NATURAL CAPITAL ASSET VALUATION OF THE MEEWASIN NORTHEAST SWALE FOR THE PRESERVATION OF SASKATOON'S NATURAL RESOURCES

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Abstract

The Meewasin Northeast Swale (Swale) is an ecologically significant site in Saskatoon, Saskatchewan, featuring 310 ha of native grassland, woodland, and riparian wetland. Unimpacted grasslands and wetlands are endangered ecosystems with exceptional productivity, yet this unique channel scar is threatened by urban development. Threats from urban development include habitat fragmentation, alteration of hydrological conditions, increased chemical and physical contamination potential, propagation of exotic and invasive species, and noise and light pollution. Natural capital asset valuation (NCAV) is the process of determining the economic, environmental, and sociocultural value of a natural resource. The purpose of this thesis is to apply NCAV to the Swale to help inform environmental decision making and to develop suitable NCAV methodology for other natural resources in Saskatoon and other Canadian municipalities.

Three valuation analyses were applied to the Swale: two benefit transfers and a hedonic regression. First, the Swale was delineated into its component ecosystems, showing that the Swale is predominantly wetland and grassland – 44% (138 ha) and 39% (122 ha) respectively – with the remaining components split between woodland, cropland, and manufactured features. The first benefit transfer used 36 ecosystem services from 20 studies to value four prioritised ecosystem services at $1.63 million per year. A follow-up to this benefit transfer used 186 values from 54 sources to value 17 ecosystem services at $7.36 million per year. Natural hazard mitigation was found to be the most valuable ecosystem service and wetland portions of the Swale are found to be the biggest contributor of value. Finally, a hedonic regression of the housing market surrounding the Swale indicated no statistically significant impacts from the Swale on nearby housing prices. However, despite the statistical insignificance, the model indicated that single-family detached homes within a 400 m walking distance of the Swale had an average increase to property value of $4,166; homes between a 400 and 800 m had an average decrease to property value of $5,689; and an unimpeded view of the Swale resulted in an average decrease of $636.

Both methods considered in this thesis may be considered to be efficient methods for valuing Saskatoon's natural capital. Benefit transfer is extremely efficient, despite its inherent uncertainty, while the hedonic pricing method is a strong site-specific method for valuing cultural ecosystem services, despite not providing significant results for the parameters of interest in this specific

scenario. These analyses are not directly comparable, but their combined information allows for a greater understanding of the benefits provided by natural resources.

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List of Abbreviations

AC: Avoided Cost

CAD: Canadian Dollar

CV: Contingent Valuation

CVM: Contingent Valuation Method

ESVD: Ecosystem Service Valuation Database

EVRI: Environment Valuation Reference Inventory

MEA: Millennium Ecosystem Assessment

NCAV: Natural Capital Asset Valuation

NGO: Non-Government Organizations

PAH: Polycyclic Aromatic Hydrocarbon

RC: Replacement Cost

SSR: South Saskatchewan River

SWM: Stormwater Management

TBL: Triple Bottom Line

TCM: Travel Cost Method

TEEB: The Economics of Ecosystems and Biodiversity

UAV: Unmanned Aerial Vehicle

UN: United Nations

USD: United States Dollar

US EPA: United States Environmental Protection Agency

Chapter 1: Background and Literature Review

The Meewasin Northeast Swale (Swale) – shown in Figure 1.1 – is a significant natural area under the management of Meewasin and located in the northeast of Saskatoon, Saskatchewan, Canada. Suburban sub-divisions have been developed to the southern edge of the Swale and are planned to continue north of the Swale. High-volume roadways cross through the Swale, fragmenting the natural prairie and wetland, while a major highway through the Swale is currently in the planning stages. Yet, there has been no major exploration of the impacts this development has had, and will have, on the Swale's ecosystems. Anticipated impacts include fragmentation, contamination from stormwater runoff and construction, noise and sound pollution, and invasion of exotic species, potentially resulting in the loss of wildlife, plant life, and ecosystem function. Determining the value – economic, ecological, and sociocultural – of the Swale in monetary terms will allow for its managers to better understand the impacts of past, present, and future management decisions. This understanding not only informs future management decisions for the Swale but can also be used to inform the management of other natural resources in Saskatoon. The objective of this thesis is to determine the value of the Swale's natural capital, while investigating how natural capital asset valuation (NCAV) may be applied to Saskatoon's resources and assist in pragmatic decision making by relevant stakeholders.

This background and literature review will cover the following topics:

- *Study Area:* The Swale is in the northeast of Saskatoon, Saskatchewan, Canada. Saskatoon has a population of approximately 272,000 (City of Saskatoon 2019) and is in the geographic south and population centre of Saskatchewan. The Swale is managed by Meewasin, a provincially mandated conservation agency tasked with conserving the cultural and natural resources of the South Saskatchewan River Valley in and around Saskatoon. The Swale is currently being managed according to a *Master Plan* written by Meewasin in 2015. The Swale is an approximately 310 ha area of interspersed native prairie, woodland, and riparian wetland. Three neighbourhoods border the Swale to the south: Silverspring, Evergreen, and Aspen Ridge. Further residential development is planned on the north border of the Swale, five roads cross through the Swale, and, in addition, a high-volume perimeter highway is tentatively planned to be constructed through the Swale.

- *Natural Capital Asset Valuation (NCAV):* Many of the natural processes of ecosystems directly or indirectly benefit people which are designated as ecosystem services. Ecosystem services include a range of benefits such as food provisioning, flood prevention, carbon sequestration, pollination, photosynthesis, and recreation values, among others. NCAV is the process of determining the value of a natural resource (or *natural capital*) and the ecosystem services provided by that resource. This value is typically a combination of economic, environmental, and sociocultural values, allowing for a triple-bottom-line approach to environmental resource management. NCAV is achieved through a variety of non-market valuation methods. The field of NCAV is relatively new, but is gaining interest in academic, industry, and governmental sectors.
- *Thesis Overview:* The goal of this thesis is to explore practical methods of NCAV by applying them to an urban natural resource in Saskatoon: the Meewasin Northeast Swale. The research presented in this thesis is divided into four chapters: the current background and literature chapter; a manuscript chapter 2 on a benefit transfer method using *a priori* professional judgement of relevant ecosystem services; a manuscript chapter 3 comparing an updated *posteriori* benefit transfer method with a hedonic pricing method; and a final chapter on potential anthropogenic impacts on the Swale, proposed monitoring strategies, the engineering significance of this research, and future research.

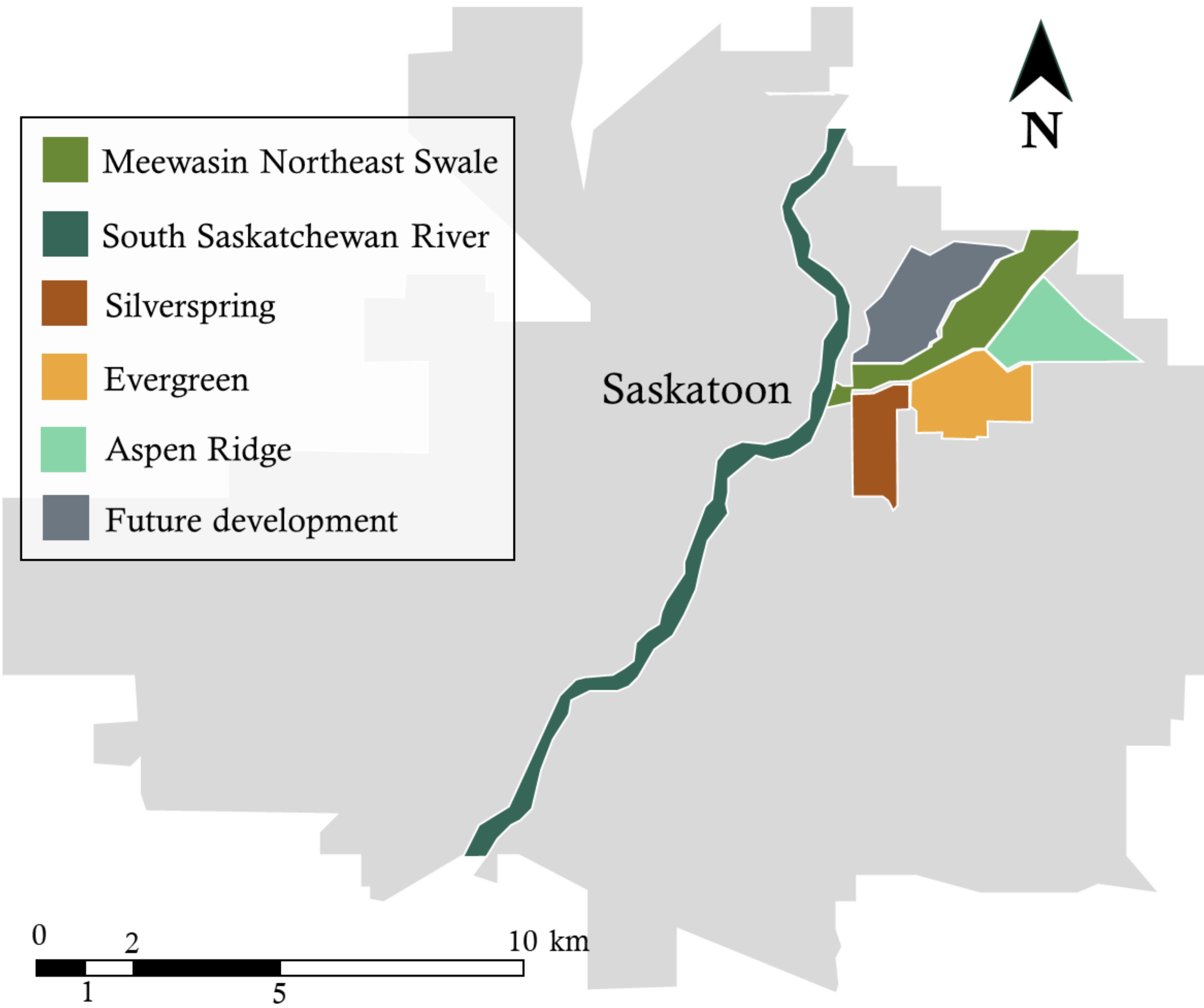

Figure 1.1: The Northeast Swale and surrounding developments with respect to Saskatoon and the South Saskatchewan River (52°08’N, 106°41’W)

1.1 Study Area

1.1.1 City of Saskatoon

Saskatoon (52°08′N 106°41′W) – shown in Figure 1.2 – is a city in the geographic south and population centre of Saskatchewan. This is a semi-arid region that annually experiences temperatures from -35 °C to 35 °C. Snowfall accounts for a significant portion of the region's annual precipitation and spring snowmelt is a major source of runoff, resulting in erosion, flooding, and contaminant transport risks. Saskatoon is the largest city in Saskatchewan with an estimated population of 272,000 as of July 2019 (City of Saskatoon 2019) and had a 5-years population growth rate of 16.5% between 2011 and 2016 (Statistics Canada 2018). Although this rate has been declining more recently, it is among the highest growth rates for Canadian cities (City of Saskatoon 2019). Most dwellings in Saskatoon are single detached homes – 56.2%, while apartments in buildings with five or more storeys contribute to less than 5% of dwellings (Statistics Canada 2018). Over 80% of commuters in Saskatoon drive cars, trucks, and vans as their primary source of transportation, while 5% of commuters rely primarily on public transit and about 8% bike or walk as their primary means of transportation (Statistics Canada 2018).

Saskatoon is located along the South Saskatchewan River (SSR), with the river running from south to north through the centre of the city. The SSR originates from the confluence of the Bow and Oldman Rivers in southeastern Alberta (49°56′00″N 111°41′30″W), further originating from the Rocky Mountains in Alberta, British Columbia, and Montana. Cities of note that these rivers pass through prior to Saskatoon include Calgary, Alberta (51°03′N 114°04′W), Lethbridge, Alberta (49°41′39″N 112°49′58″W), and Medicine Hat, Alberta (50°02′30″N 110°40′39″W). The SSR merges with the North Saskatchewan River to form the Saskatchewan River east of Prince Albert in central Saskatchewan (53°14′6″N 105°4′58″W). The largest town the Saskatchewan River passes through is Nipawin, Saskatchewan (53°21′26″N 104°01′01″W) before the river empties into Lake Winnipeg (53°11′6″N 99°15′22″W) in Manitoba.

Figure 1.2: The geographic location of Saskatoon (green) within Saskatchewan and Canada. Additionally, the Rural Municipality of Corman Park (dark grey) – containing Saskatoon (green) – and the Rural Municipality of Aberdeen (light grey) form the home of the Greater Northeast Swale.

With its location along the SSR, the preservation of the South Saskatchewan River Watershed is a major priority for Saskatoon (Saskatchewan Watershed Authority 2007). The City of Saskatoon has many environmental initiatives, such as its Climate Adaptation Plan (City of Saskatoon 2016), a state-of-the-art nutrient removal system at the Saskatoon Wastewater Treatment Plant (City of Saskatoon 2018b), and a Wetland Policy (City of Saskatoon 2013) and the City is currently developing a stormwater management plan (City of Saskatoon 2018c) and a wide-spanning Green Strategy (formerly called the Green Infrastructure Strategy) (City of Saskatoon 2018a). Additionally, Saskatoon is situated on Treaty Six Territory and the Homeland of the Métis, and any management decisions should acknowledge and be mindful of this history and seek to promote reconciliation through planning and practice.

1.1.1.1 Meewasin

Meewasin – formerly the Meewasin Valley Authority – is a provincially mandated conservation agency in Saskatchewan. Meewasin was created in 1979 through a collaboration between the City of Saskatoon, Government of Saskatchewan, and University of Saskatchewan to manage the Meewasin Valley in the South Saskatchewan River Basin (Meewasin 2018a). Meewasin's mission is to "ensure a healthy and vibrant river valley, with a balance between human use and conservation" (Meewasin 2018a).

Meewasin follows five guiding principles in its planning and management:

- Accessibility for everyone;
- Conservation of natural and heritage resources;
- Balancing human use with conservation;
- Fostering diverse interactions with nature for a varied and changing demographic; and
- Engaging public participation in planning. (Meewasin 2018a)

Meewasin's jurisdiction, called the Meewasin Valley Conservation Area, extends 30 km northeast and 14 km southwest from Saskatoon along the SSR and covers 6,700 hectares (Meewasin 2018b). The Meewasin Valley Conservation Area is home to many recreational, interpretive, and heritage sites, such as the Meewasin Northeast Swale, Saskatoon Natural Grasslands, Cameco Meewasin Skating Rink, River Landing, and the extensive Meewasin Trail.

1.1.2 The Meewasin Northeast Swale

The Meewasin Northeast Swale is a channel scar covering 310 ha in the Northeast of Saskatoon. The Swale extends 5 km from Peturrson's Ravine along the SSR to the northeast city limits. The Meewasin Northeast Swale then continues as the Greater Northeast Swale another 21 km northeast through the Rural Municipalities of Corman Park and Aberdeen. The Swale was formed as a drainage passage during the last glacial retreat about 15,000 years ago. This span of unbroken prairie, forest, and riparian wetland is a geologically and ecologically unique area – not only in the scope of Saskatoon, but within the Greater Prairie Region (Meewasin 2015). Native grasslands are regarded as one of the most endangered ecosystems on the planet (Gauthier and Riemer 2003) and over 50% of wetlands in the Prairie Pothole Region – shown in Figure 1.3 – have been drained (US EPA 2018). The Swale not only hosts these endangered ecosystems, but also a diverse range of over 200 plant species, over 100 bird species, mammals, amphibians, reptiles, and insects (Meewasin 2017). This flora and fauna includes several rare, endangered, or culturally significant species, including:

- *Plants*: crowfoot violet; western red lily; narrow-leaved water plantain; and sweet grass.
- *Birds*: Sprague's pipit; barn swallow; loggerhead shrike; horned grebe; short-eared owl; common nighthawk; and sharp tailed grouse.
- *Amphibians*: northern leopard frog. (Meewasin 2017)

The Swale is owned by the City of Saskatoon, managed by Meewasin, and is the focus of this current thesis. The remaining area composing the Greater Northeast Swale is under the jurisdiction of the Rural Municipalities of Corman Park and Aberdeen (Meewasin 2015). Including the area outside of the Meewasin's jurisdiction into future studies would be a pragmatic method to expand upon this research in the future and could highlight the importance of interagency collaboration in environmental management, as ecosystems are not reliant upon municipal borders.

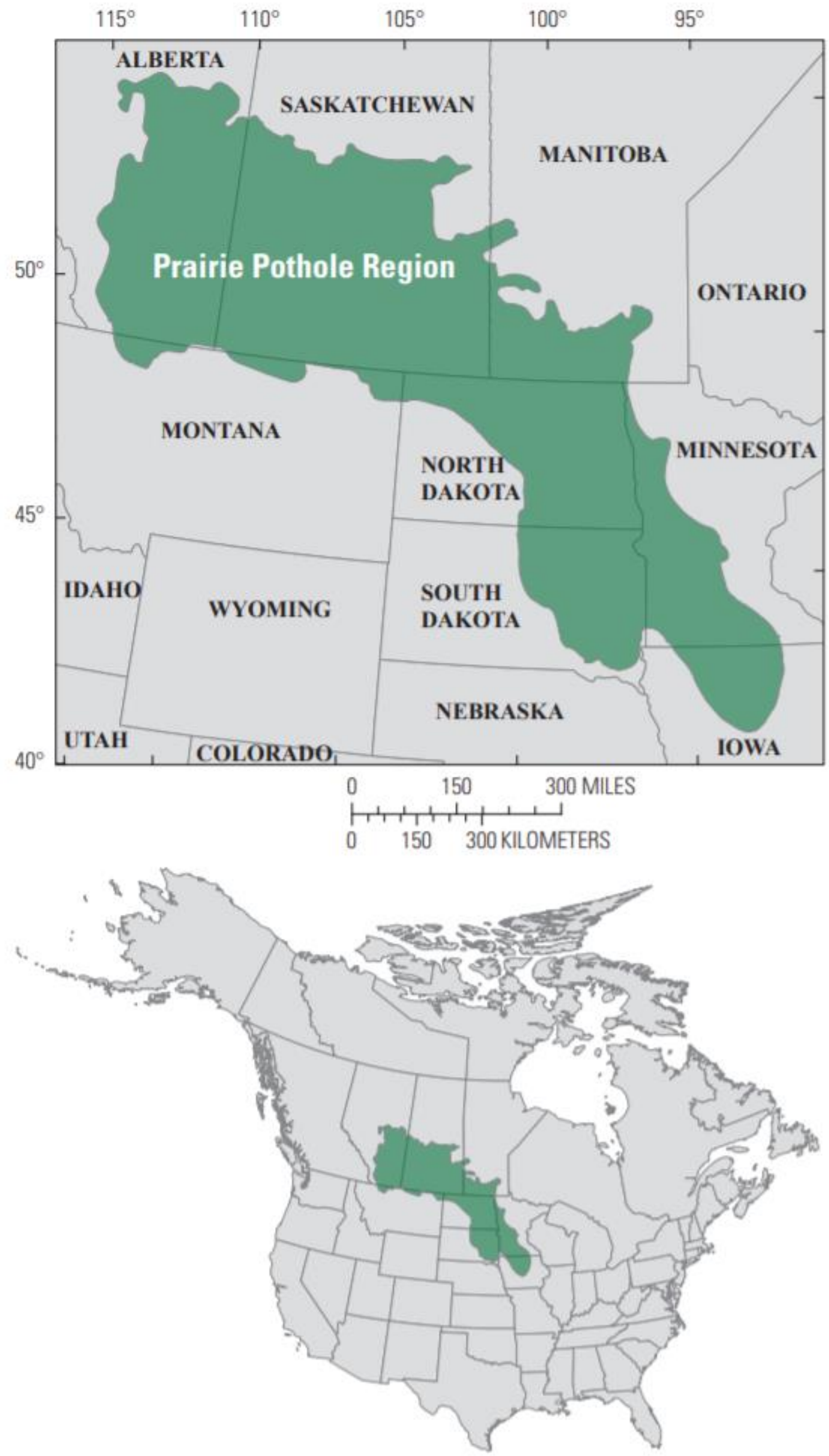

Figure 1.3: Prairie Pothole Region, shown extending from Alberta to Iowa and including the area of the Meewasin Northeast Swale (Renton et al. 2015)

1.1.2.1 Master Plan

A Master Plan for the future of the Meewasin Northeast Swale was developed by Meewasin in 2015. The Plan covers the portion of the Swale within the City of Saskatoon, and was created with goals of conserving biodiversity, fostering ecological education, interpreting nature and cultural history, supporting recreation, and supporting a communication plan (Meewasin 2015). Major design considerations included minimizing site fragmentation, accommodating wildlife corridors, and maintaining nocturnal lighting, as well as providing accessibility, safety, and connectivity for pedestrians (Meewasin 2015). The Master Plan is only conceptual in nature presenting general goals, ideas, and considerations but requiring detailed design as development of the Swale continues (Meewasin 2015).

The Meewasin Northeast Swale Master Plan (Meewasin 2015) proposes the following amenities to meet the design goals and criteria:

- The Greenway – a combination of trail corridor, ecological buffer, and transition zone surrounding the perimeter of the Swale;
- A network of primary, secondary, and tertiary trails – including a boardwalk in some areas – providing a balance between accessibility and conservation;
- Parking areas off-site;
- Seating, picnic areas, waste receptacles, and washroom facilities;
- Informational and interpretive signage; and
- An Outdoor Education Staging Area.

1.1.2.2 Anthropogenic Impacts

The Swale is a current area of focus for the managers of the City of Saskatoon and its population due to the encroaching sub-division development on its borders. Figure 1.1 shows the location of the Swale and its surrounding developments. The oldest sub-division of Silverspring was developed between 1986 and 2001. Evergreen began development in 2010 and is nearing completion, while Aspen Ridge began development in 2014. Future developments are planned to the north of the Swale as part of the University Heights Suburban Development Area. Although there have been developments around the Swale for over 30 years, there has not been any substantive monitoring of the impacts this development is having on this delicate and valuable system. This development is potentially both beneficial and detrimental to the determined value of the Swale, as proximity to the Swale allows for easier access to the Swale and its services, but may lead to the degradation of the ecosystem (and degradation of the Swale's ability to provide value) if protection of the Swale from negative impacts is poorly managed.

There are several potential anthropogenic impacts of concern for the Northeast Swale with fragmentation being one major concern (Consgrove 2018; Hooftman et al. 2003; Liernert and Fischer 2003). Fragmentation is the structural division of a habitat into smaller, potentially isolated habitats (Consgrove 2018). Central Avenue has already separated the Swale from the river, while several range roads further divide the Swale into smaller areas. As the area north of the Swale is developed, the traffic on roads through the Swale will increase. In addition to this, the North Commuter Parkway crosses through the Swale, and a proposed perimeter highway will further fragment the Swale if constructed. These roads are problematic because they can prevent the natural migration of wildlife and interrupt ecosystem processes, potentially causing degradation of the ecosystem. The encroachment of development around the Swale also alters the hydrological characteristics of the area. Urbanisation typically leads to larger runoff volumes and greater peak flows in response to storm events. Further, manufactured drainage infrastructure typically results in a faster response time, meaning earlier peak flows. Additionally, runoff from urbanised areas may introduce contaminants to the Swale, causing degraded water quality (Howitt et al. 2014). Human presence also means a risk of introducing exotic species, which can dramatically alter ecosystems (Ehrenfeld 2008). Human use of the Swale may also directly lead to the damage and displacement of wildlife. Noise and light from surrounding neighbourhoods and roadways are other anthropogenic impacts of concern which may affect natural processes (Newport et al. 2014).

1.2 Natural Capital Asset Valuation

Natural capital asset valuation (NCAV) is a rapidly growing area of interest for many Canadian municipalities (e.g. Machado et al. 2014; Kyle 2013). NCAV is the process of determining the value of a natural resource (natural capital), often for the purpose of financial accounting or environmental management. This value encompasses economic, environmental, and sociocultural benefits provided by natural capital: benefits that are known as *ecosystem services* (MEA 2005). The City of Saskatoon currently has extensive areas of natural capital that are largely unaccounted for economically. Valuing the Swale would allow for the City to better estimate its current economic value, while indicating the potential damage of development surrounding the Swale, which would allow for better informed management of the Swale in the future. In addition, this process could be extended to other natural resources, informing future decisions regarding other natural areas in the City. Valuing the Swale is an opportunity to develop a framework for the managers from the City of Saskatoon to integrate NCAV in all areas of Saskatoon. Ecosystem services and the non-market valuation techniques used for NCAV are discussed in this section.

1.2.1 Ecosystem Services

Ecosystems provide value through "ecosystem services" as presented in the Millennium Ecosystem Assessment (MEA 2005). Ecosystem services are defined as the contribution5s that ecosystems make to human well-being (TEEB 2010) that are generally divided into four main categories:

- *Provisioning*: Production of food, timber, fibre, and other "goods";
- *Regulating*: Examples include flood control, water regulation and purification, air quality purification, pollination, pest control, and climate regulation;
- *Cultural*: Services which enhance recreation, aesthetic, science, education, cultural identity, and sense of place; and
- *Supporting*: Indirectly benefit humans through maintenance of basic ecosystem processes and functions, necessary for provisioning, regulating, and cultural services. (MEA, 2005; Costanza 2012)

The term ecosystem services was first presented in 1981 (Gómez-Baggethun et al. 2010, Ehrlich and Ehrlich 1981), however, the general concept had been developed in the 1950s and possibly earlier. Ecosystem services differ from ecosystem processes and functions in one key aspect; while ecosystem processes and functions exist regardless of whether there is a human benefit, ecosystem services only exist if they benefit human well-being (Costanza 2012). Ecosystems which provide ecosystem services may be called natural capital. Natural capital does not require human activity to build or maintain, but must be combined with other forms of capital, requiring human interaction, for benefits to be realised (Costanza 2012). These other forms of capital include built or manufactured capital, human capital, and social or cultural capital (Costanza 2012).

Figure 1.4 includes a list of potential ecosystem services provided by the Swale (Meewasin 2015; Ramsar 2011), adapted from a general list by Raymond (2009). This list illustrates the wide range of services provided by the Swale and highlights how complicated the valuation of such a resource can be for stakeholders. These services range from use to non-use, market to non-market, and actively to passively reaped. Many of the services described in the figure have overlap or support the propagation of other services. These interactions between services introduces a challenge for determining a single economic value, as it is possible to double-count the benefits of related and interacting services. Finally, the benefits are provided to many different stakeholders – some close and others remote. For example, water purification and treatment benefits users downstream, while recreational use of the Swale benefits users at a local scale. This dynamic of different services benefitting different end-users is an aspect that must be considered when using NCAV to inform environmental decision making. For example, stakeholders may prioritise ecosystem services that directly provide value over those that indirectly provide value and/or provide value to non-stakeholders. The following section is a brief overview of each ecosystem service or category, providing an overview of how ecosystems provide these services and how these services benefit humans.

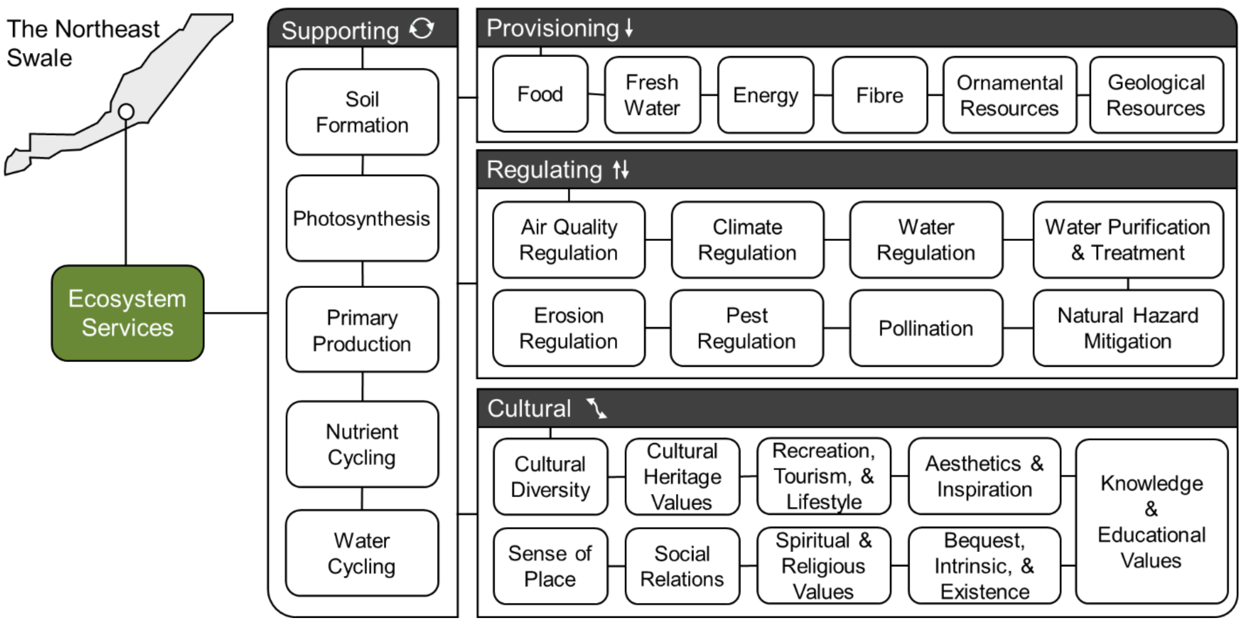

Figure 1.4: Typography of all potential ecosystem services of Swale divided into the four categories of ecosystem services

1.2.1.1 Air Quality Regulation

Air quality regulation refers to an ecosystem's ability to filter particulate and other contaminants from the atmosphere, improving local air quality. Ecosystems can both contribute chemicals and remove chemicals from the atmosphere. This is generally a strength of forests and woodlands but is also an important service provided by wetlands and grasslands. Ecosystems provide air quality regulation through acting as a sink for tropospheric ozone, ammonia, nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter, and methane (CH_4) (MEA 2005). The proximity to ecosystems increases the ability for humans to benefit from this service, but the greater presence of contaminants may result in the degradation of an ecosystem's ability to regulate air quality (MEA 2005).

1.2.1.2 Climate Regulation

This service is the Swale's ability to cycle and sequester carbon – mostly in the form of carbon dioxide (CO_2) – from the surrounding atmosphere. Climate regulation may influence both local and global climate. An ecosystem may sequester or release greenhouse gases, both potentially impacting climate at a regional or greater scale (MEA 2005). Temperature regulation in the area of an ecosystem is an example of local climate regulation, though this specific sub-service tends to receive less attention. Additionally, changes in land cover can affect local precipitation through alterations in the water cycle (MEA 2005), but this change is also not widely studied in the context of NCAV.

1.2.1.3 Water Purification and Treatment

Water purification and treatment describes the Swale's capacity to naturally purify water through processes such as nutrient cycling, clarification, and other mechanical, chemical, and biological processes. Loss of wetland ecosystems has contributed to the long-term global decline in water quality (MEA 2005). Water purification and treatment provides value through the avoided necessity of expensive water treatment and the reduction of risk of health issues from consuming and contacting contaminated waters.

1.2.1.4 Water Regulation

The Swale's water regulation capacity describes the Swale's ability to attenuate flows, store water, and respond to stochastic environmental inputs. Land cover influences the timing and magnitude of runoff, storage, infiltration, and aquifer recharge (MEA 2005). Humans gain value from water regulation due to its contributions towards creating habitat, enabling provisioning of water, mitigating natural disaster, and supporting water treatment.

1.2.1.5 Erosion Regulation

The ability of an ecosystem to prevent erosion is important, as it decreases landscape degradation and runoff contamination. This service is generally attributed to ecosystems with robust vegetation cover and adequate water regulation capacity. Land use change can result in increased erosion, which may result in increased runoff contamination and less suitable soil conditions for plant life (MEA 2005). Erosion regulation provides value indirectly to humans through the reduction of contamination and support of other services through increased structural resilience.

1.2.1.6 Pest Regulation

Pest regulation describes the ability of an ecosystem to regulate populations of pest animals, while animals that are considered pests are dependent on the land-use of surrounding areas. However, ecosystems with productive pest regulation are generally those with strong interconnectivity allowing for different demographics to interact and maintain ideal metapopulations. Changes in land use affects the prevalence of crop and livestock diseases (MEA 2005). Proximity to ecosystems allows for the appreciation of pest regulation services through the avoidance of pest-related damages.

1.2.1.7 Pollination

Pollination is an important ecosystem service for both the survival of the ecosystem and for the propagation and growth of plant-life in surrounding areas. Effective pollination requires an interconnected ecosystem with suitable habitats for pollinators. Changes to ecosystems affect the distribution and effectiveness of pollinators in the area. Losses in specialised pollinators may directly, detrimentally affect the reproductive ability of some rare plants (MEA 2005). Pollination contributes value to humans by increasing seed and fruit production within an ecosystem and in its surrounding areas.

1.2.1.8 Natural Hazard Mitigation

Natural hazard mitigation is an important ecosystem service describing the ability of an ecosystem to protect itself and surrounding areas from extreme natural weather events such as floods, droughts, and fires. It also describes the ability of an ecosystem to continue to function and provide services after such an event, in addition to recovering from damage. As an example, for coastal ecosystems, such as mangroves, natural hazard mitigation describes the reduction of damage from tropical storms and large waves (MEA 2005). Humans gain value from natural hazard mitigation through avoided costs that would have been incurred without the presence of that ecosystem.

1.2.1.9 Cultural Ecosystem Services

Figure 1.7 displays potential methods that cultural ecosystem services are benefitted by the Swale. These services can be difficult to separate, and their exact definitions vary greatly in the literature, thus they are grouped together herein. These services range from use to non-use and the ecosystem characteristics that contribute to each service vary from place-to-place and ecosystem-to-ecosystems. The benefits gained from cultural ecosystem services are non-economic such as spiritual enrichment, recreation, aesthetic experience, and cognitive development (MEA 2005).

1.2.1.10 Provisioning Ecosystem Services

Provisioning ecosystems describe the products obtained from ecosystems, such as food, fibre, fuel, and water. The provisioning of energy and resources is instrumental to the world's economies. As populations continue to grow while available productive land decreases, the importance of provisioning services will continue to rise (MEA 2005). However, provisioning services are not a large source of value for the Swale in particular, so they are not considered within this thesis.

1.2.1.11 Supporting Ecosystem Services

Supporting services maintain ecosystem functionality such that ecosystems may continue to provide other more easily identified ecosystem services. Unlike the other categories of ecosystem services, supporting services indirectly provide value or may occur over large timescales making them difficult to assess. Some regulating ecosystem services discussed above also act as supporting ecosystem services, depending on the timescale applied (MEA 2005). Because the value of supporting ecosystem services is appreciated as part of the benefits from the other ecosystem services these services support, supporting services are not directly valued or examined in this thesis.

1.2.2 Ecosystem Service Valuation

Placing a monetary value on nature is often considered to be a controversial area of research. However, the valuation of municipal natural resources is generally done for their protection from negative impacts rather than as a means of their commodification. However, value of natural areas is fundamentally about individual preferences including supply and demand. Nonmarket ecosystem service valuation is no different from conventional market-based valuation in this respect. The difference is that there is not always an easily observable, impartial market to ascertain preference from for ecosystem services. The challenge, then, is obtaining individual preferences to assist in placing a value through alternative means (Segerson 2017). When ecosystem service values are not quantified, these services can be used and degraded without compensation for the gain of those benefiting the service and the detriment of those losing a particular service. This inequality is a failure of a market's ability to account for externalities: unintended and uncompensated positive or negative impacts. Generally, laws and regulations by governing bodies are used to avoid these failures, using information about the value of the ecosystem services to help address the failures (Segerson 2017).

Most nonmarket valuation techniques were first used in the United States in the 1950s (Segerson 2017). Nonmarket valuation was substantially pushed forward in the 1980s through the passing of the *Comprehensive Environmental Response, Compensation, and Liability Act* (1980) and *Executive Order 12291* (1981) in the United States (Segerson 2017). The *Comprehensive Environmental Response, Compensation, and Liability Act* required the assessment of damages to natural resources from contaminant releases and spills (Kopp and Smith 1993; Portney 1994), while *Executive Order 12291* required the completion of benefit-cost analyses for proposed major regulations (Smith 1984). These acts/orders, and subsequent government policies, encouraged nonmarket valuation research, although it remained primarily used by economists until the early 2000s when the advent of Costanza et al. (1997) and the Millennium Ecosystem Assessment (2005) increased interest in nonmarket valuation for ecologists and other non-economists (Segerson 2017).

Several different nonmarket ecosystem service valuation methods exist, most with a history in environmental and natural resource economics dating back to the 1950s (Segerson 2017). Nonmarket valuation methods are divided into two major categories: revealed preference and stated preference. Revealed preference methods estimate value by observing behaviour (often through indirect market activity) and inferring value from those revealed preferences (Segerson 2017). Stated preference methods generally involve asking individuals questions related to their preferences and inferring values from the responses (Segerson 2017). An important difference between these two categories is the type of services they can value. Because revealed preference methods require observable behaviour, these methods can only value use services, whereas stated preference methods can account for both use and non-use services (Segerson 2017). Additionally, different nonmarket valuation techniques require different amounts of resources (time, money, and data), meaning that the feasibility and appropriateness of each method varies and is dependent on the needs of the decisionmaker and the nature of the resource (Segerson 2017). No single nonmarket valuation method is suitable for all valuation needs. In fact, multiple valuation methods may be necessary or preferable for some valuation scenarios, although caution must always be taken not to double count benefits when aggregating values (Segerson 2017). The following section is an examination of a limited selection of the different valuation methods that could potentially be applied to the Swale or other natural areas in Saskatoon and beyond.

1.2.2.1 Benefit Transfer

The benefit transfer method utilises ecosystem service values from previous study sites to estimate the value of another site (Richardson et al. 2015). The methodology is one of the newest techniques discussed herein, originating in the 1980s (Rosenberger and Loomis 2017), and motivated by the increased need for nonmarket valuation after the passing of *Executive Order 12291* (see Freeman 1984). Benefit transfer was formalised in 1992 when many top resource economists collaborated on a section on benefit transfer for the journal Water Resources Research (Rosenberger and Loomis 2017). Through the 1990s, benefit transfer was used for natural resource damage assessments in the United States judicial system (Rosenberger and Loomis 2017). Meanwhile, new benefit transfer methods and applications were being presented through the 1990s (Rosenberger and Loomis 2017), with a seminal study by Costanza et al. (1997), *The Value of the World's Ecosystem Services and Natural Capital* using benefit transfer to estimate the total value of the biosphere at $16-54 trillion per year. This study was the most ambitious use of benefit transfer to date and greatly increased the general interest in benefit transfer and nonmarket valuation. New government regulations and directives have continued to increase the need for efficient nonmarket valuation such as a benefit transfer with an increasing utilisation of ecosystem service value databases – such as the Ecosystem Service Valuation Database (ESVD) developed by TEEB in 2010 (Van der Ploeg and de Groot 2010) – for benefit transfer (Rosenberger and Loomis 2017).

Benefit transfer allows for the relatively simple valuation of ecosystem services making it a pragmatic methodology for decision-makers in the early stages of NCAV (Johnston et al. 2015).

Furthermore, the natural capital valued through benefit transfer may be of a much larger scale than the source studies through extrapolation and combination of many smaller studies (see Costanza et al. 1997). Conversely, benefit transfer may be used to interpolate between many marginally related studies to evaluate a specific area that has not been studied previously. However, benefit transfer is dependent on the quality of the data from the previous studies and professional discretion in selecting which data to use, creating a large amount of uncertainty in benefit transfer economic values. Interestingly, meta-analysis shows that many benefit transfer studies aggregate the results of several different studies with the assumption that this aggregation will reduce the error present (Johnston et al. 2015), as opposed to selecting a single *best-fit* analogue study for each ecosystem service. Regardless of the steps taken to minimise error, reporting benefit transfer results in a manner that recognises the inherent uncertainty is important. Given this method's efficiency, benefit transfer is a pragmatic choice as a first estimate of NCAV, allowing for decision makers to consider a range of potential values before continuing with more intensive methods of NCAV.

1.2.2.2 Contingent Valuation Method (CVM)

Contingent Valuation Method (CVM) is a stated preference method of nonmarket ecosystem service valuation where questions are asked of individuals to determine their willingness to pay or accept for an ecosystem good or service. This method is one of the most commonly used nonmarket valuation techniques (Boyle 2017). CVM's earliest uses were for recreational services (e.g. Davis 1963; Cicchetti and Smith 1973; Hammack and Brown 1974), with services later expanding to health, cultural values, and other nonmarket services (Boyle 2017). CVM has been subject of professional disagreements over its validity, with those critical of CVM suggesting that 'hypothetical questions can only receive hypothetical answers' (Boyle 2017). Despite this criticism, CVM became widely known for being used for the natural resources damage claim for the Exxon Valdez oil spill (Boyle 2017). To address critiques of CVM, there has been a focus on creating recommendations for how CVM studies should be designed and conducted. For example, recommendations were provided previously by a prominent National Oceanic and Atmospheric Administration panel (Arrow et al. 1993). More recently in 2012, the Journal of Economic Perspectives published a special section reviewing the past 20 years of CVM. Contributions to this section showed conflicting results varying from the conclusion that CVM has experienced 'promising progress and that well developed CVM results are more useful than no results' (Kling et al. 2012), to a continued highlighting of the issues of hypothetical bias and scoping problems (Hausman 2012).

Stated preference methods for the valuation of ecosystem services are one of the only options for valuing non-use goods (Segerson 2017). CVM involves surveying a group of people and asking them how much they are willing to pay to help maintain the existence of a resource. An alternative method is to ask how much they would be willing to accept to lose a resource. CVM studies involve constraints and trade-offs. The constraints come from the hypothetical nature of the scenarios considered, while trade-offs are involved in the balancing of clear, objective survey scenarios with approachable brevity (Boyle 2017).

1.2.2.3 Hedonic Pricing

The hedonic pricing method is a revealed preference method, based upon the assumption that the market price of a product is defined by the sum of its attributes' marginal values (Rosen 1974). The variation in product characteristics leads to variation in product price, allowing for the observation of trade-offs made for changes in specific product characteristics (Taylor 2017). Hedonic pricing is the earliest known valuation method used for an analysis of quality factors influencing asparagus prices in 1928 (Taylor 2017). Although the hedonic pricing method has been applied to a wide variety of market-based products, Rosen (1974) promoted the concept and theory for nonmarket hedonic pricing (Taylor 2017). Since 1974, the theory has remained essentially the same, while the feasibility and robustness of hedonic pricing has increased due to greater access to information and computational power.

The most common application of hedonic pricing for nonmarket valuation is of the use of housing markets to assess the impacts of changes in environmental factors, such as proximity to natural resources and quality of vegetation cover (Taylor 2017). Sander and Haight (2012) found the hedonic pricing analysis is a valuable method for capturing the aesthetic and recreational portions of ecosystem services, through features such as walking distance to urban parks, tree cover within a certain radius, and viewshed cover type. However, Brander and Koetse (2011) in a meta analysis of hedonic pricing studies found that there are significant regional differences for the value of greenspaces and for which type of greenspaces are most highly valued. Further, the selection of explanatory variables and spatial and temporal scope necessitates the need for professional discretion to determine greenspace value, while avoiding intercorrelated variables and double counting.

1.2.2.4 Replacement Cost

The replacement cost method is a revealed preference method of nonmarket valuation. Whereas the other methods discussed here focus on consumer behaviour (demand), replacement cost method uses data from the supply side for characteristics and production costs of goods and services (Brown 2017). The replacement cost method aims to determine one of two things: (1) the value of a service provided by public investment into improving existing natural capital or (2) the value of protecting an existing service from loss through public effort (Brown 2017). This method was established in 1958 by Eckstein who described the value of a service or product to be equivalent to the cost of providing comparable service by the cheapest available alternative, where no direct observable market exists for that service or product (Brown 2017). The theory behind this method relies on two key assumptions: (1) consumers do not want to pay more for a service than the cost of the cheapest equivalent substitute and (2) if improvement of the service through a public project would prevent the necessity of investing in an alternative, the avoided cost would be equally appreciated by all stakeholders (Brown 2017). Additionally, the suitability of replacement cost method for a good or service relies on three conditions: (1) the substitute provides the same benefit as the original service, (2) the substitute is the next lowest-cost alternative for providing the benefit, and (3) the substitute would be demanded at the available cost in the absence of the original service (Brown 2017).

1.2.2.5 Travel Cost Method (TCM)

TCM is a revealed preference nonmarket valuation method that functions on the principle that an individual's willingness to pay for a publicly available recreational service is equivalent to the cost of travelling to the site (Parsons 2017). TCM is divided between single-site models and random utility maximization models. Early use of TCM was for single-site models where trip cost was considered to be the price of the good, and number of trips taken over a season was considered the demand (Parsons 2017). Random utility maximization models, alternatively, consider individual preferences between available recreational sites, where the preference is assumed to be a function of site attributes (size, quality, amenities, etc.) and the cost of reaching the site (Parson 2017). TCM originated in the late 1950s (see Trice and Wood 1958) and was dominated by the geographic zonal model for TCM's first decade (Parson 2017). The zonal model involves delineating concentric (or otherwise spatially distinguished) zones around a single recreation site and tracking visitation rates and travel cost from each zone to determine a demand function for the site (Parson 2017). Although the zonal method is still occasionally used, there was a rise in interest for multiple site application in the 1970s (e.g. Burt and Brewer 1971; Cicchetti et al. 1976). The method has continued to be refined through the integration of simulated probability models, on-site sampling models, unobserved variable controls, bio-economic models, and consideration of modeling in willingness-to-pay space (Parson 2017).

1.3 Thesis Overview

Although NCAV is a growing field, it continues to be primarily of interest for environmental and ecological economics. However, there are recent examples of municipalities integrating NCAV into their accounting. As well, non-governmental organizations (NGOs) have worked towards creating standards for both corporate and government use. However, these standards tend to be very complicated and resource intensive to implement due to their generalised nature, and risk distracting users from the economic theory behind the NCAV. Therefore, this thesis explores practical methods of NCAV by applying them to an urban natural resource in Saskatoon: the Meewasin Northeast Swale.

Modified versions of the publications below make up Chapters 2 and 3 of this thesis, respectively.

Read, S. and McPhedran, K. 2019. The Meewasin Northeast Swale: Using natural capital asset valuation to value Saskatoon's natural resources. *Conference Proceedings for Canadian Society of Civil Engineering 2019, Laval, Quebec.*

Read, S. and McPhedran, K. 2019. Benefit transfer versus hedonic pricing: Assessing the value of an urban wetland ecosystem. [*In preparation*]

1.3.1 Chapter Two

This chapter is an adapted version of a conference proceeding manuscript which was presented at the Canadian Society of Civil Engineering's 2019 Annual Conference in Laval, Quebec. The goal of this manuscript was to develop an *a priori* benefit transfer to value the Swale and its key ecosystem services determined based on professional judgements of relevant stakeholders. The research identified a time-efficient method of NCAV, by using benefit transfer to apply previous worldwide ecosystem valuations to the Swale's most important services – as identified through professional judgement. The inherent uncertainty of this valuation method and the challenges associated with using a valuation database for benefit transfer are also discussed within this chapter.

1.3.2 Chapter Three

This chapter is an adapted version of a research manuscript currently in preparation. The objective of this manuscript was to continue exploring valuation methods for the Swale – specifically a *posteriori* benefit transfer and a new methodology of hedonic pricing analysis. The chapter two results included an initial simple NCAV assessment that may be accessible for managers of Saskatoon, and other municipalities, to value their natural resources. The chapter three provides an expansion of this benefit transfer method without consideration of *a priori* professional judgements on relevant ecosystems services, instead considering all services presented in Figure 1.4. In addition to this expansion, a novel site-specific method of hedonic pricing is also determined.

1.3.3 Chapter Four

Chapter four includes a summary of the results found in the previous chapters. Next, the risks to the Swale and its value are revisited and a proposed direction for monitoring of the Swale is presented for future consideration. The final section of this chapter includes future work opportunities for NCAV and ecosystem monitoring for the Swale and for Saskatoon's other natural areas.

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Chapter 2: The Meewasin Northeast Swale: Using Natural Capital Asset Valuation to Value Saskatoon's Natural Resources

Abstract

The Meewasin Northeast Swale (Swale) is a 26-kilometre long, 2,800-hectare span of ancient prairie, forest, and riparian wetland located partly in northeastern Saskatoon, Saskatchewan. Ancient grasslands and wetlands are endangered ecosystems and home to a wealth of biodiversity, yet this geologically and ecologically unique ecosystem is threatened by urban development including encroaching subdivisions and bisecting roadways. Despite these threats to the Swale's health, there has been no substantial environmental impact monitoring of this area. Additionally, the full value of the Swale – in terms of economic, sociocultural, and environmental value – has not been fully accounted for. There are two major objectives being addressed in this research. The first is to identify the three to five key ecosystem services provided by the Swale. The second is to estimate the monetary value provided by these key ecosystem services using a natural capital asset valuation (NCAV). Currently, we found that the Swale is 310 ha and dominated by wetlands 44% (138 ha) and grasslands 39% (122 ha) with limited areas for woodlands 6% (7.1 ha) and croplands 2% (19.8 ha). Overall, the ecosystem service valuation database (ESVD) data used for this study included 36 data points from 21 data sources that were used to determine 12 ecosystem service values. In total, the Swale's ecosystem services are valued at an estimated $1.6 million per year and are dominated by wetland ecosystems and the ecosystem services of water regulation ($1.03 M per year) and water purification and treatment ($447 K per year).

2.1 Introduction

The consideration of trade-offs is an integral part of environmental management decision making. Every day trade-offs are made, in Canada and worldwide, that can lead to the sacrifice of natural environmental health for the sake of manufactured capital gain. Every environmental management decision implicitly places a value on the natural environmental "capital" being managed, yet the full value of this natural capital – in terms of economic, sociocultural, and environmental value – is often misunderstood. This deficit of understanding leads to a lack of incentives to preserve natural capital – especially in urban areas where manufactured capital is highly valuable and natural capital is most threatened due to the lack of true assessment of its economic value. Natural capital should be accounted for, and evaluated to, support enlightened, environmentally-conscious decision making based on the services that ecosystems provide to humans. The Northeast Swale, an urban, data-scarce green space in Saskatoon, Saskatchewan – given its location within the City and the ongoing expansion of the City around this green space – is an ideal area to pilot an accessible method of natural capital asset valuation (NCAV) based on ecosystem services.

Ecosystem services are defined as the contributions that ecosystems make to human wellbeing (TEEB 2010). This is differentiated from general ecosystem functions (the natural processes of an ecosystem) by the concept of adding the additional requirement of consideration of the direct benefit to humans. Ecosystem services are commonly divided into four categories:

- Provisioning: The bestowment of goods, such as food, water, and energy. Since many of these goods are exchanged through a market, the valuation of provisioning services may often follow neoclassical market-based approaches (Farber et al. 2002).
- Regulating: Services which improve physical goods such as air and water purification, mitigate damage such as water regulation, or support productivity such as pollination.
- Cultural: The intangible benefits of ecosystems, such as contributing to sense of place, education, recreation, etc.
- Supporting: Services which serve to support the previous three categories, such as nutrient cycling and photosynthesis.

The term ecosystem services was first coined in 1981 (Gómez-Baggethun et al. 2010, Ehrlich and Ehrlich 1981), however, the general concept had been alluded to in the 1950s and possibly earlier. As indicated by the categories above, ecosystem services include both goods and services provided by ecosystems. Although the term started as a utilitarian concept used to point out that ecosystems have value, there has been an increasing shift towards the mapping, quantification, and NCAV of ecosystem services. This shift presents a challenge as determining the financial value of these services is not a straightforward process and will vary widely amongst different ecosystems.

The Meewasin Northeast Swale (Swale) is a natural area of geological and ecological significance in Saskatchewan, Canada. Urban development surrounding the Swale threatens this environmental feature, yet no substantive explorations of the impacts of this development have been conducted. The value – in terms of economic, sociocultural, and environmental value – of this natural capital is not fully accounted for. There are two major objectives being addressed in this research. The first is to identify the three to five key ecosystem services provided by the Swale. The second is to estimate the monetary value provided by these key ecosystem services. Although the estimated value of the Swale will only account for a minority of the services which contribute to the Swale's overall value, valuing only the key services is an accessible way to determine whether it is worthwhile to conduct the intensive work necessary for a more accurate valuation. This research will provide the first step in the creation of a methodology for NCAV for natural areas of the City of Saskatoon, and beyond. This NCAV will assist in the implementation of a triple bottom line (TBL) approach to development that includes financial, social, and environmental impacts and values in the decision-making process.

2.2 Methods

2.2.1 The City of Saskatoon and the Northeast Swale Study Area

The Swale is a channel scar covering 2,800 hectares and spanning 26 km from Peturrson's Ravine in northeastern Saskatoon to the Rural Municipality of Aberdeen (Figure 2.1). The Swale was formed as a drainage passage during the last glacial retreat, 15,000 years ago. This span of unbroken prairie, woodland, and riparian wetland is a geologically and ecologically unique area – not only in the scope of Saskatoon, but within the Greater Prairie Region (Meewasin 2015). Native grasslands are regarded as one of the most endangered ecosystems on the planet (Gauthier and Riemer 2003) and over 50% of wetlands in the Prairie Pothole Region have been drained (US EPA 2018). The Swale not only hosts these endangered ecosystems, but also a diverse range of over 200 plant species, over 100 bird species, mammals, amphibians, reptiles, and insects (Meewasin 2017). These flora and fauna include several rare, endangered, or culturally significant species, including (Meewasin 2017):

- Plants: crowfoot violet; western red lily; narrow-leaved water plantain; and sweet grass.
- Birds: Sprague's pipit; barn swallow; loggerhead shrike; horned grebe; short-eared owl; common nighthawk; and sharp tailed grouse.
- Amphibians: northern leopard frog.

A portion of the Swale – about 5 km long and 300 hectares in area, as shown in Figure 2.1 – lies within the City of Saskatoon city limits and the Meewasin Valley Conservation Area (Meewasin 2015). As this area is entirely owned by the City of Saskatoon, and managed by Meewasin, it serves as the current study area for this research. The remaining area of the Swale is under the jurisdiction of the Rural Municipalities of Corman Park and Aberdeen (Meewasin 2015). Incorporating the area outside of Meewasin's jurisdiction into this study area would be a great way to expand upon this project in the future but would be contingent on stakeholder engagement. Thus, the scope of this current natural capital asset valuation (NCAV) will be limited to the City of Saskatoon section of the Swale.

2.2.2 Mapping of the Northeast Swale

As for many natural green areas in urban environments, the Swale is composed of a variety of different ecosystems and human manufactured 'features' that each contribute to (or take away from) the value of the area through different ecosystem services (discussed in the following section). For the current analysis, the Swale was divided into its component ecosystems through satellite imagery interpretation of the Swale landscape. This delineation was adapted from Stantec's (2012) wetland classification of the Swale, while including the addition of new roadways and engineered stormwater management (SWM) areas that did not exist in the previous 2012 mapping. As ecosystems do not have objective boundaries, such a delineation is not intended to be perfect. Rather, this delineation is intended to provide an estimate of the percentage of the overall area of the Swale taken up by each ecosystem for use in the current ecosystem service valuation. As well, the boundaries change markedly over time (for example, with urban expansion) and need to be assessed frequently. Thus, future work for this research area will include up-to-date unmanned aerial vehicle (UAV or drone) imagery that will further refine the Swale delineation. This work is anticipated to commence in summer of 2019.

2.2.3 Identification of Key Ecosystem Services and NCAV

The valuation of the Swale was conducted using the benefit transfer method (Johnston et al. 2015, Richardson et al 2015). Benefit transfer is a method of taking other, similar existing ecosystem valuation data and applying it to an area it was not originally collected for. This benefit transfer allows for the implementation of existing data to areas, such as the Swale, where sufficient data are not readily available. Currently, the required previous study data were gathered from an existing ecosystem service valuation database (ESVD) (Van der Ploeg and de Groot 2010). The ESVD is a publicly available database of previous ecosystem valuation studies, consisting of 1,310 values from over 300 case studies, put together as part of the Economics of Ecosystems and Biodiversity (TEEB) initiative (Van der Ploeg et al. 2010).

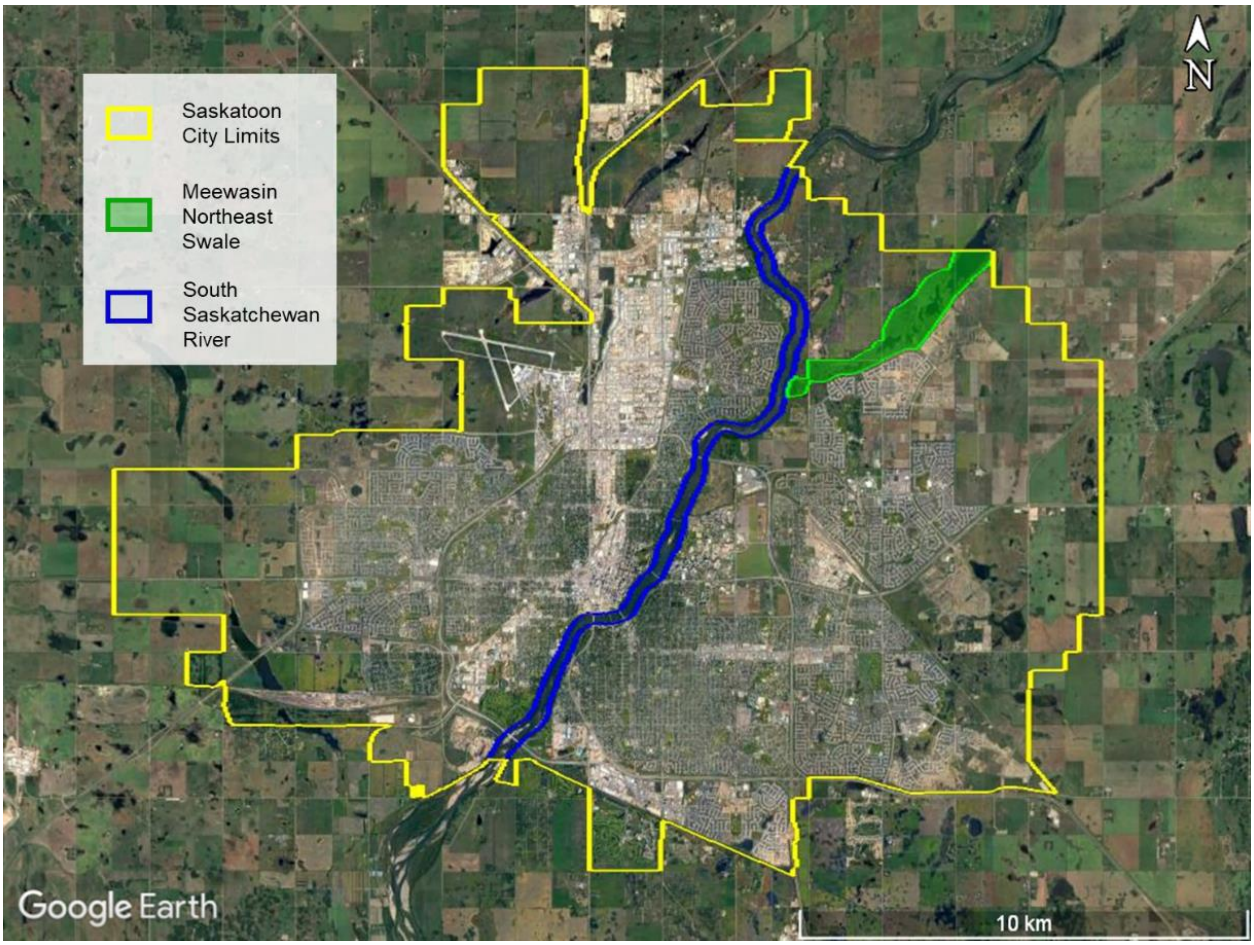

Figure 2.1: The delineation of the City of Saskatoon (yellow), the Meewasin Northeast Swale (green), and the South Saskatchewan River (blue) (52°08’N, 106°41’W)

The ESVD allows for the convenient sorting and filtering of ecosystem valuation data by ecosystem type, service, valuation method, study location, among others. The biomes and each of their respective ecosystems used for the transfer are shown in Table 2.1. Currently, values from benefit transfers were avoided, although were transferred in cases where no other suitable studies were available. Avoided cost was favoured for climate regulation and water regulation, while both avoided cost and replacement cost were used for water treatment and purification. Contingent valuation was favoured for recreation, tourism, and lifestyle, although travel cost was also included as a method for the transferred values. The specific ecosystem services, sub services and valuation methods as defined within the ESVD used in this benefit transfer are displayed in Table 2.2. Further, studies were filtered to only show those from country income groups of upper middle income, high income, and no data available. Additionally, only values reported as a currency per unit area per year (e.g., USD$/ha/y) were used as these allowed for easy extrapolation to the current study areas. Values taken were corrected for inflation (based on 2018 dollar values) and standardised to Canadian currency given the Swale location. Each of the selected studies was individually reviewed to ensure it was an appropriate analogue for the Swale; only studies deemed appropriate were then included in the analysis. Inappropriate studies were characterised by those with heavily impacted study areas, outdated methods, or statistically insignificant results. This evaluation was inherently subjective but informed by present knowledge of the Swale ecosystem. For ecosystem service combinations with multiple available studies, the average value was used (CAD$/ha/y). Finally, the values were multiplied by their calculated areas within the Swale, resulting in a value in CAD$/y. These values for each service and ecosystem and service were summed to determine an overall value for the study area. Although this method values a hypothetical, generic, pristine Swale, it functions on the assumption that the resulting value will be accurate enough to illustrate the magnitude of the Swale's worth.

Table 2.1: *A priori* ESVD biome and ecosystem selections (Adapted from Van der Ploeg and de Groot 2010)

Biome	Ecosystem
Cultivated	Other
Forests [temperate and boreal]	Forest [unspecified]
	Temperate deciduous forests
	Temperate forest general
Grasslands	Grasslands [unspecified]
	Temperate natural grasslands
Inland wetlands	Floodplains
	Peat wetlands
	Riparian buffer
	Swamps/marshes
	Wetlands [unspecified]
Woodlands	Mediterranean woodlands
	Other woodlands

Table 2.2: *A priori* ESVD ecosystem service and valuation method selections (Adapted from Van der Ploeg and de Groot 2010)

ESService	**ESSubservice**	**Value Information Valuation Method***
Climate	C-sequestration	Avoided cost Direct market pricing Mitigation and restoration cost
	Climate regulation [unspecified]	
	Gas regulation	Avoided cost Direct market pricing
Extreme events	Flood prevention	Avoided cost
Recreation	Ecotourism	Contingent valuation Direct market pricing Travel cost
	Recreation	Contingent valuation Direct market pricing Travel cost
Waste	Water purification	Avoided cost Mitigation and restoration cost PES Replacement cost
	Water treatment [unspecified]	Contingent valuation Factor income/production function Replacement cost
Water flows	Drainage	Replacement cost
	River discharge	Avoided cost
	Water regulation [unspecified]	Benefit transfer

*Benefit transfer was used where other methodologies were unavailable

2.3 Results and Discussion

2.3.1 Northeast Swale Mapping

The Swale was delineated following the mapping completed by Stantec (2012) with the inclusion of the “features” of roadways and engineered stormwater management (SWM) areas. In addition, the Swale has been separated into ecosystems including cropland, forest, grassland, and wetlands. These features and ecosystems are shown in Figure 2.2 with additional area information provided in Table 2.3.

Overall, the Swale area is 310 ha which is dominated by wetlands and grasslands at 44% (138 ha) and 39% (122 ha), respectively (Table 2.3). The remaining ecosystems have more limited areas in the Swale at 6% (7.1 ha) and 2% (19.8 ha) for woodlands and croplands, respectively. Interspersed prairie wetland and grassland provide numerous ecosystem services, including water regulation, carbon sequestration, and serve as an important breeding ground for North American waterfowl (Gascoigne et al. 2011). Although the value of woodland may most commonly be associated with timber provisioning, watershed protection and erosion regulation are perhaps the most important woodland services (Croitoru 2007). Cropland is land that has been cultivated to focus on the provisioning of food, but certain agricultural practices – such as the overapplication of fertilizers – are a risk to downstream ecosystems. Yet, cropland is not the only type of cultivated land impacting the Swale.

Manufactured features comprise of approximately 8% of the Swale area. These features include about equal areas of roadways and SWM with 4% (12.4 ha) and 4% (12.2 ha), respectively (Table 2.3). Roadways are necessary for the interconnectivity of the growing municipality of Saskatoon. However, roadways are problematic because they can prevent the natural migration of wildlife, interrupt ecosystem processes, and are potential sources of pollutant contamination (Stantec 2012). SWM takes the form of engineered wet and dry ponds within the Swale, intended to regulate and purify water from surrounding neighbourhoods during storm events and spring melt. SWM is a valuable feature within the Swale, but the influx of stormwater into the Swale from these neighbourhoods threatens the natural hydrological conditions of the Swale and the unique plant communities that are dependent on these natural conditions (Stantec 2012).

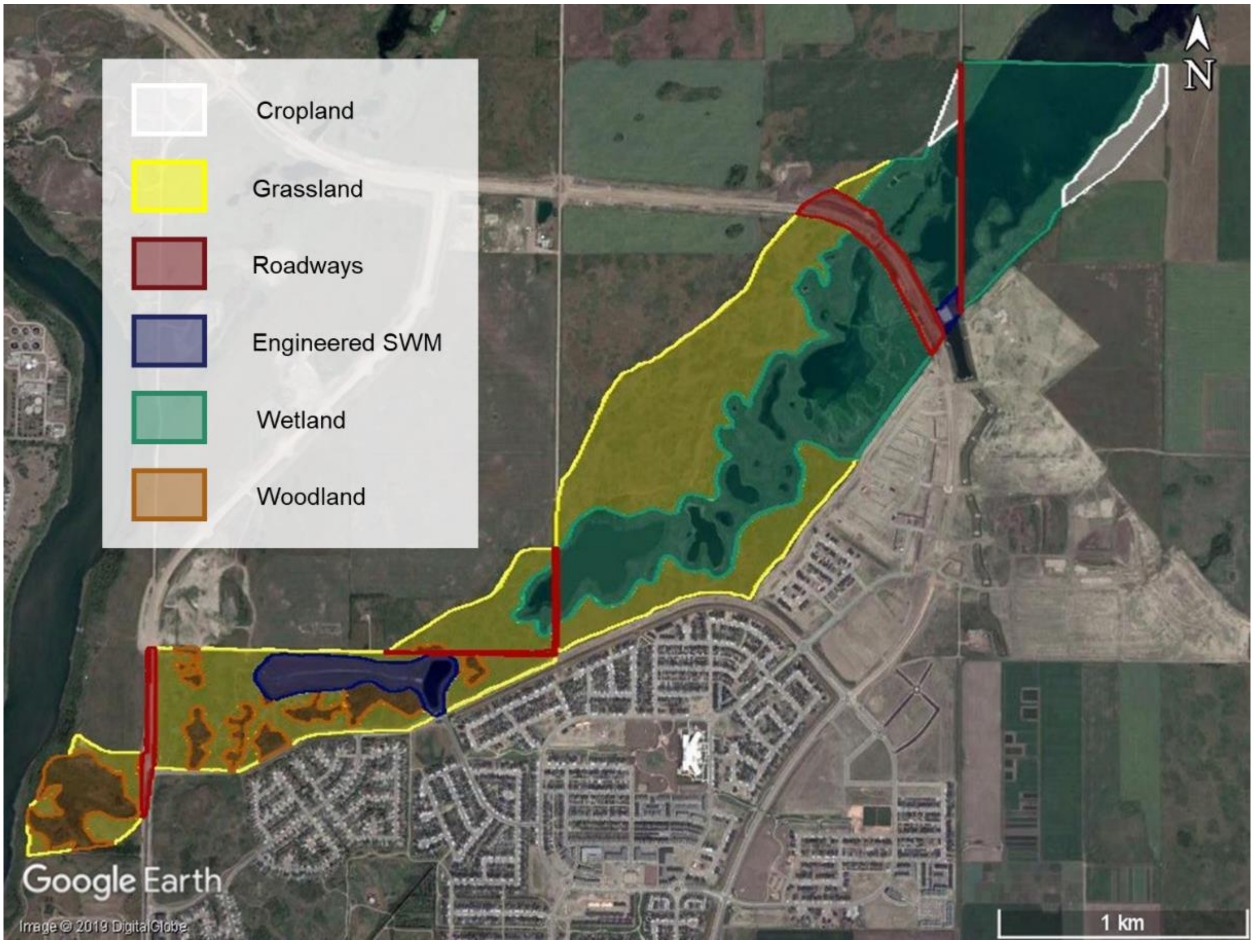

Figure 2.2: Swale ecosystems and manufactured features (52°10'N, 106°34'W)

2.3.2 Key Ecosystem Services of the Northeast Swale

As shown in Figure 2.3, the Swale enjoys a wide range of ecosystem services, adapted from Raymond et al. (2009). This full array of ecosystem services was narrowed to the four key ecosystem services that describe the unique quality of the Swale and are expected to most prominently contribute to its value. These four services – highlighted in green in Figure 2.3 – include climate regulation; water regulation; water purification and treatment; and recreation, tourism, and lifestyle. Each of these key ecosystem services benefit human society in a different way, as conceptually displayed in Figure 2.4 and discussed throughout this section.

2.3.2.1 Climate Regulation

Climate regulation, as shown in Figure 2.4(a), describes the Swale's ability to benefit society through the sequestration and cycling of carbon dioxide and other greenhouse gasses. Wetlands are well established as effective "carbon sinks", with an understood biogeochemical sequestration process, allowing for the measurement of sequestration value (Villa and Bernal 2018). This service is beneficial to society as it counteracts the accumulation of greenhouse gasses which contribute to climate change impacts. Climate regulation may also describe the ability of an ecosystem to regulate temperature in an area, but this aspect was not specifically addressed in any of the studies utilized for this valuation.

2.3.2.2 Water Regulation

Water regulation, as shown in Figure 2.4(c), describes the Swale's ability to regulate water flow, helping to mitigate flood and drought events. Water enters the Swale naturally from the northeast and from stormwater and snow melt from adjacent neighbourhoods before flowing into the South Saskatchewan River (Stantec 2012). Floods and droughts can result in significant damages and loss in productivity. The value of an ecosystem's water regulation, through avoided cost, is a function of decrease in risk of a damaging flood or drought event and the cost of such an event (Farber et al. 2002).

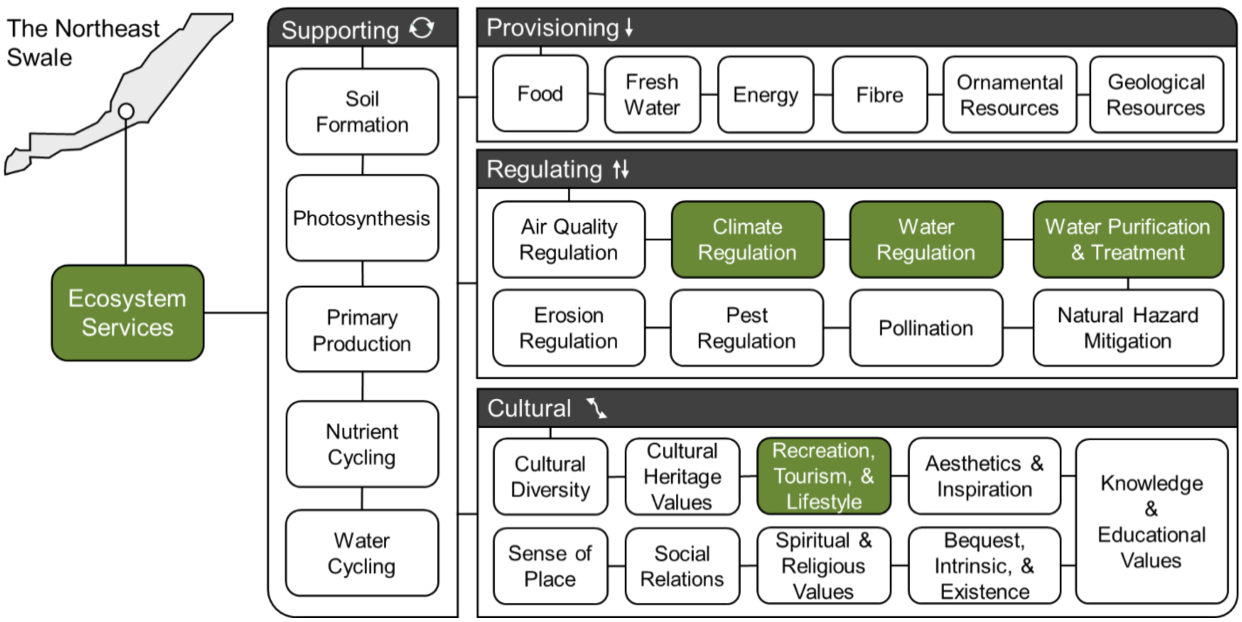

Figure 2.3: Typography of all potential ecosystem services of the Swale with selected key ecosystem services highlighted in green

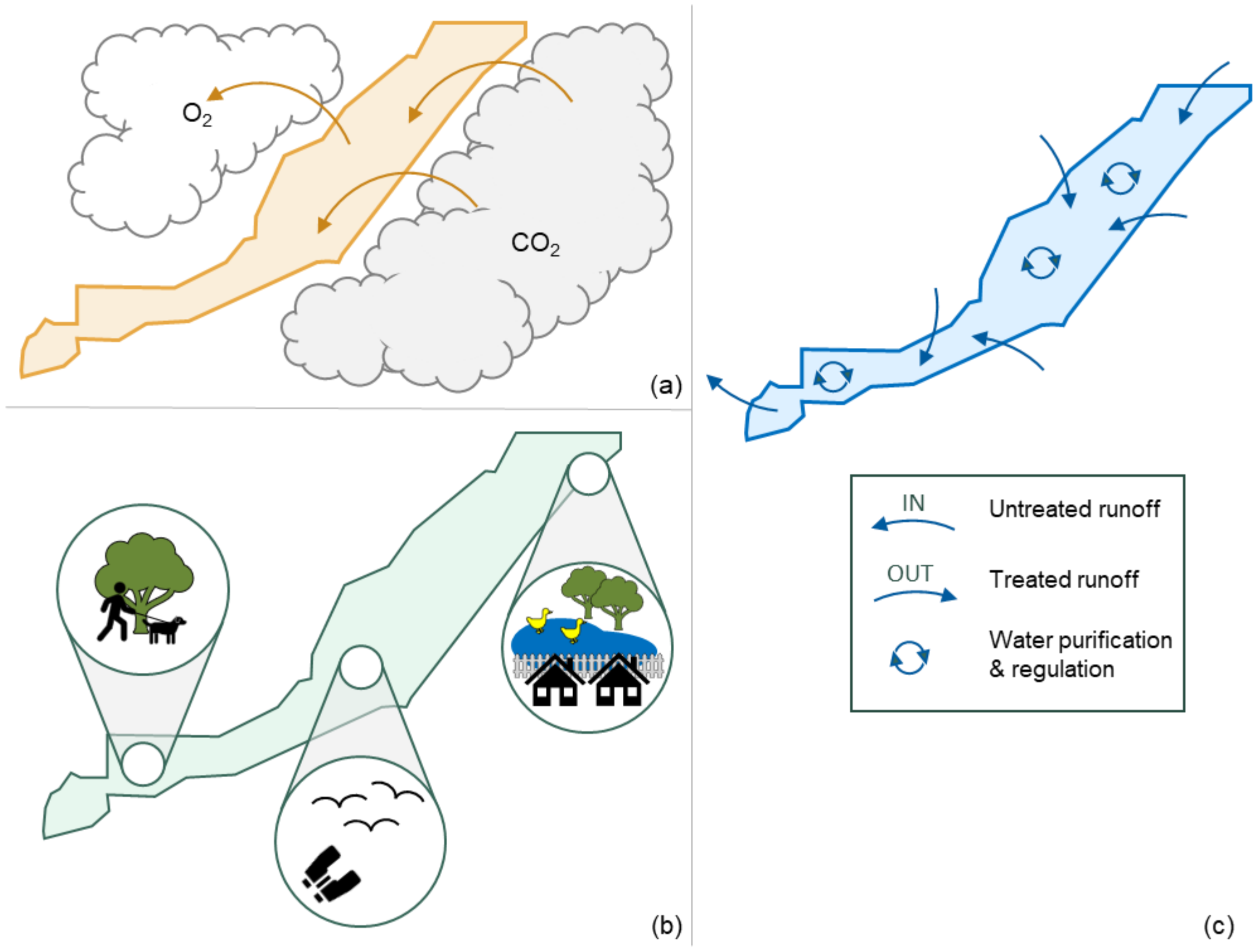

Figure 2.4: Conceptual model of swale key ecosystem services; (a) climate regulation (temperature regulation not pictured); (b) recreation, tourism, and lifestyle; (c) water regulation and water purification and treatment

2.3.2.3 Water Purification and Treatment

Also shown in panel Figure 2.4(c), water purification and treatment describes the Swale's ability to treat the water that flows through it. The flow of water through natural wetland and ground cover allows for the settling and filtration of contaminants (Brauman et al. 2007). This treatment results in purified water from storm events flowing downstream into the South Saskatchewan River, decreasing the likelihood of adverse environmental impacts and saving downstream users treatment costs. Additionally, the Northeast Swale is used to manage stormwater from surrounding subdivisions (Stantec 2012). As more stringent stormwater regulations may be introduced in the future, the Swale will potentially need to assist in meeting water quality requirements for secondary effluent into the river. However, this assumes that the Swale is a part of the treatment process, rather than a natural green area in need of protection itself.

2.3.2.4 Recreation, Tourism, and Lifestyle

Recreation, tourism, and lifestyle, as shown in Figure 2.4(b), describes the Swale's ability to attract visitors, facilitate recreational activity, and enhance lifestyle. This service is very broad, including facilitating walking through scenic trails, supporting birding due to its bird habitats, and increasing a sense of connectedness to nature for those who live in the vicinity. Cultural services, such as recreation, tourism, and lifestyle, may be abstract and difficult to valuate – as revealed preference methods are often inadequate for capturing the full value (Farber et al. 2002) – but can hold comparable value and importance as physical, market-based services (de Groot et al. 2012).

2.3.3. Swale Valuation

The delineation of the Swale shown in Section 2.3.1 above is a required step for the determination of benefit transfer that will allow the transfer of benefits for different ecosystem types to be applied to the Swale. The various ecosystems and features within in the Swale are shown in Table 2.3. A more in-depth version of this table may be found in Appendix A. Additionally, Table 2.4 illustrates the range of publication dates used for this benefit transfer. The features within the Swale, including stormwater management and roadways, provide no ecosystem services values, thus have no database values available. In fact, these features would likely be considered as negative value services; however, the estimation of this negative value is beyond the scope of the current study. Croplands, although considered an ecosystem currently, also have no database values and are not discussed further. This valuation will focus on the remaining woodland, grassland, and wetland ecosystems.

In total, the Swale's ecosystem services are valued at an estimated $1.6 million per year (Table 2.3). Most of this value can be attributed to the wetland ecosystem with the highest valuations for the water regulation ($1.03 M per year) and water purification and treatment ($447 K per year). The remaining ecosystems have marginal ecosystem services values at $12 K per year for woodlands and $56 K for grasslands. As well, the climate regulation and recreation, tourism, and lifestyle services provide $92 K and $33 K per year, respectively. For better comparison between areas, and for extension of current results to future ecosystems, consideration of a value per hectare (ha) can be used (Table 2.3). The yearly total Swale value is $5,240 per hectare per year with an analogous distribution of values to the totals discussed above. Overall, the yearly estimate appears to underestimate the Swale's value but serves as a useful starting point in its NCAV. A cruder estimate of the benefit transfer following de Groot et al. (2012) results in a valuation for the Swale of $4 million per year. Clearly the wetland ecosystem and water services are the most important areas for the Swale making their protection a priority for the City of Saskatoon. However, it should be noted that a NCAV may provide a very wide range of values making the exact valuation difficult.

Overall, the ESVD data included 36 data points from 20 data sources that were used to determine the 12 ecosystem service values shown in Table 2.3 (Van der Ploeg and de Groot 2010). These data points were distributed between the various services with most points found in water purification (17), and similar number of points in the remaining ecosystems services with 8, 6, and 5, for climate regulation, water regulation, and recreation, tourism, and lifestyle, respectively. The ESVD database provides a reasonable starting point for valuation of similar ecosystems worldwide and serves as an excellent starting point for the City of Saskatoon and Meewasin for NCAV of the Swale, and in other green areas throughout the City.

Table 2.3: Ecosystem services values for the Northeast Swale based on database values (Van der Ploeg and de Groot 2010)* (Note: the monetary values are corrected for 2018)

	Ecosystem or Feature	Area (%)	Area (ha)	Climate Regulation	Water Regulation	Water Purification and Treatment	Recreation, Tourism, and Lifestyle	Total Value
$CAD/y	Stormwater	4	12.2	—	—	—	—	—
	Roadway	4	12.4	—	—	—	—	—
	Cropland	2	7.1	—	—	—	—	—
	Woodland	6	19.8	3,847	4	5,103	3,481	12,435
	Grassland	39	122	40,830	502	14,695	98	56,126
	Wetland	44	138	47,562	1,033,449	447,532	29,603	1,558,148
	Northeast Swale	**100**	**310**	**92,240**	**1,033,956**	**467,331**	**33,182**	**1,626,710**
$CAD/ha/	Woodland			195	<1	258	176	629
	Grassland			336	4	121	<1	462
	Wetland			346	7,515	3,254	215	11,331
	Northeast Swale			**297**	**3,331**	**1,505**	**107**	**5,240**

*Studies used in this analysis: Adger et al. (1994); Brenner-Guillermo (2007); Costanza et al. (1997); Cowling, Costanza and Higgins (1997); Croitoru (2007); De la Cruz and Benedicto (2009); Dubgaard et al. (2002); Emerton (2005); Gerrard (2004); Gupta and Foster (1975); Kumari (1996); Lant and Roberts (1990); Leschine, Wellman, and Green (1997); Meyerhoff and Dehnhardt (2007); New Zealand Department of Conservation (2007); Pearce and Morgan (1994); Perrot- Maître and Davis (2001); Sala and Paruelo (1997); Secretariat of the Convention on Biological Diversity (2001); and Schuijt (2002).

Table 2.4: *A priori b*enefit transfer source publication date summary

Parameter	**Publication Year**
Min	1975
Max	2009
Average	2001
Median	2003
5th-percentile	1988
95th-percentile	2007

The benefit transfer used here focussed on studies that used specific valuation methods for each service, as discussed in section 2.3. Each of these methods was important to assess to ensure the applicability of the data for benefit transfer. For example, some ecosystem services reduce the risk of damage from other processes – natural or otherwise. An example of this is water regulation which may reduce the risk of flood and drought, thus avoiding costs associated with these events. Avoided Cost (AC) is the economic valuation method used to value these types of ecosystem services (Farber et al. 2002). Alternatively, 'ecosystem services' may be provided by human manufactured infrastructure specifically to provide analogous systems to naturally occurring services. In these cases, the value of the service may be estimated through replacement cost (RC). For example, the water purification and treatment offered by many ecosystems may be replaced by expensive manufactured treatment systems. The cost of such a system of equivalent productivity may be considered the value of the ecosystem being replaced (Farber et al. 2002). Many cultural ecosystem services are not directly associated with market activity, making them difficult to assess using revealed preference valuation methods. Contingent valuation (CV) is a stated preference method of ecosystem service valuation, allowing for the valuation of these ecosystem services. CV involves surveying a group of people to elicit their willingness to pay for access to an ecosystem service, or conversely their willingness to accept for the loss of access to said ecosystem service. Future work in the consideration of AC, RC, and CV for the Swale is being planned to produce a more accurate NCAV.

Although benefit transfer has many advantages – as discussed in the section 2.3 – its limitations are numerous and important to discuss as well. The selection of data to transfer will always involve some amount of professional bias. Additionally, there are rarely perfect analogues of ecosystems that are available for transfer. Beyond that, the actual valuation methods used for the studies being transferred are imperfect and involve further bias. In addition, although the databases such as ESVD are publicly available, the peer-reviewed studies included in the database are largely inaccessible to industry and government users, potentially resulting in the misuse of this resource. Benefit transfer will likely always be an imperfect estimate, but it fills a need for monetary valuation of natural capital without requiring a prohibitive level of time and money for many applications.

2.4 Conclusions and Future Work

There is a paradox between the acknowledged importance of NCAV and the difficulty in acquiring monetary valuation results with high certainty. However, as time passes and more research is undertaken, the uncertainty in NCAV will be reduced and the accuracy of such valuations will be improved. This study provides a framework for the NCAV of natural green areas within the City of Saskatoon starting with the Swale. There remains needed further work to improve the Swale's valuation that is currently being undertaken by our research team. In addition, future work will include:

- A contingent valuation in partnership with Meewasin and the City of Saskatoon to better estimate the cultural value of the Swale and other natural capital in the city.
- Detailed mapping of the Swale and its features using a UAV, allowing for the refinement of this valuation through more site-specific benefit transfer.
- Development of a monitoring plan, informed by the detailed mapping and this valuation, to monitor the Swale's key sources of natural capital.

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Chapter 3: Benefit Transfer versus Hedonic Pricing: Assessing the Value of an Urban Wetland Ecosystem

Abstract

The Meewasin Northeast Swale (Swale) is a 5-kilometer, 300-hectare channel scar of unbroken native prairie grasslands, woodland, and riparian wetland in Saskatoon, Saskatchewan, Canada. Untouched grasslands and wetlands are endangered, productive ecosystems, yet this geologically and ecologically unique site is threatened by urban development. Despite the threat to the Swale's health, there has been no substantial environmental impact monitoring of this area and the full economic, sociocultural, and environmental value of the Swale is not fully accounted for. Two methods of natural capital asset valuation (NCAV) were used to assign a monetary value to the Swale. A benefit transfer of 17 ecosystem services – using 186 values from 54 sources – valued the Swale at $7.3 M/yr (2018 CAD). Meanwhile, through applying hedonic pricing method to the houses within bordering neighbourhoods of the Swale it was found that the Swale does not lead to a statistically significant increase in property values. Despite the lack of significance, models showed that single-family detached homes within a 400 m walking distance had an average increase to property value of $4,166 and homes between a 400 and 800 m had an average decrease to property value of $5,689, compared to homes beyond 800 m. Additionally, an unimpeded view of the Swale resulted in an average decrease in property value of $636.

3.1 Introduction

The study and economic valuation of urban ecosystems and their relevant ecosystem services has been the topic of many studies (e.g., Jabben et al. 2015; McPhearson et al. 2013; Sander and Haight 2012) recently as natural capital asset valuation is becoming of greater interest to municipalities. These municipalities can directly benefit from increased property taxes as a result of these ecosystems increasing nearby property values, while knowledge of the ecosystem values can assist in future planning and policy making (Sander and Haight 2012). Typical positive attributes of these ecosystems found in the literature include recreational uses such as open spaces (Schlapfer et al., 2015), quality of scenery (Sander and Haight 2012), distance from green spaces (Czembrowski and Kronenburg, 2016), among others. Benefit transfer has been used to estimate the value of these ecosystem services based on the values determined by previous studies' such as using application of contingent valuation methods (e.g. de Groot et al. 2012, Costanza et al. 2014). While hedonic pricing models have also been used to estimate the effect of urban ecosystems on real estate prices, allowing for the estimation of ecosystem service values (e.g. Escobedo et al. 2015; Saphores and Li 2012; Czembrowski and Kronenberg 2016). Despite the increase in studies valuing urban ecosystems, there has been a lack of studies focused on the economic value of urban wetlands, especially urban wetlands in semi-arid regions, which is the focus of the current study's valuation of the Meewasin Northeast Swale (Swale) in Saskatoon, SK, Canada.

In this study, we first briefly review the relevant wetland ecosystem services literature. Second, we review the benefit transfer method of valuing ecosystem services and literature which makes use of this technique. Third, we review how past studies have used hedonic pricing models to determine the value of urban ecosystems based on remotely sensed and publicly available amenities and disamenities. Based on the lessons provided by this literature, we develop a hybrid approach to ecosystem service valuation that bolsters the convenient, general estimation of benefit transfer method with an ecosystem-specific, remotely sensed hedonic pricing model. This method compensates for the lack of studies specific to urban wetlands in semi-arid regions by supplementing the data available from other regions and settings with an ecosystem-specific technique. Additionally, this approach allows for the assessment of benefit transfer's suitability for semi-arid urban wetlands due to the addition of a hedonic pricing model to specifically address the cultural services of this urban ecosystem. This assessment will help inform the best methods for studying similar ecosystems, as well as other urban ecosystems, as natural capital asset valuation continues to grow as a priority for more municipalities.

3.1.1 Wetlands and Ecosystem Services

Wetland ecosystems host a rich biodiversity of organisms, offer extensive water regulation and treatment services, and help to mitigate drought and flood events. Given their intrinsic value, several studies have quantified the ecosystem services provided by wetlands and attempted to place economic values on these services (e.g. Mitsch and Gosselink 2000; WWF 2004). However, despite the recognition of these services, wetlands have historically been underappreciated, regarded as wasteland, and often drained for other uses such as residential or agricultural developments (US EPA 2018). Further, there is a lack of studies examining how the services provided by urban wetland ecosystems may differ from those provided by non-urban wetlands.

Additionally, the valuation methods used in previous studies – although rigorous – are generally restrictively time- and capital-intensive, making them unlikely to be adopted for widespread application by municipal decision makers. This reality is exacerbated by the still fledgling status of natural capital asset valuation in mainstream discussion, despite its rapid growth in popularity within certain circles of academia.

Beyond regulating and provisioning services, wetlands have also been assessed for their value in cultural services (WWF 2004; Beck et al. 2015; Palta et al. 2016). For example, recreation and ecotourism – largely in the form of hunting and fishing – are heavily recognised as valuable assets of wetlands (WWF 2004). Further, wetlands can be sites of archaeological significance, such as the New England Tableland region in Australia, where archaeological artefacts help illustrate the history of the region's aboriginal peoples (Beck et al. 2015). Additionally, Palta et al. (2016) observed how vulnerable persons gain a sense of privacy and security from urban wetlands by using them as shelter where they can bathe and sleep away from law enforcement and city environments. Urban wetlands, such as the Swale, are unique in that they typically do not have hunting/fishing as recreational benefits given their urban locations. Thus, the need for further evaluation of these wetlands is needed to better determine their intrinsic value.

3.1.2 Benefit Transfer

Benefit transfer is a method used to estimate the value of ecosystem services using various extensive valuation methods presented in previous studies and applying them to a new case study scenario (Richardson et al. 2015). These scenarios may be of a much larger scale by extrapolating from a wide range of studies or may attempt to interpolate between various studies to evaluate an ecosystem that has not been specifically studied before. Likely the most famous example of benefit transfer is the 1997 study by Costanza et al., entitled "*The value of the world's ecosystem services and natural capital*", wherein the total value of the biosphere was estimated to be within the range of $16-54 trillion per year (1997 USD). In a follow-up to that study (Costanza et al. 2014), this value was reassessed to $125 trillion per year (2007 USD). This follow up study identifies the need for updating valuations over time as the economic valuation methodology for ecosystems matures. As such, a much smaller-scale benefit transfer was conducted earlier this year on the Swale that is the focus of the current study with an estimated value of the Swale's key ecosystem services at $1.6 million per year (2018 CAD) (Read and McPhedran 2019). Currently, we expand upon this previous valuation of the Swale with an extended, more holistic benefit transfer analysis in addition to a new hedonic analysis (introduced below) for the Swale.

The benefit transfer methodology allows for the relatively simple valuation of ecosystem services making it a pragmatic methodology for decision-makers in the early stages of natural capital asset valuation (Johnston et al. 2015). However, a limitation of the benefit transfer is limited availability of previous studies, especially those that consider novel ecosystems (such as the Swale) or regions that have not been the subject of more traditional valuation techniques (Richardson et al. 2015). Further, benefit transfer is dependent on the quality of the data from the previous studies creating a large amount of uncertainty in benefit transfer economic values. Interestingly, many benefit transfer studies aggregate the results of several different studies with the assumption that this aggregation will reduce the error present (Johnston et al. 2015). Regardless of how error is mitigated in benefit transfer studies, reporting results in a way that acknowledges the uncertainty present is imperative when using benefit transfer. All factors considered, benefit transfer presents itself as a good first estimation wherein decision makers can ascertain a possible range of economic values for an ecosystem before deciding whether specific features warrant further investigations.

3.1.3 Hedonic Analyses

Hedonic analyses estimate the value of urban ecosystems – such as urban parks and urban forests – by analysing the impacts these ecosystems have on nearby property values (e.g. Escobedo et al. 2015; Saphores and Li 2012; Czembrowski and Kronenberg 2016). Sander and Haight (2012) found the hedonic pricing analysis is a valuable method for capturing the aesthetic and recreational portions of ecosystem services, through features such as walking distance to urban parks, tree cover within a certain radius, and viewshed cover type. In a study on the effect of urban forestry on property value, Escobedo et al. (2015) found that a tree on a residential property has an average marginal value of $1,586 (2015 USD) and that increases in lawn cover tend to result in a lower property value for the study area. Conversely, Saphores and Li (2012) found that increased lawn cover on properties increased individual property value in Los Angeles, although decreasing property values on the neighbourhood level. Czembrowski and Kronenberg (2016) found that large urban parks and forests have a disproportionately greater positive impact on apartment values in Lodz, Poland than small urban parks and forests. However, Brander and Koetse (2011) in a meta analysis of hedonic pricing studies found that there are significant regional differences for the value of greenspaces and for which type of greenspaces are most highly valued.

Hedonic pricing method allows for the market-based, revealed-preference valuation of cultural ecosystems as opposed to stated-preference methods, such as the contingent valuation method (Brander and Koetze 2011). Despite hedonic pricing being market-based, the method of extracting and interpreting the market data still presents many challenges. For example, the available market data must be in a large enough quantity to be statistically significant, while including sufficient explanatory variables for each sample. Further, the selection of explanatory variables is dependent on both data availability and professional judgement (Czembrowski and Kronenburg 2016), potentially resulting in significant variable omissions or correlated explainer variables (Sander and Haight 2012). Despite these challenges, the multi-variable linear regression used in hedonic pricing method is a relatively accessible, efficient analysis, when sufficient data are available.

3.1.4 Objectives

Past studies utilising benefit transfer have displayed the versatility of the method for natural capital asset valuation (NCAV), but also highlight the limited certainty intrinsic with benefit transfer using previous studies. Meanwhile, studies utilising hedonic regression have tended to largely be limited in focus on one of two options: the effects of urban forestry using remotely sensed canopy cover data on property value or the effect of proximity to urban greenspaces on property values. Therefore, this study aims to explore how benefit transfer analysis may be supplemented with hedonic pricing analysis for a more holistic natural capital asset valuation and, in turn, a more accurate economic valuation. This exploration will be facilitated through a case study on the Meewasin Northeast Swale (Swale), a semi-arid urban wetland in Saskatoon, SK. This study builds upon our previous NCAV study on the Swale (Read and McPhedran 2019) where we used a prioritised benefit transfer method using *a priori* decisions on ecosystem services based on stakeholder judgment of important services. The current study expands upon the benefit transfer used in previous study including a much larger group of ecosystem services while using the site-specific method of hedonic regression to address the uncertainty present in the cultural valuation of urban ecosystems through benefit transfer. Additionally, this study is being conducted with the goal of working towards an accessible methodology to be used by decision-makers in Canadian municipalities to better inform environmental decision making. Thus, the methodology can easily be used to determine NCAV of other urban ecosystems in Saskatoon, Canada, and beyond.

3.2 Methods

3.2.1 Study Area

The Meewasin Northeast Swale (Swale) (Figure 3.1), is a 5 km channel scar covering approximately 300 hectares which spans from Petturson's Ravine on the South Saskatchewan River in Saskatoon to the northeast city-limits of Saskatoon. Past the city limits to the North, the Swale continues as the 'Greater Northeast Swale' through the rural municipalities of Corman Park and Aberdeen. The Swale is a span of unbroken native prairie grasslands, woodland, and riparian wetland formed about 15,000 years ago as a drainage passage during a glacial retreat (Meewasin 2015). Native grasslands are regarded as one of the most endangered ecosystems on the planet (Gauthier and Riemer 2003) and over half of the wetlands in the Prairie Pothole Region of North America where the Swale is located have been drained (US EPA 2018). Further, the Swale is host to a diverse range of flora and fauna including several rare, endangered, and culturally significant species (Meewasin 2017).

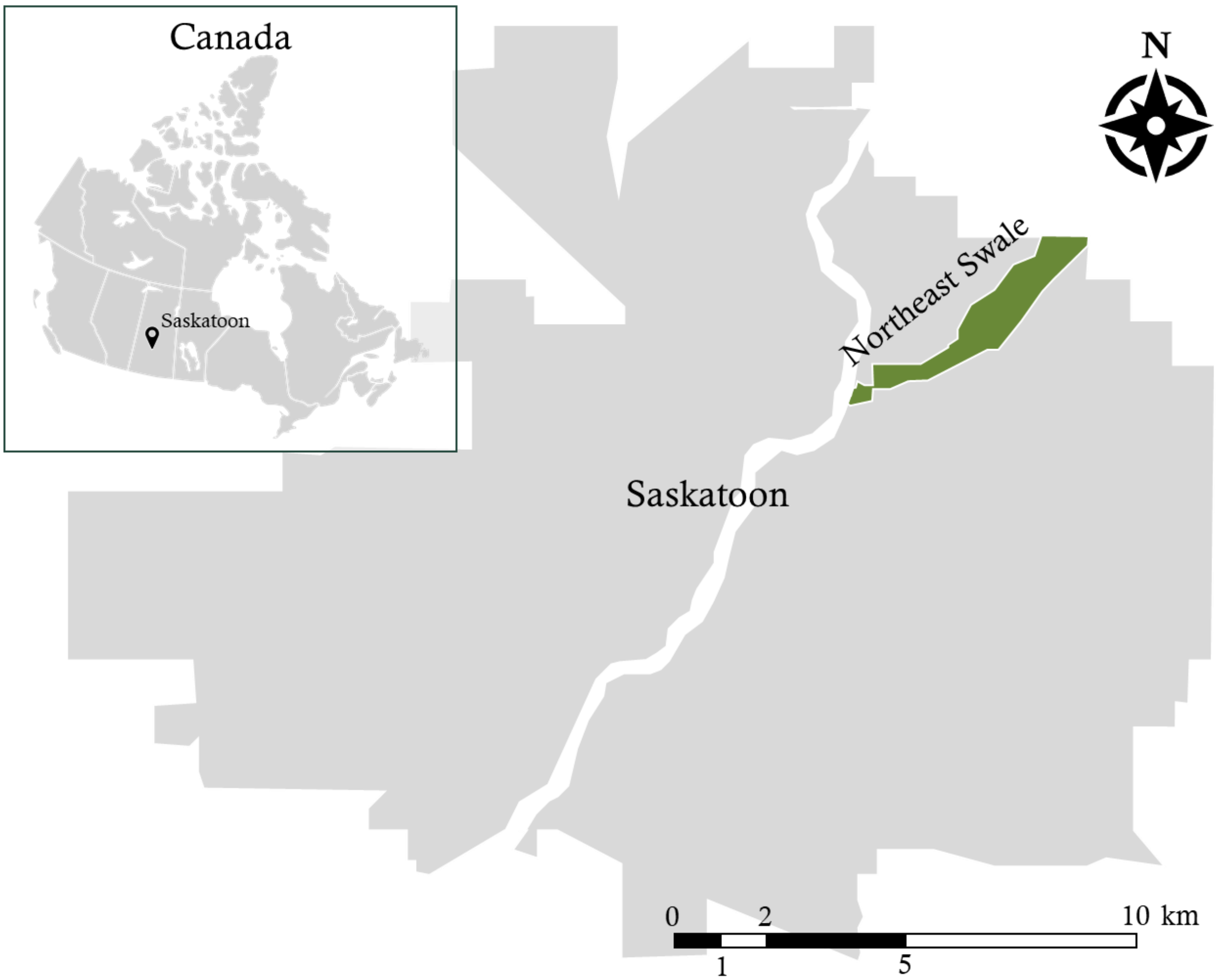

Figure 3.1: Study area of the portion of the Meewasin Northeast Swale located in Saskatoon, Saskatchewan, Canada (52°10'N, 106°34'W)

Figure 3.2: Representative photograph of the Meewasin Northeast Swale and bordering neighbourhoods. (Meewasin 2015)

The Swale is owned by the City of Saskatoon and managed by Meewasin, a provincially mandated conservation agency. The Swale is a topical area of focus due to encroaching urban development around its perimeter that has been occurring as part of the City of Saskatoon's planning and development. Three major subdivisions are currently located along the southern edge of the Swale (Figure 3.2): Silverspring, developed between 1986 and 2001; Evergreen, under development since 2010; and Aspen Ridge, under development since 2014. Additionally, future developments are planned to the north of the Swale as part of the University Heights Suburban Development Area, effectively surrounding the Swale with residential developments (Saskatoon 2019a). The current three subdivisions contribute stormwater runoff into the Swale which is directed into portions modified as engineered stormwater management (SWM) areas. Further, the increasing population around the Swale has necessitated the construction of high-traffic roadways through the Swale, including a new parkway that opened in 2018 and plans for a perimeter highway less than 1 km away from the currently completed parkway. This urbanisation is a concern as it threatens the health of the Swale through impacts such as fragmentation, increased stormwater runoff quantities and contaminants, introduction of exotic species, noise and light pollution, among others (Schneider et al. 2012; Newport et al. 2014). However, urbanisation also allows for increased local access to the Swale, especially for residents within these adjacent subdivisions, and its valuable ecosystem services.

3.2.2 Ecosystem Mapping

The Swale is composed of a several different ecosystems that may each contribute to the overall economic value of the area (Figure 3.3). This analysis utilised satellite imagery to interpret the Swale's landscape, building upon Stantec's (2012) wetland classification of the Swale. This figure is a modified delineation of the Swale into its component ecosystems, as conducted in Read and McPhedran (2019), with the removal of the roadways and engineered SWM in the current analyses given these have no widely available costs/benefits in the literature. This delineation serves as an estimate of the percentage of the overall area of the Swale taken up by each ecosystem for use in the current ecosystem service valuation, with the acknowledgement that these boundaries are created through the discretion of professional opinion and may require adjustment as the boundaries change due to urbanisation, climate change, or other impacts. Thus, future work for this research area will include up-to-date unmanned areal vehicle (UAV or drone) imagery that will further refine the Swale delineation which is currently in planning stages in our research group.

3.2.3 Benefit Transfer

A major component of the economic valuation of the Swale was conducted using the benefit transfer method (considering 17 services) (Johnston et al. 2015, Richardson et al. 2015), expanding upon our previously more limited benefit transfer (four services) (Read and McPhedran 2019) (Figure 3.4). The required previous study data were gathered from the Ecosystem Service Valuation Database (ESVD) (Van der Ploeg and de Groot 2010) which is a publicly available database of ecosystem valuation studies consisting of 1,310 values from over 300 case studies, put together as part of the Economics of Ecosystems and Biodiversity (TEEB) initiative (Van der Ploeg et al. 2010). In addition to broadening the number of ecosystem services to 17 in total, the current selection process for relevant studies was adjusted from our previous study to allow for a wider range of studies to be transferred to the Swale, under the assumption that a greater number of studies would result in a more reliable average value (Johnston et al. 2015). The full range of ecosystems selected from the ESVD for this benefit transfer are shown in Table 3.1. Additionally, the ecosystem services and subservices, as categorised within the ESVD, and their respective methodologies are shown in Table 3.2.

Values for each ecosystem type and ecosystem service that were relevant to the Swale were selected through the ESVD. Each of the selected studies was individually subjectively reviewed to ensure it was an appropriate analogue for the Swale and only studies deemed appropriate were included in further analysis. Inappropriate studies were characterised by those with heavily impacted study areas, outdated methods, or statistically insignificant results. For consistency, only values reported as a currency per unit area per year (e.g., USD$/ha/y) were used as these could be converted to standard a currency for extrapolation to the current study areas. Values were corrected for inflation based on 2018 dollar values and standardised to Canadian currency given the Swale location. For ecosystem service combinations with multiple available studies the values were averaged for use in this study (CAD$/ha/y). Finally, the values were multiplied by the representative areas as calculated within the Swale resulting in an economic value reported in CAD$/y. Values for each individual ecosystem and its relevant ecosystem services were summed to determine an overall value for the Swale on a yearly basis (Table 3.4).

Table 3.1: *Posteriori* ESVD biome and ecosystem selections. (Adapted from Van der Ploeg and de Groot 2010)

Biome	Ecosystem
Cultivated	Croplands
	Other
Forests [temperate and boreal]	Boreal/coniferous forests
	Forest [unspecified]
	Temperate deciduous forests
	Temperate forest general
Grasslands	Grasslands [unspecified]
	Savannah
	Temperate natural grasslands
Inland wetlands	Floodplains
	Peat wetlands
	Riparian buffer
	Swamps/marshes
	Wetlands [unspecified]
Woodlands	Mediterranean woodlands
	Other woodlands

Table 3.2: *Posteriori* ESVD ecosystem service and valuation method selections. (Adapted from Van der Ploeg and de Groot 2010)

ESService	ESSubservice	Value Information Valuation Method*
Aesthetic	Attractive landscapes	Contingent valuation Hedonic pricing
Air quality	Air quality regulation [unspecified]	Avoided cost
	Capturing fine dust	Benefit transfer
BioControl	Biological control [unspecified]	Benefit transfer
	Disease control	Benefit transfer
	Pest control	Benefit transfer
	Seed dispersal	Replacement cost
Climate	C-sequestration	Avoided cost Benefit transfer Direct market pricing Mitigation and restoration cost Replacement cost
	Climate regulation [unspecified]	Benefit transfer Contingent valuation
	Gas regulation	Avoided cost Benefit transfer Direct market pricing Replacement cost
Cognitive	Education	Travel cost
	Science/Research	Benefit transfer
Cultural service [general]	Cultural values [unspecified]	Benefit transfer Contingent valuation
Erosion	Erosion prevention	Avoided cost Benefit transfer Direct market pricing Mitigation and restoration cost
Extreme events	Flood prevention	Avoided cost Benefit transfer Mitigation and restoration cost
	Prevention of extreme events [unspecified]	Benefit transfer
Genepool	Biodiversity protection	Benefit transfer Contingent valuation Group valuation Other
Inspiration	Cultural use	Benefit transfer Contingent valuation

Table 3.2 (cont'd): *Posteriori* ESVD ecosystem service and valuation method selections. (Adapted from Van der Ploeg and de Groot 2010)

ESService	**ESSubservice**	**Value Information Valuation Method***
Pollination	Pollination [unspecified]	Benefit transfer
Recreation	Ecotourism	Benefit transfer
		Contingent valuation
		Direct market pricing
		Travel cost
	Recreation	Benefit transfer
		Contingent valuation
		Direct market pricing
		Group valuation
		Travel cost
	Tourism	Benefit transfer
Waste	Water purification	Avoided cost
		Benefit transfer
		Mitigation and restoration cost
		PES
		Replacement cost
	Water treatment [unspecified]	Benefit transfer
		Contingent valuation
		Factor income/production function
		Replacement cost
Water flows	Drainage	Replacement cost
	Natural irrigation	Factor income/production function
	River discharge	Avoided cost
	Water regulation [unspecified]	Benefit transfer

3.2.4 Conceptual Hedonic Model

Hedonic pricing models are based upon the assumption that the market price of a product (in this case, a property) is defined by the sum of its attributes' marginal values (Rosen 1974). Each of the marginal values are estimated by comparing the effects these varying attributes have on the market price of a sample of properties (Rosen 1974). Hedonic pricing models are typically used in studies that focus on the values of single-family detached homes, as in this study, but they may also be used for commercial properties, multi-unit residential properties, or rental units (e.g. Czembrowski and Kronenberg 2016). In this current study, we relate the assessed 2015 property tax values available through the City of Saskatoon (Saskatoon 2019b) of single-family detached homes to the structural and location attributes of the property to construct the hedonic model. Property value, Y, is generally defined as a function of n individual explanatory variables (X_n), each contributing a marginal value (β_n):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{3.1}$$

Typical explanatory variables include property characteristics such as the age of the home, size of the home, size of the plot, and location factors including proximity to greenspaces, high-volume roads, shopping centres, and schools (Sander and Haight 2012; Brander and Koetse 2011). In addition, urban forestry has also been included as an explanatory variable in previous studies (Escobedo et al. 2015; Czembrowski and Kronenberg 2016). Hedonic pricing models often include over 20 variables (e.g. Sander and Haight 2012). In the current study, however, we utilise a smaller number of explanatory variables, focussing on a large sample size of properties, using publicly available data. The data used consists of 2015 assessed property values and remotely sensed geospatial data to assess proximity to the ecosystem of interest and the viewshed of each property. These data are further explained below.

3.2.5 Assessed Property Values

The effect of the Swale's proximity to residential property values were assessed using property tax assessed value from the City of Saskatoon for 2015 (Table 3.3). These values were used due to their accessibility on the City of Saskatoon's website (Saskatoon 2019b) and their applicability towards municipal environmental management. Many of the physical parameters used as explanatory variables were obtained from the City's property tax assessment information, including parcel size, above-grade living area, no. of storeys, construction year, finished/unfinished basement, and neighbourhood development. Otherwise, the location and viewshed data were generated from satellite imagery. Swale walking distance catchment areas were delineated to walking distances of 400 and 800 metres following Noor et al. (2015) by manually sketching available walking paths (Figure 3.3). Viewsheds were analysed using onsite surveying to determine which properties have unimpeded site-lines to the Swale.

3.2.6 Empirical Hedonic Model

The following is an empirical model developed for residential single and individual multi-family home property values surrounding the study site (Table 3.3):

$$Y = \beta_0 + \beta_1 L.Area + \beta_2 P.Area + \beta_3 SplitLevel + \beta_4 TwoStorey + \beta_5 Multifamily + \beta_6 Basement + \beta_7 Age + \beta_8 AspenRidge + \beta_9 Evergreen + \beta_{10} 400m + \beta_{11} 800m + \beta_{12} View + \varepsilon \quad (3.2)$$

where *Y* is the assessed property value in 2015 CAD; *L.Area* is the above-grade living area of the residential unit in square feet; *P.Area* is the total area of the parcel in square feet; *SplitLevel* and *TwoStorey* are mutually exclusive dummy variables indicating a split-level or two-storey unit, respectively, while the default assumption is a one story unit; *Multifamily* is a dummy variable indicating a multifamily unit; *Basement* is a dummy variable indicating a finished basement in the unit; *Age* is the house age in years; *AspenRidge* and *Evergreen* are mutually exclusive dummy variables indicating the neighbourhood the property is in as Aspen Ridge and Evergreen, respectively (the Silverspring neighbourhood was the default neighbourhood assumption); *400m* and *800m* are dummy variables indicating walking distance from the Swale of approximately $x \leq 400\ m$ or $400\ m < x \leq 800\ m$, respectively, with the assumed default distance of $x > 800\ m$; *View* is a dummy variable indicating a view of the Swale from within the unit; and ε is an error term.

The empirical hedonic model was created using JMP Pro 15 by SAS. The property value variable for this sample set resembled a logarithmic distribution so was transformed by $\log_{10}$. Therefore, it is assumed that the value of a property is logarithmically dependent on the defined explanatory values. First, explanatory variables were tested for collinearity using JMP's Multivariate tool and removing one variable in case of a correlation greater than 0.8. Next, a stepwise regression was run for variable selection for minimum AICc to generate three different hedonic models: (a) the most powerful model that includes the distance terms; (b) the most powerful model that includes the view term; and (c) the most powerful model overall. The inclusion of many nominal variables in the empirical hedonic model created a challenge in objectively determining collinearity. However, through observation and professional judgment the Age variable was found to be binomially distributed and highly correlated with Neighbourhood and was removed from the model as a result. Additionally, multifamily homes and the Aspen Ridge neighbourhood were removed from the model as no pertinent data-points were available for these variables. Data used for our final model included 100 observations within the Silverspring and Evergreen neighbourhoods of Saskatoon, SK.

Table 3.3: Description of property variables from sources including the City of Saskatoon (2019) and Google satellite imagery (2019).

Variable (label)	Units	Definition
Dependent variable		
Assessed property value (**Price**)	2015 $CAD	Assessed property value from municipal property tax assessments
House attributes		
Living area (**L.Area**)	Square feet	Area of above-grade residential unit on parcel
Parcel area (**P.Area)**	Square feet	Total area of parcel
Number of storeys (**Storeys**)	Single storey Split-level Two storeys	Nominal variable; house's number of storeys (single storey, split-storey; or two storeys)
House type (**Type**)	Single family Multifamily	Nominal variable; type of residence (single family or multifamily)
Finished basement (**Basement**)	Boolean	Boolean variable; finished basement
House age (**Age**)	Years	The time since construction date of the unit
Location attributes		
Neighbourhood (**Neighbourhood**)	Aspen Ridge Evergreen Silverspring	Nominal variable; Neighbourhood (Aspen Ridge; Evergreen; or Silverspring)
Swale walking distance (**Distance**)	≤ 400 meters ≤ 800 meters > 800 meters	Nominal variable; shortest walking distance to the Swale (x≤400m; 400m<x≤800m, or x>800m)
Swale view (**View**)	Boolean	Boolean variable; view of Swale from within residential unit

3.3 Results and Discussion

3.3.1 Mapping Results

Overall, the Swale area is 310 ha which is dominated by wetlands and grasslands at 44% (138 ha) and 39% (122 ha), respectively (Figure 3.3 and Table 3.4). The remaining ecosystems have more limited areas in the Swale at 6% (7.1 ha) and 2% (19.8 ha) for woodlands and croplands, respectively. Generally, the dominant areas of interspersed prairie wetland and grassland provide numerous ecosystem services such as water regulation during flood and drought events, carbon sequestration, recreation, aesthetics and serve as important breeding ecosystems for a variety of North American waterfowl (Gascoigne et al. 2011). Typically, woodland value is most commonly attributed to its use for timber (Croitoru 2007), which is not a use for the Swale. However, it also provides watershed protection and erosion regulation services (Croitoru 2007). Cropland is land that has been cultivated to focus on the provisioning of food, but certain agricultural practices, such as the overapplication of fertilizers, are a risk to downstream ecosystems. The remaining approximately 8% of the Swale area include roadways and Engineered SWM with 4% (12.4 ha) and 4% (12.2 ha), respectively. Roadways can prevent the natural migration of wildlife, interrupt ecosystem processes, and are potential sources of pollutant contamination (Stantec 2012). While SWM threatens the natural hydrological conditions of the Swale and the unique plant communities that are dependent on these natural conditions (Stantec 2012). Given their lack of impact on the economic valuation presented herein, the Roadways and SWM areas are not included in further analyses.

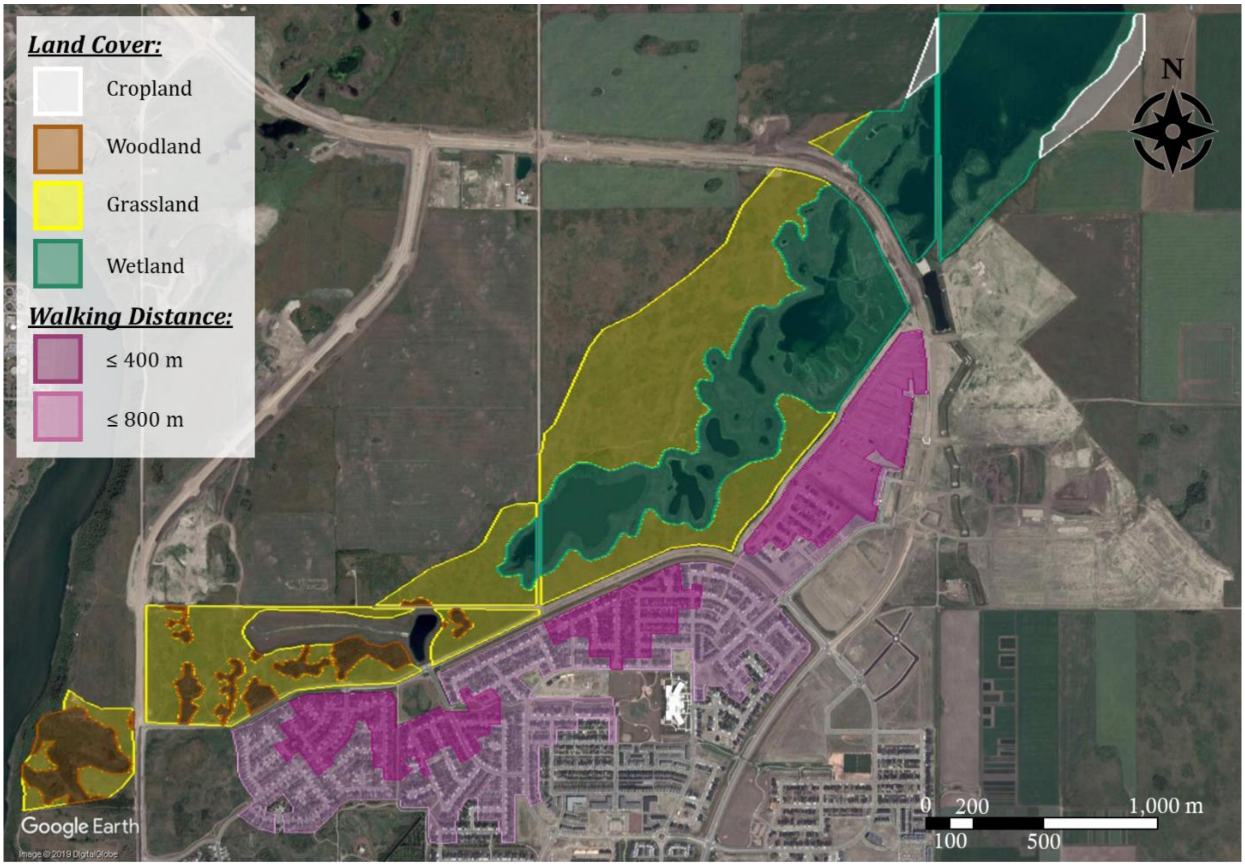

Figure 3.3: Delineation of the Meewasin Northeast Swale ecosystems and features (52°10'N, 106°34'W) (Adapted from Read and McPhedran, 2019). The walking distance areas of 400 and 800 m from the Swale used in the hedonic housing valuation are highlighted.

3.3.2 Benefit Transfer Results

The Swale provides a wide variety of ecosystem services that can be divided into four categories: provisioning, regulating, cultural, and supporting (Figure 3.4). Based on our literature review and available EVSD data, the regulating and cultural service categories were considered for the current benefit transfer as highlighted in Figure 3.4. Provisioning services were not included in the valuation as the Swale is not currently used for significant provisioning of any resources. Additionally, supporting services were not included in the valuation because their supportive nature means that their value is reflected through the rest of the services, thus are difficult to determine separately and can potentially be 'double-counted' as well.

The benefit transfer resulted in values as summarised in Table 1. A more in-depth version of this table may be found in Appendix B. Additionally, Table 3.5 illustrates the range of publication dates used for this benefit transfer. The average value of the Swale is about $7.3 M/y with a median value of $2.0 M/y with benefit transfer using 186 data points. Overall, wetlands are the greatest contributor to the value of the Swale, both in terms of per unit value ($51 K/ha/y) and overall value ($7.0 M/y). On the category level, the regulating services are a greater contributor to the value of the Swale than cultural services at $5.3 M/y compared to $2.1 M/y. Regarding individual ecosystem services, natural hazard mitigation is the most valuable ($3.6 M/y), followed by recreation and tourism ($1.6 M/y), water regulation ($958 K/y), and water purification ($443 K/y). For comparison, our previous benefit transfer of the Swale resulted in an average value of $1.6 M/y (23% of this study's average value) and a median value of $1.2 M/y (60% of this study's median value) (Table 1). The majority of this increase in estimated value is attributed to the valuation of natural hazard mitigation which was not one of the *a priori* services considered in our previous analysis. Unfortunately, our previous study had included drought and flood prevention as attributes of the water regulation ecosystem service, whereas the ESVD categorises these attributes as natural hazard mitigation. This misalignment of definitions showcases the challenges involved in avoiding "double-counting" overlapping services in a benefit transfer. If the natural hazard mitigation had been added as an additional assessed ecosystem service the average value would have been $6.7 M/y, or 95% of the current study's average. Based on this result, prioritised benefit transfers – like that conducted in the previous study (Read and McPhedran 2019) – appear to be a very comparable method of valuation to full benefit transfers, such as the one conducted in this study. However, a prioritised benefit transfer requires a high degree of understanding regarding which ecosystem services to value *a priori* to the analysis. It should be noted that the ecosystem services shown in Figure 3.4 may also be missing services not considered resulting in omitted variable bias that is an issue for both benefit transfer and hedonic pricing methodologies (Saphores and Li 2012; Sanders and Haight 2012). Thus, when updating valuations, we suggest a review of the variables and consideration of adding omitted variables in future studies.

While benefit transfer allows for the efficient valuation of even data-scarce ecosystems, it also has many limitations that must be acknowledged. The selection of studies for transfer requires professional discretion, introducing uncertainty and the potential for bias (Johnston et al. 2015). Using collected data for assessment of a study area that it was not originally intended for has inherent uncertainty that is irremovable from this method. In addition, available databases of ecosystem service values – such as the ESVD – are incomplete catalogues, subject to their own professional bias in selection and assignment of meta-data. Conversely, working outside of these databases can be prohibitively resource intensive. While each individual study has its own inherently unique methodologies and definitions, databases necessitate the standardisation of these studies into specific categories. This standardisation can result in starkly different studies sharing very similar meta-data and an appearance of false equivalency. Further, although databases such as the ESVD are publicly available, many of the studies included in the database are inaccessible to government and industry, exacerbating many of the other limitations of using databases for benefit transfer and NCAV. A specific limitation identified currently is the general lack of previous studies on urban wetland ecosystems, especially in semi-arid regions, for use in the benefit transfer method for the Swale. For this reason, the benefit transfer for the Swale was hypothesised to be an insufficient method of capturing the study area’s true economic value on its own. Thus, a hedonic regression was performed as a site-specific valuation method to test this hypothesis and to improve the assessment of the Swale’s actual NCAV.

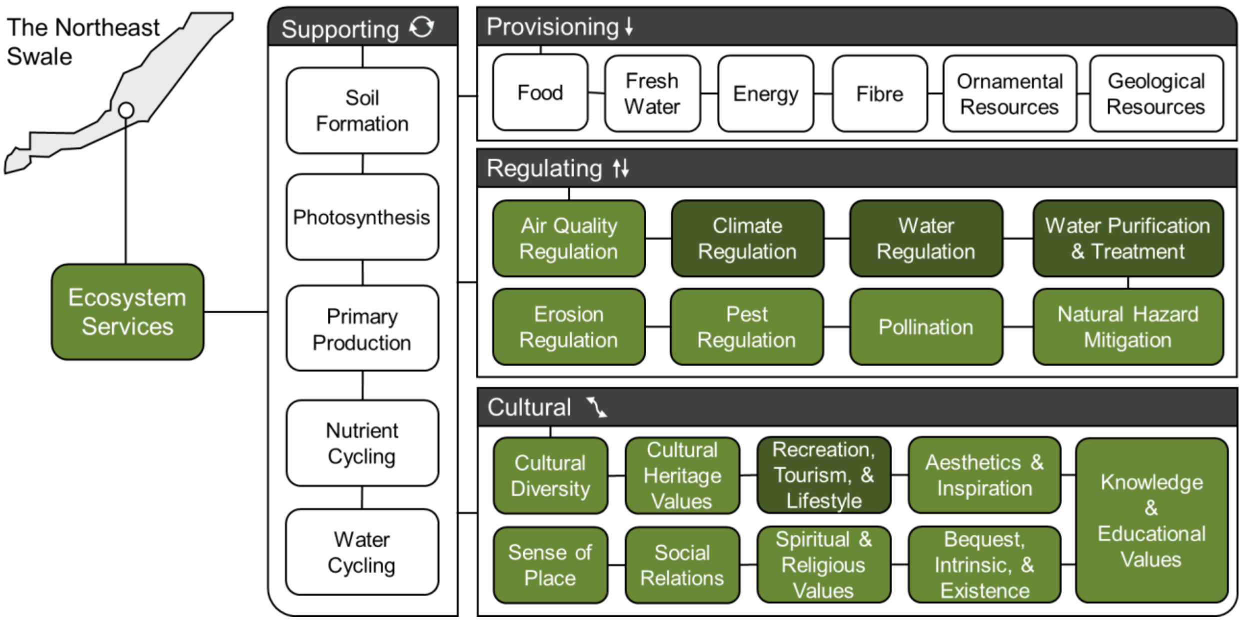

Figure 3.4: Ecosystem service typography displaying potentially significant and non-significant services. Services valued through the current benefit transfer are highlighted in light and dark green while the four services considered in our previous study are in dark green. (Adapted from Read and McPhedran, 2019)

Table 3.4: Summary of benefit transfer results in $CAD/y and $CAD/ha/y.

	Ecosystem	Area (%)	Area (ha)	Count	Average	Median	Minimum	Maximum
$CAD/y	Cropland	2	7.1	11	21,142	21,142	8,499	33,785
	Woodland	6	19.8	71	259,893	94,243	16,766	1,644,253
	Grassland	39	122	18	68,032	57,682	24,290	137,989
	Wetland	44	138	86	7,013,595	1,804,443	165,017	73,310,286
	Northeast Swale	**91**	**310**	**186**	**7,362,664**	**1,977,510**	**214,573**	**75,126,296**
	Read and McPhedran 2019	*91*	*310*	*41*	*1,730,235*	*1,237,369*	*193,877*	*5,215,882*
$CAD/ha/y	Cropland			11	2,992	2,992	1,202	4,781
	Woodland			71	13,138	4,764	847	83,119
	Grassland			18	559	474	199	1,135
	Wetland			86	51,006	13,122	1,200	533,152
	Northeast Swale			**186**	**23,750**	**6,379**	**692**	**242,342**
	Read and McPhedran 2019			*41*	*5,581*	*3,991*	*625*	*16,825*

Studies used in this analysis included: Acharya and Barbier (2000); Adger et al. (1994); Amacher et al. (1989); Anielski (2005); Barrow (1991); Bostedt and Mattsson (2006); Brenner-Guillermo (2007); Chong (2005); Costanza et al. (1997); Croitoru (2007); De la Cruz and Benedicto (2009); Department of Conservation (2007); Donaghy et al. (2007); Dubgaard (1998); Dubgaard et al. (2001); Emerton (2005); Emerton (2004); Everard and Jevons (2010); Fleischer and Tsur (2009); Gerrans (1994); Gerrard (2004); Gren (1994); Gren et al. (1995); Gupta and Foster (1975); Hougner et al.. (2006); Kirkland (1988); Kniivilä et al. (2002); Kontoleon and Swanson (2003); Kumari (1996); Lant and Roberts (1990); Leschine et al. (1997); Loomis and Ekstrand (1998); Luisetti et al. (2008); Mallawaarachchi et al. (2001); Meyerhoff and Dehnhardt (2007); Mohd-Shahwahid and McNally (2001); Pearce (1994); Perrot-Maître and Davis (2001); Phillips et al. (2008); Pimentel et al. (1995); Ruijgrok and de Groot (2006); Sala and Paruelo (1997); Schuyt and Brander (2004); Secretariat of the Convention on Biological Diversity (2001); Seidl and Moraes (2000); Seyam et al. (2001); Thibodeau and Ostro (1981); Tianhong et al. (2010); Turpie (2000); Turpie (2003); van Ierland (2005); Walsh et al. (1984); Xue and Tisdell (2001); and Zandersen et al. (2005).

Table 3.5: *Posteriori* benefit transfer source publication date summary

Parameter	Publication Year
Min	1975
Max	2010
Average	2002
Median	2003.5
5th-percentile	1990
95th-percentile	2008

3.3.3 Hedonic Model Results

Three hedonic models were developed for the housing market surrounding the Swale: (a) the most powerful model that includes the distance terms; (b) the most powerful model that includes the view term; and (c) the most powerful model overall. These three models are shown in the equations (3.3, 3.4, and 3.5) with parameter estimates presented in Table 3.6:

(a) $$\log_{10} Value = \beta_0 + \beta_1 L.Area + \beta_2 P.Area + \beta_3 OneStorey + \beta_4 SplitLevel + \beta_5 Basement + \beta_6 Evergreen + \beta_7 400m + \beta_8 800m + \varepsilon$$
$$= 5.2896504 + 0.0002053 \cdot L.Area + 0.000010832 \cdot P.Area + 0.0314857 \cdot OneStorey + 0.0134182 \cdot SplitLevel + 0.018507 \cdot Basement + 0.0220274 \cdot Evergreen + 0.0033363 \cdot 400m + -0.004744 \cdot 800m + \varepsilon \quad (3.3)$$

(b) $$\log_{10} Value = \beta_0 + \beta_1 L.Area + \beta_2 P.Area + \beta_3 OneStorey + \beta_4 SplitLevel + \beta_5 Basement + \beta_6 Evergreen + \beta_9 View + \varepsilon$$
$$= 5.2870517 + 0.0002051 \cdot L.Area + 0.000011161 \cdot P.Area + 0.031103 \cdot OneStorey + 0.013369 \cdot SplitLevel + 0.018562 \cdot Basement + 0.0220788 \cdot Evergreen + -0.0005096 \cdot \text{View} + \varepsilon \quad (3.4)$$

(c) $$\log_{10} Value = \beta_0 + \beta_1 L.Area + \beta_2 P.Area + \beta_3 OneStorey + \beta_4 SplitLevel + \beta_5 Basement + \beta_6 Evergreen + \varepsilon$$
$$= 5.3244999 + 0.0002052 \cdot L.Area + 0.000011064 \cdot P.Area + 0.0311514 \cdot OneStorey + 0.0134343 \cdot SplitLevel + 0.018592 \cdot Basement + 0.0221202 \cdot Evergreen + \varepsilon \quad (3.5)$$

The model selection was determined through stepwise variable selection assuming a linear relationship between $Log_{10}Value$ and the explanatory variables. A summary of the dataset used in the pricing model for each of these variables is presented in Table 3.7. A summary of the fit for each model is detailed in Table 3.8 and displays that each model is similarly powerful with AICc values ranging from -450.912 to -448.401 and very high R^2 values from 0.9338 to 0.9353. Actually-by-predicted plots for each of the models are available in Appendix C. However, the variables of interest (walking distance and view) were not selected in the most powerful model overall, and are statistically insignificant in their respective models, as shown in Table 3.6.

Table 3.6: Hedonic pricing model parameter estimates and statistics. *Italicized* p-values indicate significant parameters; **bolded** values indicate insignificant parameters

		Estimate			Std Error			Prob>|t|	
Term	**(a)**	**(b)**	**(c)**	**(a)**	**(b)**	**(c)**	**(a)**	**(b)**	**(c)**
β_0 **Intercept**	5.289	5.287	5.324	0.0146	0.0146	0.0144	*<.0001*	*<.0001*	*<.0001*
β_1 **L.Area**	2.05E-04	2.05E-04	2.05E-04	1.05E-05	1.05E-05	1.05E-05	*<.0001*	*<.0001*	*<.0001*
β_2 **P.Area**	1.08E-05	1.12E-05	1.11E-05	2.34E-06	2.34E-06	2.33E-06	*<.0001*	*<.0001*	*<.0001*
β_3 **OneStorey**	3.15E-02	3.11E-02	3.12E-02	4.19E-03	4.19E-03	4.14E-03	*<.0001*	*<.0001*	*<.0001*
β_4 **SplitLevel**	1.34E-02	1.34E-02	1.34E-02	4.20E-03	4.20E-03	4.18E-03	*0.0019*	*0.0021*	*0.0018*
β_5 **Basement**	1.85E-02	1.86E-02	1.86E-02	2.78E-03	2.78E-03	2.74E-03	*<.0001*	*<.0001*	*<.0001*
β_6 **Evergreen**	2.20E-02	2.21E-02	2.21E-02	3.23E-03	3.23E-03	3.15E-03	*<.0001*	*<.0001*	*<.0001*
β_7 **400m**	3.34E-03	—	—	3.86E-03	3.86E-03	—	**0.3898**	—	—
β_8 **800m**	-4.74E-03	—	—	3.26E-03	—	—	**0.1491**	—	—
β_9 **View**	—	-5.10E-04	—	—	3.26E-03	—	—	**0.8845**	—

Table 3.7: Hedonic pricing model dataset properties.

Variable	(Unit)	Mean	Minimum	Maximum	S.D.
Dependent					
Price	(CAD)	$ 540,217.00	$ 352,600.00	$ 827,800.00	116362.39
House					
L.Area	(Sq. Ft.)	1,641	1,034	2,776	425.50
P.Area	(Sq. Ft.)	6,249	3,927	11,507	1425.35
Age	(Year)	9.73	1	21	5.91
Others		**Percent** (%)			
Single Storey		27			
Split-Level		34			
Two Storey		39			
Basement [Finished]		66			
Evergreen		72			
≤ 400 m		26			
≤ 800 m		70			
View		18			

Table 3.8: Hedonic pricing model summary of fit.

	Model		
Fit parameter	**(a)**	**(b)**	**(c)**
RSquare	0.9353	0.9338	0.9338
RSquare Adj	0.9296	0.9287	0.9295
Root Mean Square Error	0.0241	0.0242	0.0241
Mean of Response	5.723	5.723	5.723
AICc	-448.4	-448.5	-450.9
BIC	-424.8	-427.0	-431.6

Table 3.9: Summary of Swale value as determined by changes in annual property tax assessments from surrounding neighbourhoods.

Variable	**Walking Distance**		**View**	**Total**
	≤ 400 m	**≤ 800 m**		
Count	697	903	112	
Value ($)	2,903,695	-5,299,642	-70,954	-2,466,901
Taxable Value (80%) ($)	2,322,956	-4,239,714	-56,763	-1,973,521
Tax rate 0.0111317				
Annual Property Tax ($/yr)	**25,858**	**-47,195**	**-632**	**-21,969**

The average house characteristics included a value of $540,217, and house and parcel square footages of 1,641 and 6,249, respectively (Table 3.7). Of the neighbourhood homes, 66% had finished basements, 72% were in the Evergreen area, 26% and 70% of homes were within 400 m and 800 m of the Swale, respectively, and 18% had an unobstructed view of the Swale. Due to the log-normal relationship between property values, the marginal contribution of each parameter is linearly dependent on overall value. Therefore, the marginal contribution of each parameter may be expressed as a percentage increase in the property value. As expected, living area, parcel area, and a finished basement positively impact property value. Fewer storeys are preferable when living and parcel area remains constant and a house is worth more in Evergreen than in Silverspring. However, it should be noted that this increased value of Evergreen houses may be attributed to the houses in Evergreen typically being newer than those in Silverspring. In addition, the correlation between neighbourhood and house age was so strong that age was eliminated as an explanatory variable due to concerns of collinearity of these variables. It should also be noted that Evergreen – as a newer community – has more modern amenities than Silverspring such as a greater prevalence of green corridors, newer schools, and a tendency towards modern housing amenities like central air conditioning.

In model (a), properties within 400 m of the Swale gain a 0.77% increase in property value when compared to properties greater than 800 m from the Swale. Interestingly, properties located between 400 and 800 m from the Swale were found to have a 1.09% decrease to property values. The positive effect of being within 400 m was expected and is consistent with the marginal values presented in previous studies (Sander and Haight 2012, Brander and Koetse 2011). However, the negative value associated with properties between 400 and 800 m was unexpected and reasons for this decrease are not known. For model (b) the results indicate that a view of the Swale decreases a property's value by 0.12%. As for the decrease for model (a) values between 400 and 800 m, the negative value associated with having a view of the Swale was unexpected. However, it can be speculated that this negative may be attributed to increased road noise and construction of roadways in this area given a major roadway for the area lies between the subdivision homes and the Swale (no houses 'back' onto the Swale directly). Interestingly, Saphores and Li (2012) found a negative valuation of non-groomed grassland previously which is consistent with our current results. Clearly further research is needed to better understand the impacts of distance and viewshed on housing values in the Swale area.

Despite these interesting results, the walking distance to the Swale and view of the Swale were not found to have a statistically significant impact on the housing market in either Silverspring or Evergreen (Table 3.6). There are a few possible reasons why these location attributes may not have been statistically significant. The first option is that view and proximity to the Swale do not fundamentally impact housing prices. However, this option is unlikely as it contradicts the findings of many other studies. The second option only applies to the distance variable, in that it is a nominal variable informed by previous studies rather than a continuous variable. The nominal nature of the distance variable as used in these models may be responsible for the distance factor being insignificant, whereas the same dataset with the consideration of a continuous distance variable may result in statistically significant results. Finally, the source of the model input data may be the issue. The input data for these models are readily available property tax assessment values which are partially derived from a model of their own. Unfortunately the model used for this assessment was not available for review for informing the current study. It is suggested that using real housing market activity to recreate these models would be useful for a more robust determination of the Swale's impact on housing prices.

For a better representation of the full impact of these housing values, the total monetary value of the Swale on the housing market within 800 m of the Swale was calculated (Table 3.9). This calculation was completed by applying the average marginal benefit of each location factor to each of the relevant properties in Silverspring and Evergreen. Assuming that the current model values are accurate, the Swale would be responsible for a decrease in nearby property values of $1.97 million. The City of Saskatoon uses 80% of the house value as the 'Taxable Value' with a current tax rate of 1.11317% of the house value. Overall, the total decrease in annual property tax collected that could be attributed to the impact of the Swale's presence on housing values is \$21,969 y^{-1}.

It is important to acknowledge that this study accounts for an incomplete picture of the Swale's value. The regression does not account for the benefit that comes from living beyond 800 m from Swale, which is the majority of the City of Saskatoon, and only accounts for the marginal value of living within 800 m. However, many people are willing to travel more than 1 km daily to green space for recreational purposes (Schipperijn et al. 2010), indicating that this valuation for the Swale is conservative. Conversely, the value being attributed to proximity to the Swale may be conflated with the positive or negative impacts of proximity to agricultural lands and other open greenspace, as the Swale is located on the outskirts of Saskatoon – variables which are very challenging to separate (Czembrowski and Kronenberg 2016). Additionally, the assessed property value from homes near the Swale could easily be doubled as development continues around its perimeter both currently and in the future. Further, newer neighbourhoods have higher concentrations of houses within walking distance of the Swale due to a greater presence of walking paths and connecting parkways, so new developments are likely to yield greater benefit from the Swale, assuming all other variables remain stable.

3.4 Conclusion

Two analyses of the Meewasin Northeast Swale's have been considered in this study including a benefit transfer and a hedonic regression. The benefit transfer used 186 observations from 54 sources to value 17 ecosystem services at $7.3 million per year (2018 CAD) which can be divided between regulating services ($5.3 million per year) and cultural services ($2.1 million per year). The second analysis was a hedonic regression of houses within bordering neighbourhoods of the Swale to determine the contributions proximity-to and view-of the Swale have on property values. Being between a 400 and 800 m walking distance of the Swale was found to results in a reduction of 1.09% of a property's value as compared to houses in the same neighbourhood that were over 800 m from the Swale. Meanwhile, being located within 400 m of the Swale adds 0.77% to a property's value compared to houses in the same neighbourhood that were over 800 m from the Swale. An unimpeded view of the Swale resulted in a 0.12% decrease in property value. This impact on property value attributed to the Swale directly impacts the City of Saskatoon through a loss in property taxes equalling $21, 969 per year.

The two analyses, including benefit transfer and hedonic regression, conducted in this study exhibit two different methodologies for the assessment of the Swale's value. These analyses each have their own advantages and disadvantages. The benefit transfer is a very holistic look at the full range of ecosystem services provided by the Swale, and how those services cumulatively contribute to a large, if somewhat abstract, monetary value. Meanwhile, the hedonic regression focusses on the very tangible concept of property value, and how the spatial factors of the Swale appear to lend value to properties, which in turn is converted into property tax – real, tangible value being gained by a stakeholder, albeit resulting here in insignificant, unlikely results. The value found in the benefit transfer is largely agnostic of the surroundings of the Swale; barring major changes in the make-up of the Swale, the benefit transfer would report very similar results before and after further development around the Swale. Conversely, the hedonic regression factors in the impacts of the Swale on every house that surrounds it, suggesting that more development around the Swale would translate potentially linearly to greater total value from the Swale. Further, this benefit transfer only factors in the marginal value of houses within an 800 m walking distance of the Swale, making for a conservative estimate of value.

An initial aspect of the motivation for this study was to see how a site-specific analysis such as hedonic pricing could bolster a benefit transfer. What we found were not directly comparable results, but instead were different expressions of the same ecosystem, both contributing to an overall story of the value and appreciation of the Swale. Through the hedonic regression we have shown that there is a willingness to pay for proximity to the Swale, but the benefit transfer suggests that this willingness to pay does not yet meet the whole value the Swale has to over – that there are externalities that our current market is missing with regards to ecosystems. One analysis or the other would not have been able to provide this conclusion. Perhaps the end goal of NCAV should not be finding one correct value, but should instead be focussed on finding different methodologies for determining this value to create a multiple lines of evidence approach to NCAV assessments in the future.

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Chapter 4: Summary of Results, Discussion, Engineering Significance, and Future Work

4.1 Summary of Results

4.1.1 Chapter 2 Results

A delineation of the Swale informs the valuations performed in this thesis and provides an account of the current state of the Swale. This delineation showed that the 310 ha Swale is dominated by wetland and grassland area – 44% (138 ha) and 39% (122 ha) respectively. The Swale is also 6% (7.1 ha) woodland, 2% (19.8 ha) cropland, with the remaining 8% (24.6 ha) composed of manufactured features, divided evenly between roadways and engineered stormwater management.

The *a priori* benefit transfer used 36 ecosystem service values from 20 studies to value four ecosystem services for the Swale. In total, this analysis values the Swale's ecosystem services at $1.63 million per year. The wetland portions of the Swale are responsible for most of its value ($1.56 million per year) providing a value of $11,300 per hectare per year, compared to an average value of $5,200 per hectare per year for the Swale. Water regulation is the most valuable ecosystem service valued for the Swale ($1.03 million per year) followed by water purification and treatment ($467,000 per year).

4.1.2 Chapter 3 Results

The same delineation of the Swale was used to inform an expansion on the benefit transfer conducted in chapter 2. The follow-up benefit transfer used 186 values from 54 sources to value 17 ecosystem services for the Swale. This analysis found a total value for the Swale's ecosystem services of $7.36 million per year. This value is divided between regulating services ($5.3 million per year) and cultural services ($2.1 million per year). Like the *a priori* benefit transfer, the wetland portions of the Swale provide most of the value ($7.01 million per year), providing $51,000 per hectare per year, compared to an average value for the Swale of $23,000 per hectare per year. Natural hazard mitigation was the most valuable ecosystem service assessed ($3.6 million per year), accounting for a large portion of the discrepancy between this analysis and the previous one presented in Chapter 2.

Finally, a hedonic regression of houses within bordering neighbourhoods of the Swale was conducted to get another perspective of the cultural value of the Swale. This analysis found no statistically significant impact from the Swale on housing prices in the area. This lack of significance is likely attributable to the source of the data and the nature of the terms of interest as nominal variables rather than continuous variables. Despite the lack of significance, models showed that single-family detached homes within a 400 m walking distance appreciated an average increase to property value of $4,166 and homes between a 400 and 800 m walking distance depreciated an average decrease to property value of $5,689, as compared to homes beyond 800 m. Additionally, an unimpeded view of the Swale resulted in an average decrease in property value of $636. This analysis found a total increase in property value within adjacent neighbourhoods due to the Swale of $1.97 million. This impact on property value attributed to the Swale costs the City of Saskatoon an estimated $22,000 in the form of property taxes per year.

4.2 Discussion and Conclusions

The Meewasin Northeast Swale is an important natural resource that provides a lot of value to the people of Saskatoon. Throughout this thesis two major methods for valuing the Swale's ecosystem services have been explored: benefit transfer and hedonic pricing. Both methods show promise as efficient methods for valuing Saskatoon's natural capital, but are not without their limitations.

Benefit transfer is extremely efficient due to its use of existing research to assign values to new sites. However, this method has a high level of inherent uncertainty, making it unsuitable for scenarios that require high precision. Additionally, benefit transfer requires access to previous studies, such as academic journal articles and government studies, which is uncommon for most government organizations and corporations. Databases such as the Ecosystem Service Valuation Database are publicly available, and therefore accessible, but being unable to access the specific studies cited by the database could lead to inappropriate studies being used for benefit transfer resulting in inaccurate results. Further, databases necessitate the reduction of complicated, study-specific parameters into generic, simplified categories, creating a potential for substantially different studies to appear equivalent in terms of meta-data. The benefit transfer method presented above is also limited in its suitability to account for ecosystem health and track changes in value. Since the values for the benefit transfer are adapted from previous studies, accurately selecting studies which reflect the specific state of a given site may be prohibitively difficult. Therefore, only changes to an ecosystem that quantifiably alter ecosystem area or change ecosystem type can be easily tracked as changes in value by benefit transfer. Additionally, the values found by benefit transfer studies are subject to change over time due to improvements in the methodologies used throughout the field (e.g. Costanza 2015).

Databases other than the ESVD are also available and may have led to different results than the current thesis. One notable example is the Environmental Valuation Reference Inventory (EVRI). EVRI was developed by Environment and Climate Change Canada, starting in the early 1990s, and is now the largest database of its kind, containing over 4,000 valuation studies (EVRI 2020). However, actual valuation figures are not as readily available through the EVRI as they are through the ESVD, making conducting a benefit transfer using EVRI problematic. However, future research can potentially use the EVRI database for an analogous study to the current thesis for comparative purposes.

The hedonic pricing method is a promising valuation method for cultural ecosystem services despite the challenges faced in this study. Compared to benefit transfer, hedonic pricing provides site-specific, market-based evidence of ecosystem value, and allows for the observation of specific value contributions. However, conducting a thorough, accurate hedonic regression requires access to detailed market activity and a strong understanding of the supporting economic theory. Hedonic pricing requires professional discretion to determine the best combination of explanatory variables for use in the regression, while avoiding the common pitfalls of double-counting and collinearity. With proper expertise and access to data, hedonic pricing analysis can be a very efficient valuation method that clearly illustrates the benefits of natural capital. The hedonic pricing method has the additional benefit of reflecting the current state of an asset without requiring up-to-date detailed measurement of site parameters. However, up-to-date valuation is limited by the availability of current market data.

An initial aspect of the motivation for this thesis was to explore potential valuation methods that could be used by municipalities and other decision makers to value natural capital. This exploration led to the identification of both a site-specific method focussing on a few specific ecosystem services and a holistic – if generalised – method of valuing all relevant ecosystem services. These analyses are not directly comparable, but their combined information allows for a greater understanding of the benefits provided by natural resources. For example, the hedonic pricing model completed in this study only accounts for a portion of the cultural value of the Swale and is reported as an overall value (CAD) rather than a flow value (CAD/yr) like in the benefit transfer. When converting the hedonic pricing result to an annual flow in the form of property tax, the absolute value is orders of magnitude less than the cultural value found in the *posteriori* benefit transfer, but the direct effect of this property tax value is easy to conceptualise. In general, caution should be taken when directly comparing or combining these results as the benefit transfer method provides a value for a hypothetical "pristine" Swale, while the hedonic regression provides a value for the Swale as-is after decades of anthropogenic impacts of the City of Saskatoon.

When conducting an NCAV study, it is important to set realistic expectations. The goal of this thesis was not to find one correct, objective value for the Swale. A singular value cannot realistically be determined, would be ever-changing with time, and even if a value was considered there is even less chance a consensus among stakeholders would be reached in agreeing upon this value. It should be noted that NCAV is a tool to assist in the conceptualisation of the importance of natural capital, not determine a single monetary value for this capital. However, NCAV is not the only 'tool in the toolbox' for natural capital assessment and should be applied with due diligence. In addition, a NCAV is not – nor is it encouraging – the commodification of nature. NCAV is simply another lens through which to view nature and how it benefits humanity, and it should be used in conjunction with all the other tools at our disposal to help form the greatest degree of understanding possible.

4.3 Anthropogenic Risks to the Swale

This thesis has quantified the benefits the Meewasin Northeast Swale provides to the City of Saskatoon and its residents. Despite this value, there are many anthropogenic risks to the Swale, and the effects these risks could have on the Swale's health and value is unknown. The initial scope of this thesis included the mapping of threats to the Swale's health and development of a monitoring plan. However, the work on NCAV took precedence and expanded in scope, causing the mapping and monitoring work to be limited to this section. Fortunately, the work done on NCAV can help inform the priorities of a monitoring plan. Through the benefit transfers conducted, I determined that wetland portions of the Swale are the most valuable and that the most valuable services provided are natural hazard mitigation, recreation, tourism and lifestyle, water regulation, and water purification and treatment. Therefore, the greatest return on investment for a monitoring plan is likely targeting threats to those services for the wetland portions of the Swale.

The following sections provide an overview of the most prominent anthropogenic threats to the Swale and recommendations for what a potential monitoring plan should consider. These threats include contamination (pesticides, herbicides, nutrients, and metals), habitat fragmentation, light and noise pollution, and exotic species invasion.

4.3.1 Fragmentation

Fragmentation from urbanization has the potential to negatively impact both flora and fauna (Figure 4.1) Fragmentation is the structural division of a habitat into smaller, potentially-isolated habitats. The movement of fauna may be impeded by fragmentation through three mechanisms: limited resource access; restricted demographic exchange; and impeded gene flow (Consgrove 2018). Habitat fragmentation may segregate individuals from required resources, negatively impacting animals on local and daily scales. Demographic exchange is restricted when individuals are unable to travel to other habitats and intermingle with other demographics, potentially resulting in unsustainable populations and patchy distributed populations on the landscape and lifetime to multi-generational scales. Impeded gene flow occurs when spatially discrete populations are unable to exchange genes, resulting in a limited gene-pool and exacerbation of genetic mutation on the regional scale over multiple generations. These three mechanisms are not mutually exclusive and can overlap in spatial and temporal influence, but it is important to distinguish between these mechanisms when creating management solutions. Even when habitats are well managed, fragmentation can pose an existential threat to plant populations (Hooftman et al 2003). Smaller populations of plants are more vulnerable to natural variability and are less attractive to pollinators, resulting in pollen limitation and lower genetic variability (Liernert and Fischer 2003). One major impact of fragmentation is the increased ratio between habitat edge and centre area. Edge areas tend to be less dense with plant-life than centre areas. Further, central plant densities tend to be greater in larger habitats, whereas densities at the edges are independent of habitat size.

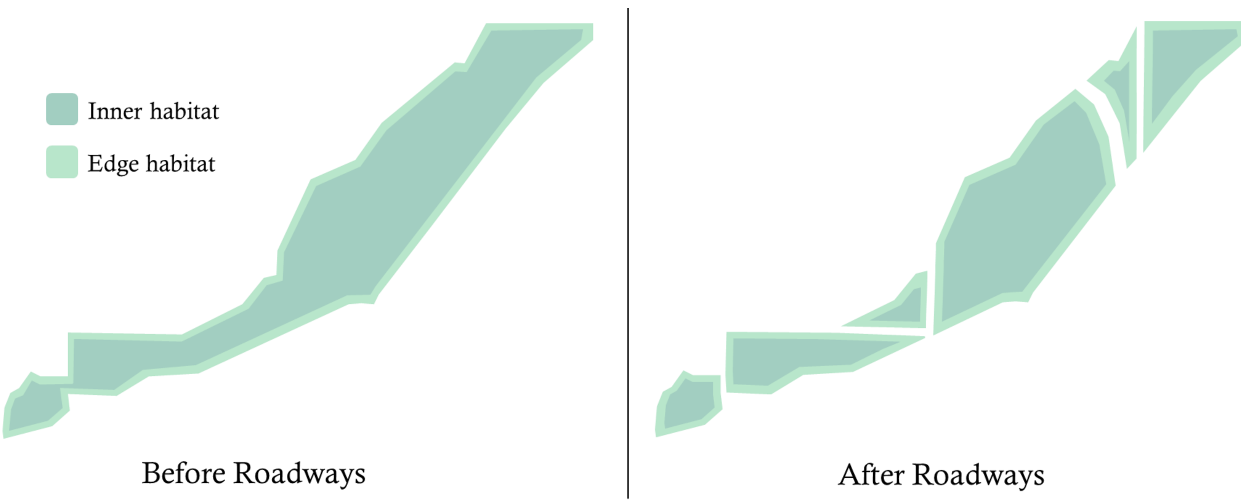

Figure 4.1: Visual representation of how fragmentation from roadways decreases habitat size and increased edge habitat area and isolation for the Swale

4.3.2 Contamination

The introduction of surficial run-off, atmospheric deposition, and groundwater recharge into the Swale are all sources of potential contamination, including pesticides, herbicides, fertilisers, fecal matter, and metals (Figure 4.2) (Howitt et al. 2014). Atmospheric processes of herbicides – such as wet and dry deposition, air-water interface exchange, and groundwater recharge – from agricultural and residential applications alone can account for detectable levels of herbicides in wetlands in central Saskatchewan (Messing et al. 2011). Increased stormwater runoff as a result of urbanisation can contribute to greater surface water pesticide contamination from pesticide applications on the regional scale. Metals are another common contaminant of concern in stormwater, typical associated with roadway runoff (Howitt et al. 2014). However, current research shows no signs of metals bioaccumulating along food chains in urban wetlands (Mackintosh et al. 2016). Polycyclic aromatic hydrocarbons (PAHs) are also commonly associate with roadway runoff due to tire wear, exhaust fumes, and bitumen surfaces (Howitt et al. 2014). Sediment in natural wetlands is another major challenge as there are rarely plans for sediment disposal, as there is risk of habitat damage associated with sediment disposal (Howitt et al. 2014). Overall, contamination impacts can be challenging to assess due to the pulsed nature of contaminant introduction (Howitt et al. 2014).

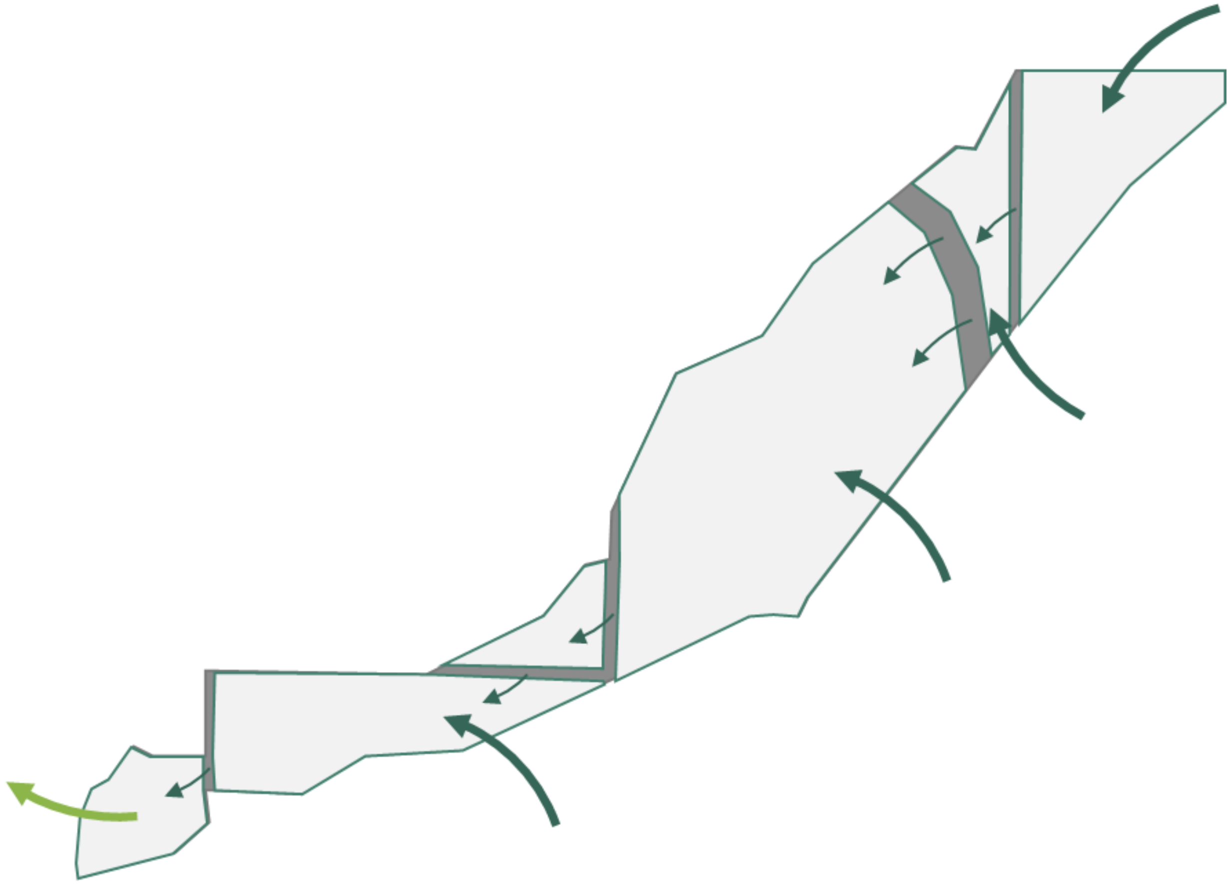

Figure 4.2: Conceptual map of high-risk contamination loading points for the Swale: roadways (grey), adjacent neighbourhood stormwater outfalls, and upstream agricultural region. Light green arrow displays Swale flow into SSR. Exotic and invasive species propagation have similar risk points.

4.3.3 Light and Noise Pollution

Light pollution can alter the natural cycles of flora and fauna (Figure 4.3). Due to the anatomical differences between humans and fauna, the exact effects of light pollution are difficult to anticipate without direct, empirical observations. Artificial lighting likely disrupts the circadian cycle of both nocturnal and diurnal fauna, potentially affecting mating success, predator vigilance, foraging, and other processes (Newport et al. 2014). Additionally, many plants and fungi have nocturnal activities that may be affected by light pollution (Newport et al. 2014). Noise pollution also negatively influences the natural mannerisms of fauna. Noise pollution can impede alarm and mating calls, serve as false alarms of predator activity, and interfere with other defensive behaviours (Newport et al. 2014). Increased noise levels have been shown to decrease both population and species richness of birds (Newport et al. 2014).

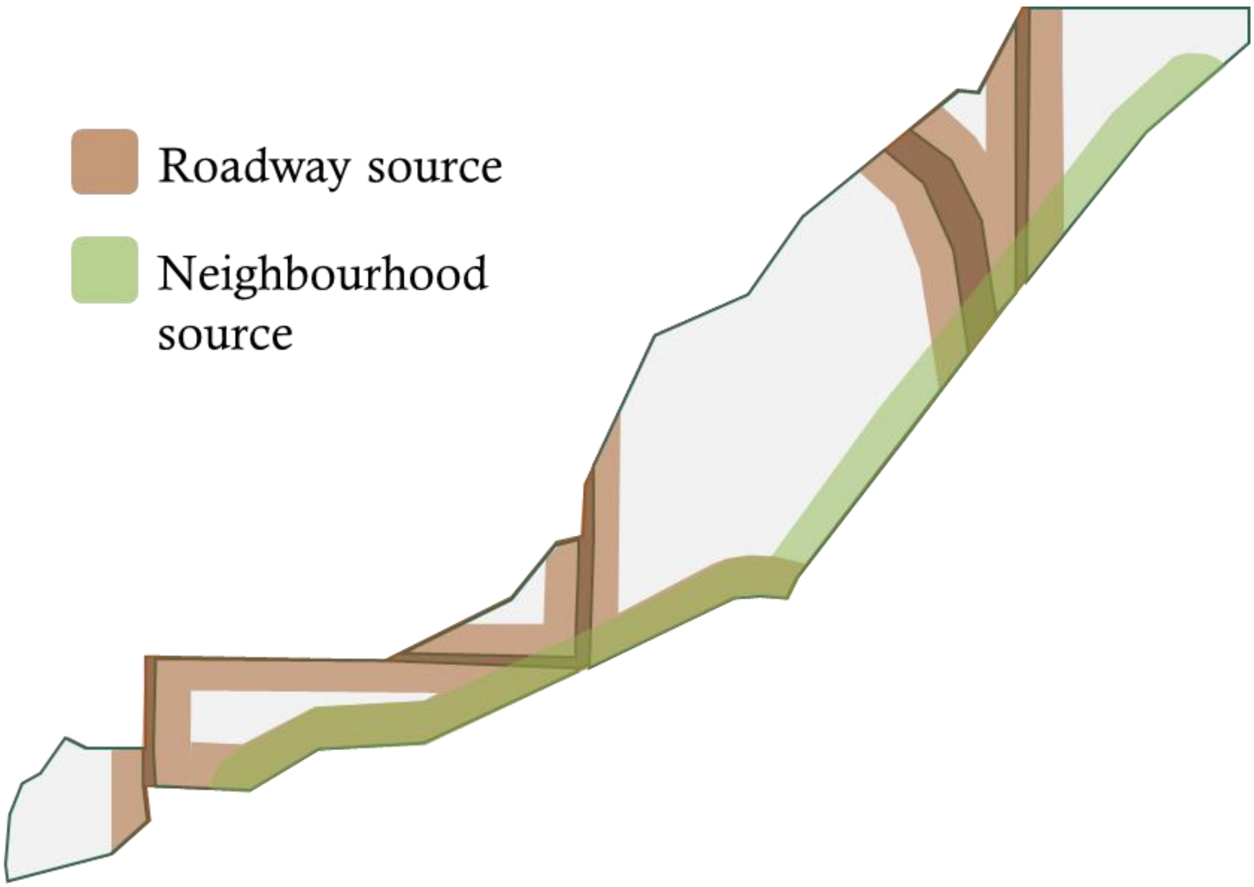

Figure 4.3: Conceptual map of light and noise pollution for the Swale, showing roadway and neighbourhood sources emanating into the Swale

4.3.4 Exotic and Invasive Species

The propagation of exotic invasive species is driven by hydrological changes, atmospheric and aqueous input of nutrients, frequent physical disturbance, large sources of exotic species' propagules, and anthropogenic dispersal of propagules (Ehrenfeld 2008). Vegetated upland tends to reduce invasion of exotic species of invasive species, regardless of whether the upland is natively vegetated or invaded (Ehrenfeld 2008). Interestingly, the presence of trails does not appear to contribute to exotic invasion (Ehrenfeld 2008). Overall, the distribution of exotic species within urban wetlands is highly variable, depending on the specific characteristics of each species and the site in question.

4.3.5 Monitoring

The NCAV conducted for the Swale shows what the greatest sources of value are for the Swale, informing what may be prioritised for a monitoring plan. In general, wetlands are the greatest contributors of value for the Swale. Three regulating services – natural hazard mitigation (generally referring to flood and drought prevention), water regulation, and water purification and treatment – are some of the most valuable services along with recreation, tourism, and lifestyle services. This suggests that monitoring should prioritise wetland areas and indicators of water regulation and treatment capacity.

Any change in landcover may alter the Swale's hydrological characteristics, affecting its ability to provide valuable regulating services (MEA 2005). General monitoring of landcover throughout the Swale – especially in areas of drainage into the Swale – would act as a useful indicator of potential change in hydrological changes but does not need to be an intensive monitoring process. Fragmentation presents the risk of plant habitat degradation, which could result in significant decreases in the Swale's ability to regulate and treat water (Hooftman et al 2003), as well as affect the aesthetic quality of the Swale (Figure 4.2). Fragmentation of the Swale is unfortunately unavoidable, given the roadways that currently pass through it, but monitoring of plant population size, density, and fitness would allow for an understanding of the extent which fragmentation is affecting the Swale allowing for countermeasures to be taken if necessary (Hooftman et al 2003). This monitoring should likely be focussed on areas where the environment has been visibly fragmented, such as near the North Commuter Parkway, but additional monitoring of plant population metrics further downstream could allow for an understanding of larger-scale effects of fragmentation and other impacts. The final priority touched on here is contamination (Figure 4.3). Increased stormwater runoff as a result of urbanisation can contribute to greater surface water pesticide, herbicide, fertiliser, fecal matter, and metal contaminants (Howitt et al. 2014). These contaminants can be harmful to native flora and fauna (Howitt et al. 2014), causing ecosystem degradation and a loss of services. Conversely, an increase of contaminants flowing into the Swale may mean a greater amount of water purification and treatment, meaning more value for Saskatoon. Due to this interesting relationship between damaging the ecosystem and appreciating more value, monitoring of surface water should take place at both the input points and a downstream point. This combination allows the assessment of the Swale's ability to remove contaminants, which is especially important given that the Swale flows into the South Saskatchewan River.

Light and noise pollution and exotic and invasive species propagation are also important impacts, but their effects are not easy to monitor (Ehrenfeld 2008; Newport et al. 2014) and are not as immediately impactful on the sources of the Swale's value (Figure 4.3).

Further research is required before any specific monitoring plan be put into place, but the above discussion provides useful, NCAV-informed, guidance on how the Swale should be monitored.

4.4 Engineering Significance

The research in this thesis aimed to take an economic subject that exists largely in the sphere of academia and apply engineering principals to develop approachable methods to generate actionable NCAV results. Engineers have a responsibility to use a triple-bottom-line approach to their decision-making and NCAV has great potential for assisting in this sort of decision-making. However, the literature review presented through this thesis shows that there is still uncertainty regarding the optimal methods of NCAV. The process of developing a suitable method of NCAV for practical use will require substantially more research and should involve extensive industry-regulatory-academic collaboration. Despite the work ahead, the research presented in this thesis is an earnest start that provides evocative results that could help inform real management decisions.

4.5 Future Work

Although the work presented within this thesis is a start towards determining how municipalities may best value and protect their natural capital, there are several directions this research could go in the future. These directions include expansion of the study area, application of the methodology towards new study areas, analysing threats to the Swale's values and designing a monitoring plan, and exploring additional valuation methodologies. Each of these opportunities are briefly discussed below.

One of the most immediate ways to expand upon this research would be to extend the study area to the full Northeast Swale, extending from Saskatoon to the Rural Municipality of Aberdeen. This area has received even less attention than the Swale and is a continuation of the same interconnected wetland ecosystem. Since management of the greater Northeast Swale would require co-management between the City of Saskatoon, Meewasin, and the Rural Municipalities of Corman Park and Aberdeen, expanding the mapping and benefit transfer to the entire Swale could help start a conversation between the stakeholders. Additionally, this expanded study area would allow for comparison of urban and rural wetlands, in terms of their value, the threats to their health, and how those values and threats are interdependent. Ecosystems are apathetic of municipal borders, so expanding the scope to the full Swale would allow for a more holistic look at this significant ecosystem.

This thesis touched upon the threats to the Swale and its services and one of the major motivations for NCAV is to justify the monitoring and protection of valuable natural capital. An excellent opportunity for future research is the mapping of threats to the Swale and design of a detailed monitoring plan. This plan could integrate the UAV recently acquired by our research group into both the mapping and monitoring. Further, potential threats from further development surrounding the Swale could be anticipated and then actively monitored throughout the full course of development, allowing for the observation of the impacts of urban development.

Two valuation methods were explored in this thesis, but there are many other methods of NCAV that could be explored and compared for the Swale and beyond. Contingent valuation method is one such method that could make for a very interesting project and help in valuing natural capital throughout the city. Applying replacement cost method to the stormwater management value of the Swale would be appropriate work for a civil engineer and could show how much value developers of new neighbourhoods around the Swale gain by using the Swale for stormwater management. Even applying a standardised method of NCAV – such as the UN's System of Environmental Economic Accounting – to the Swale and comparing the advantages and disadvantages of such a method to the previously explored methods could be an excellent opportunity for future work.

Another direction this research could go is applying it to other natural capital in Saskatoon, and potentially other municipalities in Canada. This direction would allow for the methods explored in this thesis to be further refined, allowing for efficient application to a wide variety of resources. The City of Saskatoon have expressed interest in expanding NCAV to the Small Swale and the Chappel Marsh Conservation Area in the short term, but the opportunities for NCAV in Saskatoon are endless.

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Appendix A: *A Priori* Benefit Transfer Worksheet

Ecosystem			Total		*A Priori* Benefit Transfer							
					Climate Regulation		Water Regulation		Water Purification		Recreation, Tourism, and Lifestyle	
Type	Area	Value	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr
Woodland	19.78 ha	Average	**5,862.01**	**115,960.71**	194.49	3,847.39	5,233.58	103,529.25	257.97	5,103.01	175.97	3,481.05
		Median	**3,852.06**	**76,200.38**	113.11	2,237.56	3,426.39	67,779.85	136.59	2,701.92	175.97	3,481.05
		Min	**201.01**	**3,976.40**	24.48	484.32	0.23	4.47	0.33	6.55	175.97	3,481.05
		Max	**18,936.82**	**374,603.11**	616.67	12,198.81	17,028.67	336,856.42	1,115.52	22,066.83	175.97	3,481.05
		Count	**20**	**20**	6	6	6	6	7	7	1	1
Grassland	121.57 ha	Average	**461.69**	**56,126.41**	335.86	40,830.38	4.13	502.17	120.89	14,695.89	0.81	97.97
		Median	**461.69**	**56,126.41**	335.86	40,830.38	4.13	502.17	120.89	14,695.89	0.81	97.97
		Min	**360.45**	**43,819.90**	335.86	40,830.38	4.13	502.17	19.89	2,418.31	0.57	69.04
		Max	**562.92**	**68,432.92**	335.86	40,830.38	4.13	502.17	221.88	26,973.47	1.04	126.90
		Count	**6**	**6**	1	1	1	1	2	2	2	2
Wetland	137.50 ha	Average	**11,331.71**	**1,558,148.18**	345.90	47,562.53	7,515.81	1,033,449.92	3,254.70	447,532.35	215.29	29,603.38
		Median	**8,036.48**	**1,105,042.95**	345.90	47,562.53	6,181.82	850,020.99	1,293.47	177,856.06	215.29	29,603.38
		Min	**1,062.38**	**146,081.16**	345.90	47,562.53	670.95	92,258.57	37.83	5,202.15	7.69	1,057.91
		Max	**34,710.76**	**4,772,846.59**	345.90	47,562.53	17,028.67	2,341,499.14	16,913.30	2,325,636.08	422.89	58,148.84
		Count	**15**	**15**	1	1	4	4	8	8	2	2
Total	**310.00 ha**	**Average**	5,581.40	1,730,235.30	**297.55**	**92,240.30**	**3,669.29**	**1,137,481.34**	**1,507.52**	**467,331.25**	**107.04**	**33,182.40**
		Median	3,991.52	1,237,369.74	**292.36**	**90,630.47**	**2,962.27**	**918,303.00**	**629.85**	**195,253.87**	**107.04**	**33,182.40**
		Min	625.41	193,877.46	**286.70**	**88,877.23**	**299.24**	**92,765.21**	**24.60**	**7,627.02**	**14.86**	**4,608.00**
		Max	16,825.43	5,215,882.62	**324.49**	**100,591.72**	**8,641.48**	**2,678,857.73**	**7,660.25**	**2,374,676.37**	**199.22**	**61,756.80**
		Count	41	41	**8**	**8**	**11**	**11**	**17**	**17**	**5**	**5**

Appendix B: Expanded Benefit Transfer Worksheet

Part 1 of 2:

Ecosystem			Total		Regulating Services: Air Quality Regulation		Climate Regulation		Water Regulation		Water Purification		Natural Hazard Mitigation		Pollination		Pest Regulation		Erosion Regulation		Regulation Total	
Type	Area	Value	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr	2018 CAD/ha/yr	2018 CAD/yr
Cultivated	7.07 ha	Average	**2,992.25**	**21,142.20**	136.20	962.34	242.46	1,713.12	-	-	446.78	3,156.82	-	-	34.67	244.99	52.01	367.48	169.41	1,196.99	1,081.53	7,641.74
		Median	**2,992.25**	**21,142.20**	136.20	962.34	242.46	1,713.12	-	-	446.78	3,156.82	-	-	34.67	244.99	52.01	367.48	169.41	1,196.99	1,081.53	7,641.74
		Min	**1,202.90**	**8,499.30**	136.20	962.34	242.46	1,713.12	-	-	446.78	3,156.82	-	-	34.67	244.99	52.01	367.48	92.67	654.76	1,004.79	7,099.51
		Max	**4,781.60**	**33,785.11**	136.20	962.34	242.46	1,713.12	-	-	446.78	3,156.82	-	-	34.67	244.99	52.01	367.48	246.15	1,739.22	1,158.27	8,183.97
		Count	**11**	**11**	1	1	1	1	-	-	1	1	-	-	1	1	1	1	2	2	7	7
Woodland	19.78 ha	Average	**13,138.07**	**259,893.63**	705.19	13,949.78	3,546.36	70,153.12	2.08	41.10	185.16	3,662.78	0.30	5.93	693.46	13,717.81	2,386.35	47,206.18	73.71	1,458.08	7,592.60	150,194.79
		Median	**4,764.16**	**94,243.26**	705.19	13,949.78	230.57	4,561.17	2.08	41.10	61.89	1,224.32	0.30	5.93	693.46	13,717.81	29.97	592.85	41.04	811.85	1,764.50	34,904.81
		Min	**847.57**	**16,766.34**	128.22	2,536.32	13.31	263.28	0.38	7.49	0.11	2.10	0.30	5.93	693.46	13,717.81	8.67	171.47	1.25	24.71	845.69	16,729.11
		Max	**83,119.80**	**1,644,253.15**	1,282.15	25,363.23	43,338.61	857,312.58	3.78	74.71	1,116.21	22,080.51	0.30	5.93	693.46	13,717.81	7,120.42	140,854.23	211.50	4,183.93	53,766.43	1,063,592.93
		Count	**71**	**71**	2	2	13	13	2	2	11	11	1	1	1	1	3	3	4	4	37	37
Grassland	121.57 ha	Average	**559.62**	**68,032.61**	-	-	189.95	23,092.36	8.67	1,053.78	143.61	17,458.71	-	-	55.48	6,744.21	52.01	6,322.70	108.50	13,190.21	558.22	67,861.96
		Median	**474.48**	**57,682.23**	-	-	96.73	11,759.84	8.67	1,053.78	188.97	22,972.47	-	-	55.48	6,744.21	52.01	6,322.70	71.22	8,658.58	473.08	57,511.59
		Min	**199.81**	**24,290.45**	-	-	2.56	311.31	8.67	1,053.78	20.24	2,460.51	-	-	55.48	6,744.21	52.01	6,322.70	59.88	7,279.77	198.84	24,172.29
		Max	**1,135.08**	**137,989.28**	-	-	563.78	68,538.42	8.67	1,053.78	221.63	26,943.15	-	-	55.48	6,744.21	52.01	6,322.70	231.67	28,163.89	1,133.24	137,766.14
		Count	**18**	**18**	-	-	4	4	1	1	3	3	-	-	1	1	1	1	4	4	14	14
Wetland	137.50 ha	Average	**51,006.71**	**7,013,595.91**	-	-	296.82	40,813.81	6,959.31	956,928.62	3,031.61	416,856.91	26,160.30	3,597,129.36	26.88	3,696.63	125.03	17,191.55	138.93	19,103.78	36,738.88	5,051,720.65
		Median	**13,122.90**	**1,804,443.26**	-	-	312.88	43,022.00	6,810.41	936,454.99	908.34	124,899.31	3,090.57	424,963.62	26.88	3,696.63	125.03	17,191.55	138.93	19,103.78	11,413.04	1,569,331.87
		Min	**1,200.10**	**165,017.20**	-	-	6.18	849.47	783.96	107,796.71	64.03	8,804.92	23.37	3,212.88	26.88	3,696.63	24.74	3,401.38	138.93	19,103.78	1,068.09	146,865.77
		Max	**533,152.47**	**73,310,268.73**	-	-	581.35	79,937.38	13,432.45	1,847,007.78	16,913.55	2,325,669.74	305,248.20	41,972,660.44	26.88	3,696.63	225.32	30,981.71	138.93	19,103.78	336,566.68	46,279,057.46
		Count	**86**	**86**	-	-	6	6	4	4	16	16	15	15	1	1	2	2	1	1	45	45
Total	**310.00 ha**	**Average**	**23,750.53**	**7,362,664.35**	**48.10**	**14,912.12**	**437.98**	**135,772.41**	**3,090.40**	**958,023.50**	**1,423.02**	**441,135.22**	**11,603.66**	**3,597,135.29**	**78.72**	**24,403.64**	**229.32**	**71,087.91**	**112.74**	**34,949.05**	**17,023.93**	**5,277,419.15**
		Median	**6,379.07**	**1,977,510.95**	**48.10**	**14,912.12**	**196.96**	**61,056.14**	**3,024.35**	**937,549.87**	**491.14**	**152,252.92**	**1,370.87**	**424,969.55**	**78.72**	**24,403.64**	**78.95**	**24,474.58**	**96.04**	**29,771.20**	**5,385.13**	**1,669,390.01**
		Min	**692.17**	**214,573.30**	**11.29**	**3,498.66**	**10.12**	**3,137.18**	**351.15**	**108,857.99**	**46.53**	**14,424.36**	**10.38**	**3,218.81**	**78.72**	**24,403.64**	**33.11**	**10,263.03**	**87.30**	**27,063.02**	**628.60**	**194,866.69**
		Max	**242,342.89**	**75,126,296.26**	**84.92**	**26,325.57**	**3,250.00**	**1,007,501.50**	**5,961.73**	**1,848,136.28**	**7,670.48**	**2,377,850.22**	**135,395.70**	**41,972,666.36**	**78.72**	**24,403.64**	**575.89**	**178,526.12**	**171.58**	**53,190.81**	**153,189.03**	**47,488,600.50**
		Count	**186**	**186**	**3**	**3**	**24**	**24**	**7**	**7**	**31**	**31**	**16**	**16**	**4**	**4**	**7**	**7**	**11**	**11**	**103**	**103**

Part 2 of 2:

Ecosystem Type	Area	Value	Total 2018 CAD/ha/yr	Total 2018 CAD/yr	Biodiversity 2018 CAD/ha/yr	Biodiversity 2018 CAD/yr	Aesthetics and Inspiration 2018 CAD/ha/yr	Aesthetics and Inspiration 2018 CAD/yr	Knowledge and Education 2018 CAD/ha/yr	Knowledge and Education 2018 CAD/yr	Recreation and Tourism 2018 CAD/ha/yr	Recreation and Tourism 2018 CAD/yr	Cultural Total 2018 CAD/ha/yr	Cultural Total 2018 CAD/yr
Cultivated	7.07 ha	Average	**2,992.25**	**21,142.20**	1,877.28	13,264.21	-	-	-	-	33.44	236.26	1,910.72	13,500.46
		Median	**2,992.25**	**21,142.20**	1,877.28	13,264.21	-	-	-	-	33.44	236.26	1,910.72	13,500.46
		Min	**1,202.90**	**8,499.30**	195.38	1,380.50	-	-	-	-	2.73	19.29	198.11	1,399.78
		Max	**4,781.60**	**33,785.11**	3,559.18	25,147.92	-	-	-	-	64.14	453.23	3,623.32	25,601.15
		Count	**11**	**11**	2	2	-	-	-	-	2	2	4	4
Woodland	19.78 ha	Average	**13,138.07**	**259,893.63**	996.86	19,719.62	2,924.64	57,854.35	0.40	7.96	1,623.56	32,116.91	5,545.46	109,698.83
		Median	**4,764.16**	**94,243.26**	57.32	1,133.81	2,924.64	57,854.35	0.40	7.96	17.31	342.32	2,999.66	59,338.44
		Min	**847.57**	**16,766.34**	0.07	1.32	0.15	2.96	0.01	0.26	1.65	32.69	1.88	37.23
		Max	**83,119.80**	**1,644,253.15**	8,352.08	165,218.62	5,849.12	115,705.73	0.79	15.66	15,151.37	299,720.22	29,353.36	580,660.22
		Count	**71**	**71**	14	14	2	2	2	2	16	16	34	34
Grassland	121.57 ha	Average	**559.62**	**68,032.61**	0.05	6.14	-	-	-	-	1.35	164.51	1.40	170.65
		Median	**474.48**	**57,682.23**	0.05	6.14	-	-	-	-	1.35	164.51	1.40	170.65
		Min	**199.81**	**24,290.45**	0.02	2.23	-	-	-	-	0.95	115.93	0.97	118.16
		Max	**1,135.08**	**137,989.28**	0.08	10.04	-	-	-	-	1.75	213.09	1.84	223.13
		Count	**18**	**18**	2	2	-	-	-	-	2	2	4	4
Wetland	137.50 ha	Average	**51,006.71**	**7,013,595.91**	461.52	63,460.64	2,278.70	313,328.47	-	-	11,527.62	1,585,086.14	14,267.83	1,961,875.26
		Median	**13,122.90**	**1,804,443.26**	86.54	11,899.33	1,255.29	172,606.91	-	-	368.03	50,605.15	1,709.86	235,111.39
		Min	**1,200.10**	**165,017.20**	0.24	33.14	131.77	18,118.27	-	-	0.00	0.02	132.01	18,151.43
		Max	**533,152.47**	**73,310,268.73**	4,570.85	628,506.77	6,183.83	850,298.19	-	-	185,831.11	25,552,406.30	196,585.79	27,031,211.27
		Count	**86**	**86**	18	18	5	5	-	-	18	18	41	41
Total	**310.00 ha**	**Average**	23,750.53	7,362,664.35	**311.13**	**96,450.60**	**1,197.36**	**371,182.82**	**0.03**	**7.96**	**5,218.08**	**1,617,603.82**	**6,726.60**	**2,085,245.20**
		Median	6,379.07	1,977,510.95	**84.85**	**26,303.49**	**743.42**	**230,461.25**	**0.03**	**7.96**	**165.64**	**51,348.24**	**993.94**	**308,120.94**
		Min	692.17	214,573.30	**4.57**	**1,417.19**	**58.46**	**18,121.24**	**0.00**	**0.26**	**0.54**	**167.92**	**63.57**	**19,706.61**
		Max	242,342.89	75,126,296.26	**2,641.56**	**818,883.35**	**3,116.14**	**966,003.92**	**0.05**	**15.66**	**83,396.11**	**25,852,792.84**	**89,153.86**	**27,637,695.77**
		Count	186	186	**36**	**36**	**7**	**7**	**2**	**2**	**38**	**38**	**83**	**83**

(Biodiversity, Aesthetics and Inspiration, Knowledge and Education, Recreation and Tourism, Cultural Total: Cultural Services)

Appendix C: Hedonic Pricing Method Charts

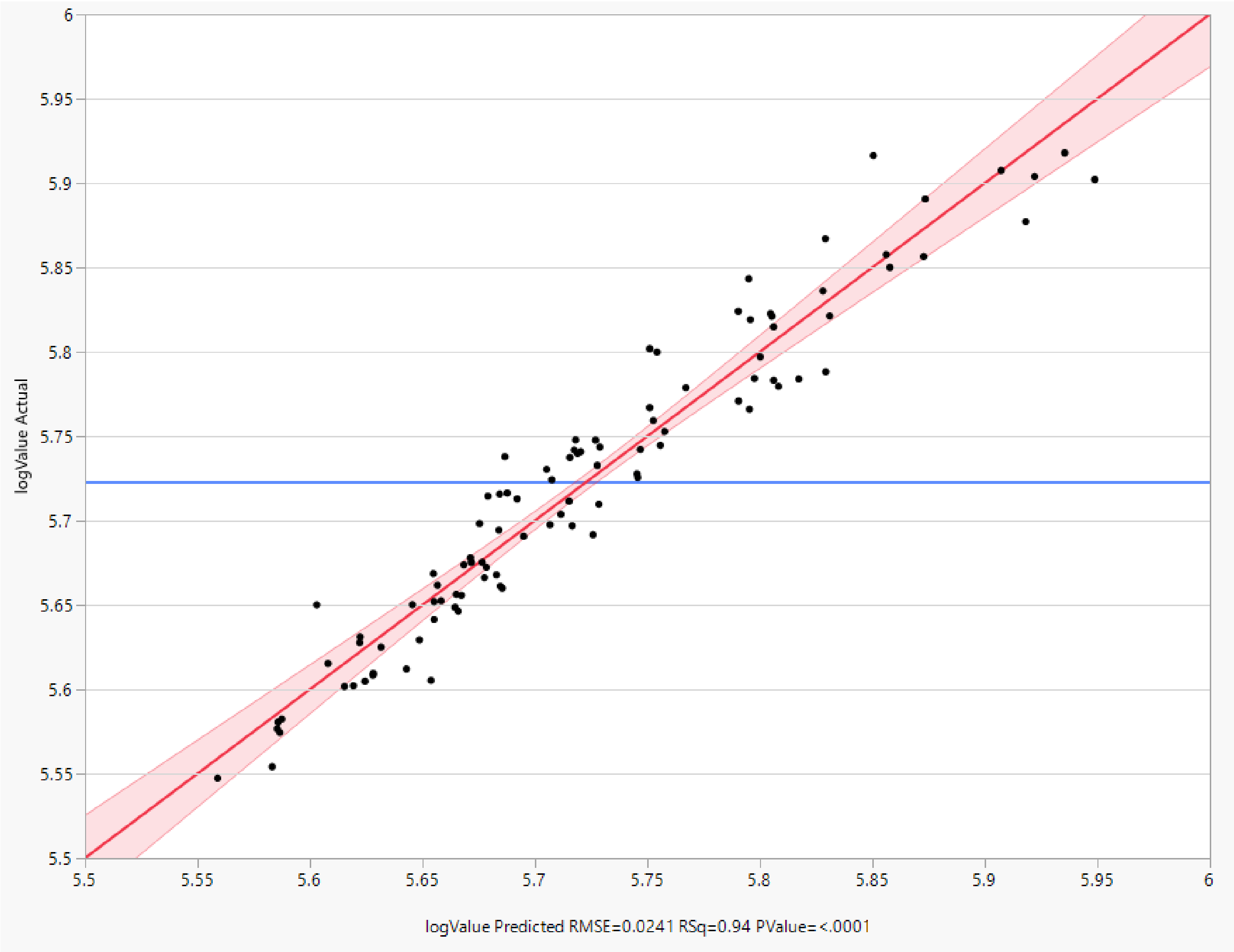

Figure C.1: logValue actual vs. logValue predicted chart for model (a)

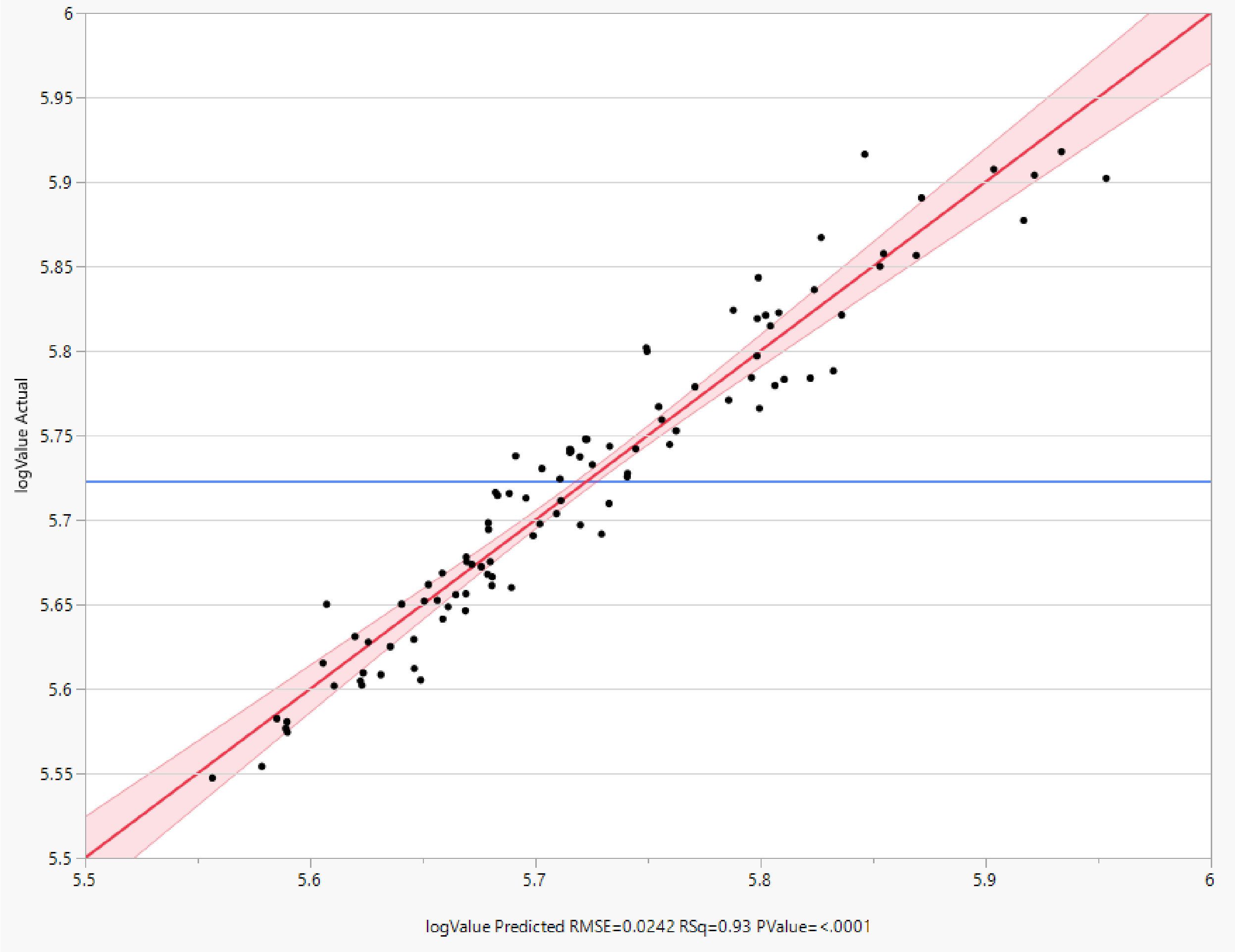

Figure C.2: logValue actual vs. logValue predicted chart for model (b)

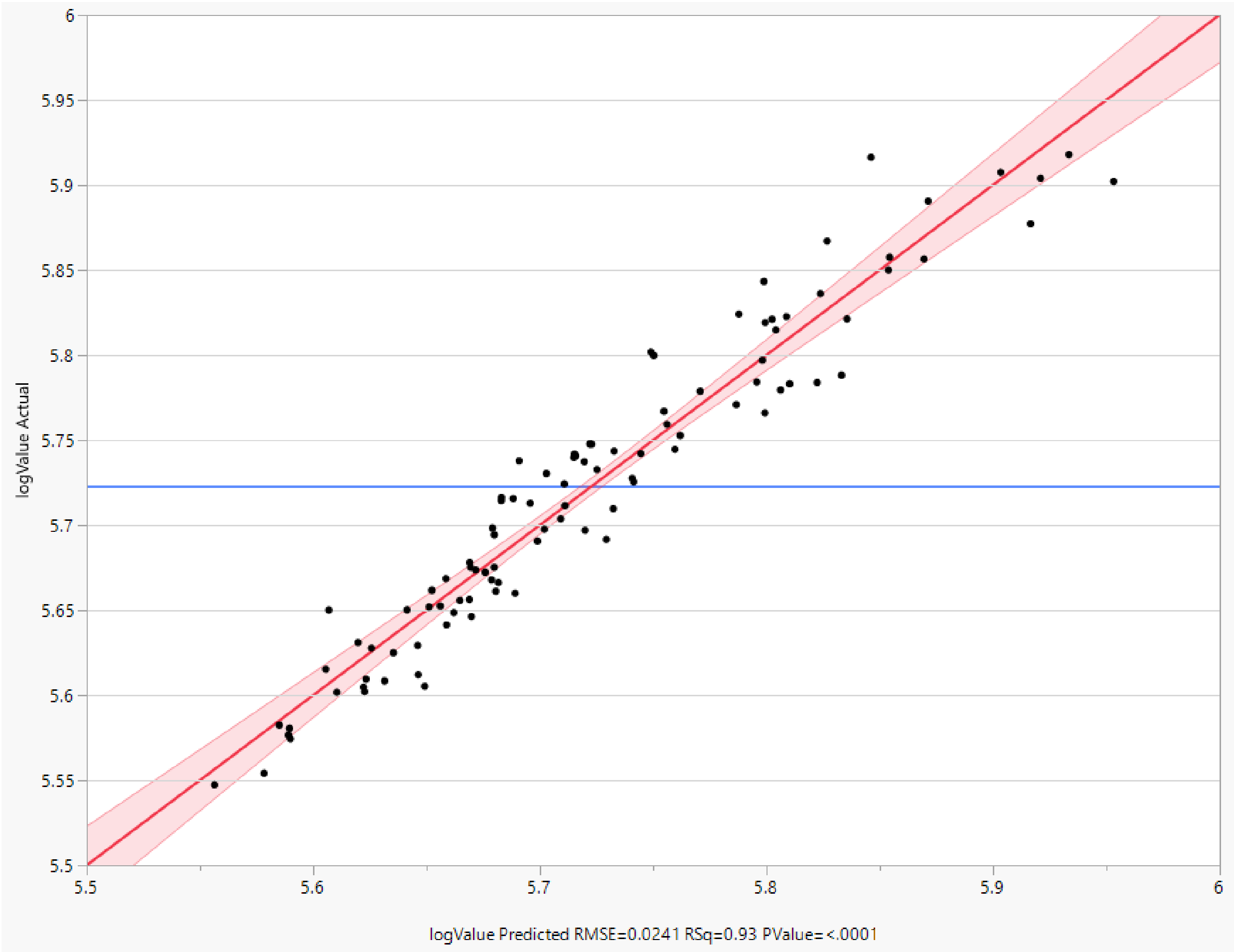

Figure C.3: logValue actual vs. logValue predicted chart for model (c)