Baseflow production from partially peat-covered catchments, Jonsvatnet, Mid-Norway

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Due to their wide areal extent and high water release capability, peatland ecosystems must have a significant, albeit hitherto poorly quantified, influence on baseflow production in partially peat-covered catchments. This study reports the baseflow production capability of both peatlands and surrounding bedrock uplands in mid-Norway, where the percent areal coverage of peatlands for twenty eight pristine catchments ranges from 1.3 % to 25.9 %. Their baseflow production capabilities, expressed as specific groundwater flux, were calculated statistically as averages over all the catchments studied. When the catchments were relatively wet, the specific groundwater flux generated by peatlands was as high as 0.0073 m/day, which was eleven times as much as that from the bedrock uplands (0.00067 m/day) with a thin and discontinuous soil cover. The flux from the peatlands decreased as the catchments became drier, but even for the driest period in this study, its value (0.00097 m/day) exceeded the specific groundwater flux from the bedrock uplands (0.00023 m/day) by four times. The baseflow production capability of the peatlands proved to be rather sensitive to changes in wetness of the catchments, compared with the peat-free bedrock uplands. The two different types of bedrock studied, i.e. greenstone/tuff and slate/phyllite, had similar baseflow production capabilities.

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Introduction

Peatlands are very common in areas with a cold, wet climate. Peatlands are classified either as rainwater-fed mires (bogs) or groundwater-fed mires (fens and swamps). They cover about 4% of the earth's total land area, 30% of the land area of Finland, 17% of Sweden, 15% of Canada and 9% of Norway (Shotyk 1988).

Physical properties such as the permeability, bulk density, water content and degree of humification of peats have been measured in various parts of the world (e.g. Boelter 1969, 1972, Romanov et al. 1975, Hobbs 1986, Mulqueen 1986). For most peats, the greatest contrast in permeability is found between the upper, periodically aerated, *acrotelm*, and the lower, less-permeable *catotelm*. The permeability contrast between these is quoted as being around three or four orders of magnitude (Ivanov 1981) and between one and eight orders of magnitude (Ingram 1983).

Many studies have been carried out on the chemical composition of peat waters, indicating acidic and nutrient-poor water chemistry for bogs, but near-neutral to alkaline, relatively nutrient-rich conditions for fen and swamp waters (Shotyk 1988). The high concentrations of organic carbon in drainage water from peatlands have recently drawn much attention from researchers in the context of lake and river acidification (McKnight et al. 1985, Gorham et al. 1986, Urban et al. 1989).

Attempts have also been made to determine the hydrological processes occurring in peatlands during and after rainfall. Their near-saturated soil moisture conditions make it likely that saturation overland flow will be the most important contributor to storm run-off generation (Burt et al. 1990), causing the run-off regime of peatlands to be 'flashy' in character. The role of groundwater flow in run-off production has largely been ignored in previous studies.

In general, a catchment consists of waterlogged systems, such as peatlands, and terrestrial systems such as mineral soil uplands and/or bedrock uplands (with a thin soil cover). The results of the above-mentioned studies make it plausible that peatlands of even a small percentage area can have a decisive

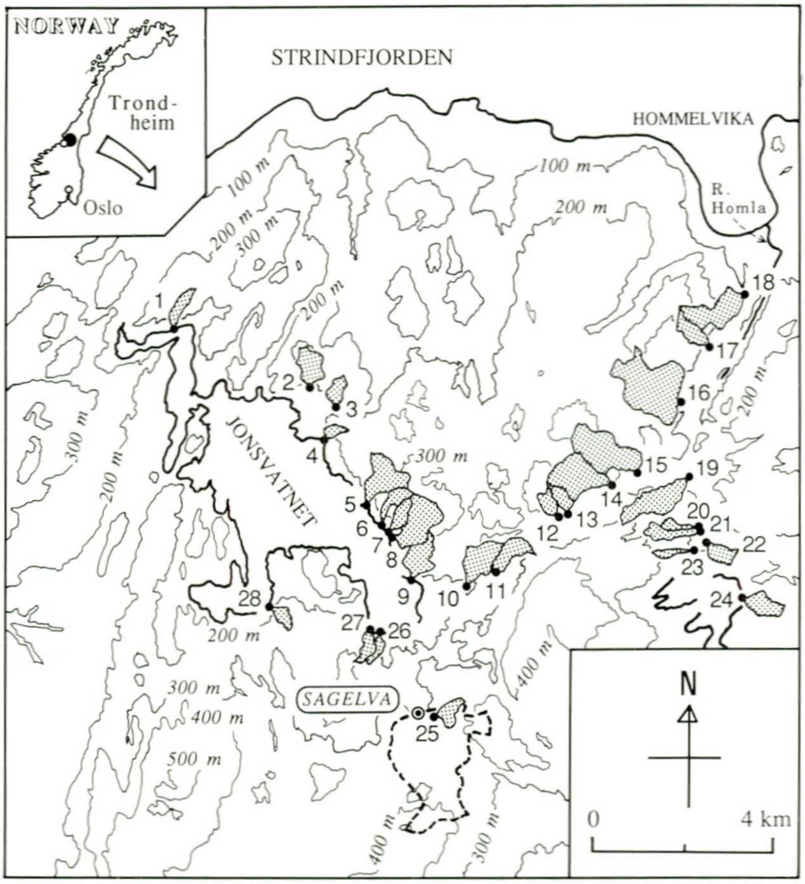

Fig. 1. The Jonsvatnet region and the studied catchments. Location of the IHD representative basin, Sagelva, is also shown. ⊙ = Sagelva hydrological station.

effect on both stream discharge and stream water chemistry from a partially peat-covered catchment. Some recent investigations support this concept from a geochemical point of view. Andersen (1987) confirmed the contribution of bogs to a higher pH in stream water by comparing partially peat-covered catchments with peat-free catchments. Moreover, carbon export from peatlands in Minnesota proved to be over 13 times greater than that from surrounding peat-free uplands (Urban et al. 1989).

Few studies have, however, investigated the relative importance of peatlands and peat-free uplands for run-off production from a partially peat-covered catchment. Quantification of the hydrological significance of peatlands for run-off production, especially during a baseflow period, has important implications for water resources development in boreal countries. The objective of this study, which was undertaken in Sør-Trøndelag county, mid-Norway, has been to clarify the baseflow production processes in just such a partially peat-covered catchment by a comparison of the baseflow production capabilities of peatlands and of surrounding peat-free uplands.

Site descriptions

Climate, vegetation and geology

The study was carried out in the vicinity of the lake Jonsvatnet to the east of Trondheim, Norway (Fig. 1). The Jonsvatnet region, which includes the International Hydrological Decade (IHD) representative basin, Sagelva, represents a largely natural ecosystem typical for southern and central parts of Norway. The annual precipitation is highly variable, averaging 1150 mm for the period 1972 to 1974 (Norwegian Institute of Technology & Norwegian National Committee for the IHD 1975)

Fig. 2. Peatland typical for the lake Jonsvatnet region. Note the surrounding uplands with an extensive area of exposed bedrock.

and about 1700 mm for the period April 1989 to March 1990 (Norwegian Institute of Technology, unpublished data).

The region is composed of lakes, peatlands and bedrock uplands. Peatlands typically lie in depressions surrounded by uplands with a thin and discontinuous cover of glacial till (Fig. 2). The peatlands generally extend down to c.4 m below the surface (Reite 1983) and are overlain by *Sphagnum* mosses. They are classified as raised bogs in the context of the swamp-fen-bog transition. The vegetation is predominantly *Vaccinium* (e.g. blueberry), associated with herb and *Sphagnum* moss undercover. There are occasional stunted and distorted pines (*Pinus sylvestris*). Surrounding bedrock uplands, dominated by natural Norway spruce (*Picea abies*), are characterized by a very thin soil cover, up to c. 10-20 cm thick, and extensive areas of exposed bedrock. Alluvium is sometimes found in the close vicinity of streams, and its thickness often reaches 20 centimetres or more.

Bedrock in the area consists of metamorphosed volcanic and sedimentary rocks of Cambrian to Silurian age (Wolff 1979). They are divided into two categories, the first consisting of greenstone and tuff, and the other of slate and phyllite (Fig. 3, after Reite 1983). Hereafter, the former is referred to as bedrock type I, and the latter as bedrock type II. Types I and II exhibit different fracture characteristics. As is obvious from Fig. 4, bedrock type I is often intensively shattered and to some extent weathered, having a relatively high secondary porosity and permeability. In contrast, the slates and phyllites of bedrock type II have a well-developed cleavage. In addition, they are typically cut by larger scale fracture planes (Fig. 5), and it is these which are likely to contribute a degree of permeability to the otherwise relatively low-permeability bedrock. Groundwater flow, therefore, is likely to be different for bedrock types I and II; a quasi-diffusive, uniform flow, in some ways similar to that in unconsolidated materials, may predo-

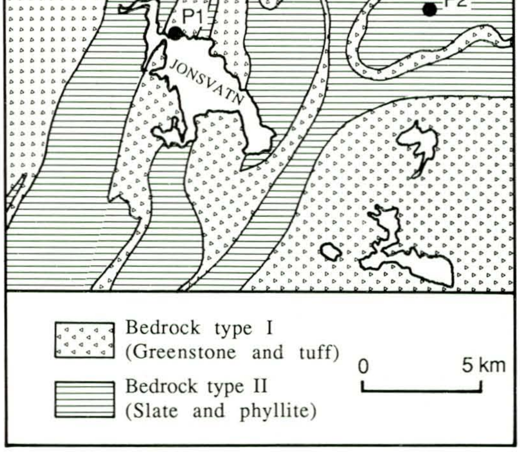

Fig. 3. Geological map (Reite 1983, simplified after Wolff 1979). Points P1 and P2 correspond to the locations of Figs. 4 and 5, respectively.

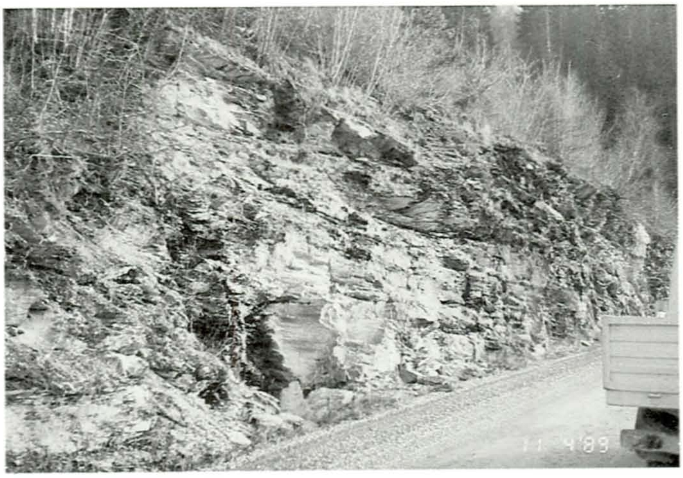

Fig. 4. Outcrop of greenstone (bedrock type I) at point P1 in Fig. 3.

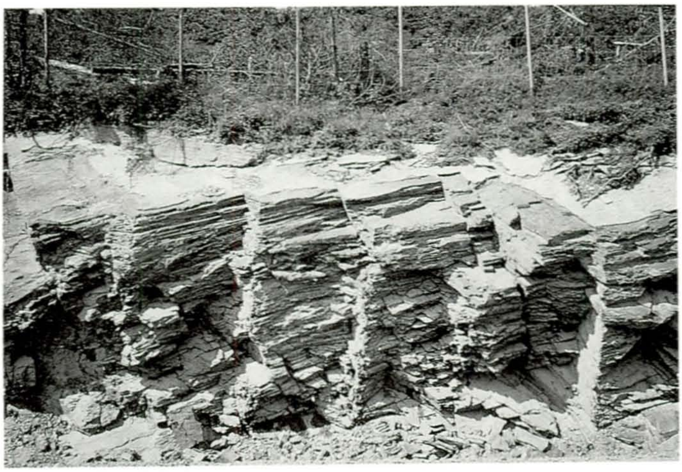

Fig. 5. Outcrop of slate (bedrock type II) at point P2 in Fig. 3

minate for type I, whereas a concentrated, preferential groundwater flow through major fractures may be predominant for type II. It should be noted here that not all the bedrock in the region is intensively fractured. Massive bedrock outcrops having few, if any, significant fractures were observed, for both bedrock types, at several locations in the Jonsvatnet region.

The studied catchments

Twenty eight pristine catchments, ranging in elevation from 140 m above sea level (a.s.l.) to about 300 m a.s.l. were selected for the study (Fig. 1, Table 1). They range from 0.099 km^2 to 1.566 km^2 in area (S_t in Table 1). Catchments Nos. 1 to 11 and Nos. 25 to 28 discharge into the lake Jonsvatnet either directly or indirectly, while others drain into Hommelvika bay via the River Homla or its tributaries. When choosing the catchments, care was taken not to include catchments with large open water bodies such as lakes.

The selected catchments are drained by streams rated from second to fifth order on Strahler's (1952) system of classification (Table 1). Of the twenty eight catchments, twelve are underlain by bedrock of type I and fifteen by those of type II. Catchment No. 15 is underlain by both types I & II, each accounting for approximately half the catchment's area.

The area of peatlands within each catchment (S_p in Table 1) was measured from maps of scales 1:25000 and 1:15000, which enabled calculation of the peatlands' areal percentage (S_p /S_t) for each catchment. Catchments No.13 and No.14, adjacent to each other, have high S_p /S_t values, 0.259 and 0.236

Table 1. Summary of physical characteristics of the studied catchments and measured discharges for the periods A, B and C. The catchment number corresponds to that in Fig. 1. For notations, see text.

No.	Stream order	Bedrock	St (km2)	Sp (km2)	Sp/St	A:Q (m3/day)	A:Q/St (m/day)	B:Q (m3/day)	B:Q/St (m/day)	C:Q (m3/day)	C:Q/St (m/day)
1	3	II	0.209	0.009	0.043	260	1.24e-3	59	2.82e-4	20	9.57e-5
2	3	I	0.337	0.032	0.095	360	1.07e-3	410	1.22e-3		
3	2	I	0.181	0.004	0.022	250	1.38e-3	140	7.73e-4		
4	2	I	0.099	0.005	0.051	79	7.98e-4	24	2.42e-4	12	1.21e-4
5	4	II	0.554	0.030	0.054	790	1.43e-3	470	8.48e-4	250	4.51e-4
6	2	II	0.169	0.013	0.077	170	1.01e-3	120	7.10e-4	29	1.72e-4
7	3	II	0.202	0.005	0.025	160	7.92e-4	110	5.45e-4	52	2.57e-4
8	4	II	0.678	0.086	0.127	1000	1.47e-3	750	1.11e-3	350	5.16e-4
9	3	II	0.366	0.053	0.145	460	1.26e-3	340	9.29e-4	100	2.73e-4
10	4	I	0.467	0.099	0.212			590	1.26e-3	230	4.93e-4
11	3	II	0.303	0.056	0.185			300	9.90e-4	160	5.28e-4
12	3	II	0.189	0.034	0.180	530	2.80e-3	300	1.59e-3	83	4.39e-4
13	3	II	0.166	0.043	0.259			260	1.57e-3	61	3.67e-4
14	5	II	0.836	0.197	0.236			1300	1.56e-3	350	4.19e-4
15	5	I/II	0.962	0.138	0.143			960	9.98e-4	550	5.72e-4
16	5	II	1.566	0.134	0.086			1400	8.94e-4	370	2.36e-4
17	3	II	0.269	0.019	0.071			120	4.46e-4	65	2.42e-4
18	4	II	0.601	0.008	0.013			470	7.82e-4		
19	4	II	0.712	0.040	0.056	810	1.14e-3	450	6.32e-4	300	4.21e-4
20	3	I	0.132	0.021	0.159			140	1.06e-3		
21	3	I	0.243	0.030	0.123			280	1.15e-3		
22	3	I	0.199	0.023	0.116	380	1.91e-3	150	7.54e-4	98	4.92e-4
23	2	I	0.108	0.003	0.028	56	5.19e-4	52	4.81e-4	17	1.57e-4
24	3	I	0.313	0.023	0.073			350	1.12e-3		
25	3	II	0.211	0.023	0.109			180	8.53e-4	120	5.69e-4
26	2	I	0.100	0.003	0.030	110	1.10e-3	42	4.20e-4	26	2.60e-4
27	3	I	0.185	0.019	0.103	300	1.62e-3	120	6.49e-4	68	3.68e-4
28	3	I	0.170	0.017	0.100	200	1.18e-3	160	9.41e-4	71	4.18e-4

Bedrock type	Field condition/ Obesrvation period		Abbreviations
I : Greenstone and tuff	A (wet cond.)	/ 23 Feb. & 1 Mar., 1990	St : Total area
II : Slate and phyllite	B (intermediate cond.)	/ 29-31 Aug. & 23 Sep., 1989	Sp : Peatland area
	C (dry cond.)	/ 4-6 Nov. & 14 Nov., 1989	Q : Stream discharge

respectively, indicating that peatlands cover about a quarter of their areas. At the other extreme, only 1.3 % of catchment No.18's area is covered by peatland.

As an example, the spatial distribution of peatland in catchment No.11 is shown in Fig. 6. Two large-scale peatlands, both of which generate streamflows, can be found; one on the upstream part of the main valley and the other on a terrace in a middle of the valley side with a very thin soil cover, if any. The thickness of the peats, as measured using a soil auger, ranged from around 20 cm at the margin to 340 cm (or more) and 270 cm respectively at the centre of the peatlands. Except at the marginal parts of the peatlands, auger-sounding typically revealed the existence of highly decomposed clayey peats of considerable thickness below low to moderately decomposed soft peats. The latter, soft peat layer, was c. 220 cm thick for the terrace peatland and c. 330 cm thick for the valley-bottom peatland). Highly decomposed peats are also reported in the lower parts of peatland profiles in other countries (e.g. Ingram 1967, 1983, Romanov 1968, Chason & Siegel 1986, Ivanov 1981), where their vertical hydraulic conductivities were found to be very low (10^{-6} to 10^{-7} m/sec., or even lower). Despite the lack of hydraulic conductivity measurements in this study, the above-mentioned facts make groundwater exchange between peats and surrounding bedrocks unlikely on a quantitatively large scale in the Jonsvatnet region.

Run-off measurements

Stream discharge in baseflow periods was measured three times between summer 1989 and winter 1990 at each of the catchment outlets. The first measurements were undertaken on 29-31 August and 23 September, 1989 (termed period B); the second on 4-6 and 14 November, 1989 (period C) and the third on 23 February and 1 March, 1990 (period A). Discharge from each catchment was measured once during a given period. The discharge from catchment No.2 was found to remain approximately constant during each of the three sampling periods, and hence it was not

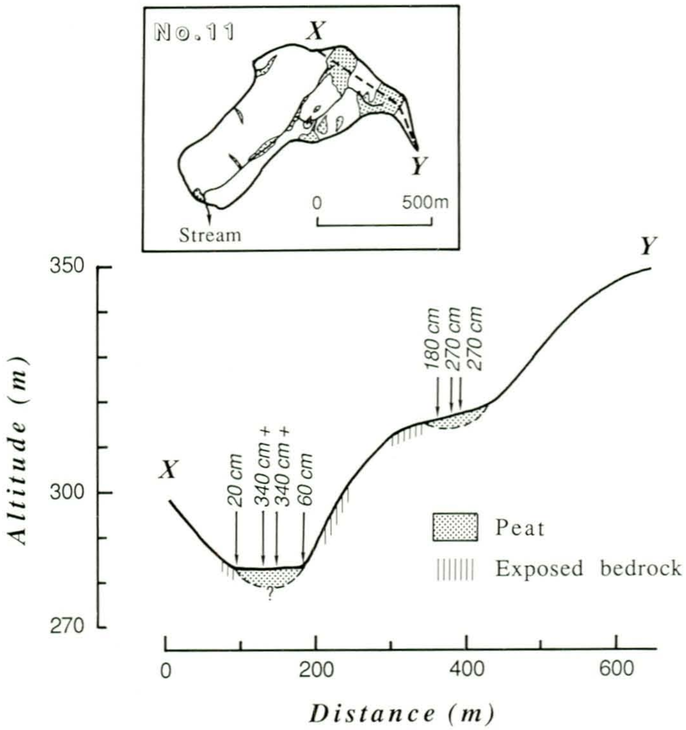

Fig. 6. Spatial distribution of peatlands in catchment No.11. Surrounding uplands are characterized by a very thin soil cover and extensive areas of exposed bedrock. Indicated figures (in cm) show the thickness of the peats.

thought necessary to correct stream discharges from other catchments for their slightly different times and dates of measurement.

A snow cover 5 to 20 cm thick lay on the ground during period A. No snow melting was, however, taking place during that period due to the extremely low prevalent temperature. In the centre of the valley-bottom peatland of catchment No. 11 (Fig. 6), the water table was observed to be very close to the peatland surface for period B, but 5-10 cm below the surface for period C. Unfortunately, the snow cover prohibited water table observation during period A. Run-off measurements were commenced only after ensuring the absence of saturation overland flow on the peatland surface.

For small streams, the stream flow was intercepted for a specific period using a large plastic bag, which enabled fairly accurate calculation of the discharge. The velocity-area method was adopted for the larger streams with more discharge. A straight reach of stream with a smooth shoreline, and no weeds or large rocks in the water, was chosen. A section of the stream was subdivided vertically into three to six segments of 0.3 - 0.5 m width. The surface velocity was determined three times at the midpoint of each segment by letting a float flow a known distance (1 - 2 m) along the stream. The depth was also measured at the midpoint of each segment. The average surface velocity was converted to the average velocity for the entire profile of each segment by multiplying by a factor of 0.85 (recommended by the Japanese Society of Civil Engineers 1985 for a stream less than 0.7 m deep). The discharge for each segment was calculated by multiplying the average velocity by the depth. The process was repeated for each segment of the cross-section, and the total stream discharge was calculated as the sum of the discharges for each segment.

To confirm the accuracy of the velocity-area method, it was compared with the «plastic bag» method on 29th August for the discharge from catchment No.2. Close agreement between the velocity-area method (350 m^3/day) and the plastic bag method (340 m^3/day) was obtained. This indicates that the velocity-area method can be satisfactory, if applied in a sensible way. Measured stream discharges (Q) for the three periods A, B and C are summarized in Table 1.

Figure 7 illustrates variation in daily run-off from April 1989 to March 1990 for the catchment Sagelva (3.4 km^2 in area), which is the only catchment having continuous records of run-off in the Jonsvatnet region. The three measurement periods in this study are also shown in the figure. It is clear from Fig. 7 that all the run-off measurements were carried out during baseflow periods, between run-off peaks. A flow duration curve (Fig. 8), which shows the number of days that certain values of discharge are equalled or exceeded, was derived from the daily run-off data of Fig. 7 for the catchment Sagelva. The average discharges during the periods A, B and C in Fig.7 correspond to the 175-day, 215-day and 265-day flow values, respectively. The studied catchments at the time of the run-off measurements were, therefore, in relatively *wet*, *intermediate* and *dry* soil-moisture conditions for the periods A, B and C, respectively.

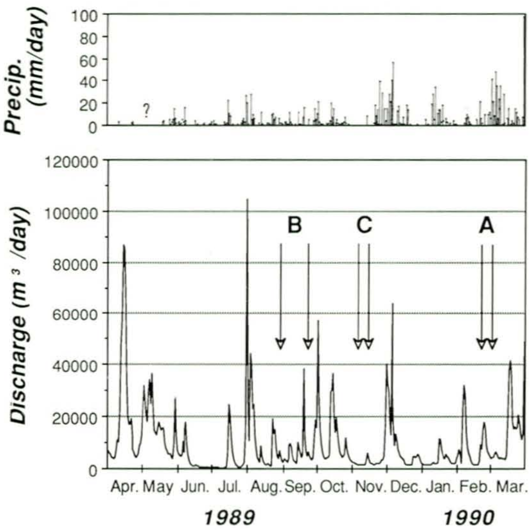

Fig. 7. Daily precipitation and run-off from the catchment Sagelva for the period April 1989 to March 1990 (measured at site ⊙ in Fig. 1). The figure is based on the unpublished data of the Norwegian Institute of Technology. Arrows indicate the three periods when field observations in this study were undertaken.

Analytical procedures

The magnitude of the baseflow production capability of both peatlands and surrounding bedrock uplands was analysed by statistical methods. For simplicity, it was assumed that each catchment consists only of peatlands and peat-free bedrock uplands (Fig. 9). It is further assumed that only two flow components, groundwater flow from the peatlands (flow a) and groundwater flow from the bedrock uplands (flow b), contribute during a baseflow period and that the flows a and b are independent. These flows discharge via stream beds to produce the baseflow from the catchment. The contribution of alluvium and/or moraine to baseflow production was assumed to be negligible in this study, due to the limited areal extent of these lithologies.

The total area of the catchment, S_t [dimension L^2], can be expressed as

$$S_t = S_p + S_b \quad (1)$$

where S_p and S_b [L^2] represent the areas of the peatlands and the bedrock uplands, respectively. Stream discharge, Q [L^3/T], at the outlet of a catchment is the sum of the groundwater discharge from the peatlands (flow a) and that from the bedrock uplands (flow b). Therefore,

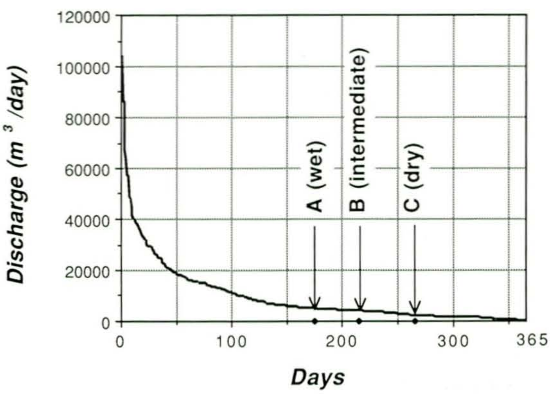

Fig. 8. Flow duration curve for the catchment Sagelva. Arrows indicate the number of days (on the abscissa) that average discharge values for the three periods A, B and C (Fig. 7) are equalled or exceeded.

$$Q = S_p.q_p + S_b.q_b \quad (2)$$

where q_p and q_b [$(L^3/T)/L^2$ or L/T] are the specific groundwater fluxes (groundwater release per unit time and area) from the peatlands and the bedrock uplands, respectively. Rearrangement of equations (1) and (2) yields

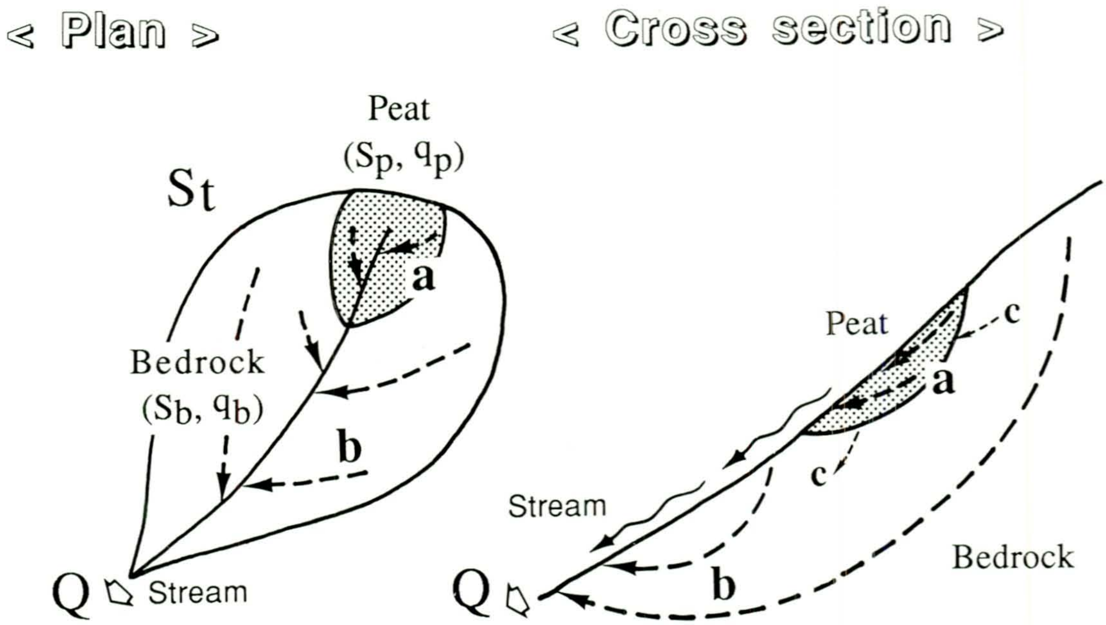

Fig. 9. Simplified representation of baseflow generation processes by two groundwater flow components, i.e. flow a from the peatlands and flow b from the bedrock uplands. Because of the presence of low-permeability, highly decomposed clayey peats in the lower parts of peatland profiles, groundwater exchange between peats and bedrock (flow c) is assumed to be negligible. For other notations, see text.

$$Q/S_t = q_b + (q_p - q_b).S_p/S_t \qquad (3)$$

Q/S_t [L/T] is the specific discharge of the catchment and S_p/S_t is the areal percentage of the peatlands in the catchment.

If the value of Q/S_t and the corresponding S_p/S_t value is known for many catchments, one can obtain q_p and q_b values graphically. By plotting Q/S_t values against S_p/S_t values (Q/S_t on the ordinate), a least-square linear regression line can be drawn. The intercept on the Q/S_t axis is q_b, while the slope of the regression line is $(q_p - q_b)$. Therefore, the specific groundwater flux from the peatlands, q_p, can also be calculated. By this procedure, the q_p and q_b values, representing the baseflow production capabilities of the peatlands and the bedrock uplands respectively, are estimated as averages over all the catchments studied.

Results and discussion

The measured discharge from a catchment was converted into its specific discharge (Q/S_t) by dividing by the catchment's area. Calculated values are shown in Table 1. The Q/S_t value for each catchment was largest for period A (wet conditions) and smallest for period C (dry conditions), with an intermediate value for period B. Q/S_t is plotted against S_p/S_t for each of the three periods in Fig. 10. All the catchments are shown in Fig. 10 for each period regardless of the bedrock type. For all three periods, there is a general positive correlation between the areal percentage of peatland (S_p/S_t) and the specific discharge from the catchment (Q/S_t). The regression line for period A has the steepest slope and the largest Q/S_t-axis intercept, followed by those for periods B and C respectively. The regression lines in Fig. 10 are expressed as

$Q/S_t = 0.0080\ S_p/S_t + 0.00067$ (r^2=0.52, n=16)
:for period A
$Q/S_t = 0.0044\ S_p/S_t + 0.00043$ (r^2=0.65, n=28)
:for period B
$Q/S_t = 0.0012\ S_p/S_t + 0.00023$ (r^2=0.30, n=22)
:for period C

The equations allow us to estimate q_p and q_b values for each period according to the procedure described above (Table 2). The

Table 2. Summary of the specific groundwater flux from bedrock uplands and peatlands for the periods A, B and C.

Period	Bedrock Uplands Flux (m/day)	Peatlands Flux (m/day)	Ratio
A (wet)	0.00067	0.0073	1:11
B (intermediate)	0.00043	0.0040	1:9
C (dry)	0.00023	0.00097	1:4

correlation coefficient between Q/S_t vs. S_p/S_t is not statistically significant for the period C. Therefore, the obtained q_p and q_b values for period C in Table 2 must be regarded as somewhat uncertain compared with those for periods A and B.

For all of the three periods, the peatlands contributed much more to baseflow production per unit area than the bedrock uplands, with the largest specific groundwater flux, q_p, during period A (wet conditions). The specific groundwater flux from the peatlands at this time, 0.0073 m/day, was about eleven times as large as q_b (0.00067 m/day), the flux from the bedrock uplands. Under dry conditions (period C), the specific groundwater fluxes from both the peatlands and the bedrock uplands were substantially reduced, to 0.00097 m/day and 0.00023 m/day respectively. Even for the dry period C, the specific groundwater flux from the peatlands was still larger than that from the bedrock uplands, but only by a factor of four times. From period A to period C, the specific groundwater flux from the bedrock uplands decreased by approximately two-thirds, whereas that from the peatlands declined by about seven-eighths. This implies that the peatlands are relatively unstable with respect to baseflow production capability compared to the peat-free bedrock uplands.

This rapid decrease in specific groundwater flux from the peatlands for drier conditions may be due to the lowering of the water table within the peats and the resultant sharp decrease in groundwater flow towards streams. According to Romanov et al. (1975), hydraulic conductivity tends to decrease rapidly in the acrotelm, from 10^{0}-10^{-2} m/sec at 1 to 2 cm depth to 10^{-5} m/sec at the lower boundary of the acrotelm. In addition, Tomlinson (1979) reported a 'critical level' for the water table at 5-6 cm below the bog surface, below which lateral groundwater flow almost ceased and run-off sharply decreased.

In the Jonsvatnet region, as was cited in the

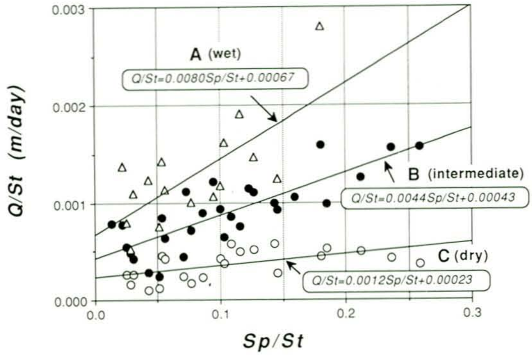

Fig. 10. Q/S_t plotted against S_p/S_t for the three periods A, B and C, with calculated regression lines.

previous section, the water table in the central parts of the peatlands in catchment No. 11 was observed to have fallen to 5-10 cm below the surface for period C. It appears that the water table, which had been located at the ground surface or in the more permeable uppermost parts of the acrotelm for periods A and B, fell below a 'critical level' in period C. As the result, a rapid decrease in the transmissivity seems to have dramatically lowered the specific groundwater flux from the peatlands.

Although the specific groundwater flux from the peatlands diminished sharply as the catchments became drier, it was still four times as large as that from the bedrock uplands even for the driest period in this study (Table 2). It is, therefore, concluded that the peatlands behave as a 'sponge' with respect to water retention and release. This result is in disagreement with the findings of Chapman (1965), Tomlinson (1979) and Burt et al. (1990), who were in doubt about the gradual release of groundwater to streams during drier periods and stressed that peatlands were poor suppliers of baseflow.

On the other hand, the bedrock uplands proved to be a relatively stable contributor to baseflow production compared with the peatlands. Therefore, the drier the catchments are, the more important the contribution of the bedrock uplands to baseflow production becomes. This may result from a significant secondary groundwater storage capacity in the bedrock (i.e. the numerous fractures dissecting the massive primary rocks).

The bedrock uplands consist of two different lithologies, i.e. greenstone and tuff (type

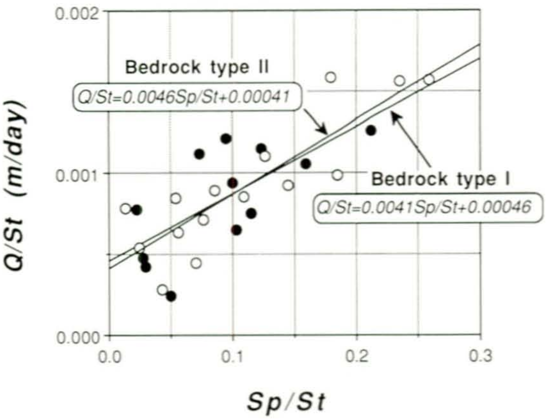

Fig. 11. Separate plots of Q/S_t for period B against S_p/S_t, for the bedrock types I (●) and II (○).

I) and slate and phyllite (type II). Figure 11 attempts to distinguish between the specific groundwater fluxes from the uplands for bedrock types I and II. The regression lines obtained for the period B are

$Q/S_t = 0.0041\ S_p/S_t + 0.00046$ (r^2=0.48, n= 12): for bedrock type I
$Q/S_t = 0.0046\ S_p/S_t + 0.00041$ (r^2=0.74, n= 15): for bedrock type II

The q_b values (0.00046 m/day and 0.00041 m/day respectively) for bedrock types I and II are almost equal. This indicates that both types of bedrock have nearly the same capability for baseflow production, despite their different fracturing characteristics.

In Japan, Takahashi (1978) reported specific baseflow production capabilities ranging from 0.0007 to 0.0009 m/day for catchments composed of the Paleozoic (partially Mesozoic) slate, chert and sandstone. The baseflow production capabilities of the bedrocks observed in the Jonsvatnet region are, therefore, of the same order of magnitude as those for Japanese catchments of nearly the same age, although the primary characteristics of the bedrock are likely to be rather different.

Concluding remarks

Peatlands are found to be large sources of baseflow in catchments in the Jonsvatnet region of mid-Norway. When the catchments were relatively wet, the peatlands generated a specific groundwater flux as high as 0.0073 m/day, eleven times the flux from surrounding bedrock uplands (0.00067 m/day) with a thin and discontinuous soil cover. The specific groundwater flux from the peatlands decreased sharply as the catchments became drier, but even for the driest period in this study, its value appeared to exceed the groundwater flux from the bedrock uplands by four times. The baseflow production capability of the bedrock uplands proved to be rather insensitive to changes in wetness of the catchments. The results from this study would seem to have important implications for water resources planning in partially peat-covered catchments, especially for drinking water supply and for hydroelectricity development during baseflow periods.

Because the peatlands remain so close to saturation, only small amounts of rainfall are necessary to raise the water table to the surface (e.g. Burt et al. 1990). It is, therefore, plausible that the water table rises rapidly to the surface during rainfall and may generate large amounts of saturation overland flow, resulting in a drastic increase in the streamflow production capability of the peatlands. In such a case, the peatlands may become almost exclusive contributors to streamflow generation. On the contrary, this study suggests that the value of specific groundwater flux from the bedrock uplands may tend towards that from the peatlands when the drying of the catchments reaches a more advanced stage than was observed in this study. Quantifying the capabilities of both the peatlands and the peat-free bedrock uplands for these two 'extreme' cases is an objective for future research in the Jonsvatnet region.

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