Modeling peat wetness for restoration

J.S Price[1] *and G. Kennedy*[2]

[1] *Department of Geography, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada, N2L 3G1. Tel: (1) 519 888-4567 ext. 5711*
Email: jsprice@watserv1.uwaterloo.ca
[2] *Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1*

Abstract

Extensive laboratory and field tests of the hydrological and mechanical character of cutover peat under the small loads associated with seasonal water table fluctuations have shown the swelling and subsiding peat soil maintains a higher water table, soil moisture, and pore-water pressure than would occur in a rigid soil. Standard modeling approaches fail to account for this. The implication of this behaviour was explored through a 1-d variably saturated flow model incorporating volume change, and volume-sensitive hydraulic parameters that simulated the impact of various peat harvesting and restoration scenarios at the Lac St-Jean peatland. The model FLOCOPS (<u>Flo</u>w in <u>Cuto</u>ver <u>P</u>eat <u>S</u>ystems) simulations suggest that poorer surface wetness occurs when there is thinner residual peat, denser peat, peat with lower compressibility, or a setting with subsurface or lateral seepage loss. More favourable conditions were simulated when restoration proceeded as soon as possible after cutting, when less or lighter vehicles are used in peat harvesting, and when ditches or bunds are employed to retain snowmelt water (or autumn rain). These results can be transferred across a variety of peat types.

Introduction

The hydrological functioning of cutover peats is strongly controlled by the structure and deformable character of the peat matrix (Price 2003; Price & Schlotzhauer 1999; Van Seters & Price 2002; and von Waldow 2002). Volume change mechanisms in peatlands are commonly identified as shrinkage, compression, and oxidation (Eggelsmann 1976, Schothorst 1977). Peat oxidation consists of irreversible subsidence due to mineralization of carbon to water and CO_2. Compression is attributed to changes in effective stress (σ') on saturated peat layers below the water table due to water table fluctuations and snow loads, and comprises primary consolidation (δ_p) and secondary compression (δ_s) components (Lang 2002). Below the water table peat volume changes are due to an equivalent change in pore water volume (Terzaghi 1943), whereas above the water table the peat undergoes shrinkage that may be less than the water loss. These changes can significantly change the saturated hydraulic conductivity (K_s) of peat (Lang 2002; Price 2003) and the water retention (θ-Ψ) curve (Schlotzhauer & Price 1999; Kennedy 2003) relating soil moisture (θ) and pore-water pressure (Ψ).

The volume change notable in cutover peat systems results in a higher and less variable water table, soil moisture and pore-water pressure than in a rigid soil (Price

Results

A good fit was achieved between elevation change, water table, soil moisture and pressure for the 1999 data. The *WT* simulation exhibits the greatest departure from observed results, being somewhat less variable. This was a moderately wet summer, compared to 1998, when dry conditions resulted in approximately 6 cm of surface elevation decline. Briefly, in Scenario #1 the model was parameterized with a very shallow residual peat thickness (50 cm), and the effects of greater vehicular traffic causing soil compaction were represented by decreasing the compressibility parameters (m_v and C_{sec}), and increasing soil density (ρ_d *and* ρ_s), and the preconsolidation pressure (P_c). Less disturbance (i.e. than presently exists) was simulated by with a thicker peat deposit (250 cm), and changing the compressibility parameters in the opposite direction than described previously. The results show volumetric soil moisture is lower when there is a small, compacted residual peat layer compared to recently abandoned thicker peat (Figure 1a).

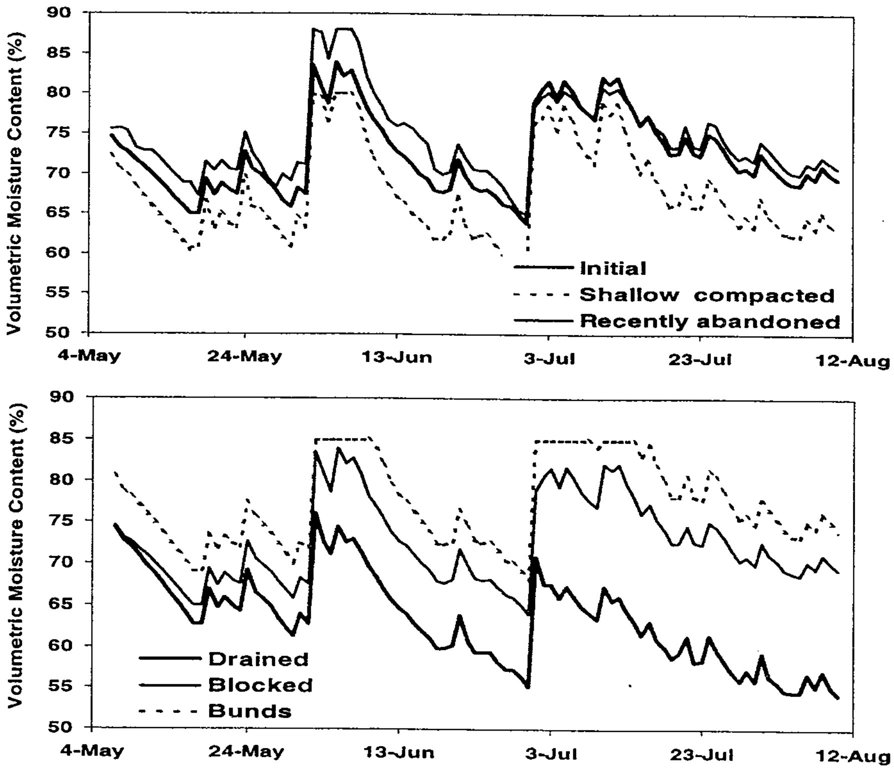

Figure 1. Simulated moisture content at 5 cm depth for **a)** scenario #1 (top) and **b)** scenario #2 (bottom).

2003). Understanding these dynamics, and representing them in a numerical model is important to planning for restoration. The objective of this paper is to evaluate various restoration measures with a numerical simulation model.

The model FLOCR (Oostindie & Bronswijk 1992), devised to represent flow in cracking clay soils was modified by Kennedy (2003) to represent one-dimensional Flow in Cutover Peat Systems (FLOCOPS). The modifications include subroutines that consider temporal variability in bulk density, peat shrinkage character and θ-Ψ relationships, volume changes due to compression, and consequent changes to saturated zone hydraulic properties (K_S, θ_S) (Kennedy 2003).

Study Area

The study was performed on an ombrogenous plateau bog from May 7th to August 13th of 1999 in a peatland near Sainte-Marguerite-Marie, in the Lac-Saint-Jean (LSJ) region of Quebec, Canada (48°47'N, 72°10'W). The climate is humid continental with a mean annual temperature of 2.2 °C, and average January and July temperatures of –17.1 °C and +17.3 °C, respectively (Environment Canada 1992). More details on the site are given by (Price, 1996; Price, 1997). The study focuses on a cutover section of the LSJ bog. Drainage and extraction operations commenced in 1990 at this site and drainage ditches were blocked in 1992. Little vegetation has re-established on the site.

Methods

The field set-up is described in detail by Price (2003) and Kennedy (2003). Theses studies also report the field data (elevation change (Δb), water table (*WT*), θ, and Ψ) at the site, against which the model was validated (Kennedy 2003). Parameterization of FLOCOPS was developed mostly through prior laboratory testing of LSJ peat material. For example, Schlotzhauer & Price (1999) measured the unsaturated hydraulic conductivity function (K-Ψ), Lang (2002) measured the peat's consolidation and permeability characteristics using standard oedometer and Rowe consolidation cells, and the soil shrinkage characteristic (SSC) that relates void ratio (e) to θ, was obtained in the laboratory by the methods described by Kennedy (2003).

Approach

The model was tested against field observations for 1998 and 1999. Here the 1999 values will be presented. By modifying parameters in FLOCOPS, several peat extraction scenarios are examined to demonstrate their implication on the hydrological response. In **Scenario #1** the model tested the effect of residual peat thickness (b), and the effects of greater vehicular traffic causing soil compaction. The parameter changes to reflect this are shown in Table 1. In **Scenario #2**, the model was parameterized to represent the effect of different restoration strategies.

Table 1. Parameters used in FLOCOPS for original simulation (field verification) and Scenario #1 simulations. Scenario #1 represents sensitivity to peat extraction technique (thickness of residual peat, compaction by machinery, etc.). Parameter changes for Simulation #1 and #2 have the same units as Field/lab values shown.

Parameter	Definition	Field/lab Values	Scenario #1 Extraction Technique	
			More	Less
m_v	Virgin compressibility (m^2 kN^{-1})	0.015		
m_r	recompression (m^2 kN^{-1})	0.0035	0.0018	0.0070
C_{sec}	Secondary compression	–0.0050	–0.0025	–0.010
P_c	Preconsolidation pressure (kPa)	4.5	6	3
ρ_s	Saturated density (g cm^{-3})	1.04	1.08	1.01
ρ_d	Bulk density (g cm^{-3})	0.1	0.12	0.08
θ_S	Saturated moisture content	0.81–0.85	0.8	0.9
B	Peat thickness (cm)	180	50	250
K_S	Saturated hydraulic conductivity (cm d^{-1})	6.1–15.0		

Discussion and Conclusion

The model FLOCOPS can be used to predict the soil moisture, as well as soil-water pressure, water table, and surface elevation in a cutover peatland. The model is sensitive to peat compressibility, and explicitly incorporates this in its simulations. The results suggest that restoration should begin as soon as possible after abandonment, and preferably on a thicker peat substrate. Moreover, blocking ditches is shown to be very effective at raising the water table, but that further surface reconfiguration may be necessary to retain spring snowmelt water, so that soil moisture conditions in the driest part of the summer remain suitable for restoration.

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