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An Ecosystem Service Assessment of Peatlands in the Eastern and Interlake Regions of Manitoba

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Written by Vivek Voora, Kyle Swystun, Rosemary Dohan and Charles Thrift

About the Authors

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Vivek manages projects related to ecosystem goods and services, sustainable agriculture and water management for the Natural and Social Capital program and the Water Innovation Centre. He is contributing to a broad range of multi-disciplinary initiatives spanning from the establishment of a World Heritage Site to devising tools for ecological infrastructure investments. He is also developing projects related to decision support systems for sustainable watershed management and linking indigenous peoples with carbon markets. He has a wide range of experiences in the environmental and sustainable development field that includes: environmental representative for a manufacturing operation; laboratory technician and supervisor for stratospheric ozone, air quality and greenhouse gas monitoring laboratories; project assistant for wastewater/stormwater quality monitoring and improvement initiatives; consultant for wind energy development projects.

Kyle Swystun, Project Officer

Kyle Swystun is a Project Officer for IISD's Natural and Social Capital Program. His work is primarily focused on watershed management, sustainable agricultural systems, and climate change adaptation and risk reduction. Kyle was previously employed as a research associate and research technician at the Centre for Earth Observation Science (CEOS) at the University of Manitoba where he participated in research campaigns studying the effects of climate change in Canada's Arctic. Kyle's graduate research was a carbon and energy balance study of a wetland tundra sedge fen located in the Hudson Bay Lowlands near Churchill, Manitoba, Canada during two consecutive growing seasons. Kyle's graduate project was part of a larger research campaign to better understand the impacts of climate change on watershed processes in the Hudson Bay Lowlands, and their subsequent effects on Hudson Bay.

Rosemary Dohan, Research Assistant

Rosemary Dohan began working as a Project Officer for the Natural and Social Capital program in July of 2010 and has been providing support for the pending United Nations World Heritage Site nomination, Pimachiowin Aki. She has also worked for Manitoba Water Stewardship and Manitoba Conservation in various contract positions. Rosemary has a Bachelor of Environmental Studies Honours Cooperative Education Program – Biodiversity and Conservation from the University of Manitoba where she completed her Honours project on the Effectiveness of Woody Debris: Piles in the Duck Mountain Provincial Forest, Manitoba.

Charles Thrift, Project Manager

Charles Thrift is currently working as a Project Manager for IISD's Natural and Social Capital program. Recent project work has centered on life-cycle assessment, studying the impacts of climate change on agricultural biomass production in Manitoba, and examining the greenhouse gas mitigation potential of sustainable agriculture. Charles has a diverse research background and has experience working with both science and policy. Before working at IISD, Charles was part of IISD's Young Canadian Leaders for a Sustainable Future internship program at the Stockholm Environment Institute, where he was working on sustainable sanitation issues in West Africa.

Executive Summary

Natural environments provide valuable and essential services for human well-being, which are referred to as ecosystem goods and services (EG&S).[1] When natural environments are destroyed, degraded or modified, their ability to provide EG&S becomes compromised. Peatlands,[2] defined as peat covered terrain with a minimum of 30 to 40 cm of peat depth, are unique ecosystems that supply a variety of EG&S.

Almost 30 per cent of Eastern and the Interlake area of Manitoba (as depicted in Figure 2) is covered by peatlands[3] that are locally and globally important in terms of the EG&S they provide. To communicate their importance to human well-being their monetary value was estimated to be CAD$128 million/year (see Table ES-1). In addition to these estimates the values of Micro-Climates, Education and Experiential Insights, Pollination, and Soil Formation EG&S were examined qualitatively. It must be noted that conservative approaches were selected to estimate the EG&S values. Additional research would be required to enhance the valuation estimates for this study.

TABLE ES-1: PEATLAND EG&S VALUE ESTIMATES FOR THE EASTERN AND INTERLAKE REGIONS OF MANITOBA

EG&S	ESTIMATED VALUE (CAD$ MILLION PER YEAR)	VALUATION APPROACH
Provisioning		
Water supply	3	Willingness to pay for improved water supply
Subsistence	1	Replacement market costs for plant and meat based food, fur, raw materials and medicines.
Regulating		
Climate regulation	15	Market value of carbon in the voluntary carbon market
Water regulation	2	Replacement cost of water retention capacity
Water treatment	74	Replacement cost of water treatment with wastewater treatment plant
Erosion control	3	Water quality improvements associated with the restoration of natural environments
Cultural		
Spiritual well-being	5	Market value of social, psychological and spiritual healing
Recreation	1	Public expenditures for park maintenance applied to the peatlands in the provincial park in the project area
Supporting		
Habitat/refugia	24	Replacement cost of peatlands habitat
Total	**128**	Estimate of EG&S values provided by peatlands in Eastern and Interlake Manitoba

[1] "EG&S are the environmental benefits resulting from physical, chemical and biological functions of healthy ecosystems and include market goods produced from ecosystems (e.g. food, fibre, fuel, fresh water, genetic resources, etc.), the benefits from ecosystem processes, (e.g. nutrient cycling, climate regulation, water purification, waste treatment, pollination, etc.) and non-material benefits (e.g. aesthetic values, recreation, etc.)" (www.gov.mb.ca/agriculture/soilwater/ecological/index.html).
[2] "Peatland ecosystems are terrestrial environments where over the long term, net primary production exceeds organic matter decomposition, leading to the substantial accumulation of a deposit rich in incompletely decomposed organic matter, or peat" (Wieder, Vitt, & Benscotter, 2006, p. 1).
[3] The peatlands spatial coverage within the project area was determined using the Government of Manitoba's Forest Resource Inventory dataset (acquired through aerial photography obtained at various times and refreshed periodically).

Natural capital is the tangible elements within ecosystems that are imperative to their proper function and ability to provide goods and services benefiting human well-being. To estimate the natural capital of peatlands in the project area, the market value of extractable peat, carbon and water stored were examined. The value of the top metre of extractable peat in the project area was estimated to be CAD$1,914 billion. The value of peat is worth approximately 50 times its stored carbon value, which is worth $34 billion, and its stored water value, which is worth $4 billion.

Although peat extraction may represent an important industry for Manitoba, the degradation of peatlands will undermine their ability to provide EG&S. Consequently, the sustainable management of peatlands requires a careful balance between ensuring that they continue supplying EG&S and sustain existing and future peat extraction operations (Chapman, et al., 2003). This study provides insight for the development of a comprehensive peatlands stewardship strategy for Manitoba.

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Introduction

Peat is partially decomposed organic matter that accumulates under water saturated conditions. A peatland describes a peat covered terrain with a minimum of 30 to 40 cm of peat depth. Wieder, Vitt and Benscotter (2006, p. 1) describe peatland ecosystems as "terrestrial environments where over the long term, net primary production exceeds organic matter decomposition, leading to the substantial accumulation of a deposit rich in incompletely decomposed organic matter, or peat."

The RAMSAR convention includes peatlands in its broad wetland definition (Article 1.1): "…areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Brander, Florax, & Vermaat, 2006, p. 225). As part of the wetland ecosystem family, peatlands provide unique environmental conditions for certain species to thrive.

One-third of the world's peatlands are located in Canada, where they cover 12 to 13 per cent of its landscape or approximately 1.19 million km^2 (The PEW Environment Group, 2011; Tarnocai, 2006). Manitoba is one of Canada's peatland rich provinces as it encompasses 192,000 km^2 of peatlands representing almost 30 per cent of its territory (Manitoba Conservation and Water Stewardship, Undated).

Natural environments or natural capital provide humanity with valuable ecosystem goods and services (EG&S) (see Figure 1), which can be thought of as financial capital within a bank account that provides regular interest. The more financial capital is liquidated the less interest is generated. Similarly, the loss of natural environments or natural capital leads to a loss of EG&S.

Manitoba's vast peatland expanses provide a number of important EG&S that are a product of healthy and functioning natural environments essential for human well-being. A variety of EG&S such as raw materials, carbon sequestration, water filtration, flood protection and natural habitats are provided by peatland ecosystems (Kimmel & Mander, 2010; Keddy, et al., 2009).

The sustainable management of peatlands requires a careful balance between ensuring that they continue supplying EG&S and sustaining existing and future peat extraction operations (Chapman, et al., 2003). The Province of Manitoba has been proactive in working toward developing a comprehensive peatlands stewardship strategy that would be the first of its kind in Canada (The PEW Environment Group, 2011). In 2011, the Manitoba government implemented a two-year moratorium on issuing new leases for peatlands (The Legislative Assembly of Manitoba, 2011). Subsequently, the Province announced in 2013 that it will extend the moratorium and suspend any new Environment Act licence applications (Province of Manitoba, 2013).

The importance of developing an effective peatlands management strategy is highlighted in Tarnocai (2006), who reports that the majority of peatlands in Canada are vulnerable to climate change. Degrading peatlands could release significant amounts of carbon, further accelerating climate change and its associated potential impacts (Carlson, et al., 2010; Glatzel, Basiliko, & Moore, 2004; Waddington, Warner, & Kennedy, 2002).

Other ecosystem alterations via agriculture, mining, commercial forestry and major hydrological construction projects may also impact peatlands and their ability to provide EG&S (Foote & Krogman, 2006). Based on a meta-analysis of 713 restored wetlands (out of which 17 were peatlands), they can only regain 74 to 77 per cent of their normal level of biogeochemical functioning, which can limit their ability to provide EG&S (Moreno-Mateos, Power, Comin, & Yockteng, 2012; Moreno-Mateos, Post-Doctoral Research Fellow, 2013). The study also revealed that smaller, depressional wetlands in cold climates recover more slowly than wetlands that are larger, hydrologically connected and in warmer climates (Moreno-Mateos, Power, Comin, & Yockteng, 2012). Bullock and Collier (2011, p. 973) affirm that a peatland "is not a renewable resource and its ecological resilience is extremely low."

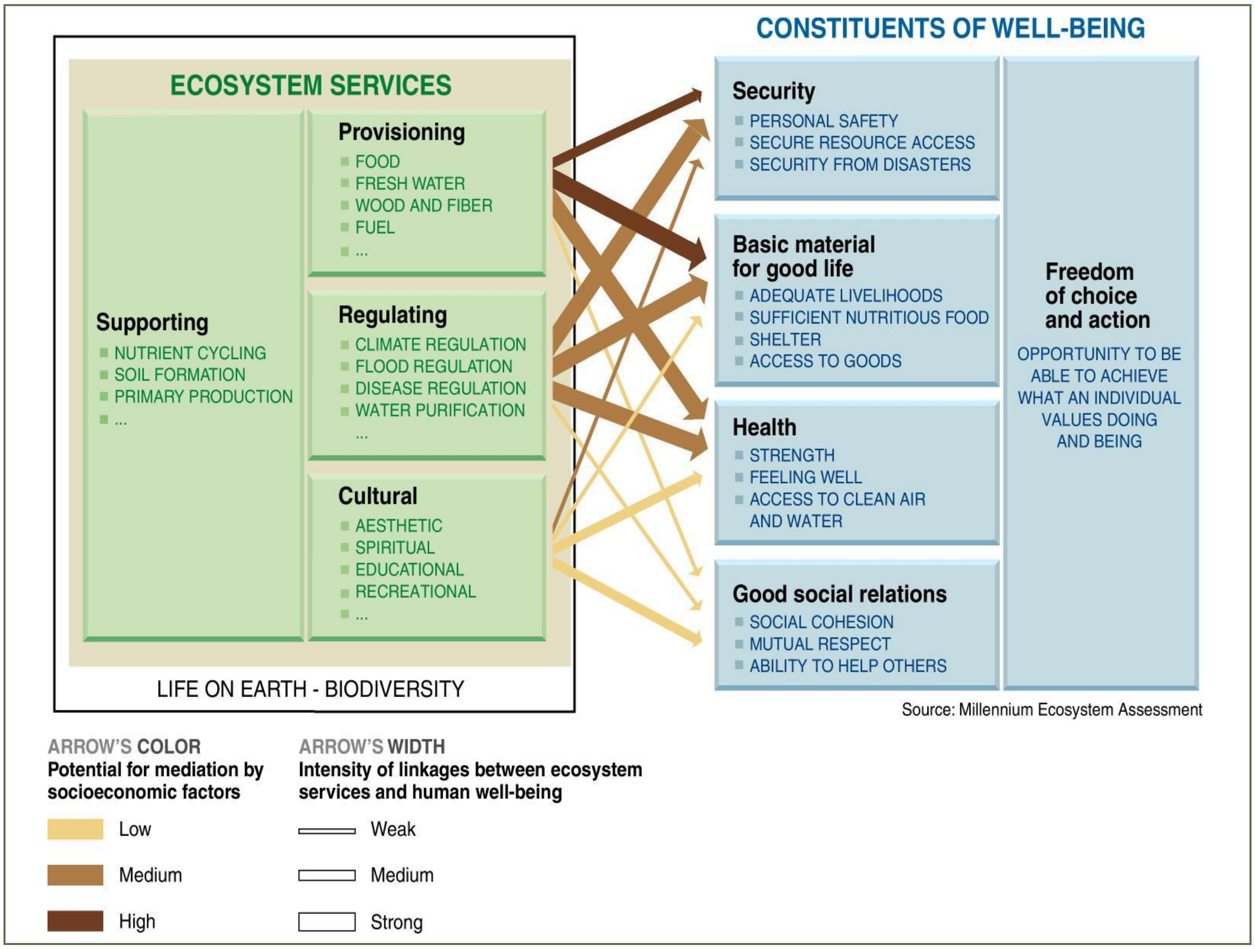

FIGURE 1: RELATIONSHIP BETWEEN EG&S AND HUMAN WELL-BEING (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005).

This study focuses on the EG&S provided by the peatlands of the Eastern and Interlake regions of Manitoba (depicted in Figure 2 and hereinafter referred to as the project area), comprised of 15 ecodistricts[4] covering a surface area of 76,356 km^2, out of which 28 per cent (or 21,164 km^2) are peatlands.[5] The project area is home to approximately 173,983 residents and 62,790 households (Statistics Canada, 2011) (see Appendix A).

[4] "Ecodistricts are integrated map units characterized by relatively homogeneous physical landscape and climatic conditions. They are subdivisions of an ecoregion and have a more uniform biological production potential. Soil Landscapes of Canada polygons are nested within ecodistricts" (Smith, Veldhuis, Mills, Eilers, Fraser, & Lelyk, 1998, p. 11).

[5] The spatial extent of the peatlands in the project area was determined using Manitoba's Forest Resource Inventory (21 Forest Management Units with a spatial resolution of 1:15840 acquired through aerial photography obtained at various times and refreshed periodically).

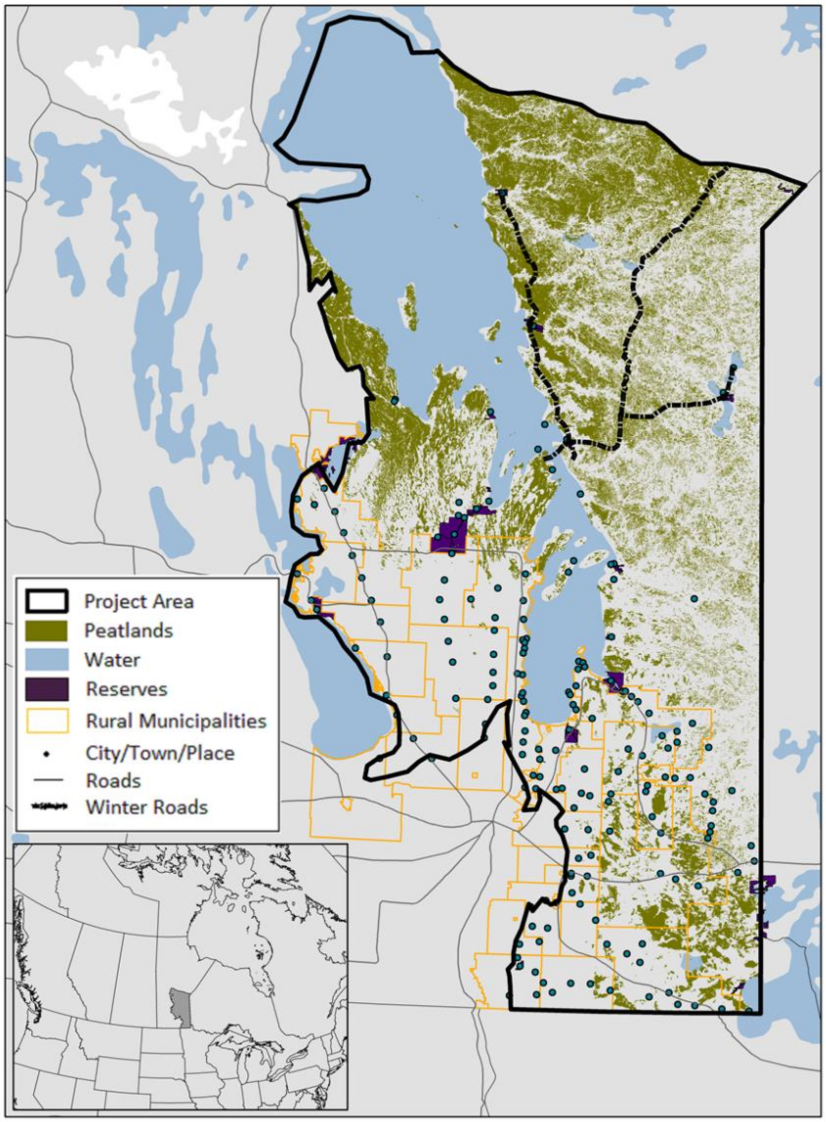

FIGURE 2: THE PROJECT AREA IS WITHIN THE EASTERN AND INTERLAKE REGIONS OF MANITOBA AND IS COMPRISED OF 15 ECODISTRICTS.

This EG&S valuation assessment provides insights for the development of a comprehensive Manitoba Peatlands Stewardship Strategy, which is imperative for the well-being of Manitobans. Some of the EG&S valuation estimates in this report must be used with caution, as they are based on information derived from similar contexts and informal data-gathering methods (phone and email inquiries). Consequently, with regard to these estimates, a number of assumptions were made to derive the numbers reported. In these instances, a more rigorous approach is required to improve the valuation estimates derived in this study.

Assessment Approach

The methodology consisted of quantifying the biophysical aspects of the peatlands in the project area, establishing the EG&S that they provide and their natural capital stocks and then estimating their potential monetary value. Quantifying the peatland biophysical aspects consisted of establishing their spatial extent and depths within each ecodistrict of the project area. A list of EG&S provided by peatlands in the project area was then determined (see Table 1). Valuation estimates were derived by gathering EG&S values from existing studies carried out within the project area or in similar contexts, by using proxies and by gathering information required to assess the replacement cost or value of the EG&S examined (see Table 2). Natural capital valuation estimates were also examined for the peat, carbon and water stored within the peatlands of the project area (see Table 3).

Biophysical Aspects

The peatlands within the project area were first identified and quantified by establishing their spatial extent and peat depth, which are essential to determine the capacity of the peatlands to provide various EG&S. For instance, spatial extent and peat depth can provide the information required to determine water filtration capacity to estimate its water treatment value.

The spatial extent of the peatlands in the project area was determined using the Government of Manitoba's Forest Resource Inventory dataset.[6] The Black Spruce Treed Muskeg, Tamarack Larch Treed Muskeg, Treed Muskeg, Marsh Muskeg, Muskeg and String Bogs subtype descriptions were assumed to indicate the presence of peatlands in the project area.

Peat depth was determined using the Agriculture and Agri-Food Canada's Soil Landscapes of Canada (SLC) version 3.2 dataset. A weighted average peat depth was calculated for each ecodistrict and data gaps were filled using information from Bannatyne (1980) and Vitt, Hasley, Bauer and Campbell (2000).

The approach taken to quantify the biophysical aspects of the peatlands in the project area resulted in a total peatland area of 21,164 km^2 (or 28 per cent of total land area). The spatial extent of peatlands by ecodistricts ranged from 59 to 6,956 km^2, while peat depths ranged from 1.1 cm to 350 cm. The estimates derived are summarized in Appendix B.

Ecosystem Goods and Services Identification and Valuation

The Millennium Ecosystem Assessment provides a typology of EG&S categorized into provisioning, regulating, cultural and supporting services. Starting from this categorization, a subset of EG&S supplied by peatlands was then derived using other lists from the literature (Anielski & Wilson, 2009; Joostens & Clarke, 2002; Kimmel & Mander, 2010).

Valuation estimates for the EG&S identified in the list were derived based on existing valuation studies within the project area or similar contexts. Table 1 summarizes the various EG&S examined for this study and the approach used to estimate their monetary values.

[6] The Forest Resource Inventory data were obtained from the Manitoba Land Inventory (mli2.gov.mb.ca/about_us/projectdetails.html). The spatial data consists of 21 Forest Management Units acquired through aerial photography, with a resolution of 1:15840, collected at various times and refreshed periodically.

TABLE 1: ECOSYSTEM SERVICE DESCRIPTIONS AND VALUATION APPROACHES.

EG&S	DESCRIPTION*	VALUATION APPROACH
Provisioning	**Basic requirements for well-being.**	
Water supply	Water supplies provided by natural ecosystems.	Willingness to pay surveys for water conservation.
Subsistence from peatland supported plants and animals	Plants and animals harvested for sustenance, clothing raw materials, and to treat ailments and wounds.	Replacement market value of edible and medicinal plants, meat from hunting activities and fur from trapping in peatland areas.
Regulating	**Maintain a habitable environment.**	
Climate regulation	Regulation of carbon dioxide concentrations through the sequestration of carbon.	Estimate the net carbon sequestration to determine its climate heating or cooling effect and its value within the voluntary carbon market.
Micro-climates	Peatland influences on micro-climates.	Estimate the value of cooling, warming and precipitation effects on the environment.
Water regulation	Prevention or dampening of flood events.	Estimate water retention and release and its replacement cost with water retention structures.
Water treatment	Removal and breakdown of water pollutants.	Estimation of nutrient uptake capacity and its equivalent cost with a wastewater treatment plant.
Erosion control	Protection of underlying soils from erosion.	Estimate the value of soil erosion prevention within agricultural landscapes.
Cultural	**Non-material benefits.**	
Recreational opportunities	Opportunities for recreation.	Management costs (salaries and operational costs) for 13 provincial parks and park reserves in the project area applied to the peatlands within them.
Personal well-being	Psychological and spiritual health.	Cost of healing services due to loss of peatlands (psychologist, social worker, spiritual and traditional healing services).
Education and experiential insights	Opportunities for observing nature and accumulating scientific and traditional ecological knowledge.	Estimate the value of scientific and experiential discovery and educational opportunities derived from them.
Supporting	**Maintain the existence of natural environments.**	
Pollination	Movement of plant genes for reproduction.	Estimate the value of pollination for agricultural operations and ecosystems.
Habitat/refugia	Suitable living space for species to evolve and breed.	Estimate peatland restoration costs required to provide habitat/refugia for various species.
Soil formation in support of agriculture and forestry	Formation of productive soils by rock weathering, decomposition and accumulation of organic matter.	Estimate the value of soil formation to support in-situ economic activities and ecosystems.

* *Descriptions were obtained from Joostens and Clarke (2002), Kimmel and Mander (2010) and Voora and Barg (2008).*

Natural Capital Valuation

The natural capital values of the peatlands in the project area were also estimated. The peat, carbon and water content of these peatlands were valued, providing a proxy for the natural capital value of the peatlands in the project area. The value of peat, which is primarily extracted for horticultural purposes in Manitoba,[7] was then compared to its carbon and water natural capital values.

[7] Peat can be harvested for multiple applications that include fibre inputs, combustible fuel, horticulture and filtration medium for wastewater.

Ecosystem Goods and Services Assessment

The peatlands EG&S examined and valued provide a general sense of their contributions to human well-being locally and internationally. The values determined for the project area are summarized in Table 2. Detailed descriptions of how they were derived are provided in the following sub-sections.

TABLE 2: EG&S VALUES PROVIDED BY PEATLANDS IN THE EASTERN AND INTERLAKE REGIONS OF MANITOBA

EG&S	ESTIMATED VALUE PER YEAR (CAD $MILLION)	VALUATION APPROACH AND ASSUMPTIONS
Provisioning		
Water supply	3	**Willingness to pay for improved water supply** • CAD$452.33/household/year in Manitoba • 10 per cent of value attributed to peatlands
Subsistence from peatland supported plants and animals.	1	**Replacement cost for food (plant based and meat based), raw materials, fur and medicines** • CAD$5,000/household/year • Applied to 50 per cent of First Nation households in the project area. • 10 per cent of value attributed to peatlands.
Regulating		
Climate regulation	15	**Market value of carbon in the voluntary carbon market** • Carbon accretion rate of 19.4 g C m^{-2} $year^{-1}$ • Average forest carbon market transaction value in 2011 CAD$8.20/$tCO_2$e.
Water regulation	2	**Replacement cost of water retention capacity** • USD$1,000 per acre/foot of storage • Assumed 1 cm storage capacity • 10 per cent of value attributed to peatlands
Water treatment	74	**Replacement cost of water treatment with wastewater treatment plant** • 3.0 kg P/ha/yr and 80 kg N/ha/yr • Wastewater treatment costs are CAD$3.50/kg of nitrogen and CAD$25.12/kg of phosphorus • 50 per cent peatlands are hydrologically connected • 10 per cent nutrient uptake capacity
Erosion control	3	**Water quality improvements associated with the restoration of natural environments** • Water quality improvements from natural environment restoration CAD$1.57/ha/year
Cultural		
Recreational opportunities	1	• Management cost for protected areas applied to the peatlands within them.
Personal well-being	5	**Market value of social, psychological and spiritual healing** • Cost for spiritual healer, psychologist and social worker CAD$810/day • 10 per cent of First Nations population requires healing services 6 times per year.
Supporting		
Habitat/refugia	24	**Replacement cost of peatland habitats** • Peatlands restoration cost are CAD$1,020 to $1587/ha • Assuming all the peatlands in the Eastern and Interlake Manitoba need to be restored • Annualizing the total value using 1per cent
Total	**128**	**Coarse estimate of EG&S values provided by peatlands in the Eastern and Interlake regions of Manitoba**

The Micro-Climates, Education and Experiential Insights, Pollination, and Soil Formation services could not be valued at this time, as more research is required to estimate their monetary value. They are discussed qualitatively in the sub-sections below to illustrate their potential value within the project area.

Provisioning Services

Peatlands provide clean water and offer suitable habitats for plants and animals used for subsistence and raw materials, which are essential to human well-being. The water supply and subsistence provisioning services from the peatlands in the study are discussed below.

Water Supply

(Definition: Slows runoff, stores water and recharges groundwater)

Access to clean water is essential for human well-being. Peatlands can regenerate groundwater by slowing surface runoff. Joostens and Clarke (2002) report that peatlands have a limited effect recharging bedrock aquifers but that peat accumulation in the lower parts of a catchment can increase groundwater levels. Rochefort et al. (2012, p. 120) state that "peatlands have the ability to self-regulate their hydrology keeping water levels relatively stable."

Studies have been conducted to assess people's willingness to pay for clean drinking water. Rollins, Frehs, Tate and Zachariah (1997) aimed to determine the willingness to pay to conserve and protect water resources by asking the following question:

Would you be willing to support a program to conserve water by repairing water distribution and sewage treatment systems in Canada, if it cost your household an additional X dollars each month?

The study determined that the average willingness to pay for Manitobans was approximately CAD$28.13/household/month (Rollins et al., 1997). Adjusting the figure for inflation[8] gives a mean willingness to pay CAD$452.33/household/year. Applying this figure to the 62,790 households in the project area (Manitoba Statistics, 2006), we get a total willingness-to-pay of CAD$28.40 million/year for access to drinking water. This willingness to pay estimate is used as a proxy to value peatland water supply services within the project area. Because peatlands provide only a portion of water supply services from the landscape, we assume that 10 per cent, or approximately CAD$3 million/year[9], can be attributed to peatlands.

Subsistence Values

(Definition: Wild plants and animals used for food, fur, medicines and materials)

A variety of plants and animals that rely on or grow within peatlands are harvested to provide for sustenance, treat illnesses and supply raw materials. Peatland plants can provide a source of food, medicine and materials (see Appendix C). Wild animals that rely on peatlands for their habitat are hunted and trapped for meat and fur. For instance, some First Nations still harvest peatland plants and animals for their subsistence (Karst, 2010).

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[8] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator, www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 1997 to 2012 is 34 per cent.

[9] $28.13/household/month × 12 months/year × 1.34 (inflation rate) × 62,790 households × 10 per cent (portion of water supply provided by peatlands) = $2.84 million/year

The replacement cost of the provisioning services that peatland plants and animals provide can be approximated. Haener and Adamowicz (2000) estimated the replacement cost for subsistence goods for a select number of First Nations living in the boreal region of Alberta. Subsistence goods were defined as wood harvesting, hunting, fishing, trapping,[10] food gathering and raw materials for crafts or traditional medicine (Haener & Adamowicz, 2000). Anielski and Wilson (2009) used and modified this estimation to be approximately CAD$5,000 to $11,000 per household/year in their study of the EG&S values of the Canadian boreal region.

Because the subsistence goods valuation estimate comes from the boreal region as a whole, we assume that 10 per cent originates strictly from peatlands (CAD$500 to $1,100 per household/year). Applying the low end of the valuation estimate adjusted for inflation[11] (CAD$535/household/year), and assuming 50 per cent of the First Nation households rely on peatland subsistence goods (3,864 total First Nations households – see Appendix D) in the project area gives CAD$1 million/year.[12]

Regulating Services

Regulating services maintain a habitable environment for various living organisms. The peatland regulating services examined consisted of climate regulation through carbon sequestration, influences on micro-climates, water regulation by estimating water retention capacity, water treatment through nutrient uptake and soil erosion prevention.

Climate Regulation

(Definition: Regulation of greenhouse gases and climatic processes)

Inter-annually, peatlands can function as a carbon sink or source depending on CO_2 and CH_4 fluxes that are primarily functions of temperature and moisture[13] (Rochefort, et al., 2012). Historically, peatlands in western Canada have and continue to function as a carbon sink (Vitt, Halsey, Bauer, & Campbell, 2000; Frolking, Roulet, & Fuglestved, 2006). Vitt et al. (2000) estimate that, by taking into account both CO_2 and CH_4 budgets, Western Canadian peatlands have had an accretion rate of 19.4 g C m^{-2} $year^{-1}$ during the past 1,000 years.

It must be noted that carbon lost through CH_4 emissions can have a significant influence on the greenhouse gas budget of peatland ecosystems (Whiting & Chanton, 2001; Rochefort, et al., 2012). Methane is a 25 (g/g) times stronger greenhouse gas than CO_2 when considered over a 100-year time frame (Forster, Ramaswamy, Artaxo, & et al., 2007). When assessing both CO_2 and CH_4 fluxes from a subarctic peatland in Sweden, Johansson et al. (2006) determined the overall greenhouse gas balance to be a net loss of 132 g CO_2e m^{-2} during the 153-day growing season period. This context- specific case illustrates the need to adequately monitor both CO_2 and CH_4 exchange when assessing peatland effects on climate change. Whether peatlands act as a source or a sink will be spatially and temporally specific.

[10] The average economic value of the furs trapped in the project area between 2005 and 2010 was approximately $176,000 (Government of Manitoba, Undated; Berezanski, 2011).

[11] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator, www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 2009 to 2012 is 7 per cent.

[12] $5000/household/year × 1.07 (inflation rate) × 10 per cent (peatland contribution to subsistence value) × 3,864 First Nation households × 50 per cent (First Nation household reliant on peatlands) = $1.03 million/year

[13] Higher water tables inhibit aerobic decomposition (CO_2 release) but promote anaerobic decomposition (CH_4 release). Conversely, lower water tables promote aerobic decomposition but inhibit anaerobic decomposition. Furthermore, high temperatures promote both aerobic and anaerobic decomposition while low temperatures inhibit both aerobic and anaerobic decomposition. Productivity peaks within an optimum range of temperatures and it decreases when temperatures are outside that optimum range.

Frolking et al. (2006) examine the CO_2 and CH_4 fluxes from northern peatlands using a number of methods (Greenhouse Warming Potential and Radiative Forcing) and conclude that peatlands have an overall cooling effect. However, they also warn that peatlands can shift to having a warming effect based on the changing environment. Long Flanagan and Cai (2010) measured the CH_4 emissions and CO_2 sequestration from a boreal fen typical of most peatlands located 80 km northeast of Athabasca, Alberta to be approximately 3.2 g CH_4 m^{-2} and 217 g CO_2 m^{-2} over a growing season (144 to 269 days from late May to late September in 2007). Converting these two figures into CO_2e and assuming that twice the amount of CH_4 is emitted on an annual basis gives 160 g CO_2e m^{-2} for methane emissions and 217 g CO_2e m^{-2} for carbon dioxide sequestration. This gives a net CO_2e sequestration rate of 57 g CO_2e m^{-2} $year^{-1}$ for one growing season.

Based on the scientific literature reviewed, using Vitt et al.'s (2000) reported carbon accretion rate to estimate the carbon sequestration rate for the peatlands in the project area is conservative[14] (Frolking, Roulet, & Fuglestved, 2006; Rochefort, et al., 2012). Applying the average forest carbon value traded in 2011 of USD$8.20/$tCO_2e$[15] (Peters-Stanley, Hamilton, & Yin, 2012) adjusted for currency, power purchasing parity and inflation[16] to the peatlands within the project area provides a total value of CAD$15 million/year[17] in carbon sequestration services.

Micro-Climates

(Definition: regulation of and influence on local climates)

Natural environments influence climate in a number of ways. Peatlands are typically located in wet depressions on the landscape. For this reason, they are cooler and more humid environments than their surroundings (Rochefort, et al., 2012). Their presence can lead to greater air humidity, fog frequency and night frosts; in addition "seasonal frost is persistent and permafrost is common in northern peatlands because of the thermally insulative properties of dry moss in the summer and transmissive properties when wet in fall and winter" (Rochefort, et al., 2012, p. 121). The loss of boreal peatlands can potentially lead to local increases in ambient temperatures and frost-free periods (Joostens & Clarke, 2002). More research is required to better understand the influence of peatlands on the micro-climate of the project area to monetarily value this EG&S.

Water Regulation

(Definition: regulation of catchment hydrology through water storage and groundwater recharge and discharge)

According to Rochefort et al. (2012) peatland form and function, which are greatly influenced by hydrological processes, regulate the water availability. Peatlands have a static and dynamic effect on regulating catchment hydrology. Water saturated peat (undrained peat is typically from 85 to 95 per cent water (Joostens & Clarke, 2002)) represents the

[14] "Average rates of carbon sequestration of ~22 to 24 g C m^{-2} $year^{-1}$ are similar to long-term accumulation rates determined from cores" (Rochefort, et al., 2012, p. 121).

[15] The carbon market value was derived based on the average price of forest carbon traded within the voluntary market (USD$9.2/$tCO_2e$) and compliance markets (USD$7.2 tCO_2e) in 2011 (Peters-Stanley, Hamilton, & Yin, 2012).

[16] The exchange rate for 2011 was CAD$0.989 for USD$1 (www.bankofcanada.ca/stats/assets/pdf/nraa-2011.pdf). The power purchasing parity between Canada and the United States in 2011 was 1.234642 (stats.oecd.org/Index.aspx?DatasetCode=SNA_TABLE4). The inflation rate from 2011 to 2012 was 2 per cent (calculated using the online Bank of Canada Inflation Calculator - www.bankofcanada.ca/rates/related/inflation-calculator).

[17] 19.4 gC/m^2/year × 3.67 (molecular weight conversion factor C to CO_2) × USD$8.20/$tCO_2e$ × 0.989 (currency conversion USD to CAD) × 1.23 (Purchasing Power Parity factor) × 1.02 (inflation rate) × 21,164 km^2 = $15.33 million/year

static water fraction, while water volumes located in and over the uppermost peat and vegetation layers represent the dynamic fraction.

Although the dynamic water storage portion of peatlands can provide some water retention, it is often limited as the peatlands are normally saturated (Rochefort, et al., 2012). Their distance to infrastructure will also influence their flood protection value. The flood protection value of the peatlands in the project area is therefore assumed to be limited due to the saturated nature of peatlands and their distances to the communities.

Assuming that peatlands provide 1 cm of storage capacity consistently throughout the year translates into a volumetric holding capacity of 0.21 km^3. Converting the water storage value of \$0.81/m^3 provided by the Red River Basin Commission (2012) to an annual flow at 1 per cent gives \$0.0081/m^3/year.[18] When modifying this figure for currency[19] and multiplying it to the dynamic water storage capacity of the peatlands in the project area, this results in CAD\$2 million/year[20] in flood protection services.

Water Treatment

(Definition: water purification and treatment via the retention, recovery and removal of excess nutrient and pollutants)

Peatlands can have different influences on water quality depending on their composition. In general peatlands improve water quality by filtering sediments, retaining and absorbing nutrients and carbon (Graham, Craft, McCormick, & Aldous, 2005). Due to their properties, peatlands have the capacity to treat secondary municipal wastewater. Joostens and Clarke (2002, p. 83) report that "results from several peatland wastewater treatment systems indicate a reduction in B.O.D., suspended solids, nitrogen and to some extent phosphorus." Although peatlands have the capacity to cleanse water from a number of pollutants, nutrient removal capacity is used as a proxy to estimate their water treatment value.

Ronkanen and Kløve (2009) examined four treatment peatlands in Finland to determine their nutrient removal efficiencies for 10 to 16 years. Two peatlands received runoff from peat extraction areas, while the other two received wastewater from polishing municipal wastewater wetlands. The peatlands receiving runoff from the peat extraction areas had a nutrient removal efficiency ranging from 2.76 to 3.50 kg phosphorus/ha/year and from 78.20 to 151.05 kg nitrogen/ha/year.

While the peatlands examined by Ronkanen and Kløve (2009) were directly connected to the wastewater they were treating, natural peatlands may or may not be hydrologically connected to the landscape, depending if they are in bog (or ombrotrophic) or fen (or minerotrophic) environments. Bogs are hydrologically independent, while fens are hydrologically connected. To determine the proportionate area of peatland bogs to fens in the project area, LandSat imagery covering a portion of the project area was examined, which showed a 50/50 split between bogs and fens when summing up their respective areas. Therefore, a 50/50 split between bogs and fens was assumed for the project area.

[18] The ecosystem service value was converted to annualized flow by using an approach utilized by the International Joint Commission (Werick, Lupi, & Leger, 2006) to estimate the wetland benefits within the Lake Ontario-St. Lawrence River System and the David Suzuki Foundation to estimate the EG&S of Ontario's Green Belt (Wilson, 2008).
[19] The currency exchange rate from USD to CAD was 0.99 in 2012 (www.bankofcanada.ca/stats/assets/pdf/nraa-2012.pdf). The purchasing power parity between Canada and the United States in 2012 was 1.223712 (stats.oecd.org/Index.aspx?DatasetCode=SNA_TABLE4).
[20] \$0.81/m^3 × 0.99 (Exchange Rate) × 1.22 (Purcharing Power Parity factor) × 1 per cent/year (annualization factor) × 1 cm × 21,164 km^2 = \$2.08 million/year

To estimate the peatlands' water treatment service value we assume that 50 per cent are hydrologically connected to the landscape.[21] Using the lower end of the nutrient removal efficiencies reported by Ronkanen & Kløve (2009) (2.76 kg phosphorus/ha/year and 78.20 kg nitrogen/ha/year) and wastewater treatment costs (CAD$21.85/kg of phosphorus and CAD$3.04/kg of nitrogen) reported by Olewiler (2004) and adjusted for inflation[22] (CAD$25.12/kg of phosphorus and CAD$3.50/kg of nitrogen), we estimate the water treatment ecosystem value provided by the peatlands in the project area to be CAD$143 million/year[23] and CAD$289.62 million/year[24] for phosphorus and nitrogen removal, respectively.

It must be noted that many peatland ecosystems are characterized by low soil nitrogen and phosphorus availability and high soil acidity (Rydin & Jeglium, 2006; Wieder, Vitt, & Benscotter, 2006). However, low nutrient availability does not necessarily suggest nutrient limitation of peatland plant communities (Chapin, Bridgham, & Pastor, 2004). Peatland plant communities occupying nutrient-poor habitats are relatively unresponsive to nutrient addition while peatland plant communities occupying nutrient-rich habitats experience increased plant growth with nutrient addition (Chapin, Vitousek, & Vancleve, 1986; Aerts & Chapin, 2000; Rochefort, et al., 2012).

It is assumed that many of the boreal peatland ecosystems within the Eastern and Interlake regions of Manitoba are characterized by high soil acidity and low nutrient availability given the close proximity of the Canadian Shield and the extensive coverage of the boreal forest within the region of interest. Therefore, the potential for additional nutrient uptake by peatland plant communities within the region of interest ought to be negligible.

Based on the information above the peatlands in the project area are likely to be in a nutrient-poor environment compared with the peatlands studied by Ronkanen and Kløve (2009). For this reason we assume that they provide only 10 per cent of the water treatment ecosystem service value estimated, or CAD$74 million/year.[25]

Erosion Control

(Definition: Peat blanket protecting the underlying soils from erosion)

Vegetated areas provide important erosion control services. Erosion can lead to infrastructure damages, water siltation that can harm fish populations, and a reduction in soil productivity for agriculture (Voora & Barg, 2008). Peat extraction can increase the vulnerability of underlying soils to erosion. Peatlands slow water runoff, which can prevent the erosion of adjacent soils. Olewiler (2004) reports that the erosion control services provided by natural environments in the Upper Assiniboine River Basin can be estimated by measuring water quality improvements, which were found to range from CAD$1.34 to $9.34/ha/year.

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[21] This coarse visual inspection estimate does not take into account groundwater connectivity. Consequently, assuming that 50 per cent of the peatlands in the project area are hydrologically connected is conservative.

[22] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 2004 to 2012 was 17 per cent.

[23] 2.76 kg P/ha/year × $21.85/kg P × 1.17 (inflation rate) × 21,164 km^2 = $149.33 million/year

[24] 78.20 kg N/ha/year × $3.04/kg N × 1.17 (inflation rate) × 21,164 km^2 = $588.66 million/year

[25] $149 million/year + $589 million/year × 10 per cent (limited nutrient uptake) = $73.8 million/year

To estimate the monetary value of the erosion control services of the peatlands in the project area we assume that maintaining them would prevent soil erosion induced water sedimentation. Maintaining the peatland would lead to a value of at least $1.34/ha/year in improved water quality (the lower estimate provided by Olewiler (2004)), corresponding to $1.57/ha/year when adjusted for inflation.[26] Therefore, the peatlands in the project area provide approximately CAD$3.32 million/year[27] in erosion control services.

Cultural Services

Peatlands provide cultural EG&S in terms of recreational opportunities, personal well-being, and education and experiential insights. Some peatlands offer recreational opportunities through interpretive nature walks. Peatlands can also provide spiritual services, as they can be intricately linked to particular beliefs. For instance, some peatland plants are used in First Nation rituals (Karst, 2010). Peatlands can be important indicators of environmental changes and allow for the historical reconstructions of natural environments.

Recreational Opportunities

(Definition: Opportunities for appreciating nature through recreation and tourism)

Peatlands offer both formal and informal recreational opportunities. Peatlands outfitted with trails, boardwalks and signs offer people formal recreational opportunities that can be enjoyable and informative. Peatlands can also offer informal recreational opportunities when saturated or frozen, as they are often clear of vegetation, allowing for easier movement through forested areas in watercrafts, snowshoes, skis or snowmobiles.

Determining formal and informal recreational values of peatlands can be a difficult task due to the public nature of the service provided. Proxies for monetary value can be ascertained by estimating the cost of trail maintenance within peatland areas and the travel expenditures required to benefit from the recreational opportunities that they provide. To estimate the travel cost associated with visiting peatlands, the total number of visitors and their places of origin would have to be known.[28]

There are currently many kilometres of recreational trail segments close to and over peatlands within the project area. The Border to Beaches trail, which is being built by the Manitoba Trails Association, will cost up to $30,000/km within boggy areas (e.g., from the south shore of Falcon Lake to High Lake) (Sitter, December 2012). This estimate does not include project management, directional signage or trail amenities (pit toilets, benches, interpretive panels, emergency shelters, etc.) (Sitter, December 2012).

[26] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator, www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 2004 to 2012 was 17 per cent.
[27] $1.34 per ha × 1.17 (inflation rate) × 21,164 km^2 = $3.32 million/year
[28] In Canada, 50,000 people visited Burns Bog in British Columbia and 6,000 people visited Miscou Island peatlands in New Brunswick.

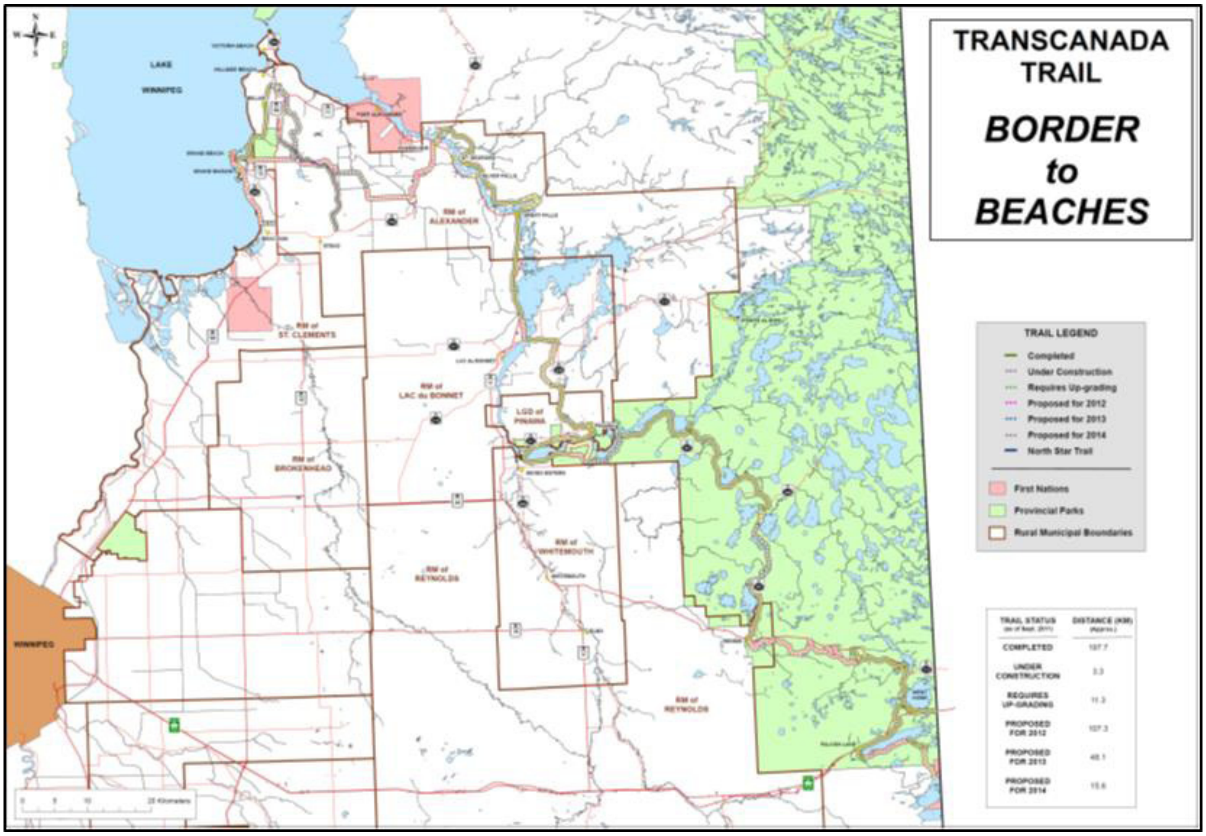
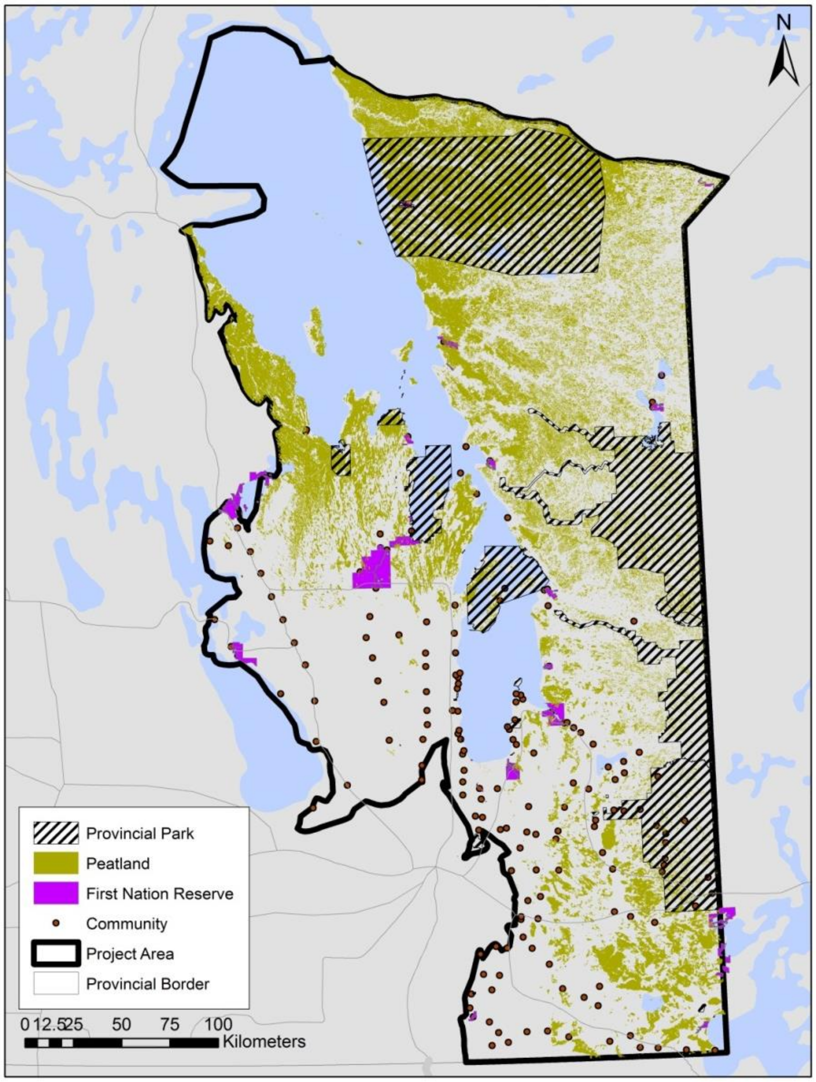


FIGURE 3: THE BORDER TO BEACHES RECREATIONAL TRAIL WILL BE BUILT CLOSE TO AND OVER PEATLANDS.

Source: Map obtained from the Manitoba Recreational Trails Association (Undated).

Peatlands of recreational interest within the project area are part of a mosaic of ecosystems prized for their wilderness and environmental integrity. Their recreational value can be estimated by determining their surface area in the provincial parks located within the project area and multiplying that surface area by the public expenditure per square kilometre for park maintenance.



Compiled by the International Institute for Sustainable Development

FIGURE 4: PROVINCIAL PARKS AND PARK RESERVES IN THE PROJECT AREA.

In 2011–2012 the Province of Manitoba spent approximately CAD$10 million on salaries and operating costs to manage 13 provincial parks in the project area covering 5,768 km^2 (Manitoba Conservation and Water Stewardship, 2012). The 13 provincial parks examined include Grand Beach, Nopiming, Hecla/Grindstone and Whiteshell provincial parks, which are the most frequented parks with peatlands in the project area. To estimate the recreational value of peatlands in these parks, their management costs (the salaries and operating costs referred to above) per square kilometre were estimated and then applied to the peatland areas within each park.[29] Appendix E provides the detailed calculations and results. This approach gave a total recreational value of approximately CAD$1 million/year. This valuation estimate is conservative as it only considers salaries and operating costs, but does not include additional costs such as capital

[29] For instance, the salaries and operating costs to manage Grand Beach, Elk Island and Patricia Beach Provincial Parks, covering a combined surface area of 36.13 km^2, amounts to approximately CAD$1.22 million. This gives a total management cost of about CAD$33,766/km^2. Applying this figure to the total peatland area in these parks (0.77 km^2) gives CAD $26,000.

expenditures and fire suppression. It must also be noted that people typically visit the parks in the project area for their natural features as a whole and not necessarily for the peatlands themselves.

Personal Well-Being

(Definition: Provides personal well-being based on belief system and values of significance)

There may be personal well-being values associated with peatlands. They are part of the boreal landscape and as such provide people with opportunities to commune with nature, which can be psychologically and spiritually healing. The disappearance of these environments could lead to various ill-effects within for people who depend on their natural environment for their psychological and spiritual well-being.

Although monetarily valuing the psychological and spiritual well-being services of peatlands within the project area would not adequately represent their value, proxies could be used to estimate this ecosystem service. For instance, the economic value of traditional healing, psychotherapy or social work can be economically valued. Assuming that, as a result of peatland losses, professionals in the traditional healing, medical or social working field provide 10 per cent of the First Nations (total population = 14,581 (Statistics Canada, 2011)) in the project area with their services at a rate of CAD$750/day (Azur, 2008) adjusted for inflation[30] ($810/day) six times per year, this represents a total value of approximately CAD$5 million/year.[31] This valuation estimate is conservative as the disappearance of peatlands may also affect the personal well-being of people who are not First Nations.

Education and Experiential Insights

(Definition: Opportunities for education training, research and discovery)

Peatlands provide important educational opportunities. They can provide living laboratories where research as well as scientific insights can lead to a better understanding of how natural environments function, which could potentially lead to a number of important and interesting discoveries. Traditional knowledge, for instance, has been gained through experiential learning and the immersion of people living in close connection with their natural environments.

Peatlands can be particularly useful in the study of climate change as they are sensitive and responsive to climatic shifts and changes in moisture (Gignac, 2001; Kirpotin, et al., 2009). Decomposition is inhibited in peatlands due to the absence of oxygen, which allows them to record the history of their environment (Rochefort, et al., 2012). This allows climatologists to use peat cores and organic matter to reconstruct historical climatic conditions, which can be invaluable in understanding the temporal and spatial climatic shifts that have occurred over time (Global Environment Centre, 2010). For instance, pollen extracted from peat cores has been used to reconstruct the progression of glaciers and land cover shifts in North America over thousands of years (see Appendix F).

The scientific information that can be gathered from peatlands is precious, as it can provide valuable insights for climate change adaptation. Valuing this information could be potentially achieved by determining the scientific expenditures required to reconstruct historical climatic environments. More research is required at this time to monetarily value these educational and experiential insights provided by the peatlands in the project area.

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[30] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator, www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 2008 to 2012 was 8 per cent.

[31] $750/person/day × 1.08 (inflation rate) × 6 days/year × 10,239 people × 10 per cent (portion of population needing care) = $4.97 million/year

Supporting Services

The valuation of supporting services is unrepresentative of their actual value as without them ecosystems would collapse. The supporting services examined include pollination, habitat and refugia and soil formation all of which are essential to the continued functioning of ecosystems and human well-being.

Pollination

(Definition: The process by which plant pollen is transferred for reproduction)

Pollination services are indispensable to maintaining and proliferating life. There are over 1,000 species of pollinating insects in Canada and approximately 70 per cent of our food crops are dependent on insects for pollination (Dyer, 2006). The US agricultural sector estimates that pollinators provide benefits amounting from USD$4 to $7 billion/year (Anielski & Wilson, 2009).

Pollination services also benefit natural environments by proliferating plant life. In natural ecosystems, the visual clues of insufficient pollination can be the local extinction of a plant species, a noticeable decline in fruit and seed eating animals, the loss of vegetation cover and ultimately, if keystone species are involved, the demise of healthy ecosystems and their services (Eardley, Roth, Clarke, Buchmann, & Gemmill, 2006, p. xii).

Although peatlands may support pollinator diversity, valuing the support provided by peatlands for pollination services was not possible at this time. More research is required to monetarily value pollination services provided by the peatlands in the project area.

Habitat and Refugia

(Definition: Habitat for species survival and proliferation)

Peatlands provide a unique habitat and refugia for a variety of flora and fauna. Seven hundred and ten vascular and non-vascular plants are commonly found within the peatlands of Canada (Warner & Asada, 2006). The rose pogonia (*Pogonia ophioglossoides*), swamp pink (*Calopogon tuberosus*), water stargrass (*Heteranthera dubia*) and fringed orchid (*Platanthera lacera*), which are found in Manitoba peatlands, are considered rare (Karcha, Mcffatt, & Smith, 2011). A large number of insects are found only or primarily in the peatlands of Canada's boreal region (The PEW Environment Group, 2011). Bogs and fens support distinct beetle species that are not found in marshes (Warner & Asada, 2006). Three specialized genera of dragonflies (*Gomphaeschna, Williamsonia*, and *Nannothemis*), 35 species of water mites, the bog katydid, sphagnum bog cricket, pitcher plant midge and pitcher plant mosquito rely on peatlands for their existence (Warner & Asada, 2006; The PEW Environment Group, 2011).

Peatlands support specific species of birds, amphibians, reptiles and mammals. There are 40 peatland bird species in Quebec (Warner & Asada, 2006). A bird survey recently completed by Karcha, Mcffatt and Smith (2011) in Bullhead, Little Deer Lake and Ramsay Point Manitoba peatland complexes revealed the presence of 47 bird species such as the boreal chickadee, least flycatcher, red-breasted nuthatch, ruby-crowned kinglet and sandhill crane. Amphibians and reptiles species such as the redsided gartersnake, blue-spotted salamander, boreal chorus frog, gray tree frog, northern leopard frog and wood frog are found in Manitoba peatlands at various times of the year. The presence of four mammal species including the American marten, moose, red squirrel and white-tailed deer were recently surveyed in the Bullhead, Little Deer Lake and Ramsay Point peatland complexes in Manitoba (Karcha, Mcffatt, & Smith, 2011).

Establishing a monetary value for habitat and refugia is challenging due to the interconnectedness of ecosystems. The disappearance of one species can initiate major shifts in or the collapse of, entire ecosystems. However, the cost of restoring wetlands and contingent valuation studies on willingness to pay to preserve habitat can be used as proxies to gauge the ecosystem service value of habitat and refugia provided by the peatlands of the Eastern and Interlake regions of Manitoba.

Rochefort and Lode (2006) report that restoring cut-over peatlands can cost in the range of USD$900 to $1,400/ha. Using the lower end of peatland restoration cost reported by Rochefort and Lode (2006) modified for exchange rate and inflation[32] gives an estimated habitat and refugia ecosystem service value of $1,133/hectare. Converting this value to an annualized flow of benefits at 1 per cent gives $11.33/hectare/year[33] in habitat and refugia services. Applying this estimate to the project area results in $24 million/year[34] of habitat and refugia services.

Soil Formation

(Definition: Accumulation of organic matter that supports soil fertility and life)

Soil formation is fundamental to maintaining ecosystem integrity. Peatland soil formation services centre on peat production, which is slowly decaying accumulated biomass under acidic and anaerobic conditions (Rochefort, et al., 2012).

Peatlands offer favourable soil characteristics to some forms of in-situ agriculture and forestry. There are 40,000 has of peatlands under cultivation for vegetable production and pastureland in Canada (Joostens & Clarke, 2002). For example, peatlands support the cultivation of wild rice in Manitoba, cranberries in British Columbia and forage crops in Newfoundland. Forestry can also be undertaken on peatlands and yields will differ, especially if it is actively managed and drained for timber production: "Canadian calculations show that draining of an existing stand is economical if it can reduce the rotation age by 30 years or more" (Joostens & Clarke, 2002, p. 94). For the most part, peatlands do not support forestry unless trees can be economically accessed during the winter or when they are dry during droughts or when artificially drained.

The soil formation of peatlands is fundamental to ecosystem integrity and cannot be adequately monetarily valued by estimating its support role for in-situ economic activities. For this reason and the likelihood that in-situ economic activities in the project area are likely limited, the soil formation services of the peatlands within the project area were not estimated.

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[32] The exchange rate for 2006 was CAD$1.134 for USD$1 (www.bankofcanada.ca/stats/assets/pdf/nraa-2006.pdf). The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator (www.bankofcanada.ca/rates/related/inflation-calculator). The inflation rate from 2006 to 2012 is 12 per cent.

[33] The ecosystem service value was converted to annualized flow by using an approach utilized by the International Joint Commission (Werick, Lupi, & Leger, 2006) to estimate the wetland benefits within the Lake Ontario-St. Lawrence River System and the David Suzuki Foundation to estimate the EG&S of Ontario's Green Belt (Wilson, 2008).

[34] USD$900 per ha × 1.134 (currency exchange USD to CDN) × 1.12 (inflation rate) × 21,164 km^2 × 1 per cent (annualizing flow of benefits) = $24.19 million/year

Natural Capital Valuation

Peatlands produce peat, which is market traded for multiple applications. Peat extraction impairs the ability of peatland ecosystem processes from providing EG&S to varying degrees and for varying durations, depending on the EG&S being considered. The value of peat for the horticultural and water treatment industries, as well as the value of the carbon and water stored, was also valued as a proxy for the natural capital value of peatlands in the project area. These capital stock valuation estimates are provided in the table below.

TABLE 3: NATURAL CAPITAL VALUES OF THE PEATLANDS IN EASTERN AND INTERLAKE MANITOBA

NATURAL CAPITAL	ESTIMATED VALUE (CAD$ BILLION)	VALUATION APPROACH AND ASSUMPTIONS
Extracted peat	1,914	Market value reported by Natural Resources Canada (2013)
Carbon	35	Market value of stored carbon in peat layers Average forest carbon market transaction value in 2011 CAD$8.10/t$CO_2$e
Water	4	Water valuation estimate based on water infrastructure expenditures for domestic water use, applied to the water stored in peatlands

The total value of peat is estimated to be worth CAD$1,914 billion as an extracted good. It must be noted that peat also has a market value for its embedded carbon. Its market value for horticultural, soil amendment and water filtration applications is 50 times greater than its combined carbon and water natural capital value.

Peat

(Definition: Organic matter comprised of decaying plants in water saturated conditions)

Peat is harvested in many parts of the world for various applications that include clothing fibre, construction materials, fuel sources, growing substrates for horticulture, and filtration mediums (Joostens & Clarke, 2002). In Ireland, Finland and Sweden peat is harvested and burned as a non-renewable form of energy (Shilstra, 2001; Zetterberg, Uppenberg, & Ahman, 2004; Kirkinen, et al., 2007). Peat is currently not used in Canada for fuel purposes and is primarily extracted for horticultural purposes and as a filtration medium for onsite wastewater management systems (Daigle & Daigle, 2001; Monson Geerts, et al., 2001). Peat extraction operations in Sprague Lake, Northwest Angle, Caribou, St. Labre, Giroux, Richer, St. Genevieve, Medika, Julius, Evergreen, Beaver Point and Gillam) are currently active in Manitoba.

Peat is commonly used in the horticultural industry for potted plants and other similar applications. For instance, the Netherlands' peat imports for horticulture were valued at approximately CAD$200 million[35] per year (Global Environment Centre, 2010). Canada has been producing horticultural peat for over half a century. Canadian sphagnum peat represented 99.9 per cent of the volume of peat products (1,216,000 tonnes) exported into the United States in 1999 (Daigle & Daigle, 2001). It must be noted that lower peat layers typically do not provide the qualities required for horticultural purposes. According to Sunterra Horticulture, the Freight on Board[36] cost for uncompressed horticultural grade peat is CAD$108 for 128 ft^3 (Dorish, 2011). In addition to horticulture, various qualities of peat are used as a soil amendment medium for various applications including landscaping and seeding recreational fields.

[35] The 2010 exchange rate of 1.3361 (average of 251 days) reported by the Bank of Canada was used to convert 150 million euros to 200 million Canadian dollars (www.bankofcanada.ca/stats/assets/pdf/nraa-2010.pdf).

[36] "A term used in shipping to refer to the place where the buyer becomes responsible for the shipment and the shipping charges" (Travel Industry Dictionary, Undated).

Some onsite wastewater treatment systems rely on peat as a filtration medium for improving water quality (Monson Geerts, et al., 2001); "The most common peat filter installed in Manitoba is the modular system which contains precompacted peat that treats the wastewater through physical filtration, adsorption and microbial activity" (Manitoba Conservation and Water Stewardship, 2009). The Premier Tech Ecoflo© onsite wastewater management systems rely on 1 tonne of fresh peat to filter water pollutants. Peat replacement costs approximately CAD$1500/tonne, which includes the labour costs in replacing and disposing of the spent filtration peat in a proper recycling facility (Premier Tech, 2011).

Based on Natural Resources Canada's revised estimate of the total value of minerals production by province, the average value of extracted dry peat from Manitoba from 2008 to 2011 corresponds to approximately CAD$230/tonne (Natural Resources Canada, 2013). Converting this mass value to a volumetric value using a dry peat density of 400 kg/m^3 (Walker, 2011) gives approximately CAD$90.47/m^3. Applying this figure adjusted for inflation (see Appendix G) to 1 metre of all the peatlands in the Eastern and Interlake regions of Manitoba corresponds to CAD$1,914.[37] The natural capital valuation estimate for peat is based on 1 metre depth, since the vast majority of peat in Manitoba is extracted for horticultural purposes and only the first metre of peat is of sufficient quality for this application. It must also be noted that this estimate assumes that all peatlands in the project area are accessible and commercially viable, which is not the case.

Restoring peatlands can take time and ensuring that they are harvested in a sustainable fashion takes careful consideration (Cleary, Roulet, & Moore, 2005; Bullock & Collier, 2011; Shilstra, 2001). Cleary et al. (2005, p. 456) state that "it would take approximately 2000 years to restore the carbon pool to its original size if peatland restoration is successful and the cutover peatland once again becomes a net carbon sink." Nevertheless, it must be noted that restored peatlands provide an increasing level of EG&S throughout the restoration period (Kimmel & Mander, 2010; Moreno-Mateos, Power, Comin, & Yockteng, 2012; Waddington & Warner, 2001).

Carbon

(Definition: The physical quantity of carbon stored in peatlands)

Peat is organic matter with important carbon content. Peat soils cover only 3 per cent of the world's surface (approximately 400 million has) but contain over 60 per cent of the earth's terrestrial carbon, or 460 gigatonnes (Bullock & Collier, 2011). The 136.7 billion tonnes of carbon stored in Canada's peatlands is the equivalent of 17 times the world's 2006 carbon emissions from the burning of fossil fuels (Carlson, Wells, & Roberts, 2009). Currently, 47.9 gigatonnes of carbon is stored within western Canadian peatlands, out of which 18 to 27.9 gigatonnes of carbon is within Manitoba[38] (Vitt, Halsey, Bauer, & Campbell, 2000). The peatlands within the project area store approximately 912 million tonnes of below-ground carbon.

This stored carbon can be valued based on carbon market trading values. In 2011, carbon credit transactions for forest carbon projects averaged USD$8.20/t$CO_2$e[39] (Peters-Stanley, Hamilton, & Yin, 2012). If we assume that the total

[37] 1 m peat depth × 21,164 km^2 × $90.47/m^3 = $1,914 billion

[38] The carbon market value was derived based on the average price of forest carbon traded within the voluntary market (USD$9.2/t$CO_2$e) and compliance markets (USD$7.2 t$CO_2$e) in 2011 (Peters-Stanley, Hamilton, & Yin, 2012).

[39] The carbon market value was derived based on the average price of forest carbon traded within the voluntary market (USD$9.2/t$CO_2$e) and compliance markets (USD$7.2 t$CO_2$e) in 2011 (Peters-Stanley, Hamilton, & Yin, 2012).

amount of carbon stored within the project area was to be released as CO_2, and adjusting for currency,[40] this represents a total capital value of CAD$34 billion.[41] Appendix H summarizes the peatland below-ground-carbon distribution within each ecodistrict in the project area and its value based on 2011 forest carbon market transaction values.

Water

(Definition: The physical quantity of water stored in peatland)

Water saturated peatlands are comprised of approximately 85 to 95 per cent water. The total estimated water retained by the peat layers in the project area is approximately 38.74 billion m^3. Estimating the total value of the water stored within peatlands of the project area can range widely depending on the quality of the water stored.

Valuing water on a volumetric basis varies widely depending on its availability, quality and at times utility. Gardner and Pinfold Consulting Economists Ltd. (2006) estimated that the domestic water use of the Albertan portion of the South Saskatchewan River is worth approximately CAD$0.93/$m^3$, based on water infrastructure expenditures. The economic value of the Assiniboine aquifer water supply located in southwestern Manitoba was estimated to range from CAD$30,000/$m^3$ to $620,000/$m^3$ (Kulshreshtha, 1994). Water is a valuable resource and economically valuing it is challenging as reflected by the range at which water is publicly sold.

Applying the Gardner and Pinfold estimate of CAD$0.93/$m^3$ and adjusting for inflation[42] to value the water stored in the peatlands of the project area gives a value of CAD$39.99 billion. Water stored within peatlands is a dynamic quantity that shifts inter- and intra-annually and is of lower quality due to the decaying organic matter with which it is in contact. For these reasons, the water stored in the project area is assumed to be worth 10 per cent of the overall value calculated, or approximately CAD$4 billion.[43]

[40] The exchange rate for 2012 was CAD$0.999 for USD$1 (www.bankofcanada.ca/stats/assets/pdf/nraa-2012.pdf).

[41] 912 Mt BGC × 3.67 (molecular weight conversion C to CO_2 equivalents) × USD$8.20 per tCO_2e × 0.99 (Currency Conversion USD to CAD) × 1.23 (Power Purchasing Parity factor) × 1.02 (inflation rate) = CAD$34.09 billion

[42] The inflation adjustment was calculated using the online Bank of Canada Inflation Calculator, www.bankofcanada.ca/rates/related/inflation-calculator. The inflation rate from 2006 to 2012 was 12 per cent.

[43] $0.93 per m^3 × 1.12 (inflation) × 38.74 billion m^3 × 10 per cent (poor water quality factor) ≅ $4.04 billion.

Conclusion

The peatlands in the project area provide important EG&S that are essential to human well-being. Although the peat they contain is prized by the Manitoba peat industry for horticulture, soil amendments and water filtration, they also provide valuable services in their natural state.

This study attempted to value the EG&S provided by the peatlands of Eastern and Interlake Manitoba, covering an area of 21,164 km^2. A total of 13 ecosystem services were examined, out of which 9 were valued. Based on this assessment, the peatlands of Eastern and Interlake Manitoba contribute $128 million/year in EG&S, with the majority of the overall value attributed to water treatment (CAD$74 million/year).

The total value of peat was coarsely estimated to be worth CAD$1,914 billion. This can be contrasted with the combined value of carbon and water stored within these peatlands, which is estimated to be worth CAD$38 billion.

It must be noted that these estimates have been derived based on existing valuation studies conducted in the project area and in other similar contexts, as well as on information gathered through informal conversations. Additional research is required to improve these valuation estimates. Nevertheless, the results communicate the importance of peatlands in their natural state to human well-being in terms of the provisioning, regulating, cultural and supporting services they provide.

Peatlands are fragile ecosystems that must be adequately managed and protected to benefit from the EG&S they provide. This point is supported by Achim Steiner, United Nations Under-Secretary General and United Nations Environment Programme Executive Director, who highlights the importance of peatlands in humanity's efforts to mitigate climate change by stating, "Just like phasing out of the old energy guzzling light bulbs or switching to hybrid cars, protecting and restoring peatlands is perhaps another key 'low hanging fruit' and among the cost-effective options for climate change mitigation" (Couwenberg & Joosten, 2007, p. 1).

The EG&S value provided by the peatlands in Eastern and Interlake Manitoba estimated in this report offers some insights for the Province of Manitoba to consider in developing the first peatlands stewardship strategy in Canada.

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Appendix A – Total Population and Households in Project Area

NAME	POPULATION	NUMBER OF HOUSEHOLDS
Arborg	1,152	465
Ashern	609	310
Beausejour	3,126	1,400
Bissett	130	55
Buffalo Point 36	162	85
Camper	547	185
Division 1, Unorganized	967	450
Division 18, Unorganized, East Part	124	60
Division 19, Unorganized	2,953	1,075
Fisher Bay	35	...
Fisher Branch	460	195
Fisher River 44A	30	...
Fisher River Cree Nation	1,160	415
Grunthal	1,479	465
Harwill	28	...
Hole or Hollow Water 10	627	150
IR Berens River 13	1,028	240
IR Black River 9	521	120
IR Bloodvein 12	673	155
IR Dog Creek 46	680	...
IR Peguis 1B	2,609	770
Jackhead 43	229	75
Little Grand Rapids	0	...
Little Grand Rapids 14, IRI	847	225
Little Saskatchewan 48	399	105
Loon Straits	5	...
Matheson Island	103	45
Mitchell	520	160
Pine Dock	50	20
Pine Falls	1,314	540
Poplar River 16	848	205
Princess Harbour	10	...
Riverton	538	215
RM of Alexander	2,983	1,375

RM of Armstrong	1,835	770
RM of Bifrost	2,976	1,010
RM of Brokenhead	4,635	1,795
RM of Coldwell	1,351	565
RM of De Salaberry	3,450	1,110
RM of Eriksdale	846	380
RM of Fisher	1,704	670
RM of Franklin	1,768	635
RM of Gimli	5,845	2,750
RM of Grahamdale	1,354	580
RM of Hanover	14,026	3,905
RM of La Broquerie	5,198	1,515
RM of Lac du Bonnet	2,671	1,095
RM of Piney	1,720	740
RM of Reynolds	1,285	535
RM of Rockwood	7,964	2,640
RM of Siglunes	1,360	625
RM of Springfield	14,069	4,905
RM of St. Andrews	11,875	4,260
RM of St. Clements	10,505	3,995
RM of St. Laurent	1,305	530
RM of Ste. Anne	4,686	1,665
RM of Stuartburn	1,535	615
RM of Tache	10,284	3,285
RM of Whitemouth	1,548	595
RM of Woodlands	3,521	1,235
Roseau River 2 IRI	588	…
Selkirk	9,834	3,975
Seymourville	118	30
St. Malo	1,148	445
Steinbach	13,524	5,100
Teulon	1,124	540
Victoria Beach	374	190
Winnipeg Beach	1,011	545
TOTAL	173,983	62,790

Appendix B – Peatland Extent and Depth by Ecodistrict

MANITOBA ECODISTRICT	TOTAL LAND AREA (KM²)	PEATLAND EXTENT (KM²)	PER CENT PEATLAND	PEAT DEPTH (M)	PEAT
370	7,361	4,655	63	1.81	8.43
371	20,690	6,956	34	2.50	17.39
373	8,200	1,588	19	3.50	5.56
375	4,708	802	17	1.86	1.49
376	2,033	413	20	2.17	0.90
377	1,493	177	12	2.46	0.43
379	3,288	1,599	49	2.03	3.24
380	2,411	140	6	1.46	0.20
671	373	59	16	1.68	0.10
676	3,897	2,674	69	1.68	4.49
677	1,606	710	44	2.05	1.46
723	8,888	847	10	1.30	1.10
724	5,496	427	8	1.57	0.67
726	3,527	117	3	1.10	0.13
846	2,385	0	0	0	0
Total	76,356	21,164	28		45.58

Appendix C – Peatland Plants

Karst (2010) compiled a list of plants growing in the boreal forest that are still being used for subsistence. The plants listed below grow within or around peatland environments. A variety of berries, tubers, roots and shoots grown within peatland environments provide important vitamins and micro-nutrients. Specially prepared plant leaves, gums, bark and others can treat a variety of illnesses and wounds. Raw materials for housing, tools and implements can be sourced from peatland plants. The tables below are provided for plants that grow within peatlands and wet area environments.

Plants providing subsistence values commonly found within peatlands

TYPE	*LATIN*	COMMON	USES	CONSERVATION	HABITAT
Moss	*Sphagnum*	Peat moss	Sphagnum has multiple uses such as soil conditioner, insulating material, source of fuel, dressing wounds and as fibers for making boards	Secure	Peatlands
Herb	*Carex*	Carex	A mix of dried specimens of several species of Carex (including Carex vesicaria) have a history of being used as thermal insulation in footwear (such as skaller used by Sami)	Secure	Peatlands
Tree	*Pinus mariana*	Black spruce	Cambium eaten; gum and tea from gum chewed and drunk to maintain good health; gum/pitch applied to wounds or slivers as salve; tea from inner bark applied to irritated skin, tips boiled in the house and branches used on floor to keep sick-ness away, as a disinfectant	Secure	Peatlands
Shrub	*Betula nana ssp.*	Dwarf birch	Leaves as beverage	Secure	Peatlands
Shrub	*Viburnum edule*	Highbush cranberry, squashberry	Fruits eaten; tea from berries for constipation; tea used as gargle for sore throat; berries boiled for cough	Secure	Peatlands, wet areas
Shrub	*Empetrum nigrum*	Black crowberry, "blackberry"	Fruits eaten; tea from berries, stems, roots, drunk for stomach ache, diarrhea, and bad colds	Secure	Peatlands
Shrub	*Arctostaphylos alpina, A. rubra, A. uvaursi*	Bearberry	Fruits eaten	Some vulnerable	Peatlands
Shrub	*Ledum palustre, L. groenlandicum, Rhododendron groenlandicum*	Marsh Labrador tea, bog Labrador tea, Labrador tea	Tea with leaves and twigs as a general tonic, taken for chills, to purify blood, asthma, cold, headaches, kidney trouble; chewed leaves applied to wounds, burns; tea from leaves and stems drunk, gargled, or used as inhalant	Some vulnerable	Peatlands
Shrub	*Vaccinium vitisidaea*	Lingonberry, lowbush cranberry, "redberry"	Berries eaten to "clean out your stomach," to relieve a spring fever; whole plant for urinary tract problems; juice drunk for kidney problems	Secure	Peatlands
Shrub	*Vaccinium caespitosum, V. myrtilloides*	Dwarf blueberry	Fruits eaten	Some vulnerable	Peatlands
Shrub	*Vaccinium oxycoccus*	Small cranberry, bog cranberry	Fruits eaten	Secure	Peatlands
Shrub	*Salix alaxensis, S. pulchra*	Alaska willow, sura willow	Leaves and shoots eaten	Some vulnerable	Peatlands, wet areas

Herb	*Rubus chamaemorus*	Cloudberry, bakeapple	Fruits eaten	Secure	Peatlands
Herb	*Pedicularis langsdorfii*	Langdorf's lousewort	Root eaten	Secure	Peatlands
Herb	*Saxifraga nelsoniana ssp., Nelsoniana*	Heart leaf saxifrage	Leaves eaten	Secure	Peatlands
Herb	*Equisetum arvense*	Common horsetail	Shoots eaten	Secure	Peatlands
Tree	*Larix laricina*	Tamarack larch	Inner bark boiled for sores and swelling, young branches made into a tea as a laxative, inner bark and gum to treat burns, leaves, inner bark to treat sore throat	Secure	Peatlands
Shrub	*Vaccinium uliginosum*	Bog blueberry	Tea from berries or whole plant to treat diabetes; root boiled to make extract taken for headaches	Some vulnerable	Peatlands
Shrub	*Ribes triste*	Red currant	Tea from whole plant used for stomach ailments; eye problems	Some vulnerable	Peatlands
Shrub	*Ribes hudsonianum*	Northern black currant	*Tea from leaves drunk in winter for general good health; fruits eaten*	Some vulnerable	Peatlands, wet areas
Tree	*Salix spp.*	Willows	Tea from bark drunk as pain reliever and for headaches; inner bark as pain-killing poultice	Secure	Peatlands

Plants providing subsistence values commonly found in wet areas.

TYPE	*LATIN*	COMMON	USES	CONSERVATION	HABITAT
Tree	*Abies balsamea*	Balsam fir	Cambium eaten	Secure	Wet areas
Shrub	*Populus balsamifera*	Balsam poplar	Cambium eaten; bud resin for cuts, sores, baby teething, toothache; leaves to draw out infection, extract from buds boiled with aspen branch bark drunk for diabetes	Secure	Wet areas
Shrub	*Corylus cornuta*	Beaked hazelnut	Nuts eaten	Secure	Wet areas
Shrub	*Ribes hudsonianum*	Northern black currant	Fruits eaten, tea from leaves drunk in winter for general good health	Some vulnerable	Wet areas, peatlands
Shrub	*Ribes lacustre*	Prickly currant	Fruits eaten	Some vulnerable	Wet areas
Shrub	*Amelanchier alnifolia*	Saskatoon or service berry	Fruits eaten	Some vulnerable	Wet areas
Shrub	*Prunus virginiana*	Chokecherry	Fruits eaten	Secure	Wet areas
Herb	*Cornus canadensis*	Bunchberry	Fruits eaten; plant steeped to treat paralysis, colds; root tea for colic	Secure	Wet areas
Herb	*Mentha arvensis*	Wild mint	Leaves as beverage and eaten	Secure	Wet areas
Herb	*Fritillaria camschatcensis*	Kamchatka fritillary (riceroot, chocolate lily)	Bulbs eaten	Secure	Wet areas
Herb	*Typha latifolia*	Broadleaf cattail	Rhizomes, stem base eaten	Some vulnerable	Wetlands
Herb	*Urtica dioica*	Stinging nettle	Plant eaten as green	Some vulnerable	Wet areas
Tree	*Betula papyrifera*	Paper birch	Bark used to make cast for broken limbs; roots, buds to treat snow blindness; bark given to teething babies; bark used to treat chapped skin, diaper/skin rash	Secure	Wet areas

Tree	*Betula spp.*	Birch	Inner bark, ashes, leaves, buds, wood for burns, bites, boils, wounds, inner bark, sap for coughs, colds, asthma, inner bark for menstrual cramps	Secure	Wet areas
Shrub	*Alnus spp.*	Alders	Leaves, bark, buds	Secure	Wet areas
Shrub	*Alnus rugosa*	Speckled alder	Bark boiled to treat liver, anemia; root extract to treat difficult labour, sore eyes, toothache	Secure	Wet areas
Shrub	*Viburnum edule*	Highbush cranberry, squashberry	Tea from berries for constipation; tea used as gargle for sore throat; berries boiled for cough; fruits eaten	Secure	Wet areas, peatland
Shrub	*Ribes oxyacanthoides*	Canadian gooseberry	Infusion from stems drunk by mothers after childbirth to stop excessive bleeding; root infusion drunk for delayed menstrual period	Some vulnerable	Wet area
Shrub	*Salix alaxensis, S. pulchra*	Alaska willow, sura willow	Leaves and shoots eaten	Some vulnerable	Wet areas, peatlands

Appendix D – First Nation Population and Households in Project Area

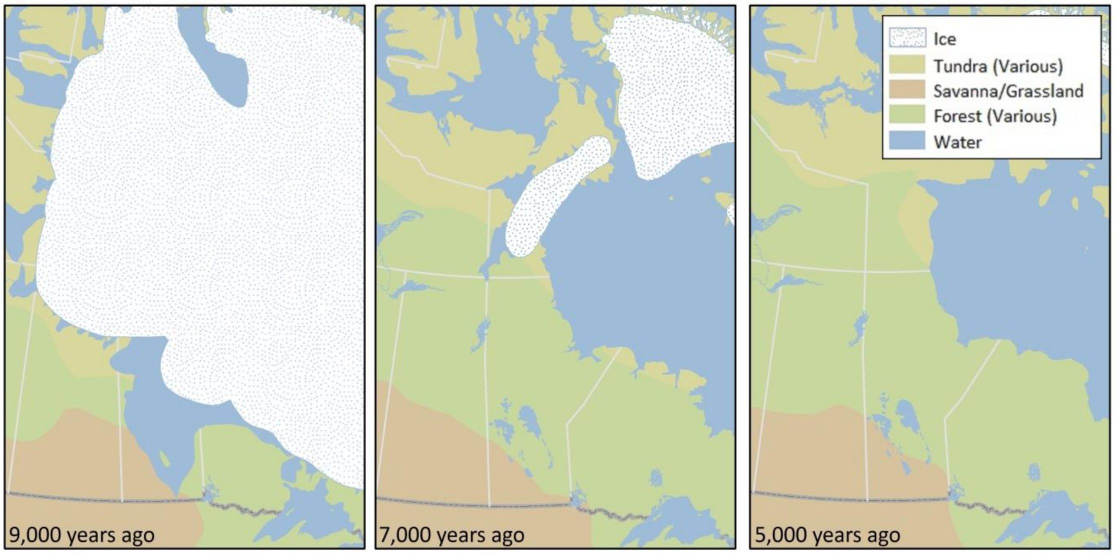
FIRST NATION	POPULATION	CENSUS YEAR	HOUSEHOLDS	CENSUS YEAR
Berens River	1,028	2011	240	2011
Black River	521	2011	120	2011
Bloodvein	673	2011	155	2011
Brokenhead	467	2006	149	2006
Dauphin River	84	2006	30	2006
Dog Creek	680	2011	185	2006
Fairford	989	2011	255	2006
Fisher River	1,160	2011	415	2011
Fort Alexander	2,099	2011	535	2011
Hollow Water	627	2011	150	2011
Jackhead	229	2011	75	2011
Little Grand Rapids	847	2011	225	2011
Little Saskatchewan	399	2011	105	2011
Pauingassi	388	2011	105	2011
Peguis	2,609	2011	770	2011
Poplar River	848	2011	205	2011
Roseau Rapids	107	2011	30	2006
The Narrows	826	2011	115	2011
Totals	14,581		3,864	

Appendix E – Provincial Park and Park Reserve Management Cost and Revenue Estimates

PARK NAMES	SALARIES	OPERATING COSTS	TOTAL COSTS	AREA (KM²)	COST PER KM²	PEATLAND AREA	MANAGEMENT COST OF PEATLANDS
Grand Beach, Elk Island, Patricia Beach	$1,022,024.99	$206,204.89	$1,228,229.88	36.13	$33,994.74	0.77	$26,211.71
Whiteshell, Whitemouth Falls	$3,673,948.47	$1,980,686.86	$5,654,635.33	3,203.34	$1,765.23	317.1	$559,637.30
Nopiming, Pinawa Dam, Pinawa Park, Poplar Bay	$368,957.17	$154,154.24	$523,111.41	1,444.6	$362.12	128.59	$46,565.96
Hecla/Grindstone, Beaver Creek, Lake St. George, Lake St. Andrew	$752,369.05	$2,244,747.19	$2,997,116.24	1,084.51	$2,763.57	139.50	$385,527.01
Grand Total			$10,403,092.86	5,768.58			$1,017,941.98

Source: Manitoba Conservation and Water Stewardship (2012).

Appendix F – Reconstruction of the Historical Landscape in North America



Appendix G – Extractable Peat Estimate

MANITOBA PEAT EXTRACTION VALUES REPORTED BY NATURAL RESOURCES CANADA						EXTRACTABLE PEAT VALUE ESTIMATE	
Year	Kilotonnes	Total Value ($ x1,000)	Mass Value ($/kg)	Inflation rate to 2012 (%)	Adjusted ($/kg)	Value of Dry Peat ($/cubic metre)	Value of Extractable Peat ($ billion)
2005	137	x	x	15.00	x	x	x
2006	97	x	x	12.00	x	x	x
2007	159	x	x	10.00	x	x	x
2008	163	7,948.00	0.23	8.00	0.25	100.57	2,128
2009	174	32,660.00	0.19	7.00	0.20	80.34	1,670
2010	167	40,552.00	0.24	5.00	0.25	101.99	2,158
2011	168	32,527.00	0.19	2.00	0.20	78.99	1,672
Total	1,065	143,687.00					
Average	152	35,921.75	0.21	8.43	0.23	90.47	1,914

Source: Natural Resources Canada (2013).

Appendix H – Peatland Carbon Storage Value by Ecodistrict

ECODISTRICT	BELOW GROUND CARBON (MILLION TONNES)	AVERAGE CARBON VALUE (CAD$ BILLION)
370	233	8.71
371	417	15.59
373	79	2.95
375	29	1.08
376	8	0.30
377	37	1.38
379	28	1.05
380	5	0.19
671	2	0.07
676	53	1.98
677	17	0.64
723	1	0.04
724	2	0.07
726	1	0.04
846	0	0.00
Total	912	34.09

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