Application of a 3D laser scanner in the assessment of a proglacial fluvial sediment budget

David Milan*, George Heritage & David Hetherington

***Department of Natural & Social Sciences, University of Gloucestershire, UK, dmilan@glos.ac.uk**

School of Environment & Life Sciences, University of Salford, UK

University of Salford — A Greater Manchester University

UNIVERSITY OF GLOUCESTERSHIRE

6th Gravel-Bed Rivers Conference, St. Jakob, GBR6, 2005

1. Aims

To demonstrate the potential of a side scanning laser for:

- rapid surveying of large areas of gravel-bed river
- providing high resolution and accurate surveys
- identifying subtle and major morphological change
- improved DEM generation and sediment budget estimation

2. Study Site

The study was carried out on the proglacial outwash fan of the Mont Miné and Ferpècle glaciers situated in the Valais region of the Swiss alps (Fig 1). Survey work concentrated on a 4000 m^2 reach of braided gravel-bed channel (d_{50}=34mm), towards the tail of the outwash fan. The channel was fed primarily by meltwater originating from the Mont Miné glacier. Meltwater discharge displays a strong diurnal signal during the summer months. The channel was dry in the early morning, facilitating laser scanning.

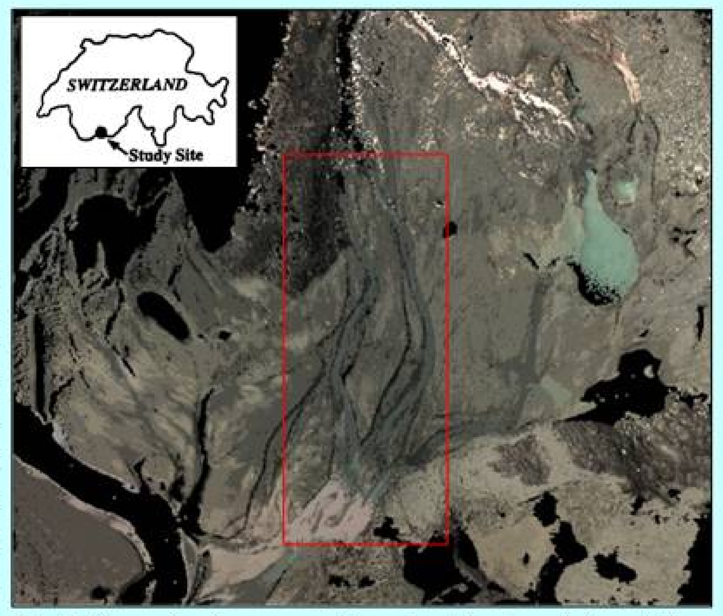

Fig 1 Merged colour scan of proglacial outwash fan of the Mont Miné and Ferpècle glaciers. Study reach is highlighted.

Fig 2 Riegl LMS Z210 side scanning laser.

Table 1 Scanner specifications

Laser Scanner Specifications
360deg horizontal
90deg vertical
5mm accuracy
0.0025deg angular resolution
8000-12000 points are acquired/second
750m radial range

3. Laser Scanning methodology

A Riegl LMS Z210 side scanning laser (Fig 2, Table 1) was used to collect a series of independent datasets recording range distance, relative height, surface colour and reflectivity. Four scans were taken of the study reach on a daily basis between 2nd and 10th June, 2004. The scans were merged using RiScan Pro post-processing software. Reflectors were used in the field to help merge the scans. An average of 17 million data points were collected on a daily basis from the study reach, with an average spacing of 0.026 m (Table 2).

Table 2 Survey point resolution

Scan date	Total points	Mean spacing (m)
2/6/04	1682111	0.0270
3/6/04	1491491	0.0254
4/6/04	1921619	0.0247
5/6/04	1837344	0.0244
7/6/04	1988003	0.0239
9/6/04	1159062	0.0329
10/6/04	1814238	0.0251

4. Scanner accuracy

Laser scan data accuracy was evaluated through the collection of 40 independent prominent surface point co-ordinates using an EDM theodolite, obtained at the same time as the laser scan survey. A contour map demonstrating the deviation in surface elevation from the EDM measurements indicates good agreement between the two datasets, and shows that most errors are within ±0.02 m (Fig 3). This provides a high degree of confidence in the detection of subtle morphological changes.

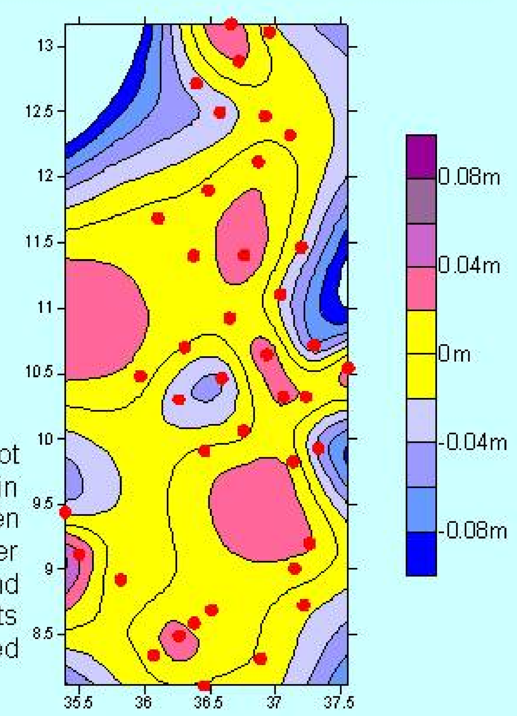

Fig 3 Contour plot of the difference in elevation between the laser scanner data and independent points (in red) surveyed with a total station

5. Production of Digital Elevation Models (DEM's) & sediment budgeting

x,y,z data were used to construct DEM's in Surfer, Golden Software™. Simple triangular linear interpolation was used to create the DEM's. More elaborate interpolation algorithms were not required due to the high point resolution. Changes in bed elevation and daily reach-scale sediment budgets were calculated by subtracting successive DEM's.

6. Morphological change results

Morphological change over the study period is demonstrated as a series of photographs (Fig 4a) and DEM's (Fig 4b). DEM subtractions are shown in Fig 4c, with scour highlighted in red and deposition in blue. Flow direction is from the top of the images to the base. The right bank is aligned with the flow direction.

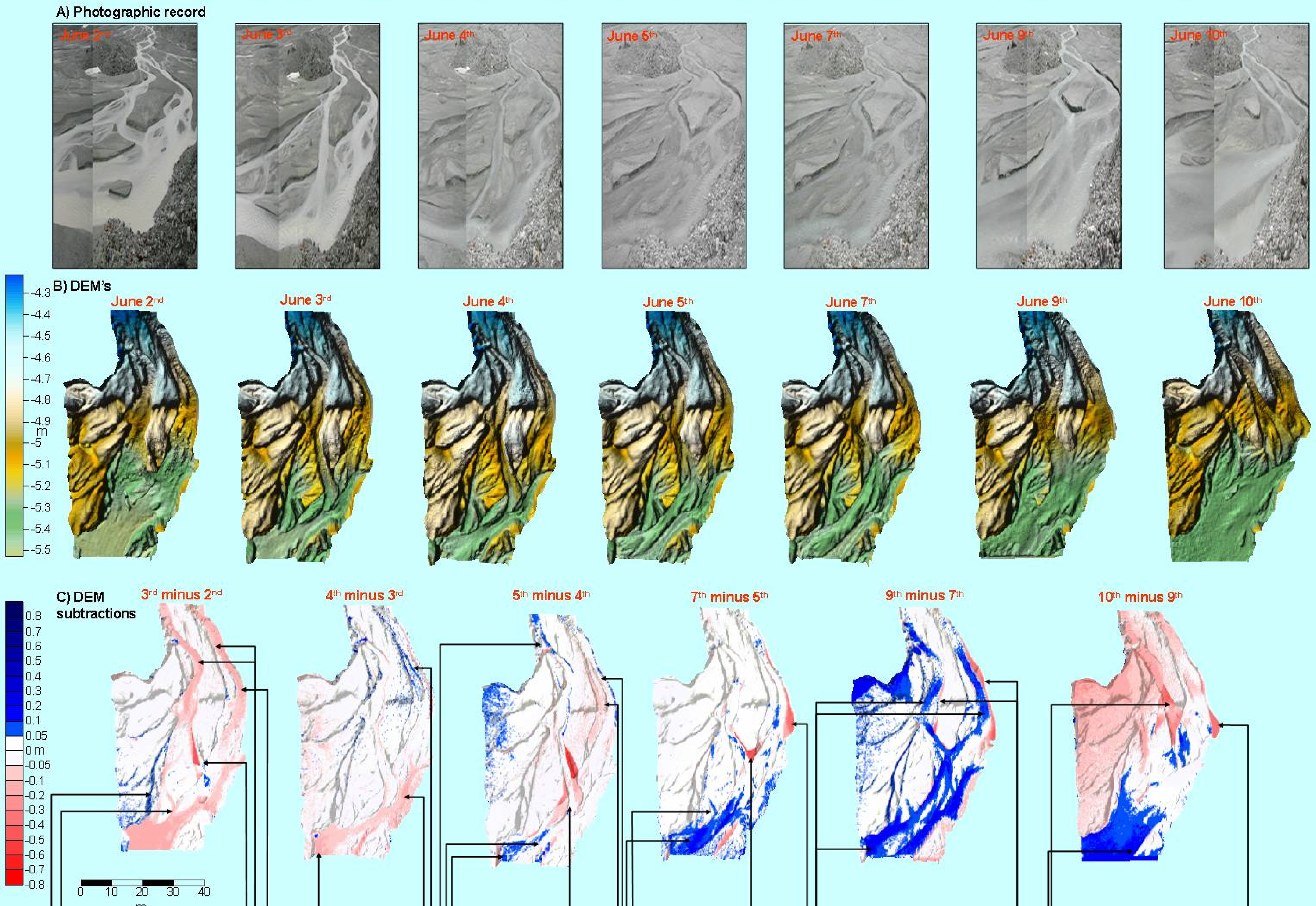

Fig 4 Daily morphological change a) photographic record, b) DEM's, c) DEM subtractions

7. Detection of subtle morphological change

From the scan in Fig 5a it is possible to identify low relief gravel lobes (x) beneath the water surface and it is also possible to pick out gravel clasts (y).

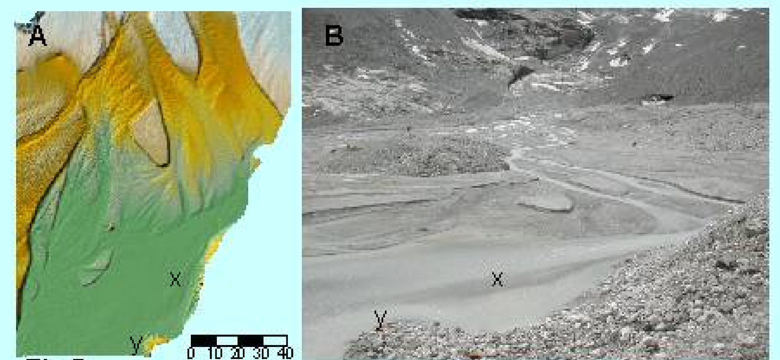

Fig 5

Fig 6

Subtle changes in morphology such as bar edge or bank erosion can also be identified. Fig 6 Shows areas of erosion in red that took place between 5th and 7th June in the left anabranch and tail of the main medial bar.

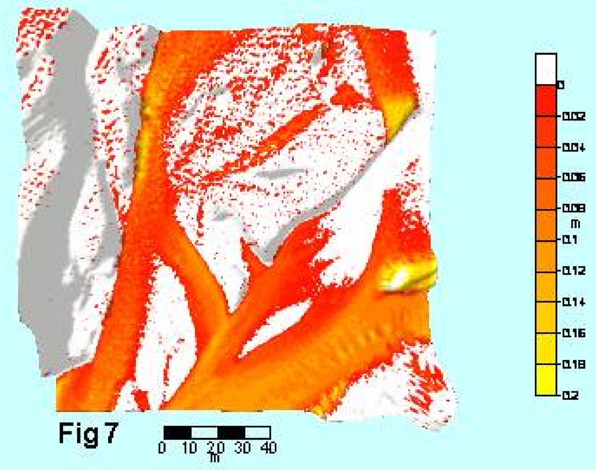

Fig 7

Fig 7 Demonstrates a DEM subtraction taken from the tail end region to the reach, the yellow zones in the chute channels indicate headward progressing scour.

8. Mechanisms of braided channel development at Mont Miné

A variety of mechanisms have previously been described to help explain braided channel change (Table 3). In this study, central-bar deposition was one of the mechanisms identified between the 4th and 5th June. However the most striking changes included two major episodes of avulsion. The first occurred between the 2nd and 3rd June, and appeared to be explained by choking avulsion where one of the anabranches filled with sediment, thus diverting flow and reactivating another anabranch. The second episode of avulsion occurred between the 9th and 10th June. Interrogation of DEM's and photographs, appears to suggest a form of apex avulsion (of the bar edge) as the trigger, rather than choking avulsion (which would have indicated deposition). This allowed flow to be diverted over the lower elevation tail of the medial bar, into the left anabranch. Head-cutting erosion then appears to have cut a new channel through the bar surface.

Table 3 Mechanisms of channel change in braided rivers

Process	Mechanism	Author
Depositional	Central bar deposition	Ashmore (1991)
	Lobe deposition	
Erosional	Chute cut-off	
	Lobe dissection	
Avulsion	Chute cut-off	
	Constriction	Ashmore (1982,), Ferguson and Werrity (1983), Leddy *et al.* (1993)
	Apex	Carson (1984); Leddy *et al.* (1993)
	Choking	Leddy *et al.* (1993)

9. Sediment budget results

The daily sediment budget results are summarised below in Fig 8, along with peak discharge data measured at the outlet to the reach. Over the whole study period there appeared to be more erosion (523 m^3) compared to deposition (307 m^3) within the reach. Between the 2nd and the 5th June erosion seems to be the dominant process within the reach, with an overall balance of 208 m^3 of erosion. Deposition appears to be dominant between the 5th and the 9th June, where there was an overall balance of 100 m^3 of accumulation. Further erosion took place possibly in response to an increase in meltwater discharge on the 10th June. However the relationship between the previous days flow peak and sediment balance was extremely tenuous, suggesting that sediment supply was more influential.

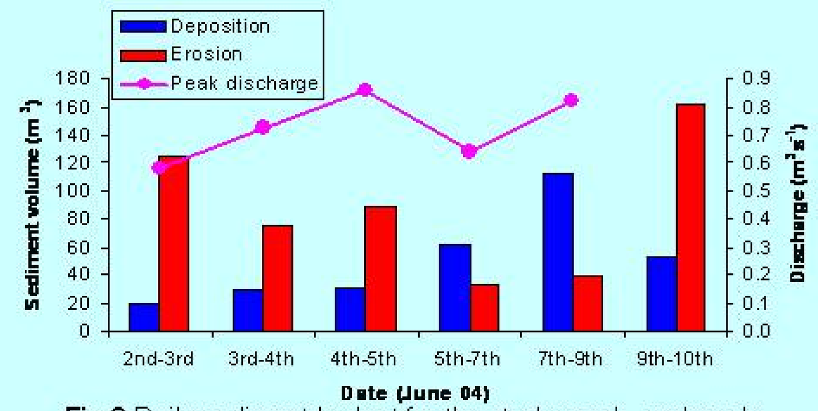

Fig 8 Daily sediment budget for the study reach, and peak flow data for the preceding day

10. Conclusions

- Laser scanning provides a means of obtaining rapid sub-grain level resolution surveys of gravel-bed rivers
- The high resolution of the surveys permits high quality DEM's to be produced which improve sediment budget estimates
- Subtle changes in morphology (±0.02m) can be identified such as changes in bar edges and banks, chute development and sub-surface lobe deposition
- Both erosional and depositional braiding mechanisms were identified over the study period including two avulsion events, and central-channel bar deposition

11. References

Ashmore, P.E. 1982 Laboratory modelling of a gravel braided stream morphology, *Earth Surf. Proc. Landforms*, **7**, 201-225.

Ashmore, P.E. 1991. How do gravel-bed rivers braid? *Can J. Ear. Sci*, **28**, 326-341.

Carson,M. 1984. The meandering-braiding threshold: a reappraisal. J. Hydrol, **73**, 315-334.

Ferguson, R.I. and Werrity, A. 1983. Bar development and channel change in the gravelly river Feshie, Scotland. Int Assoc. Sedimentol. Spec. Publ. **6**, 181-193.

Leddy, J.O., Ashworth, P.J. & Best, J.L. 1993. Mechanisms of anabranch avulsion within gravel-bed braided rivers: observations from scaled physical models, In *Braided Rivers* (ed by J. L. Best & C. S. Bristow), Spec. Publ. Geol. Soc. Lon, pp119-127.