Natural Asset Inventory & Ecosystem Service Assessment for the Town of Okotoks

FINAL REPORT

Prepared for:
Town of Okotoks

Project #1978

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Front Cover Photo:

Yellow-headed blackbird in southern Alberta. All photos in this report were taken and provided by Fiera Biological Consulting Ltd.

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Background

Municipalities rely on engineered assets, such as roads, storm water detention ponds, and water treatment plants, to deliver public services. While engineered assets are essential to the safe and efficient operation of a municipality, there is increasing awareness and recognition that municipal assets extend beyond engineered structures to include natural assets such as trees, soil, and wetlands. Like engineered assets, natural assets provide important services to citizens; for example, wetlands store water, improve water quality, and moderate climate through carbon storage, while vegetation such as trees, regulate local microclimates and reduce urban heat island effects, thereby improving physical health.

Despite the significant contribution that ecosystems make to the health, well-being, and sustainability of communities, the ecological, social, and economic value of natural assets is rarely assessed or captured in municipal asset management systems. This is because many municipalities do not have a current or comprehensive inventory of their natural assets, and further, reliable data that can be used to assign an economic value to municipal natural assets is often lacking. Consequently, the true environmental, social, and economic costs of losing a natural asset during the land development process is rarely considered at the planning stage, thereby placing natural assets at risk of being lost and converted to other land uses.

Current State of Natural Asset Inventories in Canada

In recognition of the need to increase municipal government capacity to manage natural assets, the Municipal Natural Assets Initiative (MNAI) has been working with municipalities throughout Canada to advance a consistent approach to identifying, valuing, and accounting for natural assets in their financial planning and asset management programs. Since 2016, MNAI has worked collaboratively with municipalities in British Columbia, Ontario, and the Maritimes to pilot methods that have been primarily focused on assessing the value of the stormwater services provided by natural assets under various scenarios, as well as assessing the contribution of natural assets to climate resilience. These studies have typically focused on a limited number of natural assets and ecosystem services, with the objective of assessing the economic cost of losing an asset and/or replacing lost ecosystem services with traditional engineered assets. Through this work, MNAI has raised awareness around the need to more carefully consider natural assets in municipal planning and policy, and further, has developed general guidance for developing and integrating natural asset inventories into municipal asset management systems, with the objective of creating a consistent and comparable approach for undertaking municipal natural asset assessments.

Study Purpose

Through many of their existing municipal policies, such as the Community Vision, Municipal Development Plan, Environmental Management Plan, and various action plans to promote climate resilience, the Town of Okotoks has clearly acknowledged that natural assets provide essential ecosystem services to citizens. Further, recent work completed by the Calgary Metropolitan Region Board specifically acknowledges the importance of considering ecosystem service provisioning in the identification of local and regional Environmentally Sensitive Areas. Thus, in order to support decision-making that is consistent with existing local and regional policies, this study was initiated to develop a comprehensive inventory of natural and semi-natural assets present within the Town. Further, this inventory was used as the basis for developing monetary estimates for a number of key ecosystem services that were identified by the Town as being important to the well-being of citizens. Finally, this inventory was used to evaluate a proposed land development scenario in order to demonstrate how the inventory can be used to help support decision making and to illustrate how ecosystem service values were predicted to change under a proposed future development state.

Methodological Approach

The natural and semi-natural asset inventory and ecosystem service assessment for the Town was developed following standard methods and best practices for conducting ecological and economic studies. Additionally, the existing norms and guidance developed by MNAI were considered; however, because this study included a comprehensive assessment of all large number of assets, rather than a more focused study of a limited number of assets, the MNAI guidance was adapted to be more applicable to the objectives of this study. Additionally, the approach to and focus of the study was informed by a stakeholder workshop that was held at beginning of the project, which was attended by the consulting team and key personnel from the Town and MNAI. Specifically, a list of key ecosystem services were identified in this workshop, and these services became the focus of the subsequent valuation exercise.

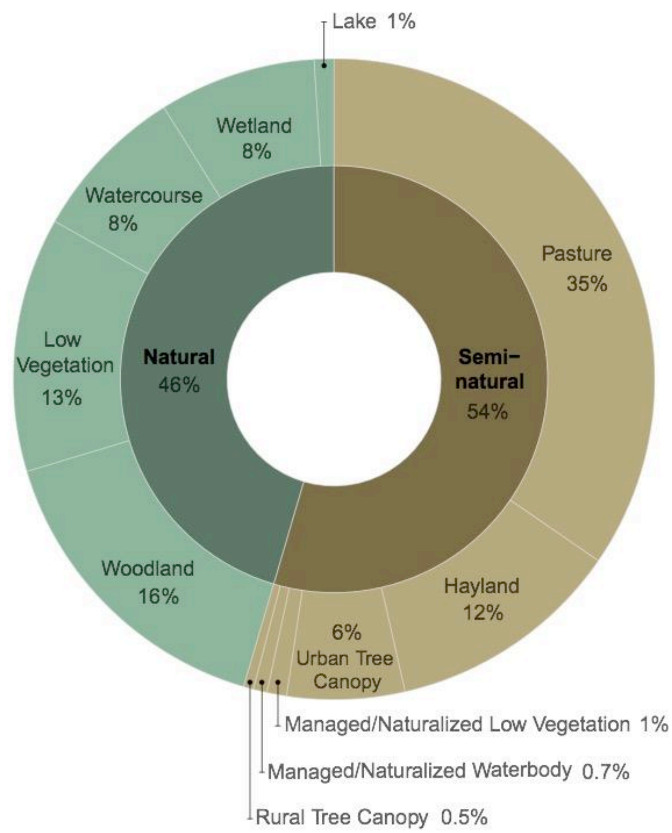
The Okotoks inventory included both natural and semi-natural assets, which were identified and mapped using land cover data derived from high resolution air photographs. Once the natural and semi-natural assets were mapped, the land cover and other spatial data was used to estimate the condition of each asset, as well as ecosystem service supply within the Town. Ecosystem service values were derived from the land cover and asset inventory, socioeconomic data, and other local or regional valuation studies. If local or regional data was not available, economic values were transferred from other relevant studies and adjusted to be applicable to the local context.

Study Findings

Summary of Natural & Semi-Natural Assets

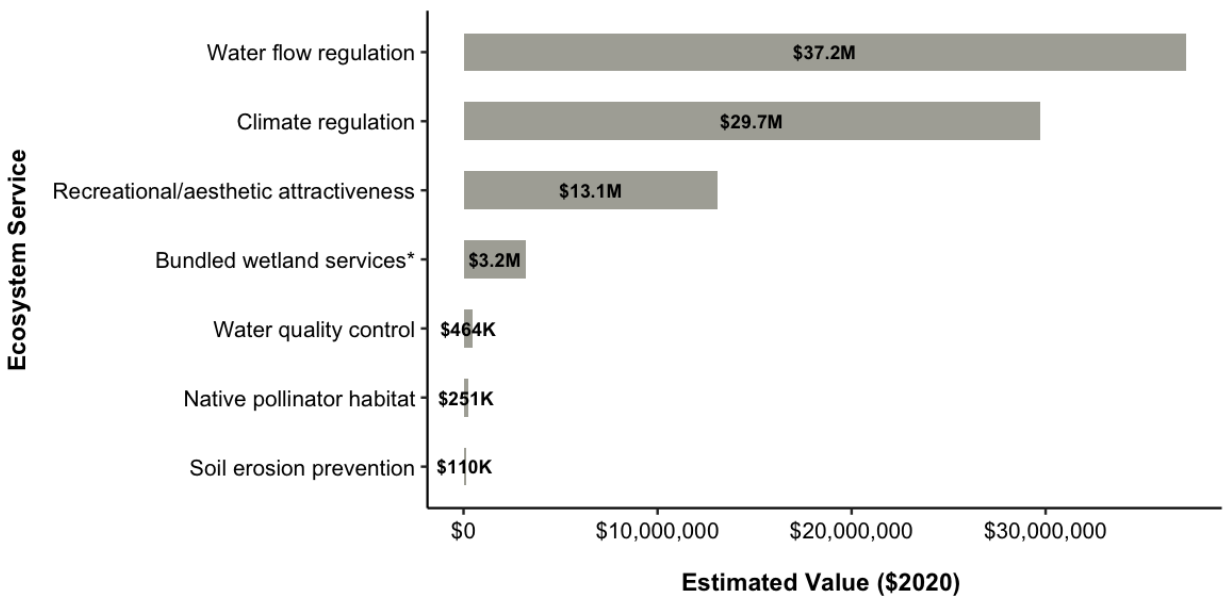
In total, 302 unique natural and semi-natural assets, covering 32% (12.4 km^2) of the Town, were identified by the inventory. When considering total area, just under half of the assets in the Town are Natural (46%), while the remaining 54% of the asset area is composed of Semi-natural assets. A relatively small number of assets (62) account for over half of the natural and semi-natural asset area within the Town, with the majority of the overall asset cover being classified as pasture, woodland, low vegetation, and hayland.

The portfolio natural and semi-natural assets in Okotoks represents a range of habitat types that support a diversity of wildlife, and these areas are foundational to the development and conservation of a local and regional network of natural assets that provide important ecosystem services to Town residents.

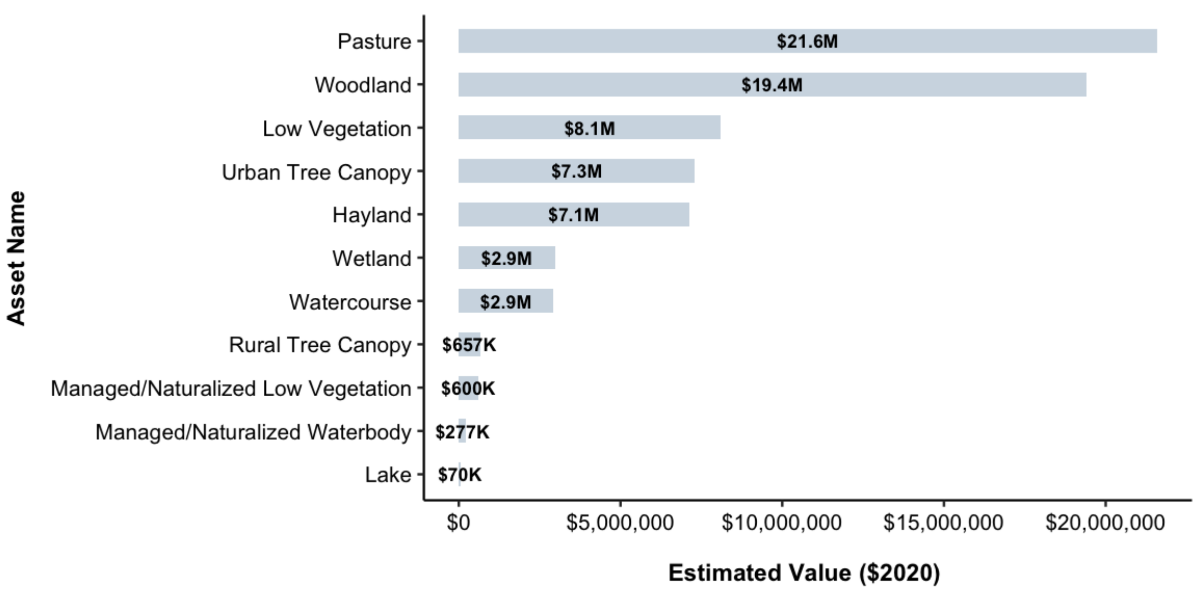


Summary of Ecosystem Service Value

The total estimated value of the ecosystem services that were evaluated in the Town of Okotoks is approximately **$84 million** ($2020). This includes estimates for water flow regulation, climate regulation, recreational/aesthetic attractiveness, water quality control, native pollinator habitat, and soil erosion potential. Water flow regulation was the highest valued service in the Town, with an estimated value of $37.2 million, followed by climate regulation, with an estimated value of $29.7 million. Summarized by asset type, pasture assets have the highest estimated ecosystem service value ($21.6 million), followed by woodland assets ($19.4 million). A number of other ecosystem services were examined as part of this study; however, these assets could only be examined qualitatively because of a lack of suitable data.



*Bundled wetland services included: water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation.



ESTIMATE OF ECOSYSTEM SERVICE VALUES IN THE TOWN OF OKOTOKS		
Ecosystem Service	**Monetary Estimate ($2020)**	**Confidence in Estimate**
Water flow regulation	$37,220,000	🔴
Climate regulation	$29,705,000	🟠
Recreational/aesthetic attractiveness	$13,106,000	🟢
Bundled wetland services (water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation)	$3,206,000	🟢
Water quality control	$464,000	🟠
Habitat for native (non-domesticated) pollinators	$251,000	🔴🟠
Soil erosion prevention	$110,000	🟠
Urban heat regulation	--	--
Habitat for non-pollinating wild plants and animals	--	--
Surface water provision (potable & non-potable water)	--	--
Ground water provision (potable & non-potable water)	--	--
Air quality regulation (e.g., dust filtration)	--	--
Harvestable volumes of wild (non-cultivated) plants or wild (non-domesticated) animals	--	--
Other cultural services	--	--
Total Quantified Monetary Estimate	**$84,062,000**	

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

Gaps and Opportunities

While this study provides important information for the management of natural areas in the Town, there are a number of gaps related to the current approach to securing and managing these areas, as well as gaps in existing information and data.

Securement and Management of Assets

While there are a number of existing tools available to the Town for the retention and management of natural and semi-natural assets, the following are opportunities for improving outcomes:

- **Establish a Conservation Reserve Policy & Natural Asset Acquisition Fund**: Municipalities have limited tools for the securement of natural assets, and often, direct purchase is the best or only option for the securement of high value assets. Establishing a conservation fund and associated conservation reserve policy that provides direction for how to allocate these funds will allow the Town to purchase high priority assets for conservation that will benefit current residents as well as future generations.
- **Develop Natural Asset Assessment & Retention Guidelines**: The Town currently follows the City of Calgary guidelines for conducting biophysical assessments of natural areas that may be impacted by land development. Creating guidelines specifically for the Town of Okotoks that outline how natural area assessments should be conducted, as well as guidelines for how natural assets should be prioritized for retention during the planning process, will create a standard of practice that should result in more consistency in how natural assets are assessed and managed as part of the planning process, and better alignment with the Town's environmental plans and policies.
- **Develop and Implement Management, Restoration & Monitoring Plans**: Municipal natural assets support ecological processes, function, and biodiversity, while also providing Town residents with important recreational, cultural, and educational opportunities that promote mental and physical health and improve the quality of life of residents. Consequently, municipal natural areas must be managed in a way that considers the habitat requirements of wildlife through the planning of appropriate land and recreational use in proximity to natural areas. To this end, developing site-specific and/or Town-wide natural area and wildlife management plans that provide high-level direction for balancing conservation with human use is important for the long-term sustainability of key natural assets and wildlife in the Town. Additionally, there may be some natural and/or semi-natural assets that may require active restoration to improve their ecological condition. In these cases developing site-specific plan that outline restoration goals, as well as an approach for measuring and evaluating restoration success, will likely improve outcomes related to maintaining ecosystem function and the resulting supply of ecosystem services.
- **Establish an Environmental Reserve Dedication & Development Setback Policy and Guidelines**: Lands that qualify as Environmental Reserve are either steep slopes or are water bodies such as wetlands, streams, and lakes that receive surface runoff and groundwater inputs from adjacent lands. As a result, ensuring that appropriate development setbacks are applied to ER lands in urban environments is essential to maintaining ecological function and public safety, including appropriate buffers to protect property and infrastructure from flood risk. Over 16% of the natural assets identified in the Town are wetlands or watercourse assets, and a significant portion of other natural and semi-natural assets are located on slopes with a gradient >15%. Thus, developing a policy that provides more clarity around what lands qualify as ER in Okotoks, in addition to specifying the development setbacks that are required on those lands, would be beneficial for creating clarity during the land planning and development process.
- **Establish a Municipal Wetland Policy**: The provincial wetland policy and its supporting directives give clear direction to municipalities that local and regional wetland management priorities will be considered in the review of *Water Act* applications that are related to wetland impacts. Thus, the Town could significantly advance wetland conservation within Okotoks through the adoption of a municipal Wetland Policy that identifies and maps key wetlands that

should be avoided and retained due to their ecological and ecosystem service value. Such a policy would be critical in communicating priorities for wetland retention and protection in the Town, which would be an important engagement and communication tool for dealing with land developers, residents, and the provincial government.

- **Develop a Tree Protection Policy or Bylaw:** Urban trees offer important ecosystem services such as urban heat regulation, wildlife habitat, soil erosion protection, air purification, as well as a range of cultural services. Consequently, protecting trees within the Town, whether they are located along street boulevards or within urban parks, is essential for maintaining these services. Adopting a tree protection policy or bylaw would provide important direction for the management of urban trees, and could include enforcement action to prevent cutting, removal, moving, pruning, and/or damage to trees located on Town property. The policy or bylaw could also include requirements for the development of a tree protection plan in instances where construction activities have the potential to damage a tree located on lands owned or managed by the Town.

Information and Data

While this study used the best information and data available, there are several gaps in our current understanding of natural assets and associated ecosystems service values:

- **Regional and Intermunicipal Assets**: Many of the natural and semi-natural assets identified by the inventory either physically extend outside the Town, or are significant components of a larger regional network of natural assets (e.g., Sheep River). Given this, regional planning and intermunicipal development plans are important tools for advancing the management of shared natural and semi-natural assets, and engaging with neighbouring municipalities, as well as municipalities that make up the larger Calgary region, will be important to ensuring that these shared assets are properly managed over the long term and for the benefit of citizens both within and outside the Town.
- **Willingness to Pay for Ecosystem Services in the Town**: Several of the ecosystem service estimates provided in this study were based on valuation techniques that do not represent willingness to pay values. To this end, the Town could benefit from undertaking revealed preference or stated preference work to acquire primary willingness to pay data for their top assets, or for assets that they believe are at risk of loss or degradation. This type of primary economic data would give the Town more reliable estimates of ecosystem service values within Okotoks.

Significance and Impact of Study

Natural asset inventories and ecosystem service assessments represent a new and emerging approach to land management in municipalities, with very few examples of comprehensive assessments in North America. In fact, this study represents the first example of a natural asset mapping and ecosystem service valuation exercise that has been undertaken by a municipality in Alberta. This comprehensive assessment gives the Town of Okotoks valuable information about the number, extent, condition, and estimated value of their natural and semi-natural assets. In turn, this information allows the Town to consider how land use and management decisions may positively or negatively impact these assets. In the short-term, this inventory allows the Town to be more proactive about identifying high-value natural and semi-natural assets, and to formulate management and/or policy responses that result in the securement and maintenance of high value assets. Over the longer-term, this inventory will serve as a foundation for identifying, mapping, and tracking the condition and status of natural and semi-natural assets within the Town, which will allow for more objective and informed decision making with respect to understanding the economic and environmental trade-offs associated with land management.

List of Terms

Acronyms

AEP: Alberta Environment and Parks

CICES: Common International Classification of Ecosystem Services

ECCC: Environment and Climate Change Canada

ES: Ecosystem Service(s)

GIS: Geographic Information System

PV: Present Value

SARA: Species at Risk Act

SCC: Social Cost of Carbon

TEEB: The Economics of Ecosystems and Biodiversity

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.

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 and can be 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 time period.

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

Ecosystem structures: biophysical architecture of ecosystems; species composition making up the architecture may vary.

Final ecosystem services: direct contributions to human well-being. Depending on their degree of connection to human welfare, ecosystem services can be considered as intermediate or as final services.

Intermediate ecosystem services: biological, chemical, and physical interactions between ecosystem components. E.g., ecosystem functions and processes are not end-products; they are intermediate to the production of final ecosystem services.

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.

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). This type of mapping allows for the quantification of the location and distribution of land cover types at a single point in time, as well as a comparison across multiple time steps to assess how the amount and distribution may be changing. Land cover mapping is essential component of many land management practices, including ecosystem service mapping and assessment.

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

Semi-natural Asset: naturally-occurring habitats that have been substantially modified or native/non-native vegetation cover that has been planted and is actively managed 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.

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

With an increasing number of Canadians living in towns and cities, urban municipalities are at the forefront of creating safe and healthy communities. In particular, municipalities are responsible for essential services such as designing and managing parks and recreational spaces, developing and maintaining road networks, handling storm water runoff, and supplying safe drinking water. Traditionally, municipalities have relied on engineered solutions to deliver many of the public services that citizens rely on, resulting in the construction of hard infrastructure such as floodways, storm water detention ponds, and water treatment plants. Further, because engineered assets are tangible, and the costs associated with their construction and maintenance are relatively easy to express in monetary terms, most municipalities have asset management systems that place an economic value on each asset.

While engineered assets are essential to the safe and efficient operation of a municipality, there is increasing awareness and recognition that municipal assets extend beyond engineered structures to also include natural assets such as trees, soil, and wetlands. Like engineered assets, natural assets provide important services to citizens; for example, wetlands store water, improve water quality, and moderate climate through carbon storage, while vegetation such as trees, regulate local microclimates and reduce urban heat island effects, thereby improving physical health. Unlike engineered assets, however, very few municipalities have a comprehensive inventory of their natural assets, nor do they calculate the economic value of the ecosystem services that flow from these natural resources. As a result, the true cost of removing versus maintaining these natural assets in terms of their value to society is rarely factored into land development decisions, and consequently, these assets are at risk of being lost or converted in favour of other land uses. With mounting costs associated with building and maintaining municipal infrastructure, which are only likely to increase as the effects of climate change intensify, municipalities are beginning to acknowledge that accounting for and actively managing natural assets as critical components of municipal infrastructure will create more livable and resilient communities.

The Town of Okotoks (hereafter the Town) has clearly acknowledged that natural assets provide essential services to their citizens. This recognition is reflected in many of the Town’s existing plans and policies, including the Community Vision, the Municipal Development Plan, the Environmental Management Plan, and various action plans that promote climate resilience. Further, recent work completed by the Calgary Metropolitan Region Board specifically acknowledges the importance of considering ecosystem function and associated services in the identification of local and regional Environmentally Sensitive Areas. Thus, in order to support decision-making that is consistent with existing local and regional policies, this study was initiated to develop a comprehensive inventory of natural and semi-natural assets present within the Town. Further, this inventory was used as the basis for developing monetary estimates for a number of ecosystem services identified as being important to the Town. Finally, this inventory was used to evaluate a proposed land development scenario in order to demonstrate how the information can be used to help support decision making, and to illustrate how ecosystem service values were predicted to change under a proposed future development state.

1.2. Current State of Natural Asset Inventories in Canada

In recognition of the need to increase municipal government capacity to manage natural assets, the Municipal Natural Assets Initiative (MNAI) has been working with municipalities throughout Canada to advance a consistent approach to identifying, valuing, and accounting for natural assets in their financial planning and asset management programs. Since 2016, MNAI has worked collaboratively with municipalities in British Columbia, Ontario, and the Maritimes to pilot methods that have been primarily focused on assessing the value of the stormwater services provided by natural assets under various scenarios, as well as assessing the contribution of natural assets to climate resilience. These studies have typically focused on a limited number of natural assets and ecosystem services, with the objective of assessing the economic cost of losing an asset and/or replacing lost ecosystem services with traditional engineered assets.

Through this work, MNAI has raised awareness around the need to more carefully consider natural assets in municipal planning and policy, and further, has developed general guidance for developing and integrating natural asset inventories into municipal asset management systems, with the objective of creating a consistent and comparable approach for undertaking municipal natural asset assessments. In particular, MNAI has created a consistent definition for municipal natural assets, which was adopted for this study:

> *The term Municipal Natural Assets refers to the stocks of natural resources 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.* (MNAI 2019a, p. 4)

A key component of this, and other natural asset definitions, 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 & 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 through time. Early definitions described ecosystem services (ES) 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 recently, definitions of ES have become 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. 2016; 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. Finally, the cascade model 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, thereby affecting the amount and quality of the final service, as well as the benefits and values derived from that service.

While the cascade model is a simplification of the complexity of ecosystems, it serves to help conceptualize the linkages between ecosystem functions and the benefits that people derive from nature. Importantly, this model communicates the need to map and measure indicators across the entire ecosystem service pathway in order to understand the supply and demand of services, and how human activities and land management interventions impact the quality and supply of these services (Potschin & Haines-Young 2017).

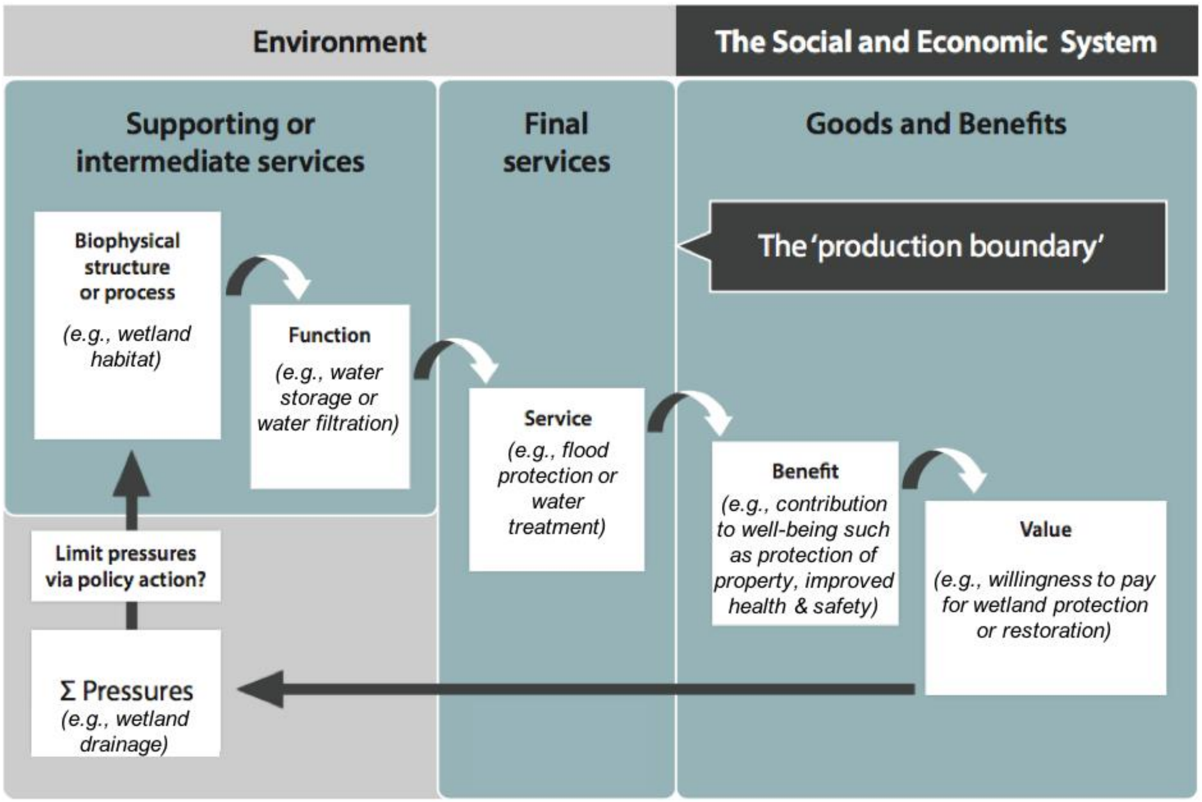


Figure 1. The cascade model. Adapted from Potschin and Haines-Young 2017.

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, MNAI 2019a, MNAI 2019b). Generally, these frameworks include the following major steps:

1) Define the purpose of the assessment and identify the natural asset(s) and/or ecosystem services that are the focus of the assessment;
2) Map the extent and location of the target natural asset(s);
3) Assess the condition of the target natural asset(s);
4) Identify the ecosystem services that are 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; and
7) Monitor and assess outcomes.

The scope of this study included steps one through five, and we detail the methods used in each of these steps below.

2.2. Defining the Purpose of the Assessment

The first step of defining the purpose of the assessment for the Town of Okotoks was completed as part of a workshop that was hosted by the Town in December 2019. The workshop was attended by a number of municipal representatives across a broad range of Departments, and included personnel with expertise in planning, urban forestry, parks management, and asset management. The Study Team also attended this workshop, along with representatives from the Municipal Natural Asset Initiative (MNAI). The focus of the workshop was to clearly define the purpose for the inventory, as well as to gather information from attendees regarding what they considered to be the priority natural assets and ecosystem services within the Town. Participants also learned about the existing guidance and norms for undertaking natural asset inventories that have been developed by MNAI.

The overarching purpose for this project, which was articulated during the workshop, is to develop a comprehensive inventory of all natural and semi-natural assets that are present within the Town, so that this information can be used to inform decision making that is consistent with existing municipal policies and statutory plans. In particular, the Town has a Community Sustainability Plan and an Environmental Master Plan, which emphasize both sustainable design and climate adaptation as key pillars of planning, development, and management within Okotoks. In addition to helping to identify key natural assets that should be retained and conserved within the Town, workshop participants indicated a desire to have a natural asset inventory that could also be used to identify management practices that may need to be modified, or natural assets that could be restored or enhanced, in order to maintain or improve the existing flow of ecosystem services and benefits that currently exist within the Town.

2.3. Mapping & Assessing Natural & Semi-Natural Assets

2.3.1. Creating a Land Cover Map

Natural and semi-natural assets were identified using a land cover map that was created specifically for use in this project. The land cover map included six cover classes: Treed, Shrubby, Grassland, Sparsely Vegetated, Open Water, and Marsh. Land cover was digitized manually in a Geographic Information System (GIS) using a series of high-resolution air photos and other supplemental data (Table 1). In addition to the land cover layer, a tree canopy layer was derived using a combination of LiDAR point cloud data and manual digitization. Land cover features were manually digitized using a minimum mapping unit of 100 m^2, while the tree canopy layer mapped individual tree canopies at a minimum mapping unit of approximately 12 m^2.

Table 1. Description of the spatial data obtained or derived for use in the mapping and assessment of natural and semi-natural assets in the Town of Okotoks.

Data Layer	Year(s)	Source	Usage
Recent Air Photo	2005, 2007, 2011, 2013, 2015, 2016, 2017, 2018	Town of Okotoks	Derivation of current land cover classes
Historic Air Photos	1950-1960	Alberta Biodiversity Monitoring Institute	Reference images to determine extent of land disturbance and modification
Defensive Mapping Project	2018	Town of Okotoks	Reference layers to confirm land cover classes and boundaries
LiDAR Digital Elevation Model (DEM)	2013	Town of Okotoks	Terrain mapping to assist with land cover classification & boundary delineation
LiDAR Point Cloud	2013	Town of Okotoks	Creation of Tree Canopy Layer to map trees to create density estimates and urban/rural tree canopy layers
Town of Okotoks Land Use Layer	2019	Town of Okotoks	Derived layer that generalizes land use zoning into general categories for the purpose of assessing surrounding land use pressure on natural assets

2.3.2. Defining Natural & Semi-Natural Assets in the Town of Okotoks

Once the land cover map was complete, it was used to identify natural and semi-natural assets. Natural assets were areas dominated by native vegetation that were predominantly undisturbed, while semi-natural assets included naturalized features (i.e., areas actively restored or enhanced), or areas that were not in a primarily natural state, but still deliver important ecosystem services to the residents of Okotoks (e.g., pasture and haylands). A description of each natural and semi-natural asset type is provided in Table 2, along with a description of the dominant land cover classes that make up each asset type.

In some instances, a single land cover class or feature may have been used to identify a natural asset; for example, features mapped as “marsh” were assigned a “wetland” asset label (Figure 2). In other cases, multiple land cover classes and features may have been grouped together to represent a single asset; for example, a contiguous area dominated by treed land cover, but also containing other land cover types such as shrubby and grassland, may have been grouped together into a single woodland asset (e.g., Figure 2). In most cases, ecological function was a primary consideration in determining whether to group multiple land cover types together into a single asset. In other instances, anthropogenic boundaries (e.g., property lines, roads, etc.) may have been used to define the boundary of an asset. Once defined, natural and semi-natural asset retained the land cover information, allowing for a summary of land cover types and areas for each individual asset.

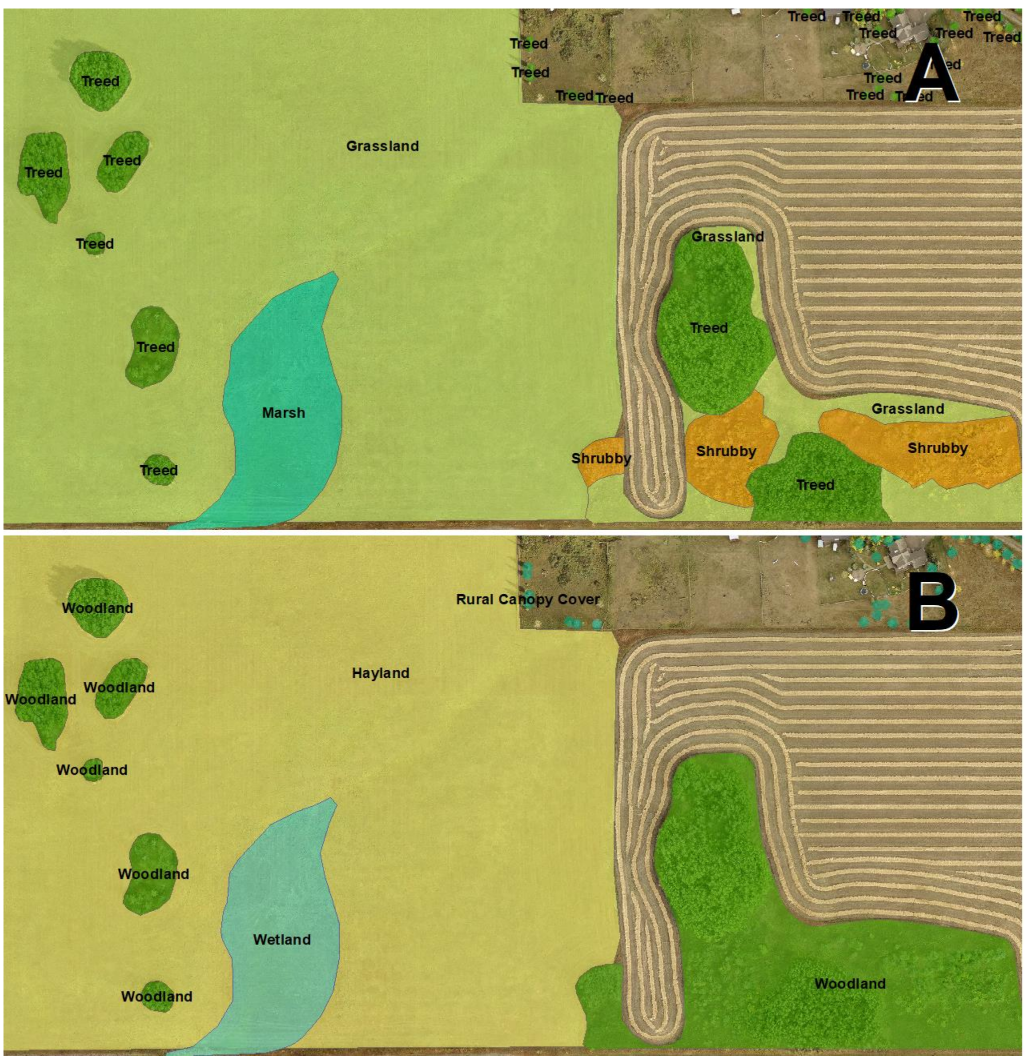


Figure 2. Example of how the land cover layer (A) was used to identify and map natural and semi-natural assets (B).

Table 2. List of Natural and semi-natural assets identified in the Town of Okotoks, along with the *dominant* land cover classes associated with each asset.

Asset Type	Asset Description	Dominant Land Cover	Land Cover Description
Natural Asset			
Woodland	Areas dominated by woody vegetation primarily composed of native species	Treed	Small to large groups of trees dominated by native species
		Shrubby	Areas dominated by woody vegetation typically <2 m in height
Low Vegetation	Areas dominated by non-woody vegetation primarily composed of native species	Grassland	Areas dominated by naturally occurring or minimally managed grasses and/or forbs
Wetland	Areas dominated by shallow water and/or predominately native vegetation that is tolerant of wet or moist soil conditions	Open Water	Shallow open water typically <2m deep
		Marsh	Low, wet areas dominated by wet-tolerant vegetation and surrounding woody and non-woody riparian vegetation
Watercourse	A visible channel where water flows, either seasonally or permanently, and the surrounding floodplain riparian areas. Channel may or may not be modified.	Open Water	Flowing water contained within a channel
		Sparsely Vegetated	Naturally sandy or rocky areas with minimal vegetation cover; primarily associated with the Sheep River floodplain
Lake	Areas dominated by deep (typically >2m) open water	Open Water	Large open water areas identified in the Town's hydrological feature layer
Semi-Natural Asset			
Pasture	Areas covered by grass and other low vegetation that is used for grazing livestock	Grassland	Areas dominated by low vegetation where there is clear evidence of animal use (e.g., trails, fences, etc.) and no evidence of soil tillage going back to 2005.
Hayland	Areas covered by grass, legumes, or other herbaceous plants that are cut for animal forage	Grassland	Areas dominated by low grass and herbaceous cover that have not been tilled or cultivated since 2005, but where there is clear evidence of vegetation being cut and bailed on an annual basis.
Managed/Naturalized Low Vegetation	Vegetated areas immediately surrounding storm water management facilities	Grassland	Areas between the normal and high-water level in storm water facilities that have been planted with grasses and other vegetation that is minimally maintained.
Managed/Naturalized Waterbody	Dugouts and other constructed, restored, or enhanced water features	Open Water	Non-natural, constructed water bodies, or naturally occurring waterbodies that have been heavily modified. Does not include constructed storm water facilities.
Urban Tree Canopy	Planted trees on private and public lands within the built-up area of Town	Treed	Single or small groups of trees associated with private yards or Town lands, such as boulevards.
Rural Tree Canopy	Trees located primarily on private property in rural areas of the Town	Treed	Single or small groups of trees primarily associated with rural residential yards.

2.3.3. Assessing Condition of Natural & Semi-Natural Assets

Generally, assets and their underlying habitats need to be in good condition to provide ecosystem services, and drivers of change can have both 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, condition, and the supply of ecosystem services are linked, 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 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 Okotoks inventory, a combination of pressure and condition indicators that could be assessed using imagery and/or existing spatial data were used to evaluate the current state of each natural and semi-natural asset (Table 3). Where possible, quantitative metrics were used to assess condition, but in some instances more qualitative measures were used. In total, five indicators were used to assess condition, and these indicators were selected because: 1) they account for a variety of ecological characteristics that are generally correlated with condition, and 2) there was suitable data available to use in the assessment. The indictors include measures that evaluate the pressure and/or condition within each asset, as well as measures that assess pressures associated with surrounding land uses. All natural assets were included in the condition assessment, but a number of semi-natural assets, including hayland, rural canopy cover, and urban canopy cover, were not assessed given the difficulty associated with accurately assessing condition for these types of features using desktop methods.

Each indicator was given a score that ranged from 1 to 3, with a score of 1 representing an asset in poor condition and a score of 3 representing an asset in relatively good condition. The approach used to score each metric is described in more detail in Table 3. To calculate a final condition score, metrics were aggregated together using an equal weighting approach, and the sum was divided by the total possible number of points by asset type. This value was then multiplied by 100 to give a final percent score ranging between 0 and 100, with higher scores representing assets considered to be in better condition.

Table 3. Indicators, methods, and data used to estimate the condition score of each natural asset in the Town of Okotoks.

Indicator	Description & Methods for Quantification	Data Used to Quantify Indicator
Habitat Diversity	The diversity of habitat and the type of habitat structure present within each asset was visually assessed and each asset was assigned a score of 1 (low diversity), 2, or 3 (high diversity). A score of 1 was assigned to assets covered by a single non-natural cover type. A score of 2 was assigned to assets with at least two land cover types, with at least one being a natural cover type. A score of 3 was assigned to assets with three or more cover types representing a range of vegetation types and structural characteristics (e.g., short, medium, and tall vegetation present together in the same asset).	2018 Air Photo, Natural Asset layer, Land Cover layer
Occurrence of Rare, Threatened or Endangered Species	Assets located within 100 m of a known occurrence of rare, threatened, endangered, or locally significant species were given a score of 3. Assets that intersected the Key Wildlife and Biodiversity Zones Layer or that were identified as an eBird hotspot were given a score of 2. All other assets were given a score of 1.	Occurrence data from ACIMS, FWMIS, and eBird; AEP Key Wildlife and Biodiversity Zone layer
Intensity of Surrounding Land Use	A generalized land use layer was created for the Town, plus a 500 m buffer, using existing land use data. Natural and semi-natural assets were buffered by 100 m and the proportional cover of each land use class was calculated within the buffer. The proportional area of each land use class was then multiplied by the intensity value for each class (see Table 4), and a land use intensity value for each asset was calculated using a weighted sum. The area-weighted land use intensity values were standardized to values between 0 and 100. Assets < 50 were scored 3 (low intensity of use), those with a score between 50 and 52.14 were scored 2, and those with an intensity value > 52.14 were scored 1*.	Land Use Layer
Disturbance within Asset	Each asset was visually inspected to determine the amount of human disturbance (e.g., pathways, development) and/or habitat modification (e.g., drainage, human maintenance such as mowing) present. Each asset was then assigned a subjective score ranging between 1 (high degree of disturbance) and 3 (minimal disturbance).	Town of Okotoks 2018 air photo, land use layer, roads layer, pathways layer
Relative Asset Size	For each natural and semi-natural asset type, total area was calculated, and a rank was assigned to assets within each class based on its percentile score. Natural assets within the top third of the ranking (i.e., the largest assets within a class) received a 3, those within the middle third of the ranking received a 2, and those within the bottom third of the ranking received a 1. For some asset types, natural breaks were used alongside the percentile distribution breaks to determine break points between classes.	Natural and Semi-natural Asset layer

*Because the Town is dominated by residential and agricultural land uses, a very large number of assets scored in the mid-range for this indicator, resulting in a very small range in cut-off values between category 2 and 3.

Table 4. Land Use classes and associated land use intensity values used to assess the intensity of surrounding land use indicator

Land Use Class	Intensity Value	Land Use Class	Intensity Value	Land Use Class	Intensity Value
Airport & Industrial	100	Residential	50	Country Residential	25
Commercial	80	Agriculture & Golf Course	40	Restricted Development District	20
Under Construction	60	Sports Fields & Park Areas	30	Environmental Protection & Reserve	10

2.4. Identifying & Assessing Ecosystem Services

2.4.1. Identifying Ecosystem Services in the Town of Okotoks

Key ecosystem services in Okotoks were discussed during the in-depth workshop with Town representatives in December 2019. During this workshop, three priorities were identified: climate change, water quality and quantity, and recreation. From these priorities, a list of key ecosystem services was developed which correspond to the key priorities identified by the Town (Table 5). It is important to note that this is not a comprehensive list of the ecosystem services delivered by the natural and semi-natural assets in Okotoks; instead, these are considered to be the Town's major regulating, provisioning, and cultural ecosystem services.

Table 5. Key ecosystem services provided by natural assets in the Town of Okotoks, adapted from the Common International Classification of Ecosystem Services (CICES) framework.

Ecosystem Service Category	Ecosystem Service	Ecosystem Good/Benefit to End-Users
Regulating	Climate regulation (carbon stock & sequestration)	Avoided costs of carbon emissions
Regulating	Urban heat regulation (microclimate regulation)	Improved thermal comfort in urban areas
Regulating	Air quality regulation	Reduction of harmful air pollutants/improved air quality
Regulating	Soil erosion prevention	Reduction of damages of sediment input into watercourses
Regulating	Water flow regulation	Avoided or mitigated damages associated with the magnitude/frequency of flood/storm events
Regulating	Water quality control	Reduction of damages of nutrient runoff into water systems
Provisioning	Surface water provision	
	Potable water provision	Drinking water
	Non-potable water provision	Water for non-drinking users (e.g., industrial)
Provisioning	Ground water provision	
	Potable water provision	Drinking water
	Non-potable water provision	Water for non-drinking users (e.g., industrial)
Provisioning	Habitat for wildlife	
	Habitat for native (non-domesticated) pollinators	Pollination contribution to yield of fruit crops
	Habitat for non-pollinating wild plants and animals	Populations of valued species (e.g., endangered species)
Provisioning	Harvestable volumes of wild (non-cultivated) plants	Wild plants (food)
Provisioning	Harvestable volumes of wild (non-domesticated) animals (i.e., hunting)	Wild animals (food)
Cultural	Recreational/aesthetic attractiveness	Recreation (e.g., hiking, running, bird watching), fitness, improved mental health, etc.
Cultural	Other cultural services	Increased environmental knowledge, local identity, artistic inspiration, social cohesion, moral well-being, etc.

2.4.2. Assessing Ecosystem Service Delivery

Once the primary ecosystem services were identified, the supply of each service within the Town was quantified. For each of the primary ecosystem services, indicators linked to the production and/or consumption of the service were selected and quantified in order 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 summary of the indicators and associated metrics that were used to assess the supply of ecosystem services in the Town is provided in Table 7. A more detailed description of how the supply of each service was quantified is provided below.

Climate regulation: Climate regulation was measured by quantifying both carbon stock and annual carbon sequestration rates. For each natural and semi-natural asset, the total area by land cover type was calculated, and carbon stock and sequestration rates for each land cover type were multiplied by the area contained within each asset (Table 6). If an asset had multiple land cover types, values were summed to calculate a total carbon stock and sequestration rate for each asset. Open water was excluded from the carbon stock and sequestration estimates because there is considerable debate regarding carbon stock and sequestration rates for this land cover type. Wetland assets were also excluded from this and all other ecosystem service indicator calculations because ecosystem services for wetlands were bundled together and valued based on area, rather than valuing each ecosystem service individually. See Section 4.3 for a discussion of how wetland assets were assessed and valued in this study.

Table 6. Carbon stock and sequestration rates used to assess climate regulation services by land cover type in the Town of Okotoks. Values were taken from Sunderland et al. (2019).

Land Cover Type	Carbon Stock (tonnes C/ha)	Carbon Sequestration (tonnes CO_2e/ha/year)
Grassland	106	1.55
Shrub	7	1.55
Sparsely Vegetated	107	0
Treed	174	10.71

Water flow regulation: An estimate of the total number of individual trees was quantified for each woodland asset, as well as for the urban and rural tree canopy assets using the canopy model that was generated from a combination of LiDAR point cloud data and manual air photo interpretation. For non-treed assets (low vegetation, pasture, hayland), generalized run-off rates were estimated using runoff coefficients (Bengtson 2010). For these estimates, we used a relative runoff rate for non-treed assets as compared to treed assets based on an average across several soil types and slopes; therefore, these are general estimates of water flow regulation only and do not represent detailed modelling of surface water flow in the Town.

Water quality control: The total area of grassland land cover was calculated for each natural and semi-natural asset in the Town, and this was used as a proxy for estimating the phosphorus-removal capacity of perennial grass cover types.

Table 7. Indicators and metrics for assessing the supply of priority ecosystem services identified in the Town of Okotoks.

Ecosystem Service	Ecosystem Service Indicator	Metric for Quantifying ES Indicator
Climate regulation	Carbon stock and sequestration	Tons of CO_2 and tons CO_2e/ha/yr estimated by land cover type and area
Urban heat regulation (microclimate regulation)	Cooling effect of natural vegetation cover	Median May to September (2017-2018) temperature values
Air quality regulation	Pollution/particulate substance filtration potential	Not quantified as part of this study
Soil erosion prevention	Soil erosion risk or erosion protection	Area of grassland cover within each asset
Water flow regulation	Water runoff volumes	Tree density for woodland and rural/urban canopy assets and estimated runoff rates for non-treed assets (low vegetation, pasture, hayland)
Water quality control	Nutrient runoff potential	Area of grassland cover within each asset
Surface water provision		
Potable water provision	Volume of available potable water	Not quantified as part of this study
Non-potable water provision	Volume of available non-potable water	
Ground water provision		
Potable water provision	Volume of available potable water	Not quantified as part of this study
Non-potable water provision	Volume of available non-potable water	
Habitat for wildlife		
Habitat for native (non-domesticated) pollinators	Populations of pollinating species	Area of assets identified as hayland and pasture
Habitat for non-pollinating wild plants and animals	Populations of non-pollinating species	Not quantified as part of this study
Harvestable volumes of wild (non-cultivated) plants	Volume of biomass that can be harvested for food	Not quantified as part of this study
Harvestable volumes of wild (non-domesticated) animals (i.e., hunting, fishing)	Population of wild animals that can be hunted for food	Not quantified as part of this study
Recreational/aesthetic attractiveness	Characteristics of natural assets that enable activities promoting health, recuperation, or enjoyment through active or passive interactions	Not quantified as part of this study
Other cultural services	Abiotic characteristics of natural assets that have passive or non-use value	Not quantified as part of this study

Surface and ground water provision: The amount of surface and ground water abstracted for potable and non-potable use can be measured using information obtained though water licenses; however, these licenses do not differentiate between the amount of water that is allocated for use and actual water use, and withdrawals that are under a specific volume do not require a license and are not tracked. Accurately calculating the volume of surface water for potable and non-potable use in the Town is complex and was considered to be outside the scope of this study.

Recreational/aesthetic attractiveness: There are a range of metrics that can be used to assess recreational/aesthetic attractiveness; 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. These data do not currently exist for the Town; consequently, the supply of this service was not quantified as part of this study.

Urban heat regulation: Landsat imagery from May through September for the years 2017 and 2018 were used to quantify median temperature values across a 30 m grid for the Town. This temperature data was then intersected with the natural and semi-natural asset boundaries to calculate a median temperature value for each asset type. A median temperature value for the "built-up" portion of the Town was also calculated using the Town Land Use layer and the 2018 air photo to delineate the extent of residential, commercial, and industrial areas within the Town.

Habitat for wildlife: The supply of habitat for populations of pollinating species was measured simply as the current area of hayland and pasture contained within the Town. Regarding the assessment of habitat for populations of non-pollinating species, there are a number of ways to assess and quantify biodiversity, ranging from primary data collection to habitat modelling; however, many of these approaches are complex and require recent and reliable data on species occurrence and distribution. While the Town of Okotoks provides suitable habitat for a range of species, completing a detailed assessment of biodiversity within the Town was outside the scope of this study.

Soil erosion prevention: The total area of grassland land cover was calculated for each natural and semi-natural assets in the Town, and this was used as a proxy for estimating the sediment-removal capacity of perennial grass cover types.

Air quality regulation: The pollution and particulate substance filtration abilities of vegetation depend on several factors including canopy type, leaf and branch density, and leaf micromorphology; thus, detailed inventories of vegetation are required to quantify the pollution removal potential of urban vegetation. This type of data does not currently exist for the Town; therefore, this service was not quantified as part of this study.

Harvestable volumes of wild (non-cultivated) plants: The distribution of wild foods such as berries or mushrooms can be mapped or modelled from field data and/or the use or consumption can be measured through surveys of residents. These data do not currently exist for the Town; therefore, this service was not quantified as part of this study.

Harvestable volumes of wild (non-cultivated) animals: The distribution of wild animals that may be harvested within the Town limits for consumptive use can be mapped or modelled from field data and/or can be measured through surveys of residents. These data do not currently exist for the Town; therefore, this service was not quantified as part of this study.

Other cultural services: Natural and semi-natural assets provide a wide range of cultural services, including providing and increasing environmental knowledge/skills among citizens, contributing to local identity, inspiring artistic expression, and improvising social cohesion and moral well-being, to name only a few. These passive use or non-use values are not observable and cannot be estimated from behavioural data, instead, surveys or experiments are required to estimate the supply and value of these services, and the collection of such data was out of scope for this study.

2.4.3. Valuing Ecosystem Services

The final step in an ecosystem service assessment is the identification of the goods and benefits of the 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. The benefits, or welfare, gained by the end-users of a natural asset providing ecosystem services is what we consider to be that asset's value. The total value of ecosystem services provided by natural assets generally consists of two sub-components (Figure 7):

- **Use values**, which include direct and indirect use values:
    - **<u>Direct use</u>** 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.
    - **<u>Indirect use</u>** 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, which reflect the value a person places on certain environmental assets that is not demonstrated through any observable behaviour (Adamowicz et al. 1998). These include 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 a particular environmental asset continues to exist, regardless of current of future use potential (existence value).

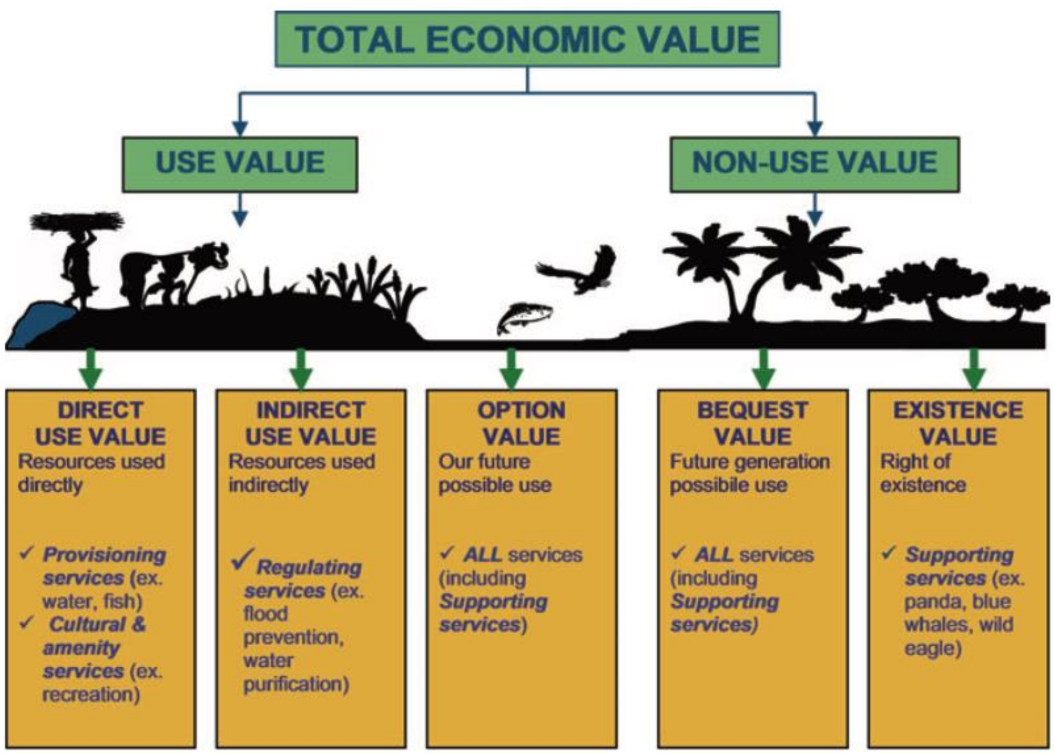


Figure 7. Use and Non-use values that make up the total economic value of an ecosystem (Source: de Groot et al. 2016).

Economic valuation attempts to measure the welfare derived from the use and consumption 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 must be used. 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 in order 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 which involves designing surveys or experiments in which participants are explicitly asked to express their WTP 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 directly ask participants what their WTP is for the continued existence of woodland caribou.
- The **benefit transfer (BT)** approach which 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. We typically strive 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 true 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. Benefits transfer allows individuals who cannot undertake primary data collection to use values estimated in comparable jurisdictions through either revealed or stated preference.

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. For example, 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 depart significantly from true WTP estimates and are therefore not reflective of the true value of an environmental good.

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 and 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. Similarly, consider a wetland that provides flood protection to a housing development. It would be incorrect to infer that a homeowner's WTP to retain the wetland is equivalent to the avoided cost of a flood, as the homeowner may be able to achieve flood protection through other means (e.g., retaining wall, dykes, culverts) whose costs differ substantially from the flood damages.

In sum, these techniques do not represent WTP estimates of end-users since the end-users' WTP for ecosystem services may differ substantially from the estimated avoided or replacement costs, making them an imperfect proxy for non-market values. Having said this, market proxies like avoided cost estimates are more readily available for natural assets in urban settings than WTP values through revealed or stated preference techniques. Furthermore, avoided cost estimates can still be of great use to the Town for municipal decision-making purposes. Our goal here is simply to provide clarity around what estimation techniques are considered to reveal true environmental values and what represent other market proxies.[1] We provide a general confidence level (low, medium, and high) for each of the estimated monetary values provided in this study based on several factors such as the valuation technique and the geographical similarity of the data.

As described in Table 7, each ecosystem service identified for the Town has an associated ecosystem service indicator. Similarly, for each ecosystem service there is a benefit that accrues to end-users in the Town, as well as an associated indicator through which those benefits can be measured. For each of the primary ecosystem services in the Town the benefits to end-users and their associated indicators have been identified and are presented in Table 8. Note that not all ecosystem service or benefit indicators identified have been measured in 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 provided by the Town's natural and semi-natural assets. 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 Town regarding pathways through which ecosystem services and natural assets impact the Town's end-point users.

2.5. Integration into Existing Asset System

In order to make the results from this study relevant and useable for the Town, the Study Team has developed an Excel-based database for the natural and semi-natural asset inventory that is compatible for integration with the Town's existing asset management software (CityWide). A separate user guide has been prepared to accompany the Excel-based database that includes details regarding the data presented in the inventory, as well as specific suggestions on how to best incorporate this inventory into the Town's CityWide database. A copy of the user guide can be found in Appendix C.

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

Table 8. Benefit indicators for priority ecosystem services identified in the Town of Okotoks (Source: Adapted from CICES framework).

Ecosystem Service	Ecosystem Service Indicator	Benefit to End-Users	Benefit Indicator
Climate regulation	Carbon stock and carbon sequestration	Avoided costs of carbon emissions	Amount of carbon stored and sequestered
Water flow regulation	Water runoff volumes	Avoided or mitigated damages associated with the magnitude/frequency of flood/storm events	Reduction in storm water runoff volumes
Water quality control	Nutrient runoff potential	Reduction of damages of nutrient runoff into water systems	Reduction in phosphorous runoff in watercourses
Surface water provision			
Potable water provision	Volume of available potable water	Drinking water	Volume of water used for drinking purposes
Non-potable water provision	Volume of available non-potable water	Water for non-drinking users (e.g., industrial)	Volume of water used for non-drinking purposes
Ground water provision			
Potable water provision	Volume of available potable water	Drinking water	Volume of water used for drinking purposes
Non-potable water provision	Volume of available non-potable water	Water for non-drinking users (e.g., industrial)	Volume of water used for non-drinking purposes
Recreational/aesthetic attractiveness	Characteristics of natural assets that enable activities promoting health, recuperation, or enjoyment through active or passive interactions	Recreation (e.g., hiking, running, bird watching), fitness, de-stressing, improved mental health, etc.	Number of households using natural assets for recreational purposes
Urban heat regulation (microclimate regulation)	Cooling effect of natural vegetation cover	Improved thermal comfort in urban areas	Improvements in mortality, morbidity, work productivity, and residential electricity use

Continued …

Table 8 *continued.* Benefit indicators for priority ecosystem services identified in the Town of Okotoks (Source: Adapted from CICES framework).

Ecosystem Service	Ecosystem Service Indicator	Benefit to End-Users	Benefit Indicator
Habitat for wildlife			
Habitat for native (non-domesticated) pollinators	Populations of pollinating species	Pollination contribution to yield of fruit crops	Crop yield increases
Habitat for non-pollinating wild plants and animals	Populations of non-pollinating species	Populations of valued species (e.g., endangered species)	Presence of valued species (e.g., endangered species)
Soil erosion prevention	Soil erosion risk or erosion protection	Reduction of damages of sediment input into watercourses	Reduction of sediment in watercourses
Air quality regulation	Pollution/particulate substance filtration potential	Reduction of harmful air pollutants/improved air quality	Reduced respiratory illness
Harvestable volumes of wild (non-cultivated) plants	Volume of biomass that can be harvested for food	Wild plants (food)	Foraged plants for consumption
Harvestable volumes of wild (non-domesticated) animals (i.e., hunting)	Population of wild animals that can be hunted for food	Wild animals (food)	Hunted animals for consumption
Other cultural services	Abiotic characteristics of natural assets that have passive or non-use value	Increased environmental knowledge/skills among citizens, local identity, artistic inspiration, social cohesion, moral well-being, etc.	Improved well-being (unobservable)

3.0 Summary of Assets

3.1. Asset Composition

In total, 302 unique natural and semi-natural assets were identified in Okotoks, covering 12.4 km^2 or 32% of the Town (Table 9). Pasture makes up the largest proportion of assets by area, and when combined with hayland, these two semi-natural assets account for 46% of the overall asset area in Okotoks (Figure 3). In addition to containing pasture and hayland assets, the more rural parts of the Town also contain a substantial proportion of the wetland assets, including a very large wetland located on lands within the West Okotoks area (Figure 4).

The built-up portion of the Town includes the majority of the natural assets, including the Sheep River and associated woodlands on the banks of the river, as well as low vegetation assets associated with escarpment lands north of the river. The urban tree canopy is also a notable semi-natural asset that makes up 6% of the areal cover of assets in the Town.

Table 9. Overview of the natural and semi-natural asset types identified in the Town of Okotoks.

Asset Type	Number of Assets	Area (km^2)
Natural Assets		
Woodland	57	1.9
Low Vegetation	35	1.6
Wetland	118	1.0
Watercourse	27	0.9
Lake	3	0.2
Semi-Natural Assets		
Pasture	26	4.3
Hayland	9	1.4
Managed/Naturalized Low Vegetation	8	0.1
Managed/Naturalized Waterbody	17	0.1
Urban Tree Canopy	1	0.7
Rural Tree Canopy	1	0.1
TOTAL	302	12.4

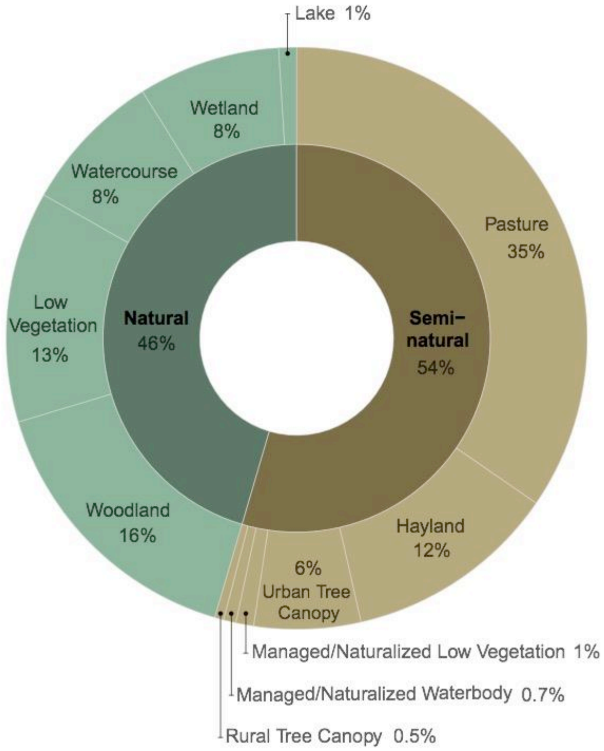


Figure 3. Proportion (by area) of natural and semi-natural assets in the Town of Okotoks.

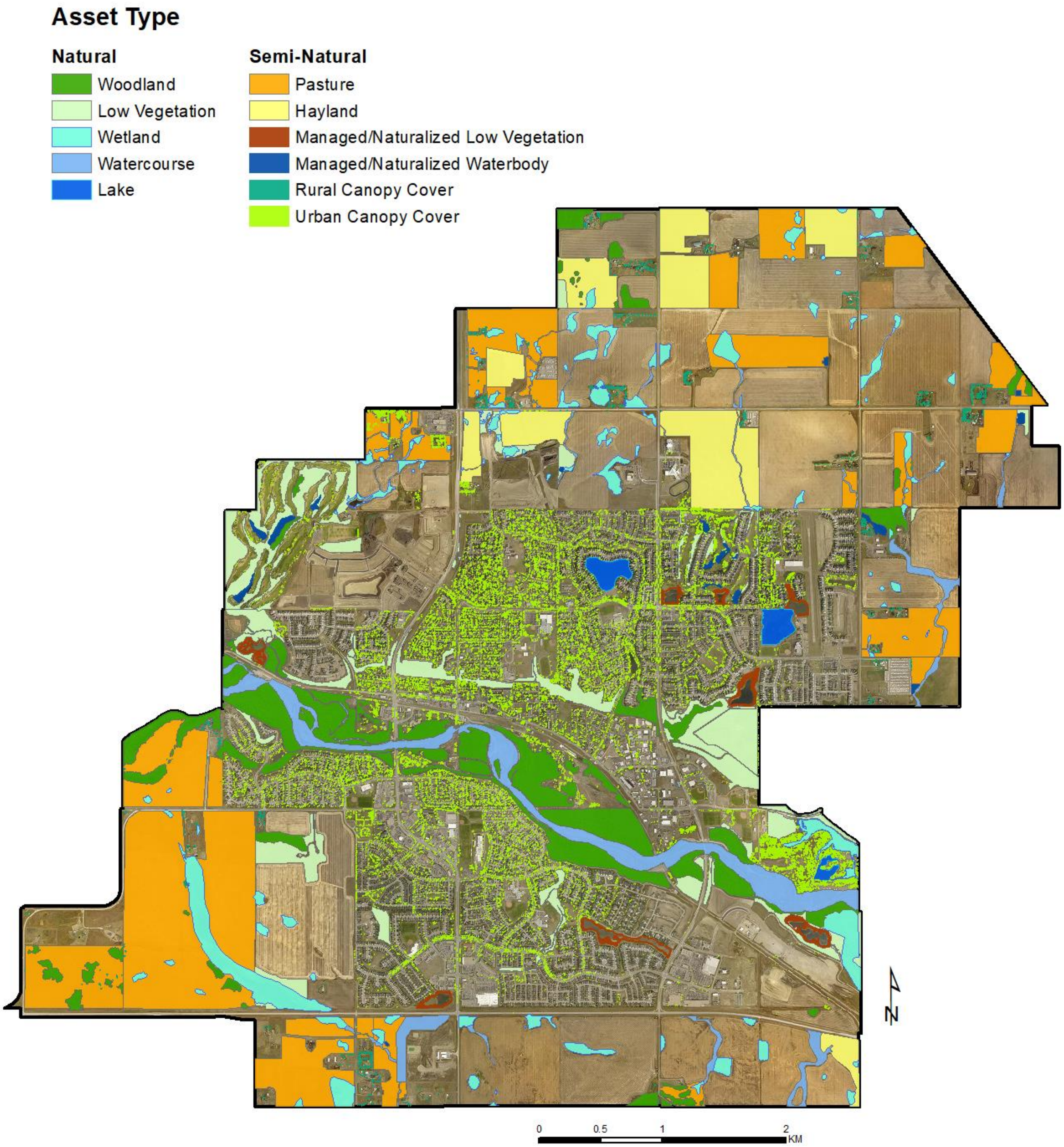


Figure 4. Map of natural and semi-natural assets in the Town of Okotoks.

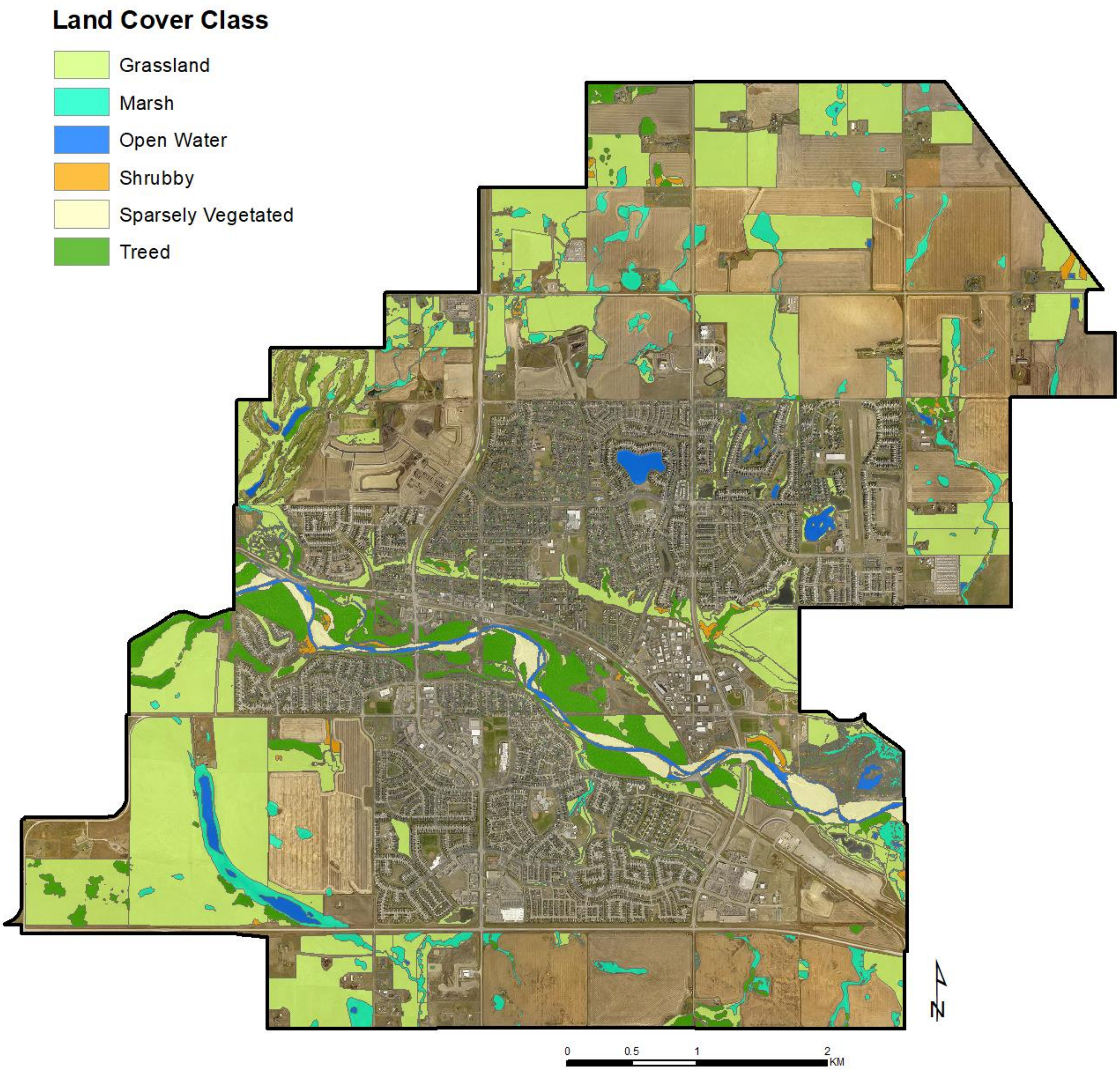


Figure 5. Land cover map of natural and semi-natural cover types in the Town of Okotoks.

3.2. Asset Condition

Condition scores for natural and semi-natural assets ranged between 33% and 100%, with an average score of 58% (Table 10). Relative to other asset types, woodland assets tended to have the highest condition scores, and in particular, the woodlands associated with the Sheep River valley were generally considered to be in good condition (Figure 6). In contrast, managed/naturalized waterbodies generally received the lowest scores, as many of these assets have been impacted by agricultural activities such as cultivation and drainage.

Table 10. Summary of condition scores assigned to natural and semi-natural assets identified in the Town of Okotoks.

Asset Type	Number of Assets	Minimum Score	Maximum Score	Average Score
Natural Assets				
Woodland	57	40.0	100	70.8
Low Vegetation	35	33.3	86.7	59.2
Wetland	118	33.3	93.3	53.4
Watercourse	27	33.3	100	56.5
Lake	3	46.7	86.7	71.1
Semi-Natural Assets				
Pasture	26	40	93.3	56.9
Hayland*	9	n/a	n/a	n/a
Managed/Naturalized Low Vegetation	8	33.3	60.0	47.5
Managed/Naturalized Waterbody	17	33.3	66.7	48.6
Urban Tree Canopy*	1	n/a	n/a	n/a
Rural Tree Canopy*	1	n/a	n/a	n/a

*Condition scores were not assigned to hayland, urban tree canopy, or rural tree canopy assets.

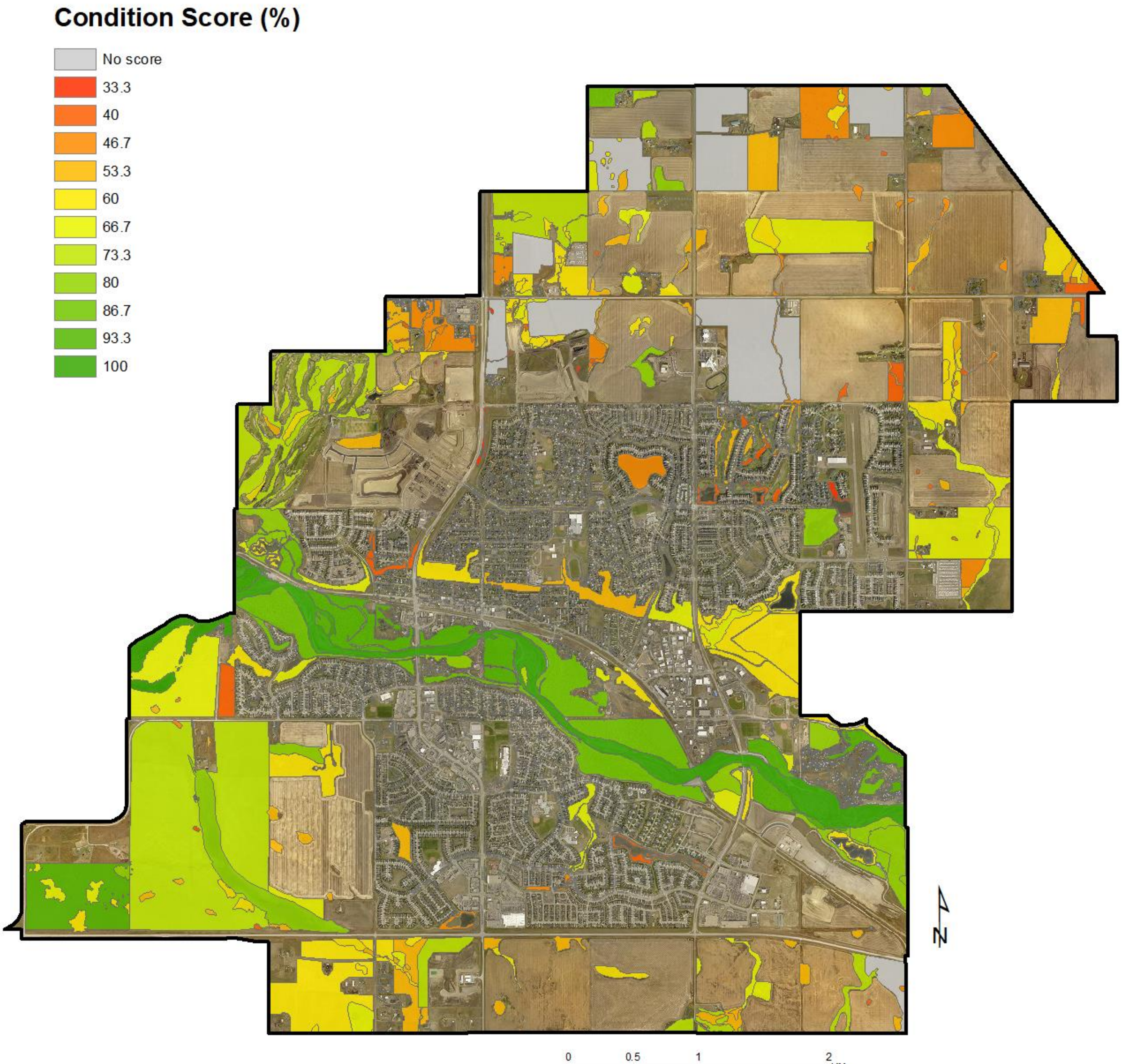


Figure 6. Condition scores for natural and semi-natural assets identified in the Town of Okotoks.

4.0 Ecosystem Service Valuations

4.1. Summary Values by Ecosystem Service

The total estimated value of the ecosystem services evaluated in the Town of Okotoks is **$84 million** ($2020). This includes estimates for water flow regulation, climate regulation, recreational/aesthetic attractiveness, bundled wetland services, water quality control, native pollinator habitat, and soil erosion potential (Figure 7; Table 11). Notably, because ecological and economic data are not available to assess every ecosystem provided by natural and semi-natural assets in the Town, this estimate is incomplete; however, it does serve to illustrate the enormous ecological, social, and economic value that these assets provide to Town residents. For the ecosystem services that could be assigned a monetary value, the water flow regulation service was estimated to provide the greatest monetary value ($37.2 million). This was followed climate regulation ($29.7 million) and recreational/aesthetic attractiveness ($13.1 million). Together, these three services account for 95% of the ecosystem service value in the Town.

A number of other ecosystem services were examined as part of this study, including urban heat regulation, habitat for plants and animals, surface and groundwater provision, air quality regulation, harvesting of wildlife plants and animals, and other cultural services. While these ecosystem services were identified as being important to the Town, monetary estimates could not be derived due to a lack of reliable data. A more detailed discussion of each of the key ecosystem services that were assessed as part of this study is provided in Section 4.3.

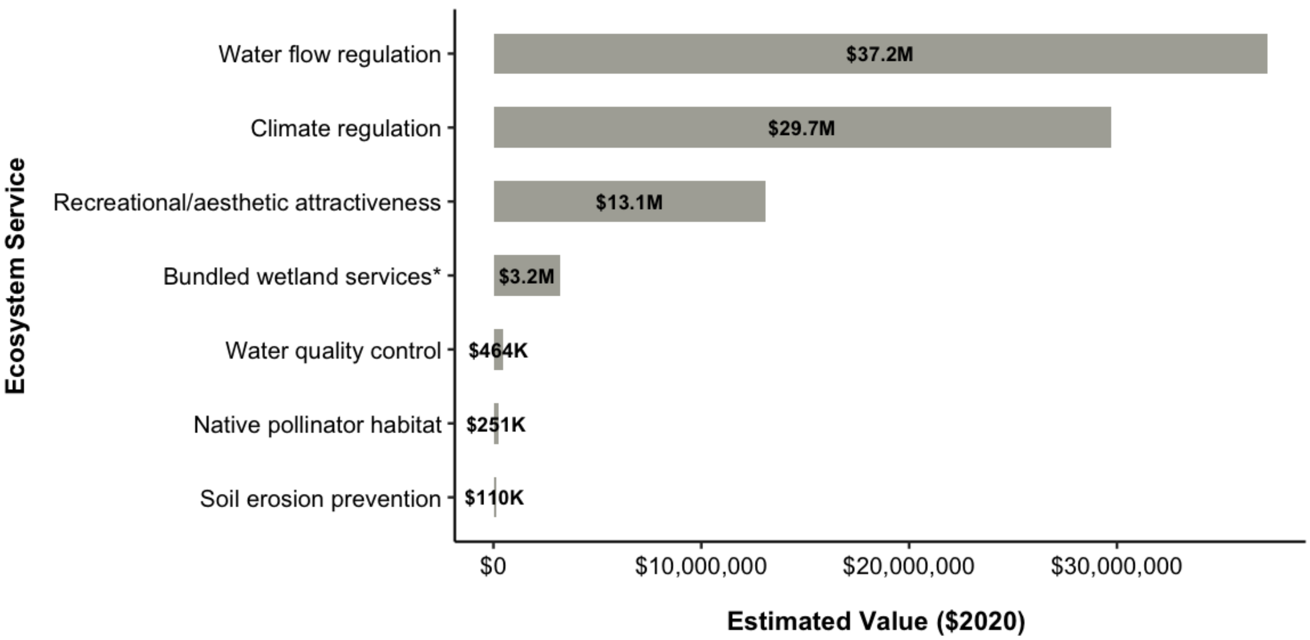


Figure 7. Monetary estimates for ecosystem services quantified in the Town of Okotoks. Bundled wetland services included water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation.

Table 11. Monetary estimates, methods, and confidence level associated with each estimate for ecosystem services in the Town of Okotoks.

Ecosystem Service	Monetary Estimate ($2020)	Method of Estimation	Confidence in Estimate
Water flow regulation	$37,220,000	Benefit Transfer (avoided cost)	🔴
Climate regulation	$29,705,000	Avoided cost	🟠
Recreational/aesthetic attractiveness	$13,106,000	Benefit Transfer (stated preference)	🟢
Bundled wetland services (water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation)	$3,206,000[a]	Benefit Transfer (stated preference)	🟢
Water quality control	$464,000	Benefit Transfer (avoided cost)	🟠
Habitat for native (non-domesticated) pollinators	$251,000	Benefit Transfer (market value)	🔴🟠
Soil erosion prevention	$110,000	Benefit Transfer (avoided cost)	🟠
Urban heat regulation	--		--
Habitat for non-pollinating wild plants and animals	--		--
Surface water provision (potable & non-potable water)	--		--
Ground water provision (potable & non-potable water)	--		--
Air quality regulation (e.g., dust filtration)	--		--
Harvestable volumes of wild (non-cultivated) plants or wild (non-domesticated) animals	--		--
Other cultural services	--		--
Total Quantified Monetary Estimate	**$84,062,000**		

Notes:

a The monetary estimate of wetlands in the Town were estimated based on an average value for a bundle of ecosystem services offered by wetland assets, as opposed to values for individual ecosystem services

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

4.2. Summary Values by Asset

Ecosystem service values summarized by asset type indicate that pasture assets have the highest estimated ecosystem service value ($21.6 million). Indeed, pasture assets make up over one third of the natural asset area in the Town (approximately 434 hectares), providing highly valued ecosystem services, particularly related to climate change regulation and water flow regulation. The second most valuable assets in the Town are woodland assets ($19.4 million), providing highly valued services related to climate change regulation, water flow regulation, as well as recreational services that, while not valued at an asset level, are offered by many of the woodland assets in the Town. Together, pasture and woodland assets account for nearly half of the estimated value of ecosystem services in the Town. Note that these estimates do not include recreational/aesthetic attractiveness values, as this ecosystem service was calculated for the Town as a whole, and thus, was not assigned to individual assets.

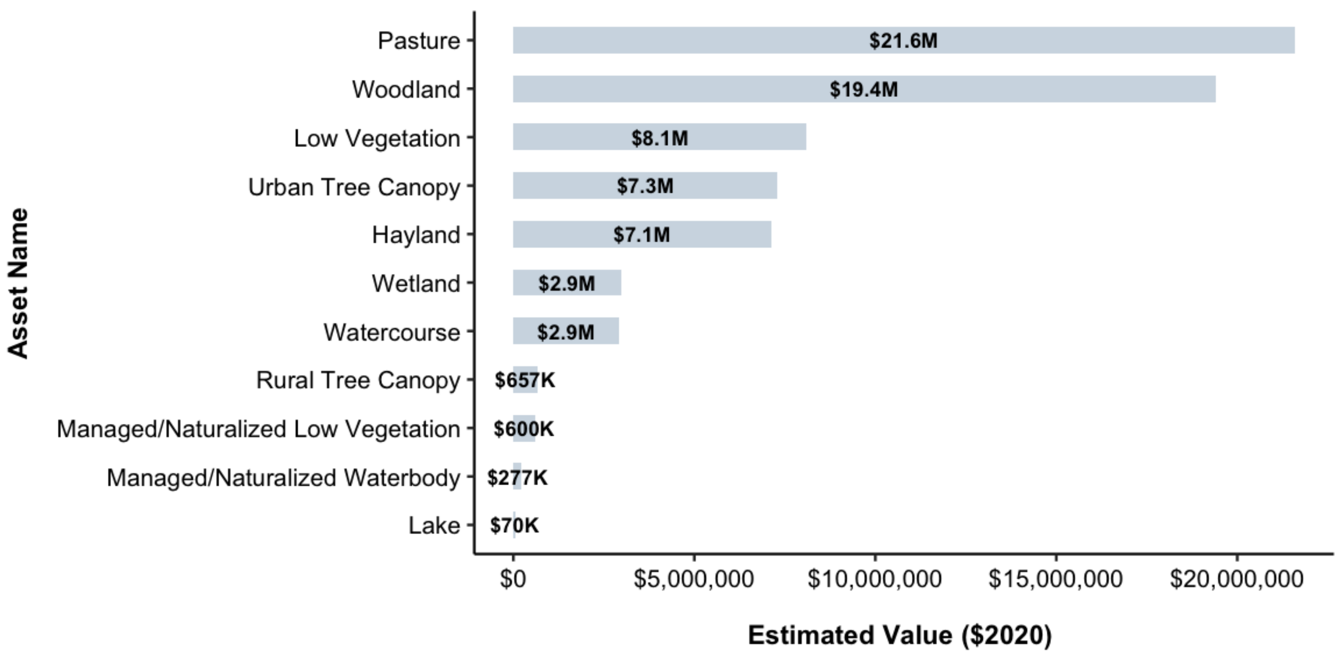


Figure 8. Monetary estimates for ecosystem services summarized by natural and semi-natural asset type.

4.3. Detailed Review of Ecosystem Service Values

4.3.1. Water Quality and Quantity

Monetary estimates were derived for two water quality and quantity services in the Town: water flow regulation and water quality control, which have a combined estimated value of **$37.7 million**.

The water flow regulation service is estimated to be $37.2 million, with a confidence rating of low.

Water flow regulation is a particularly important ecosystem service in Okotoks, as the Town has experienced several major flooding events (e.g., 2005 and 2013) and is at risk of experiencing floods at a higher frequency and severity as a result of climate change. Natural and semi-natural assets help to mitigate the impact of floods by intercepting, retaining, and slowing the flow of precipitation, and helping reduce the rate and severity of stormwater runoff and flooding damage (Nowak & Dwyer 2010). Literature on the value of water flow regulation of urban natural and assets is relatively sparse. A 2015 study published by the Canadian Forest Service (Hotte et al. 2015) cites a study of five US cities that quantifies the benefits of stormwater runoff reductions of urban trees (McPherson et al. 2005). We use the median estimate of these benefits (approximately $12.20/tree/year) along with the average density of woodlands and the urban and rural canopy cover to estimate the present value of water flow regulation of predominantly treed assets (woodland, and urban/rural canopy cover) as $61,800 per hectare. To determine the value of water flow regulation services provided by predominantly non-treed assets (i.e., low vegetation, pasture, and hayland), the value of treed assets was adjusted by the estimated difference in runoff reduction between forested and non-forested areas (Bengtson 2010), resulting in a present value of approximately $27,500 per hectare. Given the total area of each natural asset category in the Town, the total value of water flow regulation is estimated to be approximately $37.2 million.

A confidence level of “low” was assigned to the water flow regulation service estimate because it does not represent a willingness to pay measure for water flow services by Town stakeholders. Furthermore, the values that were used to derive this estimate were taken from a study that took place in several cities in the United States, which may have substantially different costs associated with stormwater runoff and flooding damage as compared to the Town. Despite these drawbacks, the benefit transfer study has relatively similar socio-economic, cultural, and ecological conditions to the Town, as it took place in North America. While the value is not necessarily robust, it still provides the Town with a high-level estimate of the value of natural and semi-natural assets in moderating surface water flow.

The water quality control service is estimated to be $464 thousand, with a confidence rating of medium.

Grasslands play an important role in the filtration and treatment of water within the Town by reducing contaminants such as phosphorous. Indeed, grasslands in the Canadian prairies have been identified as important contributors to overall water and watershed management (Bailey et al. n.d.). The monetary value of water quality services provided by grasslands are estimated using a benefit transfer value from a study of ecosystem service values in British Columbia’s Peace River Watershed (Wilson 2014). This study estimated that grasslands provide a benefit of approximately $31 per hectare per year in avoided phosphorous treatment in watercourses. Over a 50-year period, the present value of these benefits is approximately $601 per hectare. With approximately 772 hectares of grasslands in the Town boundary (not including those in wetland assets), the resulting monetary estimate for water quality services from the Town’s natural and semi-natural assets is approximately $464 thousand.

A confidence level of “medium” was assigned to the water quality monetary estimate. While this estimate does not represent a willingness to pay for water quality services by Town stakeholders specifically, we are confident in the accuracy of Wilson’s (2014) estimate of the avoided costs for phosphorous water treatment provided by grasslands in Western Canada, and the similarities in the socio-economic and cultural characteristics of the populations in B.C. and the Town of Okotoks. Thus, we believe this estimate provides the Town with useful information regarding the economic tradeoff of this ecosystem service.

4.3.2. Climate Regulation

Natural and semi-natural assets play an important role in regulating the world's carbon emissions. Assets with trees, grasses, and other plant life require carbon dioxide (CO_2) for photosynthesis. These assets store excess carbon as biomass and can ultimately act as a sink for CO_2 (Nowak & Crane 2002).

The climate regulation service for the Town of Okotoks is estimated to be $29.7 million, with a confidence rating of medium.

The value of climate change regulation services provided by the Town's natural and semi-natural assets was calculated based on the avoided costs to society of carbon emissions that are stored by the Town's assets. Carbon storage is comprised of two distinct components:

- carbon stocks, or the amount of carbon that is currently stored within a natural or semi-natural asset; and
- annual carbon sequestration, or the marginal change in carbon stocks by an asset each year.

Carbon stocks and annual carbon sequestration rates for each land cover type in the Town were sourced from Sunderland et al. (2019; Table 6).

Avoided damages associated with carbon emissions were sourced from Environment and Climate Change Canada's (ECCC) (2016) social cost of carbon (SCC) estimate of $184.80 per tonne of carbon (or $50.40 per tonne of CO_2e). Because sequestration rates are estimates of an annual service (i.e., tonnes of CO_2e sequestered per year), whereas current carbon stock are not, the valuation of the annual sequestration component of climate change regulation was estimated as the present value of sequestration over a 50-year time period. The resulting values of carbon stocks and annual sequestration for each land cover type present in the Town of Okotoks was calculated (Table 12), to derive a climate regulation estimate of approximately $29.7 million.

Table 12. Carbon stock and sequestration values for the Town of Okotoks, summarized by land cover type.

Land Cover Type	Carbon Stock ($/ha)	Annual Carbon Sequestration ($/ha)
Grassland	$19,589	$1,504
Shrubby	$19,773	$1,504
Sparsely vegetated	$19,773	$ -
Treed	$32,155	$10,394

A confidence rating of "medium" has been assigned to the climate change regulation monetary estimate. While this estimate does not represent a willingness to pay measure for climate regulation services by Town stakeholders, the Study Team is confident in the accuracy of ECCC's recent estimate of the SCC in a Canadian context, and thus, we believe this estimate provides the Town with useful information regarding the economic tradeoff of this ecosystem service.

4.3.3. Recreation/Aesthetic Attractiveness

The Town's natural and semi-natural assets provide many recreational opportunities for the community including walking, biking, picnicking, birdwatching, and more.

The value of the recreational and aesthetic attractiveness service for the Town is estimated to be $13.1 million, with a high confidence rating.

The valuation of the recreational and aesthetic attractiveness of natural and semi-natural assets in the Town was estimated using a benefit transfer value from a 1993 study on the economic value of the South Saskatchewan River to the City of Saskatoon (Kulshreshtha and Gillies 1993). The 1993 study undertook a stated preference survey of a sample of recreation users in Saskatoon to elicit their willingness to pay for river-based recreation including water-based recreation such as boating, rowing, etc., and land-based recreation near the river such as leisure walks or runs, cycling, picnicking, etc. While not all of the natural and semi-natural assets in the Town of Okotoks that offer public recreation are in close proximity to the Sheep River, many of the Town's major recreation trails such as Heritage Parkway, Sheep River Pathway, and Woodhaven Parkway are located near the river. Furthermore, it is assumed that users would have a similar willingness to pay for land-based recreation activities in highly recreated areas away from the river (such as the off-leash dog park and Beatrice Wyndham Parkway). The 1993 study found that the willingness to pay by users of the recreation areas was approximately $83 per household per year. The present value of this willingness to pay over a 50-year period is estimated to be approximately $1,590 per household. There are an estimated 9,815 private households in the Town of Okotoks (Statistics Canada 2016). According to the 2017 Alberta Recreation Survey, approximately 84% of households undertake recreation activities that "connect people to nature". Assuming this proportion holds for Okotoks, 8,245 households can be assumed to undertake outdoor recreation activities in the Town, resulting in a total recreation and aesthetic attractiveness estimate for the Town's natural and semi-natural assets of $13.1 million.

A confidence rating of "high" has been assigned to the recreational/aesthetic attractiveness monetary estimate. This estimate represents a willingness to pay measure of recreational services provided by natural assets from a Western Canadian population with highly similar socio-economic, cultural, and ecological conditions as the Town. Indeed, the City of Saskatoon offers similar outdoor recreation opportunities as the Town of Okotoks, with a primary focus on recreation opportunities provided by the river valley. While the original study is dated (1993), the Study Team adjusted the estimate to reflect $2020 estimates. Consequently, this estimate provides the Town with useful information regarding the value of recreational services provided by its' natural assets.

4.3.4. Bundled Wetland Services

Wetlands provide a myriad of valuable ecosystem services to end-users such as climate regulation, water flow regulation, and soil erosion prevention. Unlike other monetary estimates in this study, which are presented at an ecosystem service level, the value of the ecosystem services provided by wetland habitats were bundled together to derive a single value estimate at the asset level.

The bundled value of water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation for wetlands in the Town of Okotoks is estimated to be $3.2 million, with a confidence rating of high.

The estimates for wetland ecosystem services were sourced from a stated preference study of wetland economic values in Manitoba (Pattison et al. 2011). The 2011 study involved a survey of 1,980 respondents from the provincial population to estimate household willingness to pay values for wetlands. Ecosystem services of wetlands were presented as including water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation. The 2011 study estimated that

Manitobans would be willing to pay approximately $305[2] per year for five years to retain the current stock of wetlands, effectively avoiding the loss of 95,000 acres of wetlands, for a 12-year period. Turning this value into the present value of annual willingness to pay over a 50-year period yields a monetary estimate of approximately $28,576 per hectare.[3] With about 112 hectares of marsh habitat associated with both wetland and managed/naturalized waterbody assets, the total value of bundled wetland services in Okotoks is approximately $3.2 million.

It is important to note that wetland ecosystem service values are estimated in this report as an aggregated value (one value per hectare of wetlands for a set of five ecosystem services). As such, to avoid double counting, wetland assets are not included in the valuation analysis of individual ecosystem services. For example, the monetary estimate for bundled wetland services includes the climate regulation services that wetlands provide. If we were to estimate the climate regulation services of wetlands as an individual ecosystem service and include that in the Town's total natural asset value, we would be double counting those specific services from wetland assets.

A confidence rating of "high" was assigned to the wetland ecosystem service monetary estimate. This estimate represents a willingness to pay measure of ecosystem services provided by wetlands, and therefore, a true environmental value for wetland assets from a Western Canadian population with many socio-economic, cultural, and ecological similarities to the Town. As such, this estimate provides the Town with useful information regarding the value of its wetland assets.

4.3.5. Habitat for Native (Non-Domesticated) Pollinators

Natural and semi-natural assets provide habitat for a plethora of flora and fauna, including native, non-domesticated pollinators. Native pollinators such as wild bees, butterflies, flies, and moths provide economic benefits in the form of increased agricultural crop yields through pollination.

The value of the habitat for native pollinators provided by natural and semi-natural assets in the Town was estimated to be $251 thousand, with a confidence rating of low to medium.

To calculate the value of habitat provided for native, non-domesticated pollinators in the Town, a benefit transfer value from a 2009 study of the economic benefits of ecosystem services in Southern Ontario (Troy and Bagstad 2009) was applied. The 2009 study itself cites original work by Morandin and Winston (2006) who evaluated the marginal impact that increased wild bee habitat (i.e., natural grasslands) had on the crop yields of nearby canola fields. The average increase in value of nearby crop production was estimated to be approximately $23 per hectare per year. It is outside the scope of this study to evaluate the exact crop production mix within the rural area of the Town and the geographic relationship to nearby natural grasslands providing wild bee habitat; however, as an estimate, a benefit of $23 per hectare per year was applied to the hayland and pasture assets in the Town, as these assets are more likely to be within close proximity to flowering agricultural crops. The present value of this benefit over a 50-year period is an estimated $435 per ha. With approximately 576 hectares of hayland and pasture in the Town, the total estimated value of habitat provided for native, non-domesticated pollinators is approximately $251 thousand.

A confidence rating of "low to medium" was applied to this monetary estimate because it does not represent a willingness to pay for this ecosystem service by Town stakeholders. Furthermore, the crop production mix near hayland and pasture assets in the Town was not evaluated. Consequently, the pollination contribution to flowering crops is largely unknown; however, the estimate was developed from

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[2] All dollars are $2020 CAD unless otherwise stated. For a description of how historical, nominal values were inflated to $2020, please see Appendix A provided at the end of the report.

[3] For ecosystem services that provide a stream of benefits into the future, a present value estimate was calculated assuming a 50-year time period and a discount rate of 5%. For more information regarding how present values were calculated, see Appendix A provided at the end of the report.

original work on the marginal impact of wild bee habitat on crop yields that took place in Alberta (Morandin and Winston 2006). As such, we believe the estimate provided gives the Town a general sense of the economic tradeoff of this ecosystem service.

4.3.6. Soil Erosion Prevention

Grasslands play an important role in the control and retention of sediment, effectively preserving topsoil and minimizing sediment transport into watercourses.

The value of the soil erosion prevention service in the Town was estimated to be $110 thousand, with a confidence rating of medium.

The monetary estimate of soil erosion prevention was estimated using a benefit transfer value from a study of ecosystem service values in British Columbia's Peace River Watershed (Wilson 2014). This study estimated that grasslands and perennial land covers provide a benefit of approximately $7 per hectare per year in avoided sediment treatment in watercourses. Over a 50-year period, the present value of these benefits is approximately $142 per hectare. There are approximately 772 hectares of grassland (not including those in wetland assets) in the Town of Okotoks, resulting in a total water quality service value of approximately $110 thousand.

A confidence ranking of "medium" was assigned for the soil erosion prevention monetary estimate. While this estimate does not represent a willingness to pay for soil erosion prevention services by Town stakeholders specifically, the Study Team is confident in the accuracy of Wilson's (2014) estimate of the avoided costs for sediment treatment in watercourses provided by grasslands in Western Canada, and the similarities in the socio-economic and cultural characteristics of the populations in B.C. and the Town. Thus, we believe this estimate provides the Town with useful information regarding the economic tradeoff of this ecosystem service.

4.3.7. Urban Heat Regulation

For Canadians living in urban centres, the Urban Heat Island (UHI) effect can have significant economic and health impacts. The UHI effect occurs when ambient temperatures in urban centres are higher than those in rural areas. The effect occurs due to relatively less vegetative cover in urban centres, as well as a higher proportion of dark surfaces (e.g., roads, parking lots) that absorb the sun's rays and slowly radiates the heat (Health Canada 2015). The negative impacts of UHI are well documented and include increased energy and electricity demands, reduced air quality through increases in ozone, and an increase in heat stress leading to higher mortality, particularly for at-risk populations (Santamouris 2020). For example, the risk of cardiovascular mortality increases by 1.3% for the general population with increased heat exposure, while this risk increased by 8.1% for the elderly (Ibid). Within urban areas, vegetative cover is essential for regulating the UHI effect and mitigating associated impacts to health and well-being.

In order to assess the UHI effect in the Town of Okotoks, satellite imagery was used to quantify median temperature values using data from May to September of 2017 and 2018 (Figure 9). These data were then used to calculate median temperature value for each natural and semi-natural asset type, as well as for the built-up portion of the Town (Table 9). On average, areas identified as a natural asset have a much lower temperatures than semi-natural assets or built-up areas of the Town, with woodlands and assets that contain water generally having the lowest average temperatures. In comparison, semi-natural assets have higher temperature values than natural assets, but lower temperature values than built-up areas within the Town. While this analysis suggests that natural and semi-natural assets have a regulating effect on spring and summer temperature values, the urban heat regulation service offered by these assets cannot be measured directly for the Town of Okotoks. This is because we are not able to quantify average daily temperatures in the absence of natural and semi-natural assets, and therefore, we cannot measure the difference in temperature values with and without the presence of these assets.

Despite this limitation, the analysis presented here clearly illustrates that all types of natural and semi-natural land cover offer some degree of urban heat island regulation, thereby effectively reducing temperatures in the vicinity of the assets. These temperature reductions lead to economic savings for the Town by reducing costs associated with things like energy and healthcare. The Cooperative Research Centre for Water Sensitive Cities has published several academic papers and technical reports focusing on the urban heat island effect and urban heat regulation, with a focus on Australia (e.g., Rogers et al. 2018; Tapper et al. 2019; Whiteoak and Saiger 2019). Recent work by Whiteoak and Saigar (2019) suggests that the average present value of benefits over a 50-year period and at a standard discount rate of 5% of a one-degree reduction in the average daily temperature in Melbourne, Australia, is approximately $3,739 per household. These savings are associated with improvements in mortality, morbidity, work productivity, and residential electricity use. It is important to note, however, that urban heat regulation benefits in Melbourne could vary substantially from those realized in Okotoks due to the relative difference in climate and utility operations between the two cities. Despite these differences, the Melbourne study serves to illustrate the important value of natural assets in regulating microclimate within urban areas, particularly as average summer temperatures increase as a result of climate change.

Table 13. Minimum, maximum, and median summer temperature values calculated for the months May to September (2017 and 2018) for natural and semi-natural assets in the Town of Okotoks.

Asset Type	Minimum Temperature	Maximum Temperature	Median Temperature
Natural Assets			
Woodland	21.0	29.6	24.5
Low Vegetation	22.4	30.8	26.7
Wetland	21.9	31.1	25.5
Watercourse	21.6	28.9	24.1
Lake	20.6	27.9	23.6
Semi-Natural Assets			
Pasture	23.1	32.0	27.9
Hayland	23.7	29.8	26.9
Managed/Naturalized Low Vegetation	22.9	30.4	26.2
Managed/Naturalized Waterbody	22.0	27.7	24.3
Urban Tree Canopy	21.7	32.3	27.8
Rural Tree Canopy	23.1	30.5	26.0
Built-up Area	19.9	32.4	29.1

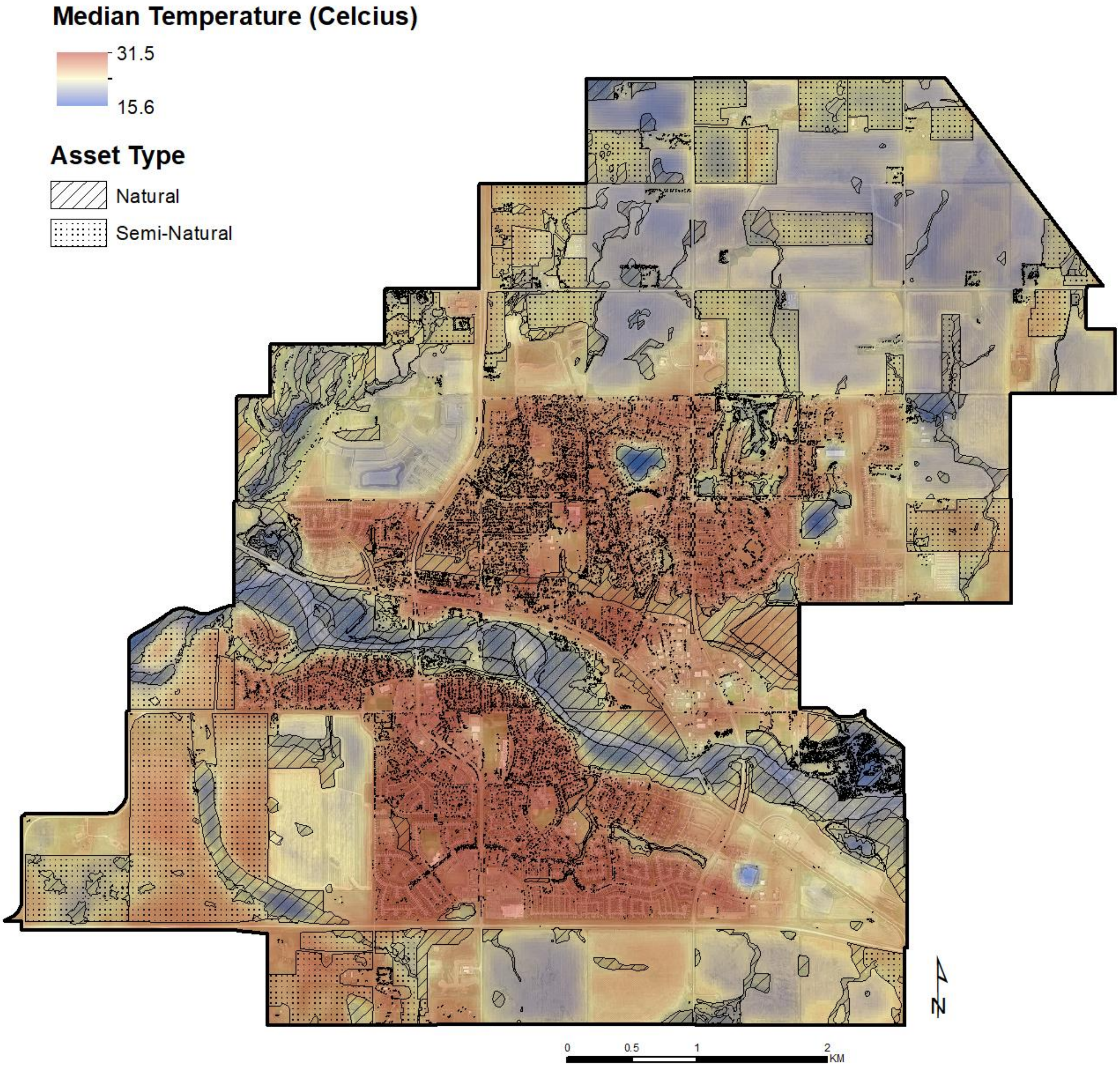


Figure 9. Median temperature values for the Town of Okotoks, as measured using Landsat satellite imagery for the months May through September (2017-2018). Areas shown in red have a higher temperature values than areas shown in blue. Boundaries of natural and semi-natural asset are shown for reference.

4.3.8. Habitat for Wildlife (Non-Pollinating Wild Plants and Animals)

Natural and semi-natural assets offer essential habitat for a variety of flora and fauna, providing end-users with the benefit of healthy populations of valued species; however, not all species are considered to provide a benefit for all end-users. Indeed, some species such as coyote and mice are considered a nuisance to many, and an individual's WTP for to conserve these populations might be zero. In an urban setting, the value of habitat provision is highest for iconic or charismatic species, as well as for species that are considered to be sensitive, threatened, or at risk due to human activities. In Okotoks, there have been confirmed records of threatened or sensitive species, as defined by the General Status of Alberta Wild Species (AEP 2015), as well as the federal *Species at Risk Act* (SARA), including:

- Northern leopard frog (Provincial Status: At Risk; Federal Status: Special Concern);
- Cutthroat trout (Provincial Status: Threatened); and
- Bull trout (Provincial Status: Threatened; Federal Status: Special Concern).

The Town is also located within the range of several sensitive raptor species, including:

- Bald eagle;
- Ferruginous hawk;
- Golden eagle; and
- Prairie falcon.

Furthermore, the Town falls within the Sheep River Corridor, which has been designated a key wildlife and biodiversity zone by Alberta Environment and Parks.

While the Town provides important habitat for a range of plant and wildlife species, the Study Team has not provided a monetary estimate for habitat for non-pollinating species services provided by the Town's natural and semi-natural assets, as welfare data regarding the economic value of this service in an urban setting is limited. Furthermore, the Town represents a small sub-set of the overall habitat for many of these species, making the attribution of value to a single Town asset challenging.

4.3.9. Surface Water and Ground Water Provision (Potable and Non-Potable Water Provision)

The Town of Okotoks is situated within the Bow River Watershed of the South Saskatchewan River Basin (SSRB). The Sheep River transects the Town and, along with ground water resources, provides drinking and non-potable water provision to residential, commercial, industrial, and agricultural users. These assets were not assigned a monetary estimate in this study for several reasons. First, groundwater was not inventoried as a natural asset. Furthermore, while the Sheep River acts as the Town's primary source of potable and non-potable water, the delivery of this service cannot be attributed to the Town's Sheep River asset alone – the source waters and the ability to regulate the River itself is outside the jurisdiction of the Town. Indeed, water delivery from the Sheep River depends on complex hydrological relationships within both the Bow River Watershed and, to a larger scale, the SSRB. As such, ascertaining a monetary estimate for water provision services provided by the portion of the Sheep River that lies within the Town boundaries presents a challenge that is outside the scope of this study. In addition, estimating the value associated with this service is problematic as potable and non-potable water provision takes place in a distorted market. Values exist for water delivery in the Town, but these values represent more than just the value of water as they include expenditures associated with construction and maintenance of delivery infrastructure, water treatment, as well as other costs. Furthermore, the lack of competition and the application of an escalating price schedule with differential rates across various user groups makes the identification of a single price for water quite challenging.

While a monetary estimate of surface and ground water provision by the Sheep River natural asset was not assigned, the importance of these services should not be understated. Approximately 9,815 households (Statistics Canada 2016) as well as over 4,000 businesses (Statistics Canada 2019) in Okotoks currently rely on potable water provision from the Sheep River. The Town's current license capacity is estimated to provide water provision for another nine years (Town of Okotoks 2020), after which a secondary source will need to be identified.

4.3.10. Air Quality Regulation

Vegetative land covers in the Town including treed, grassland, shrubby, marsh, and sparsely vegetated land covers, provide citizens with reduced instances of harmful particulate pollutants such as dust, ash, pollen, and smoke (FAO 2020). Trees are particularly important in the regulation of air quality, effectively filtering air pollutants like ozone (O_3), particulate matter less than 10 micrometres in size (PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). The air quality regulation services provided by the Town's natural and semi-natural vegetative assets benefit end-users by improving air quality and reducing the instance of respiratory illness; however, air quality improvement from tree stands in urban settings are typically very low (less than 1% air quality improvement) as compared to large tracts of contiguous tree cover found in forests (Nowak et al. 2007). As such, air quality regulation was identified as an ecosystem service provided by natural and semi-natural assets in the Town, but we do not provide a monetary estimate, as it is unlikely to have a material effect on the total value of services in the Town.

4.3.11. Harvestable Volumes of Wild Plants or Animals

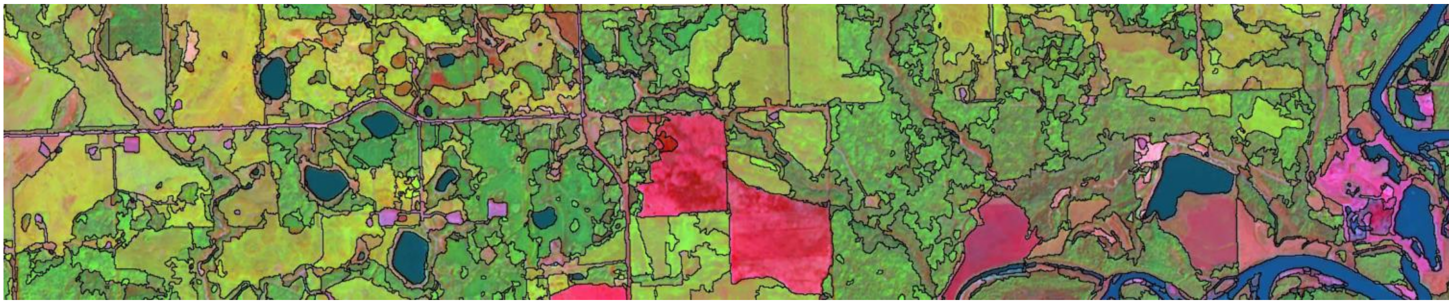
Natural and semi-natural assets in the Town such as vegetative assets (low vegetation, woodlands) as well as the Sheep River offer the provisioning service of harvestable plants or animals like berries and fish; however, this service is used primarily as a hobby for most townspeople. For example, according to the 2017 Alberta Recreation Survey (Alberta Culture and Tourism 2017), approximately 26% of households in the province undertake fishing as a recreational activity. The proportion of those that fish for consumptive purposes would be lower, resulting in a relatively low economic value. Additionally, the study does not contemplate/include the harvesting of berries or plants for traditional purposes by Indigenous peoples. As such, a monetary estimate for this service is not provided.

4.3.12. Other Cultural Services

Natural and semi-natural assets are valued for the cultural services they provide based on asset characteristics that:

- enable nature-related education and training;
- are resonant in terms of culture or heritage;
- have symbolic meaning (e.g., using nature as a local emblem);
- have an existence value; and
- have an option or bequest value (i.e., conserving nature for future generations to enjoy/use).

These passive use or non-use values are not observable and cannot be estimated from behavioural data. Instead, stated preference techniques such as surveys or carefully designed experiments are typically required to elicit value estimates. Data regarding passive and non-use values for environmental assets in an urban setting are limited and acquiring primary stated preference data was out of scope for this study; therefore, the Study Team has not provided a monetary estimate for other cultural services provided by the Town's natural and semi-natural assets.



5.0 Discussion

5.1. Impact & Significance of the Study

This study represents the first example of a natural asset mapping and ecosystem service valuation exercise that has been undertaken by a municipality in Alberta. While there are other examples of municipal natural asset studies that have been done elsewhere in Canada (see: https://mnai.ca/pilot-communities), these studies have typically focused on a single natural asset. In contrast, this study provides a complete list of the natural and semi-natural assets that currently exist within Okotoks, and for each of the assets, identifies the primary ecosystem service benefits and estimated values that flow to end-users within the Town.

This comprehensive assessment gives the Town of Okotoks valuable information about the number, extent, condition, and estimated value of their natural and semi-natural assets. In turn, this information allows the Town to consider how land use and management decisions may positively or negatively impact these assets. In particular, this inventory allows the Town to be more proactive about identifying high-value natural and semi-natural assets, and to formulate management and/or policy responses that result in the securement and maintenance of high value assets. The existence of the inventory also allows the Town to monitor and assess management and policy outcomes over time by tracking the loss of natural and semi-natural asset area, and also allows managers to identify assets that have already been secured, but would benefit from targeted management or habitat restoration to improve condition.

5.2. Gap Analysis – Securement & Management of Assets

While there are a number of existing tools available to the Town for the retention and management of natural and semi-natural assets, there are a number of gaps in the current approach that should be addressed in order to achieve the environmental outcomes specified in existing municipal policies and plans. These gaps are identified and discussed in more detail below.

5.2.1. Conservation Reserve Policy & Natural Asset Acquisition Fund

Under Section 664.2(1) of the *Municipal Government Act*, municipalities may designate an area as a Conservation Reserve if the area contains significant environmental features that are not required to be provided as Environmental Reserve. Under the Act, the purpose of a Conservation Reserve is to protect and conserve significant environmental features in a manner that is consistent with other statutory planning documents. In designating a Conservation Reserve, the municipality must compensate the landowner in an amount that is equal to the market value at the time of the subdivision approval application.

Given the limited set of tools available to municipalities to secure natural assets during subdivision, the purchase of land directly or acquisition through a Conservation Reserve may be the most effective mechanism for natural asset conservation; however, most municipalities lack the financial resources to purchase natural assets directly. Thus, several municipalities in Alberta have created a reserve fund for the purpose of acquiring natural areas for conservation. For example, the City of Edmonton established a Natural Areas Reserve Fund in 1999, and the fund is accompanied by a Natural Areas Acquisition strategy, which outlines strategic goals and criteria for the acquisition of natural areas using the conservation funds. Establishing a conservation fund for acquiring lands in the Town of Okotoks would similarly allow the Town to purchase high priority natural and semi-natural assets for conservation.

5.2.2. Natural Asset Assessment & Retention Guidelines

At present, the Town does not have a standard set of guidelines for the assessment of natural assets as part of the development of an ASP or Outline Plan, but rather, follows the City of Calgary guidelines for Biophysical Overviews and Biophysical Impact Assessments. Creating guidelines specifically for the Town of Okotoks that outline how natural area assessments should be conducted, as well as guidelines for how natural assets should be prioritized for retention during the planning process, will create a standard of practice that should result in more consistency with respect to how natural assets are assessed and managed as part of the planning process. Creating standards for assessment will also allow the Town's administration personnel to more meaningfully evaluate development proposals as they relate to natural asset retention and management.

5.2.3. Natural Asset & Wildlife Management Plans

When considered as part of a larger regional network, municipal natural assets are critical habitats for wildlife that support ecological processes, function, and biodiversity. These areas also play an important role in the lives of citizens by providing access to nature, which improves mental and physical health, as well as delivering other ecosystem services that improve the quality of life of residents. Consequently, municipal natural areas must be managed in a way that balances the needs of wildlife with appropriate land and recreational use. While the Town has existing plans that provide guidance for the management of urban parks (e.g., Sheep River Valley Management Plan and the Urban Forest Management Plan), the development of asset specific management plans at the Outline Plan stage may be important to provide guidance for management objectives and strategies that should be implemented by operational staff to ensure consistent and effective management of retained assets and the wildlife that these areas support. Further, consideration should be given to the development of a Town-wide natural area and/or wildlife management plan that outlines objectives and strategies for the management of vegetation, wildlife and their habitats, hydrology and aquatic ecosystems, human use and safety, and public education and engagement for all lands within the Town.

5.2.4. Restoration & Monitoring Plans

In some cases, natural or semi-natural assets that are retained by the Town may require active restoration to improve their ecological condition. If required, restoration activities should be site-specific, and will likely be tied to other vegetation and weed management activities. Restoration may also include activities such as improvements or enhancements to riparian habitats around wetlands and along streams, or active forest management activities (e.g., under planting of young saplings) in tree stands to ensure their sustainability. Ideally, the condition of natural and semi-natural assets retained within the Town should be monitored, evaluated, and reported on a regular basis to maintain their ecological function and the resulting supply of ecosystem services.

5.2.5. Environmental Reserve Dedication & Development Setback Policy & Guidelines

Under the direction set out by the MGA and the municipal Land Use Policies, many municipalities throughout the province have taken the initiative to enact policies that provide guidance on the dedication of lands that meet the definition of Environmental Reserve. Further, lands that qualify as ER are either steep slopes or are water bodies such as wetlands, streams, and lakes that receive surface runoff and groundwater inputs from adjacent lands. As a result, ensuring that appropriate development setbacks are applied to ER lands in urban environments is essential to maintaining ecological function and public safety, including appropriate buffers to protect property and infrastructure from flood risk.

To this end, the Town of Okotoks has provided policy guidance for dedicating ER and determining setbacks from ER lands in their draft Municipal Development Plan (Town of Okotoks n.d.). While the guidance in the draft MDP is relatively clear regarding the desire to utilize Environmental Reserve during subdivision, there may be some benefit to developing a stand-alone policy that provides more clarity around what qualifies as ER in the Town. Specifically, this policy could provide additional guidance on how to identify "slopes" (e.g., slopes above a particular percent gradient) and water bodies that would be dedicated as ER. This type of clarity would be beneficial, as over 16% of the natural assets identified in the Town are wetlands or watercourse assets, and a significant portion of other natural and semi-natural assets are located on slope with a gradient >15%.

5.2.6. Municipal Wetland Policy

The provincial wetland policy and its supporting directives give clear direction to municipalities that local and regional wetland management priorities will be considered in the review of *Water Act* applications that are related to wetland impacts. Thus, the Town could significantly advance wetland conservation within Okotoks through the adoption of a municipal Wetland Policy. The policy could use this natural and semi-natural asset inventory to identify and map key wetlands that should be avoided and retained due to their ecological and ecosystem service value. Such a policy would be critical in communicating priorities for wetland retention and protection in the Town, which would be an important engagement and communication tool for dealing with land developers, residents, and the provincial government. If this policy was adopted by Council, the policy would hold considerable weight in environmental decision-making within the region and all *Water Act* approvals would have to be consistent with the objectives outlined in the policy. The policy could also outline a process framework for undertaking wetland assessment and planning in the Town.

5.2.7. Municipal Tree Protection Policy or Bylaw

As has been illustrated in this study, urban trees in the Town of Okotoks offer important ecosystem services such as urban heat regulation, wildlife habitat, soil erosion protection, air purification, as well as a range of cultural services. Consequently, protecting trees within the Town, whether they are located along street boulevards or within urban parks, is essential for maintaining the flow and value of these ecosystem services. Adopting a tree protection policy or bylaw would provide important direction for the management of these natural assets, including enforcement to prevent cutting, removal, moving, pruning, or damage to trees located on Town property. The policy or bylaw could also include requirements for tree protection plans in instances where construction activities have the potential to damage a tree located on lands owned or managed by the Town.

5.3. Gap Analysis – Information & Data

5.3.1. Regional & Intermunicipal Assets

While the scope of this study was limited to the current boundaries of the Town of Okotoks, many of the natural and semi-natural assets identified by the inventory either physically extend outside the Town, or they are significant components of a larger regional network of natural assets. For example, the Sheep River is an important local and regional natural asset that provides significant ecosystem services, such as water flow regulation, water quality control, water provision, and habitat provision not only to residents who live within Okotoks, but to communities located both upstream and downstream of the Town. Further, assets such as the large wetland located in the West Okotoks ASP (asset #108) provide habitat for local and regional populations of wildlife, including both resident species and migratory waterfowl and songbirds. Consequently, the Town of Okotoks has an obligation to carefully manage regionally significant assets within their jurisdictional boundaries, as do neighbouring municipalities with shared assets. Thus, regional and intermunicipal cooperation is essential in the identification and management of natural and semi-natural assets that provide ecosystem services at a larger scale. Given this, regional planning and intermunicipal development plans are important tools for advancing the management of shared natural and semi-natural assets.

The Town of Okotoks currently has an Intermunicipal Development Plan with Foothills County (Town of Okotoks Bylaw 12-16); however, this plan does not specifically address the management of shared environmental resources. Consequently, the Town should consider working in collaboration with Foothills County to identify and manage key natural and semi-natural assets that extend beyond corporate boundaries. Further, the Calgary Metropolitan Region Board (CMRB) provides a forum for discussing and identifying opportunities to collaboratively manage environmental resources at a regional scale, and working through the CMRB may be an effective mechanism for identifying regionally important assets. In particular, the CMRB has acknowledged the critical importance of maintaining ecosystem function and associated services through the identification of Environmentally Sensitive Areas (ESAs). This natural asset inventory and ecosystem service assessment can serve as both an example and a platform for the identification and management of regional ESAs.

5.3.2. Willingness to Pay for Ecosystem Service in the Town

As mentioned earlier, monetary values for several ecosystem services were not calculated in this study due to a lack of reliable data. Furthermore, several estimates provided were based on valuation techniques that do not represent willingness to pay values. To this end, the Town could benefit from undertaking additional revealed preference or stated preference work to acquire primary willingness to pay 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 Town 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. In an urban context, these studies have been used to estimate the value of assets such as green spaces that offer recreational and aesthetic benefits to end-users (e.g., Kong et al. 2007), urban tree cover (e.g., Sander et al. 2010), and urban wetlands (Mahan et al. 2000). It is likely that the property assessment data used by the Town for taxation purposes could form the basis of this analysis and reduce the level of effort required for data collection.

Stated preference work is also an option for the Town to acquire robust primary natural asset valuation data. For example, the wetland valuation estimate provided in this work was based on benefit transfer data from a stated preference study in Manitoba (Pattison et al. 2011). Stakeholder values for wetlands in Manitoba were elicited through a well-designed survey whereby respondents were presented with various hypothetical programs that would provide a range of wetland retention or restoration. Under these scenarios, respondents were provided with a detailed description of the bundle of ecosystem services offered by the wetland assets (i.e., water quality control, water flow regulation, soil erosion prevention, habitat for wildlife, and climate regulation) as well as how these services would change under different programs. Respondents were then asked how much they would be willingness to pay to support each program. The resulting data allowed the authors to estimate average willingness to pay values for various degrees of wetland retention and restoration.

While the theory behind stated preference surveys and willingness to pay 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 various 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 Town should include expert survey design and implementation.

5.4. Study Limitations

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

- Natural and semi-natural assets were identified and mapped using air photographs, the most recent of which was 2018. As a result, the location, size, and boundaries of the natural and semi-natural assets included in the inventory may not accurately reflect the status and/or presence of these features at present day. Further, the natural and semi-natural assets mapped in this assessment were not 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 and semi-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); therefore, conditions scores are generally reflective of impacts that may be influencing the ecological function of an asset, but should not be considered to be a definitive assessment on the current ecological state of these assets.
- Estimates of ecosystem service values are based on an assumption that the underlying function of the natural or semi-natural asset has not been substantially impaired, and that 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 and semi-natural assets provide a wide range of ecosystem services, and not all services and their associated values could be evaluated in this study.
- The Town of Okotoks currently has a process for assessing the replacement value of Town-owned trees. This tree appraisal process assigns a dollar value to a tree based on the tree diameter, condition (i.e., health, structure, form), functional limitations (e.g., how species and location might affect condition), and external limitations (e.g., how pests and/or competing infrastructure affect condition). While the Town uses this tree appraisal to evaluate replacement costs, these costs were not integrated into the economic values that were calculated for this study.
- Collecting primary data for ecosystem service valuation was outside the scope of this study. The Study Team relied on estimates from other studies that may not be entirely representative of the ecosystem service values in the Town. Furthermore, like market goods, the values of non-market ecosystem services are not necessarily static in nature. For example, as a natural or semi-natural asset becomes scarcer, the value of the asset will likely increase. Consider a town that has only

one outdoor park area; the value of this park would be much higher for a set of end-users than if it were one of several available parks. Additionally, willingness to pay 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). Because primary data were not collected in this study, the estimates provided are not sensitive to these nuances, and as such, 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.

6.0 Conclusion

The primary objective of this project was to create an inventory of natural and semi-natural assets in the Town of Okotoks, as well as estimate the monetary value of a number of priority ecosystem services that flow from these assets This was done to allow the Town to more fully account for the value of natural and semi-natural assets, and to provide a foundation for mapping and tracking the condition and status of these assets over time. This information will allow the Town to better understand the economic and environmental trade-offs of land development in Okotoks, leading to more informed decision making.

At present, there are 302 natural and semi-natural assets that cover approximately 32% of the Town, including both aquatic (lake, watercourse, and wetland) and terrestrial (woodland, low vegetation, pasture, hayland) assets. Some of the assets are considered important local and regional wildlife corridors (e.g., Sheep River), while others are large habitat patches that likely serve as core wildlife habitat at the local and regional scale. Together, this portfolio of natural and semi-natural assets represents a range of habitat types that support a diversity of wildlife, and these areas are foundational to the development and conservation of a local and regional network of natural areas that provide important ecosystem services to Town residents.

Within the scope of this study, 13 priority ecosystem services were identified, with monetary value estimates being derived for seven of the services, which totalled over $84 million. Notably, a significant proportion of the natural and semi-natural assets within the Town are located on lands that were recently annexed from Foothills County. Thus, there is significant opportunity to consider environmental values along with the social, economic, cultural considerations as planning for development of these lands proceed.

This study provides the Town with defensible information that can be integrated into future land-use planning decisions; however, the Town should also consider developing new environmental policies and tools that can further support land use planning and decision making. These new policies and tools will ensure that important environmental assets in the Town are conserved and managed for the benefit and enjoyment of citizens over the long term.

6.1. Closure

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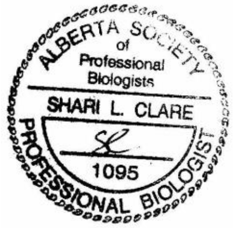

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7.0 Literature Cited

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.

Alberta Culture and Tourism. 2017. 2017 Alberta Recreation Survey.

Alberta Government. 2017. South Saskatchewan Regional Plan 2014-2024. Amended February 2017. Available at: https://open.alberta.ca/dataset/460ac866-4416-4d77-a25a-a02fab85a6ec/resource/8261ce03-aa0f-4621-8e2d-c610a72ac37c/download/south-saskatchewan-regional-plan-2014-2024-february-2017.pdf

Bailey, A.W., D. McCartney, and M.P.Schellenberg. n.d. Management of Canadian Prairie Rangeland. Agriculture and Agri-Food Canada Publication. Available at: http://www.saskforage.ca/images/pdfs/Publications/Management%20of%20Canadian%20Prairie%20Rangeland.pdf

Bengtson, H. 2010. Rational Method Runoff Coefficient Tables for Storm Water Runoff Calculation. Bright hub engineering. Available at: https://www.brighthubengineering.com/hydraulics-civil-engineering/93173-runoff-coefficients-for-use-in-rational-method-calculations/

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

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

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

Costanza R et al. 1997. The value of the world’s ecosystem services and natural capital. Nature **387**:253–260.

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

Crossman ND et al. 2013. A blueprint for mapping and modelling ecosystem services. Ecosystem Services **4**:4–14.

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

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.

Environment and Climate Change Canada. 2016. Technical Update to Environment and Climate Change Canada’s Social Cost of Greenhouse Gas Estimates.

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, Waters R. 2013. Ecosystem Service Assessment: How to Do One in Practice. Version 1, October 13. Institution of Environmental Sciences, London. Available from https://www.the-ies.org/sites/default/files/reports/ecosystem_services.pdf (accessed January 3, 2020).

Food and Agriculture Organization (FAO) of the United Nations. 2020. Ecosystem Services & Biodiversity – Regulating Services. Available at: http://www.fao.org/ecosystem-services-biodiversity/background/regulating-services/en/

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.

Haines-Young R, Potschin M. 2017. Common International Classification of Ecosystem Services (CICES) V5.1 Guidance on the Application of the Revised Structure. Page 31. Available from http://www.cices.eu/.

Hall, B.D., R.H. Hesslein, C.A. Emmerton, S.N. Higgins, P. Ramlal, and M.J. Paterson. Multidecadal carbon sequestration in a headwater boreal lake. Limnology and Oceanography **64**(S1):S150-S165.

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

Hotte, N., L. Nesbitt, S. Barron, J. Cowan, and Z.C. Cheng. 2015. The Social and Economic Values of Canada’s Urban Forests: A National Synthesis. Canadian Forest Service.

Kasparinskis R, Ruskule A, Vinogradovs I, Villoslada Pecina M. 2018. The guidebook on ecosystem service framework in integrated planning. Page 63. University of Latvia. Available from https://vivagrass.eu/wp-content/uploads/2018/10/guidebook_ecosystem_services_vivagrass-compressed.pdf (accessed November 22, 2019).

Kong, F., H. Yin, and N. Nakagoshi. 2007. Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China. Landscape and Urban Planning **79:**240-252.

Kulshreshtha, S.N. and J.A. Gillies. 1993. The Economic Value of the South Saskatchewan River to the City of Saskatoon: (II) Estimation of Recreational Use Value. Canadian Water Resources Journal **18**(4):369-383.

Maes J et al. 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosystem Services **17**:14–23.
Maes J et al. 2018. Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition in EU. Page 75. European Union, Luxembourg. Available from https://linkinghub.elsevier.com/retrieve/pii/S2212041615300504 (accessed January 2, 2020).
Mahan, B.L., S. Polasky, and R.M. Adams. 2000. Valuing Urban Wetlands: A Property Price Approach. Land Economics **76**(1):100-113.
McInnes RJ, Everard M. 2017. Rapid Assessment of Wetland Ecosystem Services (RAWES): An example from Colombo, Sri Lanka. Ecosystem Services **25**:89–105.
McPherson, G., J.R. Simpson, P.J. Peper, S.E. Maco, and Q. Xiao. 2005. Municipal Forest Benefits and Costs in Five US Cities. Journal of Forestry **103**(8):411-416.
Millennium Ecosystem Assessment, editor. 2003. Ecosystems and human well-being: a framework for assessment. Island Press, Washington, DC.
Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: synthesis. Island Press, Washington, DC.
MNAI (Municipal Natural Assets Initiative). 2019a. Developing Natural Asset Inventories: MNAI Technical Guidance. Pp 31. Version 1.0, November 2019.
MNAI (Municipal Natural Assets Initiative). 2019b. Tool Compendium: Developing Natural Asset Inventories. Pp 43. November 2019.
Nowak, D.J. and D.E. Crane. 2002. Carbon storage and sequestration by urban trees in the USA. Environmental Pollution **116**:381-389.
Nowak, D.J. and J.F. Dwyer. 2010. Understanding the Benefits and Costs of Urban Forest Ecosystems. Chapter
Pattison, J., P. Boxall, and W. Adamowicz. 2011. The Economic Benefits of Wetland Retention and Restoration in Manitoba. Canadian Journal of Agricultural Economics **59**:223-244.
Potschin M, Haines-Young R. 2016. Defining and Measuring Ecosystem Services. Pages 25–44 in M. Potschin, R. Haines-Young, R. Fish, and R. K. Turner, editors. Routledge Handbook of Ecosystem Services, 1st edition. Routledge, New York, NY : Routledge, 2016. Available from https://www.taylorfrancis.com/books/9781317687047/chapters/10.4324/9781315775302-4 (accessed November 22, 2019).
Potschin M, Haines-Young R. 2017. From Nature to Society. Pages 39–45 in B. Burkhard and J. Maes, editors. Mapping Ecosystem Services. Pensoft Publishers, Sofia.
Rendon P, Erhard M, Maes J, Burkhard B. 2019. Analysis of trends in mapping and assessment of ecosystem condition in Europe. Ecosystems and People **15**:156–172.
Rogers, C.D.W., A.J.E. Gallant, and N.J. Tapper. 2018. Is the urban heat island exacerbated during heatwaves in southern Australian cities? Theoretical and Applied Climatology **137**:441-457.
Sander, H., S. Polasky, and R.G. Haight. 2010. The value of urban tree cover: A hedonic property price model ins Ramsey and Dakota Counties, Minnesota, USA. Ecological Economics **69:**1646-1656.
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 & Buildings **207**: 109482. DOI: 10.1016/j.enbuild.2019.109482.
Statistics Canada. 2016. Census of the Population.
Statistics Canada. 2019. Requested Business Count Data.
Statistics Canada. 2020. Table 19-10-0005-01 Consumer Price Index, annual average, not seasonally adjusted.
Summers JK, Smith LM, Case JL, Linthurst RA. 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., R. Water, D. Marsh, C. Hudson, and J. Lusardi. 2019. Accounting for National Nature Reserves: A Natural Capital Account of the National Nature Reserves managed by Natural England. Natural England Research Report: NERR078.
Tanguay, M., W.L. 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.
TEEB. 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. UNEP, Geneva.
Town of Okotoks. n.d. Uniquely Okotoks Municipal Development Plan. Available at: https://www.okotoks.ca/sites/default/files/pdfs/publications/Okotoks%20MDP_DRAFT%202020-05-08%20v1.pdf.
Town of Okotoks. 2020. Personal communication with Rob Dickinson, April 17, 2020.
Treasury Board of Canada. 2007. Canadian Cost-Benefit Analysis Guide.

Troy, A. and K. Bagstad. 2009. Estimating Ecosystem Services in Southern Ontario. Ontario Ministry of Natural Resources Report.

US EPA. 2015. National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application. Page 188. EPA-800-R-15-002. United States Environmental Protection Agency, Washington, DC. Available from https://www.epa.gov/sites/production/files/2015-12/documents/110915_nescs_final_report_-_compliant_1.pdf (accessed January 2, 2020).

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 from http://www.deslibris.ca/ID/10088460 (accessed November 22, 2019).

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

von Haaren C, Lovett AA, Albert C. 2019. Landscape planning with ecosystem services: theories and methods for application in Europe.

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.

Wilson, S.J. 2014. The Peace Dividend: Assessing the Economic Value of Ecosystems in B.C.'s Peace River Watershed. David Suzuki Foundation Report.

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