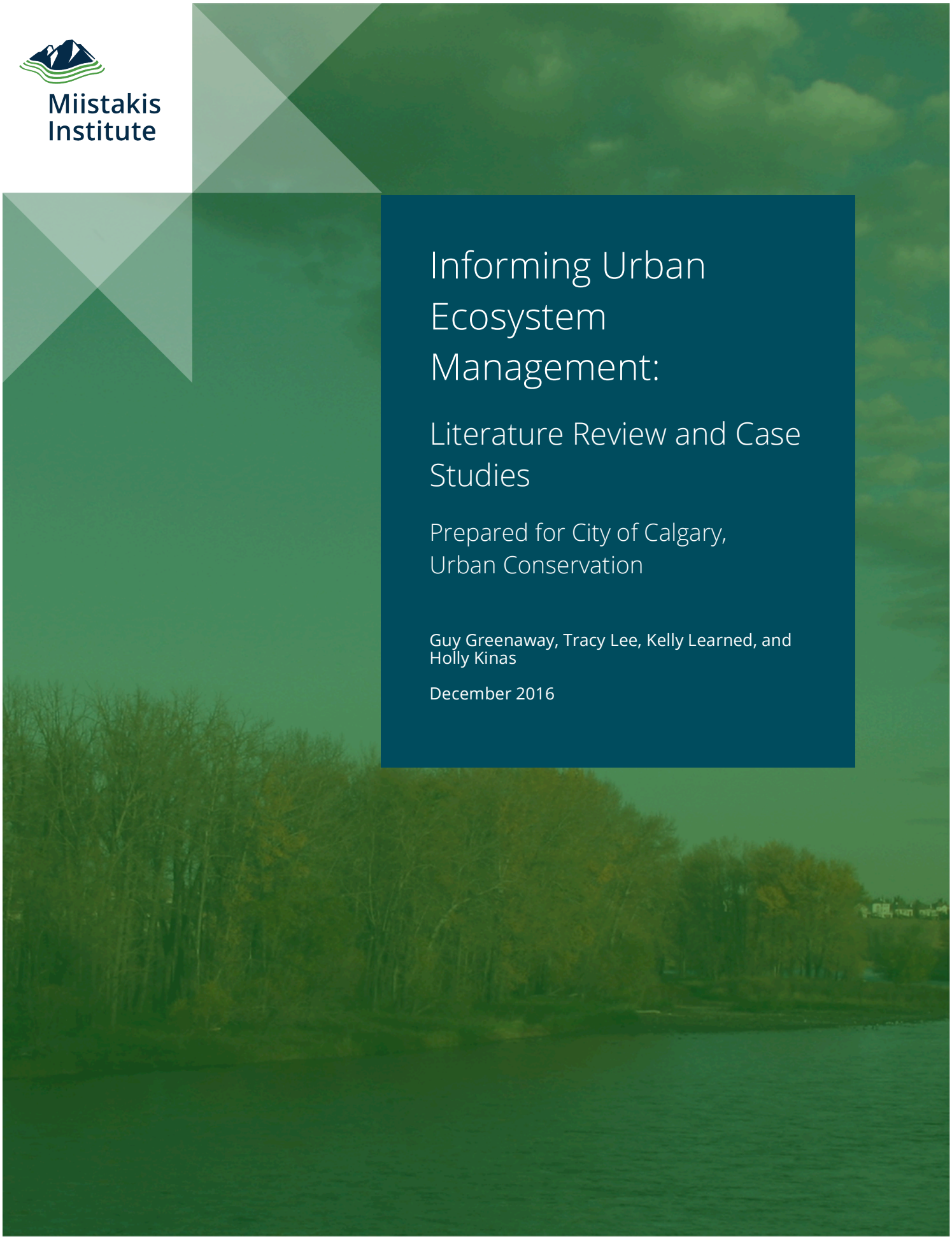

Miistakis Institute

Informing Urban Ecosystem Management:

Literature Review and Case Studies

Prepared for City of Calgary, Urban Conservation

Guy Greenaway, Tracy Lee, Kelly Learned, and Holly Kinas

December 2016

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Executive Summary

The goal of this research is to support the revision of the City of Calgary's *Natural Areas Management Plan* (NAMP) with findings from relevant literature and case studies, based on the evolving nature of urban ecosystem management. Because the mandate of the Urban Conservation portfolio is city-wide, this research is also intended to support the development of an urban ecosystem management approach for the City of Calgary.

The authors identified two key goals and associated research objectives:

1. Ensuring a scientific rationale exists to support an 'urban ecosystem management' approach for the City of Calgary; and
2. Ensuring a basis exists for translating ecological management principles into asset management approaches.

For both, the research approach included reviews of peer-reviewed and grey literature, relevant case studies, analogous jurisdictions, and relevant organizations and resources. There was no intent at this stage to deeply analyze the research nor provide management recommendations.

The review of urban ecosystem management found a robust and multi-disciplinary field, but one that is still evolving, with significant variation in underlying concepts, and limited implementation experience. The identified implementation frameworks centred around novel ecosystems, ecosystem services, natural capital, ecosystem-based adaptation and resilience, and ecological network planning. Several case studies were reviewed, with key ones being the City of Richmond, BC, the City of Kitchener, ON, and the City of Birmingham, UK.

Similarly, the review of ecological asset management found an evolving field, with the concept of *ecological assets* subject to varying and evolving definitions, with Europe being the most advanced region. The concept of *asset management* is evolving from a focus on infrastructure asset management into a more expansive view of assets, and a more integrated approach to asset management. Municipalities are adopting this change, which is creating opportunities for the inclusion of *ecological* asset management into existing frameworks.

Ecological asset management findings were reviewed against the implementation frameworks identified in the urban ecosystem management research, with natural capital and ecosystem services arising as the most commonly used. In Canada, both

asset management associations and municipal associations were found to be exploring ecological asset management in an urban context. Key case studies included the Town of Gibsons, BC and the City of Red Deer, AB.

These and further preliminary conclusions were identified and arranged by concepts, practices, and opportunities. Information gaps were identified (areas that could have been within the scope of this work), and included invasive species, pests, blue spaces, and ecosystem service valuation. Potential further research was identified including ecological asset costing approaches used in Europe, Urban Green Infrastructure (UGI), ecosystem service valuation, the concept of tolerance in natural area management, and the impacts of Municipal Government Act amendments, as well as several cases that bear further investigation.

Next steps could include an analysis of this research, particularly with reference to how it could inform open space typologies, managed/natural systems, the City of Calgary's Biodiversity Policy, and City of Calgary asset management. That could be followed by development of specific recommendations for the NAMP, urban ecosystem management, and ecological asset management in the City of Calgary.

Contents

Acronyms

The following acronyms are used throughout this report:

AIM	Atlantic Infrastructure Management Network
AUMA	Alberta Urban Municipalities Association
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
EbA	Ecosystem-based Adaptation
ES	Ecosystem Services
EU	European Union
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPMP	Integrated Pest Management Plan
MEA	Millennium Ecosystem Assessment
NAMP	Natural Areas Management Plan
NEP	Natural Environment Park
NRSI	National Roundtable on Sustainable Infrastructure
OECD	Organization for Economic Co-operation and Development
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystem and Biodiversity
TEV	Total Economic Value
UGI	Urban Green Infrastructure

Introduction

Revising a plan that is intended to maintain the ecological value of a large city's natural areas, and doing so in such a way as to provide leadership for viewing the entire city as an ecological system, but then tying it all into the existing municipal corporate culture and structure … is not a task for the faint of heart.

The goal of this report, and the research it summarizes, is to support that task – the revision of the City of Calgary's 1994 *Natural Areas Management Plan* – with findings from relevant literature and case studies.

Though we scoped the research to two topics, they are very large and the literature extensive. We are by no means suggesting this literature review was exhaustive. As well, the topic areas are heavily laden with emerging and evolving concepts and terminology that show, as yet, little consensus on even the high-level terms.

Instead, what we hoped to do was review enough of the literature and cases to identify trends and key or emerging themes. The task before the City of Calgary, Urban Conservation portfolio is not to become academic experts, but rather to have a sense as to which approaches are well-researched, which have significant gaps, and which might hold promise as being supportive or prototypical for the development of a unique City of Calgary approach to urban ecosystem management.

Roles of this research

Supporting the revision of the *Natural Areas Management Plan*

The City of Calgary's Urban Conservation portfolio has responsibility for the City's 4900 ha of natural areas, and is the designated asset manager of the City's Natural Environment Parks. This portfolio derives policy direction from the *Natural Areas Management Plan* (NAMP). The NAMP is being revised (it was published in 1994 and not since updated).

The first role of this research is therefore to provide literature and case reviews that can support staff with the revision of the NAMP. This information is based on the

evolving theory and practice of urban natural area management, and tied to the evolving mandate of the Urban Conservation unit.

Although not a focus of this research, there is recognition that 1) Urban Conservation is also revising the *Integrated Pest Management Plan* (City of Calgary, 1998), and 2) many of the tactical approaches to urban ecosystem management are the same as tactical approaches to integrated pest management. For example, the *Integrated Pest Management Plan* (IPMP):

- Uses asset management language as well, with reference to 'horticultural assets';
- Uses an 'Injury Levels' rubric that refers to the point in growth of a vegetation or pest problem where it will cause an unacceptable impact on natural and/or managed ecosystems;
- Directs that criteria for selecting treatment tactics and developing pest management strategies include those that best preserves natural or managed ecosystems; and
- Prescribes that Vegetation Control Treatment Strategies "preserve the integrity of the ecosystem"

For that reason, a research emphasis was placed on integrated approaches that would facilitate linkages of these types with the IPMP revision efforts.

As well as the two plans up for revision, a key starting point to this research was the *What We Heard* document (an internal City of Calgary review of those plans). The authors reviewed this report and identified key themes which could influence the literature and case review (these are included in *Appendix 1*: *Key Themes from the 'What We Heard' Document*).

Informing the implementation of an urban ecosystem management approach

While Urban Conservation has direct responsibility for the City's natural areas, it also has a city-wide scope that includes management of biodiversity, provides an internal consultation function for other units, develops external partnerships in order to manage and protect City assets for biodiversity, and has a strategic interest in non-City-owned natural areas.

In short, they are responsible for urban ecosystem management in the City of Calgary.

Natural areas (and by extension the NAMP) provide the pillars of the urban ecosystem, so a revision of that *Natural Areas Management Plan* must be conscious of the role it plays in this broader mandate.

The second role of this research is therefore to provide literature and case reviews that can support staff with the development of an urban ecosystem management approach for the City of Calgary. This information is based on the evolving theory and practice of urban ecosystem management and ecological asset management, and again is tied to the evolving mandate of Urban Conservation. The intent was to identify resources that are informative to applying the ecosystem approach at the urban ecosystem, park, and asset management levels.

It is important to note the distinction here between managing ecological assets, and incorporating ecological considerations into the management of non-ecological assets. Though they are connected, and can both be part of an ecosystem approach, they imply very different things at an operational level. As Urban Conservation is the asset manager for the City of Calgary's Natural Environment Parks (NEPs), the focus of this research is on informing how such ecological assets have been considered in existing asset management frameworks. However, the case examples also show how some municipalities have sought to use the integrated asset management approach to catalyze this ecological consideration of all assets.

Setting the stage for analysis and recommendations

Perhaps the hardest task for the authors was stopping at the level of literature review, and not delving too deeply into an analysis of the gathered information, nor pre-judging information filtration around emerging recommendations[1]. There was full recognition that these two steps would need to follow immediately to animate the results of this research.

Thus, the third role of this research was to put the City of Calgary, Urban Conservation in the best position possible to analyze this review to distill the data, and to inform the development of specific recommendations on both the NAMP revision and applying an urban ecosystem approach (for more details on the potential form of those two tasks, see *Next Steps*, at the end of this report).

[1] It is important to note that some interim assumptions (akin to recommendations) had to made in order to structure the literature and case review. For example, the choice of frameworks to review against represents the authors' suggestion that these are the recommended basis for such an

The need for this research

The City of Calgary's Urban Conservation business unit has responsibility for the management of the natural areas in the city, but also for maintaining the ecological health of the system as a whole. This makes them central to promoting an urban ecosystem management approach for the City of Calgary.

Cities have not traditionally been thought of as urban ecosystems, yet they are very much a community of interacting organisms and their physical environment. The more recent shift to 'urban ecosystem management', and the best practices that have evolved with that shift, have outstripped the way municipalities traditionally created management plans for natural features.

At the same time, there has been a shift in the way ecological management has been operationalized. Municipal corporations have traditionally viewed 'assets' as physical infrastructure with basic financial characteristics (life cycles, depreciation, replacement costs, etc.). However, ecological economics has blended accounting and ecology to identify 'ecological assets' – durable non-financial assets that are used to produce future benefits for citizens, but which are naturally created and/or sustained. Ecological features must now be considered in an 'asset-management' context in order to fit with how municipal corporations set priorities and allocate resources.

Thus, the revision of the City of Calgary's 1994 *Natural Area Management Plan* creates a need to understand: 1) how to incorporate ecological criteria into decision-making both broadly for the system and specifically for the natural areas that anchor the system; and 2) how to frame management of ecological features in a way that allows for their consideration in an 'asset-management' operational setting.

Objectives

Although the *urban ecosystem management* paradigm is relatively new, the City of Calgary is not the first to explore it. In both the academic literature and applied practice, there exists principles, guidelines, assessments, case studies and other information which can be drawn on to inform an ecosystem-management-based consideration of the assets for which Urban Conservation has responsibility.

Based on this, the authors identified two key goals and associated research objectives for this work:

1. Ensuring a scientific rationale exists to support an 'urban ecosystem management' approach for the City of Calgary. The knowledge areas to be investigated here would be:
    a. Integrating ecological criteria into management decisions for Parks-managed assets;
    b. Informing Council policy regarding the management of the urban ecosystem; and
    c. Understanding best practices for urban ecosystem management.
2. Ensuring a basis exists for translating ecological management principles into asset management approaches. The knowledge areas to be investigated here would be:
    a. Delineating various ecological asset types and associated management approaches;
    b. Providing a corporate-wide basis for considering ecological features as assets; and
    c. Understanding best practices for ecological asset management.

Methods

Research approach

The literature and case review tasks for this project were based on the two objectives listed above. For both background research tasks, the approach included four prongs: 1) review of peer-reviewed and grey literature, 2) review of relevant case studies, 3) review of analogous jurisdictions, and 4) review of urban ecosystem management/asset management organizations and resources.

More specifically, this included:

- Review of the City of Calgary's *Natural Area Management Plan, Integrated Pest Management Plan*, and internal *What We Heard* document
- Review of the ancillary City of Calgary plans, as identified and provided by City of Calgary, Urban Conservation staff
- Review of peer-reviewed and grey literature which propose, illustrate or review urban ecosystem management and ecological asset management practices and approaches;

- Identification and review of jurisdictions with analogous urban ecosystem management issues;
- Identification and review of instructive case studies from which the City of Calgary could learn;
- Identification of organizations/resources that provide principles, guidelines, and/or management approaches for addressing urban ecosystem management
- Collation of citations into a references database (into a Mendeley[2] database)

A primary investigator / author was identified for each objective, and a research assistant engaged to support both. The primary authors conducted initial scans, then developed a draft table of contents and key search terms. An iterative process between primary authors and the research assistant allowed for emerging 'bread crumb trails' to be identified and explored to the extent that resources allowed.

Case selection rationale

A key focus of this review was analogous cases that could provide insight to the City of Calgary regarding how the surveyed concepts might be implemented. Cases were chosen based on the following criteria (*NB: Not all cases met all criteria, so this list should be considered as a 'prioritization' screen rather than an 'exclusion' screen*):

They existed (!) – Beggars can't be choosers, and as these are relatively new concepts (and even newer to the application stage), there were not a lot of cases to choose from.

Actively addressing ecosystem management – The municipality is actively addressing some aspect of or some framework for applying an ecosystem management approach.

Actively using an ecological asset approach – Similarly, the municipality is actively seeking to use the ecological asset concept to manage their natural areas, features or functions.

Exist in an urban context – The municipality has responsibility for an urban area (which StatsCan defines as a population of at least 1,000 and a density of 400 or more people per square kilometre).

Published materials available – Because we were not doing first-person research, we relied most heavily on published materials.

[2] Mendeley is a desktop and web program for managing and sharing research papers.

Proximate to Calgary – Going on the assumption that closer municipalities will have a more similar decision-making context (legislatively, culturally, ecologically) preference was given to cases that were closer to Calgary. Having said that, the paucity of examples meant this played out as (e.g.) a preference for Gibsons BC over Llubljana, Slovenia (and only a few options in between).

It is incredibly important to note that the authors were not looking for *benchmarks* nor *analogues*. Firstly, there were too few cases to suggest, statistically, we could filter to that level. Secondly, the authors contend that applying the urban ecosystem management approach represents such ecological, political, and social complexity that 'benchmarks' and 'analogues' are a bit of a Quixotic quest. As is outlined in the results, each case has used a unique *hybrid* of the available approaches, so it is likely more fruitful to break down to the component pieces, and see which building blocks would be most applicable for the City of Calgary's unique creation.

Research questions

The research questions used to guide the first objective (scientific rationale for urban ecosystem management) were:

- How have other relevant jurisdictions approached urban ecosystem management?
- What is the emerging knowledge/practice on integrating ecological criteria into decision-making (both for natural areas and generally) for municipalities?
- How are ecosystem-wide contributions of natural assets recognized and incorporated into the municipal decision-making process?

The research questions used to guide the second objective (translation of ecological management principles into asset management approaches) were:

- What methods exist for delineating and managing different ecological asset types?
- What priority-setting methods exist for ecological asset management?
- How have other jurisdictions shifted the culture of asset management to include ecological assets; and how have other jurisdictions shifted the culture of natural area managers to frame their work in an asset management context?
- How can non-City (private, regional) ecological assets be considered in an urban ecosystem management-based approach?

Report development

To facilitate report development, the Miistakis Institute provided an interim *Table of Contents* to the City of Calgary, Urban Conservation for review and comment, prior to developing a draft report. Once prepared, the draft report was provided to the Urban Conservation for internal circulation to appropriate City staff. After examining the City's review, Miistakis developed the final report based on that assessment.

Limitations of this research

As with all research, there are limitations with this report and its findings. The authors tried to identify these up front (i.e., set scope boundaries) and conducted our reviews within these limitations:

No focus on integrated pest management – As noted above, this review did not include integrated pest management in the scope of the research. However, it was also noted that several of the tactics involved in an ecosystem approach are complementary (and at times identical) to those used in integrated pest management.

Limited analysis and recommendations at this stage – In recognition that the next phases of this work for the City of Calgary, Urban Conservation are to analyze the information, and develop a recommended approach forward, the authors provide very little in the way of analysis and recommendations.

Case reviews have limited depth – Due to the constraints of time, no case study was reviewed in depth, though some clearly merit further investigation. Rather, the authors chose to highlight the relevant characteristics of several cases, with recommendations of which might prove valuable to explore further.

Limited first-person interaction – With case reviews, the focus was on reviewing published materials, with no intent to interview key participants (though that did happen incidentally in some cases).

Not an exhaustive review – It would be grandiose to suggest this report represents an exhaustive review of any of the topics identified. Instead, the authors set time-limited boundaries around each topic, and focused on surveying broadly (seeking to identify as many trails as possible, rather than travelling any to their limit).

Structure of this document

The report is organized around the two research goals and associated objectives:

1. Developing a rationale for urban ecosystem management, and
2. Integrating ecological asset management with current asset management.

For each of those sections, the primary authors have outlined their findings. Because those sections are intended to be two parts of a whole, the authors worked to identify a common structure for presenting their information. What emerged was the "frameworks" or lenses through which both *ecological asset management* and *urban ecosystem management* could be viewed with regard to both conception and implementation. The intent of this approach was to facilitate integration of these two paradigms.

For both objectives, the key findings are summarized (and integrated) in the last section, *Conclusion*. Because this is only the first step, the "conclusions" are described as preliminary, and focus only on the authors' conclusions around the literature and case reviews.

The last section, *Next Steps*, provides suggestions for how to approach the analysis of the collected information, and development of management planning recommendations.

Rationale for Urban Ecosystem Management

In this section we introduce the concept of urban ecology, and present strengths of the approach to improving biodiversity conservation and ecosystem services that support human well-being. Grand challenges to urban ecology are reviewed and ecological approaches used to apply theory to practice are introduced.

What is an Urban Ecological Approach?

Statistics Canada estimates that over 80% of Canadians now live in cities (Statistics Canada 2014). As cities continue to grow to accommodate this population pressure, urbanization will continue to degrade natural resources, and replace natural systems with buildings, roads, industrial sites and other human activities (United Nations Department of Economic and Social Affairs 2014). While urbanization puts pressure on local ecological systems, cities are also facing one of our biggest challenges as a global community – mitigating and adapting to global climate change (Yigitcanlar & Dizdaroglu 2015). As cities continue to go through these enormous ecological changes, an *urban ecosystem approach* has been heralded as a way to build sustainability, maintain biodiversity, promote ecosystem services, and build resilience to climate change, ultimately improving human well-being (McPhearson et al 2016).

Not long ago, *urban ecology* was considered more of an oxymoron than a field of study. The study of ecology in a largely built environment where human activity has significantly altered the natural systems was considered obscure (McDonald 2016). Today urban ecology research is widespread and occurring from a wide diversity of perspectives (Forman 2016). McPhearson et al (2016) note urban ecology is an evolving field resulting in multiple theoretical and conceptual frameworks and research approaches with little coordination between them. This has limited our ability to compare research learnings across cities, and blurs the lens on understanding best approaches to incorporating ecosystem approaches into city planning.

Broadly there are two philosophical underpinnings to urban ecology: ecology *in* cities and ecology *of* cities (McDonnell 2011). Ecology in cities focuses on how ecological systems are impacted by urban systems and how urbanization impacts biodiversity and ecological function, and is predominated by (but not limited to) green spaces. Ecology of cities is founded in social-ecological theory with

perspectives from complexity, systems thinking and sustainability, and encompasses the entire city. Both perspectives are important and urban ecology should be striving for a unified approach that encompasses *ecology in cities* and *ecology of cities* (McDonald 2016).

Importance of Urban Ecology

An increased understanding of the interconnectedness of social, ecological and economic systems has led to a desire to better incorporate ecosystems into the management and policies of cities (Marcotullio & Boyle 2003). Key concerns to city managers are the degradation of the natural capital and ecosystem services important to human well-being, and the long term consequences of climate change (Guerry et al 2015). Cities are important places to explore integration of ecological approaches into planning and management because they are at the forefront of the challenges facing ecosystems that support humanity, are drivers of change far greater than their physical size, are areas where disaster risk reduction is important, are areas where savings on infrastructure development is needed, and provide opportunities for the public to connect to nature and understand its benefits (United Nations Conference on Housing and Sustainable Urban Development 2015, McPhearson et al 2015). Sustainability cannot be achieved if separated from nature (Marcotullio & Boyle 2003).

To incorporate an ecosystem approach into urban structures we need to understand the connection of natural assets to human well-being, and then integrate these learnings into management and policy contexts. In addition, there are unknowns as to how ecosystems will respond to climate change impacts and the role resilience plays in helping ecosystems respond (Guerry et al 2015). Research has shown ecosystem resilience can be promoted by incorporating consideration of natural capital and ecosystem services into urban planning, design and management (McPhearson et al 2015).

McPhearson et al (2016) summarize this in their proposed goal for urban ecology:

> *"to develop scientifically rigorous understanding of urban systems at multiple scales to inform more ecologically sensitive urban planning, design, management, and governance toward cities and urbanization processes that are more sustainable, equitable, livable, and resilient to global change."*

Challenges to Urban Ecology

Pataki (2015) describes three main operational challenges for urban ecology:

- Improved science of the built environment;
- Links between urban environment and human wellbeing; and
- Ecological science links to urban planning and design.

Urban environments are often a mosaic of remnant natural areas, constructed environments, and built areas. Within a built environment many habitats are considered "*novel*," meaning they have been significantly altered from their natural state due to human activities and are emerging as new self-sustaining ecological systems where there is no past analogue (Hobbs et al 2006). Despite a well-established understanding of natural ecosystems, research on ecosystems in built environments is limited, and represents a large data gap in urban ecology (Pataki 2015). Key questions have emerged: What leads to interactions that promote biodiversity, and how do ecosystem functions interact with the built environment? Urban ecology is still in its infancy adding complications to incorporating natural capital and ecosystem services into management decision making and application.

As the focus of cities is to provide people with healthy places to live, work and play, urban ecology is most often assessed in terms of the benefits it provides people. Simplistically, ecosystem services are the benefits humans gain the from the environment, including natural assets (or natural capital) and the supporting, regulating, and cultural services they provide (Millennium Ecosystem Assessment 2003). While there is general research linking human well-being to ecosystem services, the underlying mechanisms are not well understood at appropriate temporal and spatial scales, especially in an urban environment (Reyers et al 2013; Niemelä 2014).

Lastly, our lack of knowledge on the interaction of ecological services can lead to situations where management action to enhance an ecosystem service can lead to degradation of another service (Millennium Ecosystem Assessment 2005). Urban forests for example provide many ecosystem services beneficial to human well-being, such as air regulation (CO_2 sequestration of trees, air pollutant removal) and but they can also support disservices such perceived increases in crime (Lyytimäki & Sipilä 2009). However, the services likely outweigh the disservices by orders of magnitude.

A stronger link is needed between ecosystem science and urban planning and management, but there are currently many challenges in translating scientific discovery into practical application (Pataki 2015). McPhearson et al (2016), for example, argue that urban ecology needs to evolve to a more holistic science of cities.

Key Terms

The literature and cases reviewed highlight a number of key terms that appear repeatedly in the effort to apply an ecosystem approach to urban planning and management. Each reference lists the author's favourite or derived definition, and while reviewing these definitions will be important, the critical need will be for the City of Calgary, Urban Conservation to choose the terms which will support their management approach and then articulate their own operational definitions for each. The following is a provisional list of terms that should be considered:

- **Blue spaces**
- **Ecosystem Services**[3]
- **Ecosystem-based adaptation**
- **Ecosystem disservices**
- **Ecosystem services**
- **Ecosystem management**
- **Green Infrastructure**
- **Green infrastructure networks**
- **Green spaces**
- **Ecological infrastructure**
- **Environmental open spaces**
- **Natural/ecological assets**
- **Natural capital**
- **Novel/emerging ecosystems**
- **Resilience / Climate resilience**
- **Social-ecological Theory**
- **Sustainability**
- **Urban ecology / urban ecosystem**
- **Urban ecosystem management**

[3] 'Ecological Goods and Services' is an analogous term but is less-used in the global literature, and grown to focus more specifically on the effort to commoditize and price ecosystem services.

How are Other Cities Applying an Urban Ecosystem Approach?

The main drivers of ecosystem management (more commonly referred to in the literature as an '*ecosystem approach*') within cities are concerns of degradation of ecosystem services due to urbanization and long term consequences of climate change. To actively address these concerns in urban centres, hybrid ecological frameworks are being developed that include theory from landscape ecology, ecological goods and services, climate change adaptation and resilience, and sustainable cities (Brink et al 2016).

Here we summarize theory and key terms that are being used by urban ecologists and cities as they seek to better incorporate ecology into decision making, planning, and management. Many of these concepts are used in conjunction, and a wide variety of conceptual frameworks are starting to emerge.

Ecosystem Services and Natural Capital

The Millennium Ecosystem Assessment (MEA) sought to integrate ecosystem concerns into decision making and outlined an ecosystem services framework as a plausible approach (Millennium Ecosystem Assessment 2005). The MEA defines ecosystem services as the benefits that humans obtain from ecosystem functions, or as contributions from ecosystems to human well-being (Millennium Ecosystem Assessment 2003, TEEB 2011). Taking an ecosystem services approach can help a city in three ways:

- Focusing attention on value from locally-derived services, which can help with the integration of natural capital concepts into decision making;
- Helping decision makers better understand impacts of decisions and polices in relation to urban ecosystems; and
- Promoting more effective communication to the public on consequences of a decision relating to environment (TEEB 2011).

The ecosystem services approach therefore provides a powerful way to advance sustainable urban development because it helps people understand the role of natural systems to human well-being (Reyers et al 2013, Wilkinson et al 2013). Recently there has been a strong trend of incorporating ecosystem services into planning process with the assumption that this will lead to development decisions that are inclusive of ecology and will help a city better understand the trade-offs

between natural systems and urban development (Albert et al 2016). Recognising the importance of this, much research has focused on mapping, quantifying and valuing ecosystem services (Woodruff & BenDor 2016). However, there has been less research and empirical evidence devoted to the question of whether incorporating an ecosystem service approach into planning improves the ecological sustainability of a city (Raudsepp-Hearne et al 2010).

Numerous researchers have outlined frameworks for integrating ecosystem services into planning (Albert et al 2016, Ahern et al 2014, Dobbs et al 2011) but the most well recognized is The Economics of Ecosystems and Biodiversity (TEEB), which outlines a seven step framework for cities to consider ecosystem services:

- Step 1: Specify and agree on the problem or policy issue with stakeholders
- Step 2: Identify which ecosystem services are most relevant
- Step 3: Determine what information is needed and select assessment methods
- Step 4: Assess (future changes in) ecosystem services
- Step 5: Identify and assess management/policy options
- Step 6: Assess the impact of the policy options on the range of stakeholders (TEEB 2011)

Specifying or agreeing to the problem or policy issue is an important first step because ecosystem services are part of a complex system that is driven not only by complex interactions between animals and abiotic features but by social and political contexts (Fisher et al 2009).

Once the ecosystem services that are most relevant have been identified, there are well-defined methods for measuring, mapping and modeling ecosystem services in the literature (Fisher et al 2009).

Although there are many assessments in the academic literature on specific services in urban environment (Dobbs et al 2011, Albert et al 2016, Baró et al 2014), urban case studies where an ecosystem service approach has led to integration of ecosystems into city planning and management are not common.

Case Study

BIRMINGHAM UK, ECOSYSTEM APPROACH TO PLANNING

A valuable example of the use of the ecosystem services approach by a large municipality is the City of Birmingham, UK. Birmingham recently released a *Green Living Spaces Plan* with the goal of becoming a 'green city', and to integrate an ecosystem approach into City planning and management. The Plan identifies natural spaces and features as natural capital and applies an ecosystem services framework (Birmingham City Council 2013). The plan re-shaped the role of parks and green spaces in Birmingham's vision to become a greener City.

"This Green Living Spaces Plan introduces a new approach that of valuing all the city's natural spaces and features as Natural Capital, by applying the latest scientific thinking behind the National Ecosystem Assessment."

-- Green Living Spaces Plan

A cross disciplinary working team established seven working principles to complete the green vision: An Adapted City, The City's Blue Network, A Healthy City, The City's Productive Landscape, The City's Greenways, The City's Ecosystems, and The City's Green Living Spaces.

To accomplish the Green Living Spaces Plan six topics were considered: aesthetics and mobility, flood risk, local climate, education, recreation, and biodiversity. Each of these topics was mapped for demand with areas of high supply and low demand at one end of the scale and areas of low supply and high demand on the other. The six maps were overlaid to portray areas within the City where natural capital is supporting multifunctional ecosystem services. Although the plan is founded in ecosystem services theory it incorporates concepts from green infrastructure, ecosystem based adaptation, and resilience and sustainability planning.

Birmingham recognized barriers to implementation of the Green Living Spaces Plan across City departments, and has attempted to address this though development of cross disciplinary and stakeholder group, led by a Green Commission, launched by Birmingham City Council.

Ecosystem-based Adaptation and Resilience

Climate change threatens the sustainability of cities and poses increased risks to urban ecosystems (IPCC 2014). Ecosystem-based adaptation (EbA) has been widely proposed as a locally-based response to reduce adverse effects of climate change by building resilience of ecosystem services (Munang et al 2013). The Convention on Biological Diversity (CBD) defines EbA as, "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change." Recently, the CBD (2010) evolved the definition to "sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities."

EbA is built on the notion that a healthy functioning ecosystem is more resilient (greater flexibility) and therefore better able to adapt to ecosystem stress, such as climate change (Munang et al 2011). Restoring or maintaining ecosystem resilience therefore reduced the vulnerability of communities to climate change (Sudmeier-Rieux et al 2006). Ecosystems provide services that play a role in adaptation to climate change, for example, risk reduction of natural disasters (floods, drought), food security, sustainable water management and livelihood diversification (Munang et al 2013).

One of the main strengths of EbA is its potential to achieve multiple benefits. For example an EbA strategy to sustainably manage wetlands and floodplains has multiple benefits, such as the maintenance of water flow and water quality, flood control, and water storage all of which contribute to the reduced risks of drought. Benefits beyond reducing vulnerability to natural disaster include improved recreational opportunities (fishing), regulation of water, and enhanced carbon storage. Given the multiple benefits of EbA's, they are often termed *no regret strategies*. That is, given the un-certainty around the frequency and extent of environmental impacts expected from climate change, EbA actions will still provide benefit to communities even if climate change impacts are less severe than predicted (Doswald & Osti 2011, Munang et al 2013).

Although EbAs are gaining in popularity they are considered under-utilized as an approach for climate change adaption when compared to more traditional actions such as built infrastructure development (Wamsler et al 2016). A more typical response to flood control is to take an engineering-intensive approach and invest in hard or grey infrastructure to prevent further flooding (e.g., reservoirs or levees).

Although in many cases hard infrastructure may be an appropriate response, EbA can complement those more traditional approaches to adaptation, and have the benefit of working with nature instead of against it (which is often the case in more traditional approaches to adaptation).

One of the key challenges to implementing EbA approaches is mainstreaming the concept into urban planning (Wamsler et al 2016). Geneletti and Zardo (2015) reviewed European cities' climate change adaptation plans and found that EbA strategies were outlined in the majority of plans but most lacked specificity and details to enable implementation. Munroe et al (2011) highlight some other challenges to implementing EbA programs, such as:

- Technical challenges, such as design and implementation knowledge;
- Limited public awareness about EbA and the multiple benefits associated with an ecosystem approach;
- Organizational challenges arising from the diversity and number of partners that need to be engaged in these projects;
- Overall capacity limitations (institutional, financial and technical);
- Lack of technical knowledge within agencies needed to champion EbA; and
- Political need for policy integration.

Haines-young and Potschin (2015) established an EbA framework which includes following considerations (extracted from Brink et al 2016):

- *Ecological structures*: identification of the "hardware" of ecosystems, e.g. watersheds, forests, gardens and green roofs.
- *Ecological functions and processes*: identification of the natural-science basis underlying EbA, e.g. how wetlands provide flood protection
- *Adaptation benefits*: the contribution of ecosystems to the reduction of climate impacts, e.g. flood protection and reduced climate-related mortality and morbidity.
- *Valuation*: the assignment of a monetary or non-monetary, quantitative or qualitative value to a benefit in order to assess its contribution to adaptation e.g. costs that are avoided, or improved quality of life.
- *Ecosystem management practices*: actions that benefit adaption through the maintenance, preservation, restoration or creation of ecological structures. e.g. a new green space law

Novel or Emerging Ecosystems[4]

Traditionally, ecosystem management has focused on restoring damaged ecosystems back to their historic natural state, with the principle that native systems are most beneficial to achieving ecological goals. Management actions are focused on removing the stressors to the system (Grumbine 1997). A *novel ecosystem* approach challenges the traditional approach to ecosystem management, as it acknowledges that, especially in urban environments, ecosystems are rapidly changing and a new way of thinking is needed to ensure management of 'novel' or 'emerging' ecosystems as they provide benefits to humans and other species (Hobbs et al 2013, Kowarik 2011).

There is no agreed-upon definition of novel ecosystems, but Truitt et al (2015) suggest a working definition of *"an ecosystem modified by anthropogenic drivers (changes in hydrologic, nutrient, physical, or biotic conditions) during historic or present time that substantially changes ecosystem functioning."* Although there are exceptions, the majority of researchers use "novel" to refer to ecosystems shaped by human influence and their impact on abiotic and biotic features (Morse et al 2014), which while a result of human intervention, do not require human intervention to maintain them (Hallet et al 2013). The major anthropogenic stressors that drive an ecosystem toward novel include local site impacts such as invasive species and land conversion away from a natural state to global impacts such as climate change (Mascaro et al 2013). These stressors are exacerbated in urban environments where a built environment dominates the landscape and natural systems occur in small patches and networks (Perring et al 2013). Generally an ecosystem termed novel has changed state whereby it is not practically possible or it's considered impossible to reverse the ecosystem back to its historical state (Hobbs et al 2006, Truitt et al 2015).

Although novel systems can't be restored to their historic state they still have ecological values and can be considered as a component of the urban ecosystem. Novel ecosystems have conservation value by supporting biodiversity, and ecosystem services such as carbon sequestration and storage, air quality and noise reduction, flood mitigation and water quality, and spiritual and health benefits to people (Perring et al 2013). Supporters of the novel ecosystem concept argue that these systems play an important role and management goals should be focused on

[4] Though there is some nuance, this report will treat 'novel' and 'emerging' ecosystems as synonymous concepts.

maintaining valuable ecosystem functions. In a novel ecosystem approach, management focuses on steering *novel* ecosystems away from an undesirable state or toward a desirable state (Hobbs et al 2013), and restoring *hybrid* ecosystems to their historic state.

Identification of Novel Ecosystems

Novel ecosystems have been influenced by anthropogenic changes, land conversion, and or species invasions (Hallett et al 2013). A novel ecosystem is composed of species configurations that are different than the historical configuration where reversibility to natural state is not possible. A system that is moving away from a natural state and has new species configurations but the system is deemed reversible is termed a *hybrid* system (Hallett et al 2013). A hybrid system can still be converted back to a more native state, and management goals therefore focus on restoration or on preventing an ecosystem shift, while a novel system is irreversible resulting in a different set of management goals. Since hybrid and novel ecosystems have differing types of management goals, distinguishing between when a system is considered hybrid versus novel is important. The distinction between a hybrid and novel ecosystem is based on understanding of trigger points that cause an ecosystem to cross a threshold where it becomes an alternative state (Hallett et al 2013).

To identify trigger points, research has focused on indicators that may precede a regime shift (Hastings & Wysham 2010). Morse et al (2014) provide examples of leading indicators for determining if a threshold has been crossed including, changes to "species composition, species diversity, salinity levels, pH, productivity, decomposition rate, relative change in trophic level biomass, nutrient cycling rates, or distribution of a particular habitat element, either biotic or abiotic, in the ecosystem". Despite intense study and some success in identification of leading indicators for regime shifts, management application in this area remains a challenge (Hastings & Wysham 2010).

Challenges to the Novel Ecosystem Approach

The novel ecosystem approach is not without challenges and there are concerns both with the concept and implementation.

The literature review found what Truitt et al (2013) refer to as a tension between 'biocentric' perspectives (concerned regarding impacts on biodiversity) and

'anthropocentric' perspectives (concerned regarding relationship to ecosystem services). Murcia et al (2014) express apprehension that the concept is being applied prior to scientific validation with empirical studies, and outline a number of concerns including moving away from the precautionary principle which promotes restoring degraded ecosystems, problems identifying ecological thresholds which define when a system is novel and novel ecosystems may be seen as a replacement to more traditional approaches.

The biggest challenge to the novel ecosystem approach relates to the identification of when a system is novel. Identification of a novel ecosystem is identified by crossing an ecological threshold, a point where a small change in environmental conditions leads to large changes in an ecosystems state (Suding & Hobbs 2009). Identifying an ecosystem threshold requires long term datasets that account for traditional ranges of variability across spatial and temporal scales (Murcia et al 2014). Metrics to determine ecological thresholds and if a changed ecosystem state is irreversible are not often known and may be impractical to determine, increasing the difficulty in applying the novel ecosystem concept to management. In addition, irreversibility tends to be defined by costs and political will over ecological infeasibility. Given the urgency of ecosystem degradation, managers are using heuristic threshold models where the underlying assumptions are not empirically tested (Suding & Hobbs 2009). There are varying opinions on if this disconnect between theory and practice of ecological thresholds could lead to poorer decisions (Suding & Hobbs 2009, Murcia et al 2014).

There are concerns relating to unintended outcomes of accepting a concept that has not been rigorously tested such as novel ecosystems being a licence to impunity; and that it may send conflicting messages to governments who are investing in large scale conservation projects to restore biodiversity (Standish et al 2013, Murcia et al 2014). There is concern that adopting a novel ecosystem approach undermines restoration efforts and legitimizes governments not addressing ecosystem degradation. Hobbs et al (2013) argue that the novel ecosystem approach is not against traditional conservation, nor does it legitimize non-action to restore natural systems to historic reference points. Instead it is a pragmatic way to address systems that are highly human-influenced and usually not considered as part of urban ecosystems, and therefore not managed for values that contribute to ecosystem function.

Case Studies

A search for case studies where a novel ecosystem framework was utilized in an urban environment produced only one example (from Kitchener, Ontario). Although case studies were found where a novel ecosystem framework was used to direct management goals and decisions they were not from an urban perspective. A few examples were found where researchers have explored the novel ecosystem approach in urban areas, such as:

- Urban rivers as novel ecosystem, where by researchers suggest a shift in management from trying to return urban rivers to nature states, to one that manages for increased ecosystem services and building resilience in urban system (Francis 2014).

CITY OF KITCHENER, ONTARIO

Shea (2016) tested a novel ecosystem framework for publically owned natural areas in Kitchener Ontario. Southern Ontario continues to face an increase in population and urbanization leading to increased pressure on natural areas from recreation, encroachment, and invasive species.

Using a novel ecosystem framework developed by Hulvey et al (2013), natural areas in Kitchener were assessed to identify natural, hybrid and novel ecosystems. To define parks as natural, hybrid or novel, a number of indicators were used to determine ecosystem condition relating to human impacts, invasive species and wildlife features. For example, detailed inventories of species richness were undertaken in three parks, these were compared to historical species records to determine how much the parks had altered from their historical state (Shea 2016). The author noted that the approach was based on a rapid assessment and that concluding if a site is hybrid or a novel ecosystem without long term comprehensive studies of the ecosystem is problematic (Harris et al 2013).

Ecological thresholds present a serious challenge. Shea (2016) identified the strength of this process was the novel ecosystem framework enabled consideration of ecosystem management under different scenarios and could help to prioritize resources spent on restoration. Generating a better understanding of human impacts, wildlife features and invasive species for each park provided direction as to where they should be maintaining historical conditions versus managing a park as a hybrid or novel ecosystem.

Ecological Network Planning

Ecological network planning is an approach for managing the ecological elements in a city that play a role in promoting sustainability and resilience, producing ecological goods and services, and maintaining biodiversity (Pandit et al 2015). Ecological network planning sees natural areas and semi-natural areas as part of one interconnected system instead of managing them as separate isolated components (Ignatieva et al 2011). Although there are slight differences in definitions, the literature tends to consider research on *green infrastructure networks* and *ecological infrastructure* as similar approaches, and these approaches are included in this section.

Liquete et al (2015) suggest key criteria for identifying elements of a green infrastructure network, those that play a multifunctional role in ecosystem services and/or support species movement (connectivity) within the network. The first criteria focused on ecosystem services that support human well-being with a focus on regulating and maintenance services such as air regulation and water purification. A proxy can be used to help map the ecosystem service being considered, for example air quality regulation can be measured by deposition velocity of air pollutants on vegetation (Liquete et al 2015). The second criteria can be understood through a selection of indicator species and species connectivity modeling to identify movement opportunities based on landscape ecology concepts. The European Commission used this approach to map the green infrastructure network across Europe. They found that the resulting map prioritized green spaces that played a role in maintaining services important to human well-being while taking into consideration key areas for biological conservation (European Commission 2013).

Although cities have had success in identifying and mapping their ecological networks, it can be difficult to implement ecological network planning because it often conflicts with urban development planning (Oh et al 2011). Pandit et al (2015) refer to the ecological network as "*infrastructure ecology*" and suggest this reframing will help city managers take a more integrative approach to management of ecological systems.

In this example, the researchers developed an urban infrastructure ecology framework where grey and green infrastructure is integrated, leading to better management decisions. The framework outlines a process for identifying blue land (water resources such as lakes, rivers, streams, wetlands), green land (urban parks,

forests, farmland and other semi natural green spaces), and grey land (roads, electrical grid, artificial drainage systems and utilities). These three types of lands interact through exits (flows of human waste) and arteries (permit flows of materials between components, such as traffic lines, ecological corridors and wind and water flows) (Pandit et al 2015). The authors also propose indicators and critical values for measuring urban ecological infrastructure (Table 1).

Table 1: Proposed indicators and critical values for measuring urban ecological infrastructure

Measurement Indicator	Definitions	Critical Value
Ratio of water for urban use versus natural use	Ratio of water used for urban life and production to that used for basic functions of the natural ecosystem.	Lower than 35%
Land for ecosystem services	Ratio of area of urban agriculture, forestry, grasslands, wetlands, and nature reserves to area of urban construction.	No less than twice the area of construction land
Renewable energy use ratio	Ratio of geothermal, solar energy, wind energy, biomass energy, hydropower, and other renewable energy usage to the total energy usage.	No less than 10%
Ratio of native species	Ratio of native species to all species.	No less than 65%
Recycling rate	Recycling rate of renewable materials in urban metabolism.	No less than 90%

Adapted from Pandit et al (2015)

Case Studies

Numerous Cities have implemented ecological network planning approach including:

- Richmond, BC, has developed an EN Management Strategy (2015) based on ecosystem services, green infrastructure and protected area network.
- Surrey, BC, has developed a Green Infrastructure Network (GIN) (2014), consisting of an interconnected system of natural areas and open space that conserves ecosystems and functions for human and wildlife well-being.
- Metro Vancouver, BC developed Connecting the Dots: Regional Green Infrastructure Resource Guide[5] to support the development of a regional GIN Strategy of Metro Vancouver (2013).

[5] http://www.metrovancouver.org/services/regional-planning/PlanningPublications/ConnectintheDots.pdf

- Edmonton, Alberta has developed a Natural Connections: Integrated Conservation Plan[6] which applied an out-come based ecological network approach to the conservation of Edmonton's Natural Areas.
- Green Surge case studies – cities across Europe, which used an Urban Green Infrastructure (UGI) as a strategic planning approach that aims at developing networks of green and blue spaces in urban areas designed and managed to deliver a wide range of ecosystem services (Hansen et al 2015).

CITY OF RICHMOND, BC, ECOLOGICAL NETWORK

The City of Richmond, BC is a valuable case study. Richmond has the following vision to support their ecological network approach:

> *The Ecological Network is the long-term ecological blueprint for the collaborative management and enhancement of the natural and built environments throughout the city, within neighbourhoods, and across land- uses and development types in order to achieve ecologically connected, livable and healthy places in which residents thrive* (City of Richmond 2015).

Richmond took an ecological network approach to enable more cohesive management of natural areas and ecosystem services. They felt this approach enables actions that strengthen the ecological network, ultimately leading to a more holistic approach to land use (City of Richmond 2015).

The ecological network was identified using a science-based approach, whereby important elements (akin to ecological assets) were mapped. These included natural hubs (>10 hectares), natural sites (<10 hectares), riparian areas, corridors and connectivity zones, riparian areas, shorelines, and parks and greenways. In addition, the following ecosystem services were considered: temperature regulation, soil stability, clean air, clean water, carbon sequestration, pollination, and drought and flood mitigation (City of Richmond 2012).

Lastly, a *green infrastructure network* was considered as an expansion to the *ecological network*. Criteria for this included: storm water ponds that capture rainwater and reduce runoff; riparian corridors that capture and convey runoff, but

[6] https://www.edmonton.ca/city_government/environmental_stewardship/strategy-biodiversity-protection.aspx

also provide habitat: agricultural hedgerows and trees that support wildlife habitat; and community gardens that support pollinators (City of Richmond 2012).

Integrating Ecological Asset Management with Infrastructure Asset Management

Ecological Asset Management

A review of the literature and cases shows an on-going evolution in asset management. From the more typical focus on built infrastructure assets and their management, this field has broadened to a consideration of assets as all things we value and depend on. Asset 'management' has seen a corollary expansion, and grown to include managing ecological or natural assets – those elements of the natural world we value and depend on.

Thus, to understand *ecological* asset management, one must first understand what municipal *infrastructure* asset management is.

Asset Management Overview

In Canada, the National Roundtable on Sustainable Infrastructure formed in 2005/2006, involved approximately 50 organizations from all across Canada, and represented all levels of government, First Nations, non-governmental organizations and academia. These groups joined resources to address national concerns on infrastructure, and eventually moved towards facilitating discussions on the development of sustainable infrastructure across the country (National Round Table on Sustainable Infrastructure, 2007).

A sub-group of the NRSI called the Canadian National Asset Management Working Group developed *An Asset Management Governance Framework for Canada.* The framework identifies community sustainability as the core objective of asset management — building environmental, financial and social resilience and adaptability to face a changing world.

This group defined asset management as:

> *"An integrated business approach involving planning, finance, engineering and operations to effectively manage existing and new infrastructure to maximize benefits, reduce risk and provide satisfactory levels of service to community users in a socially, environmentally and economically sustainable manner."* (National Asset Management Working Group, 2009)

Provincially, according to the Alberta Urban Municipalities Association, municipal asset management is defined as:

> "*the process of managing a municipality's assets in a cost effective manner, by analyzing the life cycle of all the assets in a community in order to develop information about future maintenance, new developments and capacity resource*" (AUMA n.d.)

Asset management practices mainly deal with physical infrastructure and are often referred to as tangible (can be touched), capital (lasts over time) and assets (have a measured value). Hence the term now often used by municipalities, *tangible capital asset management*. (British Columbia Government Finance Officers Association, n.d.)

Most asset management systems use two main categories to organize assets:

- Linear assets – water infrastructure, sewer infrastructure, roads, sidewalks and bridges
- Discrete assets – land, buildings, vehicles, equipment

The benefits of asset management include:

- Prolonging asset life and aiding in making informed decisions regarding rehabilitation, repair and replacement concerns;
- Meeting consumer demands with a focus on system sustainability;
- Setting rate based on sound operational and financial planning;
- Budgeting focused on activities critical to sustained performance;
- Meeting service expectations and regulatory requirements;
- Improving response to emergencies; and
- Improving security and safety of assets. (AUMA n.d.)

What are Assets?

Assets include physical infrastructure (or networks) owned by local governments that serve defined communities where the system as a whole in intended to be maintained indefinitely to a specified level of service by the continuing replacement and refurbishment of its components. Assets may also include natural assets and the ecosystem services they provide (Hein et al 2016, Obst et al 2016, European Commission et al 2013, Merz 2009). Municipal assets typically include:

- Transportation systems/networks
- Drainage and flood protection systems

- Parks and recreation facilities
- Water utilities (water supply, waste water and storm water systems)
- Solid waste facilities
- Libraries, administration, and other community facilities
- Fleet

(Ministry of Community Sport and Cultural Development & Asset Management BC, 2014, The NAMS Group 2008 - 2016, 2016)

As discussed in *Rationale for Urban Ecosystem Management* (above), inter-dependency within a particular network and also from one network to another implies a degree of complexity within and between asset networks. For example, failure of one component may impact or undermine the ability of other networks to perform, as in the case of a backed up storm water drain that floods a road and impedes traffic movement (The NAMS Group 2008 - 2016, 2016).

What is Infrastructure Asset Management?

The goal of infrastructure asset management is to meet a required level of service, in the most cost effective manner, through the management of assets for present and future generations. That means existing and future assets should be considered.

The key elements of infrastructure asset management are:

- Taking a lifecycle approach
- Developing cost-effective management strategies for the long-term
- Providing a defined level of service and monitoring performance
- Understanding and meeting the impact of growth through demand management and infrastructure investment
- Managing risks associated with asset failures
- Sustainable use of physical resources
- Continuous improvement in asset management practices (The NAMS Group 2008 - 2016, 2016)

The Asset Management Framework

There are common elements to how municipalities (or industry) approach asset management. Frameworks typically include an inventory of assets, an assessment of the required level of service, risk analysis, and financial costs over time (lifecycle costs). The following is an excerpt from the United States Environmental Protection Agency's *Asset Management Best Practice Guide* (United States Environmental

Protection Agency, 2008). It uses five core questions to guide a practitioner through developing an asset management plan:

- What is the current state of the system's assets?
- What is the required 'sustainable' level of service?
- Which assets are critical to sustained performance? (It is important to know which assets are required to sustain the system's performance so EPA developed a simple rating system to prioritize assets).
- What are the minimum lifecycle costs?
- What is the best long-term funding strategy? (This includes operation and maintenance funding as well)

Shifting Toward an Integrated Approach to Asset Management

There is some evidence to suggest that Canadian municipalities are moving towards an asset management approach that integrates traditional infrastructure assets and ecological assets.

Infrastructure Canada recently approved Alberta's asset management approach that aims to provide capacity building for municipalities (Municipal Affairs Government of Alberta, n.d.). The overall goal of Alberta's asset management approach is to help municipalities optimize their infrastructure and other physical assets in order to continue receiving federal Gas Tax funding. The Government of Alberta's Municipal Sustainability Strategy Advisory Committee will guide the asset management approach developed by Municipal Affairs (Municipal Affairs Government of Alberta, n.d.). While there is no explicit statement in Alberta's asset management approach regarding ecological infrastructure or integration of asset management approaches, it is important to be aware of where overall guidance for asset management is 'housed' within the Province. If Calgary decides to work toward and integrated asset management approach, it may be strategic to discuss strategy and gain support from the Province for an integrated asset management approach.

Asset Management BC developed, *Asset Management for Sustainable Service Delivery: A BC Framework* (Asset Management BC, n.d.)This framework is evidence of how asset management in Canada is evolving to not only include 'grey' or what is traditionally considered infrastructure, but it also includes the integration of natural infrastructure. The following statement from the Framework identifies why BC is integrating traditional and natural ecosystem services in an asset management

approach:

> "*Communities build and maintain infrastructure to provide services. These services support quality of life, protect health and safety, and promote social, economic and environmental well-being. Failure to care for infrastructure, manage natural resources and protect the services provided by nature, risks degrading - or even losing - the services communities enjoy and future generations will rely on*". (Ministry of Community Sport and Cultural Development & Asset Management BC, 2014)

British Columbia's approach to sustainable service delivery asset management is being termed as a paradigm shift (Ministry of Community Sport and Cultural Development & Asset Management BC, 2014) because it is taking a sustainable approach to asset planning and management, and considers asset management before the asset is built, or takes a 'design with nature' approach.

> "*Sustainable service delivery integrates all the principles of asset management. It understands the value of land-use planning; and it understands the impacts that land-use planning has on service delivery. It also integrates the 'design with nature' philosophy*."
>
> (Ministry of Community Sport and Cultural Development & Asset Management BC, 2014)

In the Town of Gibsons, BC, instead of thinking of assets as engineered or 'grey' infrastructure, they have taken the perspective that "[t]here is increasing evidence that municipalities can reduce risks further, and save more resources, by also considering natural assets such as wetlands, forests, foreshores and rivers in their asset management processes. Protecting and managing nature to provide municipal services is not new..." (Machado & Brooke, 2016). Machado and Brooke (2016) go on to say there are strong synergies between asset management processes and the measurement and management of natural capital that make it practical for municipalities to use this approach.

According to the Asset Management Report Card completed by Canada Infrastructure in 2014, and citing data from the inaugural 2012 report, municipalities across Canada are identifying infrastructure requirements and deficits that may greatly outweigh the available resources. (Canada Infrastructure, 2014). This reality may have encouraged municipalities to consider infrastructure in new and unique ways such as green or existing natural infrastructure. Evidence includes the Canadian case studies discussed below from Gibsons, British Columbia and Red Deer, Alberta. As well, this call from the Atlantic Infrastructure

Management Network (AIM) is further evidence of the move toward integrating ecological and infrastructure asset management:

> "*Atlantic Infrastructure Management Network (AIM) is interested in creating awareness among municipalities in Atlantic Canada of the services that natural capital assets can provide as an alternative or supplement to engineered infrastructure*." (Atlantic Infrastructure Management Network, n.d.)

Ecological Asset Management

Though the literature is limited, the research and practice around ecological asset management appear to suggest two approaches are emerging, one growing out of market considerations and one out of ecosystem service considerations.

Several descriptions of 'ecological asset management' focus on a market-based approach that is meant to be implemented in the context of regulating industry or development and the effects on what are identified as ecological assets (Miller, 2003, Stoneham et al 2012). The ecological asset management approach that Miller (2003) describes below offers an approach to encourage positive environmental outcomes using market forces. In the case of natural areas, it is typically government (the municipality) that identifies, protects, manages and monitors a natural area municipal asset. Something to keep in mind may be the potential for using market-based tools like offsite levies to incentivize developers' work towards the environmental objectives of the municipality.

> "*Eco-asset management [ecological asset management] is characterized as a market-based approach with promise for maximizing the productivity of natural resources to promote economic vitality, protect environmental and public health, improve the human condition, and accelerate global progress toward a sustainable future. For government agencies and other stakeholders, market-based approaches promise solutions for achieving environmental goals more efficiently and at lower cost, as well as for addressing complex challenges such as climate change, water shortages, and biodiversity loss*" (Miller, 2003).

Miller suggests that eco-asset management should be used to harness market forces to preserve, enhance, restore, and create (PERC) the natural capital. The intent is to create sound, efficient markets for allocating the goods and services furnished by the natural ecosystems that regulate Earth's atmosphere, supply life's essentials (nutrients, water, and energy), and otherwise nurture a growing global population (Miller, 2003).

The European Commission and the UN Statistical Commission have been working for some time to clarify what 'ecosystem assets' are, and to develop mechanisms for them to be valued, accounted for, and managed as assets. Their focus emerged at the level of the System of National Accounts (SNA[7]), and the conception of *environmental assets* as "naturally occurring entities that provide environmental functions or services" (OECD 2005). The SNA focus has been on those environmental services that provide a demonstrated economic benefit (European Commission et al 2013).

More recently, the *System of Environmental – Economic Accounting* (SEEA) has emerged that has taken a broader view. As well as "ecosystem assets" that are priced within the market, SEEA uses a Total Economic Value approach that includes direct use value, indirect use value, option value, and non-use values (European Commission et al 2013).

Research findings also revealed that ecological asset management is not a common term on its own. Often it is used in conjunction with or within frameworks such as natural capital, ecosystem services, or green infrastructure. Those concepts and ecological asset management are discussed further in the sections below.

Ecosystem Assets

Not surprisingly, as an emerging field, there is tremendous variation in the terminology around ecological assets, ecosystem assets, environmental assets, etc.

The delineation of assets in European Commission et al (2013) is a potentially useful typology. They start with a higher-level category of "environmental assets" which includes natural-occurring but non-living assets (e.g., energy and minerals), 'produced assets' (e.g., crops and timber), as well as "ecosystem assets". The sub-category of "ecosystem assets" focuses on the spatial areas that have biotic and abiotic components, but the emphasis (and what makes it an asset) is on that those elements function together as a system. They also suggest that "ecosystem assets" should be distinguished from the individual components contained within that spatial area (soil, water, plants, animals), and also from "ecosystem characteristics"

[7] "The System of National Accounts (SNA) is the internationally agreed standard set of recommendations on how to compile measures of economic activity. The SNA describes a coherent, consistent and integrated set of macroeconomic accounts in the context of a set of internationally agreed concepts, definitions, classifications and accounting rules." UN Statistical Commission (http://unstats.un.org/unsd/nationalaccount/sna.asp)

which relate to the ecosystem's structure, composition, processes or functions (e.g., biodiversity or resilience).

They concede that "ecosystem capital" might be an analogue for "ecosystem asset", but suggest it is more appropriately used in a well-being calculation, along with human capital, produced capital and social capital. They also argue that the concept of 'assets' lends itself better to both monetary and physical measurement, while 'capital' tends to be associated with just monetary measurement. Finally, they reference the concept of 'critical' natural capital (which presumably could be extended to "critical ecosystem assets"), as that natural capital which is not replaceable, or whose functions/services cannot be substituted.

Ecological Asset Management in Urban Areas

The Case for Urban Ecological Asset Management in Urban Areas

Ecological asset management in urban areas is an emerging concept and an even newer practice. There is therefore a limited amount of research to support a detailed analysis of the challenges and benefits of this approach. As mentioned above, a significant challenge is that different terms are used synonymously, making it difficult to provide a single comprehensive analysis of urban ecological asset management based on the concepts that arise in urban ecosystem management, such as novel ecosystems, natural capital, ecosystem services, or green infrastructure.

Recognizing that nature, and the ecosystem services that it provides, are an integral part of a community's infrastructure (and asset) system may be a significant paradigm shift in some municipalities. To gain recognition involves finding agreement internally and with the public that the ultimate vision for sustainable service delivery is that communities would protect, preserve, restore and manage natural assets in the same way that they manage engineered assets.

The case studies below highlight that a critical part of operationalizing ecological asset management is making the case for urban ecological management as an integrated component of municipal asset management.

Challenges and Benefits of Urban Ecological Asset Management

The authors chose to explore the literature and cases around ecological asset management using the same ecosystem-based approaches or 'frameworks' as were identified through the review of the rationale for urban ecosystem management (novel ecosystems, natural capital, ecosystem services, and green infrastructure). It is not a perfect fit, but each contributes something unique to the consideration of urban ecological asset management, and in many of the cases reviewed, the asset management approach was in fact a hybrid of two or more of these approaches.

Since asset management approaches are based on determining what the assets of a municipality include, each framework was reviewed based on how it was organized or classified, and what some of the inherent challenges and opportunities are in attempting to classify ecological assets under each one.

A number of approaches use natural capital or ecosystem services frameworks to work towards the preservation, protection or restoration of ecosystem services and natural capital systems.

A key challenge to ecological asset management is defining what the intended outcomes are, and understanding how it integrates with other asset types as a system. Because asset management principles (or sustainable service delivery) tend toward integration, looking at natural areas in isolation from the system of ecological and other municipal assets is a challenge in itself.

A final challenge worth noting is that urban ecology has emerged as a multidisciplinary field with many of the tools needed for advancing cities' sustainability and resilience (McPhearson et al 2016). However, the literature and cases suggest this requires the proponents of the approach (i.e., City of Calgary, Urban Conservation) to expand the conversation of urban ecology and natural asset management beyond their staff team.

Frameworks for Urban Ecological Asset Management

Novel Ecosystems

'Novel' or 'emerging' ecosystems is a developing concept and has not yet evolved to the stage where there is a dedicated body of research that defines 'novel ecosystem asset management' approaches.

On this spectrum, ecosystems can be categorized into *natural* (limited human influence and ecologically self-sustaining), *novel* (significant human influence historically, yet currently ecologically self-sustaining, able to provide ecosystem services, but low likelihood of being restored to natural), or *hybrid* (on-going human influence, but capable of being restored to a natural state) (Hobbs et al 2014, Truitt et al 2015).

The novel ecosystem concept can be applied in an asset management context as a way to characterize assets. For example, if a park is considered an asset, it may or may not be a novel ecosystem. Likewise, if the land base of a park is divided into various habitat types which are considered different asset classes, each may be judged to be novel or not. Ecological criteria would be used to judge ecological assets on natural/hybrid/novel scale.

Hobbs et al (2014) outline that novel ecosystem approaches are used as a landscape management framework that incorporates all systems across the spectrum of degrees of alteration, provides a fuller set of options for how and when to intervene, uses limited resources more effectively, and increases the chances of achieving management goals.

In the study by Truitt et al (2015), options for managing novel ecosystem (assets) are categorized as 'manage against', 'tolerate', and 'manage for', providing a conceptual basis for identifying management approaches associated with these different 'asset types.'

Natural Capital

Natural capital comprises two major components:

- Abiotic - natural capital comprises subsoil assets (e.g. fossil fuels, minerals, metals) and abiotic flows (e.g. wind and solar energy).
- Biotic - natural capital or ecosystem capital consists of ecosystems, which deliver a wide range of valuable services that are essential for human well-being.

The services that nature provides for free are often not accounted for and, therefore, not properly valued by decision-makers (David Suzuki Foundation, 2014). The concept of natural capital is therefore a method for characterizing ecological assets in a manner that makes sense in market economics. Natural capital

frameworks evaluate the benefits that nature provides, and calculate the economic value of these assets in a way that 'internalizes' what would otherwise be market 'externalities.'

As noted above, the SEEA work (European Commission et al 2013) suggests that natural capital does not lend itself well to an asset management approach as its focus on monetary valuation is a challenge for the physical valuation needs of asset management. However, several of the valuation techniques used for ecosystem services (e.g., avoided cost, replacement cost, hedonic pricing, contingent valuation, and others) could have direct applicability for municipalities seeking to identify a dollar value for ecosystem assets.

The term 'performance' is commonly used in grey infrastructure asset management and refers to condition or quality and quantity of an asset. Similarly, natural capital assets may be assessed for level of performance and how likely it is to change in the future. In a report for the British Assessment Bureau, the authors suggested that thinking about the performance of an asset versus thinking about an asset in the economic terms of 'supply' and 'demand' was beneficial in that the evaluation of asset performance allowed for links to policy objectives, processes, and principles as well as science (Dickie et al 2012). This approach could work well in the municipal decision making context.

The EU Biodiversity Strategy to 2020 (European Union 2011) directed efforts to map and assess ecosystems and their services, assess the economic value of the services and promote the integration of the values into accounting and reporting systems. This is further ahead than where municipalities in Canada are today and it will be important to further analyze the progress and lesson's learned from the actions of the EU.

Ecosystem Services

Simply put, ecosystem services are the benefits we derive from nature. Since the concept arose, a significant amount of work has been undertaken to refine it, and we are fortunate that the Millennium Ecosystem Assessment (2005) took on the Herculean role at an international scale of developing a foundational classification system (Table 2).

Table 2. Ecosystem services identified by the Millennium Ecosystem Assessment

Provisioning	Regulating	Cultural
Food and fiber	Air quality maintenance	Cultural diversity
Fuel	Climate regulation	Spiritual & religious values
Genetic resources	Water regulation	Knowledge systems (traditional & formal)
Biochemicals, natural medicines, pharmaceuticals	Erosion control	Educational values
Ornamental resources	Water purification & waste treatment	Inspiration
Fresh water	Regulation of human diseases	Aesthetic values
	Biological control	Social relations
	Pollination	Sense of place
	Storm protection	Cultural heritage values
		Recreation & ecotourism
Supporting[8]		
Primary production		
Photosynthesis (production of oxygen)		
Soil formation & retention		
Nutrient cycling		
Water cycling		
Provisioning of habitat		

Adapted from Millennium Ecosystem Assessment (2005)

However, while the Millennium Ecosystem Assessment (2005) was successful developing a high-level classification scheme for ecosystem services, despite on-going efforts (Costanza et al 2014, Bagstad et al 2012, Fisher and Turner 2008, de Groot et al 2010, Haines-Young and Potschin 2009), there has not been a consistent approach to the valuation and management application of the ecosystem service concept. Wallace (2007) points out other important components of an effective decision process are required, including spatially and temporally defined goals, mechanisms for evaluating management feasibility and risks, clarity as to the individuals/communities to be included, and what scale decisions will apply.

The potential application of ecosystem services to ecological *asset* management is rooted in the two distinct but necessary components of an 'ecosystem service': *ecological function* and *human benefit* (e.g., growth of the tree is an ecological

[8] There is debate as to whether *supporting services* represent 'double-dipping' in terms of accounting for the benefits of ecosystem services. For this reason, the Common International Classification of Ecosystem Services (CICES) uses only the first three categories (http://cices.eu).

function, our use of it for timber is the benefit we derive). This dichotomy allows for the *ecological function* to be assessed in ecological terms (the *condition* of the asset), and the *human benefit* to be assessed in terms of derived advantage (the *service level* of the asset).

The characteristics and decision contexts are highly influential on fine-scale ecosystem service classification, and interactions among species and their abiotic environment are complex, which means there is not one classification scheme that will be adequate for the many contexts in which ecosystem service research may be utilized (Fisher, Turner, & Morling, 2009).

An Alberta example of categorizing and assessing ecosystem services is *Ecosystem goods and services southern Alberta: A framework for assessing natural asset condition* prepared by O2 Planning and Design Inc, for Alberta Environment (2009). The assessment was a modification of the Australian Ecosystem Services Project and used the approach of identification of ecosystem services, research on their importance, and ultimately a ranking of relative importance

The scale of this project was for the southern Alberta geographic area and analyzed the role of ecosystem services in relationship to the maintenance of the assets and the production of the goods, a qualitative evaluation of the relative importance of the ecosystem services to southern Alberta, and the impact that anthropogenic activity has on the services. Though the scale is different than the City of Calgary's scale, the way the ecosystem services and associated assets were categorized may be worth further review.

> *Radical transformations will be required to move from conceptual frameworks and theory to practical integration of ecosystem services into decision-making, in a way that is credible, replicable, scalable, and sustainable. There remain many highly nuanced scientific challenges for ecologists, economists, and other social scientists to understand how human actions affect ecosystems, the provision of ecosystem services, and the value of those services. At least as demanding are the social and political challenges associated with incorporating this understanding into effective and enduring institutions, to manage, monitor, and provide incentives that accurately reflect the social values of ecosystem services to society.*
>
> -- Daily and Matson, 2008

Green Infrastructure

Green infrastructure refers to an interconnected green space network (natural and semi-natural features, green spaces, rivers and lakes) that is planned and managed for its natural resource values and for the associated benefits it confers to human populations. Individually, these elements are green infrastructure assets, and the roles that these assets play are green infrastructure functions. When appropriately planned, designed and managed, the assets and functions have the potential to deliver a wide range of benefits – from providing sustainable transport links to mitigating and adapting the effects of climate change (Landscape Institute 2013.

Green infrastructure assets range from provincial parks, lakes and forest to urban interventions such as green roofs and street trees. They can be specific sites at the local level or broader environmental features at the landscape scale within and between rural and urban areas such as wetlands, large natural patches of vegetation and mountain ranges. Green infrastructure functions are the roles that these assets can play if planned, designed and managed in a way that is sensitive to, and includes provision for, natural features and ecosystem services. They may have obvious primary functions, but each asset can perform different functions simultaneously. For example, street trees add aesthetic quality to an urban area, but will also reduce airborne pollution, provide shade, reduce urban heat island effects, mitigate wind chill and turbulence and increase biodiversity. (Landscape Institute, 2013).

The literature suggests a different conception of 'green infrastructure' is emerging in North America versus Europe. The European approach is exemplified by the Green Surge research collaborative, who refer to Urban Green Infrastructure (UGI), and define it as such:

> "*Urban green infrastructure planning is understood as a strategic planning approach aiming at multifunctional networks of green and blue spaces that deliver a variety of ecosystem services – or in other words: benefits to people. These networks are designed for different spatial levels, linking up neighbourhoods, districts and cities with the peri-urban area and the wider city region*" (Anton et al 2016).

They go on to state that the four principles are green-grey integration, connectivity, multi-functionality, and social inclusion. Several similarly broad conceptions of green infrastructure from Europe appear in the literature, many with a dependence

on the ecosystem services concept to measure the viability of the infrastructure (Li et al 2016, Haase et al 2016, de Groot et al 2010).

In North America, 'green infrastructure' often has similar wording, but the emphasis is decidedly on hydrological functions (especially stormwater) and the ability to mimic natural functions (cleansing and infiltrating rainfall) (Girling et al 2008, Water Environment Federation 2015). The Institute for Sustainable Communities (nd) describes green infrastructure thus:

> "*Green infrastructure design reduces the total water flowing into natural and manmade waterways and maximizes opportunities for natural, on-site groundwater recharge. It represents a holistic method of stormwater management …*" (Institute for Sustainable Communities nd)

The City of Calgary's *Municipal Development Plan* (2009) already contains reference to 'green infrastructure', defining it as "an interconnected network of natural green and engineered green elements that provide ecological services (e.g., water filtration, air filtration and food production) in urban environments." It goes on to differentiate (and define) natural green and engineered green elements, state that it requires a strategic approach to conservation and growth management, and assert that green infrastructure "elevates the ecological services that these green spaces provide to the same level as traditional forms of infrastructure" (City of Calgary 2009).

The green infrastructure literature has become noticeably more colourful as well, as "blue infrastructure" assets and "blue spaces" are factoring more significantly in the concepts of a green infrastructure and ecological networks, in reference to the rivers, lakes, wetlands and streams within an urban ecosystem (Sander and Zhao 2015, Li et al 2016, Haase et al 2016, Childers et al 2015, de Groot et al 2010).

Integrating Ecological Asset Management with Current Approaches to Asset Management

A number of case studies were reviewed, several of which are included in the attached references. The following two case studies were chosen for a more detailed consideration because they represented advanced, local, integrated ecological asset management approaches that may prove instructional for the City of Calgary, Urban Conservation.

Town of Gibsons, BC: Towards an Eco-Asset Management Strategy

A pioneering approach is being undertaken by the Town of Gibsons, British Columbia, to place nature and the municipal services that it provides at the core of the Town's municipal infrastructure system. The Town is considering the role of engineered assets such as roads and storm sewers, as well as the role of natural assets such as forests, aquifers, creeks, wetlands and foreshores that provide essential civil services to citizens (Town of Gibsons, 2015).

The concept the Town of Gibsons based their Ecological Asset Management approach on includes ecosystem services, natural capital, and asset management and is adapted from *The Benefits of Canada's Protected Areas: A Scoping Study on Ecological Goods and Services Valuation* (Town of Gibsons, 2015)

The benefits of a natural asset focus for Gibsons were:

- Save money,
- Reduce risks, and
- May also have implications far beyond the Town itself.

The Town developed an assets inventory and financial statements to include eco-assets, and are implementing strategies to manage the assets. Gibsons needed to reduce the number and value of the assets they owned and operated and reduce the maintenance costs for those assets they retained – all while meeting community expectations for services. Due to the financial implications and the realization that Gibsons' ability to replace needed infrastructure was limited, they needed to get creative. By simply recognizing that the services provided by a key natural asset – the Gibsons Aquifer – the Town had a motivation for more informed decisions and better risk management. The Town's research helped staff determine that if the aquifer became degraded, then engineered assets would be required to provide the same services, at a cost that could be calculated based on costs in other municipalities. Conversely, a well-managed aquifer provides clean drinking water in perpetuity and reduces the risk of liabilities for new water purification and storage infrastructure.

The Gibsons case study shows natural and engineered assets being analyzed within the framework of an asset management system – a system to provide sustainable (economic, environmental and social) service delivery to citizens. The ecological asset management approach is part of the Town's strategic plan 2013 – 2014 and is considered to be in its early stages. Gibsons adopted a policy that explicitly defines

and recognizes natural assets as an asset class. They were one of the first Canadian municipalities to do this.

Municipal approaches to identifying and categorizing natural capital or natural assets are often done in isolation from asset management, requiring the municipality to justify their priority and required funding because one is 'nice to have' while the other is 'essential' (e.g., when parks and open space 'competes' with engineered infrastructure). In the Gibsons case, they documented their financial realities and shifted the 'nice to have' over to the 'essential' services column.

City of Red Deer, Alberta: The Value of Ecological Assets and Services

The City of Red Deer is undertaking a process to more accurately assess and establish the appraisal value of natural features based on dollar, aesthetic and natural values of the ecological assets and services.

This project proposes that utilizing ecological valuation methods will result in greater conservation efforts and a more accurate ecological and economic assessment of the community's natural features. In turn, the City of Red Deer hopes this will lead to a more effective distribution of ecological valuation information to City departments for their planning and operations, and will eventually be incorporated into a Geographic Information System (GIS). Work in this area is ongoing and ties in with other Parks Environmental programs.

The City of Red Deer is currently working on several fronts to more clearly establish the program, including exploring the following:

- Definitions of natural features as ecological assets and services.
    - They may include protected ecological assets and functional protected assets
- The use of standardized and newly emerging valuation methods and Ecological Management System (EMS) database/mapping inventories to help calculate the monetary, aesthetic and natural values of the ecological assets and services .
- How the local economy can more accurately reflect the value of ecological assets and services.
- How City departments can more accurately assess and use the ecological valuations in their plans, guidelines and daily business. (City of Red Deer, 2016)

An update on the valuation of ecological assets and services program was provided during a recent call with Grant Moir, a team member with Ecological Services, Parks Planning and Technical Services with the City of Red Deer. The City of Red Deer is close to finalizing the inventory of ecological and amenity assets and completing the integration and categorization of those assets into the asset management system. Ecological assets included such things as natural features, urban tree inventory, shrub beds and grasslands (including the neighbouring vicinity outside Red Deer's municipal boundary). The amenity assets were hard infrastructure such as playground structure, pathways, benches, etc. Mr. Moir stated that the City will be completing the verification of different features in the near future and the information will be publicly available at that time. The next step in the process will be to assess the dollar and ecological value of the natural asset.

To date, they have completed a database for all weed control sites within the municipality and have developed financial measures for each in terms of operation and management and the required/different types of integrated pest management approaches. In the near future, the city hopes to complete a valuation of natural areas based on their inventory of assets.

Conclusion

Because this literature and case review is intended only as a first information-gathering step in the review of the City of Calgary's *Natural Areas Management Plan*, the authors have only sought to summarize their findings in this concluding section.

The *Preliminary Conclusions* focus only on the authors' conclusions around the literature and case reviews, knowing that a more fulsome analysis is required to. It includes the key findings of the review, the places where the scope could have been expanded, and suggestions for potential further research.

The *Next Steps* section suggests some bread-crumb trails that could be followed in the next phases, separated into potential routes for 'analysis' and then to the ultimate goal of 'recommendations' for how this knowledge could be applied in the review of the *Natural Areas Management Plan*.

Preliminary conclusions

Key findings

While the literature and cases in these two topic areas – urban ecosystem management and ecological asset management – covered a wide territory, there were several distinct key learnings that emerged in the review. In compiling these, the authors considered them (or tried to) from the perspective of the City of Calgary, Urban Conservation and the need to review the *Natural Areas Management Plan*.

These findings represent the authors' assessments of the status of the topics, trajectories in the research, keystone concepts, and where literature or cases indicated important possibilities.

The findings are grouped under three categories: Concepts, Practices, and Opportunities. Each of those is further divided by the two research topics, *urban ecosystem managemen*t and *ecological asset management*.

Although the authors are not including any recommendations at this point, it would be fair to say several of the key findings could be considered *signposts* to a recommendation.

Concepts

URBAN ECOSYSTEM MANAGEMENT

- The term 'urban ecosystem approach' is becoming more common than 'urban ecosystem management', and reflects the use of multiple frameworks in one management context.
- 'Ecosystem approaches' – including theory from ecosystem services and natural capital, ecosystem-based adaptation, novel ecosystems and ecological networks – are all being considered in urban planning, design and management.
- Urban ecology is an evolving field which is currently based on multiple theoretical and conceptual frameworks and research approaches with little coordination between them.
- Concept of Ecology *in* Cities (perspective of keeping ecosystem natural and focused on green spaces) has evolved to Ecology *of* Cities (integrating ecology into economic and social systems, and focused on city as whole).
- The 'novel' (or 'emerging') ecosystem concept is increasing in prevalence, but is dogged by significant tension between those who feel it represents a viable way of framing conservation action in human-influenced systems, and those who feel it used as an excuse for inaction in conserving or restoring ecosystems to a high standard.
- Like most newer management concepts, 'urban ecosystem management' is marked by a plethora of competing terms, contradictory definitions, and near-synonyms, greatly complicating the effort to identify consensus or trends in the literature.
- Ecosystem services are well-recognized as a key mechanism for helping laypeople understand the role and importance of natural systems for human well-being.
- The term and concept 'ecosystem services' has much greater international use and less focus on commoditization; the term 'ecological goods and services' is more common in North America, and tends to indicate research and cases related to commoditization of ecosystem services and payment for ecosystem service programs.
- Ecological networks, green infrastructure networks, ecological infrastructure, urban green infrastructure (UGI) all refer to functionally analogous concepts, and all have some conceptions of connectivity at their core.

- Urban environments likely support novel ecosystems.
- Much of the literature uses the term *novel ecosystems*, while other sources use *emerging ecosystems*. 'Emerging' may in fact be more appropriate as it explicitly accepts that these systems are constantly changing, while 'novel' suggest a new 'end point' has been reached.
- Some identification of indicators for shifts to novel ecosystems has occurred, but significant challenges exist with threshold identification, lack of empirical data and subsequently modelling uncertainty
- While protected areas remain a core focus for maintaining biodiversity, urban ecosystem management is stepping out of the bounds of natural areas to include ecological networks and ecosystem services.
- The concept of 'blue infrastructure' (an area's rivers, streams, lakes and wetlands) is becoming more prevalent in the literature on natural area and open space management in urbanized areas.

ECOLOGICAL ASSET MANAGEMENT

- The theory of 'assets' and practice of 'asset management' are clearly evolving beyond the traditional conception of built infrastructure. There is a shift to a broader concept of *assets* as being everything we value and depend on, and of *asset management* as being necessarily integrated.
- Urban ecological asset management is very new as a concept, and as such there is significant debate around definitions and frameworks.
- Sustainable asset management has typically referred to assets being financially or physically sustainable. Increasingly this concept is being broadened to include 'environmental sustainability.'
- 'Ecosystem services' may be an effective concept for assessing ecological assets as the function/benefit structure pairs well with the condition/service level structure of asset assessment.
- Conceptions of 'green infrastructure' vary in the literature with a heavier focus in North America on stormwater management and mimicking nature, and in Europe on ecological networks and connectivity.
- Natural capital and ecosystem services are the most frequently-returned terms (related to the identified ecosystem-approach frameworks) when searching for ecological asset management.

- While ecosystem services and natural capital have very similar underlying concepts (utilitarian view of nature, production and use of services), at a practical level they differ as natural capital focuses more on marketization and commoditization, while ecosystem services is heavily focused on non-market values.

Practices

URBAN ECOSYSTEM MANAGEMENT

- The diversity of fields in which urban ecology is appearing highlights that it is a multi-disciplinary endeavour, emphasizing that successful conceptualization, integration, and implementation will require involvement from many sectors, and ultimately many city departments.
- Degradation of natural capital and ecosystem services are key concerns identified in urban ecology, and commonly-cited motivations for action.
- Three grand challenges to urban ecology are improving the science of the built environment; better linking urban environment and human wellbeing; and better linking ecological science to urban planning and design.
- Case studies highlight that multiple frameworks are being considered for integrating ecology into urban planning, design and management.
- There are numerous methods for measuring ecosystem service value (yield, function, cost), but no consensus, largely due to the different needs to which this ecosystem service valuation might be applied.
- Ecosystem services, biodiversity, ecological networks are coming into the mainstream of urban management.
- Ecological networks are appearing much more regularly as a term and as an analysis framework for environmental open spaces, natural areas.
- Cases of the application of novel ecosystem management approaches in an urban context are limited.
- The distinction between historic/native, hybrid, and novel ecosystems is important in management terms because 'hybrid' ecosystems can be restored to their historic state, while 'novel' ecosystems cannot.
- Little has been done regarding the management application of novel ecosystem indicators.

ECOLOGICAL ASSET MANAGEMENT

- Evidence suggests Canadian municipalities are increasingly moving toward integrated asset management.
- The existing infrastructure asset management framework appears capable of accommodating 'ecological assets,' with some arguing they are inextricably linked.
- Though few, there are applicable examples of urban ecological asset management, with relevance for the City of Calgary.
- Market-based ecological asset management is being proposed as a way to regulate development and industry.
- Urban ecological management frameworks are applicable to urban ecological asset management, but each framework may provide a different implementation function. For example:
    - 'Novel ecosystems' could be used as a way to *categorize* ecological assets;
    - 'Ecosystem services' could be used as a way to *value* ecological assets;
    - 'Natural capital' could be used as a way to *monetize* ecological assets;
    - 'Ecological networks,' 'Urban green infrastructure' and 'resilience' could be used to assess the *function/performance* of ecological assets.
- The literature and cases emphasize the importance of identifying why you are classifying and valuing ecological assets (purpose-oriented classification).
- Integration of 'green infrastructure' and 'grey infrastructure' is recognized as important, but few practical examples exist.
- Practical application examples suggest corporation-wide asset management goals and desired levels of service must be determined to successfully integrate infrastructure and ecological assets.

Opportunities

URBAN ECOSYSTEM MANAGEMENT

- Attempts to address urban ecological degradation and concerns regarding climate change have led to 'hybrid' conservation approaches from the fields of landscape ecology, ecosystem services, climate change adaptation, and sustainable cities.

- The literature and the practical application of urban ecology appears to be far more developed in Europe than other regions of the world, owing largely to the trans-national initiatives of the European Union.
- The leaders on working to integrate ecosystem services into urban planning appear to be the TEEB group (The Economics of Ecosystems and Biodiversity).
- Novel systems are likely not currently managed for ecosystem values but can play an important role in biodiversity conservation and supporting ecosystem services.

ECOLOGICAL ASSET MANAGEMENT

- The on-going shift to integrated asset management by municipalities creates opportunities for 'ecological assets' to be mainstreamed.
- Europe's understanding of ecological asset management is way ahead of Canada's or the United States', at all of the urban, regional, national and international levels.
- European Union and their *System of Environmental-Economic Accounting* have been advancing the acceptance internationally of a broad conception of 'environmental assets', and clear delineation of 'ecosystem assets.'

Information gaps

The intent was to scope this literature and case review relatively tightly to two key topics, primarily because the research possibilities behind the revision of a *Natural Areas Management Plan* could be endless.

That being said, there are areas that were out-of-scope, but which emerged through the review as potentially have been valuable to have had in scope. These include the following:

- *Invasives species* – Invasive species (especially plant species) represent an obvious nexus between the *Natural Areas Management Plan* and the *Integrated Pest Management Plan*, and are a significant part of the work of Urban Conservation both on the IPM and the Natural Environment Parks sides of the portfolio. It would therefore have been worthwhile to include them in this review.

- *Pests* – Similar to the point above regarding invasives, 'pests' would have been good to include as they become a key focus of tolerance to change, novel ecosystems, and ecological networks.
- *Blue Spaces* – It is apparent from the literature that the integration of 'green spaces' and 'blue spaces' is becoming a key focus of ecological networks, ecosystem services, and natural area planning.
- *Ecosystem service valuation* – As ecosystem services arose so frequently as a paradigm for assessment in both the ecological asset literature and the urban ecosystem management literature, it would have been valuable to include a consideration of ecosystem service valuation in an urban context.

Potential further research

Beyond the gaps in the research identified above, there are areas that were explored, but where further exploration might be valuable for City of Calgary, Urban Conservation. These include:

LITERATURE

- The **ecological asset costing approaches taken in Europe** which are Total Economic Value (TEV) approaches, and the experimental ecosystem accounting model (SEEA) as they have potential for assisting ecological asset valuation in a urban ecosystem setting.
- The **Urban Green Infrastructure (UGI)** concept now prevalent in Europe (and especially promoted by the multi-national Green Surge group), merits further consideration as it is well developed and may be a good model for applying an ecological network approach in Calgary. (NB: They are slated to release a new publication in 2017 by Haase et al: "Urban Green Infrastructure Planning: A Guide for Practitioners")
- As noted above, ecosystem services is arising repeatedly in the context of both asset management and urban ecosystem management. It would be worthwhile to **explore valuation of ecosystem services in the context of urban natural areas**.
- The **concept of tolerance** is well developed in the pest management realm, but will likely have increasing relevance for natural area management as it explores novel ecosystems, ecological networks that include non-city-owned assets, etc., and would be worth exploring further.

CASES

Several cases (from both specific municipalities and associations) arose as being valuable, but some had particular relevance; understanding their methods and effectiveness in more detail could be valuable. These include:

- Town of Gibsons, BC
- City of Kitchener, ON
- City of Birmingham, UK
- The Federation of Canadian Municipalities (they are building an infrastructure assessment tool which will include ecological asset management)
- The BC Framework for Asset Management (provides a step by step guide on how to develop an asset management plan that could be valuable for City of Calgary, Urban Conservation).

One final possibility for further research is the new Modernized Municipal Government Act and the in-development City Charters. The City of Calgary will now have a new municipal purpose – "environmental stewardship" and with it new environmental bylaw powers. It would be valuable to consider the application of an urban ecosystem management approach in the City of Calgary based on this evolving context.

Next steps

It is the authors' understanding that the City of Calgary, Urban Conservation will be following this literature and case review work with (potentially) two additional steps. For that reason, the natural progression to *analysis* and *recommendations* was intentionally limited.

However, the following suggestions are offered as potential areas of focus for the next steps.

Phase II: Analysis of the reviewed literature and cases

Although some preliminary assessment was provided above regarding what the case and literature review told us, there is no actual link yet made between the

gathered information and the creation of a revised *Natural Areas Management Plan*. The following analyses could potentially facilitate that connection:

- How can this work inform the development of new natural open space types;
- What does this work tell us about managing natural vs managed ecosystems;
- How does this work inform Calgary's Biodiversity Policy goals;
- Which urban ecology and ecological asset management concepts (e.g., urban green infrastructure, ecosystem approach, ecological network, environmental assets, ecosystem assets, ecological asset management) should be clarified and defined for potential use within the City of Calgary; and
- What does this work tell us about how the City of Calgary asset management approach could be modified.

Phase III: Plan implementation recommendations

Once the above analyses (and/or others) were completed, the logical next step would be to prepare concrete recommendations for using the *urban ecosystem management* and *ecological asset management* information to develop specific elements or supporting components of the revised *Natural Areas Management Plan*.

Though it is premature to go too far down this road before undertaking the analyses that would inform this step, the following are potential recommendation areas:

- Creation of an ecological asset typology to inform the NAMP;
- Creation of a revised natural area typology based on ecological network theory;
- Creating a operational management framework based on both ecological asset types and open space (natural area) types;
- Valuation rubric for urban ecological assets based on ecosystem services;
- Integration of infrastructure asset management with ecological asset management in a City-wide context;
- Refinement of Habitat Condition Rating based on other frameworks (UGI, ES, ecological networks);
- Development of an 'urban green infrastructure' definition and framework for the City;

- Development of definitions for key urban ecosystem management and ecological asset management concepts from a City of Calgary perspective; and/or
- Implementation of the experimental ecosystem accounting model for natural area asset management.

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Appendices

Appendix 1: Key Themes from the 'What We Heard' Document

As noted in the *Methods* section of this report, a key starting point to this research was the *What We Heard* document (an internal City of Calgary review of those plans). The authors reviewed this report and identified key comments and themes which would influence the literature and case review. These included (authors' emphasis):

Natural Area Management Plan

Strengths

- "The NEP classification table into different management categories (e.g., supporting, major, special protection) is easy to understand, and **management guidelines based on park categories are well laid out** and very prescriptive."
- "Many elements set **precedent for the biodiversity strategic plan** and have ongoing value."
- "NAMP recognizes importance of natural areas and that where conflicts exist between users and biodiversity, **biodiversity trumps recreation**."

Weaknesses

- "Sections requiring updating include:"
    - "**Benefits of Natural Environments in Urban Centres** (ecosystem services should be referenced; other benefits documented for biodiversity strategy should be added),"
    - "**Inventory** (summarize HCR, connectivity work, and table of hectares of each land cover/habitat type)."
- "The **habitat types and descriptions need to be updated**/refined based on categories used in HCR/EII; remnant prairie and intact forests should be included."
- "Habitat descriptions should describe how they align with **Natural Subregions.** Management guidelines based on habitat type are still relevant but need updating."
- "The Natural Area Systems **seem to be conceptual connectivity** but don't correlate with any management guidelines or policy."

- "**Natural Environment Category Guidelines** table needs modification; categories **should be revisited** (e.g., what is benefit, are categories sufficient, how meaningfully implemented)."
    - Special Protection Natural Area, Major Natural Area, Supporting Natural Area, Other Parks with NA Zones
- "the **guideline on diversity is directly related to biodiversity strategy**, and portion on habitat size relates to concept of target areas for each habitat type.
- "NAMP **should address the concept of urban ecosystems rather than pristine wilderness**."
- "It should include all **habitat**, wildlife, flora, including reference to the importance of **pollinators and beavers** in the landscape. It should emphasize the **importance of restoration/naturalization**, **conservation** of parks, and **connectivity** between urban habitats. "
- "NAMP **should describe how to integrate park uses into the urban setting**."
- "It should specify actions that must be reported to Council (e.g., developing pest management strategy, **naturalization/restoration strategy**, **urban wildlife strategy**"
- "General updates needed include: … **buffers/interface management** concepts should be more clearly articulated"

Current Practices

- "The NAMP should include considerations for buffers/interface management and integration of wetland/stormwater management"

Opportunities

- "The plan can be **integrated** with the … Our **BiodiverCity Strategic Plan** … Biophysical Impact Assessment (BIA) Framework, Environmental Open Space (EOS) policy, Habitat Restoration Project Framework, and Park Management Plans."
- "It should be integrated with **all policies that mention healthy environmen**t, biodiversity, and conservation."
- "It should clearly link to the Municipal Development Plan **open space typology** (Table 2.2)."
- "It should be better integrated with the **Habitat Condition Rating**, Ecological Integrity Index, updated habitat inventory,"
- "NAMP should align with Water Resources' management of **watersheds at the regional scale**, stormwater constructed wetlands (e.g., wetlands

classified as PUL), and provide clarity on what is covered under Wetland Conservation Plan versus NAMP or some other document."

- "NAMP **could be a biodiversity management plan that Parks can steward on Corporate-wide lands** (similar to how IPM supports other Business Units as needed)."
- "NEP management should focus on **how natural areas support biodiversity**, their capacity to do so being impacted over time, operational **costs of maintenance until restoration is needed**, and capital costs of restoration once thresholds are reached."