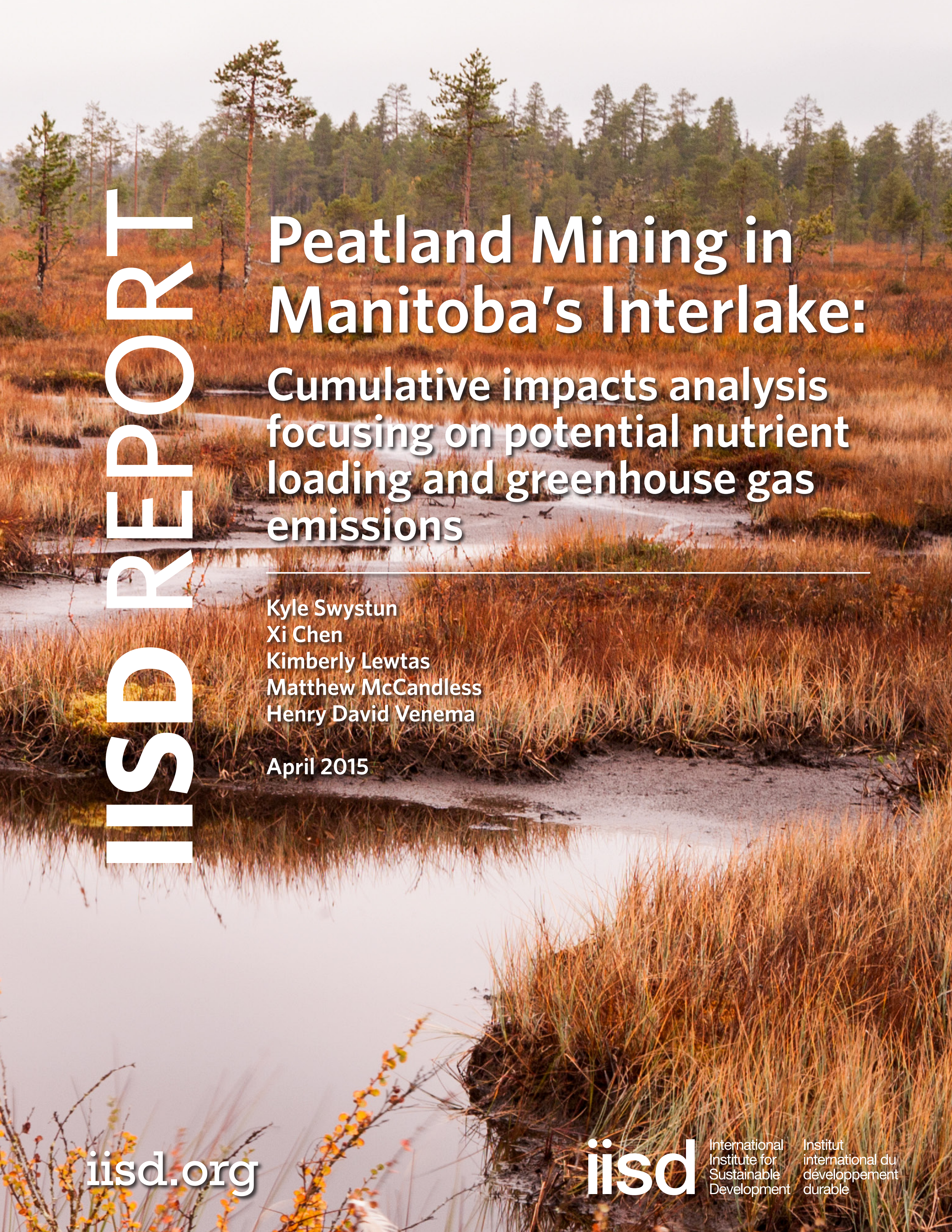

IISD REPORT

Peatland Mining in Manitoba's Interlake:

Cumulative impacts analysis focusing on potential nutrient loading and greenhouse gas emissions

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Peatland Mining in Manitoba's Interlake: Cumulative impacts analysis focusing on potential nutrient loading and greenhouse gas emissions

April 2015

Written by Kyle Swystun, Xi Chen, Kimberly Lewtas, Matthew McCandless and Henry David Venema

Executive Summary

Peat has been mined in Manitoba for over 70 years and currently represents approximately 13 per cent of Canada's horticultural peat production. Manitoba peat producers are interested in expanding mining activities in Manitoba's Interlake, and this report quantifies the implications of this expansion for Lake Winnipeg nutrient loading and Manitoba's greenhouse gas emissions. The technical analysis in this report will be incorporated into a cumulative environmental assessment on peat mining in Manitoba's Interlake.

Nutrient leaching from active peat mines within Manitoba would not exceed 0.40 kilograms (kg) P ha^{-1} yr^{-1} and 15.00 kg N ha^{-1} yr^{-1} based on available data and peer-reviewed research. Total phosphorus and total nitrogen loads to Lake Winnipeg from current peat lease holdings in the Interlake would not exceed 5.1 tonnes P yr-1 and 191 tonnes N yr$^{-1.}$ Total phosphorus and total nitrogen loads to Lake Winnipeg from all current peat lease holdings within Manitoba would not exceed 12 tonnes P yr^{-1} and 449 tonnes N yr^{-1}. These potential nutrient loads to Lake Winnipeg from peat mining operations represent a small proportion of the yearly loads of phosphorus and nitrogen to Lake Winnipeg.

Greenhouse gas emissions from land-use change due to active peat mines within Manitoba would not exceed 13.47 tonnes CO$_2$e ha^{-1} yr^{-1} based on peer-reviewed research.[1] Total greenhouse gas emissions from current peat lease holdings in the Interlake would not exceed 0.17 million tonnes CO$_2$e yr^{-1}.[2] Total greenhouse gas emissions from current peat lease holdings within Manitoba would not exceed 0.4 million tonnes CO$_2$e yr^{-1}. In 2010, Manitoba's greenhouse gas emissions from all sectors totalled 19.8 million tonnes CO$_2$e.

Mitigation strategies for greenhouse gas emissions and nutrient loads to Lake Winnipeg include carbon credit trading; commencement of peatland restoration/rehabilitation immediately following the completion of peat extraction; and utilization of sedimentation ponds, treatment lagoons, constructed wetlands and peak runoff control coupled with a biomass harvest.

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[1] CO$_2$e ha^{-1} yr^{-1} = carbon dioxide equivalent produced by hectare per year.

[2] CO$_2$e yr^{-1} = carbon dioxide equivalent produced per year.

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1.0 Introduction

Recent developments in Manitoba have placed the spotlight on peat mining in the province. Concerns regarding the expansion of peat mining activities into new areas of the Interlake region have highlighted the need to further resolve policy on the issue. The Government of Manitoba has entered into an agreement with the International Institute for Sustainable Development (IISD) to produce a framework for a cumulative environmental assessment (CEA) to evaluate peatland development in Manitoba's Interlake and inform future government actions.

The purpose of CEAs is to study the effects of undertakings or developments more comprehensively than conventional environmental impact assessments (EIAs). CEAs consider the effects of multiple undertakings over a widely defined area at longer timescales than single-project EIAs. Since the Canadian CEA guidelines were developed in 1999, the practice has been applied primarily in the Alberta Oil Sands. There are no Canadian examples of CEAs being carried out for peatland, but in 1984 a CEA was done for peat mining in the U.S. state of North Carolina.

Two priority issues have been identified by the Government of Manitoba: (i) nutrient loading to Lake Winnipeg and (ii) greenhouse gas emissions. In order to evaluate the potential impact of increased peat mining in the Interlake on these two priority issues, estimates were calculated based on available information. The purpose of this report is primarily to present the estimated impacts of peat mining on the two issues identified by the government.

This report begins with a snapshot of the peat mining industry in Manitoba (Section 2) before outlining the concept of cumulative environmental assessment (Section 3) and how it can apply to peat mining in Manitoba. The impacts of peat mining on nutrient loads to Lake Winnipeg (Section 4) and greenhouse gas emissions (Section 5) are estimated based on the environmental priorities of the Government of Manitoba. Other potential impacts from peat mining in Manitoba are introduced (Section 6), as well as potential mitigation options (Section 7). In Section 8, the report concludes with an assessment of the applicability of the CEA framework for peat mining in Manitoba and makes some recommendations regarding how to improve the mitigation and impact estimates presented in this report.

2.0 Peat Mining in Manitoba

Canada's total peatland extent is approximately 113 million hectares, with Manitoba representing 17 per cent, or 19.2 million hectares (Daigle & Gautreau-Daigle, 2001). Canada is the largest producer of horticultural peat in the world, producing approximately 1.3 million tonnes of peat in 2010 (Natural Resources Canada, 2012). Manitoba peat production represents 13 per cent of this national total amounting to 167,000 tonnes of peat (Natural Resources Canada, 2012). Manitoba's average peat production is approximately 621,000 cubic metres (Paul Short, Canadian Sphagnum Peat Moss Association, personal communication, n.d.) predominately extracted from ombrotrophic peatlands (bog). There is some sedge peat extraction occurring in southeast Manitoba, but it represents a very small proportion of the total peat harvest. Almost all of Manitoba's extracted peat is exported for horticultural use to markets in the United States and Mexico (Jamie McLennan, Premier Tech Horticulture, Connie Proceviat, Sun Gro Horticulture, personal communication, n.d.).

Peat mining operations began in Manitoba around 1940. The first peat mine site in Manitoba was located at Julius Bog, more commonly known as Moss Spur, and is currently operated by Sun Gro Horticulture. Moss Spur is located at 49.99°N, 96.13°W, between the towns of Beausejour and Whitemouth on the Canadian Pacific railway. Currently, Manitoba peat producers employ 124 full-time and 122 part-time workers.

There are currently several active peat mine sites in Manitoba, operated by several different peat producers. The main peat producers in Manitoba are Sun Gro Horticulture, Premier Tech Horticulture, FPM Peat Moss, Jiffy, Berger and Sunterra. Active peat mine locations in Manitoba include Beaver Point (51.42°N, 96.86°W), Evergreen Bog (50.08°N, 96.16°W), North Julius Bog (50.05°N, 96.19°W), Moss Spur (49.99°N, 96.13°W), Elma Plant (49.77°N, 95.93°W), Grioux Bog (49.59°N, 96.51°W), St. Labre Bog (49.51°N, 95.89°W) and Caribou Bog (49.39°N, 95.35°W). The majority of active peat mine sites are located in southeast Manitoba, with a few in the Interlake. Many peat producers are looking to expand activity further into the Interlake and along the east side of Lake Winnipeg: 1) Hay Point Bog (51.16°N, 96.86°W), 2) Ramsay Point Bog (51.38°N, 96.96°W) and 3) Deer Lake (51.51°N, 96.88°W).

3.0 Cumulative Environmental Assessment

CEAs are required of proponents whose projects may cause interactions with other actions, with the environment or between components of the environment (The Cumulative Effects Assessment Working Group & AXYS Environmental Consulting Ltd., 1999). Before a CEA is performed, EIAs have to be done to study the impacts brought by individual undertakings. The Canadian Environmental Assessment Act requires proposed projects to do EIAs, including "construction, operation, modification, demolition, or abandonment of a physical work, or other physical activities specified by regulation" (Canadian Environmental Assessment Act, 2012, Section 1.2).

There are several types of cumulative effects: physical–chemical transport, nibbling loss (a gradual disturbance), spatial and temporal crowding (too much happening in a limited area and period) and growth-inducing potential (induced actions from current actions) (The Cumulative Effects Assessment Working Group & AXYS Environmental Consulting Ltd., 1999). CEAs use the EIAs of individual projects to examine the environmental effects of multiple projects in a specified area. An individual project is deemed acceptable if the cumulative effects caused by the combination of the project and other actions are within reasonable limits. Therefore, a CEA proceeds based on a solid EIA that focuses on individual projects. Compared to an EIA, a CEA requires a more complex approach based on the fact that it covers a larger area, lasts a longer period, considers multiple actions, includes actions from other time periods (past, present or future) and evaluates the broader significance of these factors.

There are several phases involved in undertaking a CEA.

3.1 Scoping

At the scoping stage, regional issues of concern and valued environment components (VECs) are determined. Issues of concern are issues that will affect reviewers' decision making. VECs are components requiring monitoring and analysis of potential impacts. Issues of concern and VECs can be identified from such sources as scientific papers, communication with stakeholders, comments from local residents, field tours, surveys, environmental organization concerns and industry concerns. As a general rule, VECs from an individual project EIA are further studied in a CEA. A CEA may also include specific VECs that are not used or studied in individual EIAs.

After identifying VECs, spatial and temporal study boundaries have to be determined. A list of rules to establish spatial boundaries is given in the *Cumulative Effects Assessment Practitioners' Guide* (The Cumulative Effects Assessment Working Group & AXYS Environmental Consulting Ltd., 1999).[3] Spatial boundaries should be adjustable, since requirements and limitations may change. Different VECs in one single assessment can have different spatial boundaries, depending on their physical properties. With regard to establishing temporal boundaries, the guide recommends the timeline should start from the time before the action to the time that pre-action conditions become re-established. In many cases, temporal boundaries might shrink or expand due to the level of available information.

Cumulative impacts may also come from other actions within or outside the project area that are likely to affect the VECs. These actions might be either past, existing or future actions unrelated to the specific activities under review. Information on these activities and their effects can be gathered from, for example, site visits, land-use maps, aerial photos, environmental databases, land-use planning registers, interviews and consultations with emissions control regulators, stakeholders, residents and development plans.

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[3] All subsequent references to the *Cumulative Effects Assessment Practitioners' Guide* are from this source and will be henceforth referred to simply as the *CEA Practitioners' Guide*.

3.2 Analysis of Impacts

The first step of the impact analysis stage is to collect regional baseline data for the VECs. The analysis can be achieved by several methods: impact models to study cause–effect relationships between actions and VECs (e.g., operation of roads results in contamination of receiving waters), using geographic information system (GIS) to study spatial impacts (e.g., mapping to assess loss of wildlife habitat), VEC indicators to measure numerical values (e.g., landscape indices including cleared area, edge area, stream crossing density and so on) and numerical models to study quantitative analysis of physical–chemical effects (e.g., air emission rates). A combination of two or more methods is appropriate. For example, the Cold Lake Oil Sands Project does its CEA using several approaches, including three workshops (scoping, assessment and mitigation) that provide information for the framework, and 35 impact models to study interactions between the project and environmental components. Both qualitative and quantitative analysis were involved in the assessment (Imperial Oil Resources Ltd., 1997).

3.3 Identification of Mitigation Options

The identification of mitigation options can range from the same types of mitigation recommended in EIAs to longer-term and region-wide management to efficiently reduce cumulative effects. Regulatory agencies should provide direction on regionally appropriate mitigation measures. A typical mitigation concept suggested by some regulatory agencies is called "no net loss", which requires any disturbed land or watershed to be replaced by a same area with pre-action capabilities to support original productivity. There is no recorded application of the "no net loss" concept for peatlands mining in Canada yet; however, some projects apply reclamation as a method of mitigation using a similar concept.

3.4 Evaluation of Significance

Mitigation will not correct all impacts on VECs. Therefore, the significance of effects after mitigation (residual effects) should be evaluated, as this indicates whether or not changes have the potential to become irreversible. Determination of the likelihood of an effect follows the guidance provided by Canadian Environmental Assessment Act (CEAA) based on two criteria: the probability of occurrence and scientific certainty. Significance measurement has the following scales:

SCALE	LIKELIHOOD IN NUMBERS	LIKELIHOOD
None	No effect will occur	No effect will occur
Low	<25% chance of occurring	Minimal chance of occurring
Moderate	25%–75% chance of occurring	Some chance of occurring
High	>75% chance of occurring	Most likely chance of occurring

The *CEA Practitioners' Guide* presents a table of significance from a Cold Lake Oil Sands Project to show the methods of evaluating the significance. The attributes include direction, scope, duration, frequency, magnitude, significance and confidence. Each has a scale followed by an explanation of how the scale is measured. The scale measurement table is an example taken from the *CEA Practitioners' Guide* (see Appendix C).

Thresholds are also used to evaluate significance, as they indicate the point where the cumulative impacts on VECs may become irreversible. According to the *CEA Practitioners' Guide*, "thresholds may be expressed in terms of goals or targets, standards and guidelines, carrying capacity, or limits of acceptable change" (p. 46). Usually, cumulative effects caused by one action are deemed acceptable if the cumulative effects caused by all the actions within the regional boundary do not exceed the threshold. Uncertainties may emerge at any step of determining significance, and the *CEA Practitioners' Guide* offers considerations to handle uncertainty.

3.5 Follow-Up

Follow-ups are conducted in order to review the environmental assessment and determine the effectiveness of mitigation in the following situations (Davies, 1996):

- There is some uncertainty about the environmental effects of other actions, especially imminent effects.
- The assessment of the action's cumulative effects is based on a new or innovative method or approach.
- There is some uncertainty about the effectiveness of the mitigation measures for cumulative effects.

3.6 Priority VECs Identified by the Province of Manitoba

Historically, peatland mining was regulated primarily under Manitoba's Mines and Minerals Act (for allocation and distribution of peat harvest rights) and The Environment Act (to ensure that the environmental impacts of peat mining are monitored and minimized). In addition to standard industry regulation, recent policy undertakings in Manitoba have focused attention on peat and new regulation under Manitoba's Mines and Minerals Act (June 2013), extending the moratorium on new peat leases. The extended moratorium applies to 90 pending peat leases and to all new peat lease applications.[4] A new regulation under The Environment Act also prevents the issuance of licences for expansion of peat mine operations. The single outstanding licence under review from Sunterra is not affected by the moratorium, because the application was received prior to establishing the moratorium. Manitoba's Conservation and Water Stewardship department has also indicated that no peat mining would occur in Manitoba parks. A peatlands stewardship strategy was released on April 30, 2014[5] and The Peatlands Stewardship and Related Amendments Act received royal assent on June 12, 2014.

3.6.1 Lake Winnipeg Eutrophication

Lake Winnipeg, the 10th largest freshwater lake in the world, has been under severe ecological stress due to overloading of nitrogen and phosphorus. This overloading has resulted in algae blooms and beach closures affecting recreation and the fishing industry in the lake. The ecological concerns around Lake Winnipeg have received international attention, and strategies to address the situation are being developed.

In June 2011 the Province of Manitoba enacted the Save Lake Winnipeg Act, which acknowledged that "Lake Winnipeg and its watershed continue to receive excessive amounts of phosphorus and nitrogen that result in algae blooms of increasing intensity and frequency." The act affects land and water management, municipal planning and agriculture; it also placed a two-year moratorium on new peat leases.

Based on the above legislation and in discussions with officials from Manitoba Conservation and Water Stewardship, nutrient loading to Lake Winnipeg from peat mining operations was identified as a key environmental concern of the Government of Manitoba.

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[4] 16 peat leases in southeastern Manitoba (815 hectares) and 74 peat leases in the Interlake (8,019 hectares) are pending.

[5] Peatland Stewardship Strategy Report: http://www.gov.mb.ca/conservation/peatlandsstewardshipstrategy/pdf/peatlands_strategy_tmw_now.pdf

3.6.2 Greenhouse Gas Emissions

Peatlands are large carbon sinks, and attention is frequently paid to their stewardship as a means of mitigating emissions of greenhouse gases (Ward, Connolly, Walsh, Dahlman, & Holden, 2000). Long-term rates of net carbon accumulation in northern peatlands range from 10 to 35 grams C m^{-2} yr^{-1} (Ovenden, 1990) with a long-term average of 24.5 grams C m^{-2} yr^{-1} (Turetsky, Wieder, Halsey, & Vitt, 2002). Policies for claiming carbon credits for peatland stewardship have been explored as carbon offsets in international carbon markets. Similar policy research has been taking place in countries such as Ireland, Norway and Sweden (Olsson, Andersson, Lennartsson, Lenoir, Mattsson, & Palme, 2012; Renou-Wilson et al., 2004; Department of the Environment, Heritage and Local Government, 2007).

The issue of climate change is taken seriously by the Government of Manitoba, and strategies have been developed to promote the reduction of greenhouse gas emissions. The policy document Beyond Kyoto (Government of Manitoba, 2008) references the carbon storage capacity of boreal forests and peatlands. Further recognition of their carbon storage role was made along with an announcement on peatland stewardship in December 2009 (Government of Manitoba, 2009).

Based on the above policy actions and in conversation with representatives of the Manitoba government, it was determined that the flux of greenhouse gases from peatlands should also form the basis of an initial impact analysis.

4.0 Nutrient Loading to Lake Winnipeg

The nutrient dynamics of peatland are a function of peatland type; minerotrophic peatlands (fens) tend to retain nutrients while ombrotrophic peatlands (bogs) tend to lose nutrients (Halsey Vitt, & Trew, 1997; Prepas et al., 2001). Drainage required for peat extraction will increase peat decomposition by increasing aerobic conditions within the peat column, while increasing peat temperature and substrate availability. This increase in decomposition results in the leaching of nutrients that were previously locked in organic compounds contained in partly decomposed peat. Peatlands can contain up to 500 tonnes C, 20 tonnes N, and 0.5 tonnes P within the top metre of peat per hectare, so even a small increase in mineralization could potentially result in large loads downstream (Miller, Anderson, Ray, & Anderson, 1996). Thus, peat extraction activities could potentially cause higher nutrient loads and suspended solid concentrations in downstream waters (Heikkinen, 1990).

Scandinavian researchers have published several articles over the past decades regarding peat mining wastewater and downstream impacts (Granberg, 1985; Sallantaus & Patila, 1983; Sallantaus, 1984, 1986; Heikkinen, 1990; Kløve, 2001; Kløve, Sveistrup, & Hauge, 2010). Peat extraction requires peatland drainage, which immediately raises concerns about downstream water quality impacts such as increased loads of suspended solids, nitrogen, phosphorus and acidity (Granberg, 1985; Sallantaus & Patila, 1983; Sallantaus, 1984, 1986). Granberg (1985) determined that the eutrophication of a small lake (54 square kilometres) in central Finland was a slow process spanning three decades, attributed to the ditching and canalization of the adjacent forest and bogs within the runoff area of the lake. Peat mining wastewater treatment has also been thoroughly researched, with the review of treatment techniques that direct the peat mine wastewater to adjacent pristine peatlands or constructed wetlands allowing the wastewater nutrients to be sequestered by the vegetation and/or adsorbed to the peat (Ihme, Heikkinen, & Lakso, 1991; Heikkinen, Ihme, Osma, & Hartikainen, 1995a; Heikkinen, Ihme, & Lakso, 1995b; Huttunen, Heikkinen, & Ihme, 1996; Kløve, 2000; Koskiaho & Puustinen, 2005).

Runoff from a peat extraction site in Finland in the mid-1990s revealed that the estimated annual leaching of P and N was 0.16 to 0.38 kg P ha^{-1} and 10.73 to 15.00 kg N ha^{-1}, respectively (Kløve, 2001). Runoff and groundwater from four bogs were examined near Sept-Iles, Quebec (50.25°N, 66.33°W) during the summer of 1984 (Moore, 1987). Moore (1987) found significant increases in ammonium (< 0.2 mg NH4+-N L^{-1}) and total dissolved phosphorus (< 0.03 mg P L^{-1}). Moore (1987) concluded that changes in runoff volume and channelized flow runoff might substantially increase loading of dissolved organic carbon (DOC) and nutrients to aquatic ecosystems despite the minor water quality changes associated with peat extraction activities. A cumulative impacts study of peat mining in North Carolina found total nitrogen doubled (6.1 and 12.1 kg N ha^{-1}) and total phosphorus more than tripled (0.29 and 1.04 kg P ha^{-1}) in runoff from peat mines compared to pristine peatlands (Gale & Adams, 1984). Drainage water quality analysis from the St-Charles Plain peat mine in Kent County, New Brunswick (46.60°N, 64.92°W) revealed higher total phosphorus (< 0.6 mg P L-1) and total organic carbon (< 45 mg C L^{-1}) concentrations and low levels of dissolved mercury with no evidence of bioaccumulation of mercury in the biota near the peat mine (Surette, Brun, & Mallet, 2002). Principal component analysis and cluster analysis of water quality data from 36 stations in the Richibucto River drainage basin in New Brunswick showed that high nutrient concentrations were primarily found near peat harvesting sites and waterways receiving treated municipal effluent (St-Hilaire et al., 2004). This would suggest that peat mining wastewater could potentially contribute substantially greater loads of phosphorus and nitrogen than natural pristine peatlands. Pavey et al. (2007) found significantly higher amounts of suspended sediment concentrations in runoff from harvested peat bogs than pristine bogs in New Brunswick. St-Hilaire et al. (2006) found current management practices of peat mining drainage water in New Brunswick to be suboptimal for the spring season, with suspended sediment concentrations exceeding the provincially mandated limit 50 to 80 per cent of the time. Clément et al. (2009) investigated the impacts of elevated suspended sediment loads from peat harvesting activities on the aquatic habitat of the East Branch Portage River, New Brunswick, and found no conclusive evidence of elevated loads affecting fish abundance. However, Ouellette et al. (2006) investigated the impacts of peat deposition from peat harvesting activities into an estuarine environment in New Brunswick on sand shrimp abundance and found a significant reduction in the number of shrimp in areas of high peat concentration compared to areas of low peat concentration.

4.1 Estimated Total Phosphorus and Total Nitrogen Loads to Lake Winnipeg From Peat Mining Operations

The current issued peat licence area within Manitoba is 12,875 hectares and does not include peat licences under review. The total peat lease block area within Manitoba is currently 29,960 hectares: 12,711 hectares in the Interlake and 17,249 hectares in southeast Manitoba. Potential loads of total phosphorus (TP) and total nitrogen (TN) to Lake Winnipeg, assuming active peat extraction across all areas, were calculated using four different methodologies: 1) utilizing water quality data from active peat mine operations within Manitoba provided by Manitoba Conservation and Water Stewardship, 2) utilizing water quality and water quantity data from the Beaver Point peat mine site in Manitoba's Interlake operated by Sunterra Horticulture, 3) utilizing TP and TN load estimates from a cumulative impact study of peat mining in North Carolina (Gale & Adams, 1984) and 4) utilizing TP and TN load estimates in peat mining wastewater from Central Finland (Kløve, 2001). The following four sections will describe the methods used in the nutrient load estimations.

4.1.1 Method 1 (M1): Water Quality Data From Existing Manitoba Peat Mine Locations

Water quality data were provided for the Beaver Point peat mine location by Manitoba Conservation and Water Stewardship. Total areal coverage of issued peat licences within Manitoba is 12,875 hectares. Total issued licenced peat mining area in the Interlake is 4742 hectares; licencing under review amounts to 665.7 hectares (Suntera expansion in the Interlake); and no licences are currently under appeal (Appendix D). These "under review" values are not included in the water quality and greenhouse gas estimates, only issued licences.

Mean TP and TN concentrations of 0.082 and 2.50 mg L^{-1}, respectively, were calculated using data from all peat mine locations and measurement intervals. The TN concentration may appear higher than expected (e.g., Wind-Mulder, Rochefort & Vitt, 1996; Wind-Mulder & Vitt, 2000), but this includes both inorganic and organic nitrogen with the assumption that the majority of TN is organic nitrogen. A maximum runoff amount of 200 millimetres was assumed for all locations, which would result in a runoff coefficient of approximately 0.5, which would vary depending on the amount of summer precipitation. Assuming all 12,875 hectares are under extraction, there would be a resulting total yearly load of TP and TN to Lake Winnipeg of 2.1 and 66 tonnes yr^{-1}, respectively.

4.1.2 Method 2 (M2): Water Quality and Quantity Data From Sunterra Horticulture Beaver Point Peat Mine

Water quality and water quantity data were provided by Manitoba Conservation and Water Stewardship for the Beaver Point peat mine site, operated by Sunterra Horticulture. The Beaver Point peat mine site (51.42°N, 96.87°W) is located within the Mill Creek drainage basin adjacent to the west shore of Lake Winnipeg, alongside Provincial Road 234. The Beaver Point peat mine quarry leases QL-1321, QL-1324 and QL-1322 total 378 hectares, with the majority of this area draining into Mill Creek. The estimated areal extent of the Mill Creek drainage basin is assumed to be approximately 1,500 hectares.

Water flow was measured weekly at the Beaver Point peat mine site from the Mill Creek bridge crossing on Provincial Road 234 weekly from April 19, 2012 to October 10, 2012. Flows ranged from 450 to 12,500 litres per minute, with a mean flow of 4,200 litres per minute. Peak flows were measured during the last two weeks of June.

Water quality data were collected twice during this same period on May 4, 2012 and August 16, 2012, from the same Mill Creek Bridge crossing location at Provincial Road 234 and from the sedimentation pond effluent. Total phosphorus concentrations were almost twice as high (0.11 and 0.06 mg P L-1) in the sedimentation pond effluent compared to TP concentrations in Mill Creek on August 16. Total phosphorus in the sedimentation pond effluent was also higher than Mill Creek on May 4 but only about 27 per cent higher. Total nitrogen was also higher in the sedimentation pond effluent compared to Mill Creek but only approximately 25 per cent higher on both dates.

The calculated total water volume for the entire measurement period using the weekly water flow data was just over 1.1 million cubic metres. Total runoff was then calculated to be 72 millimetres, assuming a 1,500 hectare drainage basin. Recorded precipitation was 295 mm at the Gimli, Manitoba weather station, which is approximately 88 kilometres south of the Beaver Point peat mine site, thus yielding a runoff coefficient of 0.24.

Mean TP and TN from water samples taken from the sedimentation pond effluent are 0.08 and 1.94 mg L^{-1}, respectively. Using the aforementioned total water volume recorded in Mill Creek, the calculated loads of TP and TN into Lake Winnipeg from the Beaver Point peat mine site are 85 and 2148 kg yr^{-1}, respectively. Assuming the majority of the nutrient load is from the main portion of the Beaver Point peat mine site (215 hectares) would result in areal TP and TN loads of 0.40 and 9.99 kg ha^{-1} yr^{-1}, respectively. These calculated yearly nutrient loads are very likely overestimating the actual loads given that the water flow measurements are taken in Mill Creek, which is draining a much larger area than the area draining into the sedimentation pond. Unfortunately, there was no water flow data collected from the outflow of the sedimentation pond.

4.1.3 Method 3 (M3): Cumulative Impacts of Peat Mining in North Carolina—Water Quality Data

The impacts on downstream water quality were investigated in the mid-1980s in North Carolina (Gale & Adams, 1984). Gale & Adams (1984) determined that approximately 1.04 kg P ha^{-1} yr^{-1} and 12.10 kg N ha^{-1} yr^{-1} were transported downstream from peat mining sites within coastal North Carolina. These nutrient loads were calculated using a total runoff of over 600 mm. Scaling these yearly nutrient loads down—assuming the lower runoff amount of 200 mm—yields a yearly TP and TN load of 0.34 kg P ha-1 yr-1 and 3.95 kg N ha^{-1} yr^{-1}, respectively. Using these nutrient loads and assuming all 29,960 hectares of peat mine lease area are under extraction simultaneously would result in yearly loads of TP and TN to Lake Winnipeg of 10.2 and 118 tonnes yr^{-1}, respectively.

4.1.4 Method 4 (M4): Peat Mining Runoff Water Quality in Central Finland

Kløve (2001) studied the runoff water quality from a peat mine in Central Finland (62.03°N, 25.20°E), during two consecutive years (1995 and 1996). The mean annual January air temperature is -10.0°C and the mean annual July air temperature is 15.7°C. The mean annual precipitation is 660 mm, of which 300 mm forms runoff.

Kløve (2001) found the annual leaching of TP and TN to range from 0.16 to 0.38 kg P ha^{-1} yr^{-1} and 10.7 to 15.0 kg N ha^{-1} yr^{-1}, respectively. This nutrient load estimation will use the upper bound of both ranges of 0.38 kg P ha-1 yr-1 and 15.0 kg N ha^{-1} yr^{-1}. Using these nutrient loads and assuming all 29,960 hectares of peat mine lease area are under extraction simultaneously would result in yearly loads of TP and TN to Lake Winnipeg of 11.4 and 449 tonnes yr^{-1}, respectively.

4.2 Summary

TABLE 1. Estimated TP and TN loads into Lake Winnipeg from peat mining drainage water using four different nutrient calculation scenarios (Manitoba, North Carolina, and Beaver Point) applied to current Manitoba peat mining Environmental Act Licences (issued), Interlake peat mining lease block holdings, Southeast Manitoba peat mining lease block holdings and total peat mining lease block holdings.

	HA		TONNES YR^{-1}			
	AREA	**NUTRIENT**	**M1**	**M2**	**M3**	**M4**
Licences (issued)	12,875	TP	2.1	5.2	4.4	4.9
Lease (Interlake)	12,711	TP	2.0	5.1	4.3	4.8
Lease (SE Manitoba)	17,249	TP	2.8	6.9	5.9	6.6
Total Lease Area	29,960	TP	4.8	12.0	10.2	11.4
Licences (issued)	12,875	TN	66	129	51	193
Lease (Interlake)	12,711	TN	65	127	50	191
Lease (SE Manitoba)	17,249	TN	89	172	68	259
Total Lease Area	29,960	TN	154	299	118	449

__M1__: All available peat mining TP and TN loads used from Manitoba Conservation and Water Stewardship; __M2__: North Carolina cumulative impacts of peat mining study (Gale & Adams, 1984) TP and TN loads used; __M3__: Beaver Point peat mine wastewater TP and TN loads used; __M4__: Central Finland peat mine wastewater loads used (Kløve, 2001).

TABLE 2. Estimated TP and TN loads into Lake Winnipeg from peat mining drainage water using four different nutrient calculation scenarios (Manitoba, North Carolina and Beaver Point). Nutrient loads are given in kilograms per hectare of extracted peat per year.

	KG HA^{-1} YR^{-1}			
Nutrient	M1	M2	M3	M4
TP	0.16	0.40	0.34	0.38
TN	5.14	9.99	3.95	15.00

__M1__: Mean TP and TN loads calculated from all existing peat mine data provided by Manitoba Conservation and Water Stewardship; __M2__: North Carolina cumulative impacts of peat mining study (Gale & Adams, 1984); __M3__: Beaver Point peat mine wastewater TP and TN loads used; __M4__: Central Finland peat mine wastewater loads used (Kløve, 2001).

TABLE 3. Contribution of existing Manitoba peat mining sites to annual TP and TN loads to Lake Winnipeg

			TONNES YR^{-1}							
	HA		M1 TO M4		STATE OF LAKE		% OF TOTAL ANNUAL LOAD			
	AREA	NUTRIENT	L1	H1	L2	H2	L1/L2	L1/H2	H1/L2	H1/H2
Licences (issued)	12,875	TP	2.1	5.2	3,384	13,043	0.06	0.02	0.15	0.04
Lease (Interlake)	12,711	TP	2.0	5.1	3,384	13,043	0.06	0.02	0.15	0.04
Lease (SE Manitoba)	17,249	TP	2.8	6.9	3,384	13,043	0.08	0.02	0.20	0.05
Total Lease Area	29,960	TP	4.8	12.0	3,384	13,043	0.14	0.04	0.35	0.09
Licences (issued)	12,875	TN	50.9	193	51,737	122,491	0.10	0.04	0.37	0.16
Lease (Interlake)	12,711	TN	50.2	191	51,737	122,491	0.10	0.04	0.37	0.16
Lease (SE Manitoba)	17,249	TN	68.1	259	51,737	122,491	0.13	0.06	0.50	0.21
Total Lease Area	29,960	TN	118	449	51,737	122,491	0.23	0.10	0.87	0.37
						Min TP	0.06	0.02	0.15	0.04
						Max TP	0.14	0.04	0.35	0.09
						Min TN	0.10	0.04	0.37	0.16
						Max TN	0.23	0.10	0.87	0.37

M1 to M4: Method 1 to method 4; **L1***: lower bound of all methods;* **H1***: upper bound of all methods; State of Lake: Environment Canada and Manitoba Water Stewardship (2011);* **L2***: State of Lake lower bound;* **H2***: State of Lake upper bound.*

Based on available water quality from existing Manitoba peat mining sites, mean TP and TN concentrations of 0.082 and 2.50 mg L^{-1} were calculated, respectively. Average TN concentrations in tributaries draining into Lake Winnipeg range from 0.49 (Saskatchewan River) to 2.52 (Red River) mg L^{-1} (Environment Canada & Manitoba Water Stewardship, 2011). Average TP concentrations in tributaries draining into Lake Winnipeg range from 0.019 (Saskatchewan River) to 0.354 (Red River) mg L^{-1} (Environment Canada & Manitoba Water Stewardship, 2011). Thus, wastewater from Manitoba peat extraction operations contains similar TN concentrations to the Red River and similar TP concentrations to the Brokenhead River.

Average TP and TN concentrations within the South Basin and Narrows regions of Lake Winnipeg are 0.113 and 0.869 mg L^{-1}, respectively (Environment Canada & Manitoba Water Stewardship, 2011). McCullough et al. (2012) calculated a four-year mean Lake Winnipeg TP concentration in the South Basin and Narrows regions of 0.17 mg L^{-1}. Thus, the wastewater from Manitoba peat extraction operations contains higher TN concentrations and lower TP concentrations than Lake Winnipeg.

Calculations were also completed to estimate the loading of TP and TN to Lake Winnipeg from the proposed Ramsay Point and Deer Lake sites in Manitoba's Interlake (Appendix C).

Despite the limitations of the nutrient leaching estimations (Table 2) from Manitoba peat mines, they are within the range of measured nutrient leaching from other peat mine locations (e.g. Kløve, 2001; Kløve, Sveistrup, & Hauge, 2010). Kløve (2001) estimated annual leaching of TP and TN from peat mining sites in Finland to range from 0.16 to 0.38 kg P ha^{-1} and 10.73 to 15.00 kg N ha^{-1}, respectively. The TP peat mining wastewater concentrations using M1, M2 and M3 are all within the TP range of Kløve (2001). The TN peat mining wastewater concentrations using M1, M2 and M3 are all lower than the TN range of Kløve (2001).

Estimated annual provincial TP and TN loads to Lake Winnipeg range from 3,384 to 13,043 tonnes P ha^{-1} yr^{-1} and 51,737 to 122,491 tonnes N ha^{-1} yr^{-1} (Table 3), respectively. The potential contributions of nutrient leaching from potential Manitoba peat mining sites to the annual TP and TN loads to Lake Winnipeg range from 0.02 to 0.35 per cent and 0.04 per cent to 0.87 per cent (Table 3), respectively.

5.0 Greenhouse Gas Emissions

There are large peat deposits in Western Canada that store 48 million tonnes of carbon and cover approximately 365,000 square kilometres, with the majority (57.8 per cent) of this peatland carbon contained within the borders of Manitoba (Vitt, Halsey, Bauer, & Campbell, 2000). These peat deposits have been sequestering carbon dioxide and accumulating peat for thousands of years (Zoltai & Vitt, 1990; Kuhry, Halsey, Bayley, & Vitt, 1992) with some locations reaching over 5 metres in depth (Bannatyne, 1980; Vitt et al., 2000). Horticultural peat producers extract these peat deposits to sell to growers or use it as a plant fertilizer amendment. In Manitoba, horticultural peat extraction commenced several decades ago, and many companies are looking to expand extraction into the Interlake and east of Lake Winnipeg.

A life-cycle analysis determined the greenhouse gas emissions from Canadian peat extraction to be 0.89 million tonnes of CO_2e in 2000 (Cleary, Roulet, & Moore, 2005). End-use peat decomposition is the largest source of greenhouse gases from peat extraction, accounting for 71 per cent of total emissions. Land-use change accounted for 15 per cent, peat transportation accounted for 10 per cent, and extraction and processing accounted for 4 per cent of total emissions (Cleary et al., 2005).

The following section includes a brief literature review of greenhouse gas exchange of pristine peatland ecosystems near or similar to Manitoba peatlands, bogs under peat extraction, pre-restored bogs and bogs under restoration. A simple land-use change greenhouse gas emission estimate will be calculated for all peatlands of interest by horticultural producers contained within their lease and licence agreements.

5.1 Pristine Peatland Greenhouse Gas Exchange

The following is a review of greenhouse gas exchange research at four pristine northern peatland sites: 1) The BOREAS-NSA, 2) Mer Bleue Bog, 3) Marcell Experimental Forest and 4) Alberta bogs. The focus will primarily be on the annual exchange of CO_2 and methane (CH_4), assuming nitrous oxide (N_20) emissions to be negligible.

5.1.1 BOREAS-NSA, Northern Manitoba

The Boreal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) is a diverse area of wetland and upland ecosystems, located near Thompson, Manitoba (55.91°N, 98.42°W). The average annual air temperature is -3.9°C and the average annual precipitation is 585 mm, 232 mm of which falls as snow.

Interannual measurements of CO_2 exchange at a fen within the NSA found the ecosystem to be a net source of CO_2 to the atmosphere (+1129 kg CO_2 ha^{-1} yr^{-1}) during the growing season of 1994 and then a net sink of CO_2 to the atmosphere (-3359 kg CO_2 ha^{-1} yr^{-1}) during the growing season of 1996 (Joiner, Lafleur, McCaughey, & Bartlett, 1999).

Methane emissions from an open low shrub bog within the NSA were measured to be 75 mg CH_4 m^{-2} d^{-1} on average (Bubier, Moore, Bellisario, Comer, & Crill, 1995). Assuming a 100-day period of emission would result in a total annual CH_4 flux of 75 kg CH4 ha^{-1} yr^{-1}. The spatial variability in log CH_4 flux was mostly explained by a combined variable of mean season peat temperature at the average position of the water table (Bubier et al., 1995).

5.1.2 Mer Bleue Bog, Ontario

Mer Bleue Bog is a well-studied pristine ombrotrophic peatland located 10 kilometres east of Ottawa, Ontario (45.41°N, 75.48°W). The climate is characterized as cool continental, with a mean annual air temperature of 6°C and an average annual precipitation of 943 mm, 235 mm of which falls as snow.

Interannual measurements of the CO_2 exchange at Mer Bleue Bog indicated that the bog was, on average, an annual sink for CO_2 of -2050 kg CO_2 ha^{-1} yr$^{-1,}$ ranging from -340 to -2780 kg CO_2 ha^{-1} yr^{-1} from 1998 to 2002 (Lafleur, Roulet, Bubier, Frolking, & Moore, 2003). A six-year mean net-CO_2 sink of -1474 kg CO_2 ha^{-1} yr^{-1} was calculated from measurements taken from 1998 to 2004 (Roulet et al., 2007).

Methane flux measurements from Mer Bleue Bog indicated an annual source for CH_4 ranging from 50 to 250 kg CH_4 ha^{-1} yr^{-1} (Moore et al., 2011). A six-year mean CH_4 flux of 49 kg CH4 ha^{-1} yr^{-1} was calculated from measurements taken from 1998 to 2004 (Roulet et al., 2007).

The mean annual carbon balance of Mer Bleue Bog (incorporating net ecosystem CO_2 exchange, CH_4 emissions, and export of dissolved organic carbon) is estimated to be -215 ± 390 kg C ha^{-1} yr^{-1} (Roulet et al., 2007). During the six-year period, the bog ranged from a source of 140 kg C ha^{-1} yr^{-1} to a sink of -890 kg C ha^{-1} yr^{-1} (Roulet et al., 2007). Interannual variability in net ecosystem CO_2 exchange during a 10-year timeframe (1998 to 2008) was found to be mainly driven by cyclic seasonal changes in meteorology (Teklemariam, Lafleur, Moore, Roulet, & Humphreys, 2010).

Mer Bleue Bog is a shrubby bog with many differences from most bogs in Manitoba. Mer Bleue Bog is also an eastern Canadian bog with greater atmospheric inputs of nitrogen and phosphorus than Manitoba's bogs. Thus, carbon flux will most likely differ between Manitoba bogs and Mer Bleue Bog (D. Vitt, personal communication, n.d.).

5.1.3 Marcell Experimental Forest, Northern Minnesota

The Marcell Experimental Forest is a 1,141 hectare area in Minnesota (47.53°N, 93.47°W) dedicated to the study of forest management and hydrology in peatlands and uplands. The site has an average annual air temperature of 3°C and an average annual precipitation of 770 mm, 230 mm of which falls as snow.

Micrometeorological measurements of CO_2 exchange were made at the Bog Lake Peatland (47.32°N, 93.28°W) located in the Chippewa National Forest, adjacent to the Marcell Experimental Forest. The bog ecosystem was a net source of CO_2 to the atmosphere (+2,603 kg CO_2 ha^{-1}) during the growing season of 1991 and then a net sink of CO_2 to the atmosphere (-1173 kg CO_2 ha^{-1}) during the growing season of 1992 (Shurpali , Verma, Kim, & Arkebauer, 1995).

Methane fluxes were measured at an open bog within the Marcell Experimental Forest with a calculated annual flux of 431 CH_4 ha^{-1} yr^{-1}, most of which is emitted during the thawed period (Dise, 1992). Further research at the same location found the methane flux to be largely controlled (r2 = 0.91) by water table position, peat temperature and degree of peat humification (Dise, Gorham, & Verry, 1993). Earlier research at this site found the annual methane flux to be 310 kg CH_4 ha^{-1} yr^{-1} (Crill et al., 1988). These high methane fluxes are not characteristic of ombrotrophic bogs, suggesting that this site is more than likely a poor fen (D. Vitt, personal communication, n.d.).

5.1.4 Alberta Bogs

Carbon dioxide camber flux measurements were taken at 10 bog sites (Wieder et al., 2009) across a 12,000 km^2 area near Wabasca, Alberta (55.97°N, 113.85°W). Wabasca has an average air temperature of 1.3°C and average annual precipitation of 475 mm, 113 mm of which falls as snow. Wieder et al. (2009) estimated that the bogs within the

Wabasca study region currently represent a sink of approximately 77 ± 28 grams C m^{-2} yr^{-1} with a fire return interval of 123 ± 26 years. An average non-winter air temperature increase of 2°C would still result in an annual carbon uptake of 36 ± 12 grams C m^{-2} yr^{-1}, but increasing the fire return interval to 61 years (with no warming) would convert these bogs to a net carbon source to the atmosphere (Wieder et al., 2009). The Alberta bogs are considered to be most similar to the potentially harvested Manitoba bogs (D. Vitt, personal communication, n.d.).

5.2 Peat Extraction and Restoration Greenhouse Gas Exchange

Horticultural peat extraction disrupts peatland ecosystem function by removing vegetation and lowering the water table, which increases aerobic decomposition and arrests photosynthesis and converts these CO_2 sinks into persistent CO_2 sources to the atmosphere (Waddington & Price, 2000). Carbon dioxide emissions can increase up to 400 per cent with the water table drawdown necessary for peat extraction (Silvola, 1986; Waddington, Warner, & Kennedy, 2002). Furthermore, peat extraction activities increase concentrations (Glatzel, Kalbitz, Dalva, & Moore, 2003) and export (Waddington, Toth, & Bourbonniere, 2008) particulate and dissolved carbon that could potentially be released as CO_2 or CH_4 to the atmosphere from downstream ecosystems.

Recent evidence indicates that the net carbon sink function of a degraded peatland ecosystem can be returned in less than 10 years after restoration (Waddington, Strack, & Greenwood, 2010). New extraction techniques, like the new acrotelm transplant method, can significantly reduce greenhouse gas emissions from peat extraction activities, and can re-establish peat accumulation and peatland carbon storage function much more efficiently than traditional peat extraction methods (Waddington, Plach, Cagampan, Lucchese, & Strack, 2009). However, much of the Sphagnum peat contained within the acrotelm is considered a high-value product by industrial peat producers.

5.2.1 Bois-des-Bel Peatland

The Bois-des-Bel peatland is a treed bog located in the Bas-Saint-Laurent region of Quebec (47.88°N, 69.45°W). The average annual air temperature is 3°C, and the average annual precipitation is 926 mm, 250 mm of which falls as snow. Peat extraction at Bois-des-Bel commenced in 1972.

Carbon dioxide emissions from a portion of the bog that was not restored totalled 8,983 kg CO_2 ha^{-1} during the growing season (Waddington et al., 2010). A portion of the bog that was one year post-restoration was determined to be a net CO_2 source of 17,527 kg CO_2 ha^{-1} (Petrone, Waddington & Price, 2001), while a portion of the bog two years post-restoration was determined to be a net CO_2 sink of approximately -733 kg CO_2 ha^{-1} during the growing season (Waddington et al., 2010).

Three years post-restoration, CH_4 emissions were 42 kg CH_4 ha^{-1} from May to October, which was 4.6 times greater than the pre-restored site, but they were not significantly different from each other or zero (Waddington & Day, 2007).

5.2.2 Finland and Sweden

The mean annual emissions from peatlands under active extraction in Finland and Sweden are 16.5 kg CH_4 ha^{-1} yr^{-1}, 0.9 kg N_2O ha^{-1} yr^{-1}, and 6,970 kg CO_2 ha^{-1} yr^{-1} (Maljanen et al., 2010) which were calculated from five studies (Alm et al., 2007; Shurpali et al., 2008; Hyvönen, et al., 2009; Nykänen, Silvola, Alm, & Martikainen, 1996; Tuittila et al., 2000).

5.3 Summary

TABLE 4. Review of CO_2 and CH_4 balances at pristine bogs, bogs under extraction and bogs in various stages of restoration.

			T HA^{-1} YR^{-1}		
CONDITION	**SITE**	**SOURCE**	**CO_2**	**CH_4**	**CO_2e**
Pristine	N. Peatlands	Gorham (1991)	-1.72	0.05	-0.50
	BOREAS-NSA	Joiner et al. (1999)	-1.12		-1.12
	BOREAS-NSA	Bubier et al. (1995)		0.08	1.73
	MBB	Lafleur et al. (2003)	-2.05		-2.05
	MBB	Roulet et al. (2007)	-1.47	0.05	-0.34
	MBB	Moore et al. (2011)		<0.25	<5.75
	MEF	Shurpali et al. (1995)	-0.72		-0.72
	MEF	Dise et al. (1992)		0.43	9.89
	MEF	Crill et al. (1988)		0.31	7.13
	Alberta Bogs	Wieder et al. (2009)	-2.82		-2.82
Pre-restoration	BDB	Waddington et al. (2010)	9.98*		9.98
1 yr post-restoration	BDB	Petrone et al. (2001)	17.53*		17.53
2 yr post-restoration	BDB	Waddington et al. (2010)	-0.73*		-0.73
3 yr post-restoration	BDB	Waddington & Day (2007)		0.04*	0.92
Extraction	Canada	Cleary et al. (2005)	10.19	0.02	10.65
	Fin. & Swe.	Maljanen et al. (2010)	6.97	0.02	7.43

BOREAS-NSA: The Boreal Ecosystem-Atmosphere Study Northern Study Area; MBB: Mer Bleue Bog; MEF: Marcel Experimental Forest; BDB: Bois-des-Bel; Fin: Finland; Swe: Sweden. **Growing season CO_2 and CH_4 balances.*

The CO_2 balance of bogs under extraction is significantly altered, resulting in large fluxes of carbon to the atmosphere during the life of the peat mine (Table 4). Post-extraction peatland restoration research in Quebec has achieved some success in re-establishing the self-regulatory mechanisms that enable functional peat accumulation returning the ecosystem to net-CO_2 sink (Lucchese et al., 2010; Waddington et al., 2010).

Pristine bogs tend to emit less CH_4 than other peatland types. This reduced CH_4 flux is primarily due to lower water tables in bogs, which inhibit the production of CH_4 and facilitate the oxidation of CH_4 within the peat column. Also, bogs do not contain aerenchymatous species that facilitate the transfer of CH_4 from the anaerobic peat layers to the atmosphere (Joabsson, Christensen, & Wallén, 1999). Bogs under active extraction tend to emit even less CH_4 due to the increased aerobic conditions within the peat column associated with bog drainage (Table 4). Methane emissions from peat mine sites, which are often bogs, can generally be assumed to be negligible (Strack & Waddington, 2012).

TABLE 5. Estimated land-use change greenhouse gas emissions from peat extraction in Manitoba assuming all licence and lease areas are under extraction, using two different greenhouse gas emission rates of 10.65 tonnes CO_2e ha^{-1} yr^{-1} (Cleary et al. 2005) and 13.47 tonnes CO_2e ha^{-1} yr^{-1} which incorporates the emission rate under extraction from Cleary et al. (2005) and the undisturbed peatland baseline flux from Wieder et al. (2009).

	HA	MILLION TONNES CO_2E YR^{-1}	
	AREA	CLEARY ET AL. (2005)	WIEDER ET AL. (2009)
Licences (issued)	12,875	0.14	0.17
Lease (Interlake)	12,711	0.14	0.17
Lease (SE Manitoba)	17,249	0.18	0.23
Total Lease Area	29,960	0.32	0.40
Total CDN peat mining emissions (2010)		1.2	
Total MB emissions (all sectors, 2012)		19.8	

Two methods were used to estimate land-use change greenhouse gas emissions from Manitoba peat operations. The first method used a greenhouse gas emission rate of 10.65 tonnes CO_2e ha^{-1} yr^{-1} (Cleary et al., 2005) which assumed undisturbed bogs sequester 27 grams CO_2-C m^{-2} yr^{-1} and emit 4 grams CH_4-C m-2 yr-1 (Gorham, 1991) resulting in an undisturbed bog net-greenhouse gas flux of 24 grams CO2e m-2 yr-1 to the atmosphere. The second method used a greenhouse gas emission rate of 13.47 tonnes CO_2e ha^{-1} y^{r-1}, which assumed that undisturbed bogs sequester approximately -2.82 tonnes CO_2e ha^{-1} yr^{-1} (Weider et al., 2009) based on chamber data collected across several bogs in the Wabasca region of Alberta. The second method assumes bog CH_4 emissions to be negligible (Strack & Waddington, 2012). The greenhouse gas emission rate determined for the second method is considered more realistic given the similarity of the Alberta bogs to the potentially harvested Manitoba bogs (D. Vitt, personal communication, n.d.). The estimated greenhouse gas emission rate is only considering land-use change emissions (15 per cent of total), which are calculated by taking the difference between the average greenhouse gas flux from areas under extraction, abandoned and under restoration and the average greenhouse gas flux from those same areas undisturbed.

Currently, total annual land-use change greenhouse gas emissions from peat extraction in Manitoba would not exceed 0.4 million tonnes CO_2e yr-1 (Table 5) assuming all lease block holdings by horticultural peat producers are mined simultaneously (29,960 ha) and a greenhouse gas emission rate of 13.47 tonnes CO_2e ha^{-1} yr^{-1}. Total greenhouse gas emissions in Manitoba from all sectors totalled 19.8 million tonnes CO_2e (Environment Canada, 2012) with peat mining potentially representing 2 per cent of Manitoba's total greenhouse gas emissions. Furthermore, greenhouse gas emissions from peat extraction in all of Canada totalled 1.2 million tonnes CO_2e in 2010 (Environment Canada, 2012).

6.0 Other Ecosystem Components

Development of peatlands for mining will have impacts beyond nutrient loading and water quality, but these impacts are less understood in the Manitoba context. This section provides a brief summary of other ecosystem components of potential relevance for a Manitoba peat mining CEA. The VECs listed below are drawn from EAPs of Manitoba peat mining projects (KGS Group, 2011a, 2011b).

6.1 Biophysical Environment

Peatlands are habitats that support diverse species, including mammals, birds, fish, amphibians and reptiles. The impacts on animals can be evaluated based on indicators such as diversity of animals, habitat areas and animal fatalities.

6.1.1 Mammals

Manitoba EAPs refer to data provided by the Manitoba Conservation Data Centre (MBCDC, n.d.) for the Mid-Boreal Lowland Ecoregion covering the Interlake area. This ecoregion is a habitat for moose, black bear, wolf, lynx, red fox and snowshoe hare. EAPs indicate that “currently there are no occurrences of wildlife species of concern listed within the MBCDC for the project study area” (KGS Group, 2011a; 2011b).

Site visits in 2010 and 2011 identified the presence of American marten, moose, red squirrel and white-tailed deer at Bullhead, Little Deer Lake and Ramsay Point Bogs. Additional species were identified in previous visits, including the American beaver, American black bear, northern grey wolf and snowshoe hare. None of the mammals are classified as very rare or rare (KGS Group, 2011b). Site visits in 2010 at Hay Point Bog identified moose and northern grey wolf as two present species and both are listed as abundant and secure (KGS Group, 2011a).

6.1.2 Birds

Birds might be affected by noise, vibration and plant operation activities. The MBCDC website identifies 11 bird species unique to the Mid-Boreal Lowland Ecoregion and classifies the piping plover as endangered (MBCDC, n.d.). However, the piping plover was not identified within the peat mining areas (KGS Group, 2011a, 2011b).

Bird surveys conducted at the Sunterra project sites identified 47 bird species. In addition, 53 and 32 species were identified during previous visits (KGS Group, 2011b). According to the EAP, except for the olive-sided flycatcher, which is listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), none of the bird species are classified as of concern (KGS Group, 2011b). Surveys conducted at the Sun Gro mining sites identified 19 bird species, none of which are listed as species of concern (KGS Group, 2011a). Thus, the authors of the EAPs concluded that the impact caused by peat mining to be insignificant on birds.

6.1.3 Fish

Fish are protected under the Fisheries Act, and might be affected by drainage and sediment loading, which can affect water quality. Fish species can be identified by surveys using methods such as electrofishing and minnow traps within the drainage ditches. No fish were captured at the drainage at Sun Gro mining sites (KGS Group, 2011a). The Little Deer Lake and the Ranger Lakes near the Sunterra mining site were stocked with walleye, according to a 2002 survey (KGS Group, 2011b). Other smaller-bodied fish, such as the Canadian mud minnow, stickleback and fathead minnow are found in nearby water bodies (KGS Group, 2011b).

It was found that low water levels, dams and vegetation may block fish passage (KGS Group, 2011a, 2011b). However, the authors of the EAPs deemed the overall impact of peat mining to be insignificant on fish.

6.1.4 Amphibians and Reptiles

The boreal chorus frog, gray tree frog, northern leopard frog, wood frog and red-sided garter snake were identified in the 2010 and previous surveys at Sunterra mining sites (KGS Group, 2011b). Surveys conducted at Sun Gro mining sites during 2010 identified two species: gray tree frog and northern leopard frog (KGS Group, 2011a).

The authors of the EAPs deemed the overall impact of peat mining on amphibians and reptiles to be insignificant.

6.1.5 Vegetation

Bogs sustain a variety of vegetation species, including ones that are very rare or rare (Statistics Canada, 2005). Field visits at both Sunterra and Sun Gro mining sites indicated that the typical dominating vegetation species is Sphagnum moss with light to moderate trees (KGS Group, 2011a, 2011b). Both the Manitoba Conservation Data Centre and site visits indicated that there were no vascular species identified as very rare or rare in the mining area (KGS Group, 2011a, 2011b). First Nations communities have expressed concerns regarding the loss of medicinal plants due to peat mining operations.

Vegetation has to be cleared before peat mining, which causes a large decrease of plant cover and affects the diversity of plants in the mining area. Indicators to examine impacts include an abundance of vegetation and diversity of plants (Imperial Oil Resources Ltd, 1997). Impacts to vegetation within the broader region and assuming restoration success were determined to be insignificant (KGS Group, 2011a, 2011b).

6.1.6 Soil

Test holes at different mining sites completed by KGS Group in 2011 examined the layers of peat soil. At Sunterra mining sites, the top 0.15 to 0.6 metres is a layer of the live Sphagnum peat followed by a 0.15–5 metre thick organic peat layer (KGS Group, 2011b). At Sun Gro mining sites, the live Sphagnum peat layer is around 0.15 metres followed by a 3.0 to 4.2 metre-thick organic peat layer (KGS Group, 2011a). Clay or rock layers present underneath the organic peat layer at both sites (KGS Group, 2011a, 2011b). Peat harvesting removes the top live peat layer and part of the organic peat layer: the average amount of peat harvested is 850 m^3 per hectare.

Leaks and spills during site preparation and operation might cause soil contamination. Soil condition is monitored annually to ensure no significant impact (KGS Group, 2011a, 2011b).

6.1.7 Groundwater

In Manitoba, information on groundwater flows around the peat locations is limited, and such information is not included in project EAPs. It has been found that the clay layer isolates groundwater from the mining layer and prevents contamination caused by spills and leaks. Thus the authors of the EAPs deemed the impact on groundwater from peat mining to be insignificant (KGS Group, 2011a, 2011b).

6.2 Socioeconomic Environment

In addition to the effects of peat mining on the natural environment, the impacts and benefits on the human environment have also been considered in Environment Act proposals for Interlake peat mining operations.

6.2.1 First Nations

Manitoba's Interlake is a region with several First Nations communities and includes the traditional land-use areas where hunting and harvesting are carried out.

6.2.2 Employment

In North Carolina, it was observed that peat mining can increase local employment and immigration (Gale & Adams, 1984). Migrants bring an increase in residents, school students and retail sales to the project area. In Manitoba, Sunterra employs 30–35 people from the regional area and Sun Gro employs 25 (KGS Group, 2011a, 2011b).

6.2.3 Transportation

Peat mining activities bring increases in road traffic during construction and operation, as well as transportation from site after production. The impact is typically measured by number of trucks per day.

6.3 Monitoring and Follow-up

Typically, monitoring and remediation of impacts is mandated through environment licences issued by the Province of Manitoba. These include: annual soil monitoring, surface water runoff flow monitoring, total suspended solids (TSS) and pH in weekly collected surface water samples analysis, additional water monitoring as developed with Manitoba Conservation, annual vegetation monitoring and weekly TSS in pond discharge monitoring (KGS Group, 2011a, 2011b).

7.0 Mitigation

Restoring a complex peatland ecosystem to its pre-extraction condition is not possible (Rochefort & Lode, 2006), but measures ought to be taken to restore key peatland ecosystem functions or rehabilitate the harvested area to serve another beneficial purpose within a human lifetime. The main long-term objective of post-extraction peatland restoration is to re-establish self-regulatory mechanisms that will enable functional peat accumulation (Quinty & Rochefort, 2003). Short-term objectives of post-extraction peatland restoration include: 1) re-establishment of peatland plants, especially Sphagnum (or brown) mosses and 2) restoring the hydrological regime typical of peatlands (i.e., rewetting) (Quinty & Rochefort, 2003). Essential peatland functions include: 1) adequate ecosystem productivity allowing carbon sequestration, 2) nutrient cycling, 3) re-establishing vegetation structure allowing for increased animal and plant biodiversity and 4) restoring the ability to resist biological invasion (Rochefort & Lode, 2006). A second post-extraction option is to rehabilitate the harvested area and transform it into a new functioning wetland, agricultural cropland or a forestry plantation (Daigle & Gautreau-Daigle, 2001).

Currently, there is very little evidence from field observations at abandoned milled peatlands showing spontaneous recolonization by Sphagnum mosses (Rochefort & Lode, 2006). Current peatland restoration techniques have succeeded in re-establishing a moss layer on previously mined peatland surfaces (Rochefort & Lode, 2006). However, there have been challenges in maintaining constant water levels due to the hydrophysical characteristics of the old exposed peat at mined locations (Price & Whitehead, 2001). Challenges are expected to persist until there is sufficient organic matter accumulation (i.e., the development of a new acrotelm) to ensure that the water table in a drought year does not drop below the new layer of organic matter into the old exposed peat (McNeil & Waddington, 2003). Thus, the successful peatland restoration of a mined peatland area necessitates the re-establishment of a functional acrotelm.

Bois-des-Bel Bog in Quebec is a well-known site of active peatland restoration research in Canada. A simple ecohydrological model of the Bois-des-Bel Bog was used to estimate the time required to develop a new acrotelm, with results indicating that it would take 17 years post-restoration to accumulate a 19 cm thick acrotelm (Lucchese et al., 2010). Further research at the Bois-des-Bel Bog determined that the net carbon sink function can be restored in less than 10 years post-restoration (Waddington et al., 2010). New extraction techniques, like the new acrotelm transplant method, can significantly reduce greenhouse gas emissions from peat extraction activities and can re-establish peat accumulation and the peatland carbon storage function much more efficiently than traditional peat extraction methods (Waddington et al., 2009).

There is evidence of elevated nutrient levels in peat mining wastewater, with estimates of annual leaching of TP and TN reaching as high as 0.38 kg P ha^{-1} yr-1and 15 kg N ha^{-1} yr^{-1}, respectively (Kløve, 2001). Kløve (2001) estimated average wastewater TP and PO$_4$-P to be 0.16 and 0.02 kg P ha^{-1} yr^{-1}, respectively, and average wastewater TN, NO$_3$-N, and NH$_4$-N to be 12.6, 3.6, and 4.2 kg N ha^{-1} yr^{-1}, respectively. Scandinavian peat extraction operations have had success mitigating nutrient loads discharged from operations by re-directing wastewater to adjacent wetlands or constructed wetlands to allow wastewater nutrients to be sequestered by vegetation and/or adsorbed by the peat (Ihme et al., 1991; Heikkinen et al., 1995a; Heikkinen et al., 1995b; Huttunen et al., 1996; Kløve, 2000; Koskiaho et al., 2005). Nutrient loads from peatland drainage can also be reduced using well-constructed sedimentation ponds, constructed floodplains and peak runoff control (Kløve, 2000; Marttila & Kløve, 2009).

Post-extraction peatland rehabilitation is the transformation of the peat mine site into a new functioning wetland, agricultural cropland or a forestry plantation (Daigle & Gautreau-Daigle, 2001). A peatland rehabilitation method gaining popularity is paludiculture, which is agriculture and/or forestry on wet and rewetted peatland that seeks to cultivate plant species that: 1) thrive in saturated conditions, 2) produce valuable biomass and 3) facilitate the accumulation of peat. Rehabilitation is an alternative to restoration with the potential for enhanced greenhouse gas sequestration (Maljanen et al., 2010; Mander et al., 2012; Jarveoja et al., in press) and nutrient uptake (Cicek et al., 2006) with the additional benefits associated with the harvest of biomass (Cicek et al., 2006; Mander et al., 2012; Jarveoja et al., in press).

Successful peatland restoration requires several years to succeed; therefore, it is imperative that restoration commence as soon as possible to diminish post-extraction greenhouse gas emissions and nutrient loads downstream. It is recommended that peatland restoration/rehabilitation commence immediately after the extraction of all the economically viable peat at each location if possible. In addition to restoration/rehabilitation of peat mine sites, mitigation of the environmental effects of peat mining can be carried out while active mining is taking place. Management of nutrient loading during production can be accomplished through management of runoff in appropriately designed sediment ponds or lagoons. Harvesting of biomass through paludiculture can further reduce nutrient loading. Similarly, trading of carbon credits can neutralize the greenhouse gas emissions of peat harvesting.

8.0 Conclusions

In summary, our study has determined that CEA is a reasonable methodology for assessing peat mining in Manitoba. CEA analyzes the interaction between each mining activity and environmental components and the interaction with other activities (past, present or future), and evaluates the interactions based on direction, duration, frequency, magnitude, etc. CEA determines the significance of activities based on the previous evaluation deducting the correction brought by mitigation.

TP and TN loads into Lake Winnipeg from Manitoba peat mining operations would not exceed 0.40 kg P ha^{-1} yr^{-1} and 15.00 kg N ha^{-1} yr^{-1} or 12 tonnes P yr^{-1} and 449 tonnes N yr^{-1}, respectively, representing about 0.35 per cent and 0.87 per cent of total annual loads to Lake Winnipeg, respectively. Further refinement of these calculations would require improved water quality and quantity data from current peat mining operations. Mitigation strategies for TP and TN concentrations within discharged wastewater include the use of sedimentation ponds, constructed wetlands and peak runoff control combined with biomass harvest.

Land-use change greenhouse gas emissions from Manitoba peat mining operations would not exceed 13.47 tonnes CO_2e ha^{-1} yr^{-1} or 0.4 million tonnes CO_2e yr-1, which represents about 2 per cent of Manitoba's current total annual greenhouse gas emissions. Improving the greenhouse gas emission estimates would require the collection of carbon flux data from bogs within Manitoba. Mitigation strategies for greenhouse gas emissions include the trading of carbon credits and the commencement of restoration/rehabilitation immediately following extraction.

Besides priority components, evidence from literature (Manitoba EAPs and North Carolina CEA) suggests that peat mining will have an impact on other VECs. Additional analysis requires stakeholders' input to list VECs and assist in evaluation; these VECs are thus not examined for Manitoba at this time.

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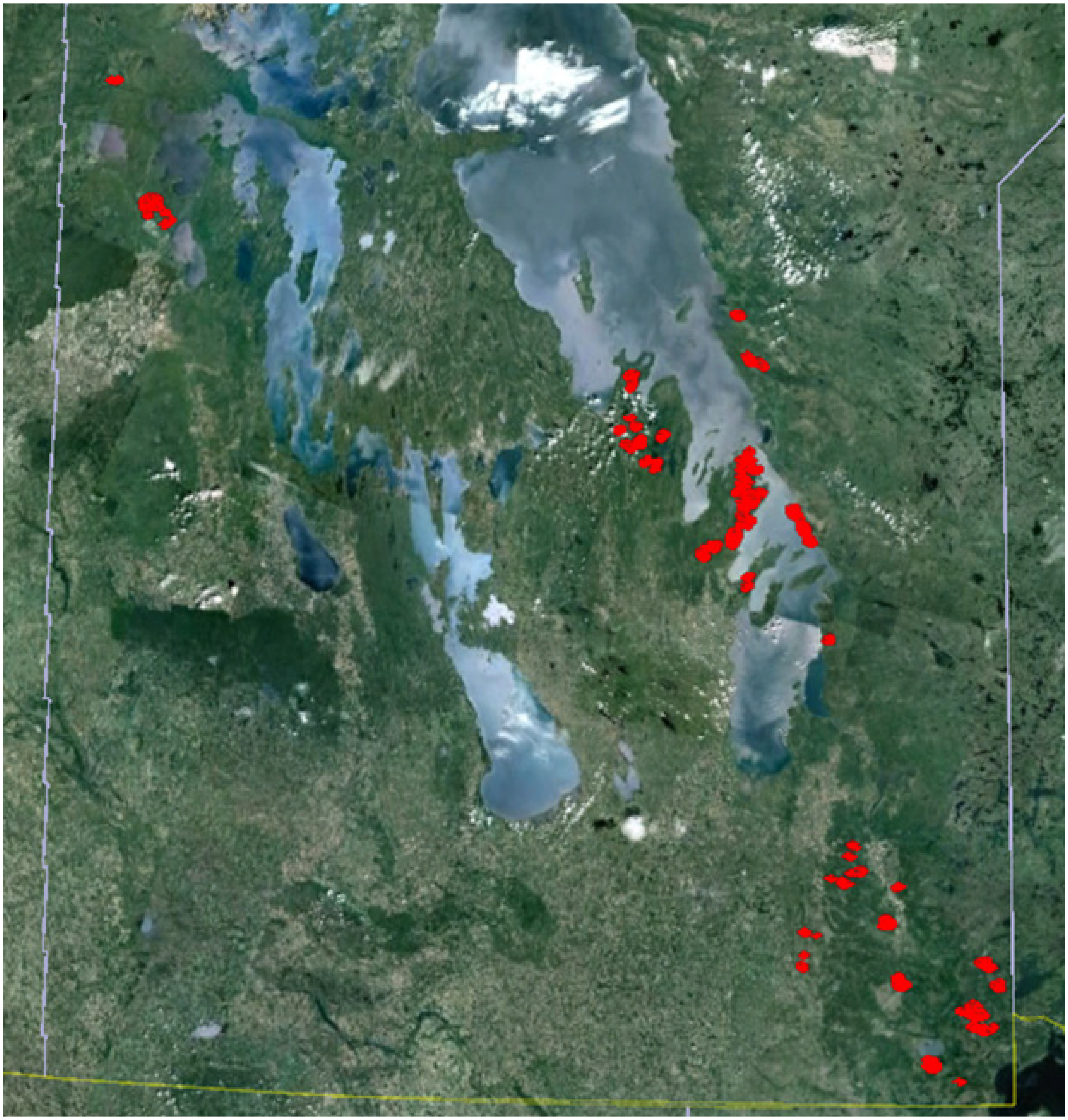
APPENDIX A. Manitoba Peat Mining Water Quality Data Provided by Manitoba Conservation and Water Stewardship

LOCATION	DATE	TN MG L^{-1}	TP MG L^{-1}
Caribou Bog	14-Nov-06	3.78	0.086
	14-Nov-06	3.70	0.079
	14-Nov-06	3.74	0.096
	28-Apr-09	1.93	0.038
	19-Aug-09	3.70	0.086
	19-Aug-09	3.09	0.086
	10-Jun-10	1.04	0.014
	10-Jun-10	2.01	0.044
	10-Jun-10	2.11	0.045
	02-May-11	1.89	0.059
	02-May-11	2.14	0.036
	02-May-11	1.99	0.031
	27-Jul-11	2.92	0.103
	27-Jul-11	2.50	0.072
	27-Jul-11	8.50	0.672
	12-Oct-11	3.86	0.076
	12-Oct-11	3.86	0.067
	12-Oct-11	4.54	0.119
Giroux Bog	14-Nov-06	0.90	0.034
	14-Nov-06	1.91	0.170
	14-Nov-06	0.51	0.018
North Julius	28-Jun-11	1.60	0.115
	13-Oct-11	2.73	0.114
South Julius	28-Jun-11	1.39	0.025
	13-Oct-11	1.57	0.056
Moss Spur	28-Jun-11	1.57	0.034
	13-Oct-11	1.38	0.051
Evergreen	28-Jun-11	1.18	0.036
	13-Oct-11	2.96	0.065
Elma	28-Jun-11	2.18	0.022
	13-Oct-11	2.01	0.033
Beaver Point	04-May-12	1.21	0.038
	16-Aug-12	2.02	0.074
Mean		**2.50**	**0.082**

APPENDIX B. Current Manitoba Peat Mining Lease Blocks



APPENDIX C. Nutrient loading from Ramsay Point and Deer Lake Peat Licences

The table below estimates the loading of phosphorus and nitrogen to Lake Winnipeg from the proposed Ramsay Point and Deer Lake sites in Manitoba's Interlake.

TABLE C1. Calculated totals of total nitrogen (TN) and total phosphorus (TP).

		PHOSPHORUS		NITROGEN	
	AREA	AVERAGE LOADING ESTIMATE	% OF TOTAL LAKE WINNIPEG LOAD	AVERAGE LOADING ESTIMATE	% OF TOTAL LAKE WINNIPEG LOAD
UNIT	HECTARES	TONNES PER YEAR	%	TONNES PER YEAR	%
All existing Manitoba peat mining licences	12,875	4.2	0.06%	109.8	0.10%
All Interlake peat leases	12,711	4.1	0.06%	108.3	0.10%
All southeast Manitoba peat leases	17,249	5.6	0.08%	147.0	0.14%
All Manitoba peat leases	29,960	9.6	0.14%	225.0	0.23%
Ramsay Point and Deer Lake licence areas	2,771	0.3	0.004%	8.1	0.009%
Ramsay Point and Deer Lake licence with nutrient mitigation	2,771	0	0%	0	0%

Overall, the licence areas would contribute 0.3 tonnes of phosphorus and 8.1 tonnes of nitrogen to Lake Winnipeg annually. This equates to around 0.004 per cent and 0.009 per cent of the annual loads of 7655 tonnes of phosphorus and 90,701 tonnes of nitrogen to the lake[6].

Wastewater treatment methods considered practically suitable and evaluated in other jurisdictions for peat mines include: 1) field ditch structures, 2) sedimentation ponds, 3) peak runoff control, 4) overland flow fields, 5) grassed infiltration areas, 6) peat redistribution areas, 7) soil infiltration and 8) chemical treatment. Research results from peat mines in Finland suggest that combining multiple wastewater treatments can reduce suspended solids, TN, and TP loads to near zero.[7] Combining these wastewater treatment methods with an annual biomass harvest (e.g., cattail) could potentially reduce nutrient loads to Lake Winnipeg below undisturbed background levels. As these measures have not been implemented in Manitoba, research would be required to determine their success within the Manitoba context.

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[6] Average 1999 to 2007 loading estimate from State of Lake Winnipeg report: www.manitoba.ca/waterstewardship/water_quality/state_lk_winnipeg_report/pdf/state_of_lake_winnipeg_rpt_technical_low_resolution.pdf

[7] Water treatment methods in peat production: old.peatsociety.org/user_files/files/jkl%20seminars%202010/technology/vayrynen_water_treatment11%206%202010.pdf

APPENDIX D. Licenced and leased peat mining area in Manitoba.

TABLE B. Issued and under review licenced area in Manitoba.

LICENCE HOLDER	LOCATION	REFERENCE	AREA (HA)
Issued			
Sunterra	Interlake	EAL #2288R	378
Berger	Interlake	EAL #2969E	2548
Sun Gro	Interlake	EAL #2964E	1816
Premier	SE Manitoba	EAL #2721	3522
Berger	SE Manitoba	EAL #2581R	1583
FPM	SE Manitoba	ELA #2783	1627
Jiffy	SE Manitoba	ELA #2941R	596
Sun Gro	SE Manitoba (Moss Spur)	ELA #2780R	197
Sun Gro	SE Manitoba (Julius Lake South)	ELA #2481	427.85
Soils Are Us	-	ELA #2478	16
T.R. & P. (o/a Reimer Soils)	-	ELA #2499	51
Evergreen Peat & Fertilizer Ltd.	-	CEC Order #305	113
Under review			
Sunterra expansion	Interlake	-	665.7
Total licenced area			
Total licenced peat in Manitoba = 12,975 hectares			
Total licenced peat in Interlake = 4,742 hectares			
Total peat licence “under review” = 665.7 hectares			
Total peat licence “under appeal” = 0 hectares			

Note: Values, March 2015.

Source: Darrell Ouimet (CWS), personal communication.

TABLE C. Issued and pending leased area in Manitoba.

ISSUED (AREA, HECTARES)	
125 peat leases in SE Manitoba	17,249
63 peat leases in Interlake	12,711
Total	**29,960**
Pending (area, hectares)	
16 peat leases in SE Manitoba	815
74 peat leases in Interlake	8,019
Total	**8,834**

Note: Values, March 2015.

Source: Mike Fedak (MMR), personal communication.

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