Forest Sciences

Prince Rupert Forest Region

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Surface Water Discharge and Groundwater Storage Patterns in a Hypermaritime Bog Near Prince Rupert, B.C.

Research Issue Groups:

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Introduction

Relationships between precipitation and surface water/groundwater within an open bog in the Prince Rupert area were examined to determine if there were hydrological linkages to the surrounding forests. By definition, bogs are peatlands that receive water input exclusively from direct precipitation (NWWG 1997). Consequently, they are normally considered hydrologically isolated from groundwater and surface water in the surrounding landscape. There is some evidence, however, that this isolation is less absolute than previously thought (Siegel et al. 1995). From an operational forestry perspective it is essential to establish this relationship in order to understand the implications of disturbance in the surrounding forest on these sensitive wetland ecosystems.

The rugged landscape of the Prince Rupert area contains a complex mosaic of ecosystems including bogs, fens, bog forests, and bog woodlands, interspersed with upland forests on the steeper terrain. This bog-forest complex has developed, as a consequence of the gentle relief and mild, wet hypermaritime climate. Wetlands often occur adjacent to forests that may be harvested. Very few studies have examined the hydrology of bogs in this hypermaritime environment (Siegel 1988) or their relationship to the surrounding landscape.

Typically, bogs have two main soil layers. The top layer is 10-50 cm thick and contains living and dead but poorly decomposed plant material (roots and the remains of vascular and non-vascular vegetation). The lower layer is composed primarily of perpetually saturated, well-decomposed organic material (NWWG 1997). The surface layer is the most active hydrologically, and the flow rates may be several orders of magnitude greater than the lower layer (Ingram 1983). Consequently, when the water table is near or at the surface of the bog, the water is free to move though the more active surface layer (Waddington and Roulet 1997).

Whether bogs are hydrologically connected to, or isolated from, the surrounding forest ecosystem has operational implications. For example, if bogs are hydrologically isolated, and no physical logging operation occurs directly on the bog surface, then what is done above or below it on a slope may not greatly affect the hydrology of the bog. Each case, however, must be evaluated individually, to assess hydrological linkages and potential operational impacts. The objective of this extension note is to characterize the nature and strength of the linkage between a bog that has developed within a complex landscape and the adjacent forests, specifically with the Western hemlock - Sitka spruce - Lanky moss (04) and Western redcedar - Western hemlock - Salal (01) site series in the CWHvh2 biogeoclimatic variant (Banner et al. 1993).

This study was part of the HyP[3] Project (pronounced 'hip cubed'; Pattern, Process, and Productivity in Hypermaritime Forests), an integrated forest research project aimed at developing ecologically based guidelines for the management of cedar-dominated forests currently outside the operable land base. For an overview of the project see Extension Note #38 (Banner and Shaw 1999).

Site Description

The study site is located in Diana Lake Provincial Park, located about 20 km southeast of Prince Rupert, British Columbia (54º 18' N, 130º 26' W). The area is in the Coastal Western Hemlock biogeoclimatic zone, Very Wet Hypermaritime subzone – Central variant (CWHvh2) (Banner et al. 1993). The hypermaritime climate has mild temperatures (daily means: July 12.9ºC, January 0.8ºC), high annual rainfall (2552 mm) and low evapotranspiration. The wetlands consist of sloping bogs (site series 32; Banner et al. 1993), bog woodlands (12), and bog forests (11). Interspersed within this bog-forest complex are productive western hemlock-Sitka spruce forests (04), less productive Redcedar-cypress-hemlock forests (01) and moderately productive Redcedar-Sitka spruce swamp forests (13). The 04 forests are generally found on steeper well-drained slopes.

The bog study site is approximately 4.4 ha in area (Turunen 1999). Contained within the bog is a well-defined stream that flows from west to east and has a catchment area of 0.7 ha. Surface water pools cover approximately 10% of the bog catchment area. These pools dry out during the summer months after approximately 10 days without rain. In the foreground (north) of the oblique air photograph (Figure 1) is the 04 productive forest, and on the southern side of the bog the forest grades from 12 to 01 site series. The bog is slightly sloping with the high point to the west and north. In Figure 1, the stream can be seen to originate on the western edge (right side), flowing roughly east across the bog.

Methods

A 500 m north-south transect (Figure 2) and a shorter west-east transect were established through several of the ecosystem types. The upper section of the north-south transect consists of several site series: 04-13-32-11(01). The productive 04 forest occupies the steep upper slope of the transect and is separated from the bog by a narrow section of swamp forest (13) (Fitzgerald et al. *in press*), the gentler slope below the bog grades from site series 12 to 11 and finally to 01.

Water table elevation was recorded using a network of five automatic recording wells; three of the wells were installed systematically along the north-south transect, and two wells were on the west-east transect. Surface flow from the bog was measured at a 60° V-notch weir installed at the outflow of the bog stream (Figure 3). Stage was recorded hourly at the weir using an

Figure 1. Oblique air photograph of the study site. North is at the bottom of the page. Bottom foreground is (04) productive forest. Bog is the open area in the middle of the photo. The bog stream forms on the west (right hand) side and flows towards the east. A boardwalk can be made out coming from 04 across the bog and then towards the 12-11 site series at the upper right corner of the page.

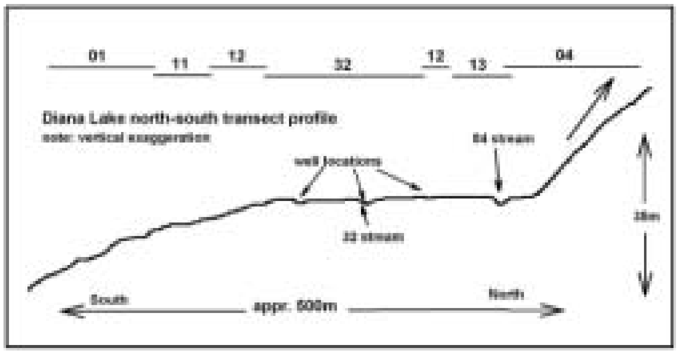

Figure 2. Cross sectional view of the Diana Lake north-south transect. Site series are listed above profile. Study site is located on site series 32, open bog, near the centre of the transect profile. Note that flow direction of the 04 and 32 streams is towards the east (towards the reader).

automatic recording well, and stage records were later converted to discharge by establishing a stage – discharge relationship (see Dingman 1994). Rain was collected on the bog using a tipping bucket rain gauge connected to a data logger.

To estimate the change of volume of water on the bog the following formula (Fetter 1994) was used:

Groundwater storage = water yield per volume soil x catchment area x water table elevation change [1]

The water budget for the bog was determined using the equation:

Precipitation = stream discharge + evapotranspiration +/- groundwater storage [2]

Results and Discussion

Groundwater from the northern edge of the bog flows east-southeast and groundwater from the southern edge flows east-northeast, converging at the stream formed at the topographic low along the centre of the bog. Water budgets for two rain events, July 22nd and July 28th, were used to determine if there were water inputs to or exports from the bog. This would indicate whether the bog was hydrologically linked to or isolated from the surrounding forested areas. During the July 22nd event 17 mm of rain fell in 20 hours; during the July 28th event 56 mm fell in 47 hours (Figure 4a). The water table responded rapidly during the July 22nd event, rising from 14.5 cm below ground surface to just 2.9 cm in 15 hours. The July 28th event response was similar, although the water table was initially closer to the surface, starting at –10 cm and reaching –3.0 cm 10 hours into the storm (Figure 4b).

Figure 3. Bog stream weir. 60º v-notch weir measures discharge on bog stream. Note stage recorder to left behind the weir.

During rainfall events the water table on the higher ground south and north of the stream rose more than the water table nearest the stream (Figure 4b), indicating an increase in the hydraulic gradient, hence surface and groundwater flow towards the stream. Surface water collected in the bog stream was rapidly removed from the bog. Different bog stream responses were observed for the two events (Figure 4c). At the start of the July 22nd event, the average water table in the bog was low. The storm delivered only enough water to raise the water table close to the surface but not enough to create significant surface flow at the bog stream; only 13 m^3 of flow was produced (Figure 5). The significantly larger July 28th event, which occurred when the bog water table was initially nearer to the surface, produced 350 m^3 of discharge (Figure 5).

The different runoff response to the two storms reflects the role of the water storage capacity of the bog soil. For the July 22nd event, using the water budget equation (2), it was found that 121 m^3 rain fell on the bog. Of this amount, 106 m^3 was taken up in groundwater storage (equation 1), 13 m^3 discharged over the stream weir, accounting for 119 m^3 of the 121 m^3 input (Figures 4b & c). Evapotranspiration over the duration of the storm event was likely negligible, thus was ignored. The July 28th event was quite different. For this event, input from rainfall was 400 m^3, an amount exceeding the bog ground water storage capacity; the excess water (350 m^3) was discharged. Of the remaining water, 9 m^3 was stored as groundwater (equation 1) and 41 m^3 was

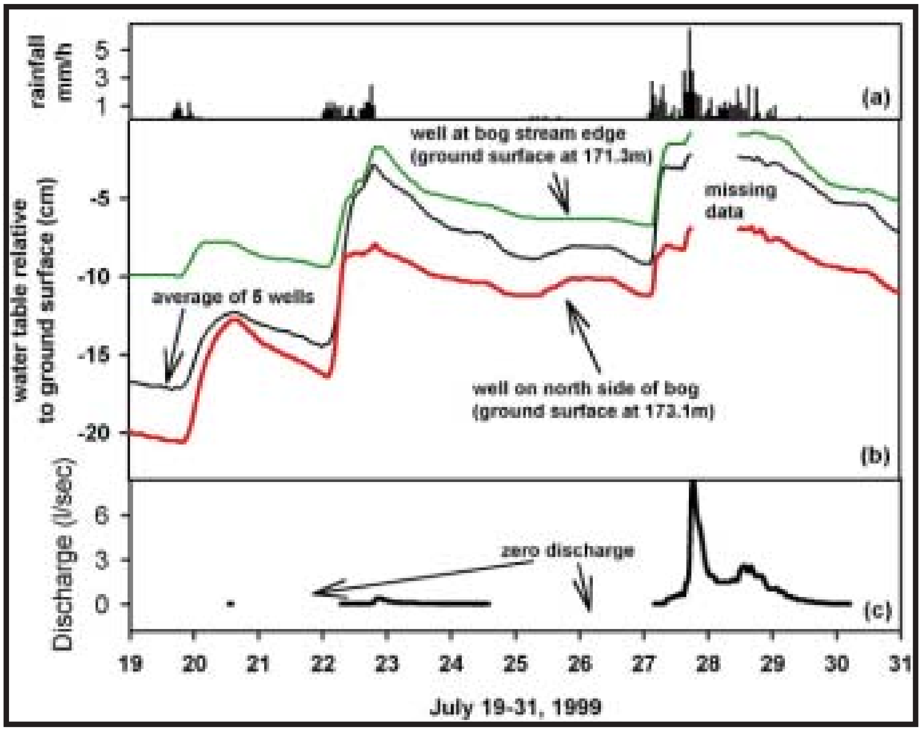

Figure 4. (a) Precipitation; (b) bog water table elevation relative to ground surface; and (c) discharge recorded at the bog weir.

stored in surface pools, which covered about 10% of the catchment area. Evapotranspiration was not measured but between rain events the absence of flow from the bog stream suggests evapotranspiration was the primary method of lowering the water table in the bog during this period. Between the July 22nd and July 28th events (Figures 4b, c) the bog discharge was zero but the average water table dropped 1.2 cm.

Conclusions

The full accounting of the input, storage and discharge from two storms, one following a dry period, the other a wetter period, demonstrates the hydrological independence of this bog system from adjacent ecosystems. During the first event, most rainfall could be accounted for by the change in water storage within the bog - almost no water was lost by drainage. For the second event, inputs could mostly be accounted for by discharge and storage change (water table rise).

Despite the macro-scale topographic gradient between the bog and the adjacent forested areas there was no apparent hydrologic linkages between them as seen by the lack of water inputs from these areas. This lack of water transfer between the forest and bog was due to subtle differences in elevation and flowpaths at the margins of these two systems. Strong seepage losses at the foot of the forested 04 slope (Fitzgerald et al. *in press*) are constrained in a seepage channel that skirts the perimeter of the bog on its northern side. Rain falling on the southern side near the bog margin may flow downhill to the 11 then 01 site series, but this loss was minor. Given the absence of streamflow in the bog between rain events, groundwater seepage through the peat, either to the stream, or toward the margins, was minimal.

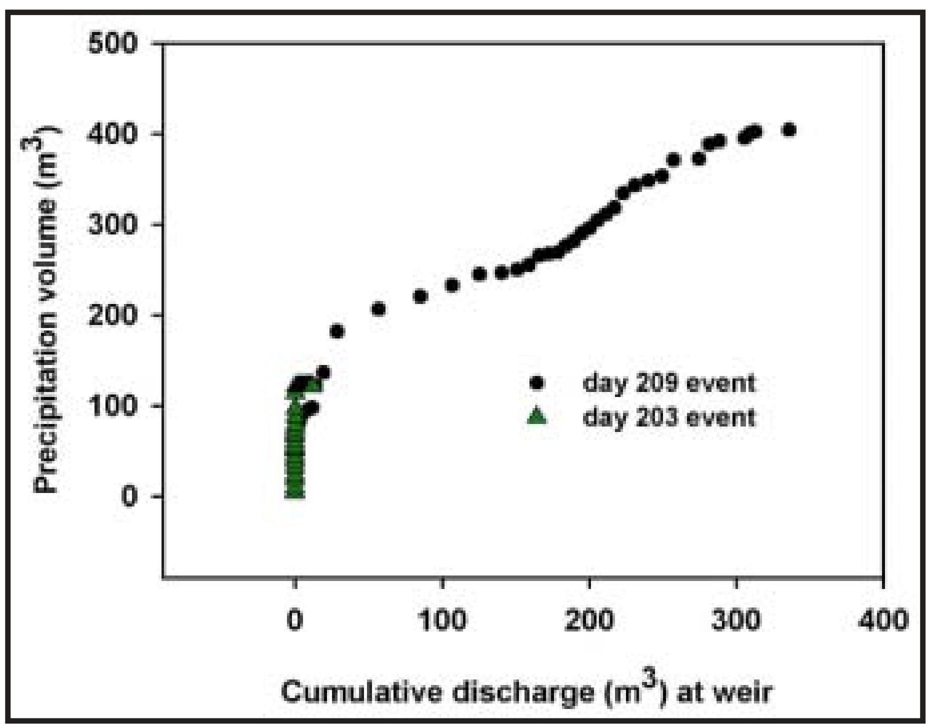

Figure 5. Cumulative weir discharge plotted against total precipitation volume. Each triangle (event 203) or dot (event 209) represents one hour. Note the vertical rise in precipitation volume for event 203 with no discharge change until very end of the storm. Most of the rainfall in the day 203 event is taken up by groundwater storage.

Operational Implications

Possible hydrological impacts to wetlands from forestry activities include cutting off of water supply to the wetland and adding additional water to the wetland. Both of these actions may initiate changes in the bog hydrology that could impact on wetland functioning. Water flow to wetlands could be cut-off due to logging road construction at the base of slopes that feed the wetlands, while water flow could be supplemented through additional inputs to streams that feed wetlands after forest canopy removal.

If forestry activities occurred on the slopes above this particular bog, it is unlikely there would be any direct consequence for the bog's hydrological integrity. This is because the bog is isolated from the adjacent forested hillslope by a small stream, which intercepts the runoff from this slope. As long as machinery refrained from traversing the bog or the bog margins, there would be little hydrological impact to the bog.

Peatlands on the outer coast are highly variable since the nature of the landscape produces bogs in many different topographical and hydrological settings. In order to avoid impacts to bogs when harvesting, it will be important to assess whether these wetlands are hydrologically connected to the area being planned for harvest. This can be done by surveying the area for topographical breaks and streams that would indicate whether the forest and bog were hydrologically linked or isolated.

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