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Analysis

Wetlands, Flood Control and Ecosystem Services in the Smith Creek Drainage Basin: A Case Study in Saskatchewan, Canada

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ABSTRACT

This paper applies a social return on investment (SROI) analysis to the issue of flood control and wetland conservation in the Smith Creek basin of southeastern Saskatchewan, Canada. Basin hydrological modeling applied to wetland loss and restoration scenarios in the study area provides local estimates of the ecosystem service (ES) provision related to flood control and nutrient removal. Locally appropriate monetary values are applied to these services to gauge the cost effectiveness of wetland conservation funding at two levels: flood control capacity alone and then incorporating a suite of ES. SROI ratios for flood control alone provide ratios between 3.17 (retention) and 0.80 (full restoration) over 30 years; when other ES are included, the ratios increase, ranging from 7.70 (retention) to 2.98 (full restoration) over 30 years. Retention of existing wetlands provides the highest SROI and therefore we argue that government policy should focus on preventing further loss of wetlands as a strategic investment opportunity. Overall, these results indicate that wetland retention is an economically viable solution to limit the financial, social and environmental damages of flooding in Saskatchewan specifically and the Prairie Pothole Region (PPR) generally.

1. Introduction

The Canadian Prairies are characterized by level to rolling landscapes interspersed with small post-glacial topographic depressions known as potholes, resulting in the label of Prairie Pothole Region (PPR). The deep, nutrient rich soils resulting from these glacial and post-glacial deposition processes created land suitable for agricultural production and human settlement and form the agriculturally productive southern regions of the Canadian Prairie Provinces of Manitoba, Saskatchewan and Alberta. A continental climate characterized by low temperatures, development of a seasonal snow cover and frozen soils in winter and rainfall when there is high infiltrability to unfrozen soils in summer results in highly seasonal surface-water runoff that is primarily driven by spring snowmelt (Gray, 1970). Lakes, rivers and pothole wetlands are recharged by the annual snowmelt, and spring flood events are a natural and expected annual occurrence (Buttle et al., 2016; Dumanski et al., 2015; Gray, 1970; Pomeroy et al., 2007; Wheater and Gober, 2013). While sparsely populated, the Canadian Prairies are an iconic part of the Canadian landscape and agriculture industry.

The low topographical relief and poorly developed surface drainage system that characterizes much of Saskatchewan has meant the southern regions of this province are particularly susceptible to flood events (Government of Canada, 2016a; Gray, 1970; Dumanski et al., 2015). The frequency distributions of extreme runoff events are not controlled by the frequency of precipitation but by the transformation of precipitation from snowfall to snowpack, to runoff and after wetland storage to streamflow (Shook et al., 2013). In recent years, the frequency and severity of floods has increased due to the extreme weather events associated with climate change (Pomeroy et al., 2009) and 2010 through 2014 have been some of the wettest years on record (Buttle et al., 2016; Chun and Wheater, 2012). There has been a dramatic shift in the sources of runoff in Smith Creek, SK since the 1990s. Before the late 1990s about 85% of streamflow volume was derived from snowmelt runoff and all streamflow peaks occurred in the March–May period; the stream normally dried up in late May. Since 2009 however rainfall is involved in 55% of streamflow volume and for the first time in any record, was involved in generating peak flows in 2012 and 2014 (Dumanski et al., 2015). Runoff efficiency in the basin has increased 12-fold over this period, but there are no trends or changes to annual

Abbreviations: ES, Ecosystem Services; SROI, social return on investment; NPV, Net Present Value; TN, total nitrogen; TP, total phosphorous; PPR, Prairie Pothole Region; CRHM, cold region hydrological modeling platform

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precipitation volumes despite increasing temporal concentration of precipitation in multiple day springtime events and a shift to less snowfall and more rainfall as temperatures increase.

Excess surface water on the landscape has a substantial negative impact on the agriculture industry and local private and public infrastructure (Ahmari et al., 2016; Szeto et al., 2015). In 2010 there was a record number of acres un-seeded (eight million) and drowned (four million) (Government of Saskatchewan, 2014a) in Saskatchewan due to excessive soil moisture conditions.[1] Infrastructure damage to roads, households and communities caused by flooding has been significant, and many urban and small-town homeowners faced extensive damage and associated insurance costs (Ahmari et al., 2016; Szeto et al., 2015). Due to these collective occurrences, provincial policy-makers and stakeholders have identified extensive coverage of the landscape by water – from either snowmelt or extreme rainfall – as one of the most serious environmental challenges in the province (Saskatchewan Water Security Agency, 2016a).

Significant financial resources have been required to compensate for these damages (Saskatchewan Water Security Agency, 2016b). These resources have come from private insurance, provincial and federal governments, or a combination of both (Ahmari et al., 2016). In addition, public and private expenditures on water control structures – such as dykes and dams – and rebuilding roads and buildings are significant. Further, surface drainage networks have been expanded to remove water from the landscape at significant cost (Saskatchewan Water Security Agency, 2016c). The extreme rainfall and flood events led to federal government disaster payouts to Saskatchewan of CAD$245 million in 2011 and CAD$160 million in 2014 (Government of Canada, 2016b) and the probability of these events and the use of the federal government disaster assistance program in the prairie provinces is expected to increase in future years more than in other regions of Canada (Government of Canada, 2016b).

Exacerbating these water quantity impacts is the associated transport of significant levels of nutrients such as phosphorous and nitrogen within these floodwaters. Algae blooms and water quality concerns in Lake Diefenbaker have prompted research into the water quality of the lake and sources of the nutrient loading (Abirhire et al., 2015). Further, as much of southern Saskatchewan is within the Lake Winnipeg basin, surface water loaded with phosphorous and nitrogen from Saskatchewan has negative implications for downstream residents of Manitoba (Water Innovation Centre, 2010).

Research initiatives to understand the scientific processes of flooding and natural control mechanisms from wetlands have been improving over the last several decades internationally (Brander et al., 2013; Golden et al., 2017; Kadykalo and Findlay, 2016; Watson et al., 2016), nationally (Fang et al., 2010; Pomeroy et al., 2016; Yang et al., 2016) and provincially in Saskatchewan (Fang et al., 2010; Pomeroy et al., 2009; Shook, 2016; Shook et al., 2013). Results from these studies indicate that the pothole wetlands of the prairie landscape act as a natural flood control mechanism (Pomeroy et al., 2014; Shook et al., 2013) and result in a significant value in terms of ES. These wetlands act as storage on the landscape, controlling the severity of the release of water and minimizing the damage from floods (Dumanski et al., 2015). In what may seem contradictory, the drainage networks promoted by provincial prairie governments in the 1960–80s to expand and enhance agricultural production are likely increasing the flood damages to downstream users (Government of Canada, 2016b; Pomeroy et al., 2014; Saskatchewan Water Security Agency, 2016c). Wetland drainage in basins allowed swift removal of excess water from the local landscape, but came with a cost to downstream producers and communities, and placed increased pressure on both water control structures, roads and homes. The very projects designed to reduce the impact of high water levels has contributed to the problem.

ES provision from wetlands was recognized by the government of Saskatchewan in 1995 when a provincial wetland policy was drafted and legislated (Government of Saskatchewan, 1995). Unfortunately, this policy has not been effectively implemented (SWSA, 2012) and despite their importance as a natural flood control mechanism, the loss of pothole wetlands continues relatively unabated; Ducks Unlimited Canada estimated that 250,000 ha of wetlands have been lost in southern Saskatchewan between 1950 and 2010, and that 11.3 ha of wetlands continue to be lost each day (Yang et al., 2012). In 2014 the province of Saskatchewan released the Saskatchewan Plan for Growth, an ambitious roadmap for focussed and disciplined economic growth within the province that builds[2] upon its natural resource and agricultural advantage and recognizes that natural ecosystems provide indirect benefits to society and environment – and the importance of protecting these natural environments and water resources for future generations (Government of Saskatchewan, 2014b). Despite recent scientific advances of wetland function and government interest in wetland protection, economic studies exploring wetlands as a flood mitigation tool in Saskatchewan are scarce.

We attempt to address this limitation by exploring the possibility of investment in prairie pothole wetland conservation as a natural alternative to physical infrastructure solutions to flooding, and incorporate an expanded suite of ES associated with wetlands of the Prairie Pothole Region. Using locally specific biophysical data on annual basin discharge and nutrient reduction by wetlands, conduct a social return on investment (SROI)[3] analysis – a conceptual and quantitative approach that incorporates social and environmental values into a traditional benefit cost analysis – that is conceptually familiar to policy makers and the general public. Using a case study from the Smith Creek basin in southeastern Saskatchewan, we pose two research questions:

1) *Do wetland ecosystems in this area present a viable financial option to mitigate the impact of flood events in Saskatchewan specifically, and the Canadian PPR in general?*
2) *Is wetland conservation an economically viable solution to address a suite of environmental issues in Saskatchewan specifically, and the Canadian PPR in general?*

We contribute to the existing literature on the subject of wetland conservation by linking the costs and benefits of wetland conservation in a traditional business case format. While economic analyses of wetland drainage in prairie Canada (Cortus et al., 2011; Packman, 2010) and benefit analysis (Pattison et al., 2011) do exist, to our knowledge few studies have taken this approach for wetland conservation (Pattison-Williams et al., 2017) and no studies have taken this approach in Saskatchewan. We intend to link the local biophysical benefits and cost data in a way that will both contribute to the academic knowledge and be a useful decision-making tool for government policy-makers.

The paper will describe the case study area from southern Saskatchewan and the Smith Creek basin; provide an overview of SROI and basin hydrological modeling methods; and present results from a "flood control" return on investment and then SROI. These results will be further discussed in the context of wetland conservation policy in Saskatchewan specifically and Canada generally.

2. Background

2.1. Ecosystem Services and Wetland Loss

Natural ecosystems provide the foundation of a functioning human

[1] Although 2011 had more significant flooding, the provincial average of seeded acres was higher than in 2010.

[2] The Plan for Growth identifies six core growth activities: infrastructure growth, education, economic competitiveness, increased international trade, advancing natural resource strengths, and fiscal responsibility (Government of Saskatchewan, 2014b).

[3] SROI is a principles-based method for measuring environmental and social values not currently incorporated in conventional financial accounting. This approach has been used effectively by various organizations, including the New Economics Foundation in the UK and the Canadian Evaluation Society.

society. We rely on our landscapes for the food that feeds us, the materials that house us, the clothes that cover us and for the water that we drink. Expanding human populations and increasing consumptive demand has strained these ecosystems and compromised the ecological integrity of the natural world (Millennium Ecosystem Assessment, 2005). Dramatic agricultural and urban expansions have significantly altered the landscape. The Millennium Assessment estimates that 60% of global ecosystems are being used at an unsustainable rate (Millennium Ecosystem Assessment, 2005).

Wetlands have been identified as one of the most ecologically diverse and productive ecosystems on the planet (Millennium Ecosystem Assessment, 2005). They are also one of the most threatened by advancing economic development and climate change; 64% of the world's wetlands have disappeared since 1900 and there has been a 40% decrease in a global sample of wetlands since 1970 (Dixon et al., 2016). This trend is also observed in Canada. Since European settlement in the 1800s, it is estimated that approximately 20 million ha of wetlands in Canada have been drained for agricultural purposes and the total loss in the settled areas is approximately 70% of historical levels (Olewiler, 2004). This loss has occurred despite increasing commitments by governments internationally, such as the Ramsar intergovernmental treaty on wetlands implemented in 1975; nationally, such as the 1991 Canadian Federal Wetland Policy (Government of Canada, 1991); and provincially, such as the 1995 wetland policy (Government of Saskatchewan, 1995).

Currently no comprehensive wetland inventory exists in Saskatchewan. Generalizations on wetland loss in the settled areas of the province are difficult to make due to high regional variation and methodological treatment of drought and flood years (PHJV, 2008). However, several studies provide approximations: Dahl and Watmough (2007) estimate a 4.1% gross loss from 1985 to 2000; and Ducks Unlimited Canada estimate that 250,000 ha of wetlands have been lost in southern Saskatchewan between 1950 and 2010 and that 11.3 ha of wetlands are lost per day (Yang et al., 2012). Identified causes for wetland loss include agricultural conversion, population growth, industrial development, management practices and lack of enforcement of government policies (Dumanski et al., 2015; Government of Saskatchewan, 1995; Huel et al., 2000).

Advancing scientific understanding of the ecosystem functions from wetlands has quantified the nutrient removal levels, carbon of sequestered by vegetative growth, and the regulation of water-flow on the landscape (Bernal and Mitsch, 2012; Cohen et al., 2016; Marton et al., 2015; Rains et al., 2016). These services impact the communities in different ways and at different spatial and institutional scales (Hein et al., 2006). Local individuals and communities suffer from contaminated water and lost recreational values; regional impacts accrue from regulation services such as water quality and ecological health; and international stakeholders derive benefit from regulation services and biodiversity (Hein et al., 2006). Thus the loss of natural ecosystems such as wetlands is no longer the sole concern of environmentalists and policy makers – eutrophication of recreational lakes, increased flooding and contaminated drinking water sources have brought the issue into the "backyards" of many communities across Canada (Olewiler, 2004) and impacts individuals, communities and governments in different, yet important ways.

In economic theory, the concept of ES began in the late 1970s with the utilitarian framing of ecosystem functions to enhance public interest and advocacy towards biodiversity conservation (Gómez-Baggethun et al., 2009). An important international guide on the economic valuation of wetlands is found in Barbier et al. (1997) and several studies have been conducted within Canada (Liu et al., 2008; Pattison et al., 2011; Rooney et al., 2015; Yang et al., 2010, 2016). Despite the increasing conceptual role that ES play in the scientific literature and policy dialogue, practical and cost-effective methods to monetize ES to inform public policy are limited due to financial and time constraints. Contingent valuation studies require extensive public surveys and careful technical design (Carson, 2011; Pattison et al., 2011) and reverse auctions require extensive public engagement and research expertise (Boxall et al., 2013; Hill et al., 2011). Research to identify an appropriate way to incorporate ES understanding within policy decisions is ongoing.

2.2. Wetland Policy Context

Since the settlement of Canada, nearly 20 million ha of wetland have been drained for agricultural purposes alone (Environment Canada, 2013). Canada formally acknowledged the value of wetland ecosystems when it signed the Ramsar Convention on Wetlands in 1971, and was also the first national government to enact a wetland policy in 1991 (Government of Canada, 1991). Despite these actions, wetland loss continues today, continuing to have a negative impact on the natural environment and quality of human life across the country.

The Saskatchewan government was among the first Canadian provinces to develop and adopt a wetland policy. The 1995 policy was created to *encourage sustainable management of wetlands and to restore or rehabilitate degraded wetland areas* (Government of Saskatchewan, 1995). Formed in consultation with representatives from the existing government bodies at the time[4] and in consultation with the general public, this policy provided a foundation for wetland conservation in the province. However, in subsequent years, the responsibility of wetland protection was moved from across government agencies: from the Saskatchewan Wetland Conservation Corporation (SWCC) in 1995; the Saskatchewan Watershed Authority (SWA) in 2005; and currently within the Water Security Agency (WSA) established in 2012. In the WSA's Strategic Plan for 2013–14 (SWSA, 2012), wetlands are mentioned twice in the goals: 1) initiate work on a new provincial wetland policy and 2) continue to work with the Prairie Habitat Joint Venture (PHJV) to conserve wetlands in the province. In addition, the 2015 Agricultural Water Management Strategy seeks to achieve a balance between the benefits of drainage[5] and the resultant damage from flooding (SWSA, 2017a). Although the need to initiate an effective provincial drainage policy in the province is important, and the WSA seems to recognize that the current policy is ineffective, wetlands continue to be lost with severe consequences on agriculture, infrastructure and habitat in the province. Change has become so necessary that, in 2011, the Saskatchewan Association of Rural Municipalities (SARM) passed a resolution to lobby the provincial government to enforce provincial drainage legislation.[6]

3. Study Area: Smith Creek Basin

The study area is a representative agricultural drainage basin in southern Saskatchewan that has local and national importance (Fig. 1-A) and has been subject to high levels of wetland conversion primarily for agricultural development. The Smith Creek Basin is located in the southeast, approximately 60 km from the City of Yorkton, Saskatchewan and includes the town of Langenburg. It is situated in the headwaters of the Upper Assiniboine River Basin and drains into the Assiniboine River, the Red River and ultimately into Lake Winnipeg. Smith Creek Basin is considered to be representative of a typical prairie basin in terms of wetland distribution and function (Pomeroy et al., 2014). Wetlands have been identified as an important source of natural capital (Troy and Bagstad, 2009), providing a broad sweep of ES. These include improving surface water quality, ensuring sustainable drinking water sources, mitigating the impacts of drought and floods, mitigating the impacts of climate change, providing habitat for wildlife and maintaining and enhancing biodiversity.

[4] Saskatchewan Wetland Conservation Corporation, Saskatchewan Agriculture and Food, Saskatchewan Environment and Resource Management, Saskatchewan Municipal Government and Sask Water.

[5] Drained wetlands provide more arable agricultural land.

[6] A drainage moratorium has been implemented in the Quill Lakes Basin (SWSA, 2017b).

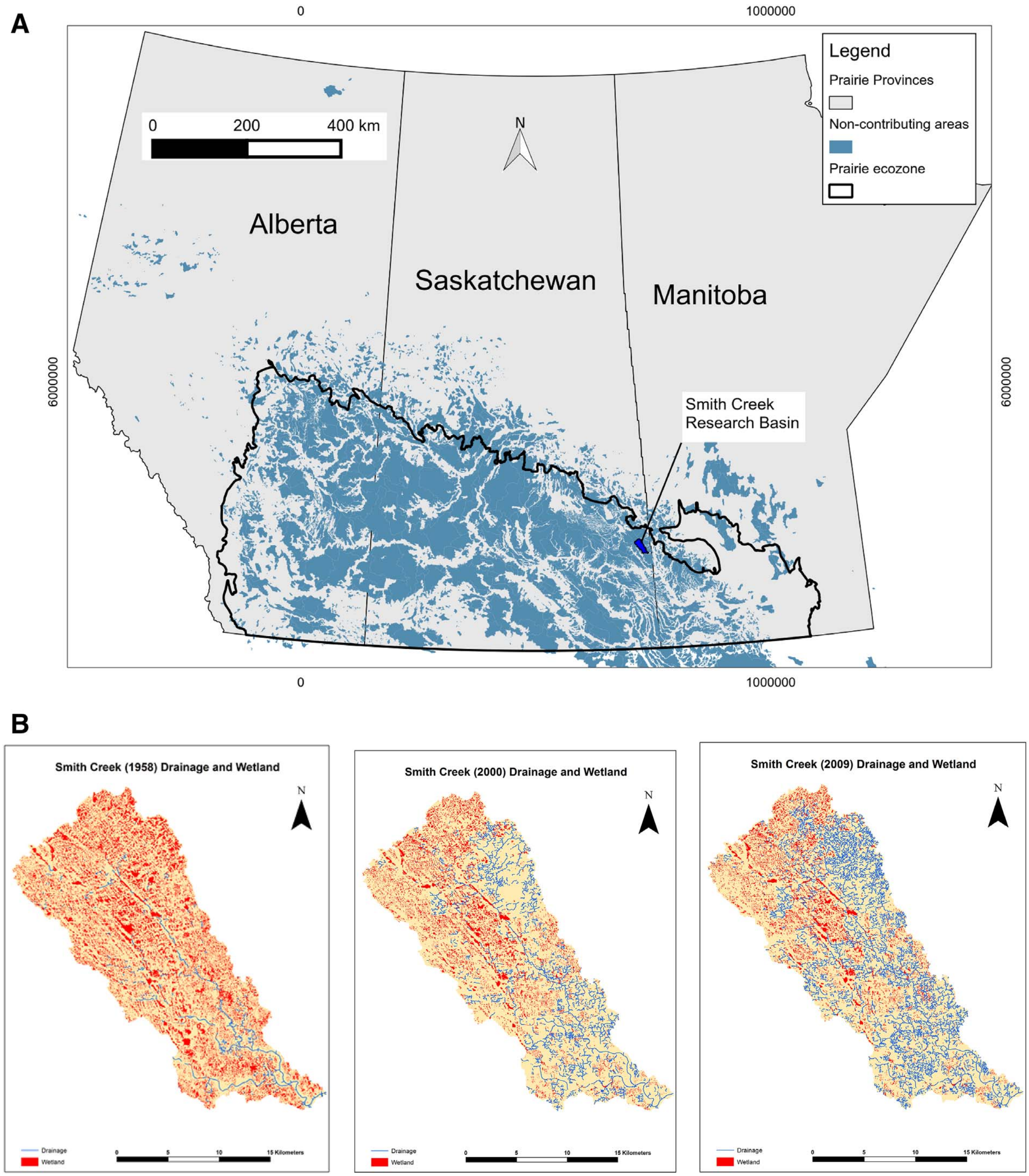

Fig. 1. A. Location of Smith Creek basin in southeastern Saskatchewan with the basin contributing areas and agricultural zone of the Canadian Prairies outlined.
B. Smith Creek basin wetland areas and drainage channels in 1958, 2000 and 2009 as determined by aerial photograph analysis by DUC and mapped onto the drainage basin area determined by Pomeroy et al. (2014) using a high resolution LiDAR-based digital elevation model.

A wetland inventory in the Smith Creek basin conducted in 2007 determined that 6568 ha of wetlands exist on the landscape (Yang et al., 2012). In 1958 when the earliest comprehensive wetland inventory was conducted in the watershed 8804 ha were in existence. During this 49-year period, approximately 2236 ha were lost primarily due to the construction of drainage ditches for agricultural development. Other studies using different methodology confirm these results and show even higher levels of wetland loss (Guo et al., 2012) (see Fig. 1-A and B).

4. Methodology

A multi-disciplinary approach was employed to address the research questions and the utility of ecosystem service valuation to serve as a conservation tool for southern Saskatchewan generally and the Smith Creek basin in particular. Hydrological modeling results were used as the basis on which to conduct a SROI analysis: first on the flood control services and then an expanded array of ES provided by wetlands in the basin. Wetland area in 2007 is used as a baseline for existing wetlands; scenarios are developed based upon restoration and loss of 25, 50 and 100% of these levels (Table 1).

Table 1
Wetland restoration and loss scenarios in the Smith Creek basin between 1958 and 2007. Source: Yang et al. (2012)

Scenario	Wetland area	
	Hectares	Change
Rest100	8804	2236
Rest50	7685	1117
Rest25	7105	537
Existing	6568	0
Loss25	4926	(1642)
Loss50	3277	(3291)
Loss100	0	(6568)

4.1. Social Return on Investment

Decisions on expenditure in the public and private sectors often require a business case analysis to justify investment. We expand the traditional cost-benefit analysis to include extra-market values in a SROI framework. SROI has been used successfully to justify expenditure on natural areas conservation (Anielski et al., 2014; Barbier, 2011; Nicholls et al., 2012).

The Net Present Value (NPV)[7] and SROI ratio for three wetland loss scenarios, retaining existing wetlands and three wetland restoration scenarios were provided for three time periods: the initial year, 10 years and 30 years. The annual costs and benefits over the retention time were discounted and summed for the present value using the following formula:

$$PV = \sum_{t=1}^{T} \frac{TC_i^t}{(1+r)^t}$$

where TC is the total cost (or benefit), r is the discount rate and t is the time period summed over the total time period T. The fixed costs for wetland restoration were incorporated as an up-front cost in the initial year. This calculation is used for both the costs and the benefits,[8] which are subtracted from each other to determine the NPV in 2017 Canadian dollars using a 3% discount rate.[9] The SROI ratio is calculated by dividing the present value benefits by the present value costs; a ratio greater than one indicates that benefits exceed the costs, and vice versa (Žižlavský, 2014). The following subsections outline the methodology we used to determine the benefit and cost estimates within the SROI analysis.

4.2. Benefit Estimation

4.2.1. Flood Control Estimation

Wetlands help to control flooding by regulating the flow of water by providing surface water storage during spring snowmelt and periods of high rainfall. The relationship between wetland storage and contributing areas to predict impacts of wetland drainage in the Smith Creek basin was determined using the Prairie Hydrological Model (Pomeroy et al., 2007, 2014).

The Prairie Hydrological Model configuration of the Cold Regions Hydrological Model (Pomeroy et al., 2007, 2014) was developed to include improved snowmelt and evaporation physics and a hysteretic relationship between wetland storage and runoff contributing area (Shook et al., 2013). A revised model (Pomeroy et al., 2014) was used to simulate the snow regimes on and the streamflow runoff from five sub-basins and the main basin of Smith Creek for six years (2007–2013), with good performance when compared to field observations. Measured streamflows in Smith Creek over this period included the highest annual flow volume on record (2011) and high flows from heavy summer rains in 2012. The Prairie Hydrological Model was run over the 2007–2013 period for various wetland extent scenarios that included the 1958 historical maximum, measured extents in 2000 and 2008, a minimum extent that excluded drainage of conservation lands and an extreme minimum extent involving complete drainage of all wetlands in Smith Creek basin.

Results from this model indicate that both annual discharge and peak daily stream-flow have a high sensitivity to wetland drainage in years that were not preceded by exceptionally wet conditions. Historical wetland drainage has significantly increased peak discharge and total volumes of water in extreme flood events, and has therefore exacerbated the infrastructure damage arising from extreme events such as experienced in Saskatchewan in 2011 and likely in 2014. Even in moderate to low flow years, the wetland drainage that has occurred between 1958 and 2008 in the Smith Creek basin has resulted in markedly higher annual flow volumes, with increases of between 45 and 273% (Pomeroy et al., 2014). This long term higher outflow puts stress on receiving water bodies such as Lake Winnipeg and also carries a concomitantly higher nutrient load that negatively impacts the aquatic ecology of the receiving water body. Although the PHM results are not direct inputs into our SROI framework, they affirm the important role wetlands play in managing the flooding in the Smith Creek watershed.

While financial values of these flood control benefits specific to the Smith Creek basin are not available, several studies regarding the financial estimation of the flood control ES provision are found in the literature (Brander et al., 2013; Kadykalo and Findlay, 2016; Watson et al., 2016). Specifically, Brander et al. (2013) survey the literature and calculate a mean flood control provision of CAD$279.05 per hectare of wetland in agricultural landscapes of Canada.[10] When this value is applied to our scenarios, an annual loss of flood control value of CAD $1.83 million is estimated under total wetland loss, while CAD$2.46 million of flood control prevention is provided under total restoration (Table 2).

Table 2
A summary of the annual flood control capacity of Smith Creek basin wetlands in southern Saskatchewan and their associated economic benefit in 2017 Canadian dollars (CAD$) under several loss and restoration scenarios.

Scenario	Wetland area		Total benefit[a]	
	Ha	Change	Change in benefit (Total ha × $/ha) $/yr	Total benefit (Total ha × $/ha) $/yr
Rest100	8804	2236	623,942	2,456,742
Rest50	7685	1117	311,626	2,144,427
Rest25	7105	537	149,911	1,982,712
Existing	6568	0	0	1,832,800
Loss25	4926	(1642)	(458,301)	1,374,500
Loss50	3277	(3291)	(918,217)	914,584
Loss100	0	(6568)	(1,832,800)	0

[a] Based upon a CAD$279.05 benefit per hectare of intact wetland (Brander et al., 2013).

[7] NPV is the value in the present of a sum of money in comparison to a future value when it has been invested at compound interest. Present value, or discounted present value, is the value of an income stream determined on the date of valuation (Žižlavský, 2014).

[8] All costs and benefits used in this analysis are converted to 2017 CAD$ using the Consumer Price Index and relevant currency conversions.

[9] Stern (2007) suggests that traditional measures of discount rates are often too high when applied to the environment, and that the value of environmental services may increase into the future, as they become more scarce. Therefore lower discount rates should be considered.

[10] Brander et al. (2013) provides a value of $223 USD (2007) per wetland hectare for “regulating services”, with a 95% confidence interval. We have converted this value to 2017 CAD$.

Table 3
A summary of the annual phosphorous removal capacity of Smith Creek wetlands and their associated economic benefit in 2017 in CAD$ under several loss and restoration scenarios.

Scenario	Wetland area		TP load	Change of TP load		Per Ha removal (ΔTP/ΔHa)	Per Ha benefit	Total benefit[a] (Total ha × $/ha)
	Ha	ΔHa	kg/yr	Δkg/yr	Δ%	kg/yr	$/ha/yr	$/yr
Rest100	8804	2236	2210	(2540)	(53)	1.14	513	4,520,742
Rest50	7685	1117	4180	(580)	(12)	0.52	234	1,799,947
Rest25	7105	537	4460	(290)	(6)	0.54	243	1,728,218
Retention	6568	0	4760	0	0	0.44	196	1,286,915
Loss25	4926	(1642)	5300	550	11	0.33	149	732,156
Loss50	3277	(3291)	6290	1530	32	0.47	212	693,852
Loss100	0	(6568)	11,670	6910	145	1.05	473	0

[a] Total benefit based upon a CAD$450.43 per kg removal cost (O'Grady, 2008).

4.2.2. Other Benefit Estimation

While flood reduction is an important issue in the context of southern Saskatchewan and provincial scales, there are other associated wetland ES to consider that are dependent upon functioning prairie pothole wetlands. These ES include nutrient removal (phosphorous and nitrogen), biodiversity enhancement, carbon sequestration and recreation and tourism benefits. In recognition of possible issues of double counting and spatial scales, conservative estimates from Canadian agricultural landscapes were used where available.

4.2.2.1. Nutrient Removal. Wetlands have the ability to store and accumulate phosphorous in sediment layers and plant biomass. Yang et al. (2012) provide estimates of the phosphorous load in Smith Creek under the various scenarios. If 25% of wetlands were lost, there would be a resultant 550 kg (11%) increase in the annual total phosphorous (TP) loading to the basin; this quantity would increase to 6910 kg (145%) under complete loss. Alternatively, restoring all wetlands in the basin would retain an additional 290 kg of TP in 25% restoration to 2540 kg under full restoration (Table 3). Estimations of the cost of TP removal vary based upon context (Conservation Ontario, 2003; Johansson and Randall, 2003; Sano et al., 2005) and whether the pollution derives from point or non-point sources (Buda et al., 2012; Qiu, 2013; Water Environment Association of Ontario, 2010). In our analysis we use an estimate of CAD$450.43 per kg TP removal cost (O'Grady, 2008)[11] that equates to a total benefit of CAD$4.52 million annually under full restoration.[12]

The TP removal capacity of wetlands is a key benefit in terms of water quality concerns from non-point source agricultural run-off (Johansson and Randall, 2003; O'Grady, 2008; Stephenson et al., 2010; United States Environmental Protection Agency, 2015; Water Environment Association of Ontario, 2010). When landowners drain wetlands, the water and associated nutrients move off the landscape and into watercourses. If producers manage the movement of water by retaining wetlands, they also manage the movement of nutrients. Water quality concerns both locally and downstream from nutrient run-off can be stopped by retaining wetlands on the landscape.

Nitrogen can be similarly modeled (DeBoe et al., 2017; Olewiler, 2004; Stephenson et al., 2010; United States Environmental Protection Agency, 2015). Wetland restoration scenarios increase the total nitrogen (TN) retention capacity from existing levels by 12,610 kg under full restoration, and decrease loading retention of TN by 18,610 kg under complete wetland loss. When linked with a CAD$57.16 per kilogram removal cost,[13] these numbers equate to a value of approximately CAD$2.84 million annually under full restoration and a commensurate decrease under a complete loss scenario (Table 4).

4.2.2.2. Other Benefits. A challenge when determining the recreation value of wetlands in the high degree of local variation – such as proximity to urban areas, numbers of waterfowl, demographics of the local population, etc. While no specific study in the Smith Creek basin on the recreation value of wetlands has been conducted, there is a significant amount of waterfowl hunting and other recreation activities that are enjoyed by local community members and visitors. Based upon estimates on wildlife viewing, hunting and watersport values from a comparable watershed in southern Saskatchewan (Olewiler, 2004), we apply a value of CAD$19.60 per hectare annually to the scenarios.[14] This estimate results in an increased recreation value of CAD$172,557 annually under full restoration and a commensurate loss of value under complete wetland loss (Table 5).

Additionally, carbon sequestration is another ES provided by wetlands that is highly relevant in terms of climate change scenarios and federal taxation efforts in Canada aimed at curbing carbon emissions. According to Badiou et al. (2011) wetlands in the PPR contain on average 205 t of carbon per hectare, and when they are drained 89 t are lost to the atmosphere. The annual per hectare benefit of wetlands under retention and restoration scenarios is highly variable, and it takes many years for restored wetlands to become carbon sinks (Badiou et al., 2011; Neubauer, 2014). Therefore, we take a conservative approach and estimate that loss scenarios lead to a one-time release of 326 t of CO_2e per hectare; the retention scenario will retain a conservative 3.25 t of CO_2e per hectare (Badiou et al., 2011)[15]; and that the restoration scenarios will provide no carbon benefit. Based upon the CAD$20 per tonne carbon tax currently implemented in Alberta (Government of Alberta, 2017), retention and restoration of wetlands would provide CAD $426,920 in carbon capture benefit, while full loss of wetlands would both remove that benefit (Table 5) and further exacerbate climate change with a release of 2.1 million tonnes of CO_2e with a commensurate cost of CAD$43.3 million (see Fig. 2). Greater benefits are anticipated with implementation of an anticipated federal carbon tax across Canada in 2018, including

[11] This value is a conservative estimate based upon TP removal costs for mitigating non-point source pollution in a central Canadian agricultural landscape (O'Grady, 2008). When inflation is considered from 2008, the CAD$400 value described in (O'Grady, 2008) increases to CAD$450.43 in 2017.

[12] While the changing marginal benefits of TP removal are reflected in the non-linear relationship between scenarios, greater exploration of this nuanced relationship is beyond the scope of this study.

[13] As we are not aware of any specific estimates of TN removal costs in the Canadian Prairies, we chose this estimate based a mid-range value of non-point agricultural TN offsets in the USA (Stephenson et al., 2010). Our estimate is converted to 2017 CAD$ per kg and should be considered conservative, as it is lower than estimates provided by the United States Environmental Protection Agency (2015). This number can be revised as more regional specific information becomes available.

[14] We recognize the rich body of literature researching the recreation and hunting value of wetlands, but chose to retain this conservative value for the purpose of this study, as it is from a nearby Saskatchewan watershed. Further, a detailed exploration of the recreational value of wetlands is beyond the current scope of this research.

[15] The conversion between C and CO_2e is 3.66. We consider our estimate conservative because we are assuming that under restoration scenarios there will be zero carbon benefit. While restored wetlands begin sequestering carbon immediately, the balance between CO_2 uptake and methane emission results in a radiative switchover time – the time it takes for a restored system to become a radiative sink – estimated to be longer than the 30-year period that our SROI is based upon.

Table 4
A summary of the annual nitrogen removal capacity of Smith Creek wetlands and their associated economic benefit in CAD$ under several loss and restoration scenarios.

Scenario	Wetland area		TN load	Change of TN load		Per Ha removal (ΔTP/ΔHa)	Per Ha benefit	Total benefit[a] (Total ha × $/ha)
	Ha	ΔHa	kg/yr	Δkg/yr	Δ%	kg/yr	$/ha/yr	$/yr
Rest100	8804	2236	26,360	(12,610)	(32)	5.64	322	2,838,068
Rest50	7685	1117	35,760	(3220)	(8)	2.88	165	1,266,558
Rest25	7105	537	37,450	(1530)	(4)	2.85	163	1,156,669
Retention	6568	0	38,980	0	0	2.07	118	775,769
Loss25	4926	(1642)	41,080	2110	5	1.28	73	361,717
Loss50	3277	(3291)	42,780	3810	10	1.16	66	216,918
Loss100	0	(6568)	57,590	18,610	48	2.83	162	0

[a] Total benefit based upon a CAD$57.16 per kg removal cost (Stephenson et al., 2010).

Table 5
A summary of the additional services in CAD$ provided by Smith Creek wetlands based upon comparable benefit estimates of wetland ES provision.

Scenario	Wetland area		Phosphorous removal	Nitrogen removal	Tourism and recreation	Carbon storage	Total
	ha	Change	$/yr	$/yr	$/yr	$/yr	$/yr
Rest100	11,237	3647	4,520,742	2,838,068	172,557	426,920	7,958,287
Rest50	8502	912	1,799,947	1,266,558	150,621	426,920	3,644,047
Rest25	7773	183	1,728,218	1,156,669	139,262	426,920	3,451,069
Retention	7590	0	1,286,915	775,769	128,733	426,920	2,618,337
Loss25	7211	379	732,156	361,717	96,543	320,167	1,510,583
Loss50	5693	1897	693,852	216,918	64,239	213,037	1,188,045
Loss100	0	7590	0	0	0	0	0

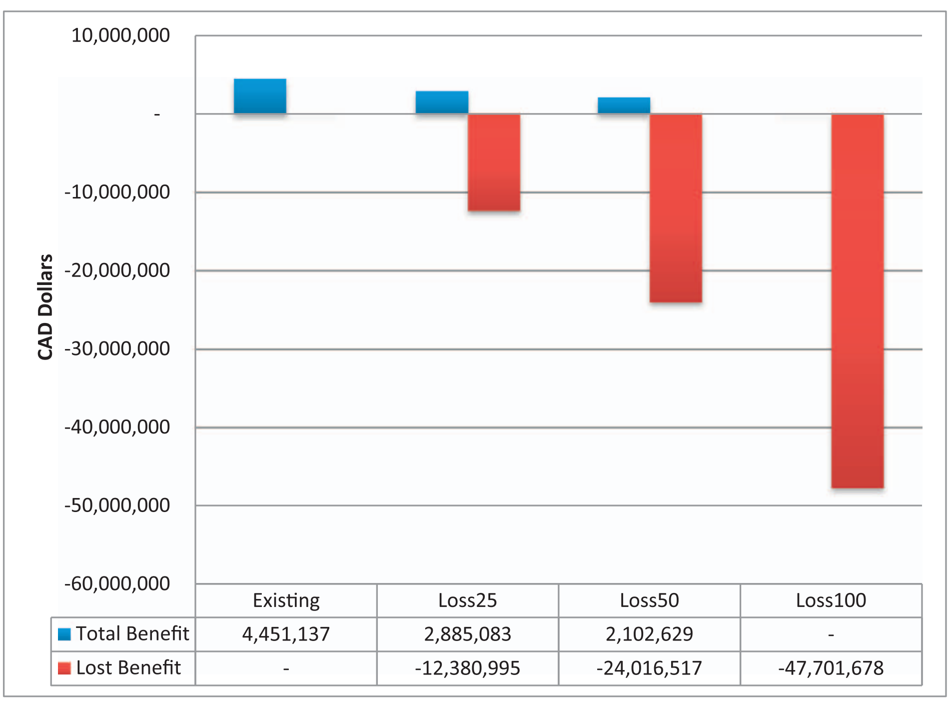

Fig. 2. The total lost ES benefits from various wetland scenarios in the Smith Creek basin in southern Saskatchewan in 2017 in CAD$.

Saskatchewan and its increasing scale of taxation over time (Government of Canada, 2016a, 2016b). This information supports the importance of retaining wetlands due to the resultant increased cost of the released carbon currently stored in the wetlands. It also should be considered highly conservative, as it does not include damage costs associated with loss of carbon sequestration capacity (Ackerman and Stanton, 2012; Anthoff et al., 2009) and the reality of a federal carbon tax.[16]

Wetlands provide more services than those described above, such as groundwater recharge, increased property value for houses and intrinsic biodiversity values. However, in the absence of primary estimates from the Smith Creek basin, these services are left out of this analysis. Their exclusion is an indication that the wetlands values described in the analysis should be considered conservative estimates of benefits.

4.3. Costs of Conservation

While specific costs of wetland restoration and retention can be difficult to gauge, for the purposes of this study the costs associated

[16] To be implemented across Canada in 2018.

with retention and restoration activities are divided into two general categories[17]: fixed costs to restore wetlands and opportunity costs to keep wetlands from an alternative land use.

Fixed costs are the specific financial requirements to physically restore a drained or degraded wetland (Packman, 2010). For example, removing dirt from a filled wetland requires machinery and administrative costs; a drainage ditch needs to be plugged (Cortus et al., 2011; Melorose et al., 2010). Opportunity costs are financial returns that accrue from the next most profitable alternative. For example, keeping wetlands in their natural state forgoes the financial opportunity that could result from agricultural production or acreage development. Accurate knowledge of opportunity costs is important for long-term wetland retention, as the majority of wetland area is found on private land in southern Saskatchewan. If development pressure is exerted from agricultural sources, then the opportunity cost is related to rental rates, based upon the current price of agricultural commodities and expected crop yields (Brethour et al., 2007; Cortus et al., 2011; Packman, 2010). If pressure is exerted by urban expansion, then opportunity costs are related to returns from housing, retail, or industrial prices.

Table 6 provides estimates of the cost of wetland restoration and retention that corresponds to the various scenarios. Restoration costs are considered an up-front expenditure of CAD$13,585 per hectare restored (unofficial estimate from Ducks Unlimited Canada), and opportunity costs are based on the rental rates are obtained from the Saskatchewan Ministry of Agriculture, and determined to be CAD $88.01 per hectare of agricultural land (Government of Saskatchewan, 2012).[18] A clear message from these cost estimations is that once a wetland is lost, it is relatively expensive to restore.

5. Results

The following section provides our results at two levels. We first conduct a SROI considering flood reduction benefit alone – under both loss and restoration scenarios – and then conduct a similar analysis with an expanded array of ES.

5.1. Flooding Return on Investment

The control of surface water is very important in this province. As such, a separate comparison is made between the estimated financial benefits of flood reduction with the costs of retention and restoration.

5.1.1. Lost Flood Control Benefit

Prior to retention and restoration analyses, it is important to consider the financial implications of no wetland conservation initiatives in the basin. Using the drainage or loss scenarios and estimated per hectare flood control rates by wetlands, it is estimated that complete drainage of Smith Creek wetlands would equate to a CAD$1.83 million annual financial loss from the existing conditions (Table 7).

5.1.2. Retention and Restoration Scenarios

A comparison of the benefits and costs of retaining and restoring wetlands in the Smith Creek basin is provided in Table 8. The flood control benefit from the existing wetlands was determined by multiplying the total number of wetland hectares by the annual per hectare flood control rate of CAD $279.05 per hectare. Costs were determined by multiplying opportunity cost (CAD$88.01 per ha) by the total number of wetland hectares retained or restored, and when wetlands were restored, the additional up-front restoration cost (CAD$13,585 per ha). The present value of benefits and total costs were added and discounted for the various time frames, and subtracted to determine the NPV, and divided to determine the SROI.

Our results indicate that for all wetland conservation scenarios the flood reduction benefits of wetlands cover the costs of retention. Retention of existing wetlands provides the highest return on investment of 3.17 (Table 8). The ratio becomes smaller in the restoration scenarios due to high restoration costs assumed to occur in the first year. When considering longer time horizons (10 and 30 years) the flood control benefits of these wetlands approaches, and in some cases surpasses, the costs of restoration.

5.2. Social Return on Investment

The SROI builds on the principles of the traditional cost benefit analysis, but is specifically intended to incorporate social and environmental values into an economic analysis. As such, it can be considered an appropriate framework for wetland retention and restoration comparisons. However, missing market approximations for these services renders this a partial, and therefore conservative, estimate of the SROI provided by wetlands in the Smith Creek basin.

5.2.1. Lost Social Benefit

When additional wetland benefits are included in the analysis, the financial loss from wetland drainage is higher than when considering the flood reduction capacity alone. Complete loss of wetlands would result in CAD$47.70 million in lost benefits (Fig. 2), primarily due to the high level of carbon emitted when wetlands are drained.

5.2.2. Retention and Restoration Scenarios

The economic feasibility of restoring wetlands to provide additional societal benefit is presented in Fig. 3. Retention of existing wetlands in the Smith Creek basin provides a net benefit to society with a SROI of 7.70, indicating that for every CAD$1 spent on wetland retention Saskatchewan and downstream residents receive CAD$7.70 in benefit (Fig. 3). The wetland restoration scenarios assume that the existing wetland base will be maintained, and that restoration costs will occur in the first year. The restoration of 25%, or 537 ha of wetlands, generates a net loss in the first year due to initial restoration costs (SROI of 0.61) in the first year, but this increases to 4.75 over 30 years as the costs of restoration are recovered over time. Complete restoration of 100% of historical wetlands is unlikely to occur but is provided for context. The restoration of all historic wetlands (2236 ha) again generates a net loss in the first year due to initial restoration costs, but does become positive over time. The related SROI with each of these scenarios is 0.22, 1.60 and 2.98, respectively (Fig. 3).

The results from this section indicate that retention of existing wetlands presents the highest SROI. A return of CAD$7.70 for every CAD$1 invested is an excellent investment option, and even full restoration of drained wetlands provides an attractive alternative after approximately 10 years.

5.3. Sensitivity Analysis

We conducted a sensitivity analysis to determine how responsive the analysis is to changes in the input variables (benefit estimates, opportunity costs and restoration costs) and what inputs have the most significant influence on the SROI ratio. Due to the magnitude, the most significant variable influencing the analysis is the cost of restoration. Should the cost of wetland restoration decrease to half of the current level – a hypothetical situation resulting from lower costs to secure the land for restoration – the benefits from restoring 25% of wetland over a 10-year period increase from 3.22 to 4.51 (Table 9). We tested each of the variables[19] in a similar manner and

[17] Nuisance costs are a third category described in the literature (Cortus et al., 2011; Packman, 2010) but are not considered in this analysis due to limited availability of southern Ontario estimates.

[18] More recent published references to agricultural rental rates in Saskatchewan do not exist, however we confirmed with agricultural groups in Saskatchewan that this number is consistent with 2017 rental rates.

[19] Results from further sensitivity analyses – encompassing flood control alone, the various time periods, restoration levels and increases and decreases of wetland benefits (TN, TP, C and recreation) – are not provided in this study due to space constraints.

Table 6
A summary of annual cost estimates of wetland retention and restoration scenarios in the Smith Creek watershed under several loss and restoration scenarios in CAD$.

Scenario	Wetland area		Restoration cost	Opportunity cost	Total cost
	Total (ha)	Change (ha)	$/ha	$/ha	$
Rest100	8804	2236	30,375,381	774,836	31,150,216
Rest50	7685	1117	15,170,913	676,334	15,847,247
Rest25	7105	537	7,298,134	625,330	7,923,464
Retention	6568	0	0	578,050	578,050
Loss25	4926	(1642)	0	433,506	433,506
Loss50	3277	(3291)	0	288,452	288,452
Loss100	0	(6568)	0	0	0

Table 7
A comparison of the lost flood control benefit of wetlands in the Smith Creek basin in CAD $.

Scenario	Hectares remaining	Current benefits $/year	Change in benefit $/year
Retention	6568	1,832,800	0
Loss25	4926	1,374,500	(458,301)
Loss50	3277	914,584	(918,217)
Loss100	0	0	(1,832,800)

Table 8
Comparison of the benefits and costs of wetlands for flood retention in the Smith Creek basin under several wetland restoration scenarios over 1, 10 and 30 years in CAD$.

Scenario	Options	Total benefits	Total costs	Net Present Value	Ratio
100% restoration	Initial year	1,832,800	31,150,900	(29,318,100)	0.06
	10 years	16,103,184	37,183,889	(21,080,705)	0.43
	30 years	37,001,408	46,018,883	(9,017,475)	0.80
50% restoration	Initial year	1,832,800	15,850,802	(14,018,001)	0.12
	10 years	16,103,184	21,116,990	(5,013,806)	0.76
	30 years	37,001,408	28,829,045	8,172,363	1.28
25% restoration	Initial year	1,832,800	7,920,456	(6,087,656)	0.23
	10 years	16,103,184	12,789,196	3,313,988	1.26
	30 years	37,001,408	19,919,209	17,082,199	1.86
Retention	Initial year	1,832,800	578,050	1,254,751	3.17
	10 years	15,634,159	4,930,881	10,703,278	3.17
	30 years	35,923,697	11,330,029	24,593,668	3.17

found that the relatively high SROI ratios observed in our analysis indicate that retention and restoration of wetlands are financially viable even with much higher restoration and opportunity costs, or alternatively with lower estimates of wetland benefits.

6. Discussion and Conclusion

Our analysis presents a financial case for the retention and restoration of wetland ecosystems in the Smith Creek basin and, by extension, similar prairie basins in southern Saskatchewan and the Canadian PPR. Investment in wetland conservation provides a positive SROI: every CAD$1 invested in retention yields CAD$7.70 in flood control, nutrient removal, recreation, flood control and carbon sequestration; and every CAD$1 invested in 25% restoration of lost wetlands yields CAD$3.22 over a 10-year time frame. While further research is necessary to understand the variability of benefit estimates associated with TP, TN and water quantity, our results convey a clear message: having wetlands on the landscape mitigates major environmental concerns in the province, such as flooding and water quality, which are having significant impacts on the residents of the province and downstream jurisdictions.

In 2014 the province of Saskatchewan released the Saskatchewan Plan for Growth, an ambitious roadmap for focussed and disciplined economic growth within the province that builds upon its natural resource and agricultural advantage (Government of Saskatchewan, 2014b). By 2020 the government envisions Saskatchewan as a global leader in food production, with increased food and value-added production, and increased international agricultural exports. In addition to the direct financial benefit from natural resource development and production, the Plan for Growth also recognizes that natural ecosystems provide indirect benefits to society and environment – and the importance of protecting these natural environment and water resources for future generations (Government of Saskatchewan, 2014b).

Our results from this representative basin support the conclusions articulated in the Plan for Growth and the WSA Agricultural Water Management Strategy by providing economic evidence that wetland retention and restoration is an effective and environmentally sustainable approach to mitigating damage from flooding – one of the major environmental issues facing Saskatchewan today. Given this evidence, government programs that continue to support – explicitly or implicitly – unmitigated wetland drainage can be expected to exacerbate the negative impacts of persistent flooding and reduce other wetland ES.

In Saskatchewan, there are an estimated 200,000 unlicensed drainage works. Currently, WSA activities include bringing previously unauthorized wetland drainage into compliance although rarely requiring wetlands to be restored (Fuller, 1995). In addition, WSA is working with Saskatchewan Conservation and Development Associations to facilitate organized drainage of multiple basins and it is clear this action will have a negative impact on wetlands and the ES they provide. Removing water off the landscape through organized drainage projects may be an effective solution to deal with excess water in agricultural landscapes. However, if these same projects result in additional wetland drainage they will likely be offset through increased downstream flooding and loss of ES. Further, provincial and federal tax dollars are spent annually to support excess moisture insurance and disaster relief programs[20] for agricultural producers, and these may indirectly

[20] Programs to address excess moisture for landowners provided by Saskatchewan Agriculture (Government of Saskatchewan, 2011). The Canada Saskatchewan Excess Moisture Program was started in 2010 in response to this issue (Government of Saskatchewan, 2010).

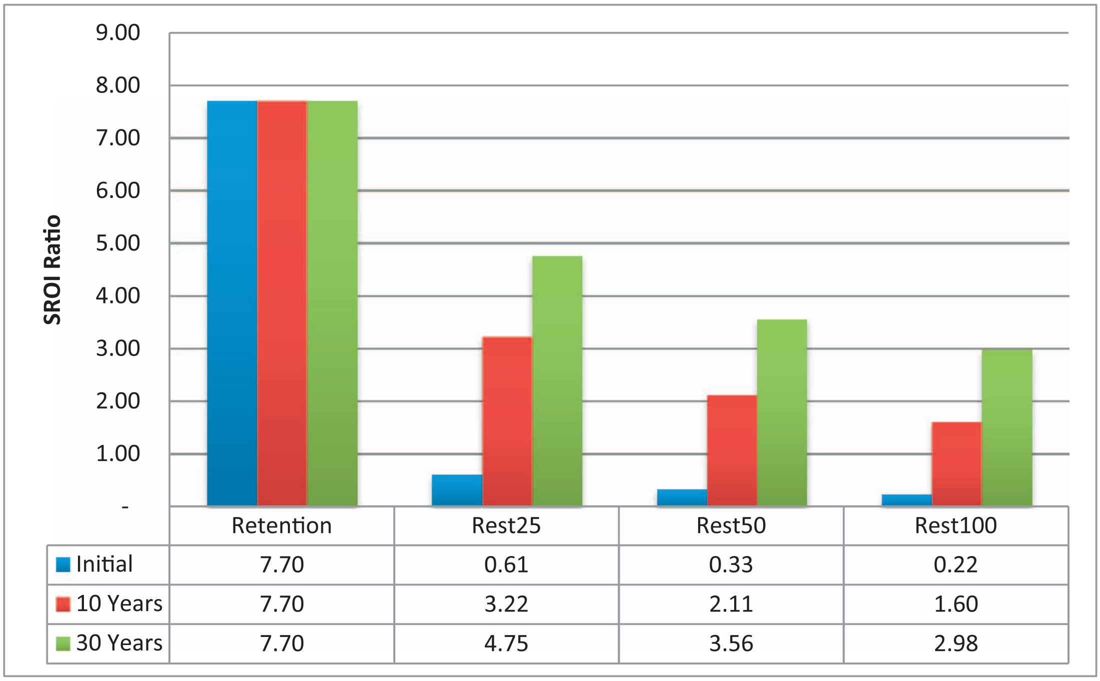

Fig. 3. The SROI from various wetland scenarios in the Smith Creek basin of southern Saskatchewan in CAD$.

Table 9
Sensitivity analysis for 25% wetland restoration over a 10-year period when wetland restoration costs are half of 2017 levels in CAD$.

Variable	Baseline assumption (CAD$)	Baseline ratio	New assumption (CAD$)	New ratio
Land rental rate	88.01	3.22	88.01	4.51
Restoration costs	**13,585.00**	**3.22**	**6792.50**	**4.51**
Flood removal	279.05	3.22	279.05	4.51
TP removal	450.43	3.22	450.43	4.51
TN removal	57.16	3.22	57.16	4.51
Carbon tax	20.00	3.22	20.00	4.51
Recreation value	19.60	3.22	19.60	4.51

incentivize ongoing wetland drainage. The Parliamentary Budget Officer (PBO) of Canada estimates that Disaster Financial Assistance Arrangements (DFAA) costs from floods are the largest of all weather events (CAD$673 million) and represent 75% of DFAA's weather payouts (Government of Canada, 2016b). From 2005 to 2014 Manitoba, Saskatchewan and Alberta accounted for 82% of all DFAA weather event costs – almost all of which are a result of flooding. Given this evidence, even indirect support of unmitigated wetland loss will exacerbate persistent flooding problems that result in an ever-growing need for large disaster payouts. Incorporating these disaster payments is beyond the scope of this study, but is an area of future research that is expected to enhance the value of wetlands and the SROI they provide.

There is evidence that the general public in Saskatchewan is also aware of and concerned for wetland loss. A representative survey of wetland perceptions from approximately 800 Saskatchewan adults in 2012 (Enns, 2012)[21] determined that 93% of respondents felt that wetlands play an important role in the health of an environment and that 87% of respondents were concerned about the overall wetland loss rate in the settled areas of Canada. Although wetland loss itself was not considered to be the most pressing environmental concern among respondents, it was directly linked to those that were ranked highest: drinking water quality and health of lakes and rivers (Enns, 2012). Sixty-three percent of all respondents felt that farmers should not be able to drain wetlands on their property, and among the agricultural producers surveyed, 84% indicated concern about wetland loss in Canada.

The protection of the ES values of wetlands and other natural ecosystems is necessary to ensure environmentally and economically sustainable growth in Saskatchewan. As scientific understanding of the benefits that wetlands provide to society increase, and this information is communicated to decision-makers and the general public, there has been an expectation among conservationists that stakeholders will increasingly demand the protection of these resources for economic and quality of life reasons. While in some cases this has occurred, in other cases this awareness has not translated into action, despite the increasing evidence that draining wetlands is not always a rational economic decision (Balmford et al., 2002; Costanza et al., 2014; Golden et al., 2017; Pattison-Williams et al., 2017; Wheater and Gober, 2013). Further research is necessary to understand the myriad of issues involved in this seemingly contradictory narrative – such as perspectives between upstream and downstream users, power dynamics between rural and urban perspectives and concerns of private and public property rights – to properly frame wetland conservation within the public sphere.

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[21] Agriculture Council of Saskatchewan (2013) conducted a survey on native prairie ecosystems that supported the position that Saskatchewan residents are aware of environmental issues and value water quality maintenance as one of the most important ES provided.

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