Chapter 2

Role of Hydraulic Conductivity Uncertainties in Modeling Water Flow through Forest Watersheds

Marie-France Jutras and Paul A. Arp

Additional information is available at the end of the chapter

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1. Introduction

Soil hydraulic conductivities at saturation (K_{sat}) are highly variable in space and time. For example, K_{sat} varies along vertical and lateral flow paths depending on directional changes in soil texture, density, and structure [1, 2, 3]. Temporal changes are caused by changes in soil structure and bulk density (D_b) in response to, e.g., (i) gradual soil formation processes, and (ii) operationally induced soil compaction or de-compaction due to various land-uses [4]. Changes in weather and climate also affect K_{sat} through freezing and thawing [5, 6], swelling and shrinking [7], extent of rooting and related organic matter build-up [8]. This chapter explores how changes in hydraulic conductivity may affect modelled rates of water flow through forested watersheds, with flows referring to infiltration, percolation, run-off, inter-flow, base flow, and stream discharge. This is done by way of sensitivity analyses centered on two well-studied watershed studies, referring to Moosepit Brook, Nova Scotia [1, 9] and Turkey Lakes, Ontario [1, 10]. Also addressed are:

K_{sat} impacts on the retention of soil water and the transmittance of the same towards streams as influenced by evapotranspiration from open conditions to forests [14];

the relationship between K_{sat} and the state of organic matter decomposition, as characterized by the von Post index from fibric (H1) to fully humified or sapric (H10) [11, 12, 13].

The sensitivity analysis is based on using the forest hydrology model ForHyM2 [1, 15] to determine how scenario-set K_{sat} variations affect soil water retention and flow including stream discharge through the watersheds. The scenarios vary K_{sat} by changing organic matter (OM) and sand content from their actual values within the 0 to 100% per soil weight range.

2. Quantitative background

The equations used for estimating the sensitivity of K_{sat} on account of changes in soil texture, structure, density and organic matter content is given by [16], as follows:

$$\log_{10} K_{sat} = a + 7.94 \log_{10}(D_p - D_b) + 1.96\ \mathrm{SAND} \tag{1}$$

$$D_b = \frac{1.23 + (D_p - 1.23 - 0.75\ \mathrm{SAND})(1 - \exp(-\ 0.0106\ \mathrm{DEPTH})}{1 + 6.83\ \mathrm{OM}} \tag{2}$$

$$\frac{1}{\mathrm{Dp}} = \frac{\mathrm{OM}}{\mathrm{Dp_{om}}} + \frac{1 - \mathrm{OM}}{\mathrm{Dp_{min}}} \tag{3}$$

where, Dp_{om} is the particle density of OM (1.3 gcm^{-3}), Dp_{min} is the particle density of mineral soils (2.65gcm^{-3}), SAND and OM are dry soil weight fractions (fine earth fraction only), DEPTH is the mid depth of each soil layer (cm), "a" represents K_{sat} when D_p-D_b = 1 g cm^3 and SAND = 0%. Fig. 1 illustrates how variations in D_b, OM, and SAND affect K_{sat} in general.

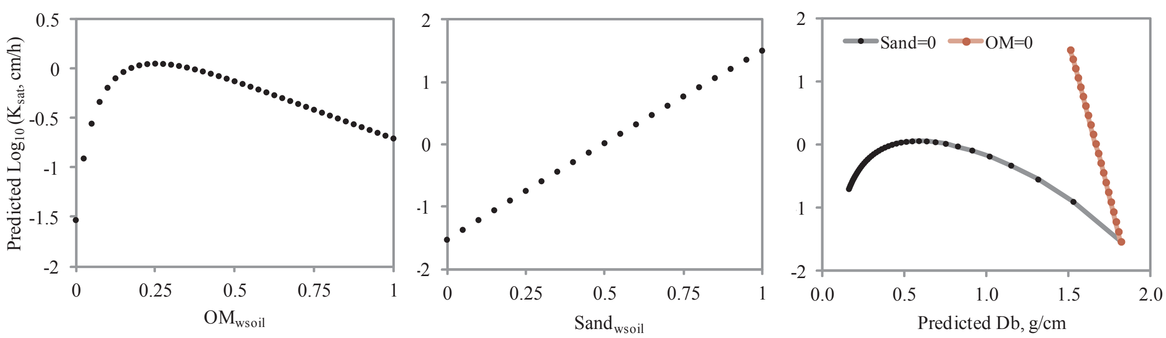

Figure 1. Left and middle: how $\log_{10}K_{sat}$ varies with increasing OM, and sand fraction. Right: Changes in $\log_{10}K_{sat}$ and Db when OM and Sand fraction = 0.

For organic soils, it is important to adjust a, D_b, and D_p in Eqs. 1 to 3 by extent of organic matter decomposition and humification [12, 11, 17, 13, 18, 19]. These adjustments are based on the von Post humification index ([11, 20], Table 1) as follows:

$$D_b = 0.035 + 0.0159\ vP\ (\mathrm{R2} = 0.93) \tag{4}$$

$$D_{pom} = \frac{D_b}{1 - \phi} \tag{5}$$

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$$\phi = 100.38 - 76.7D_b \; (R^2 = 0.99) \tag{6}$$

$$a = (2.05 \pm 0.2) - (0.046 \pm 0.004)vP^2 \; (R^2 = 0.89) \tag{7}$$

where vP is the von post index (Table 2) and ϕ is the soil porosity. Fig. 2 illustrates the relationship between the von Post adjusted $\log_{10}K_{sat}$ (Eqs. 1, 4-7) and $\log_{10}K_{sat}$ based on literature sources. Fig. 2 shows (i) a plot of actual versus best-fitted K_{sat} values (left), and actual as well as best-fitted K_{sat} values with increasing organic matter humification in peaty soils (right).

Peat Class	von Post Index	Squeeze Test: Exudate condition	$\log_{10}K_{sat}$	K_{sat} [1] cm h^{-1}	D_b [2] g cm^{-1}	D_p [2] g cm^{-1}
Fibric	H1	Water colourless	3.15	1406.48	0.05	1.44
Decomposition: none to slight; Amorphous content: low	H2	Water yellowish	2.88	756.62	0.07	1.41
	H3	Water brown, muddy; no peat	2.55	356.24	0.08	1.39
Mesic	H4	Water dark brown, muddy; no peat	2.15	141.08	0.10	1.37
Fibers still recognisable; Decomposition: moderate to strong; Amorphous content: medium	H5	Water muddy; some peat	1.66	46.20	0.11	1.36
	H6	Water dark brown; 33% peat	1.09	12.40	0.13	1.36
	H7	Any water very dark brown, 50% peat	0.43	2.72	0.15	1.35
Sapric	H8	66% peat, Water pasty	-0.32	0.48	0.16	1.34
Fibers unrecognisable; Decomposition: very strong to complete; Amorphous content: high	H9	Nearly all peat; paste uniform	-1.16	0.07	0.18	1.34
	H10	100% peat paste; no water	-2.09	0.006	0.19	1.34

[1]Eq. 1 from [16]

[2]Eqs. 4-5 from [12]

Table 1. von Post humification index, with K_{sat}, D_b and D_p for 100% OM content according to Eqs. 1 and 4 to 7; adapted from [21] and [11]

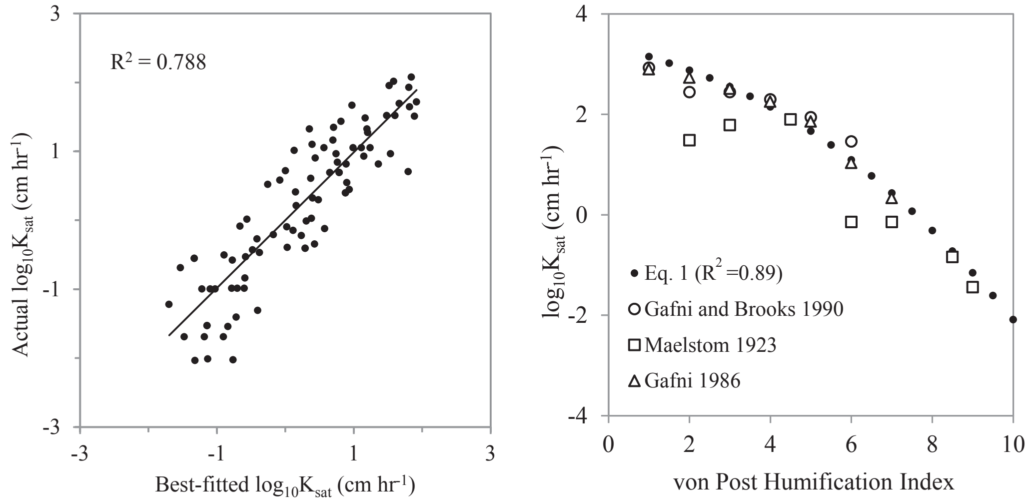

Figure 2. Best-fitted $\log_{10}K_{sat}$ versus actual data from New Brunswick and Nova Scotai, Canada, as seen in [1] and [16] (left), best-fitted $\log_{10}K_{sat}$ versus von Post humification index from literature sources (right).

3. Methods

The two study areas, Moosepit Brook and Turkey Lakes, have contrasting terrain (generally flat versus hummocky), climate (maritime versus continental), vegetation (mostly coniferous versus deciduous), and soil parent material (ablation till versus basal till) (Table 2, Fig. 3)

Eight scenarios were adopted to examine the impacts of K_{sat} variations on water flow through these locations, as follows: the actual soil conditions in terms of soil texture and organic matter (Scenario 1, Table 3), varying the soil texture sand, silt, or clay (Scenarios 2, 3, and 4), and varying the soil organic matter content (Scenarios, 5, 6, 7, and 8).

Scenario 1:

1. Actual soil texture and OM content

Scenarios 2 to 4: Changing soil texture

2. Sand = 95% sand, 1% silt, 4% clay
3. Silt = 7% sand, 87% silt, 6% clay
4. Heavy clay = 25% sand, 25% silt, 50% clay

Scenarios 5 to 8: Changing organic matter content

5. Half actual OM

6. Double actual OM
7. No OM throughout entire soil profile
8. 100% OM throughout entire soil profile using the von Post profile of FF = 3, A&B = 5, C = 9, Subsoil = 10.

Watershed characteristics	Moosepit Brook	Turkey Lakes
	Nova Scotia (NS)	Ontario (ON)
Abbreviation	MP	TL
Latitude (N)	44°28'	47°03'
Longitude (W)	65°03'	84°25'
Area (ha)	1670	1050
Elevation (m)	100-150	350-400
Slope (%)	1	8
Deciduous:coniferous	50:50	100:0
Rooting habit	Medium	Deep
Forest floor depth (cm)	5	7
Mineral soil: depth (cm); texture	50; SL	60; SilL
Subsoil: depth (cm); texture	70; LS	100; LS
Bedrock	Metamorphic greenschist slate	Metavolcanic basalt
Land Formation	Glacial till	Ablation till on basal till
Topography	Rolling	Undulating to rolling
Mean yearly temperature (°C)	7.02	4.52
Mean yearly snow depth (cm)	5	23
Mean yearly rainfall (mm)	1140	790
Model Run Years	1999-2004	1997-2004

Table 2. Site description for the Moosepit Brook and Turkey Lakes watersheds.

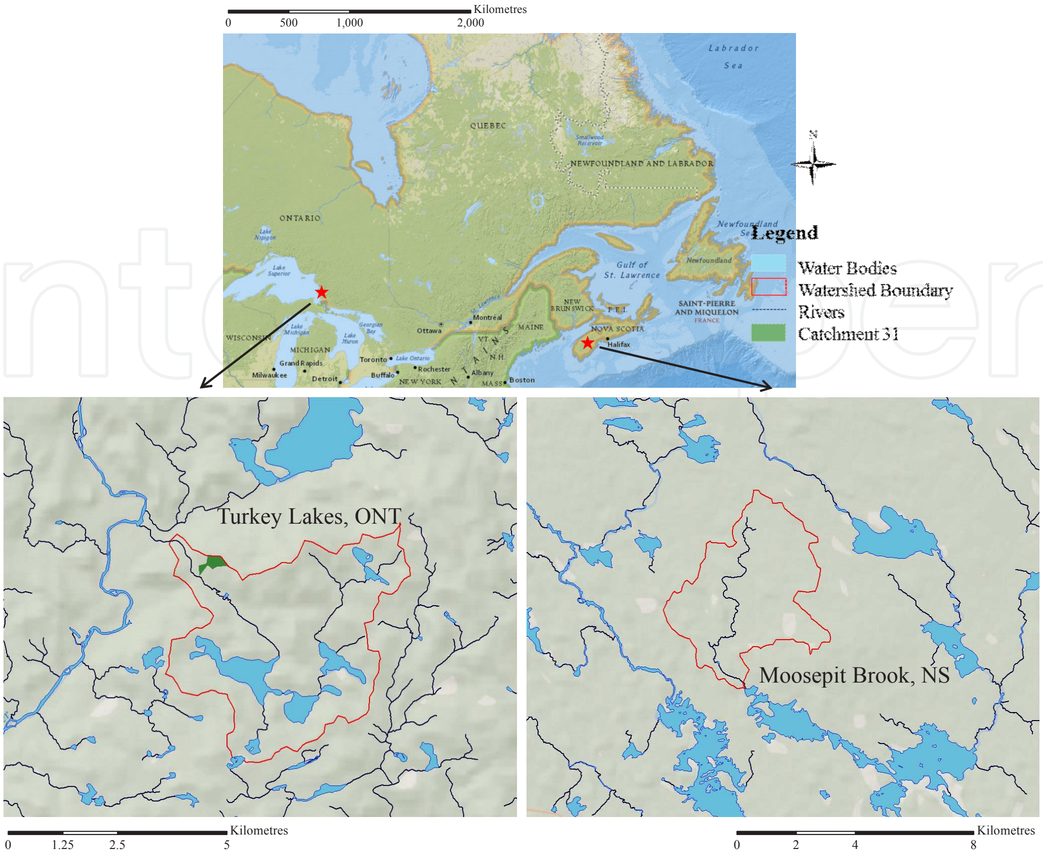

Figure 3. Locator maps for the Turkey Lakes (left) and Moosepit Brook (right) study areas.

Actual watershed inputs: Scenario 1

Horizon	Moosepit Brook, NS					Turkey Lakes, ONT				
	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OM (%)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OM (%)
A	21	66	24	10	4.5	15	66	24	10	5
B	21	66	24	10	9	30	66	24	10	3
C	50+	82	12	6	4.5	50+	22	65	13	2

Table 3. Actual scenario soil input for Moosepit Brook and Turkey Lakes.

The sand texture percentages for scenarios 2-4 demonstrate the effects of varying texture on K_{sat} from sandy and sandy loam soils to silty and clayey soils (Fig. 4). The organic matter levels for scenarios 5-8 were chosen to demonstrate the effects of changing the organic matter on content from very small in mineral soils to fully organic soils. For the 100% organic soil condition (Scenario 8), three sub-scenarios were chosen to account for variations in forest cover from 100 % (fully forested), 50% (varying from forested to boggy) and 0% (open moss and shrub-covered bogs with no trees). This is to demonstrate how varying K_{sat} levels from high to low increase the amount of water available for evapotranspiration

Each scenario was used for initializing the ForHyM2 requirements for soil texture and organic matter by soil layer, with the A and B layers representing the top soil conditions, and the C layer representing the subsoil conditions Table 2). Layer-specific values for $D_{p,}$ D_b and K_{sat} were then generated automatically via Eqs. 1 to 3. All other site-specific input requirements for daily weather (rain, snow air temperature), slope, aspect, elevation and soil layer depths were kept the same. Scenario 1 was used to refine the Eq. 1 estimates for K_{sat}, by adjusting the K_{sat} adjustment multipliers for surface run-off, interflow (forest floor, A&B layers combined), baseflow (C layers combined), infiltration, and soil percolation from the forest floor to the topsoil, and from the topsoil to the subsoil. The calibrations were done by matching modeled with actual stream discharge a the daily level, using local weather records for daily rain, snow and air temperature as model input. Modelled snowpack depth was also calibrated using daily snowpack data. The ForHyM2 model runs were done for 1999 – 2004 for Moosepit Brook, and for 1997-2002 for Turkey Lakes.

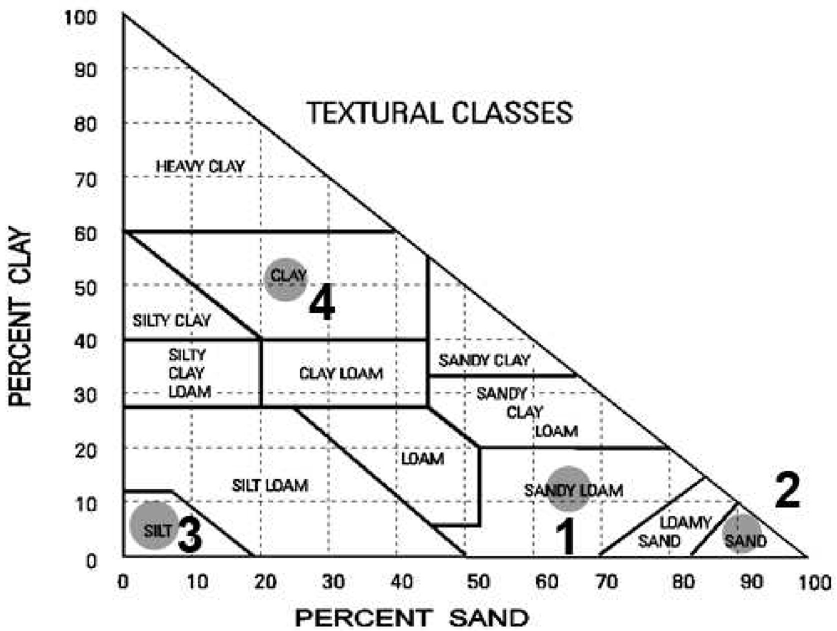

Figure 4. Mineral texture class triangle for fine soil showing texture classes for scenarios 1 - 4 (adapted from CANSIS 2000).

4. Results

The results of this analysis are shown in Tables 3 to 8 and in Figs. 5 to 12 for the Moosepit Brook and Turkey Lakes study areas. Tables 3 and 4 inform about the Scenario-based changes on Dp, Db and K_{sat} for each of the two sites by topsoil and subsoil. The Db numbers indicate that the subsoil at both locations is compacted, with K_{sat} values typically 10 to 50 times lower in the subsoil than in the topsoil. Since the soil texture is sandier at Moosepit Brook than at Turkey Lakes, K_{sat} values remain higher in the subsoil at Moosepit Brook than at Turkey Lakes. Changing the topsoil texture from the actual values changes K_{sat} by about 5x upwards, and by about 10x downwards at both locations. These K_{sat} changes are similar for the somewhat coarser subsoil at Moosepit Brook. In contrast, subsoil K_{sat} is not much affected by increasing the clay and silt content, but increases with increasing sand content towards 95% by a factor of 147

Table 5 and Fig. 5 inform about the 5-year cumulative effects of the texture and OM changes on ForHyM2-modelled run-off, forest floor interflow, topsoil interflow, baseflow and stream discharge in terms of modelled mm per study period, and also in terms of modeled flow rate percentages per stream discharge. As shown, the interflow and baseflow percentage contributions to stream discharge so compiled are very sensitive to K_{sat} as well as basin slope: for intermediate K_{sat} values, interflow would dominate the base flow contributions to stream discharge within the steeper watershed at Turkey Lakes (average slope = 8%). The reverse would occur at the flatter Moosepit Brook watershed (average slope = 1%). Low subsoil permeability at Turkey Lakes would further accentuate this difference. In detail, base flow would dominate in both watersheds or at any location within the watersheds with high soil permeability and where the subsoil would not be blocked by impervious bedrock. In contrasts, locations with low overall soil permeability and low slopes would be most variable in terms of their cumulative run-off, interflow and baseflow contributions, varying from mostly baseflow to mostly interflow (Fig. 6). For example, mineral soils with high silt content (Scenario 3) would support more lateral flow in the topsoil as opposed to soils with high sand content (Scenario 2). Doubling the OM in the mineral soil (Scenario 5) would also increase baseflow, whereas reducing OM (Scenario 6) would induce the opposite. The extent of water infiltration in Scenario 4, as modeled, would be midway between Scenarios 2 and 3

Site	Scenarios	K_{sat}, cm h^{-1}		D_b, g cm^{-1}		D_p, g cm^{-1}	
		Mineral	Subsoil	Mineral	Subsoil	Mineral	Subsoil
Moosepit Brook	1: Actual	48.40	5.95	0.95	1.61	2.48	2.59
	2: Sand	162.90	29.15	0.93	1.50	2.48	2.59
	3: Silt	3.05	0.15	1.00	1.86	2.48	2.59
	4: Heavy clay	7.15	0.50	0.99	1.80	2.48	2.59
	5: Double OM	60.60	13.30	0.72	1.48	2.33	2.54
	6: Half OM	31.35	2.70	1.14	1.70	2.56	2.62
	7: No OM	12.60	0.75	1.41	1.83	2.65	2.65
Turkey Lakes	1: Actual	39.80	0.10	1.09	1.85	2.55	2.61
	2: Sand	136.25	14.70	1.06	1.54	2.55	2.61
	3: Silt	2.50	0.05	1.15	1.92	2.55	2.61
	4: Heavy clay	5.80	0.10	1.15	1.84	2.55	2.61
	5: Double OM	56.05	0.30	0.90	1.68	2.45	2.57
	6: Half OM	30.55	0.05	1.19	1.85	2.59	2.61
	7: No OM	14.50	0.00	1.39	2.06	2.65	2.65

Table 4. Results for various levels of sand and OM against K_{sat}, D_b and D_p for Moosepit Brook and Turkey Lakes.

Figs. 6 to 9 inform about the changes in daily variations in run-off, interflow and baseflow for both locations as the soil texture changes from actual to sandy, silty and clayey (Scenarios 1 to 4, respectively, Figs. 6, 7), and soil organic matter content changes actual to 0.5 and 2 x, and 100% (Scenarios 1, and 5 to 8, Figs. 8, 9). As shown, these flows would peak faster with increasing K_{sat} (increasing sand and organic matter content), and would saturate the lower soil layers more quickly with decreasing K_{sat} and decreasing pore space, or increasing bulk density. Among the scenarios, the largest textural change on the flow regime was incurred by increasing the silt content within the already compacted subsoil at Moosepit Brook. Note that organic soils with 100% sapric organic matter would also have very low interflow and baseflow rates, and would therefore lead to relative fast soil saturation as well.

Site	Scenario	Runoff (mm)	%²	Interflow FF (mm)	%²	Interflow A&B (mm)	%²	Base flow (mm)	%²	Total Discharge (mm)
Moosepit Brook	1	2.7	0.1	202.3	4.8	682.8	16.1	3341.2	79.0	4229.0
	2	2.6	0.1	202.4	4.7	512.0	11.9	3580.4	83.3	4297.0
	3	7.0	0.2	209.5	5.1	2653.0	64.4	1251.5	30.4	4121.0
	4	2.7	0.1	202.4	4.8	1609.7	38.3	2391.4	56.9	4206.0
	5	2.6	0.1	202.3	4.8	450.0	10.6	3578.0	84.5	4233.0
	6	2.7	0.1	202.4	4.8	964.0	22.8	3054.8	72.3	4224.0
	7	2.7	0.1	202.3	4.8	1675.8	39.8	2329.9	55.3	4210.7
	8	0.0	0.0	594.8	13.2	3771.1	83.4	153.7	3.4	4519.6
	8¹	0.0	0.0	612.4	11.6	4495.9	85.3	161.0	3.1	5269.3
	8²	0.0	0.0	668.6	10.6	5487.3	86.7	171.1	2.7	6327.0
Turkey Lakes	1	1.1	0.0	375.9	9.1	2990.0	72.2	772.9	18.7	4139.0
	2	3.3	0.1	376.1	8.8	301.0	7.1	3588.5	84.1	4269.0
	3	114.9	2.8	521.2	12.8	2635.0	64.8	796.5	19.6	4068.0
	4	19.4	0.5	389.1	9.4	1965.0	47.3	1782.1	42.9	4156.0
	5	2.2	0.1	376.1	9.1	2314.0	55.8	1454.4	35.1	4146.0
	6	0.5	0.0	375.8	9.1	3273.0	79.2	485.6	11.7	4135.0
	7	0.0	0.0	374.8	9.1	3457.0	83.9	290.7	7.1	4122.0
	8	0.0	0.0	69.8	1.5	4250.5	92.1	292.9	6.3	4613.1
	8¹	0.0	0.0	70.9	1.2	5463.3	93.6	305.0	5.2	5839.2
	8²	0.0	0.0	72.6	1.0	6609.0	94.6	305.0	4.4	6986.5

¹ 50% coverage ² 10% coverage

² % values refer to the calculated percent contributions of run-off, FF interflow A&B interflow and baseflow to stream discharge.

Table 5. Lateral stream discharge by cumulative and percent runoff, interflow, and base flow for scenarios 1-8 for Moosepit Brook (1999-2004) and Turkey Lakes (1997-2004).

Assessing the waterflow through peatland locations within each of the two watersheds, and setting the state of decomposition of the peat equal to H1, H4, H7 and H10 produced the results compiled in Table 6. As shown, organic soils mostly composed of fibric to mesic peat (H1) would support deep percolation and baseflow, whereas organic soils mostly composed of humic peat (H10) would contain pooled water from the subsoil upwards to the surface, thereby encouraging surface run-off

Note also from Table 4 and 6 that the changing K_{sat} values for decomposing peat would also have strong effects on forested peatland evapotranspiration and on stream discharge: the lower K_{sat}, the higher would be the rate of water retention and subsequent forest water uptake and evapotranspiration during the growing season (Fig. 10). In contrast, the higher K_{sat}, the faster water would be lost due to quick baseflow (Fig. 11). Outside the growing season, run-off increases, as modeled and as to be expected (Fig. 10 and 11)

Site	von Post	Runoff (mm)	%	Interflow FF (mm)	%	Interflow A&B (mm)	%	Base flow (mm)	%	Total Discharge (mm)
Moosepit Brook	H1	0.00	0.0	1.09	0.0	53.00	1.1	4618.27	98.8	4672.35
	H4	0.00	0.0	20.27	0.4	222.67	4.9	4291.43	94.6	4534.38
	H7	0.00	0.0	240.34	5.9	184.86	4.5	3676.06	89.6	4101.26
	H10	3275.13	97.3	74.12	2.2	13.32	0.4	4.67	0.1	3367.25
Turkey Lakes	H1	0.00	0.0	0.08	0.0	0.84	0.0	5954.36	100.0	5955.27
	H4	0.00	0.0	1.03	0.0	7.64	0.1	5641.93	99.8	5650.61
	H7	0.00	0.0	55.87	1.2	8.18	0.2	4655.45	98.6	4719.50
	H10	3057.12	97.7	50.55	1.6	4.51	0.1	16.86	0.5	3129.03

Table 6. Lateral stream discharge by cumulative and percent runoff, interflow, and baseflow for scenario 8 to represent 100% peat surface deposits (von Post index set at H1, H4, H7, and H10 for the entire profile) underneath forest cover at each of the two locations.

The extent water retention in terms of mm per soil layer is illustrated in Fig. 12 for the two study locations as modeled for the actual soil (Scenario 1) and for organic soil conditions (100% organic matter content, Scenario 8), starting the soil moisture content at field capacity for January 1. For the slowly draining peatland scenario (Scenario 8), subsoil moisture levels would increase from field capacity towards saturation in about one year. For the well-drained upland soil conditions (Scenario 1), K_{sat} values would be sufficiently high so that soil moisture conditions would fluctuate around the field capacity, depending on season as well as rainfall and snow melt events

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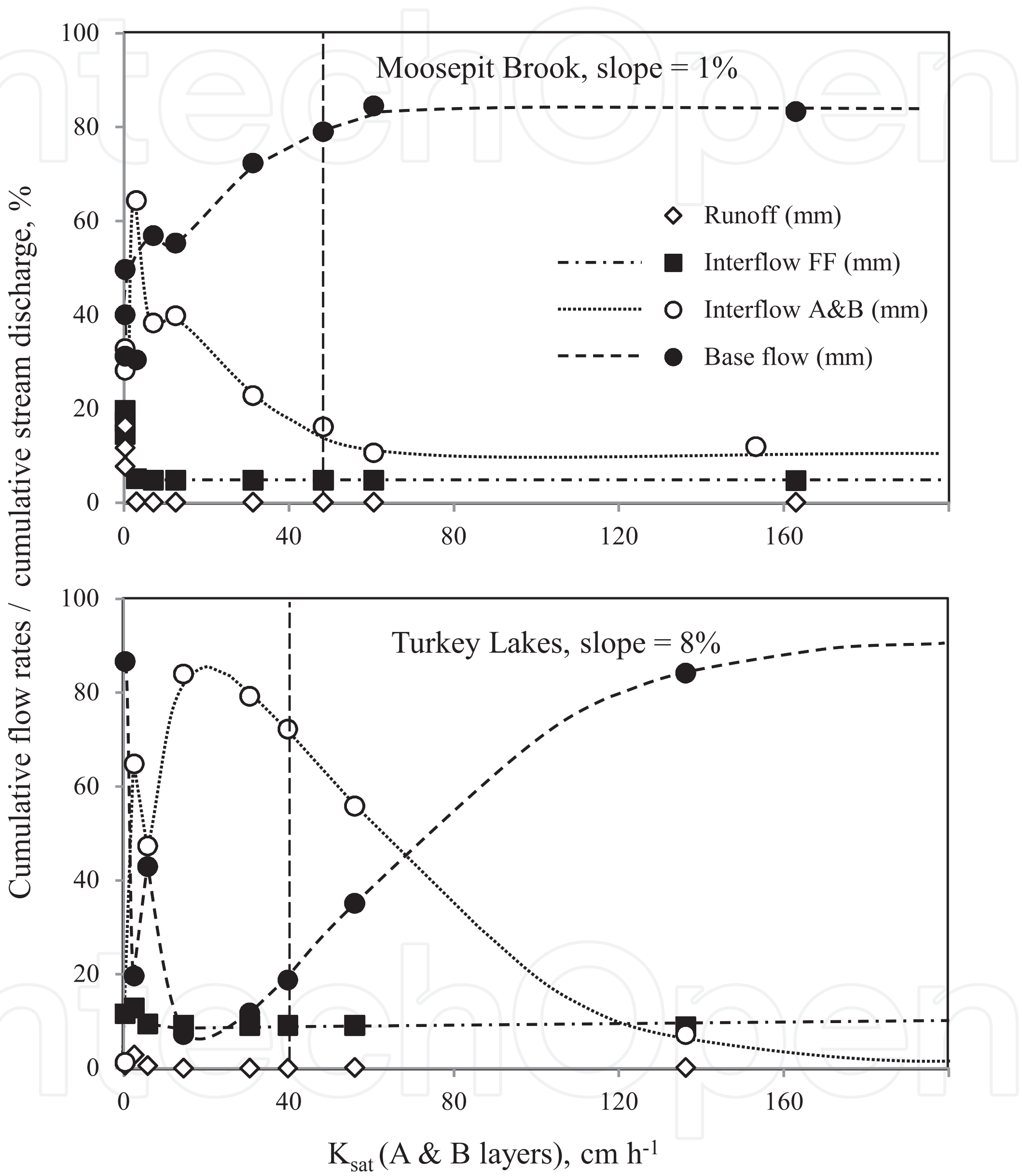

Figure 5. K_{sat} of the A&B layers by cumulative stream discharge % for Moosepit Brook (top), and Turkey Lakes (bottom) across all 8 scenarios (vertical dashed line represents the actual scenario)

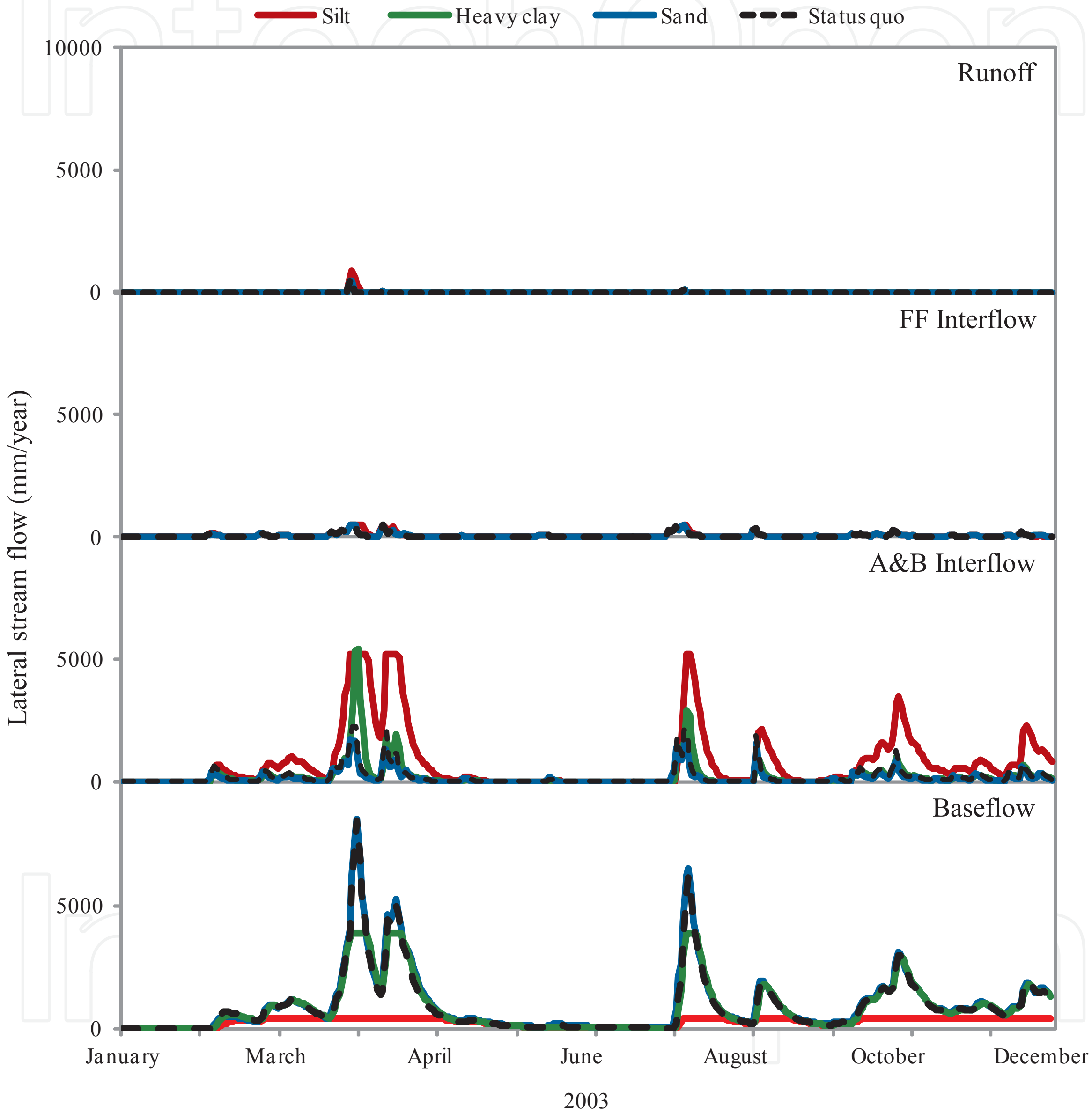

Figure 6. Run-off, forest floor and A&B interflow and base flow for Moosepit Brook, by scenario from actual to sandy, silty and clayey (Scenarios 1 to 4, respectively; 2003)

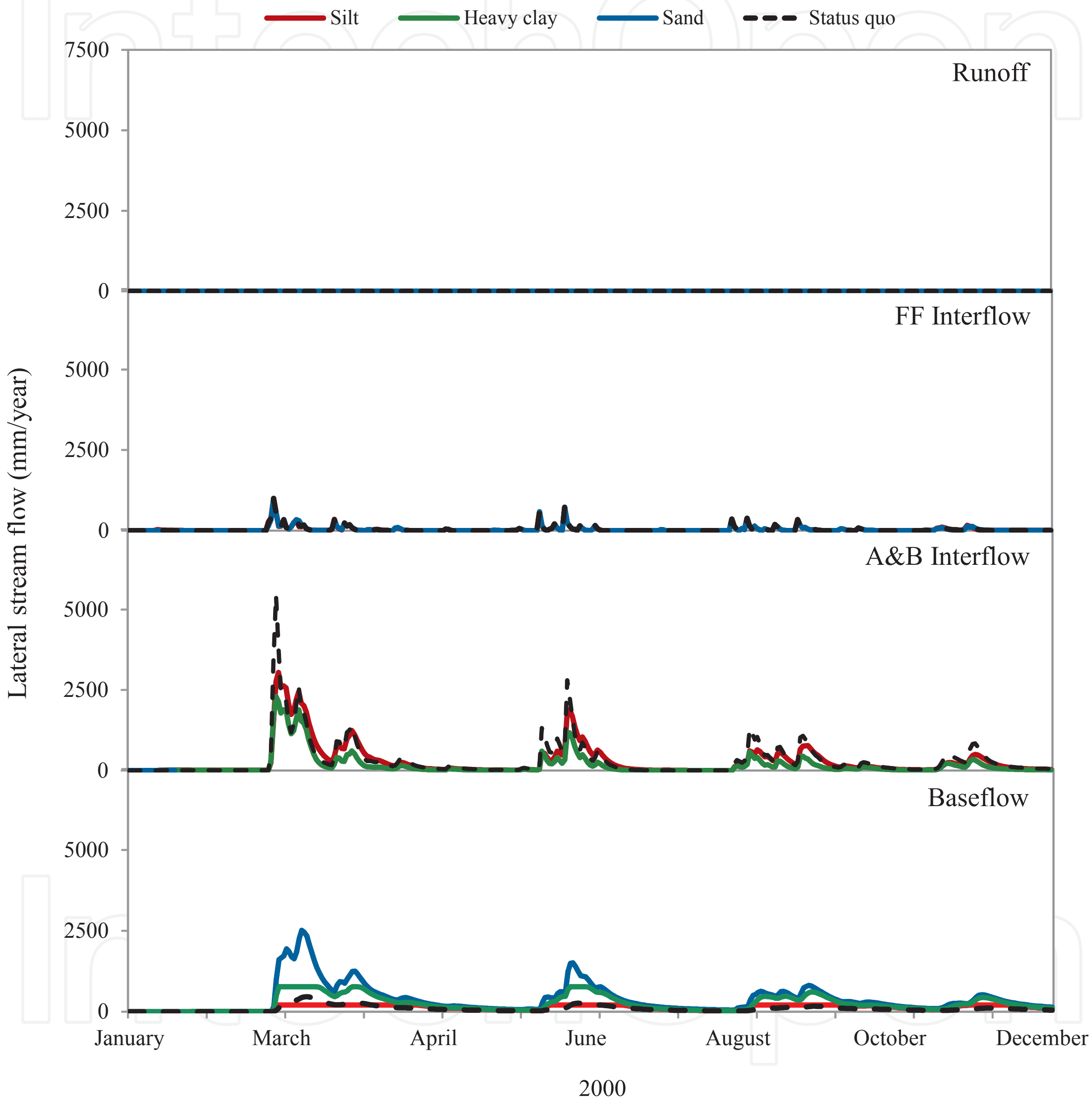

Figure 7. Run-off, forest floor and A&B interflow and base flow for Turkey lakes, by scenario from actual to sandy, silty and clayey (Scenarios 1 to 4, respectively; 2000), no runoff for any of the scenarios

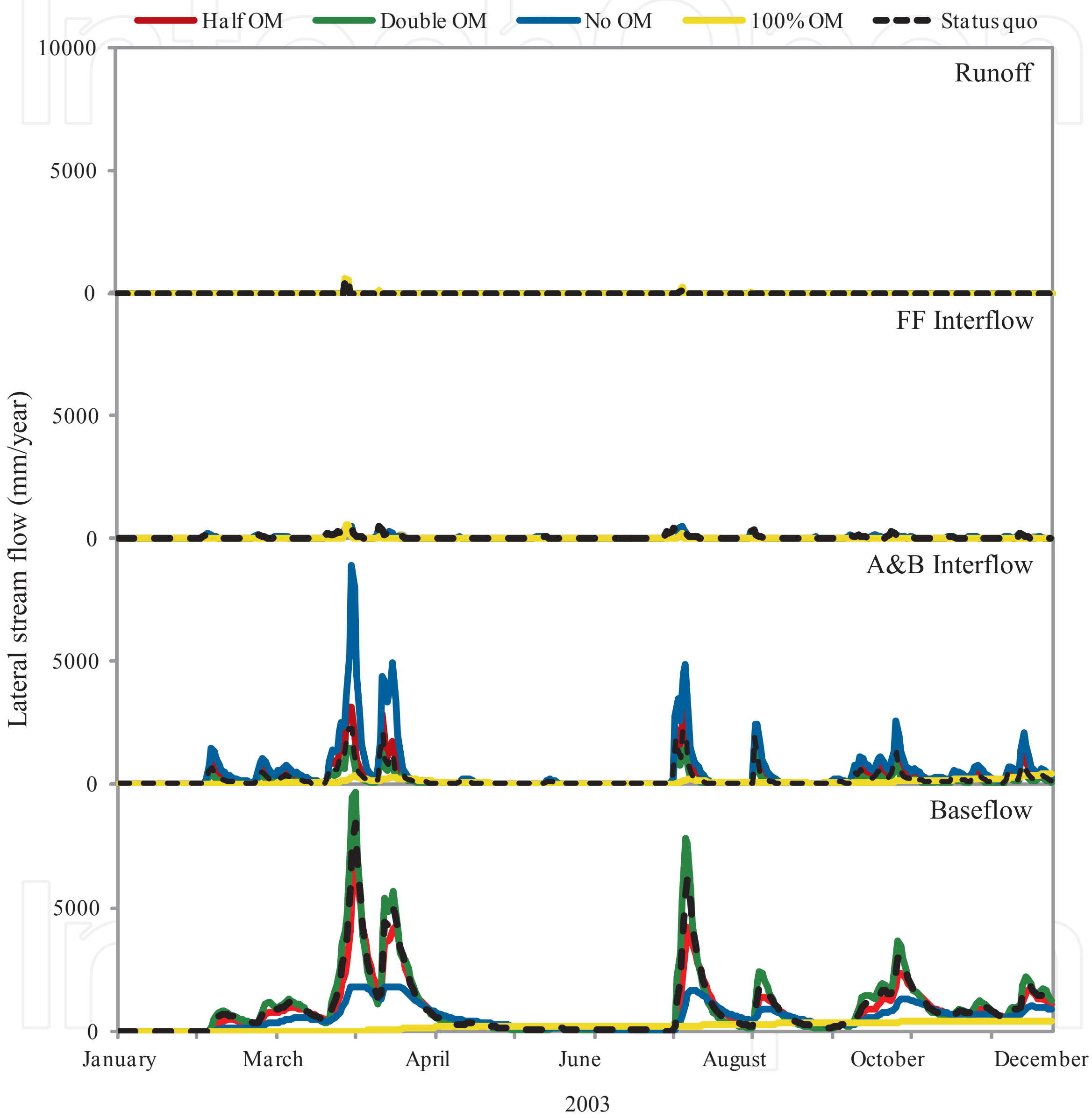

Figure 8. Run-off, forest floor and A&B interflow and base flow for Moosepit Brook, by scenario from actual to no, 0.5x and 2x actual organic matter content, and 100 % sapric organic matter (Scenarios 1 and 5 to 8, respectively; 2003)

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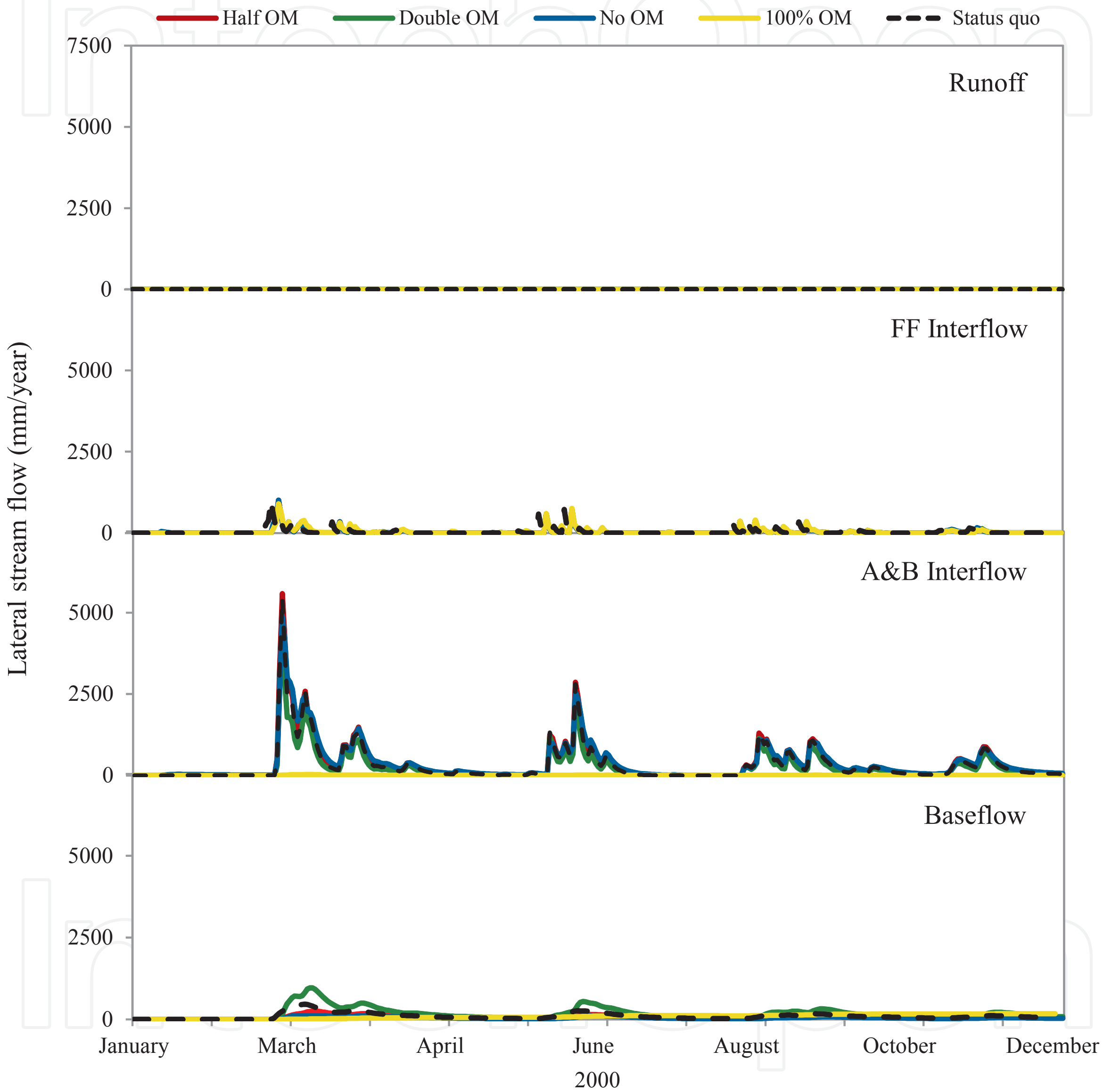

Figure 9. Run-off, forest floor and A&B interflow and base flow for Turkey Lakes, by scenario from actual to no, 0.5x and 2x actual organic matter content, and 100% sapric organic matter (Scenarios 1 and 5 to 8, respectively; 2000), no runoff for any of the scenarios.

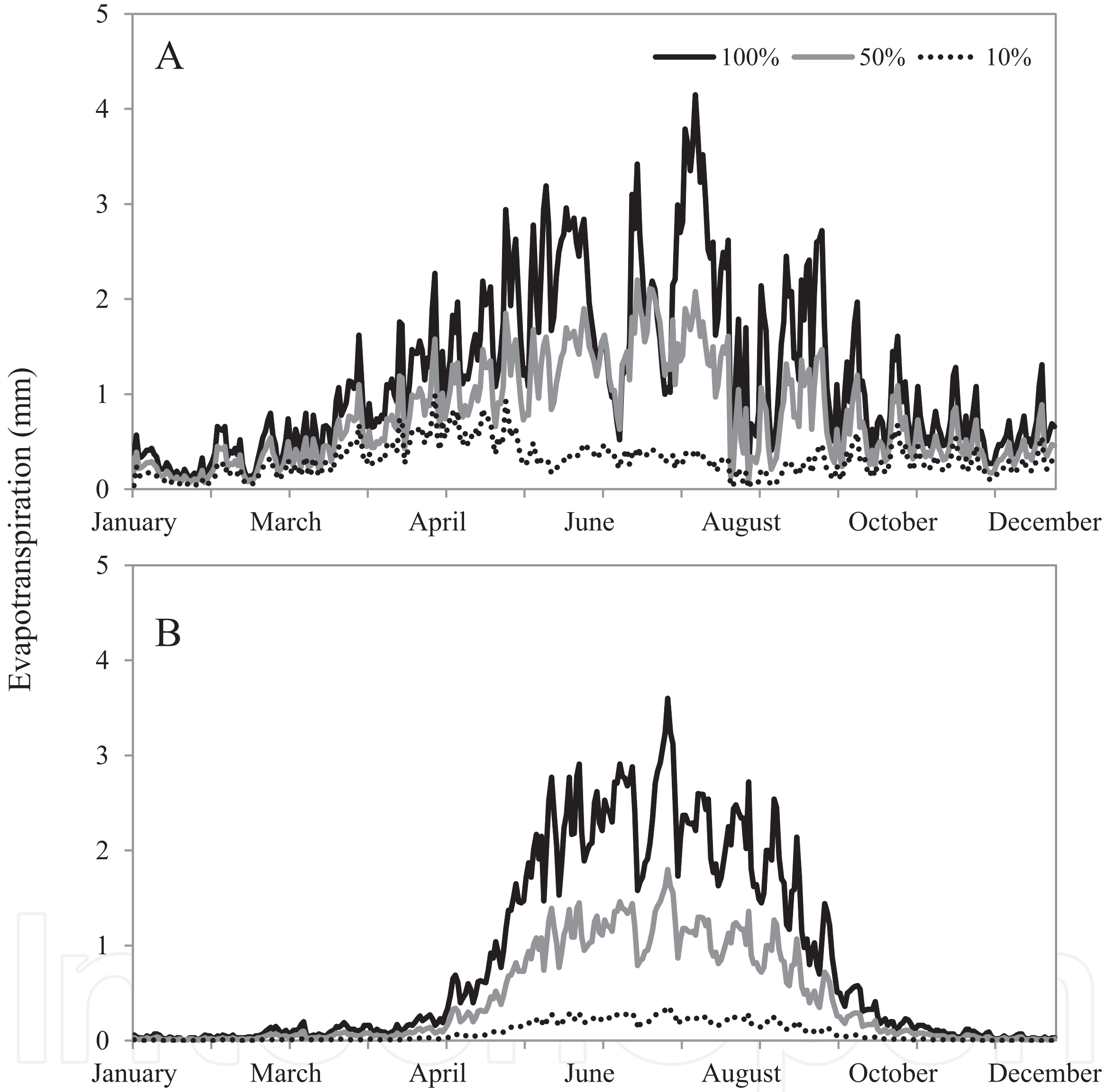

Figure 10. Evapotranspiration at Moosepit Brook (A) during 2003 and Turkey Lakes (B) during 2000, for Scenario 8 (100% OM), with actual (100% vegetation), Scenario 8[1] (50% vegetation), and Scenario 8[2] (10% vegetation). Note the difference in the extent of the growing season: wide for Moosepit Brook (maritime climate), and narrow for Turkey Lakes (continental climate).

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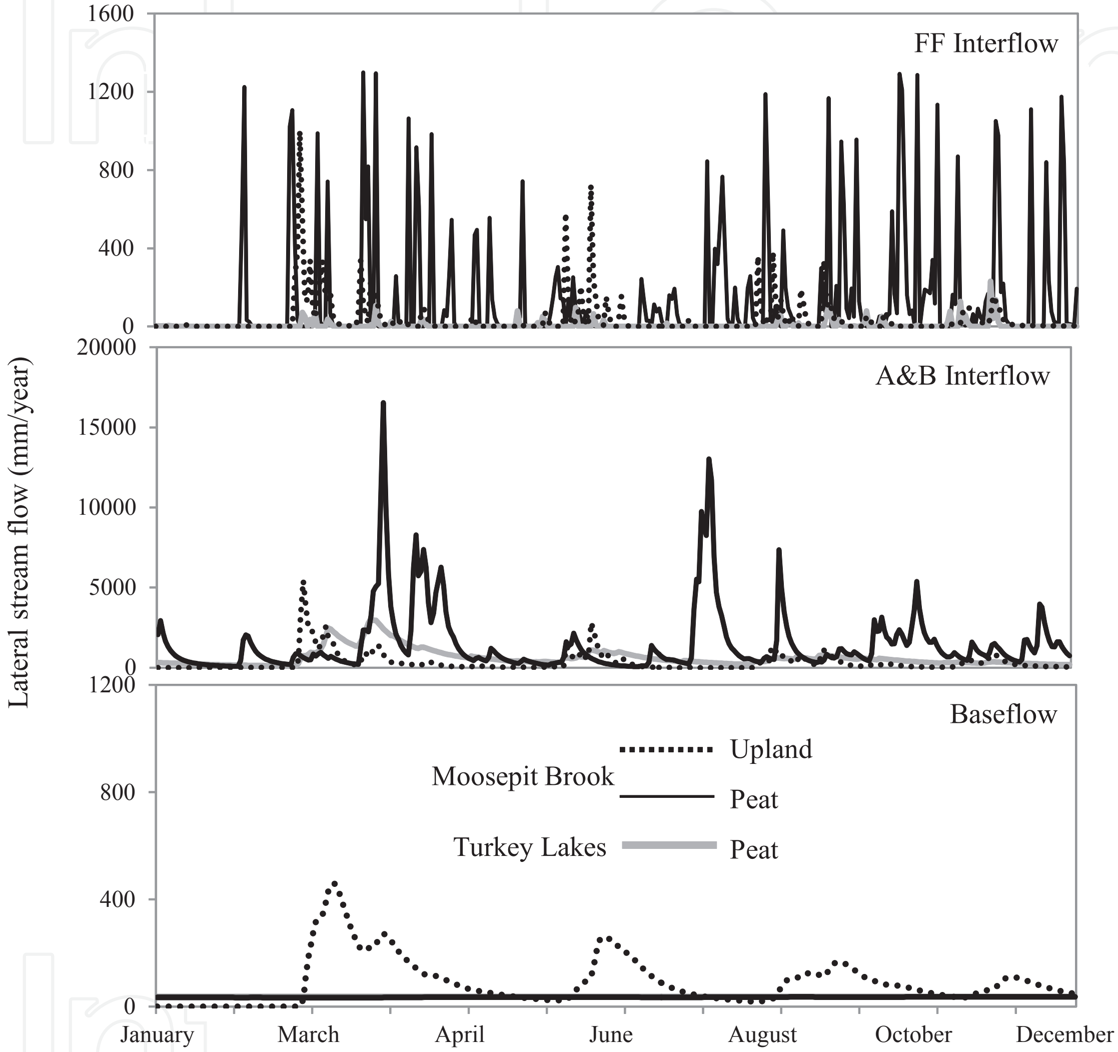

Figure 11. ForHyM2 estimated rates for daily forest floor and A&B interflow and base flow for peatland locations with a fibric - mesic – sapric layer profile at Moosepit Brook and Turkey Lakes, with 100% forest cover. Also shown: upland interflows and baseflows for the Moosepit Brook watershed (2000).

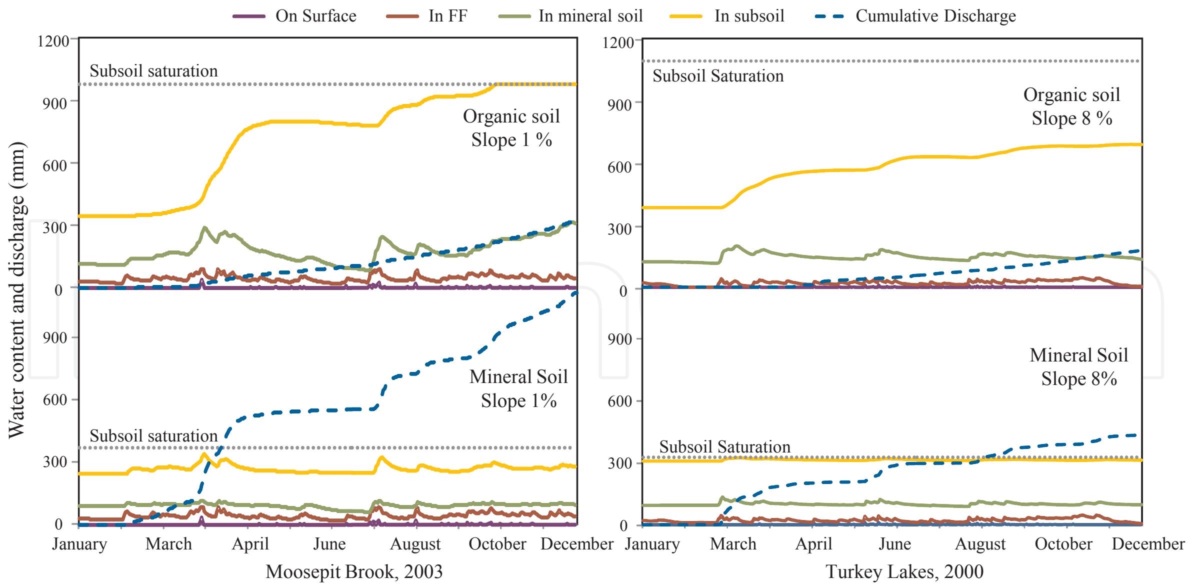

Figure 12. Soil water content on the surface, in the forest floor, in the mineral soil, and in the subsoil, as well as the cumulative discharge for Scenario 8 regarding organic soil (100% OM, top), and actual mineral soil conditions (bottom), for Moosepit Brook (2003, left) and Turkey Lakes (2000, right). Simulations start with unsaturated soil condition. Discussion

The above watershed-based K_{sat} evaluations have shown that the effective K_{sat} values for downward and lateral flow generally vary by a factor of 2 to 3 in comparison to corresponding values generated via Eqs. 1-3 [1]. As illustrated via Table 5 and subsequent figures, these variations lead to uncertainties in quantifying how water percolates through watersheds as run-off, interflow and baseflow (Fig. 5). These uncertainties also affect the flow response time, ranging generally from small delays to extended periods of flow as K_{sat} values decrease (Figs. 6 to 9). Across watersheds, however, flows tend to be well synchronized, regardless of major differences in texture, density, and organic matter content [28]. Typically, watersheds with the more compacted soils and therefore low K_{sat} values will be more peaked and will therefore be flashier than watersheds that allow deep percolation [25, 26, 27, 2]. The strongest impact of shallow to deep flow would deal with the water quality: deep water percolation during summer would lead to cooler and purer stream and seepage water with elevated pH than shallow water percolation [6]. During winter, deep percolation and persistent base flow would be warmer compared to the frost-affected surface water on poorly drained soils [6, 5]. Water flowing along the surface would also be more colored towards brown and more acidic than the more filtered and mineral-exposed water flowing at greater soil and subsoil depth [28]

While organic matter and soil density would not change drastically throughout undisturbed watersheds, such changes would occur during and after times of intense surface operations, especially under poor weather conditions. For example, forest operations during times of poor soil trafficability lead to ruts and increased soil compaction [29, 30]. In turn, soil compaction leads to lower K_{sat} values and therefore lower infiltration and hence higher surface run-off rates, thereby accelerating soil erosion and subsequent sediment transfer to streams and lakes [4]. Trails across the slopes of watersheds also affect downslope flow by compacting the soil underneath the trails, which means more water retention upslope along the trails, therefore leading to weather-effected trail destabilization, unless ditches and cross drains are installed to divert the water away from the trail beds [31]. Changes in forest cover could lead to changes in rooting space, which would – in turn – reduce the organic matter content within top and subsoils. This reduction would then alter the overall interplay between surface runoff, interflow and baseflow. Similarly, variations in climate from wet to dry (induces soil shrinking, may reduce root biomass), from frozen to non-frozen (induces collapse of frozen soil structures) would also affect K_{sat} and flow through soils by affecting the organic matter build-up, the state of soil organic matter humification, and overall changes in granular, blocky and columnar soil structures

The main advantage of the above K_{sat} formulation is that it allows for daily weather-related projections concerning downward and lateral water flow rates in forested to non-forested watersheds from times when soils are at saturation to times when soils are dry. At times of soil saturation, this quantification can then be used to estimate the effects of flow on soil stability and stream discharge. At times of drought, this quantification is can be used to estimate the effects of no flow on the remaining water reserves within soils and watersheds with and without peatland components (Fig. 12). Using ForHyM2 has the additional advantage of conducting these calculations year-round, summers through winters, based on already existing daily weather records, and extending these by way of daily, weekly, monthly or annual weather forecasts

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Author details

Marie-France Jutras and Paul A. Arp

*Address all correspondence to: arp2@unb.ca

Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, Canada

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