CONTRIBUTION OF THE DEMING GLACIER TO STREAMFLOW IN THE MIDDLE FORK NOOKSACK RIVER 2003 AND 2003 SUMMER MELT SEASONS

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ABSTRACT

In the North Cascade Range, Washington snowpack accumulation and the resultant ablation provides critical summer water resources. Direct measurement of ablation on the Easton Glacier during 2002 and 2003 allowed determination of glacier runoff from the adjacent Deming Glacier. The summer of 2002 was relatively cool and wet and followed a wet winter, as a result the contribution of the Deming Glacier reached a high of 23.9% of total flow. In 2003 a drier summer followed a dry winter and the maximum glacier contribution was 30.9% with three months of greater than 20% contribution

INTRODUCTION

The spatial and temporal variation of snowpack accumulation, snowpack ablation and consequent alpine runoff is crucial to determining regional summer water resources in the North Cascades Range, Washington. Glaciers alone provide 750 million m^3 of runoff each summer (Fountain and Tangborn, 1985). Today with all 107 glaciers observed by the North Cascade Glacier Climate Project (NCGCP) in retreat the available glacial area for melting is increasing. In areas such as the Middle Fork Nooksack River this is a vital resource that is being impacted.

DEMING GLACIER

The Deming Glacier advanced from the early 1950's up to 1979. A slow retreat began by 1987. The terminus of the glacier was visited in 1987. A return visit in the fall of 2002 noted a retreat of 360 m by the terminus of this glacier (Figure 1). In 2003 the area of the glacier is 4.6 km^2. This glacier will continue to retreat in the foreseeable future as the downcutting of streams in the terminus area and the lack of crevassing in the lower 700 m of the glacier indicate little movement. However, the terminus area of the glacier is thick and retreat will continue at a slow steady pace. Because this glacier along with Coleman Glacier the most heavily crevassed in the North Cascades it is not safe to directly work on this glacier to complete mass balance measurements. However, because of the aforementioned consistency in ablation rate at glacier elevations from glacier to glacier monitoring the mass balance of the adjacent Easton Glacier provides a direct measure of ablation. The two glaciers are in contact for much of there length as well.

In 2002 a wet winter with considerable avalanching was followed by a cool early summer and average summer with considerable rainfall. The result high streamflow contributions from the summer rain and the late melt of lower elevation snowpack dominate the runoff in the Middle Fork. In August and September the contributions of the Deming Glacier increased to 24% and 19% respectively of total; Middle Fork flow.

The winter of 2003 yielded below normal snowpack. The early summer remained on the cool side. However, July and August were warm and dry resulting in less non-glacier flow. The Deming Glacier contributed more than 20% of the total flow from July-September and over 30% in August.

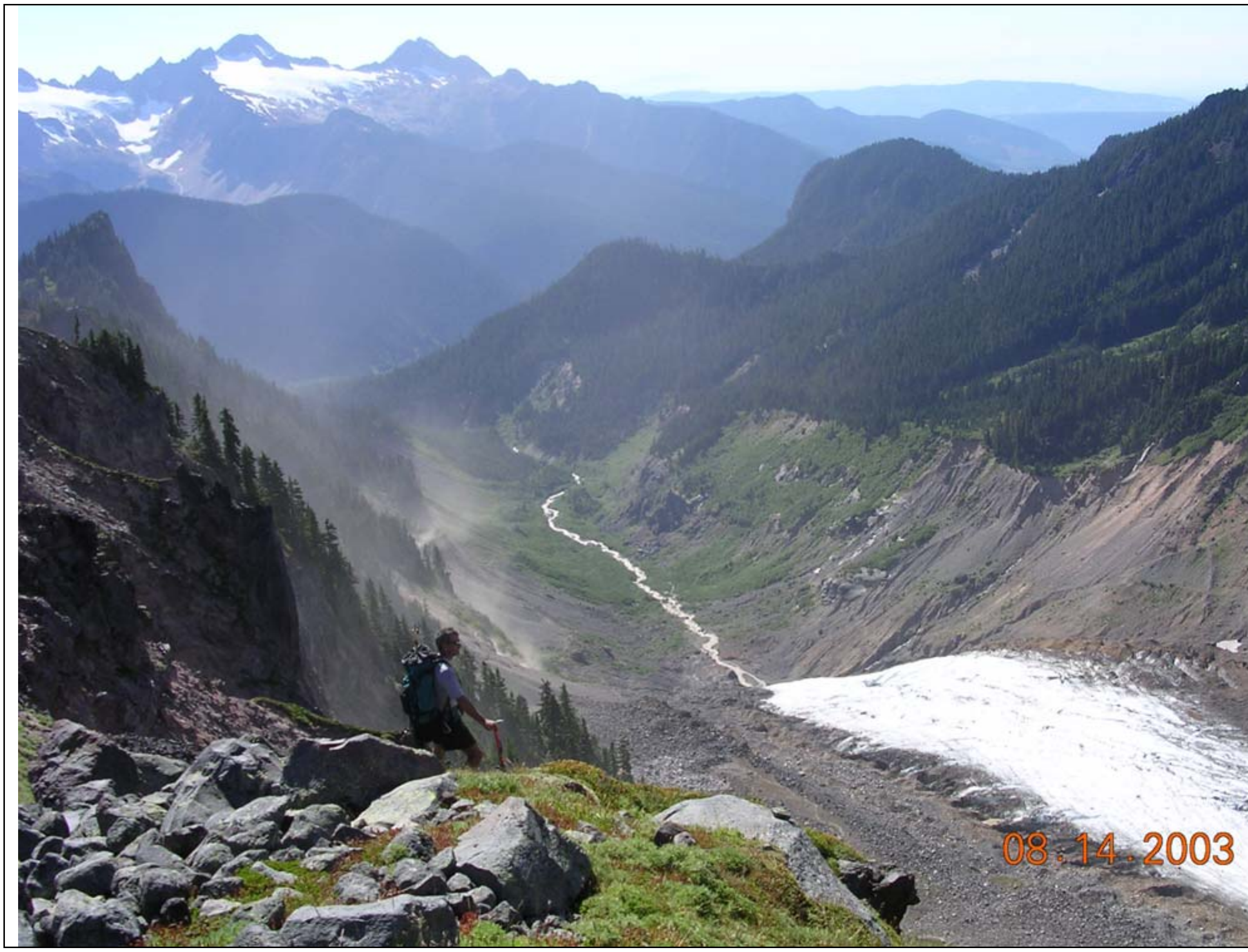

Figure 1: Terminus of the Deming Glacier in 2003. Note the rockfall stirring up dust on the left. The glacier terminus in 1987 was at the prominent increase in vegetation beyond the glacier terminus.

Contribution of Glacial Runoff to Stream Flow

In the North Cascades the dominant non-glacial snowmelt season is from May to June. The primary glacier meltwater season begins in June, peaks in August, and ends when the weather turns cold in early October. This glacial runoff period corresponds with the period of lowest streamflow in the North Cascades. During the low flow period, generally August and September, melting of glacial ice provides a substantial percentage of total streamflow in glaciated river basins. The amount and timing of glacial meltwater input to streams depends on annual variations in climate and the areal extent of the glacier.

How will changes in glaciers area affect instream flow? Streamflow changes occurring due to glacier retreat have been observed in the Lewis Glacier Basin, near Rainy Pass, as it drains into Granite Creek. In August 1985, Lewis Glacier had an area of 0.09 km and released 0.15×10^6 m^3 of runoff. By August 1990, Lewis Glacier had disappeared, and runoff from the former glacier basin was 0.04×10^6 m^3, only 27% of the glaciated flow, despite the presence of some relict glacier ice, even though total monthly precipitation was the same.

Glaciers have moderated the decrease in summer streamflow in basins where they have significant glacier covered area. This moderating ability will decrease as glacier area decreases; thus glacier retreat is likely to cause significant declines in dry month streamflow in the Middle Fork Nooksack River Watershed. We have determined the current glacial contribution of glacier meltwater to instream flow during the the summer in this watershed.

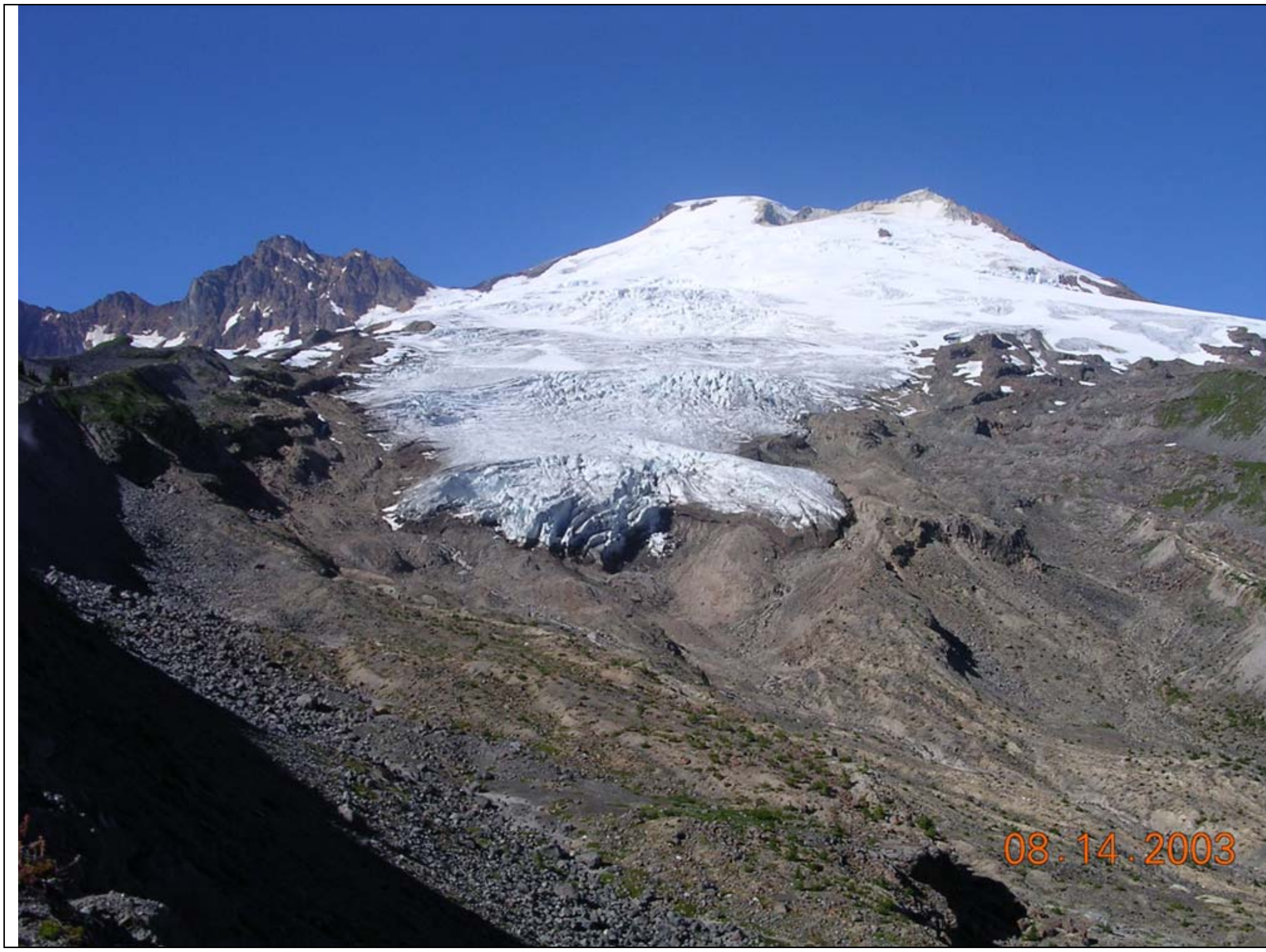

Figure 2. Easton Glacier in August 2003. The Deming Glacier and the Easton are in contact in the accumulation zone. Deming glacier is the left area of snow beyond the first snow covered ridge.

DATA SETS

The following data sets are used: 1) Monthly ablation measurement on Easton Glacier (Figure 2) which is adjacent to the Deming Glacier 2) Snowpack ablation at four snotel sites during June of each year. 3) Daily snow water equivalent, precipitation and temperature data from the Elbow Lake USDA Snotel site located 5 km from the glacier. 4) Streamflow data from the Middle Fork Nooksack from the USGS.

From 1000-1900 m the USDA Snotel network provides an excellent network of snowpack and temperature data recorders in the North Cascades, but no sites are found on or adjacent to the highest accumulation areas, which are glaciers. The necessity of using Snotel sites and glaciers to adequately identify snowpack water resources in the North Cascades is emphasized by the difference in mean maximum winter accumulation in SWE from 1.17 m at the ten USDA Snotel sites, ranging in altitude from 1000-1900 m, and 2.93m at nine glacier locations ranging from 1650-2200 m. By July 15 the nine glacier locations still average 1.3 m SWE, while the Snotel sites have no snowpack remaining. Thus, Snotel sites provide a good indicator of late spring and early summer runoff and glaciers a better measure of mid and late summer runoff. This is true for the Deming Glacier where the MF Nooksack, Wells Creek and Elbow Lake sites provide good local information on lower elevation snowpack in the Middle Fork Noosack River Basin.

Mass balance measurements have been made using the same methods at the same time of the year on nine North Cascade glaciers by NCGCP (Pelto, 1996; and Pelto and Riedel, 2001). On Easton

Glacier this consists of a series of stakes emplaced in the glacier and checked periodically through the summer season to directly measure ablation. Revisiting each site through the ablation season and measuring the emergence of each stake identifies the ablation rate. The maximum snowpack depth and water equivalent is also determined at specific locations at approximately the same time each year utilizing probes driven through the snowpack on the glacier. This also provides a direct measure of glacier ablation. The mean ablation measured over the entire glacier for a given month is used in preparing Table 1.

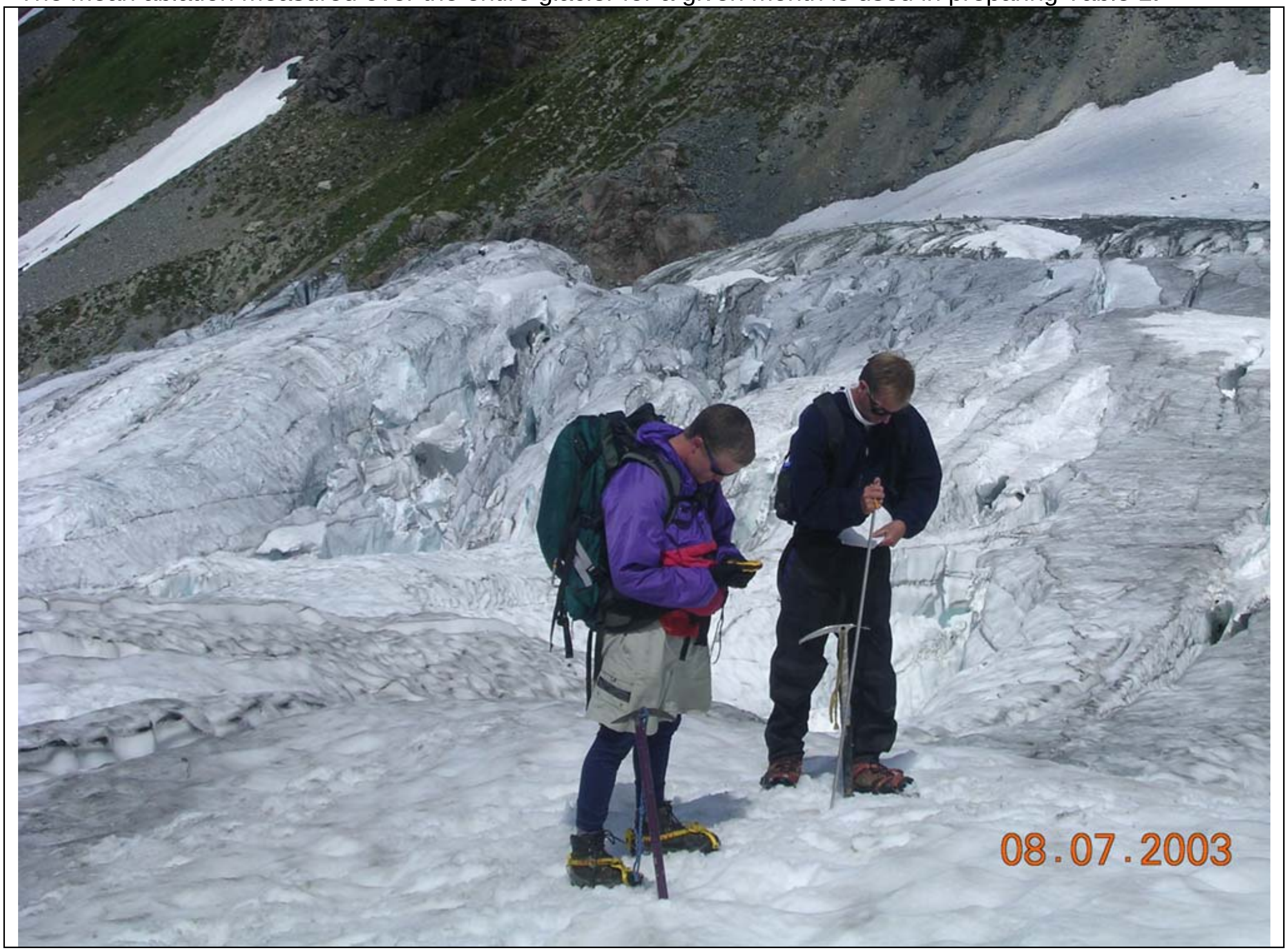

Figure 3. Measuring ablation on Easton Glacier Joe Wood and Mauri Pelto.

SNOWPACK AND GLACIER ABLATION

Early in the melt season (April-June 15), ablation is dominated by melt at the lower elevation range (>1500m) in alpine basins (Pelto, 1996; Fountain and Tangborn, 1985). Ablation during May at Snotel sites from 1000-1500 m, averages 0.018 m/day, while at sites from 1500-1900 m average ablation is 0.012m/day, and above 1600 m on glaciers average ablation is 0.08 m/day . Snowpack ablation is reduced somewhat for the Snotel sites are that more protected by surrounding forest (Wells Creek).
Snowpack is lost from the lower sites in May or early June.

Average ablation after June 1 is limited to data from Snotel sites above 1500 m and glaciers. At the three stations, when snowpack endured throughout all of June, ablation ranged from 0.027 -0.032 m m/day. June ablation on South Cascade, Easton and Columbia Glacier, during these same June periods, ranged from 0.23-0.29 m/day, averaging 0.027 m/day. The correlation from glacier to glacier for the same time periods is 0.86-0.99, indicating that ablation conditions become increasingly consistent on glaciers as the summer melt season develops. Correlation in daily ablation rates for the three Snotel sites is 0.79-0.92 indicating that in the elevation zone from 1500-2000 m across the North Cascades ablation after June 1 has a comparatively low degree of variability.

By early July snowpack beyond the glacier margins is limited, Snotel sites have lost their snowcover, and yet streamflow is still heavily dependent on snow and ice melt from glaciers (Fountain and Tangborn, 1985; Pelto, 1996). From July-September glaciers are the primary area of residual snow and ice ablation. This region has the highest melt rates during this period, while other inputs are at an annual low (Rasmussen and Tangborn, 1976). Thus, glaciers ameliorate low flow conditions (Fountain and Tangborn, 1985; Pelto, 1993). In heavily glaciated basins such a Baker River from 20-45% of the total input is from glacier melt during the latter part of the summer (Pelto, 1996; Post et al; 1971).

Ablation measurement on nine North Cascade glaciers for twenty-nine discrete two to six week periods during this part of the ablation season yield mean ablation rates of 0.036 m/day, 0.038 m/day and 0.028 m/day for July, August and September respectively. The correlation in mid and late season ablation between each glacier exceeds 0.95 indicating the degree to which the regional summer climate is consistent across the North Cascades.

CONCLUSIONS

The Deming Glacier provides from 15-30% of the total streamflow of the Middle Fork of the Nooksack River from July-September currently. The main predictor of snow melt is ablation as noted in Table 1. Summer precipitation and heavy winter snowpack reduce the glacier contribution. With continued glacier retreat the contribution of the glacier will continue to decline for any given climate condition.

To model ablation on this glacier from climate data can be completed with an additional year of more detailed baseline data in conjunction with the existing twenty year NCGCP ablation, USDA climate data. This would entail emplacement of ablation stakes on a centerline transect on the Easton Glacier to be checked bi-weekly all summer long.

	Streamflow mean (cfs)	Temp era-ture F	Precipitation inches	Snotel ablation (m we)	Easton Ablation (m we)	Deming Area (km)	Deming Runoff (m3)	Middle Fork Nooksack Flow (m3)	Deming/ total	Deming/ total %
Jun-02	1086.3	53.1	5.7	1.1	**0.85**	4.6	3910000	79684015.68	0.0491	**4.9**
Jul-02	625.4	58.5	1.3	1.45	**1.25**	4.6	5750000	47404519.49	0.1213	**12.1**
Aug-02	317	57.8	1.6		**1.25**	4.6	5750000	24028194.24	0.2393	**23.9**
Sep-02	248	51	3.5		**0.75**	4.6	3450000	18191692.8	0.1896	**19**
Jun-03	592.6	55.3	2.3	1.17	**0.95**	4.6	4370000	43469343.36	0.1005	**10.1**
Jul-03	421.4	61	0.3		**1.43**	4.6	6578000	31941580.61	0.2059	**20.6**
Aug-03	271.4	60.2	0.2		**1.38**	4.6	6348000	20571772.61	0.3086	**30.9**
Sep-03	247.8	55.9	4.6		**0.85**	4.6	3910000	18177022.08	0.2151	**21.5**
Correlation with Easton Ablation	-0.20	0.949	-0.88							

Table 1. Middle Fork Nooksace River stream discharge and Deming Glacier discharge. The temperature and precipitation at Elbow Lake and ablation at snotel sites and on Easton Glacier.

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	Maximum (inches)	Maximum swe (m)	elevation
Fish Lake	33	0.8382	1030
Harts Pass	46	1.1684	1905
Lyman Lake	64	1.6256	1805
Miners Ridge	54	1.3716	1890
Park Creek	44	1.1176	1405
Rainy Pass	41	1.0414	1460
Stampede Pass	47	1.1938	1190
Stevens Pass	42	1.0668	1245
Thunder Basin	33	0.8382	1285
Wells Creek	31	0.7874	1280
Easton	160	4.064	2200
Lynch	150	3.81	2200
Columbia	120	3.048	1650

Table 2. Maximum snowpack in meters and inches of swe.

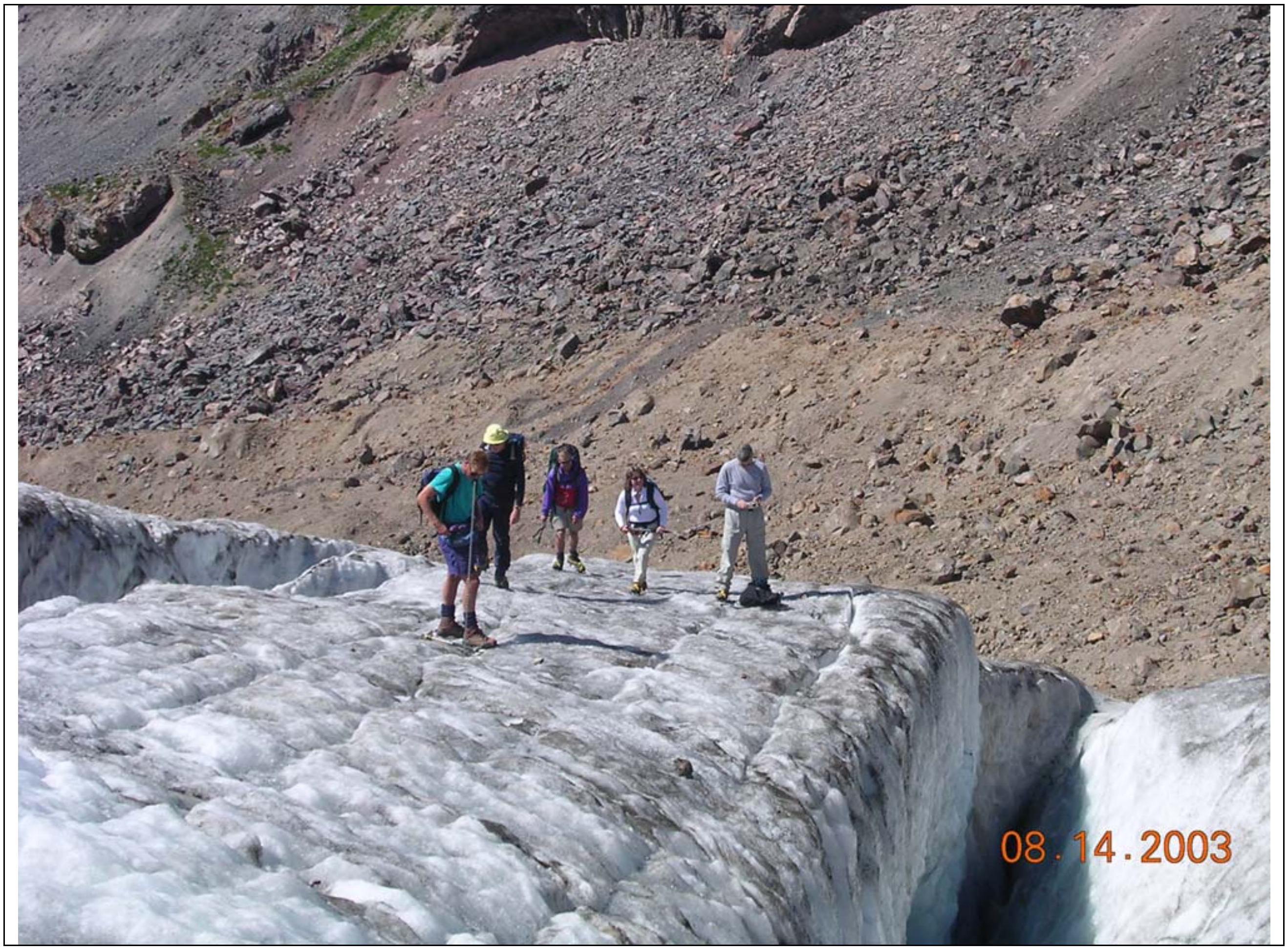

Figure 4. A day on the glacier.