SUB-ICE SPRINGMELT WATER CIRCULATION IN A SMALL LAKE

Jean Roberge and Gerald Jones
INRS-Eau, 2700 Einstein, C.P. 7500, Ste-Foy, QUEBEC, G1 V4 C7

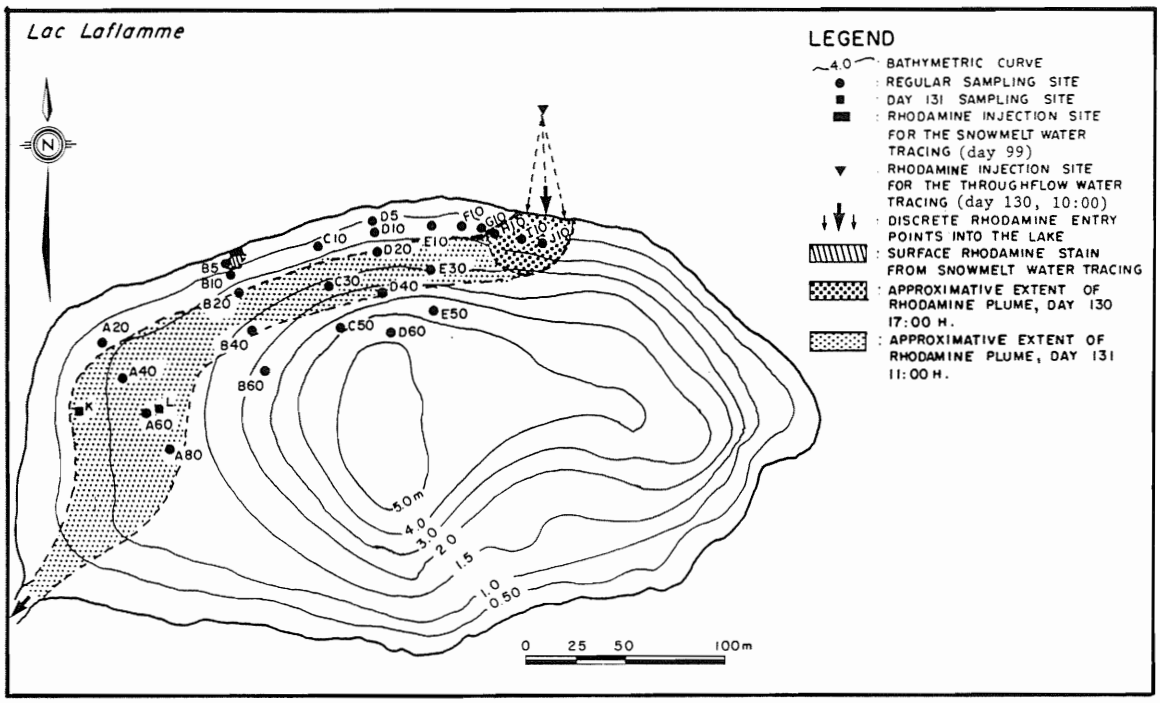
EXTENDED ABSTRACT

In a small boreal headwater lake, the sub-ice circulation of waters from 5 distinct origins (lake premelt water, lake snowpack meltwater, ice cover meltwater, groundwater and hillslope throughflow water) was studied during springmelt. A network of access holes was used to monitor the sub-ice temperature, conductivity and pH profiles. The study also included springmelt hydrology monitoring and the tracing of snowbank meltwater and throughflow water with rhodamine.

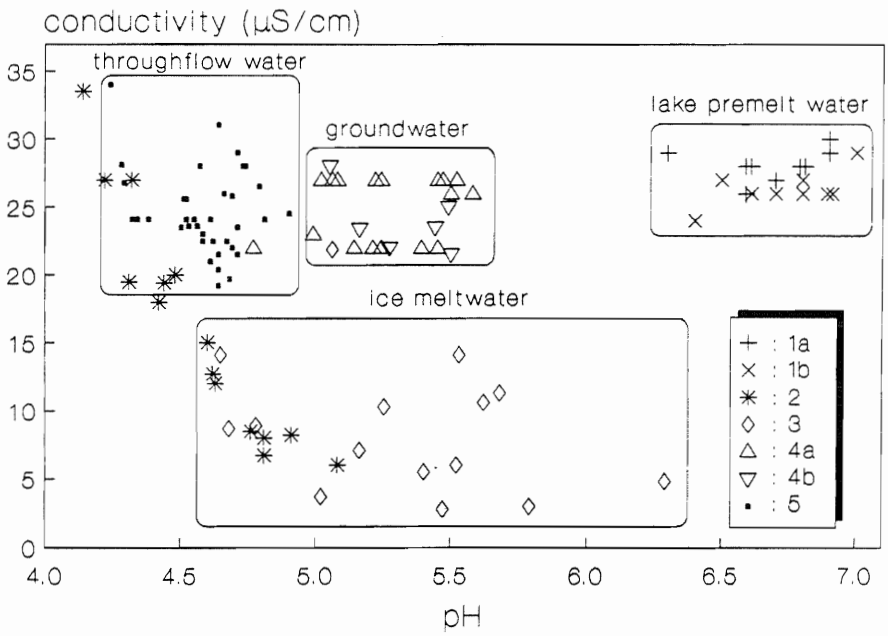
Conductivity and pH appeared to be efficient parameters for discriminating most of the water types considered. The lake surface snowmelt, icemelt and hillslope throughflow all formed sub-ice floating strata similar to those reported in Scandinavia, northern United States and Ontario. Snow and ice meltwaters layered beneath the ice forming a floating stratum ≈20 cm thick. It moved toward the outlet under laminar flow conditions (observed average velocity: 1 m/h), driven mainly by nearshore snowbank meltwaters. Groundwater influx did not layer but, due to its temperature, gradually mixed with and replaced the underlying premelt water. The throughflow occurred late in the season. Its inflow also formed a floating layer 20-40 cm thick. For this layer, the tracer indicated an average velocity >20 m/h and transitional conditions between laminar and turbulent flow.

The more acidic layer was formed by hillslope throughflow but the more acidic lake outflow was caused by snowmelt water. It occurred before the groundwater had become an important contributor to the lake discharge. The thermal layering segregated throughflow and lake surface melt waters which were evacuated more rapidly. It reduced the renewal of the deeper water. Beneath the ice cover, groundwater was the only inflow able to renew the lake premelt water. The springtime soil infiltration capacity, allowing the groundwater recharge, limited the duration and importance of throughflow water layering.

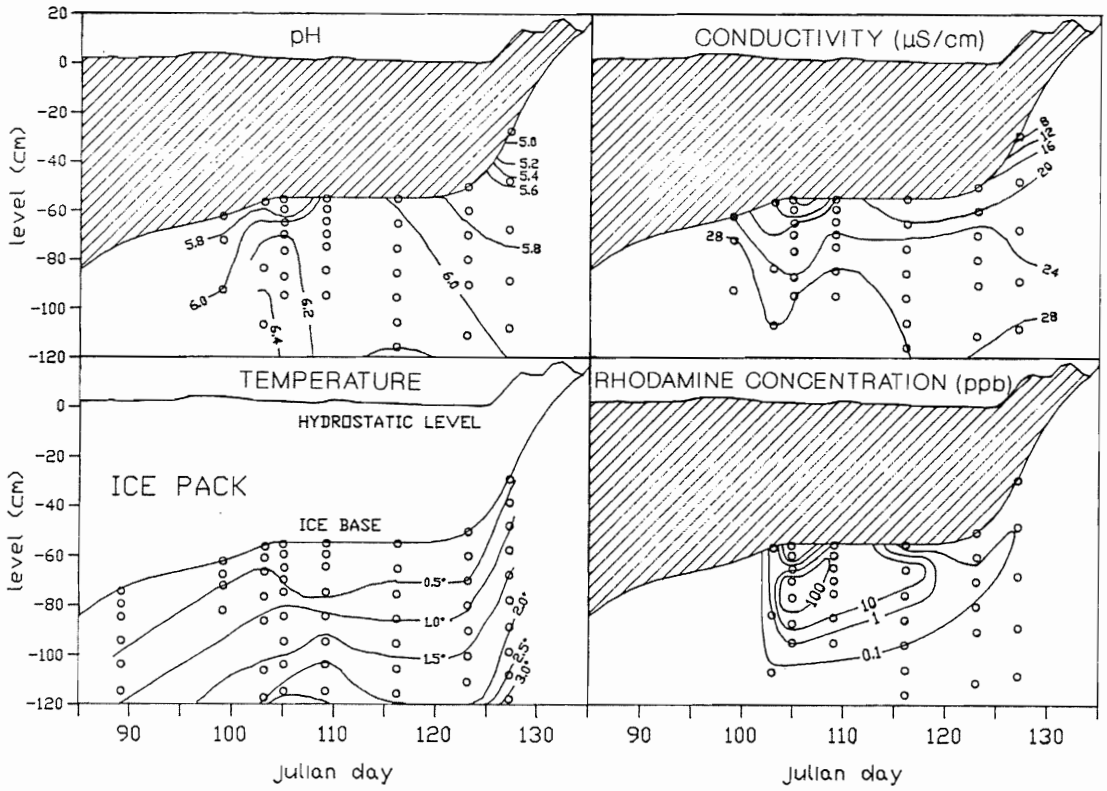
The layering process protects the lake deeper water from the direct influx of pollutants associated with springmelt but also increases its impact on the shallow and nearshore waters and on the outlet. It is likely to be active in any given ice covered lake. Its importance and the relative contribution of the lake surface meltwaters and hillslope surficial waters (throughflow, overland flow or channelized runoff) would vary accordingly with numerous factors such as the lake/basin area ratio, the soil thickness, permeability and frost conditions and the melt rates.



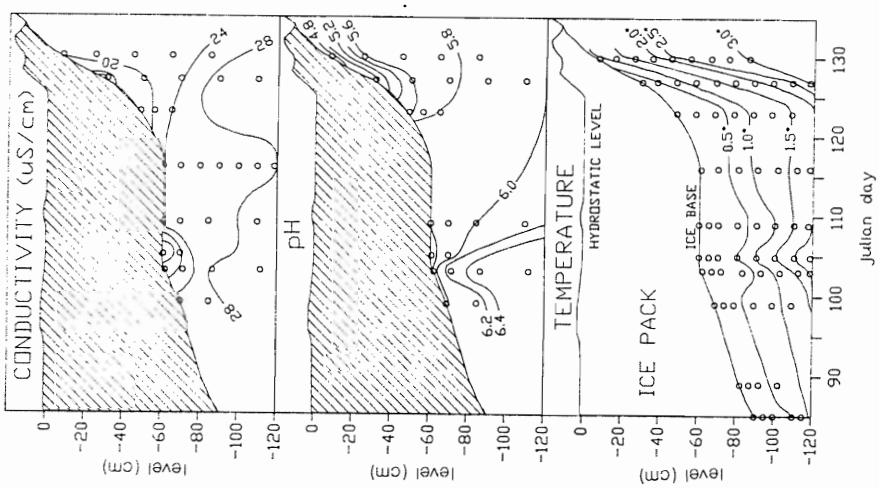
Lac Laflamme bathymetry with location of the sampling sites and the visible rhodamine traces.



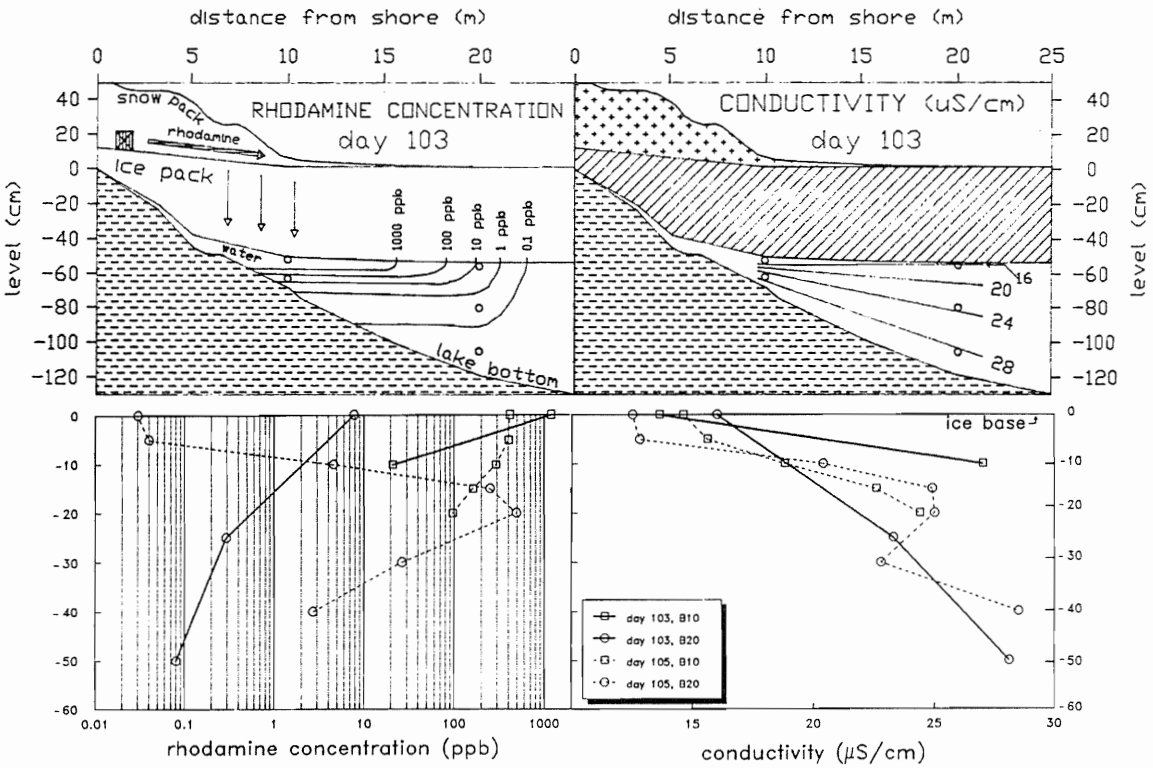
The segregation of water sources using pH and conductivity. Sample identification; 1a: lake centre during winter, 1b: outlet during winter, 2: snowmelt at an open site, 3: ice cover, 4a: piezometers (1983), 4b: observation well (1988), 5: throughflow streams.



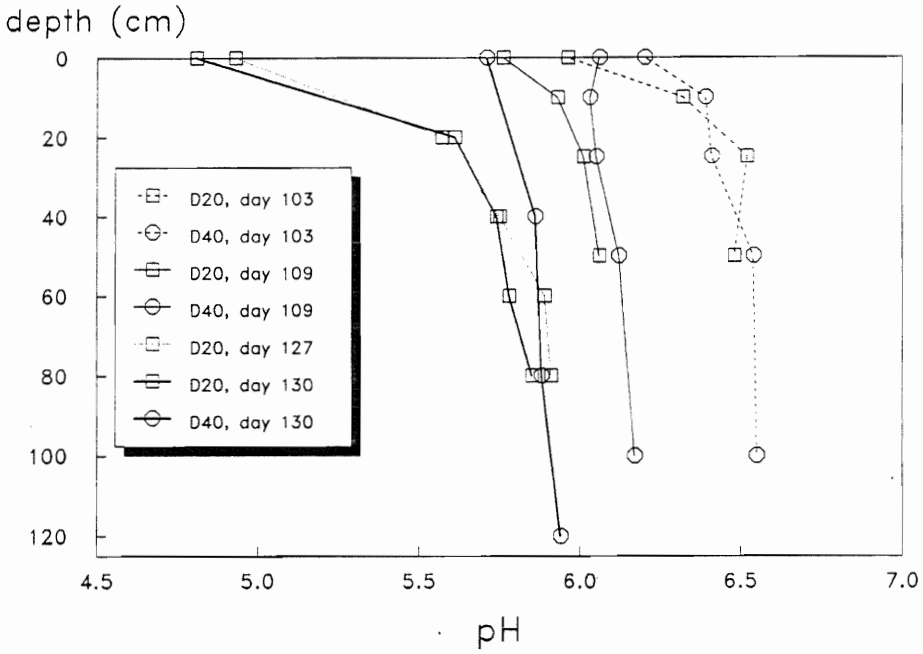
Sub-ice temperatures, pH, conductivities and rhodamine concentrations at B20 during the springmelt. The measurements or sampling points are indicated by open circles.



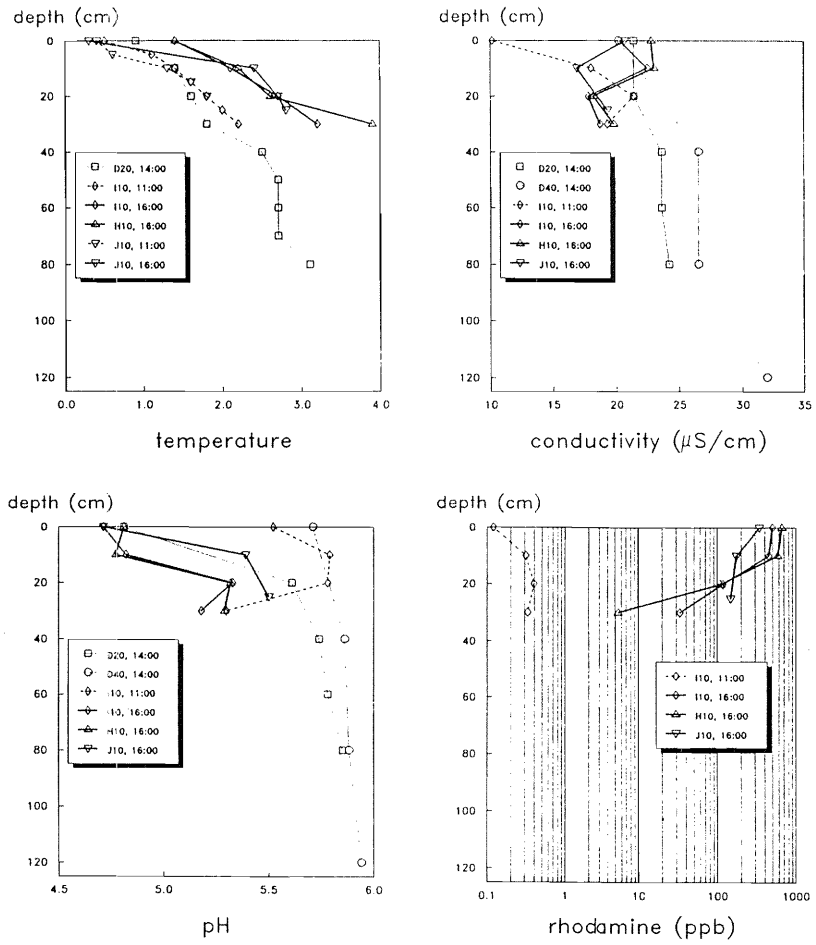
Sub-ice temperatures, pH and conductivities at D20 during the springmelt. The measurements or sampling points are indicated by open circles.



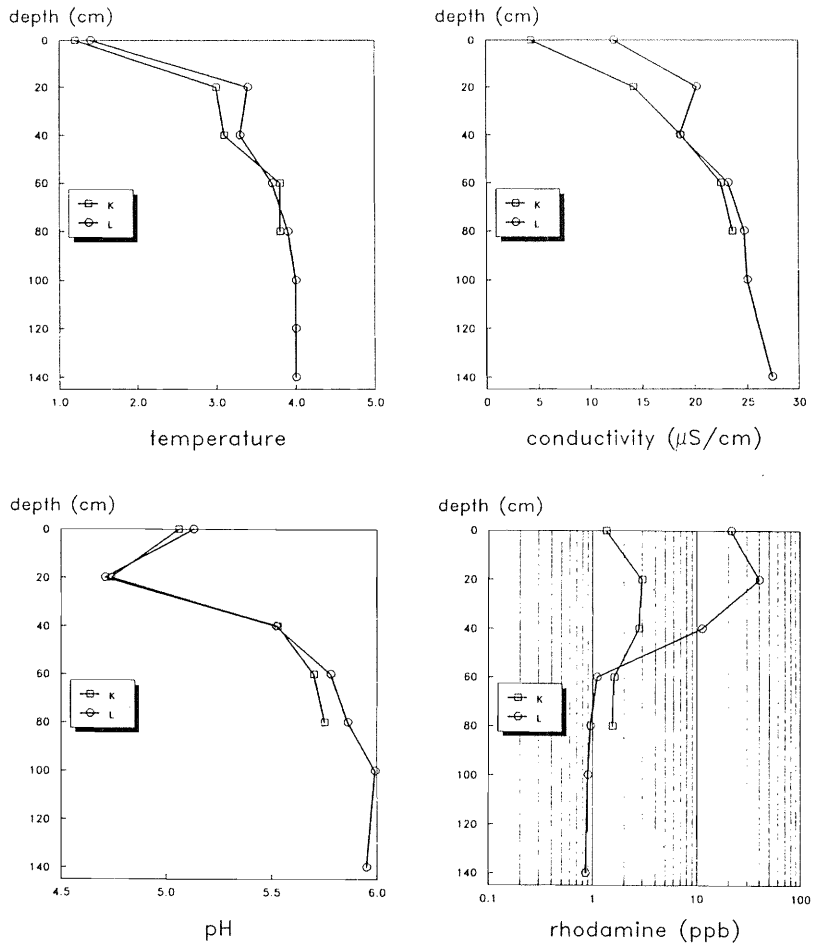
Sub-ice rhodamine and conductivity distribution at B10 and B20 showing the presence of a meltwater layer. On the upper diagrams, the measurements or sampling points are indicated by open circles.



Profiles for various dates at D20 and D40 showing the gradual pH decrease below 40 cm depth considered as groundwater dilution of premelt water.



Temperature, conductivity, pH and rhodamine profiles obtained on day 130.



Temperature, conductivity, pH and rhodamine profiles obtained on day 131.