



Above and Below Ground Carbon Inventory of Poplar River First Nation Traditional Territory

REPORT

A report prepared for Poplar River First Nation, July 2009
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Poplar River First Nation

July 2009

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SUMMARY

Global concern over increasing concentrations of the greenhouse gases, carbon dioxide and methane, in the atmosphere promotes the need to better understand the quantities of carbon stored in the vast boreal forests of Canada, and their role in the cycling of carbon. Canada contains approximately one third of the world's boreal forests, occupying more than half of Canada's total land area. Important within the boreal zone are peatlands, ecosystems containing the highest concentrations of carbon. Peatlands have accumulated carbon from the atmosphere over the past 8,000 years and represent an enormous carbon store, crucial to be maintained intact in the present period of rising carbon dioxide levels in the atmosphere. Within Canada peatlands cover 12.3% of the land area and contain more than 150,000 million tonnes of carbon, an estimated 60% of Canada's carbon stock.

Poplar River First Nation, on the east side of Lake Winnipeg, is situated in a region where more than half of the land area is covered by peatlands. In support of their participation in Pimachiowin Aki, an affiliation of First Nations and provincial parks nominated by Manitoba and Ontario as a UnescoWorld Heritage Site representing the boreal forest, Poplar River undertook an above- and below-ground carbon inventory. The study estimates that the Poplar River Traditional Territory, approximately 862,000 ha in area, contains about 27.768 million tonnes of carbon above ground. Below ground, primarily in fens and bogs, the Territory contains 416.318 million tonnes of carbon or 15 times that found above ground. This is an estimated 0.3 % of Canada's peatland carbon.

EXECUTIVE SUMMARY

Ecological services are perceived from processes that operate within ecosystems and have value that is inherent and economic. The benefits of ecological services are manifest at local, regional, and global scales and are therefore tangible and important. Uncertainty in certain aspects of ecosystem processes, such as carbon sequestration or release, are important considerations in the context of climate change. This is especially true within boreal Canada where it is well known that a globally large store of carbon is present in the abundant peatlands and forests. To document the role of the ecological services involved in storing carbon in and on their natural landscape, the Poplar River First Nation has taken a first step to quantifying the above and below-ground carbon reserves in their traditional territory.

Standard methods to simultaneously estimate both above ground carbon (AGC) and below ground carbon (BGC) are not presently available at the federal and provincial levels. Today, maps of peat and land cover are not yet developed as an integrated product. Instead, the information available is biased towards merchantable timber. Our best current estimates of carbon in peatlands in Canada are mapped at national or regional scales. Nevertheless, improvements in estimating AGC and BGC be derived from independent data sources, with various levels of spatial detail. This is apparently the first attempt by a First Nation to estimate simultaneously AGC and BGC in Manitoba, and possibly the first in Canada. .

This report provides the first preliminary estimate of AGC and BGC for the Poplar River First Nation Traditional Territory (PRTT). BGC was estimated using the method published by Vitt *et al.* (2000) using peatland information from ecological land classification maps archived at the University of Guelph. AGC was estimated using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) (Kurtz *et. al* 2008). Initial validations of the BGC and AGC estimates, respectively, were assessed using a limited set of peat cores from the Traditional Territory and the primary literature.

Preliminary estimates of AGC are limited to areas of merchantable forest. AGC estimates include biomass and dead organic matter for above and below ground which for the PRTT total 27.767568 million tonnes. BGC estimates for wetland areas, (i.e. fen, bog, and marsh, total 416.317771 million tonnes. Therefore, this preliminary estimate indicates that the BGC stored in the PRTT is about 15 times that found in the above ground sources studied. The estimate of total carbon stored in the Traditional Territory is 444 million tonnes.

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Ray Rabliaskas, Lands Management Coordinator, Poplar River, Manitoba is the proponent for this study.

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Alex Koiter reviewed published literature on Canadian peatlands and contributed to the preparation of the Introduction. Empirical field data on peatland depths were made available from winter field survey undertaken by Waylon Bittern of Poplar River First Nation, Paul Martin of IDIG Soil Survey Consulting Inc., Erik Eising of Bio-Mass Fractionation Canada, and David Martin in early 2009.

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1.0 INTRODUCTION

UNESCO World Heritage Site

The Poplar River Anishinabek First Nation, along with three neighbouring First Nations from Northern Manitoba and Northwestern Ontario joined together in a unique cooperative relationship to advance their common interest in self-government and protection of their respective territories. This relationship is represented in the Protected Areas Accord of 2002 with Pauingassi, Little Grand Rapids and Pikangikum First Nations. (Poplar River First Nation Asatiwisipe Aki, 2009).

To further promote long-term protection of their lands, not only for their own purposes but also in the national and global interests, these First Nations have joined with two provincial parks, Atikaki Wilderness Park in Manitoba and Woodland Caribou Park in Ontario, to pursue UNESCO World Heritage Site status for their co-joining lands. World Heritage Sites may represent outstanding natural heritage, such as significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals, or outstanding cultural heritage representing the evolution of human society and settlement over time (Manitoba Wildlands, 2009a). This World Heritage Site nomination serves to protect both natural and cultural heritage.

This nomination has been acknowledged and supported by the World Conservation Union that manages the world heritage sites program for UNESCO for the boreal ecozone. Canada's Minister of the Environment endorsed the nomination in April 2004. Manitoba Premier Doer, Conservation Minister Struthers, Hydro Minister Chomiak, and Finance Minister Selinger have all publicly supported the World Heritage Site nomination (Manitoba Wildlands, 2009b).

Poplar River First Nation has demonstrated leadership, not only in protection of their lands, but also in activities to increase scientific understanding of them and record indigenous knowledge. Towards this end, the First Nation worked with the Natural Resources Defence Council (NRDC) to help frame a recommendation at the 3rd IUC World Conservation Congress in Bangkok in 2004 that called upon Canada, Russia and all boreal forest nations to recognize, preserve and protect ecological processes that sustain the overall health of boreal forest regions. At a workshop at the Bangkok Congress on the Boreal Forest Conservation Framework, co-hosted by the Canadian Boreal Initiative and the NRDC, Poplar River was among those speaking on their engagement in the Framework and innovative models for implementing it. The IUC recommendation acknowledges the need to "facilitate and continue to fund needed scientific, technical, indigenous and local community activity to assist in the nomination and designation of boreal forest regions as recognized international sites. World Heritage Sites such as the indigenous-led *Atikaki/Woodland Caribou/Accord First Nations - Manitoba and Ontario nomination*, recently placed on Canada's official Tentative List for World Heritage Sites" (Manitoba Wildlands, 2009c) are examples.

Prior to this, Poplar River First Nation Elders recognized that Aboriginal wisdom wasn't necessarily enough to protect the land and their way of life at present. The Elders decided that the community would work with scientists to document the functions and value of the land in more languages and forms of knowledge. This eventually evolved into the development of a comprehensive land protection and management plan - the Asatiwisipe Aki Lands Management Plan - a precedent-setting effort among First Nations in the world's boreal region (Poplar River First Nation, 2005). This Plan was prepared with assistance from the Canadian Boreal Initiative. Poplar River's plan is a full-scale blueprint of how the community is documenting,

protecting, and sustainably managing forests, wildlife and other natural resources in the Poplar River Traditional Territory (PRTT). The plan outlines the following core components: respecting traditional knowledge; benefiting from environmental analysis; developing economic opportunities, including protection of traditional hunting, trapping and fishing activities; and creating sustainable tourism opportunities (Manitoba Wildlands, 2009d).

This land management plan documents the ecological integrity of the traditional territory and encourages natural science research for topics such as carbon sequestration and the roles of boreal forest in mitigating climate change. Environmental monitoring and cooperative research studies are foreseen as part of the implementation of the Asatiwisiipe Aki land management plan.

As stated by the National Round Table on Environment and Economy (NRTEE, 2005), the boreal serves as one of the planet's most important carbon reservoirs, preventing large amounts of carbon dioxide and methane from being released into the atmosphere. Most of the carbon is held in peat deposits, soils, lake sediments, and trees. Historically, boreal ecosystems are carbon sinks but during climate change, the boreal has the potential to become a major source of greenhouse gases, as the results of larger and more frequent fires, infestation and tree-kill by pests, and loss of peatlands. Attention on the carbon stored in the PRTT is by implication attention to maintaining the stored carbon intact and therefore the reduction of the above threats to its integrity.

The Boreal Forest

The boreal forest is one of the earth's largest biomes, encompassing an area approximately 14.3 million km² (Kasischke et al., 1995). This biome consists of a mixture of parklands, forests, lakes, wetlands, and taiga (NTREE, 2005). It has been estimated that approximately 714,000 million tonnes of carbon is stored in world's boreal forest regions (Apps et al. 1993; Kasischke et al., 1995). This represents >37 % of the total amount of carbon stored in terrestrial biospheres (Kasischke et al., 1995). The majority of the carbon stored within the boreal forests biome, 419,000 million tonnes, is contained in the soils of the largely treeless peatlands within the boreal that cover almost 2.6 million km² (Kasischke et al., 1995). Apart from the wetlands, the majority of the carbon is still stored below-ground, within the mineral soils and dead vegetation, with the above-ground vegetation representing the smallest component of stored carbon (Kasischke et al., 1995).

Canada contains approximately one third of the world's boreal forests. This represents more than one half of Canada's total land area (NTREE, 2005). As such, Canada has responsibility over a significant store of the world's carbon. The manner in which the boreal forests, within Canada and world wide, are managed can have an appreciable impact on the loss of stored carbon. Due to the concerns over the increasing concentrations of carbon dioxide (CO₂) and methane (CH₄) in the atmosphere and their global warming potentials, there is a need to better understand the role of boreal forests in the cycling of carbon. Kasischke et al. (1995) have identified four main processes that control the storage and release of carbon in boreal ecosystems: (1) the rate of plant growth; (2) the rate of decomposition of dead organic matter; (3) the rate of formation of permafrost; and (4) the frequency and severity of fires. These four processes are controlled by a mutually dependent set of biological and physical properties and characteristics including climate, topography, hydrology, soil, and flora and fauna (Kasischke et al., 1995).

In addition to sequestering carbon and producing oxygen, the boreal forest biome provides many other essential ecological services including improving water quality and regulating its flow, maintaining biodiversity and the cycling and storage of nutrients. Perturbations of the ecosystem, including climate

change itself, can effect the carbon cycling and alter the functionality of the ecosystem as a whole. Understanding how climate change will affect soil carbon dynamics is important in developing management strategies to help mitigate the loss of carbon to the atmosphere and to protect the boreal forests and the ecological services they provide.

The effects of increasing atmospheric concentrations of CO₂ and CH₄ on climate change, in terms of magnitude, duration and implications, are still debatable. There is uncertainty as to the sensitivity, responses and feedback mechanisms of the boreal regions to changes in the climate. Warmer temperatures in the boreal regions, for example, may push the northern extent of the boreal region further north and increase primary production. These changes would result in an increase in the uptake of carbon from the atmosphere. Conversely, the effects of increasing temperatures may also result in increased decomposition rates, and increases in the frequency and intensity of forests fires. These would result in an increase the release of carbon to the atmosphere. The interactions of these processes and the net result on the carbon cycle is difficult to predict. The problem of prediction is also confounded by the variation in biological and physical properties that exist across the landscape.

Peatlands

Peatlands represent a major store of the world's land-based carbon. They cover an estimated 3 - 4% of the earth's land surface (Gorham 1991) and store 25% of the world's terrestrial carbon, an amount roughly equivalent to 3/4 of the total amount of global atmospheric C. Thus, the fate of peatlands on the globe can influence concentrations of greenhouse gases (GHG) in the atmosphere.

Peatlands are most concentrated in the northern hemisphere and are an asset and a responsibility largely of northern nations. North America has about 40% of the world's peatlands (Irish Peatland Conservation Council). The total area of peatland in North America is 1,735,000 km². Peatlands cover 12.3%, i.e., 1,113,270 km² of Canada's 9,041,742 km² land area, contain over 150,000 million tonnes of carbon, about 60% of Canada's carbon stock (Figure 1). They occur in every province of Canada and in nearly every state of the United States. The main peatland areas in Canada occur in Manitoba, Ontario, Alberta and Saskatchewan. Canada's peatlands are among the most extensive of the world's peatlands and relatively the least threatened by development pressures.

The purpose of this study is to obtain an initial estimate of both above- and below-ground carbon inventories in the 862,000-ha PRTT. The baseline estimates of above- and below-ground carbon will lead to a better understanding and documentation of the significant and on going ecological and biological processes in the boreal forest represented by the PRTT. Establishing the carbon inventory baselines will provide a reference set of data against which future measurements can be compared. These comparisons will allow for the assessment of the impacts of climate change and management practices and policies on the carbon stocks within the PRRT. The objectives of this study were (1) to estimate the above- and below-ground carbon inventory in the 862,000-ha Poplar River Traditional Territory (PRTT); and (2) to identify significant information gaps and areas for further research.

2.0 STUDY AREA

The 861,718 ha Traditional Territory of Poplar River First Nation (Poplar River First Nation 2005) spans 52° 35' to 53° 20' north latitude on the east side of Lake Winnipeg (Figure 4) and is located in the Western Boreal Shield ecozone (Figure 5).

The Poplar River First Nation Traditional Territory occupies a topographic and ecological gradient that runs east to west (Figure 6). In the east, low and undulating Precambrian Shield topography dominates the area which gives way to extensive low land areas along the east *shore* of Lake Winnipeg. Figure 7 displays the distribution of wetland and non-wetland classes across the study area.

The topographic gradient of the PRTT is shown as a schematic of ecologically distinct land classes in Figure 8. Wetlands (i.e. fen, bog, and marsh) dominate the PRTT (54%) with merchantable timber (23%) being the second-most abundant landcover. Non-merchantable timber areas have a sparse forest cover and tend to occupy ecotones between well developed wetlands and upland areas and, total about 5% of the PRTT. Woody shrub landcover are also found along the edges of low lying areas, and total about 8% of the study area. In this study, the available data for estimating below ground carbon and above ground carbon do not overlap in space. BGC estimates are derived from wetlands, whereas AGC is represented mainly by merchantable timber areas. Data are not currently available for treed rock areas, barren rock, and non-merchantable timber. Woody shrubs are considered to be carbon neutral, implying growth and decomposition are considered to be approximately balanced. The proportions of landuse classes found within the PRTT is listed in Table 1.

Jack Pine, Black Spruce, and Trembling Aspen account for nearly 90% of the merchantable area (Figure 9) of which their distribution is shown in Figure 10.

3.0 METHODS

3.1 Overview of data sources, classification nomenclature, and data integration

This section provides an overview of methods used to develop the BGC and AGC estimates given that some of the methods employed are strongly technical. Detailed descriptions of the information found in this overview are found in Appendix A1.

Two data sources were required to develop AGC and BGC estimates. Ecological Land Classification (ELC) maps interpreted from aerial photography (1:60,000) provided the best classification nomenclature and delineation of peatlands and all other (i.e. non-merchantable forest) areas. Manitoba's Forest Resource Inventory (FRI) mapping, also derived from aerial photography at 1:60,000 scale, but mapped at about 1:24,000 scale provided the best classification of merchantable stand types and delineation of the boundaries of the stands.

In order to adopt the "best of each map", the two data products needed to be merged. In brief, the ELC classification was adept at classifying wetlands (i.e. marsh, fen, bog) of which the latter two are abundant with peat, but provided only a general classification of forest. The merchantable stand polygons were

therefore, used to replace the corresponding ELC forested areas. Differences in map scale and classification taxonomy required that the proportion of the polygons represented by the wetland classes (bog, fen, marsh) be adjusted relative to the higher precision of the stand areas provided by the merchantable FRI polygons.

Appendix A1 lists the detailed steps required to integrate the ELC and FRI data products into a single topological dataset, and an assessment of the differences in geometry and the efficacy of the redistribution of the proportions of polygon areas in the final integrated carbon map.

3.1.1 Below Ground Carbon (BGC)

ELC maps shared by the University of Guelph covering the PRTT at 1:250,000 scale were based on the classification nomenclature of the National Wetland Working Group (NWWG 1998) and Ecological Land Classification system. Wetland classification methods are described in Vitt *et al.*, 2000 and Halsey *et al.*, 1997. The scale of the output ELC mapping interpreted from the aerial photography was approximately 1:100,000.

The classification system of the ELC enables within polygon heterogeneity of each wetland class, and a vegetation modifier to indicate if the wetland is forested, wooded, or open. For example, the attribution of a single polygon is:

F6_{OT}Z4_T

This classification indicates a 60% fen (F) coverage that is mixed open (O) and wooded (T) with a 40% non-wetland area (Z) which is wooded (T).

BGC was estimated for the PRTT according to the method of Vitt *et al.*, (2000). The steps to estimate carbon storage as according to this method are as follows: 1) inventory of peatland distribution by peatland type, 2) estimates of current maximum depth distributions of peat, 3) calculation of surface and below ground storage volume by peatland type using area and maximum depth adjusted for basin topography, 4) carbon content of organic matter in peat, 5) profiles of organic matter density distinguished by peatland type, and 6) above ground carbon content of biomass of vascular plants by peatland type on a mass-area basis. We did not need to employ calculations to account for the temporal patterns of peatland initiation and expansion, as well as long-term catotelm decomposition, that were included in Vitt *et al.*, (2000).

We employed two validation trials within seven map tiles (1:50, 000 scale) where comparisons could be direct to assess: 1) if methods and data used by Vitt *et al.* (2000) at a sub-national scale apply equally well to a much smaller area, found on the eastern extent of the published study area, and 2) we used local data of higher precision to learn of any potential improvement to results. For the PRTT, we substituted improved elevation data from NASA's Shuttle Radar Topography Mission (SRTM) to derive slope corrections for basin topography. We also used higher precision polygon boundaries from Manitoba's FRI, as described above, to better delineate wetlands from productive forests.

Peat validation data were collected using a peat corer during survey of areas accessible by boat during July 2007 and by winter road February 28 – March 2, 2009 (Appendix A1). Samples collected on March 3, 2009 used a Dutch auger.

Appendix A1 provides detailed description of the ELC classification, conversion of the paper maps to digital, and provides data tables for each peat validation site in the PRTT.

3.1.2 Above Ground Carbon (AGC)

Above Ground Carbon (AGC) includes organic biomass from live and dead softwood and hardwood stems, branches, coarse and fine root systems, foliage, and leaf litter which are known individually as carbon pools. The absolute quantity of carbon held within a pool at a specified time is defined as carbon stocks (IPCC 2000). The carbon balance of a forest at the landscape level is determined by many factors - the past disturbance regime, as reflected in the age-class structure, by current growing conditions and disturbance patterns, and by forest management activities (Kurz *et al.* 2002).

The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is a generic modeling framework which was applied at an operational landscape level to calculate above ground carbon in the PRTT. Carbon was calculated assuming no disturbance conditions since the time of forest inventory (average elapsed time since inventory is 26 years). The capacity to model disturbances such as fires, afforestation, natural succession, insect disturbance, and anthropocentric land use changes exists among others (Kurtz *et. al* 2008).

The CBM-CFS3 model requires defining six different inputs: 1) Classifiers and Values which defines leading species and their site classes; 2) A definition of the age classes of stands; 3) Disturbance events which define what disturbances are anticipated to affect different stands at different age classes and the proportions of the stand the disturbance is expected to affect; 4) Transition Rules which define following disturbance what type of stand replacement is predicted to occur; 5) Inventory which determines the types of leading species and site classes are present and their respective areas (Table 2), and; 6) Growth and yield curves based on leading species. The model inputs used to generate the carbon estimates are archived on the accompanying DVD under filename: FRI_Vol_Formatted.xls.

All model inputs were readily available using Manitoba Conservation Forestry Branch Forest Resource Inventory (FRI) data except growth and yield curves which have not been developed for this area. However, since growth and yield are expressed at m³/ha, existing known volumes were aggregated by leading species and site class to produce average volumes common on those sites at different age classes (Table 3).

Although many merchantable stand volumes were available to create reasonable averages of volume by age class (over 16,000 stands), some assumptions were required. Since all of the stands were classified as 'merchantable', stands in lower (younger) age classes were absent and volumes at these age classes had to be interpolated (Table 4). Where volume was unavailable for stands in higher (older) age classes, static volumes were assumed since the last known average volume.

This demonstration of the output by the CBM-CFS3 model is not considered valid given that several important inputs to the model were absent, such as the effects of fire, but this trial shows how the model may assist understanding how carbon availability over time may change. As is, the growth and yield curves implemented are likely to under-represent carbon sequestration from vigorous growth of young stands in the process of regeneration from disturbance and over-represent volumes of stands that are experiencing decline at post-rotation ages.

Two sources of carbon are disregarded by the CBM-CFS3. Woody shrubs are disregarded as carbon pools based on the assumption that the carbon content is neutral (i.e. equivalent carbon is sequestered in annual growth as is released through annual decay) (Natural Resources Canada 2008). Peat carbon dynamics are also not currently modelled because of a paucity of knowledge on the impacts of management, disturbances, and climate change on fluctuations in the water tables of peatlands (Kull *et. al.* 2007) necessitating the ELC approach described above.

Two additional sources of carbon were not modelled due to lack of supporting data: 1) areas of non-merchantable timber including treed rock did not have any volumes associated with them, precluding

integration into the CBM-CFS3 model and 2) areas of peat that were wooded or forested would have nominal forested volumes were not included for the same reasons. It is estimated that these two sources combined represent approximately 11% of the study area.

Forest inventory in this area occurred, on average, 26 years ago. The CBM-CFS3 model was run projecting 25 years into the 'future' assuming no disturbances. Results described below are categorized into five, 5 year interval time steps starting at year 0 representing carbon at the year of inventory to year 25 representing carbon stocks of current day.

4.0 RESULTS

4.1 Below Ground Carbon

4.2 Validation

4.2.1 Peat depth

Comparison of the maximum peat depth data used by Vitt et al. (2000) to peat cores depths (Appendix A1) from the PRTT shows they are in general agreement. PRTT validation data shows local variation in peat depth within a single peat polygon can be large, but the average maximum depth of peat in the PRTT (181.0 cm) using the available data (Figure 12) is identical (i.e. 181.1 cm) to that used by Vitt et al. (2000). We therefore used the data of Vitt et al. (2000) to estimate BGC given the sample size of in the PRTT was small, and was biased to the western extent of the study area. Table A1-4 in Appendix A shows the fen and bog types, maximum peat depths, and ELC classifications at all sampling sites.

4.2.2 Below ground carbon estimates

4.2.2.1 Comparison of the Vitt et al. (2000) method to higher precision data used within the Poplar River Traditional Territory

The higher precision (HP) input data used in the PRTT resulted in an estimate for the validation area (5 map tiles) that was a total 43.5 million tonnes greater (13%). Variation in carbon estimates among tiles is greater for the higher precision dataset. For map tile 53D/13 the HP data was the lowest, at 32 kg/m² BGC, or about 0.68x of the corresponding result provided by Vitt et al. (2000). In contrast, the highest HP data estimate was about 1.8x that of Vitt for map tile 63H/2. The lower resolution data used by Vitt is evidenced by a smaller standard deviation (6.3) when compared to the HP trial (15.3). The use of local data appears to have accounted for about 2.3 times more variability in the local distribution of BGC. On average, the Vitt et al. (2000) estimate was lower, resulting in about 46 kg/m² whereas the HP trial was 53 kg/m².

4.2.2.2 BGC estimate for the PRTT

Using the higher precision local data and the method of Vitt et al. (2000), the total estimated BGC carbon for the PRTT is 461.317771 million tonnes. Marsh areas are few in the PRTT. These areas contributed very little to the estimate, just 1.053756 million tonnes.

4.3 Above Ground Carbon

Total estimated carbon for the PRTT today is 27. 767568 million tonnes or 144.5 tonnes /ha in areas containing merchantable timber. Carbon values can be divided categorically into two main groupings: biomass and dead organic matter (DOM) which, in turn, contains carbon stocks which are comprised from both above and below ground sources.

Above ground biomass includes merchantable stems, fine and coarse branches and twigs, and foliage for all softwood and hardwood species. Below ground biomass includes is composed of fine and coarse roots for softwood and hardwood species. Above ground DOM includes litter, deadwood and very fast, fast, medium and slow decaying dead organic matter (such as branches, twigs, or stems). Below Ground DOM includes very fast, fast, medium, slow decaying dead organic matter (such as fine and coarse root systems) and soil carbon. The merchantable timber carbon stocks in tonnes in 5 year intervals from inventory year (year 0) to present day (Year ~25) assuming no disturbance scenarios are shown in Table 5.

5.0 CONCLUSIONS

With a novel hybrid spatial dataset that effectively describes wetland types (fen, bog, marsh) and upland classes including merchantable forests at the scale of the Poplar River Traditional Territory (PRTT), we have provided the first above ground and below ground estimates of carbon to support objectives by the Poplar River First Nation to seek status of a UNESCO World Heritage Site. Preliminary estimates indicate that the BGC availability in the PRTT far exceeds that stored in merchantable timber areas, perhaps suggesting that most of this carbon store is less prone to disturbance when compared to AGC.

We used a published model for estimating BGC developed at a sub-national scale (Vitt et al 2000) and applied it to the much smaller PRTT, found within, but at the eastern extent of the sub-national model study area. The transferability of the model across geography and scale was assessed by comparing peat depth data from both studies, and the use of larger scale (i.e. more detailed) mapping with improved delineation of wetland and merchantable stand boundaries and topography. The available local validation data on peat depth data agreed well with that used by Vitt et al. (2000). The inclusion of local forest and topographic data of higher precision is necessary when information is needed at the forest stand level or when the location of BGC is desired. In this study, the use of Manitoba's Forest Resource Inventory markedly improved the certainty of the boundary between merchantable forests and wetland, and when coupled with precise slope information, the results of this study suggest that the sub-national approach of Vitt et al. (2000) to the PRTT would have underestimated BGC by about 13%.

6.0 RECOMMENDATIONS

1. Validation studies of the depth of peat by peatland type are scarce but are important. In particular, studies at local scales are uncommon and are needed to appreciate variation in the volume of peat overlying the parent material. More sampling is required in the study area.

Additional sampling will also reveal more precise bulk density values essential to calculate carbon.

2. Methods are needed to estimate AGC in non-merchantable forest areas. The importance of this component is probably low for most studies given that such areas would often have much higher below ground carbon.
3. Assessment of the degree of impact of perturbances on carbon stores, such as fire, has not been assessed and should be quantified for the PRTT where forest fire and regrowth are known to occur. At present it is unknown if this effect is large or small.
4. Regional inter-disciplinary working groups are needed to better define carbon modelling approaches for application in resource use studies, especially where wetlands are abundant and co-occur with uplands. In the PRTT, information is lacking to estimate AGC in the ecotones between areas of deep peat and merchantable forests. Growth curves are also absent for many areas with topography like the PRTT in areas of limited road access.

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TABLES

Table 1. The proportions of land use classes found within the PRTT. Data source: Manitoba FRI.

Land Use / Land Cover	Area (ha)	Study Area Proportion
Peat (bog, fen or marsh)	454,104.14	53.58%
Merchantable Timber	192,176.77	22.68%
Non-Merchantable Timber (without Inventory)	67,295.66	7.94%
Non-Merchantable Timber (with Inventory)	42,911.84	5.06%
Treed Rock	39,968.40	4.72%
Inland Water	33,954.66	4.01%
Beaver Flooded Areas	16,225.25	1.91%
Small Islands	367.85	0.04%
Anthropocentric Land Uses: Roads, Gravel Pits, Airstrips	340.40	0.04%
Bare Rock	99.10	0.01%
Protection Forest	11.98	0.00%
Agriculture	9.82	0.001%
TOTALS	847,465.87	100.00%

Table 2. Description of Merchantable Forest Inventory in Poplar River Traditional Area.

Leading Species	Site Quality	Cutting Class	Total Area (ha)	Average Merchantable Volume (m3/ha)
Balsam Poplar	1 (Good)	pre-rotation age (3)	8.0	64.95
Balsam Poplar	1 (Good)	rotation age (4)	3.9	26.53
Balsam Fir	1 (Good)	pre-rotation age (3)	79.9	112.90
Balsam Fir	1 (Good)	rotation age (4)	27.0	94.77
Black Spruce	1 (Good)	pre-rotation age (3)	17,108.9	87.75
Black Spruce	1 (Good)	rotation age (4)	8,598.8	84.09
Black Spruce	1 (Good)	post-rotation age (5)	820.2	91.05
Black Spruce	2 (Moderate)	pre-rotation age (3)	15,142.1	66.70
Black Spruce	2 (Moderate)	rotation age (4)	3,897.7	59.52
Black Spruce	3 (Poor)	pre-rotation age (3)	16,733.9	65.67
Black Spruce	3 (Poor)	rotation age (4)	1,443.4	43.73
Jack Pine	1 (Good)	pre-rotation age (3)	8,389.7	98.63
Jack Pine	1 (Good)	rotation age (4)	3,655.7	94.82
Jack Pine	1 (Good)	post-rotation age (5)	342.1	104.17
Jack Pine	2 (Moderate)	pre-rotation age (3)	62,151.1	57.45
Jack Pine	2 (Moderate)	rotation age (4)	20,216.9	56.27
Jack Pine	2 (Moderate)	post-rotation age (5)	421.5	75.07
Trembling Aspen	1 (Good)	pre-rotation age (3)	21,520.3	118.49
Trembling Aspen	1 (Good)	rotation age (4)	3,351.4	93.21
Trembling Aspen	1 (Good)	post-rotation age (5)	479.1	98.97
Trembling Aspen	2 (Moderate)	rotation age (4)	3,044.3	82.59
Trembling Aspen	2 (Moderate)	rotation age (4)	1,127.6	50.36
Tamarack/Larch	1 (Good)	pre-rotation age (3)	40.2	85.52
Tamarack/Larch	1 (Good)	rotation age (4)	25.1	50.21
Tamarack/Larch	2 (Moderate)	pre-rotation age (3)	3,115.1	73.05
Tamarack/Larch	2 (Moderate)	rotation age (4)	113.5	67.31
Other Hardwood	1 (Good)	pre-rotation age (3)	19.6	110.39
White Spruce	1 (Good)	pre-rotation age (3)	102.5	134.56
White Spruce	1 (Good)	rotation age (4)	197.2	127.73
Total/Average:			192,176.77	81.95

Table 3. Growth and yield expressed as m³/ha. Bolded figures were interpolated and where upper age classes were not available, static volume following the last known volume was assumed.

Species	Site Class	Age Class (age in yrs)									
		0	20	40	60	80	100	120	140	160	180
Balsam Poplar	Good (1)	0	32.5	64.9	26.5	26.5	26.5	26.5	26.5	26.5	26.5
Balsam Fir	Good (1)	0	28.2	56.5	112.9	94.8	94.8	94.8	94.8	94.8	94.8
Black Spruce	Good (1)	0	29.3	58.5	87.8	84.1	91.1	91.1	91.1	91.1	91.1
Black Spruce	Moderate (2)	0	6.4	12.8	32.0	53.4	66.7	59.5	59.5	59.5	59.5
Black Spruce	Poor (3)	0	13.1	26.3	39.4	52.5	65.7	43.7	43.7	43.7	43.7
Jack Pine	Good (1)	0	32.9	65.8	98.6	94.8	104.2	104.2	104.2	104.2	104.2
Jack Pine	Moderate (2)	0	19.2	38.3	57.5	56.3	75.0	75.0	75.0	75.0	75.0
Trembling Aspen	Good (1)	0	59.2	118.5	93.2	99.0	99.0	99.0	99.0	99.0	99.0
Trembling Aspen	Moderate (2)	0	41.3	82.6	50.4	50.4	50.4	50.4	50.4	50.4	50.4
Tamarack / Larch	Good (1)	0	28.5	57.0	85.5	50.2	50.2	50.2	50.2	50.2	50.2
Tamarack / Larch	Moderate (2)	0	9.6	19.2	28.8	38.5	57.7	57.7	67.3	67.3	67.3
Other Hardwood	Good (1)	0	55.2	110.4	110.4	110.4	110.4	110.4	110.4	110.4	110.4
White Spruce	Good (1)	0	33.6	67.3	100.9	134.6	127.7	127.7	127.7	127.7	127.7

Table 4. Comparison of total carbon (C) estimates made according to the method of Vitt *et al.* (2000) and again with higher precision mapping and slope data for 5 complete map tiles where the results of both studies could be compared directly. Results are shown

NTS 1:50K MAPSHEET	Total C (Tonnes) (Vitt <i>et al.</i>)	C (kg/m ²) (Vitt <i>et al.</i>)	Total C (Tonnes) (Higher Precision Data)	C (kg/m ²) (Higher Precision Data)
53D/13	39,111,726	47	30,430,178	32
63A/14	34,223,284	56	36,065,586	39
63A/15	49,797,041	42	52,433,398	56
63A/16	42,227,278	45	39,874,514	43
63H/1	38,868,651	53	68,977,535	74
63H/2	51,702,279	37	62,717,187	67
63H/3	44,068,597	42	53,029,913	57
Totals/Averages	299,998,856	46	343,528,311	53

Table 5. Merchantable Timber C Stocks (biomass and DOM) in Tonnes in Five-year intervals from Inventory Year (Year 0) to Present Day (Year ~25) assuming no disturbance scenarios.

Time Step	Biomass Above Ground	Biomass Below Ground	Dead Organic Matter Above Ground	Dead Organic Matter Below Ground	Totals
0	5,499,495	1,305,643	5,004,915	15,162,151	26,972,203
5	5,689,520	1,345,313	5,037,212	15,208,810	27,280,856
10	5,806,171	1,369,752	5,074,499	15,265,448	27,515,870
15	5,848,971	1,379,052	5,112,259	15,329,751	27,670,032
20	5,817,649	1,373,327	5,146,190	15,399,339	27,736,504
25	5,779,150	1,366,245	5,152,225	15,469,949	27,767,568

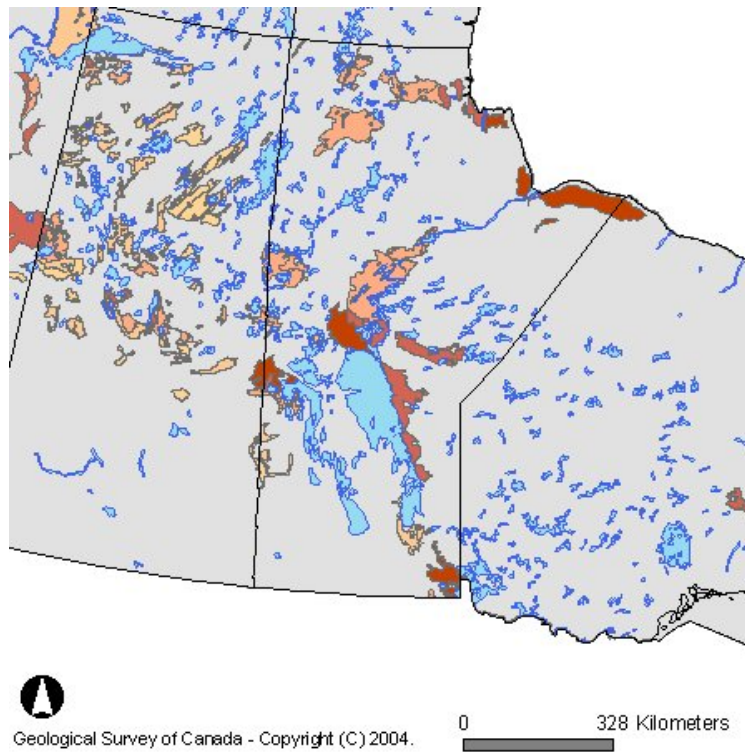


Figure 1. Extent of land covered by bogs and fens where the orange indicates 20-25%, medium brown, 35-55%, and dark brown, 55-75%. From: Natural Resources Canada Canadian Peatland Database.

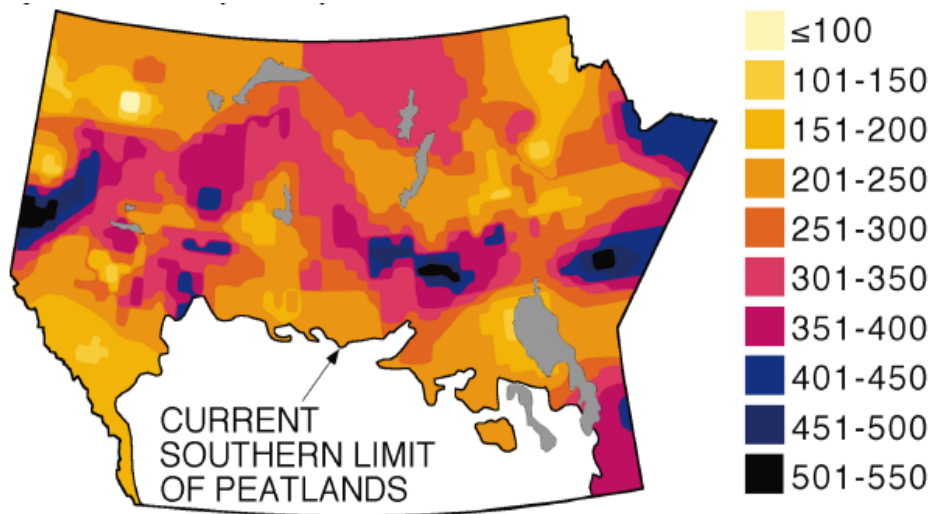


Figure 2. Contoured maximum depth for peatlands on Alberta, Saskatchewan, and Manitoba. Values are in cm. From Vitt et al., 2000.

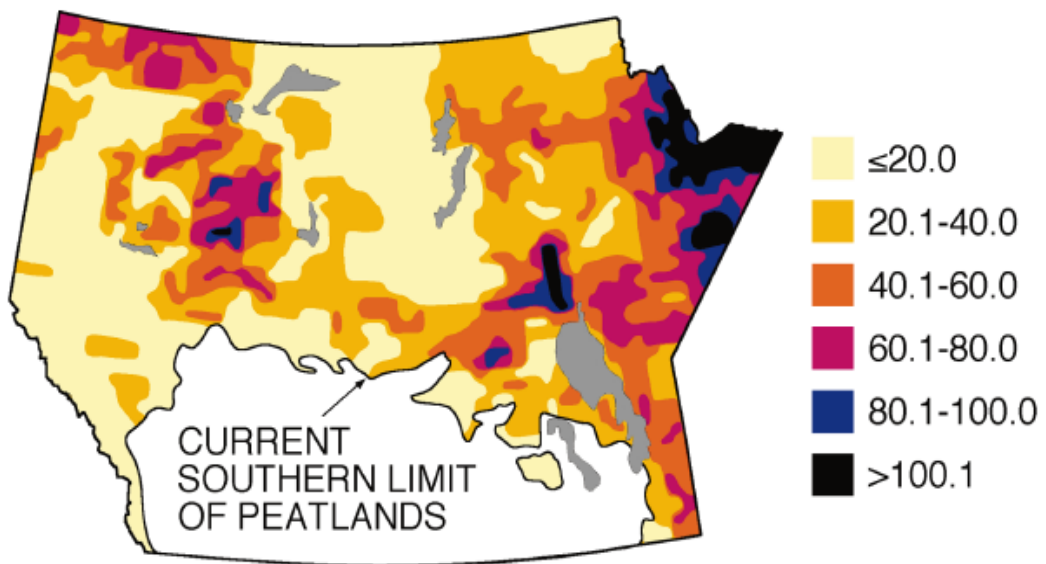


Figure 3. Contoured current carbon storage in the surface and below-ground component of peatlands of Alberta, Saskatchewan, and Manitoba. Values are in kg/m². From Vitt et al., 2000.

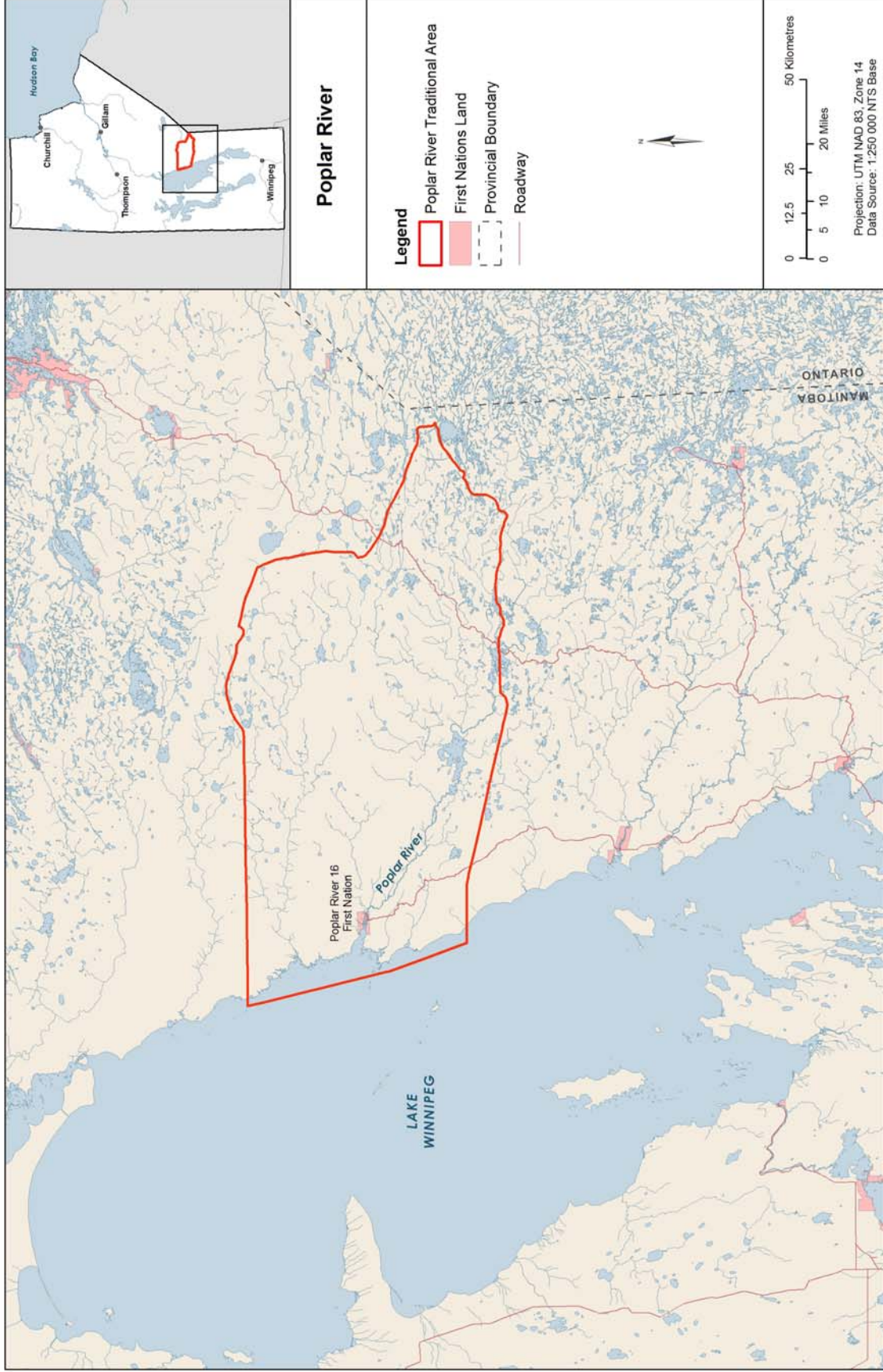


Figure 4. The Poplar River Traditional Territory study area on the east side of lake Winnipeg.

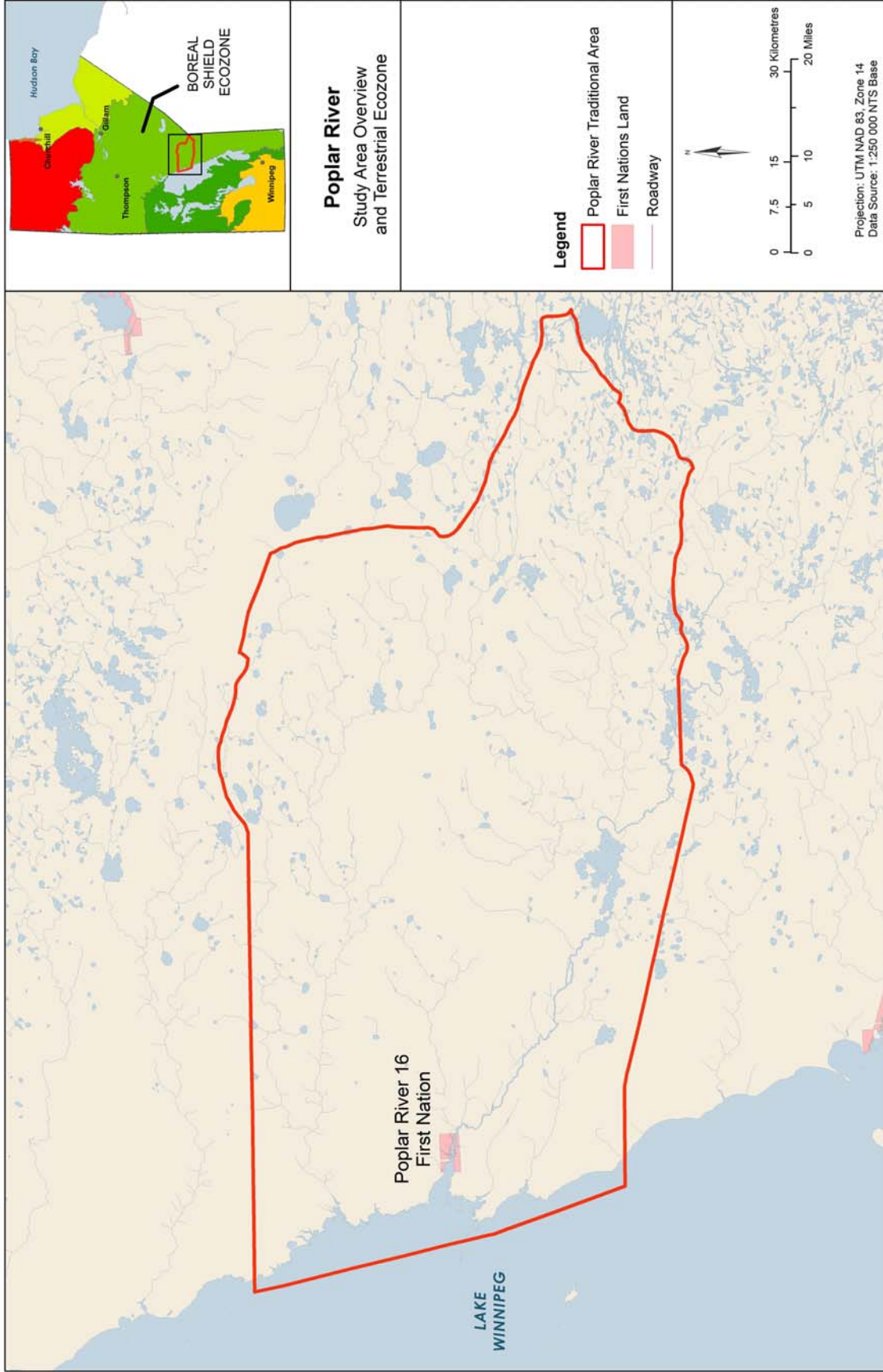


Figure 5. The Poplar River Traditional Territory study area and terrestrial ecozone.

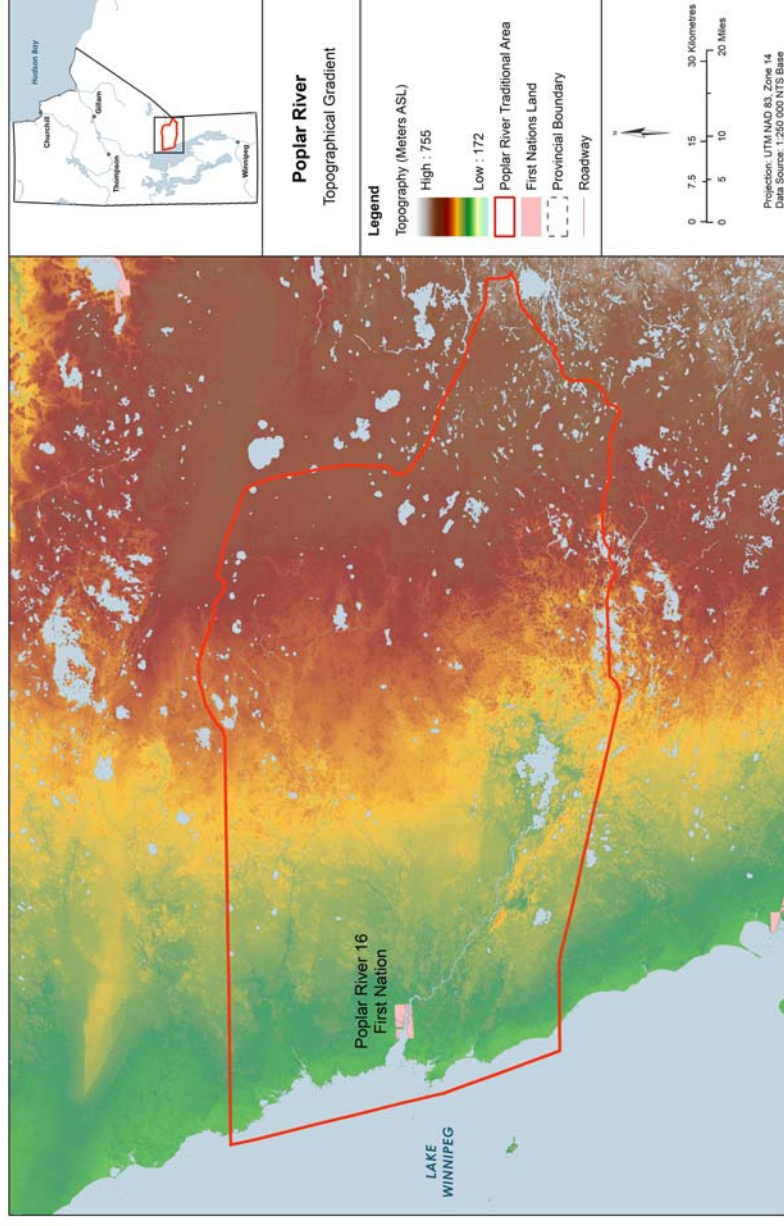


Figure 6. The Poplar River Traditional Territory topographical gradient.

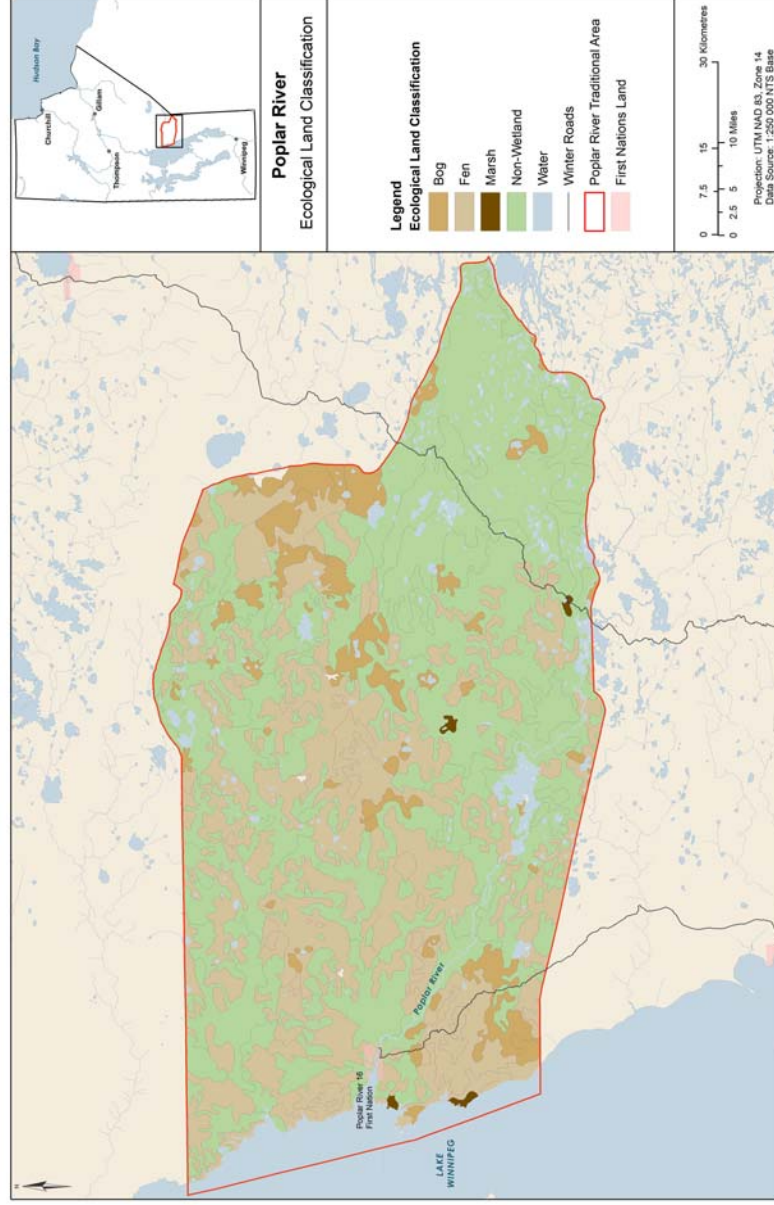


Figure 7. Distribution of wetland and non-wetland classes in the study area.

LAND CLASSES, THEIR PROPORTIONS, AND CARBON STOCKS IN THE POPLAR RIVER TRADITIONAL TERRITORY

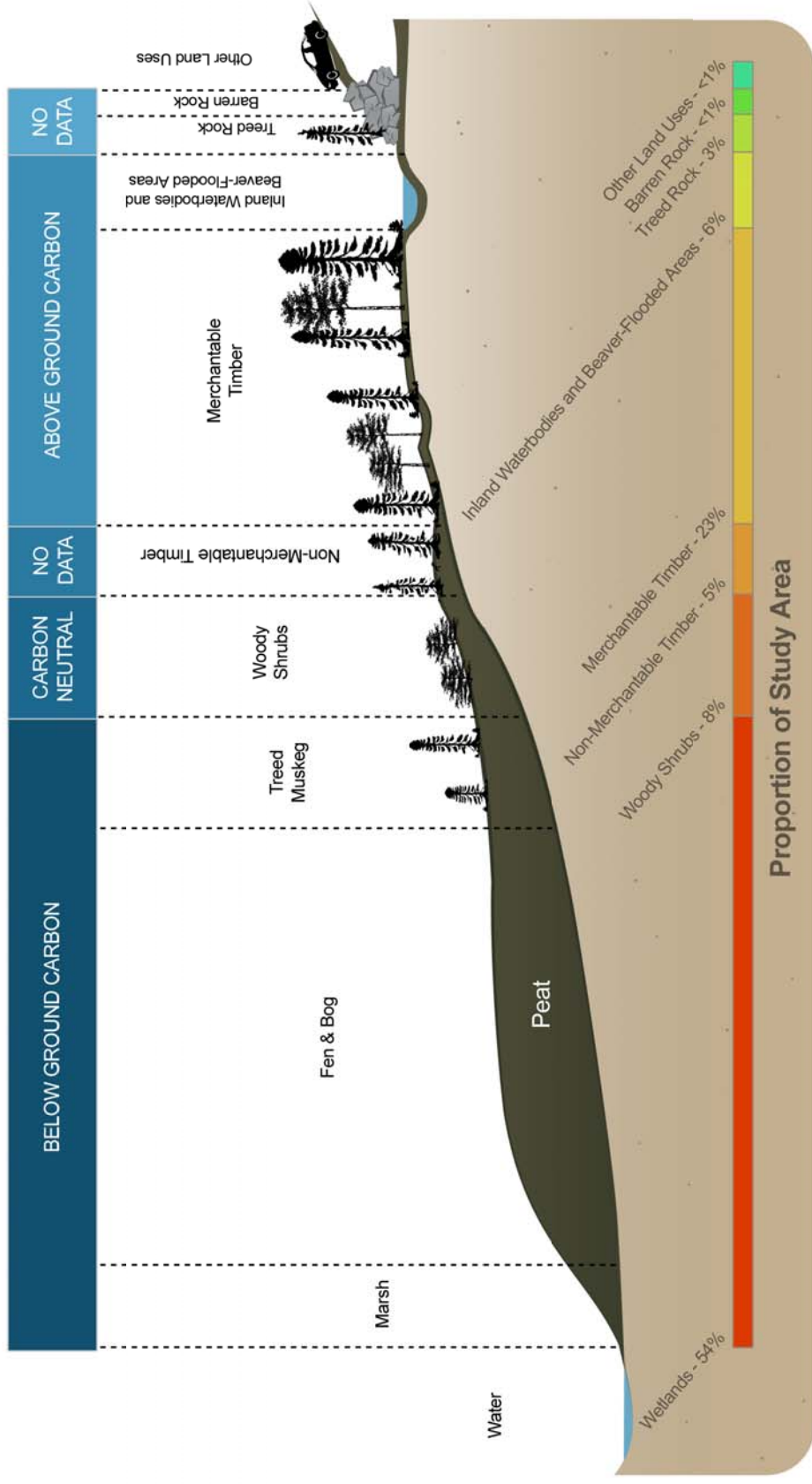


Figure 8. Ecological Land Classes typically found along the topographic gradient in the PRTT showing the area (%) represented by the main types of landcover in the area. Title blocks indicate what sources of carbon were or were not accounted for in this preliminary study.

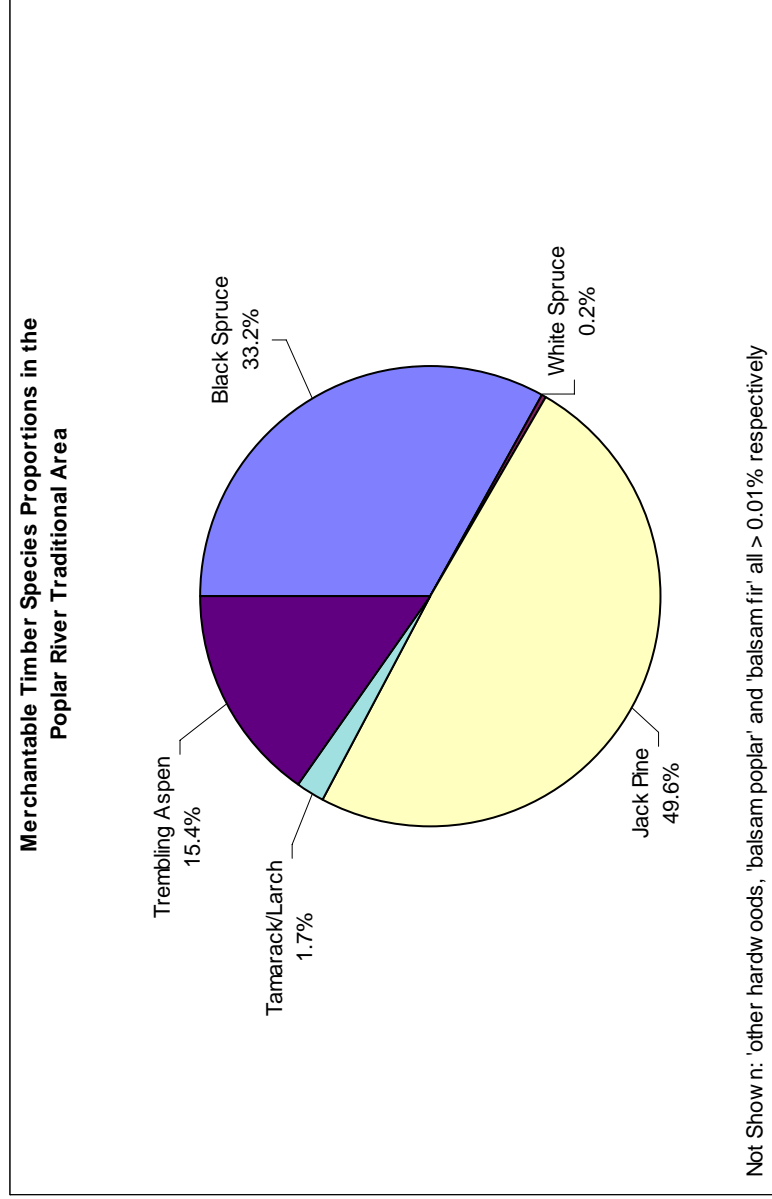


Figure 9. Area of leading/dominant tree species in merchantable stands in the PRTT. Data source: Manitoba FRI.

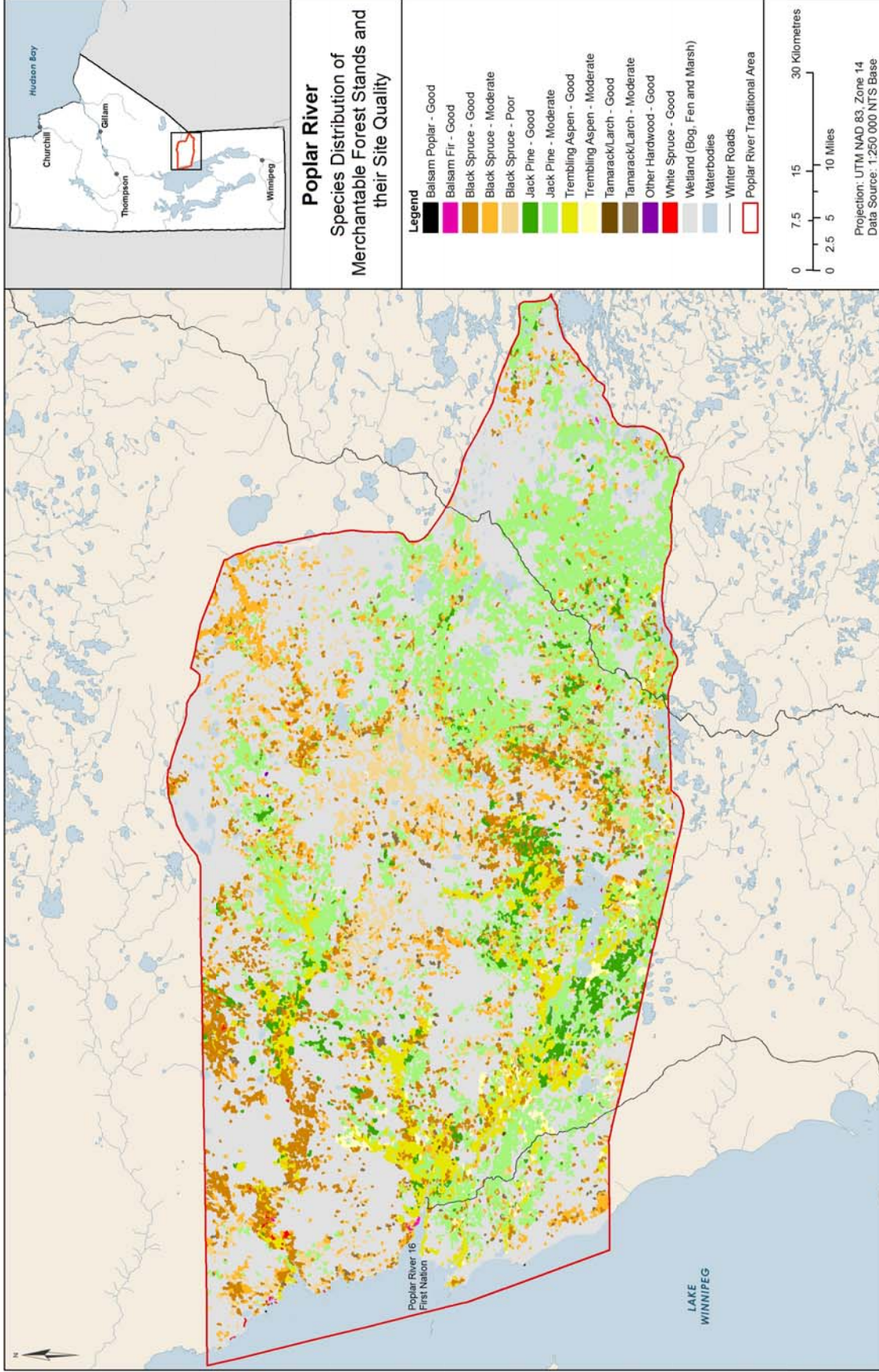


Figure 10. Proportions of leading/dominant tree species within in merchantable stands in the PRTT.

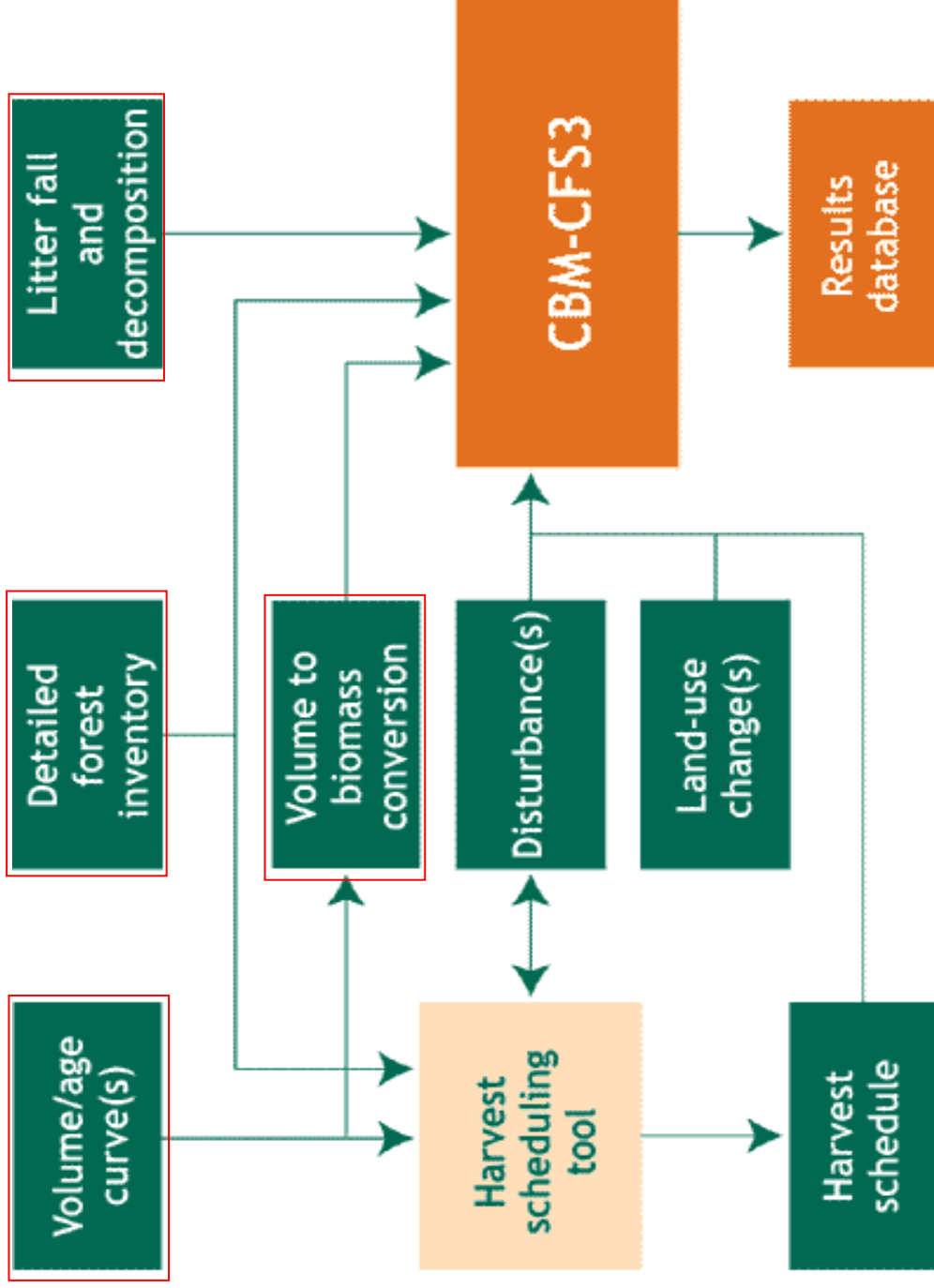


Figure 11. Data inputs (green boxes) display CBM-CFS3 modelling input capabilities; Green boxes with red outlines were used in this application. (Figure taken from Kull et al. 2007.)

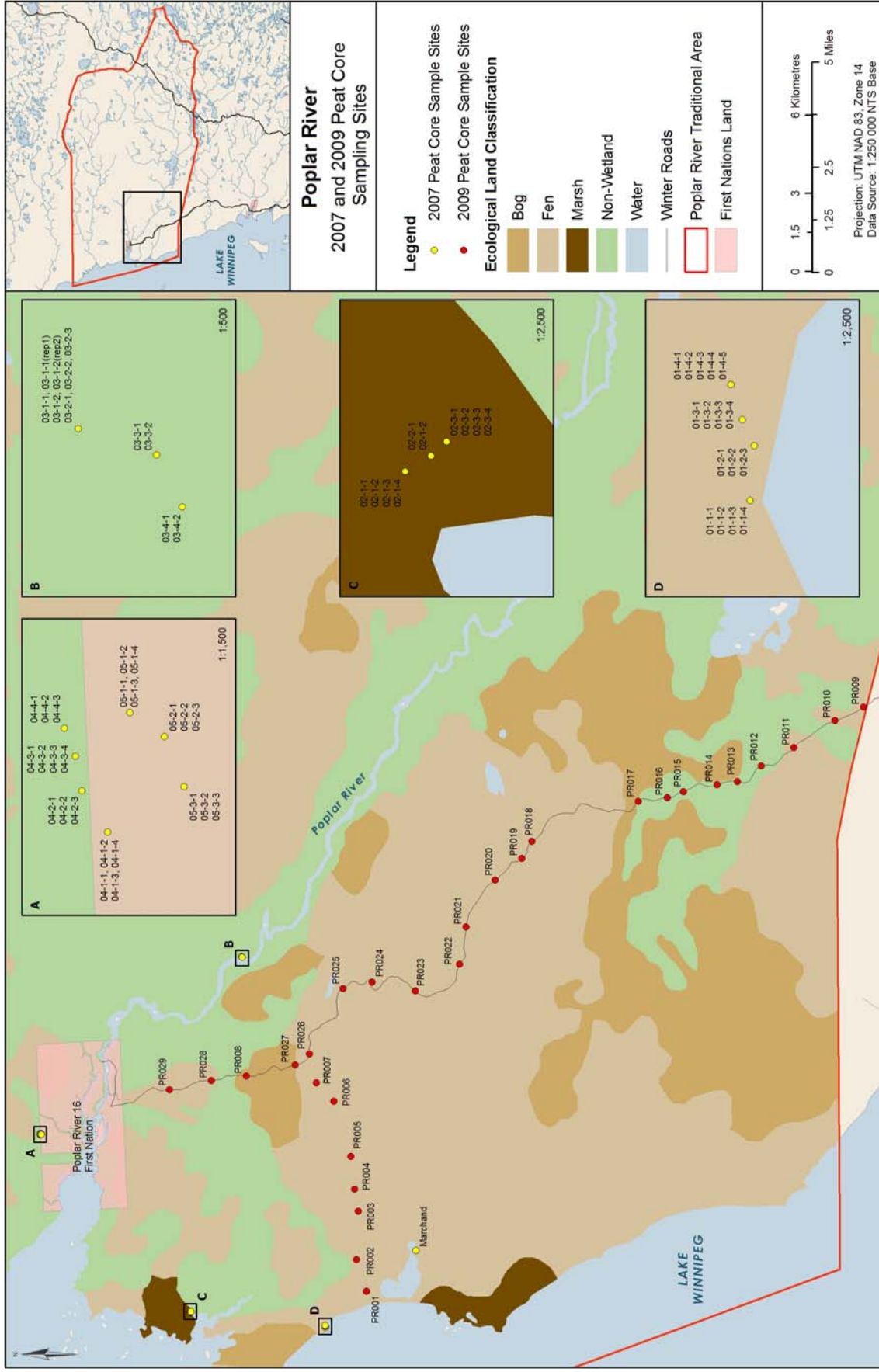


Figure 12. Site locations where a peat corer or dutch auger was used during summer 2007, and winter 2009.

APPENDIX A1.

POPLAR RIVER CARBON INVENTORY TECHNICAL SUMMARY

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TECHNICAL APPENDIX 1: POPLAR RIVER CARBON INVENTORY TECHNICAL REPORT

1.0 INTRODUCTION

The purpose of this project was to develop a method to calculate above ground carbon (AGC) and below ground carbon (BGC) for the Poplar River Traditional Territory (PRTT). Methods were designed to support carbon calculations at a regional scale and, as a result, incorporated more precise data inputs than former sub-national carbon inventories.

2.0 DATA INTEGRATION AND DATA MANAGEMENT FOR BELOW GROUND CARBON

2.1 Generating Ecological Land Classification Polygons and Isolating Wetland Areas

Four National Topographic Service (NTS) 1:250, 000 scale maps were received from PDK Projects Inc. with hand-drawn polygon boundaries derived using the National Wetland Working Group (NWWG 1998) or Ecological Land Classification (ELC) system (for methods on wetland classification see *Vitt et. al, 2000, Halsey et. al. 1997*). Map sheets 53D, 53E, 63A and 63H were each scanned at 300 dots per inch (dpi). The 300 dpi mapsheets were georectified using ESRI ArcGIS software averaging a 65 meter Root Mean Square (RMS) error.

Wetland boundaries were digitized as polylines. Polygons were then built from the polylines to ensure edge matching and planar topology (no gaps or overlaps between polygons) with 100% coverage of the Poplar River Traditional Area. The three hundred¹ wetland polygons were attributed with National Wetlands Working Group wetland classification nomenclature referred to herein as ELC (shown in Table A1-1)

Codes “F”, “B” and “M” represent fen, bog and marsh wetland classes respectively. A “Z” code was also present in the ELC data received representing non-wetland areas.

For each polygon, proportions (in 10% intervals) of up to a maximum of three wetland classes were provided. Vegetation modifiers were provided as subscripts to proportions and wetland landforms as superscripts. In some cases, there were two vegetation and wetland modifiers indicating heterogeneity in the observed area. The following two examples represent ELC polygon attributes in the Poplar River Traditional Area:

¹ Four polygons were not labeled with ELC attributes which comprised 12.9 km² in area or 0.15% of the study area. These areas are referred to as “ELC unknown”.

F6_{OT}Z4_T indicates a 60% coverage that is mixed open and wooded with a 40% non-wetland area which is wooded

B4^{xi}_F Z4 F2^p_{OT} represents an area with a 40% coverage of forested mixed permafrost bog with internal lawns, a 40% non-wetland area, and a 20% patterned, open/wooded .

Two field programs were undertaken in summer 2007 and winter 2009 to sample peat cores and depths (discussed in Section 3.1). Figure A1-1 displays 2007 and 2009 sample sites and the ELC polygons in the Poplar River Traditional Territory displayed by their leading wetland class.

2.2 Stratifying Wetland Areas from Open Water, Forested Areas, and other Land Use Areas

As the ELC areas were collected representing a mixture of bog, fen, marsh and / or non-wetland classes, it was necessary to parse out each wetland class (bog, fens) to calculate wetland class areas and ultimately to calculate below ground carbon volumes. The following sections describe how water, forested areas and other land uses were stratified into homogeneous sub-units (see Ravindranath & Ostwald, 2008) then subtracted from the ELC polygon areas retaining wetland classes eligible for below-ground carbon calculations. Marsh areas were treated separately described in Section 3.7.

2.2.1 Delineating Water

Open water areas were removed by subtracting the National Topographic Service's (NTS) 1:250,000 scale² water polygons from the ELC polygons, effectively creating 'donut holes' in the ELC polygons where lakes and major rivers were present.

2.2.2 Delineating Forested Areas

As the ELC classification examples above illustrate, wetlands (bog and marsh) were frequently interspersed with non-wetland areas represented by the code "Z". Of the 296 attributed ELC polygons, 276 or 93% contained non-wetland proportions.

To accurately calculate below ground carbon, forested areas needed to be removed from the wetlands using a Manitoba forest inventory product called the Forest Resource Inventory (FRI). To enable the exclusion of portions of the ELC polygons that were represented by the "Z" code, the FRI and the ELC polygons were merged together to produce 44,900 polygons with both the FRI and the ELC attributes. FRI polygons such as densely forested areas, rocky areas or other areas with unsuitable characteristics for below ground carbon storage were removed. This process is described next.

At the highest classification level, FRI divides areas into land and water classes. Water classes were excluded from the ELC polygons. Because the FRI is collected at a 1:15,840 scale, water area boundaries were more precise than the NTS 1:250,000 water areas previously excluded. Where FRI water overlapped ELC data, the FRI water classification was adopted. Where FRI land areas overlapped the less precise ELC water areas, an 'error' classification was adopted due to a lack of ELC data (Figure A1-2). This error comprises 70.5 km² or 0.8% of the study area.

² The NTS 1:250,000 water body polygons can have up to a 150 meter discrepancy from their actual horizontal location. Therefore, at this scale, lakes and other water bodies may have a smoothed or generalized appearance and smaller water bodies may not be represented at all. The 1:250,000 scale NTS was selected because it matched the scale at which the ELC polygons were received and therefore, by utilizing the 1:250,000 NTS water bodies, no overall data precision is lost. This scale does, however, have some implications for modeling carbon stores discussed below.

At the next level of classification, the FRI delineates forested and non-forested areas. Forested areas are divided into productive (merchantable) forested areas (codes 1-600 under the LND_ID field) and non-productive forested areas (codes >700 under the LND_ID). All productive (merchantable) timber and non-merchantable timbered areas were excluded from below ground carbon calculations. These areas were used to calculate above ground carbon stores. Non-productive forested classes such as treed rock (LND_ID 710-713), protection forests and small islands (<2ha) (LND_ID 730, 732) were also excluded because of their low capability to produce below ground carbon.

2.2.3 Delineating Other Land Use Areas

Other land use class areas such as cropland, cleared lands, townsites, airstrips, roads, gravel pits, dumps sites and areas flooded by beavers were also excluded from below ground carbon calculations. Table A1-2 displays a summary of land categories in the study area and their eligibility for above or below ground carbon calculations.

2.2.4 Recalculating Wetland Proportions

Once water, forest and other land use areas were removed from ELC polygons, the proportions of bog, fen and marsh needed updating because formerly their proportions were mixed with non-forested classes.

For each wetland class, where T_A is total polygon area, where Z_A is the area of the non-wetland class (Z proportion/10 x polygon area), and where B_{OLD-P} , F_{OLD-P} or M_{OLD-P} is the former proportions of wetland classes, the recalculated proportions of Bog wetland class were derived by:

$$B_{PROP} = ((B_{OLD-P}/10) \times T_A) + (B_{OLD-P} / (B_{OLD-P} + F_{OLD-P} + M_{OLD-P}) \times Z_A;$$

new fen proportions were derived by:

$$F_{PROP} = ((F_{OLD-P}/10) \times T_A) + (F_{OLD-P} / (F_{OLD-P} + B_{OLD-P} + M_{OLD-P}) \times Z_A;$$

and, new marsh proportions were derived by:

$$M_{PROP} = ((M_{OLD-P}/10) \times T_A) + (M_{OLD-P} / (M_{OLD-P} + F_{OLD-P} + B_{OLD-P}) \times Z_A.$$

Figure A1-3 illustrates an ELC polygon prior to excluding non-wetland classes and the results following exclusion of non-wetland classes.

Variance between the old and new proportions was tested and averaged +3% for bog and -3.6% for fen. Variance could not be assessed for marsh given the small sample size, $n = 2$. Other possible explanations for high individual polygon variances, which amounted to 50% in one polygon and 40% in two polygons of were shifting patterns of land use in the time interval between FRI inventory and the ELC survey, fire patterns, survey errors, or transcription error.

At this stage, areas for each key wetland type were calculated. Fens are divided into three categories: 1) Patterned fens: denoted with a subscript of 'p'; 2) Wooded or Forested fens: with a superscript starting with 'T' or 'F'; or 3) Open fens: with a superscript starting with an 'O'. Patterned fens, whether open, wooded, or forested are treated distinctly. Bogs have two classifications: 1) Permafrost bog denoted with an 'x'; and 2) Non-permafrost bogs with no 'x' notation.

3.0 CALCULATION OF BELOW GROUND CARBON

Calculating carbon involves generating gross volumes for the three types of fens and two bog types for which peat slab depths and areas are critical inputs. Following gross volume calculations, a correction factor for slope basin undulations is applied which reduces the depth of the peat slab. To convert these corrected volumes into C values, a bulk density factor is applied. Details of this process is described in the ensuing paragraphs.

3.1 Overview of Sampling Programs

Field programs were undertaken in summer of 2007 and winter of 2009. In 2007, twenty-nine peat core samples were collected at five sites. These sites were clustered in boat-accessible areas proximal to the community of Poplar River. Sixty peat cores were collected in 2009 at 18 sites that were distributed linearly along the winter road linking Berens River to Poplar River (Figure A1-1 displays the distribution of field sample sites). Due high costs of accessing other areas of the Poplar River Traditional Territory, sampling was not distributed more evenly across the study area.

3.2 Calculating Gross Peat Depths

The process for peat depth calculations involves determining the maximum peat depth at a sample site and its' replicates. Following determination of maximum peat slab depth in centimeters, the slab depth is downward adjusted for basin slope undulations. Together, the 2007 and 2009 field program generated an average maximum peat depth of 183 cm (Table A1-3). Table A1-4 shows all samples. Ten marsh samples, averaging 164 cm depth, were treated separately as they are considered non-accumulating wetland areas (pers. comm. L. Halsey, 6 June 2009).

Because of the clustered nature of peat core sampling, peat depths from the 2007 and 2009 sampling programs could not be extrapolated to all peat areas in the study area. Instead, these peat depths were treated as a validation for the peat depths published in Vitt *et. al.* (2000) to determine whether these published depths would be acceptable for use in the PRTT study area.

Vitt *et. al.* (2000) maximum uncorrected peat depths for mapsheet 63A14, where all the field samples occurred, was recorded as 207 cm. Field samples, also uncorrected for slope, averaged 184 cm suggesting that a low-to moderate overestimate of peat depth by Vitt *et. al.* in the study area. We next compared peat depths corrected for slope basin topology.

3.3 Calculating Corrected Peat Depths and Volumes

Vitt *et. al.* (2000) corrected for slope in the following way: (1) peat volumes on level slopes (1-3%) were multiplied by a 98% estimated occupancy area; (2) peat volumes located on undulating slopes (4-9%) was corrected at a 93.5% estimated occupancy, (3) peat on rolling slopes (10-15%) by 87.5%; and, (4) and peat on hummocky slopes (16-30%) was corrected to a 77% volume adjustment. In mapsheet 63A14, Vitt *et. al.* peat depth was corrected using the 0.875 multiplier for rolling slopes resulting in modifying the 207cm maximum depth to 181cm adjusted depth. Sufficient discrepancies remained between Vitt *et. al.* 181cm corrected value and our corrected value (assuming the same rolling slopes) of 161cm.

To identify if the source of this discrepancy could be identified, the authors tested whether a slope classification refinement and therefore, an adjustment in the corresponding multiplication factors, could explain the variance between the two adjusted values.

3.4 Refining Topography

In 2000, NASA's Shuttle Radar Topographic Mission (SRTM) collected digital elevation for over 80% of the world's surface (CGIAR Consortium for Spatial Information, 2008). A SRTM digital elevation model was used to calculate a percent slope grid at a 90 m by 90 m pixel resolution for the Poplar River Traditional study area. This slope grid was derived using ArcGIS's Spatial Analyst tool, then reclassified to four slope percent classes described above from Vitt *et. al.* (2000).

Slopes values for all 64 samples located in 64A14 were overlaid with the slope grid, averaging 1.76% slope with all values falling within the 1-3% slope category, indicating that at the sample locations, depths would be more accurately be corrected with the 98% multiplier associated with "level" topography. Therefore, our original unadjusted peat depth average of 184.0, adjusted to 98% of its value for occupied peat area, was 180.3cm; a value very similar to the Vitt *et. al.* estimate of 181.1cm.

Given comparative results between actual field sample depths and the Vitt *et. al.* depth estimates in 64A14 and since not all regions in the study area were sufficiently sampled in the 2007 and 2009 sample programs, Vitt *et. al.* (2000) peat depths by 1:50,000 mapsheet were adopted as a reasonable proxy for peat depths elsewhere in the study area. We recognize that further validation through field sampling at other locations would add confidence to this process.

Slope classes and their respective multipliers were developed to adjust for area occupied, nevertheless, instead of applying them on a mapsheet basis, they were applied at a polygonal scale to add precision to the model. The application of the slope multiplier is described next.

3.5 Attributing Files with the Basin Slope Adjustment Multiplier

A shapefile was derived from the NTS index to store mapsheet numbers and Vitt *et. al.* peat depths. This file was intersected with the ELC polygon file generated from the process described in section 2.0 in order to split polygons by NTS sheet boundaries and to populate a gross maximum peat depth field. This shapefile contained 427 wetland polygons.

To populate the multiplier to adjust for variances in slope basin topology, a zonal histogram was created from the slope grid (slopes classified as 1 (level), 2 (undulating), 3 (rolling), and 4 (hummocky – knob and kettle)). The zonal histogram output provided a pixel count of each slope class in each polygon. The pixel counts were used to derive the percentages of each slope class for each polygon to divide areas for which to apply the appropriate slope multiplier calculating biomass. Three small polygons were excluded because their area was not large enough to contain one pixel.

Ninety seven percent of wetlands were located on 'level' slopes (1-3%); slightly more than two percent were found on 'undulating' slopes (4-9%) and about 0.5% of peat areas were found on 'rolling slopes' (10-15%). No peat existed on hummocky- knob and kettle terrain in the study area.

The next step was to process volumes and carbon.

3.6 Calculating Peat Volumes and Carbon

Bulk density values, adopted from Vitt *et. al.* (2000), shown in table A1-5, were multiplied with slope corrected depths and multiplied by the five types of wetland classes to produce total carbon values for each

of the 427 wetland polygons. Total carbon values were normalized by the total study area to produce C expressed as kg/m^2 .

3.7 Calculating Marsh Volumes and Carbon

Marsh volumes were calculated using the same bulk density and process as fen wetland classes. Ideally, a bulk density specifically for marsh types will be developed from the field sampling to improve precision of this calculation.

FIGURES

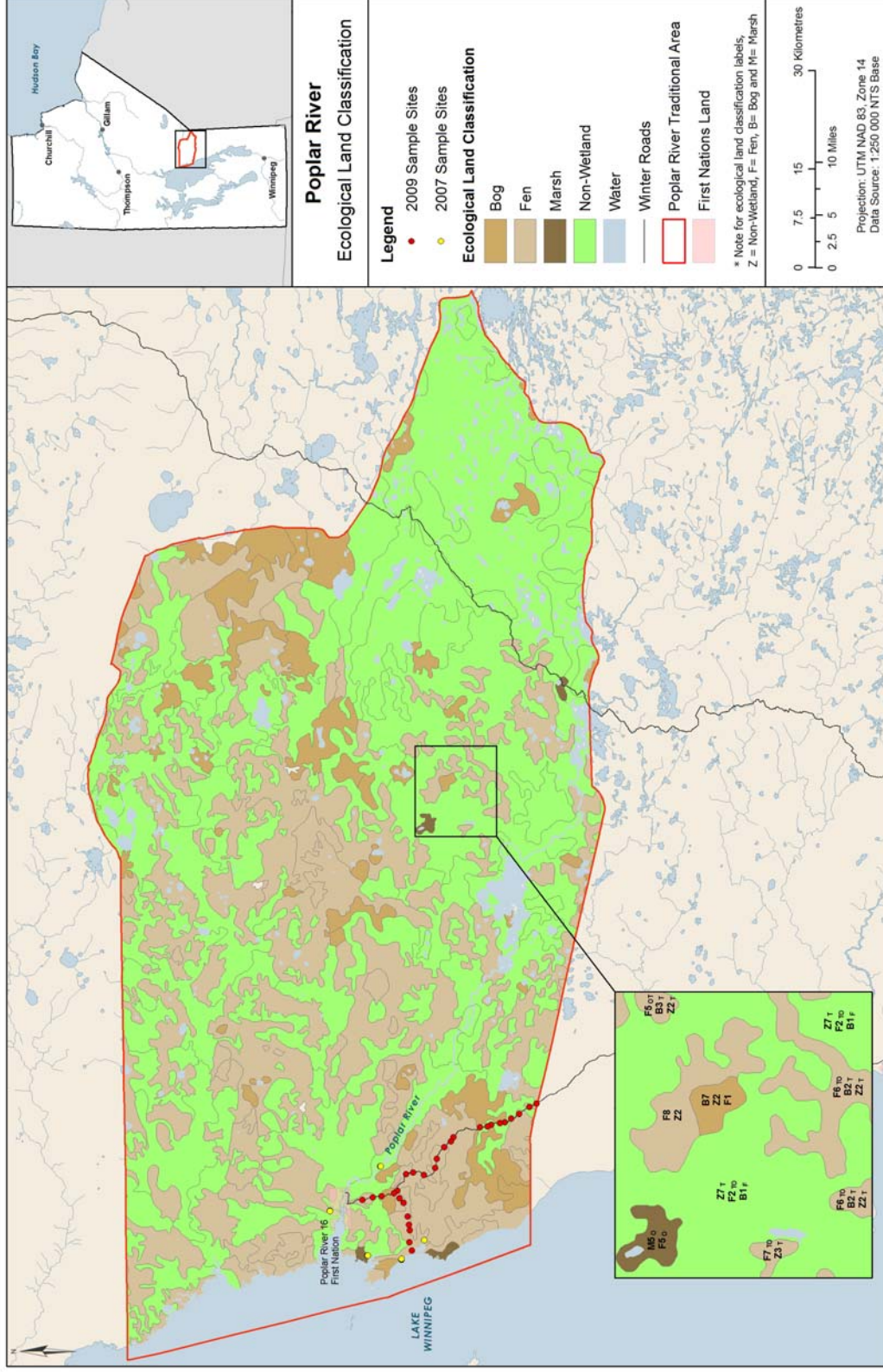


Figure A1-1. Ecological Land Classification for Poplar River Traditional Area and Peat Core Sample Locations (2007 & 2009)

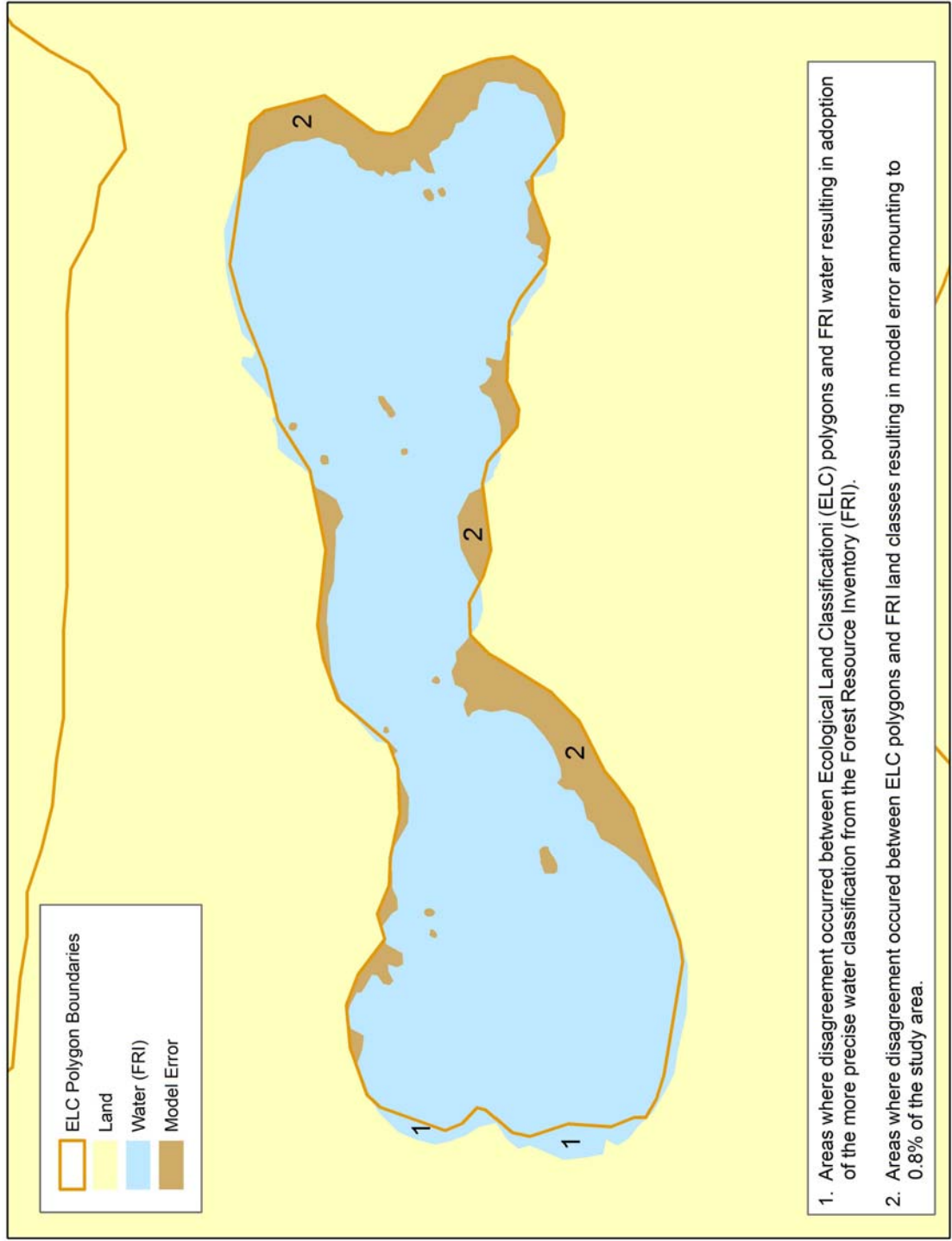


Figure A1-2. Description of FRI and ELC Disagreements

1. ELC polygon creation 2. Exclusion of non-wetland classes 3. Redistribution of ELC proportions

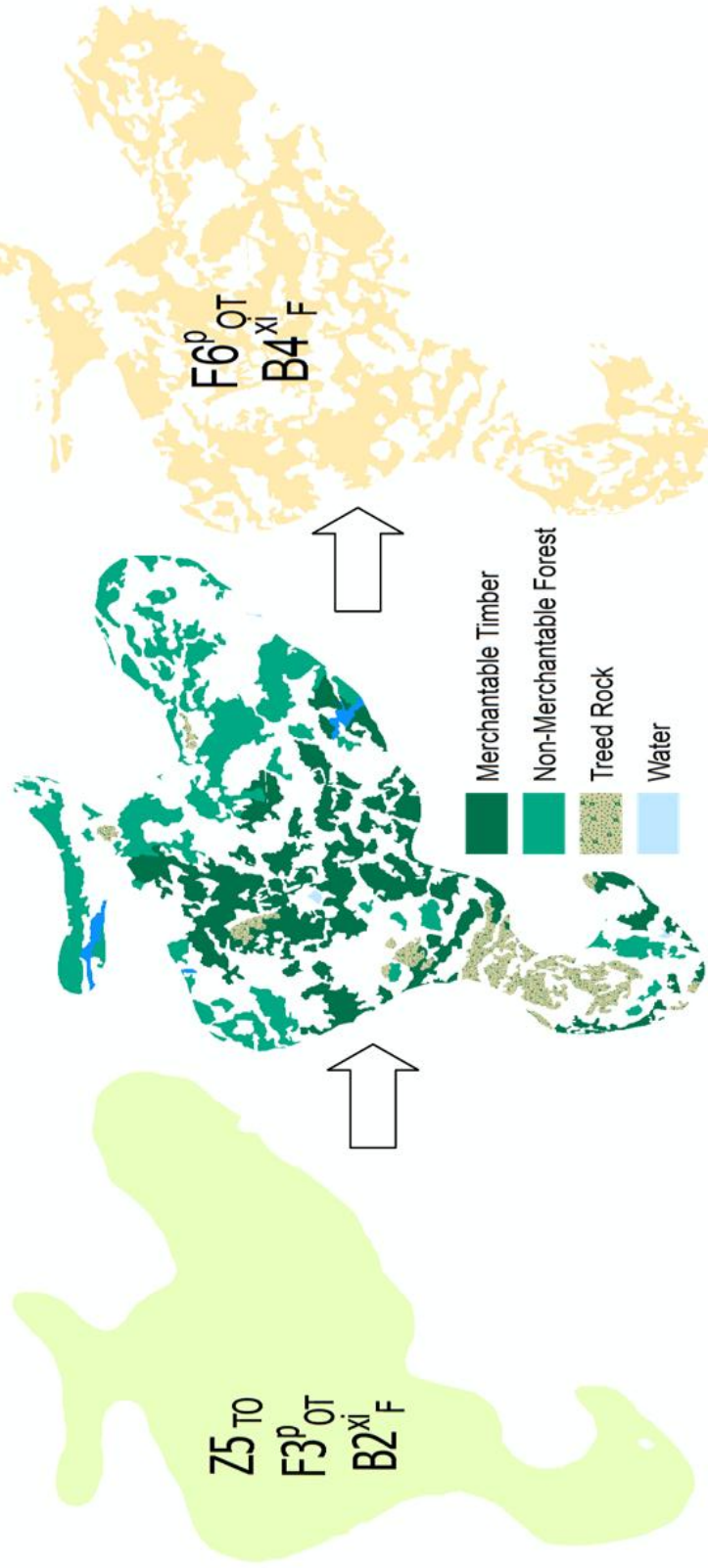


Figure A1-3. Excluding Non-Wetland classes and redistributing ELC proportions

TABLES

Table A1- 1. Wetland Classification System (adapted from Halsey. et. al. 1997, p. 244).

Classification Level	Attributes	Code
Wetland Class	Bog	B
	Fen	F
	Marsh	M
	Swamp	S
	Shallow Open Water	W
Vegetation Modifier	Forested (>70% tree cover)	F
	Wooded (>6%-70% tree cover)	T
	Open (<=6% tree cover)	O
Wetland Landform Modifier	Patterned	P
	Permafrost	X
	Type 2 internal lawns	I
	Nonpatterned	N

Table A1- 2. Land Categories Present in Study Area and Eligibility for Above / Below Carbon Inventory Calculations

CATEGORY	DESCRIPTION	FOREST RESOURCE INVENTORY CODE (LND_ID)	ELIGIBLE FOR ABOVE GROUND CARBON CALCULATIONS	ELIGIBLE FOR BELOW GROUND CARBON CALCULATIONS
LAND (1-899)	PRODUCTIVE (1-699)	(01 - 39) (40 - 79) (80 - 89) (90 - 99)	Y (Merchantable)	N
			N (Non-Merchantable: No species. Composition)	N
			N (Non-Merchantable: Species. Composition)	N
FORESTED (1-799)	Treed Muskeg (unspecified species)	(700)	N	Y
	Black Spruce Treed Muskeg	(701)	N	Y
	Tamarack Larch Treed Muskeg	(702)	N	Y
	Treed Rock (unspecified species)	(710)	N	N
	Jack Pine Treed Rock	(711)	N	N
	Black Spruce Treed Rock	(712)	N	N
	Hardwood Treed Rock	(713)	N	N
	Willow / Alder	(720)	N	Y
	Willow	(721)	N	Y
	Dwarf birch	(723)	N	Y
	Protection Forest	(730)	N	N
	Small Islands	(732)	N	N
	NON-FORESTED (800-899)	BARREN-BARE ROCK	(800) (802)	N N
AGRICULTURE		(812)	N	N

		Land clearing	(815)	N	N
		Moist Prairie	(822)	N	Y
	MEADOW	Wet Meadow	(823)	N	Y
		Marsh Muskeg	(830)	N	Y
	MARSH / MUSKEG	Muskeg	(831)	N	Y
		String Bogs	(832)	N	Y
		Marsh	(835)	N	Y
		Mud / Salt Flats	(838)	N	Y
		Sand Beaches	(839)	N	Y
		Unclassified	(840)	N	Y
		Townsite / Residential Sites	(841)	N	N
		Airstrips	(842)	N	N
	UNCLASSIFIED	Roads / Railroads / Dikes / Dams	(843)	N	N
		Transmission Lines / Pipelines	(844)	N	N
		Gravel Pits / Mine / Dump Sites	(845)	N	N
		Beaver Floods	(848)	N	N
		Unclassified	(900)	N	N
WATER (900)	UNCLASSIFIED	Rivers	(901)	N	N
	RIVERS	Lake Winnipeg	(991)	N	N
	LAKES				

Table A1- 3. Peat Core Sample Distribution and Peat Depths

Peat Polygon ID	Sample (n)	Fen Type	Bog Type	ELC Classification	Maximum Peat Depth (cm)
46	1	Open Wooded	Wooded	B1.7T F8.3OT	200
51	2	Patterned / Open Wooded	Wooded	B1.3T F8.7pOT	318
58	6	Treed	Wooded	B2.5T F7.5TO	260
86	3	Open / Wooded	N/A	F100T	318
100	8	Wooded	Wooded	B1T F9T	191
102	1	Open	N/A	F100	90
109	2	Wooded / Open	Wooded	B6.7T F3.3TO	165
113	20	Open	N/A	F100	206
121	10	N/A	N/A	M100	164
126	2	Open	N/A	F100	170
134	11	Open	N/A	F100	65
179	24	Wooded	Wooded	B2.5T F7.5iT	159
Average (excluding marsh polygon ID 121)					183

Table A1- 4. 2007 and 2009 Peat Core Sample Locations, Depths and ELC Classification at Sample Sites

NAME	X (UTM 14)	Y (UTM 14)	DATE/TIME	MAX CORE DEPTH* (cm)	BOG TYPE	FEN TYPE	ELC CLASS
PR001	608711	5862530	2/28/2009 10:14	250	N/A	Open	F100
PR002	609932	5862916	2/28/2009 10:30	180	N/A	Open	F100
PR003	611778	5862846	2/28/2009 12:08	260	Wooded	Wooded	B1T F9T
PR004	612622	5862989	2/28/2009 1:08	300	N/A	Open	F100
PR005	613879	5863127	2/28/2009 1:25	120	N/A	Open	F100
PR006	615990	5863783	2/28/2009 1:54	200	Wooded	Wooded	B1T F9T
PR007	616696	5864448	2/28/2009 2:37	120	Wooded	Wooded	B1T F9T
PR008	616962	5867135	2/28/2009 2:56	100	Wooded	Wooded/Open	B6.7T F3.3TO
PR009	631117	5843494	3/1/2009 9:40	280	Wooded	Open Wooded / Patterned	B1.3T F8.7pOT
PR010	630597	5844589	3/1/2009 10:44	355	Wooded	Open Wooded / Patterned	B1.3T F8.7pOT
PR011	629554	5846158	3/1/2009 11:38	200	Wooded	Open Wooded	B1.7T F8.3OT
PR012	628857	5847411	3/1/2009 12:54	115	Wooded	Wooded	B2.5T F7.5TO
PR013	628259	5848327	3/1/2009 1:28	90	Wooded	Wooded	B2.5T F7.5TO
PR014	628136	5849107	3/1/2009 2:09	275	Wooded	Wooded	B2.5T F7.5TO
PR015	627867	5850397	3/1/2009 3:11	250	Wooded	Wooded	B2.5T F7.5TO
PR016	627634	5851004	3/2/2009 9:12	400	Wooded	Wooded	B2.5T F7.5TO
PR017	627505	5852129	3/2/2009 10:09	430	Wooded	Wooded	B2.5T F7.5TO
PR018	625956	5856193	3/2/2009 11:43	155	Wooded	Wooded	B1T F9T
PR019	625317	5856583	3/2/2009 12:09	180	Wooded	Wooded	B1T F9T
PR020	624485	5857602	3/2/2009 1:08	430	N/A	Open / Wooded	F100T
PR021	622685	5858720	3/2/2009 2:09	350	N/A	Open / Wooded	F100T
PR022	621261	5858959	3/2/2009 2:49	175	N/A	Open / Wooded	F100T
PR023	620227	5860663	3/2/2009 3:23	140	Wooded	Wooded	B1T F9T
PR024	620568	5862310	3/3/2009 10:14	250	Wooded	Wooded	B1T F9T
PR025	620319	5863429	3/3/2009 10:33	90	N/A	Open	F100
PR026	617809	5864719	3/3/2009 10:53	330	Wooded	Wooded	B1T F9T
PR027	617397	5865254	3/3/2009 11:07	230	Wooded	Wooded/Open	B6.7T F3.3TO
PR028	616795	5868474	3/3/2009 11:22	200	N/A	Open	F100
PR029	616433	5870082	3/3/2009 11:46	140	N/A	Open	F100
1-1-1	607338	5863967	7/13/2007	200	N/A	Open	F100
1-1-2	607338	5863967	7/13/2007	200	N/A	Open	F100
1-1-3	607338	5863967	7/13/2007	200	N/A	Open	F100
1-1-4	607338	5863967	7/13/2007	200	N/A	Open	F100
1-2-1	607364	5863969	7/13/2007	140	N/A	Open	F100
1-2-2	607364	5863969	7/13/2007	140	N/A	Open	F100
1-2-3	607364	5863969	7/13/2007	140	N/A	Open	F100
1-3-1	607364	5863973	7/13/2007	200	N/A	Open	F100
1-3-2	607364	5863973	7/13/2007	200	N/A	Open	F100
1-3-3	607364	5863973	7/13/2007	200	N/A	Open	F100
1-3-4	607364	5863973	7/13/2007	200	N/A	Open	F100
1-4-1	607427	5863982	7/13/2007	250	N/A	Open	F100
1-4-2	607427	5863982	7/13/2007	250	N/A	Open	F100
1-4-3	607427	5863982	7/13/2007	250	N/A	Open	F100
1-4-4	607427	5863982	7/13/2007	250	N/A	Open	F100

1-4-5	607427	5863982	7/13/2007	250	N/A	Open	F100
2-1-1	607908	5869279	7/13/2007	205	N/A	N/A	M100
2-1-2	607908	5869279	7/13/2007	205	N/A	N/A	M100
2-1-3	607908	5869279	7/13/2007	205	N/A	N/A	M100
2-1-4	607908	5869279	7/13/2007	205	N/A	N/A	M100
2-2-1	607920	5869259	7/13/2007	150	N/A	N/A	M100
2-2-2	607920	5869259	7/13/2007	150	N/A	N/A	M100
2-3-1	607931	5869247	7/13/2007	130	N/A	N/A	M100
2-3-2	607931	5869247	7/13/2007	130	N/A	N/A	M100
2-3-3	607931	5869247	7/13/2007	130	N/A	N/A	M100
2-3-4	607931	5869247	7/13/2007	130	N/A	N/A	M100
3-1-1	621527	5867304	7/13/2007	50	N/A	Open	F100
3-1-2	621527	5867304	7/13/2007	50	N/A	Open	F100
3-1-1 (rep1)	621527	5867304	7/13/2007	50	N/A	Open	F100
3-1-2 (rep2)	621527	5867304	7/13/2007	50	N/A	Open	F100
3-2-1	621527	5867304	7/13/2007	110	N/A	Open	F100
3-2-2	621527	5867304	7/13/2007	110	N/A	Open	F100
3-2-3	621527	5867304	7/13/2007	110	N/A	Open	F100
3-3-1	621523	5867292	7/13/2007	50	N/A	Open	F100
3-3-2	621523	5867292	7/13/2007	50	N/A	Open	F100
3-4-1	621515	5867288	7/13/2007	45	N/A	Open	F100
3-4-2	621515	5867288	7/13/2007	45	N/A	Open	F100
4-1-1	614705	5875010	7/13/2007	165	Wooded	Wooded	B2.5T F7.5iT
4-1-2	614705	5875010	7/13/2007	165	Wooded	Wooded	B2.5T F7.5iT
4-1-3	614705	5875010	7/13/2007	165	Wooded	Wooded	B2.5T F7.5iT
4-1-4	614705	5875010	7/13/2007	165	Wooded	Wooded	B2.5T F7.5iT
4-2-1	614724	5875022	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
4-2-2	614724	5875022	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
4-2-3	614724	5875022	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
4-3-1	614740	5875025	7/13/2007	190	Wooded	Wooded	B2.5T F7.5iT
4-3-2	614740	5875025	7/13/2007	190	Wooded	Wooded	B2.5T F7.5iT
4-3-3	614740	5875025	7/13/2007	190	Wooded	Wooded	B2.5T F7.5iT
4-3-4	614740	5875025	7/13/2007	190	Wooded	Wooded	B2.5T F7.5iT
4-4-1	614753	5875030	7/13/2007	135	Wooded	Wooded	B2.5T F7.5iT
4-4-2	614753	5875030	7/13/2007	135	Wooded	Wooded	B2.5T F7.5iT
4-4-3	614753	5875030	7/13/2007	135	Wooded	Wooded	B2.5T F7.5iT
5-1-1	614760	5875000	7/13/2007	160	Wooded	Wooded	B2.5T F7.5iT
5-1-2	614760	5875000	7/13/2007	160	Wooded	Wooded	B2.5T F7.5iT
5-1-3	614760	5875000	7/13/2007	160	Wooded	Wooded	B2.5T F7.5iT
5-1-4	614760	5875000	7/13/2007	160	Wooded	Wooded	B2.5T F7.5iT
5-2-1	614749	5874984	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
5-2-2	614749	5874984	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
5-2-3	614749	5874984	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
5-3-1	614726	5874975	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
5-3-2	614726	5874975	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT
5-3-3	614726	5874975	7/13/2007	150	Wooded	Wooded	B2.5T F7.5iT

*maximum peat depth including transition to clay horizons

Table A1- 5. Bulk Density Values (mg/cm³) for Six Different Wetland Classes

Wetland Type	Bulk Density (mg/cm ³)
Bog, Permafrost	0.0429
Bog, Non-Permafrost	0.0429
Fen, Treed	0.0475
Fen, Patterned	0.0475
Fen, Open	0.0475
Marsh, Open	Used Fen Values

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