

SHORT NOTES

SHORT-LIVED DAMMING OF A HIGH-ARCTIC ICE-MARGINAL STREAM, ELLESMERE ISLAND, N.W.T., CANADA

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ABSTRACT. The discharge pattern of the "Schei River", which drains a 91.2 km² partly glacierized catchment on Ellesmere Island, is dominated by diurnal oscillations reflecting variations in the melt rate of snow and ice in the basin. Superimposed on this diurnal pattern are numerous short-lived discharge fluctuations of irregular periodicity and magnitude. The characteristics of such irregular fluctuations are described and attributed to periodic collapse of the glacier margin and concomitant damming of the main tributary of the "Schei River". Collapse is initiated by the river undercutting the ice margin, and tends to be most frequent in the latter part of the flow season during periods of high discharge. Release of ponded water following the collapse of such ice dams may engender significant flood events.

RÉSUMÉ. *Barrage provisoire d'un écoulement liquide latéral en bordure d'un glacier du Haut-Arctique, Île d'Ellesmere, N.W.T., Canada.* La courbe des débits de la "Schei River" qui draine un bassin versant de 91,2 km² partiellement englacé dans l'Île d'Ellesmere est dominée par des oscillations diurnes qui reflètent les variations dans la vitesse de fusion de la neige et de la glace dans le bassin versant. Surimposés à ce comportement diurne on constate de nombreuses débauches de courtes durées de périodicité et de grandeur irrégulières. Les caractéristiques de telles fluctuations irrégulières sont décrites et attribuées à un écroulement périodique du bord du glacier avec barrage du principal affluent du "Schei River". L'effondrement est dû au râpement par la rivière du bord de la glace et tend à être le plus fréquent dans la dernière partie de la saison d'écoulement durant les périodes de haut débit. Le déclenchement de la débacle de l'eau stockée après l'effondrement par de tels barrages de glace peut engendrer des crues significatives.

ZUSAMMENFASSUNG. *Kurzzeitige Abdämmung eines Stromes am Eisrand in der Hocharktis, Ellesmere Island, N.W.T., Kanada.* Der Abflussgang des "Schei River", der ein teilweise vergletschertes Becken von 91,2 km² auf Ellesmere Island entwässert, ist durch tägliche Oszillationen gekennzeichnet, die Schwankungen in der Abschmelzrate von Schnee und Eis innerhalb des Beckens widerspiegeln. Dieses tägliche Muster ist jedoch von kurzzeitigen Abflussschwankungen mit unregelmässiger Periode und Grösse überlagert. Die Besonderheiten solch unregelmässiger Schwankungen werden beschrieben und dem periodischen Zusammenbruch des Gletscherrandes sowie der damit verbundenen Abdämmung des Hauptzuflusses zum "Schei River" beigemessen. Der Zusammenbruch wird durch das Unterschneiden des Eisrandes durch den Fluss eingeleitet und tritt am häufigsten in der späteren Abschmelzperiode während der Zeiten hohen Abflusses auf. Die Freigabe aufgestauten Wassers nach dem Einbruch solcher Eisdämme dürfte signifikante Hochwasserereignisse hervorrufen.

INTRODUCTION

Hydrologic observations were carried out during the summers of 1973–75 on the "Schei River", which drains a 91.2 km² partly glacierized catchment in south-central Ellesmere Island (lat. 78° N., long. 82° W.; Fig. 1). The discharge of this river, like that of other high-Arctic glacial streams (e.g. Adams, 1966), exhibits regular diurnal fluctuations in response to variations in the rate of melting of snow and ice in the catchment (Ballantyne, unpublished; McCann and others, unpublished; McCann and Cogley, 1977). Examination of continuous stage records for the "Schei River", however, revealed the existence of short-lived fluctuations in discharge, sometimes of considerable magnitude, superimposed on the regular diurnal cycles. This note describes the characteristics of such irregular discharge fluctuations and suggests a probable cause.

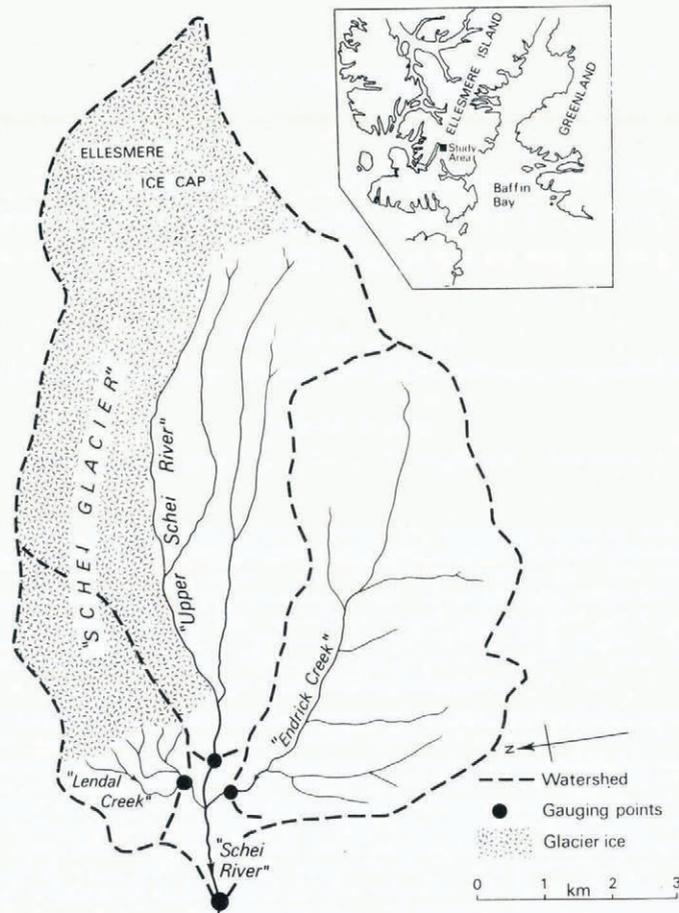


Fig. 1. The "Schei River" basin, Ellesmere Island, showing the glacierized area and the sub-division of the basin into three tributary catchments. The names "Schei Glacier", "Schei River", "Upper Schei River", "Lendal Creek", and "Endrick Creek" are unofficial.

CHARACTERISTICS OF DISCHARGE FLUCTUATIONS

Figure 2 shows the discharge of the "Schei River" for three periods during the 1974 flow season. The diurnal cycle is evident on each of the nine days depicted, with discharge reaching a minimum in the mornings and peaking in the afternoon or evening. The regularity of the cycle is interrupted on each day, however, by abrupt drops and rises in discharge, marked by the numbers 1-3. These numbers identify examples of three types of short-term discharge fluctuation with the following characteristics:

- Type 1.* An abrupt fall in discharge followed immediately by an equally abrupt and brief rise to a level higher than that preceding the initial fall (e.g. 30 July).
- Type 2.* An abrupt fall in discharge succeeded by a brief return to the previous rate of flow, then a sudden and brief rise to greater discharge (e.g. 31 July).
- Type 3.* An abrupt fall in discharge quickly followed by a return to previous rates of flow with no apparent increase in discharge above "expected" levels (e.g. 9 August), although the stage trace often remained unsteady for some time afterwards.

All three types of fluctuation occurred each year throughout the period of discharge measurement (late June to late August) with types 1 and 3 being most common. The drop in discharge associated with each event varied in magnitude from about 0.5 to $7.5 \text{ m}^3 \text{ s}^{-1}$.

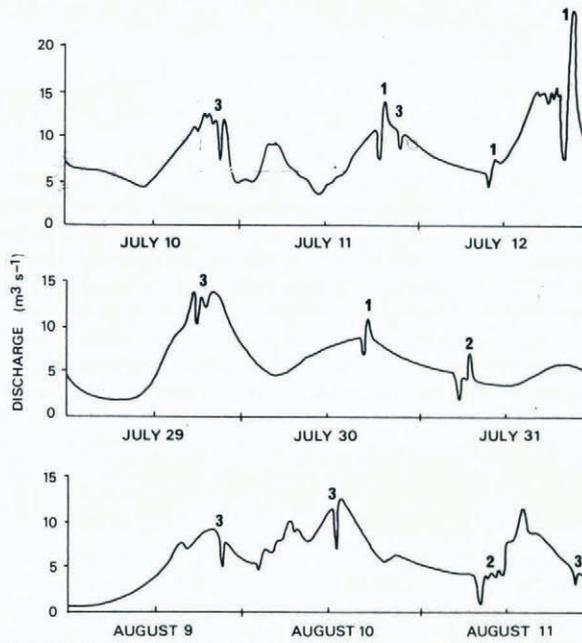


Fig. 2. Discharge of the "Schei River" on nine days of the 1974 flow season, illustrating the three types of short-term discharge fluctuation described in the text.

THE CAUSE OF DISCHARGE FLUCTUATIONS

In the summer of 1975, water-level recorders were installed on each of the three main tributaries of the "Schei River" (Fig. 1). Two of these, the "Upper Schei River" and "Lendal Creek", drain partly glacierized terrain; the third, "Endrick Creek", is fed mainly by snow melt. The stage records for these tributaries showed that short-lived discharge irregularities occurred only on the "Upper Schei River" (Fig. 3), and cannot therefore be attributed to meteorological events or irregularities in melt rate. Moreover, the common feature of all observed discharge fluctuations, irrespective of type, was an initial abrupt drop in discharge suggesting sudden retardation of flow.

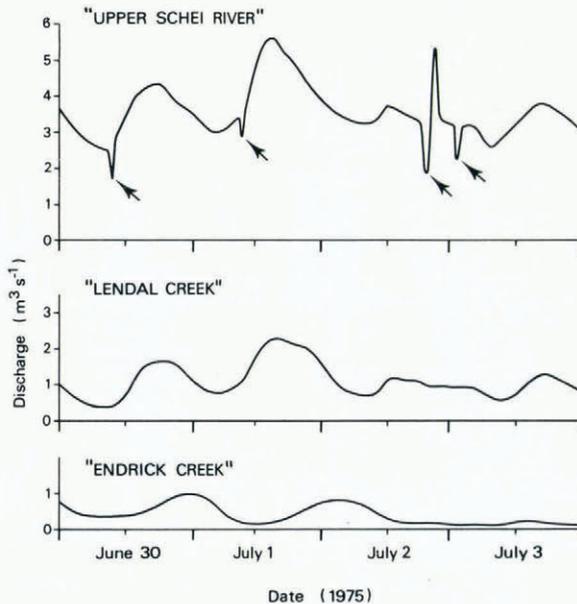


Fig. 3. Discharge of the three main tributaries of the "Schei River", 30 June-3 July 1975. Short-term discharge fluctuations on the "Upper Schei River" are arrowed.

The "Upper Schei River" occupies an ice-marginal position along most of its course above the gauging point (Fig. 1). Near the glacier snout the river flows for *c.* 2 km between steep (30–50°) rock slopes and an ice cliff up to 30 m high. During the course of the 1975 run-off season, the river was observed to melt a diagonal slot under the ice cliff along the line of the underlying rock slope. By early August 1975, this slot had locally reached an estimated depth of 25 m, and at several points along this reach the undermined ice margin had collapsed, filling the gorge with blocks of ice up to 20 m thick and leaving a concave scar on the glacier above. From this evidence it would appear that periodic collapse of the ice margin and concomitant damming of the river were common, providing a mechanism for the abrupt cessation of flow recorded down-stream in the form of short-term discharge irregularities. The development of an undercut slot in the course of the 1975 run-off season suggests that the slot cut in the previous summer was closed during the intervening winter months (September–June), presumably through plastic deformation of the glacier sole and forward movement of the ice margin.

DISCUSSION

All three types of discharge fluctuation can be satisfactorily explained by the mechanism described above. The type 1 pattern suggests initial ponding of water behind an ice dam followed by sudden breaching of the dam under hydrostatic pressure and rapid release of the ponded water. In this context it is significant that blocks of glacier ice often appeared down-stream following this type of event. The type 2 pattern suggests initial damming of the river until the ponded water rose over the level of the dam, allowing a resumption of "normal" flow before the dam collapsed. The lack of any sudden rise in discharge above "normal" levels during the type 3 event suggests slow destruction of the ice dam, probably by melting.

The timing of discharge irregularities also lends support to their interpretation in terms of damming following collapse of the ice margin. On Figure 4, which shows the magnitude and frequency of discharge irregularities over a period of 47 d and the hydrograph of the "Upper Schei River" for the same period, it is apparent that discharge fluctuations tend to occur during periods of generally high discharge and to be rare early in the flow season. Ice-margin collapse would be expected to be more frequent at times when discharge is high and undercutting rapid, and to be infrequent early in the season before a sizeable slot had been melted under the ice.

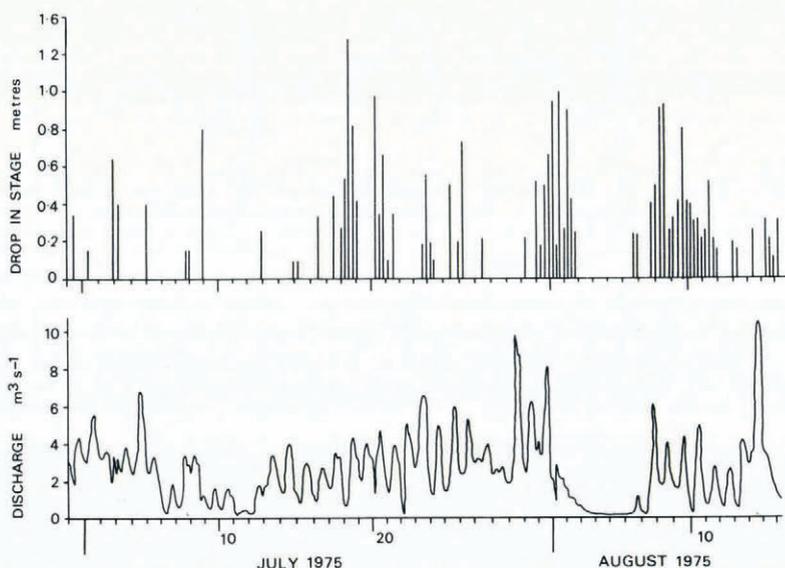


Fig. 4. Magnitude (measured by drop in stage in metres) and frequency of short-term discharge fluctuations, and the hydrograph for the "Upper Schei River", 30 June–16 August 1975.

The timing of the discharge irregularities shown on Figure 4 also exhibits pronounced clustering, for example on 18 July, 20 July, 30 July to 2 August, and 7–12 August. This suggests non-stationarity in the timing of such events, in that one event could apparently trigger a series of further events at short intervals. This is consistent with explanation of the discharge irregularities in terms of collapse of the ice margin; collapse of a part of the margin might be expected to weaken adjacent sections, leading to a series of falls at relatively short intervals.

The temporary damming of Arctic ice-marginal streams by an ice, slush or snow barrier has been reported by Adams (1966), Church (1972), and Wendler and others (1973). Indeed, the 1961 hydrograph for the Ermine River on Axel Heiberg Island (Adams, 1966) shows several short-term discharge fluctuations similar to those described above. It would appear, therefore, that damming of streams flowing along the margins of Arctic glaciers is not uncommon. Furthermore, although the short-lived increases in discharge that result from the sudden breaching of such ice dams are rarely of exceptional magnitude, some may engender significant flood events, such as that on 12 July 1974 (Fig. 2), which resulted in discharge 50% greater than any other recorded during the same season.

ACKNOWLEDGEMENTS

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