Characterizing Groundwater Processes in a Northern Hybrid
Peatland Complex, Schefferville (Québec)

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Introduction

Peatlands are generally defined as wetlands that have accumulated a superficial layer of peat greater than 30 cm. Peat represents the *in situ* waterlogged accumulation of organic material consisting of partially decomposed remains of plants and contains approximately 50% of carbon by weight (Roehm, 2003). Peatlands are estimated to cover 3% of the Earth’s land surface, with 80% occurring in temperate-cold climates in the northern hemisphere (Limpens et al., 2008). Recent carbon budget assessments indicate that boreal and subarctic peatlands store between 270 and 340 Pg of carbon (1 Pg = 10^{15} g), which would account for 15 to 30% of the world’s soil carbon (Turunen et al., 2002; Limpens et al., 2008). Given their long-term role as an important carbon repository, northern peatlands have the potential to significantly alter the atmospheric carbon budget and future climate if they were to act as a carbon source.

Approximately 12% of the land area of Canada is covered by peatlands (Quinton et al., 1998; Tarnocai, 2006). In Canada, peatlands are mainly classified based on their genesis: bogs, fens, swamps, and marshes. Bogs tend to have lower total dissolved solids content (TDS) than fens and are thought to be predominately ombrotrophic (rain-fed), whereas fens are assumed to be minerotrophic, as a result of the mixture of precipitation and groundwater sources. Differences such as vegetation covers and topographic settings generally reflect the mentioned chemical dichotomy and have been used as compelling criteria to classify peatlands (National Wetlands Working Group, 1997). Swamps and marshes are generally covered by large standing water bodies and are not the focus of this research.

The moisture content of peat below the water table varies between 91 to 98% by volume and is a critical factor in the origin and development of peatlands (Ivanov, 1981). For more than 50 years, peatlands have been viewed as a two-layered system comprising an upper active peat layer with a high hydraulic conductivity called the acrotelm and a deeper inert layer, with lower hydraulic conductivity called the catotelm. The hydraulic conductivity of humidified peat tends to significantly decrease with depth (Ivanov, 1981), an observation that has been interpreted to suggest the lack of flow between the base of the peat column and the underlying mineral soil layer. Most hydrological studies of peatlands have consequently focused on surface runoff processes from a water budget perspective with little or no focus on flux of water through deeper
peat (McKenzie et al., In Press). However, several hydrogeologic studies have shown this assumption to be incorrect with groundwater flow through deeper peat being dynamic, with flow reversals and pore water flushing (Siegel et al., 1995; Devito et al., 1997; Quinton et al., 1998; Reeve et al., 1999).

**Study area**

Schefferville, Québec (54°48’N, 66°49’W) is located near the center of the Labrador-Ungava peninsula on the shore of Knob Lake. The geology of the area comprises sedimentary and metamorphic rocks of the Labrador Trough (e.g. iron formations, through shales, slates, cherts, and quartzites to dolomites) that were affected by subsequent folding and faulting that is responsible for the predominant northwest-southeast strike of surficial geologic features. Repeated glaciations led to the gentle topography of the landscape consisting of low ridges and valleys (Granberg, 1989). The regional climate is characterized by cold winters and relatively cool summers with mean January and July temperatures of -23 and 12°C, with a mean annual precipitation of 793 mm, out of which half falls as snow (Moore, 1987). On average, snow covers the ground from late October to early May. Schefferville is located at the limit between the Atlantic boreal and the High subarctic wetland regions where spatial wetland coverage is 25 to 30% and occurs in the zone of widespread discontinuous permafrost, although permafrost is absent in the shallow valleys were most wetlands are found (National Wetland Working Group 1997, Quinton et al., 1998).

**Preliminary Fieldwork**

In August, 2008, I visited numerous peatlands within the Schefferville region in order to select potential research sites. Total dissolved solids, pH, and temperature from surface waters and several peat column depths were recorded for 6 peatlands (Figure 1). A piezometer nest of small diameter Polyvinylchloride (PVC) monitoring wells were installed at the Peltier wetland complex (54°50’N, 66°51’W) to measure hydraulic gradients and hydraulic conductivity at both 40 and 80 cm depth. Hydraulic conductivities were estimated from the Hvorslev method (Hvorslev, 1951). Values between $10^{-4}$ and $10^{-6}$ cm s$^{-1}$ were obtained, which is in general agreement with published data (Rycroft et al., 1975; Quinton et al., 1998; Reeve et al., 1999).
The Leo peatland complex is of particular interest (54°40'N, 66°36'W). TDS and pH profiles from within the peatland are in two groups – some locations are circumneutral with higher TDS, and other locations are acidic with low TDS content (Figure 1 and 2). This indicates that there are possibly both minerotrophic and ombrotrophic elements to this single wetland. Of particular note is that part of the complex is located on the side of a gently sloping hill. This observation is remarkable because peatlands are thought to develop on relatively flat, poorly drained soils. A stream with considerable discharge is located at the bottom the hill. The stream emerges discreetly in the form of small channels at the end of the Leo peatland and progressively increases in size as the channels merge into each other downhill.

Objectives

Based on the preliminary field data collected in August, 2008, the proposed MSc research will focus on the Leo peatland. The apparent mixture of minerotrophic and ombrotrophic derived water in the Leo peatland is unique, and provides an opportunity to understand what hydrologic factors control the development of peatlands into bogs or fens. The traditional hypothesis that the lack or presence of groundwater flow will significantly determine the development of a peatland into a defined class can therefore be ideally tested in a site that presents both bog and fen-like features. For that reason, our study objectives are to (1) develop a three-dimensional finite-difference groundwater flow model of the Leo hybrid peatland, calibrated to field data, (2) conceptualize and characterize how the groundwater flow system controls the unique morphology of the Leo hybrid peatland, and (3) develop a theory to explain how the Leo peatland was able to develop on a hillslope.

Methodology

Two fieldwork expeditions to Schefferville are scheduled for June and late August, 2009. The field work will be focused on the Leo peatland, and will include: (1) detailed site mapping (cm vertical resolution), (2) installation of a boardwalk platform, (3) installation of piezometers and water table wells, (4) slugs tests to estimate hydraulic conductivity, and (5) rehabilitating the Leo stream gage.

Numerical groundwater models are used to study the processes that control a flow system. To our knowledge, there are few studies that use groundwater models for
northern peatlands and none that have linked adjacent ombrotrophic and
minerotrophic peatlands as part of the same flow system. The Leo peatland will be
modeled using MODFLOW, the three-dimensional finite-difference groundwater flow
model developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988).

The bedrock and the ground surface represent respectively the bottom and top
boundaries of the model. It is likely that the ability of the bedrock to transmit water
vertically to the mineral soil layer is very small and thus negligible. Therefore the
bedrock will be modeled as a no flow boundary across the bottom. In peatlands, the
water table lies usually only a few centimeters below the ground surface, which can be
neglected and allow us to model the top boundary either as a constant head or a flux
boundary representing net recharge. Other presumed sources of water to the peatland
include precipitation and groundwater. Hydraulic conductivity measurements combined
with the measured hydraulic head and groundwater discharge (as measured at the
downstream weir) will be used for the calibration of the groundwater model. The
calibration will be achieved by varying the measured hydraulic conductivity and
balancing the different inputs of water (precipitation and groundwater) in order to be
consistent with respectively the measured hydraulic head and measured discharge of
the Leo stream.

**Time Schedule**

The required coursework for my degree will be completed by the end of the
current semester (April 2009). Two fieldwork expeditions are scheduled for summer
2009 to complete the data acquisition necessary for the modeling component of the
proposed research. The conceptual framework of the groundwater model has already
been developed and can be easily adapted to the field data. The fall 2009 semester will
be dedicated to the development of a groundwater model of the Leo peatland complex.
The spring 2010 semester will be focused on writing and submitting my thesis (April
2010).
References


Hvorslev, M.T., 1951. Time lag and soil permeability in groundwater observations. *U.S. Army Corp of Engineers Waterways Experiment Station, Bulletin*, 36, Vicksburg, Mississippi.


**Figures**

Figure 1. TDS and pH of several peatlands in the Schefferville area. The majority of the sites have TDS contents lower than 100 mg L\(^{-1}\) and slightly acidic pH values. The TDS content for Leo and Aries goes up to 212 and 184 mg L\(^{-1}\) and pH values up to 8.6.
Figure 2. Map of TDS from the Leo peatland complex. The peatland slopes downhill, trending towards the NNW. The TDS content is in majority lower in the Leo Hilltop peatland than in the Leo Hillslope peatland. It generally increases with decreasing surface elevation, towards where the slope of the peatland is greater. The stream weir, indicated as Q station, is located at the western side of the Leo Hillslope peatland and captures all of the groundwater discharge from the Leo complex.