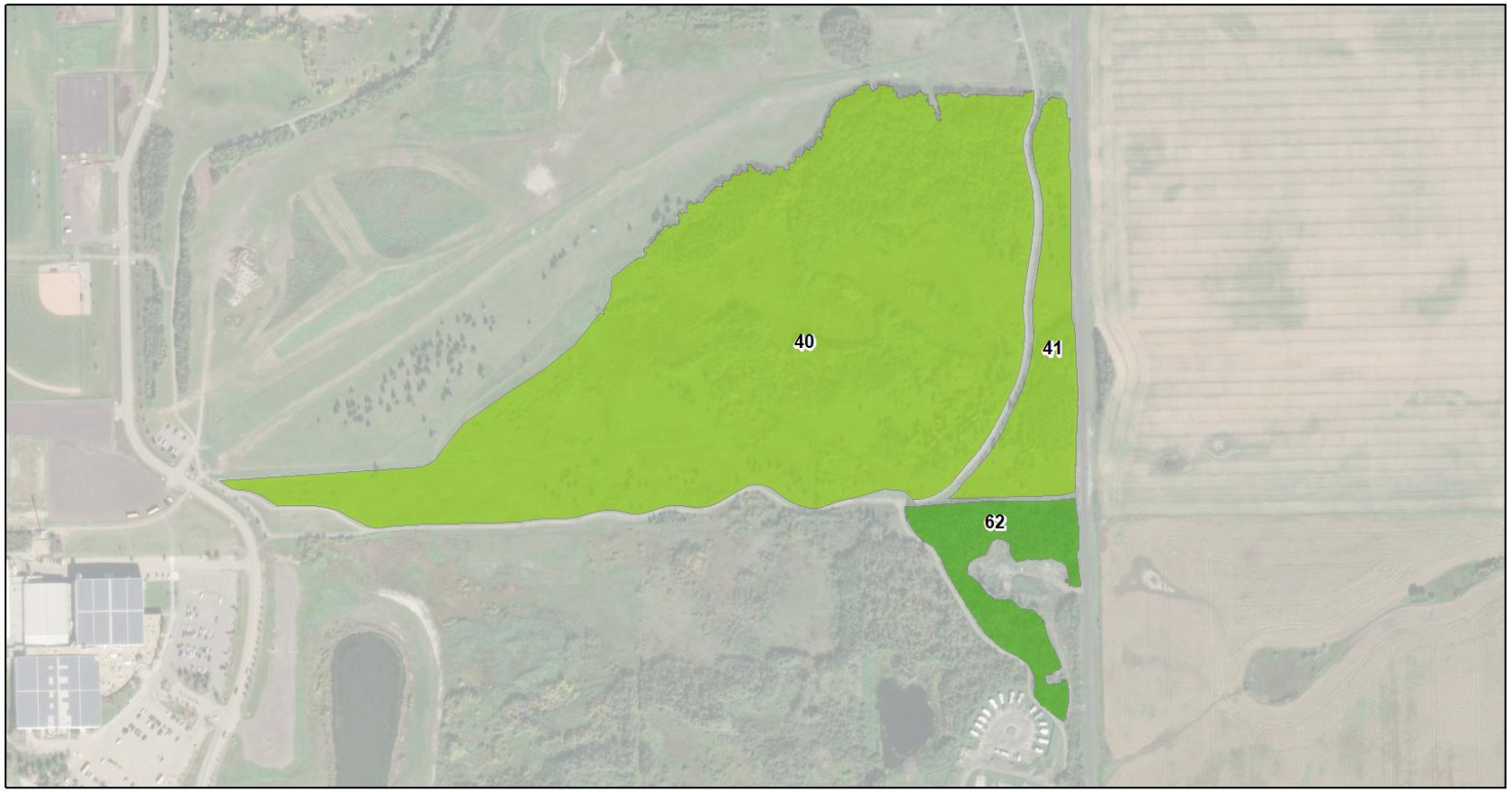


Figure A-4. Field condition scores for assets associated with Peace Park (Assets 40, 41, and 62).

Appendix B: InVEST Model Inputs & Parameters

Water Flow Regulation – Urban Flood Risk Mitigation Model

Spatial Dataset	Source
Soil Hydrologic Groups:	Agrisid Soil Information cross-referenced to soil hydrologic group information
Land Cover:	1 m updated land cover created by Fiera Biological Consulting

Parameter Values	Source
Curve Numbers:	US Army Corps of Engineers Hydrologic Engineering Center look up tables (see Table B1)
Rainfall Depth:	Value of 100 mm, as determined in consultation with the City of Leduc

Table B-1. Curve number data used in the InVEST Urban Flood Risk Mitigation model for the City of Leduc.

Land Cover Class	CN A	CN B	CN C	CN D
Agriculture	56	72	81	85.5
Building	98	98	98	98
Commercial	98	98	98	98
Construction	77	86	91	94
Gravel Area	77	86	91	94
Gravel Trail in Park	77	86	91	94
Industrial	98	98	98	98
Low Cover	49	69	79	84
Lowland Graminoid	1	1	1	1
Lowland Woody	1	1	1	1
Manicured	49	69	79	84
Mixed Use	98	98	98	98
Open Water	1	1	1	1
Paved Area	98	98	98	98
Paved Trail in Park	98	98	98	98
Rail	77	86	91	94
Residential	98	98	98	98
Road (Gravel)	77	86	91	94
Road (Paved)	98	98	98	98
Shrub	35	56	70	77
Sidewalk	98	98	98	98
Tree	36	60	73	79

Atmospheric Regulation – Carbon Storage Model

Spatial Dataset	Source
Land Cover:	1 m updated land cover created by Fiera Biological Consulting

Parameter Values	Source
Carbon Pool Values:	Wetland values were acquired from two sources: aboveground carbon was determined from Goyette et al. (2024) and belowground carbon was determined from DUC (2017). Values for all other land cover classes were taken from InVEST example data, which is based on values provided by the IPCC (2006) (see Table B2)

Table B-2. Carbon pool values used in the InVEST Carbon Storage and Sequestration Model for the City of Leduc.

Land Cover Class	C Above	C Below	C Soil	C Dead
Agriculture	4	3	18	1
Building	0	0	0	0
Commercial	0	0	0	0
Construction	0	0	0	0
Gravel Area	0	0	0	0
Gravel Trail in Park	0	0	0	0
Industrial	0	0	0	0
Low Cover	6	6	20	2
Lowland Graminoid	20	289	0	0
Lowland Woody	95	289	0	0
Manicured	1	1	20	0
Mixed Use	0	0	0	0
Open Water	0	0	0	0
Paved Area	0	0	0	0
Paved Trail in Park	0	0	0	0
Rail	0	0	0	0
Residential	0	0	0	0
Road (Gravel)	0	0	0	0
Road (Paved)	0	0	0	0
Shrub	8	8	25	3
Sidewalk	0	0	0	0
Tree	200	130	130	65

Appendix C: Economic Calculations

Accounting for Inflation

In instances where monetary estimates were taken from older sources, nominal dollar values (i.e., the dollar value in the year it was estimated) were adjusted to real 2024 dollars to reflect the general change in prices over time (i.e., inflation). Inflation adjustments were done using Statistics Canada's average annual Consumer Price Index (CPI), a numeric indicator of consumer price changes in Canada (Statistics Canada 2025). The inflation adjustment formula is provided below:

$$Dollars\ in\ current\ period = Dollars\ in\ previous\ period \times \frac{CPI\ for\ current\ period}{CPI\ for\ previous\ period}$$

Discounting

For ecosystem service benefits that take place in the future, values need to be adjusted to account for economic time preferences. Economic time preference refers to the general preference for monetary benefits today as compared to benefits of equivalent value in the future. Discounting a future stream of benefits is done to make values fully comparable at a single point in time, in other words, to ensure all values are represented in Present Value (PV) terms. It is important to note that discounting does not imply that the value of the asset is diminishing over time. The act of discounting simply takes the stream of future benefits and adjusts it to account for economic time preferences. The formula for discounting a stream of future benefits to PV is provided below:

$$PV\ (B_0, \ldots, B_n) = \sum_{i=0}^{n} \frac{B_i}{(1+r)^i}$$

PV = Present value of a future stream of benefits
B_i = Benefits accruing in period i
r = Discount rate

The choice of discount rate is a controversial topic, as valid arguments exist for selecting higher or lower rates depending on the social rates of time preference. The Treasury Board of Canada Secretariat (2022) recommends a discount rate of 3% to 7%. We use a discount rate 5% for all PV calculations in this study based on the average of the Treasury Board's recommendation, and in line with other Canadian studies (e.g., Tanguay et al. 1995; Elgie et. al 2011)

The time period selected for discounting future streams of ecosystem services is 50 years. A 50-year time period is the standard planning horizon that the City has adopted in previous growth studies. It is important to note that there is uncertainty with respect to what the quantity/condition of natural assets will look like in the City over time. This assumption essentially assumes that a similar stock of assets will persist into the future (in this case, for 50-years) to produce the stream of annual benefits.
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Appendix D: Spatial Data Deliverables

Table D-1. List and description of the spatial data layers created as part of the Natural Asset Inventory and Ecosystem Service Assessment project for City of Leduc.

Name of Dataset	File Name	Description	Format
Natural Asset Inventory	Natural_Asset_Inventory	Natural assets and all ES, condition, and special interest attributes and score.	Vector/Polygon
Natural Asset Land Cover	NA_Land_Cover	Land cover classes within the natural asset boundaries.	Vector/Polygon
Natural Asset Cover Types	NA_Cover_Types	Simplified cover types (woody, wetland, water, grassland) within the natural asset boundaries.	Vector/Polygon
Natural Asset Field Condition	FieldCondition_NAs	Field condition scores for natural assets assessed in the field (subset of assets).	Vector/Polygon
Land Cover 2024	LandCover_2024	Land cover dataset for the City of Leduc updated to 2024.	Raster
Predicted Runoff	Predicted_Runoff	InVEST Urban Flood Risk Mitigation model output showing runoff values per pixel (mm).	Raster
Runoff Retention	Runoff_Retention	InVEST Urban Flood Risk Mitigation model output showing runoff retention volume values per pixel (m3).	Raster
Predicted Carbon Storage	Predicted_Carbon_Storage	InVEST Carbon Storage model output showing the amount of carbon stored in each pixel (metric tons). NOTE: Sequestration was not modelled in InVEST as was determined using values based on literature review and land cover types.	Raster
Mean Summer Temperature	Mean_Summer_Temp	Layer derived from Landsat image analysis showing the median summer temperature for 2014-2024.	Raster



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