Structural Adaptation of a High Alpine Gauging Station (Vernagtbach, Oetztal Alps / Austria) to Greatly Enhanced Glacial Discharge

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Abstract

In 1973 the gauging station, Pegelstation Vernagtbach, was constructed at an elevation of 2,640m, in a basin covering 11.44sq.km. with glacierisation of approximately 80 per cent. Discharge has been monitored since then at a temporal resolution of one hour, which allows a detailed analysis of the processes governing the glacial runoff regime. Remarkable glacier mass losses since the 1980s have led to increased mean runoff values. Connected with this glacier shrinkage, the extent of the firn region of Vernagtferner has been greatly reduced to less than one tenth of the glacier area. As a result, meltwater production has increased, temporary storage of meltwater in the firn is strongly diminished, and the diurnal fluctuations of discharge have been amplified dramatically during the past five years. The measuring capacity of the gauging station of $10m^3/s$ was repeatedly surpassed by 50 per cent in the summer of 1994, causing damage to the station that was connected with the first significant data loss. A structural adaptation of the gauging station to these altered runoff conditions was completed in the fall of 1995, with the aim of achieving an increase in measuring capacity without having to enlarge the cross-sectional area of the measuring channel.

Introduction

The monitoring of discharge from glacierised high alpine basins is a very difficult and important task for the following reasons:

- discharge is highly variable, with strongly marked seasonal variations as well as pronounced diurnal changes during the melt season;
- high kinetic energy of water flow may transport a rather high material load, ranging from fine-grained sediment to rocks and boulders, which by their temporary deposition often change the riverbed geometry;
- sediment transport causes heavy abrasion and silting of the measurement structure, and harsh climatic conditions are a critical factor in the measuring systems; and
- long-term climatic fluctuations influence glacier behaviour, which in turn is reflected in runoff values.

Discharge measurements, however, are essential for the assessment of water resources. In the current discussion of the possible effects of climate changes, runoff from high alpine regions is of key interest as it is primarily governed by the melting of snow and ice, which is closely linked to the prevailing meteorological conditions. A recent treatment of this topic is provided by Braun and Escher-Vetter (forthcoming).

As a direct result of research efforts during the International Hydrological Decade (IHD), 1965-1974, the gauging station of Vernagtbach, situated at 2,640masl in the Oetztal Alps (see Fig. 1), entered into operation in the fall of 1973 (Bergmann and Reinwarth 1977), and more than two decades of runoff measurements are now available, 20 years records of which have been published in full (Escher-Vetter and Reinwarth 1995).

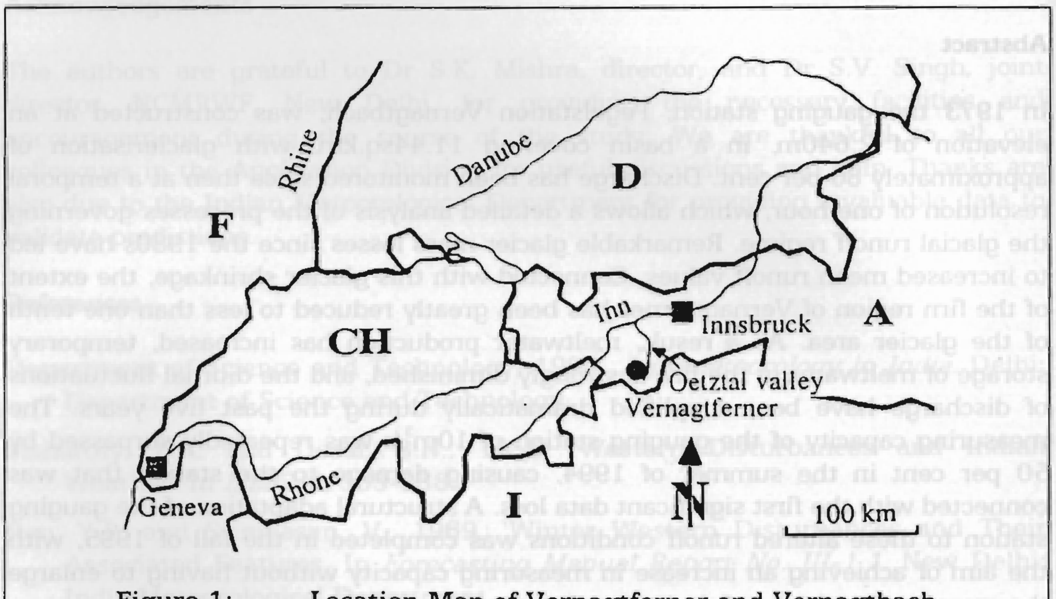

Figure 1: Location Map of Vernagtferner and Vernagtbach

Glacier Mass Balance and Discharge from Vernagtferner

Figure 2 shows the cumulative values of the annual net mass balance of Vernagtferner since 1964/65. After a period of 17, years characterised by slightly positive or nearly balanced budgets, consistent mass losses have been occurring since the early 1980s. As a consequence of these mass losses at Vernagtferner, a clear trend towards higher annual and maximal hourly discharges can be observed for Vernagtbach, draining the basin of Vernagtferner (basin area = 11.4 km^2, see Fig. 3). The mean annual discharge recorded at the site since 1974 has almost doubled since then, and the maximal hourly discharge was usually higher than 900 $ls^{-1}km^{-2}$ (mean hourly specific value with respect to the glacierised area of 9.1sq.km. or 79% in 1990) during the past ten years. An exceptionally high specific discharge of over 1,600 $ls^{-1}km^{-2}$ was observed in August 1994 (H. Behrens, personal communication) when the gauging station was damaged, and the first significant data losses occurred since measurements began (see also Fig. 5).

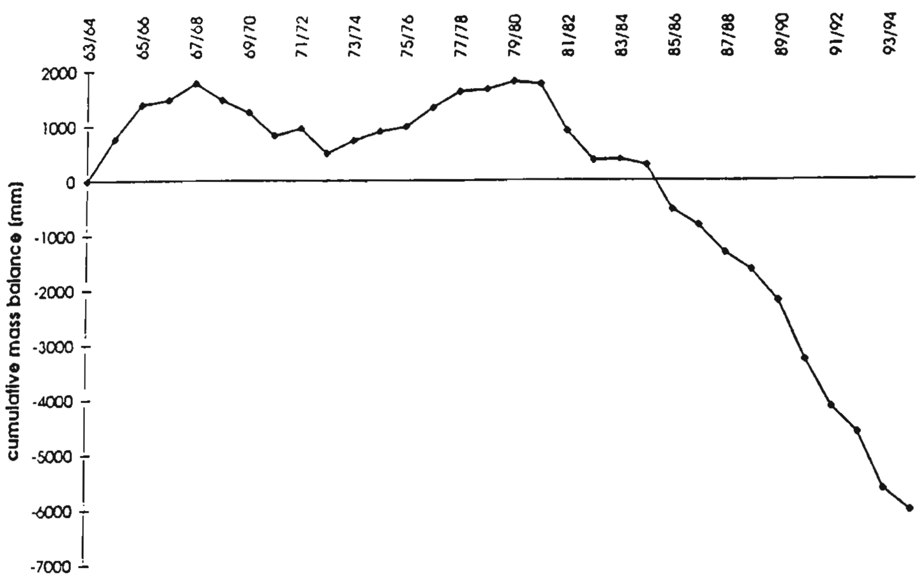

Figure 2: Cumulative Mass Balance Summing up Annual Mass Balance (Values, as determined by the Direct Glaciological Method of Vernagtferner, Oetztal Alps, since 1964/65)

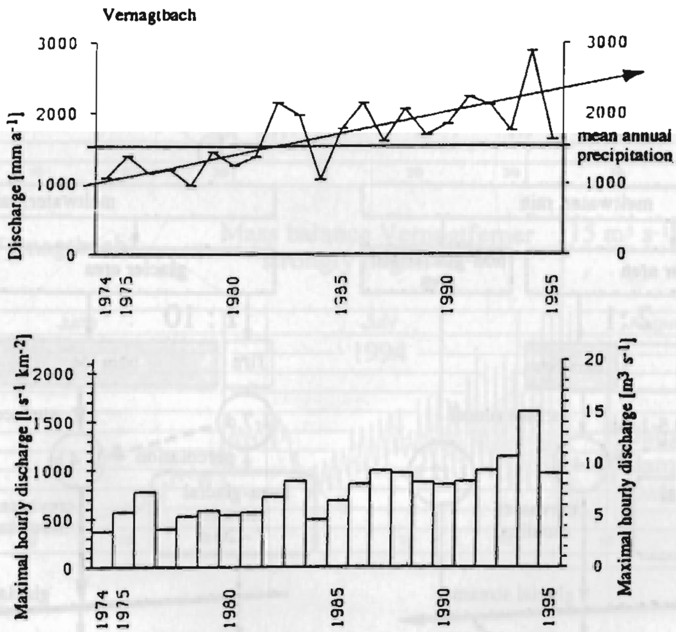

Figure 3: Discharge of Vernagtbach, Oetztal Alps, 1974-1975, a) Annual, and b) Maximal Hourly Discharge (Mean annual basin precipitation (=1,554mm/y) is based on measurements 1973-1985)

Oerter and Reinwarth (1988) came up with a first analysis of the dominant runoff processes by relating the annual maximal discharge of Vernagtbach to melt or rainfall events. On 1 August 1983, the maximal melt-induced peak discharge of $8.3 m^3 s^{-1}$, corresponding to 885 $ls^{-1}km^{-2}$ (specific value with respect to the glacierised area of 9.35sq.km. or 82% of the total basin area) was observed, and on 24 August 1987 the highest rainfall-induced peak of $9.35 m^3 s^{-1}$, corresponding to 817 $ls^{-1}km^{-2}$ (specific value with respect to the total basin area). Escher-Vetter and Reinwarth (1994) extended the analysis to the data current as of 1993, using mean daily maxima of discharge. They demonstrated that the melt-induced portion of glacial runoff has become increasingly more dominant in the past years. This is related to the succession of strongly negative net mass balances since 1982 which have resulted in an ever-increasing portion of bare ice area and the decreased size of the firn area of Vernagtferner, the latter covering minimally about 10 per cent of the glacier area at the end of the 1994 ablation season (Fig. 4). This shift in the areal distribution of ice and snow dramatically altered melt and runoff conditions, as further exemplified by the diurnal variation of discharge typical of the early 1980s and the 1990s (see Fig. 5). Under balanced mass budget conditions, the extent of the firn area is about 70 per cent of the total glacier area, and meltwater runoff is delayed for days by percolation through the firn as well as by intra-glacial storage (for more details concerning meltwater pathways and storages see Oerter et al. 1981). As a result, diurnal variations of discharge are rather small, with peak runoff in the afternoon in the order of $5 m^3 s^{-1}$ and minimum flow of about $2 m^3 s^{-1}$ before sunrise. The examples of the summers of 1991 and 1994 show that meltwater runoff from the bare ice surfaces with typical travel times of a few hours (i.e., 1 - 4 hours as indicated in Fig. 4) becomes dominant, and peak discharge values of over $10 m^3 s^{-1}$, as well as rather low values of less than $2 m^3 s^{-1}$ at night, can be observed.

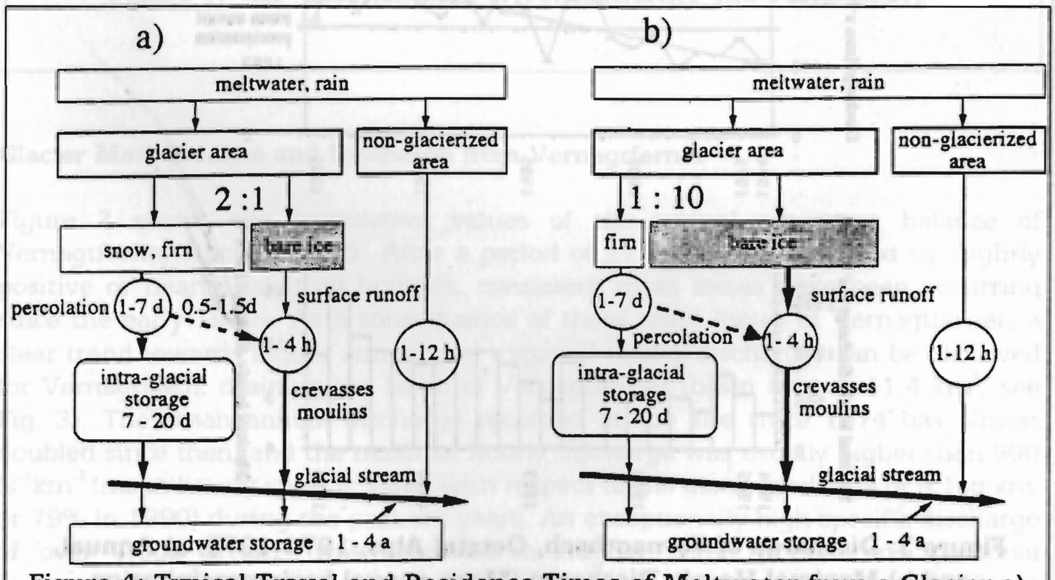

Figure 4: Typical Travel and Residence Times of Meltwater from a Glacier a) Under Mass Balance Equilibrium Conditions (well-expanded firn area), and b) After a Sequence of Strongly Negative Mass Balances (such as in 1994)

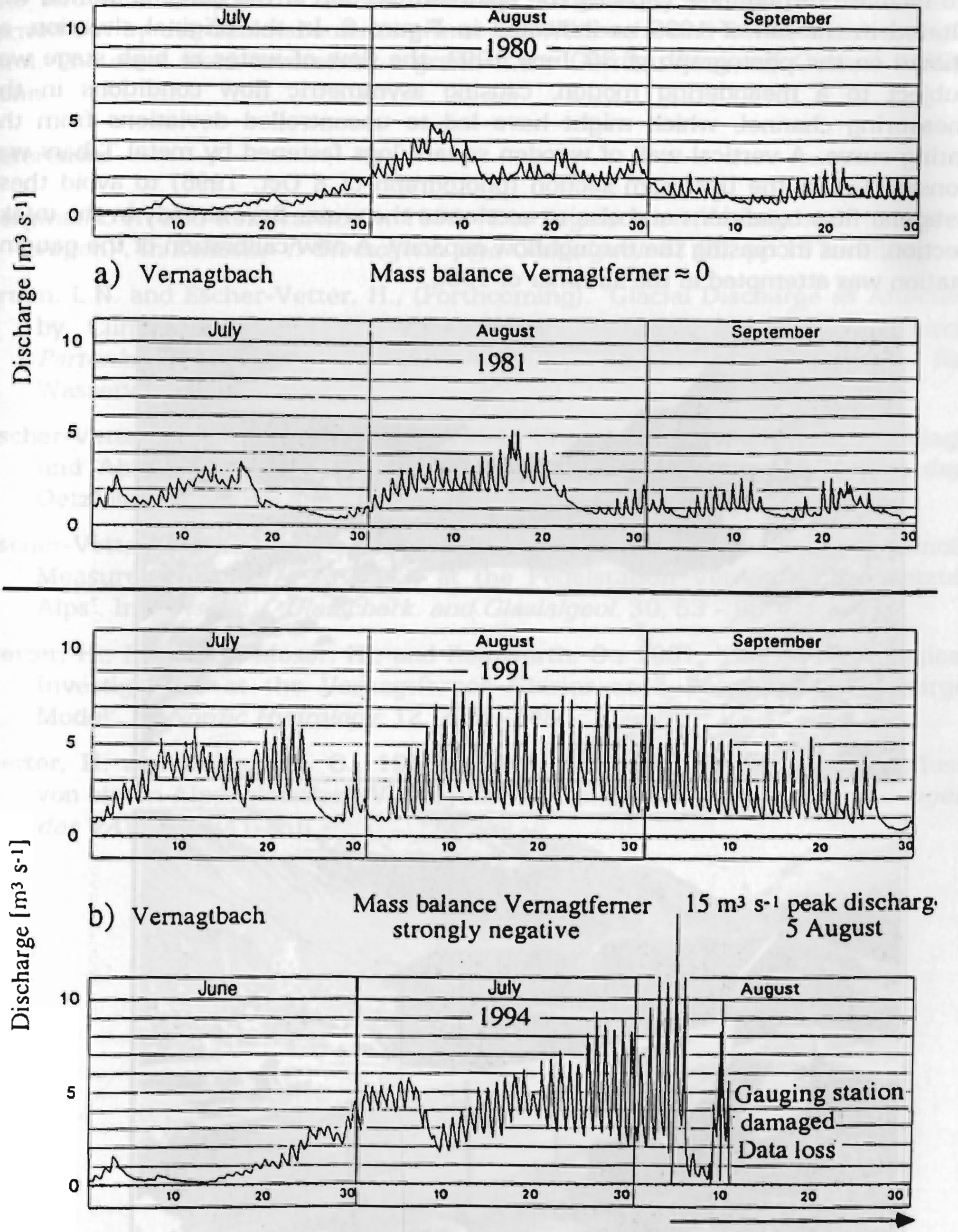

Figure 5: Runoff Hydrograph, Demonstrating the Diurnal Fluctuations of Discharge of Vernagtbach a) As Typical of a Balanced Mass Budget for Vernagtferner and b) After a Sequence of Strongly Negative Mass Balances

Structural Changes of the Gauging Station

To increase throughflow capacity the upstream section of the gauging station was altered in the fall of 1995 as indicated in Figure 6. In the original situation, as shown on the photograph of 30 June 1993, the flow of water at high stage was subject to a meandering motion, causing asymmetric flow conditions in the measuring channel, which might have led to uncontrolled deviations from the rating curve. A vertical wall of wooden square logs fastened by metal T-bars was constructed in the upstream section (photograph of 8 Oct. 1995) to avoid these irregular flow conditions and also to accelerate the water flow already in the intake section, thus increasing the throughflow capacity. A new calibration of the gauging station was attempted in the summer of 1996.

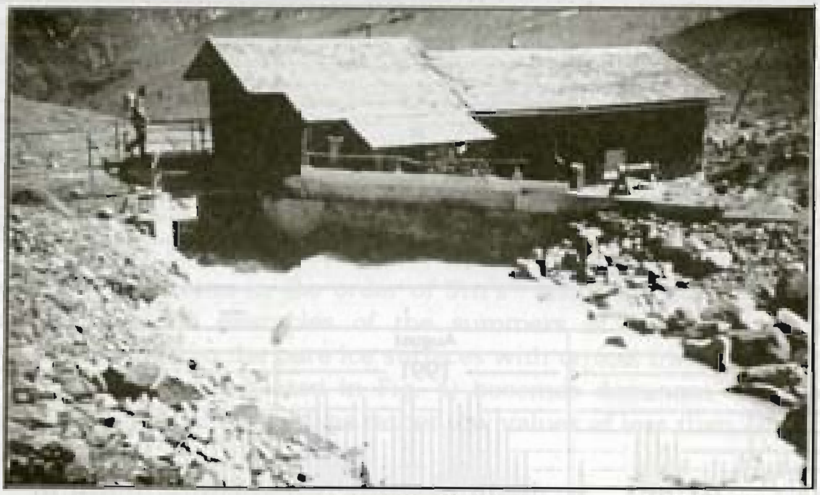

Figure 6: Structural Changes in the Upstream Section of the Vernagtbach Gauging Station to Increase Throughflow Capacity. Upper Photograph (30 June 1993): The Original Situation; Lower Photograph (8 Oct. 1995): After the Construction of Wooden Wall with a Concrete Lower Section

Acknowledgements

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