LAHAR HAZARD IN THE BELHAM RIVER VALLEY, MONTSERRAT. J. Barclay , J. Alexander, A. Darnell and, J. Sušnik. School of Environmental Sciences, University of East Anglia, Norwich, England, U.K. NR4 7TJ. (J.Barclay@uea.ac.uk)

Introduction: Rain falling on loose volcanic debris over the Soufriere Hills Volcano, Montserrat, West Indies generates hazardous flash floods, or lahars. These rainfall-induced lahars vary greatly in discharge and sediment concentration in space and time. They differ from examples documented on other volcanoes in that: (a) the eruption has been ongoing since July 1995 generating repeated pulses of excess sediment, (b) rainfall is the only significant trigger, and (c) the system is small with short distance to the sea and relatively low altitude at the catchment top. For much of the volcanic eruption, the Belham River Valley (BRV) has marked the boundary between the 'Safe Zone' (full-time occupation) to the north, and the 'Daytime Entry Zone' (occasional occupation during daylight hours only) to the south. With the burial of the Belham River Bridge by lahars all traffic between these two zones now crosses the river bed: directly through the lahar flow path. This traffic includes agricultural, industrial, maintenance, tourist and residential users. Thus the periodic inundation of the BRV by fast flowing, sediment-charged flood water poses a significant hazard and will continue to do so for many years after the eruption ceases. We have been monitoring and characterizing the changing morphology and sedimentology of the BRV resulting from these lahars since January 2001, using high resolution rainfall data, dGPS surveys, sedimentological mapping and latterly GIS.

'Typical' flow behaviour: Prior to the eruption the BRV was subject to periodic flooding but since 1997 greater magnitude discharge events occur from the same rainfall patterns particularly as a result of vegetation removal and rilling of debris-strewn slopes. These lahars have much higher sediment concentrations than might be expected for a river channel of this catchment size. Nonetheless lahars between 2001 and 2006 were predominantly concentrated 'normal' stream flow with little evidence for debris flow. A correlation between high rainfall days (> 10 mm) and the generation of lahars becomes more apparent later in the rainy season. There was considerable temporal and spatial variation in the nature of the flows with variable incision and infilling of channels. Between 2001 and 2004 around the bridge area these lahars resulted in a mean aggradation of ~ 0.4 m yr^{-1}[1].

Extreme flow behaviour: There have been two exceptional flow events in the BRV: 20th March 2000 and 21st May 2006. Both of the lahars were associated with primary volcanic activity. Deposits from the March 20th 2000 flow suggest that a component of this flow was non-Newtonian and there is evidence for an increase in the fines component that is attributed to bulking from synchronous ash fall. The lahar activity on 20th May 2006 caused more geomorphic change in the BRV than observed on any other individual day since the onset of the current eruption.. Despite this, rainfall volume and intensity were unexceptional and the high impact of this flow is attributed to a change in runoff associated with vegetation damage (from acid rain resulting from unusual activity of the volcano in the catchment) with a secondary impact from sediment bulking during flow [2]. The contribution of ashfall was not sufficient to produce non-Newtonian flow at any stage. The modification of valley morphology in May 2006 has caused subsequent flows to be strongly out of equilibrium with the channel form, slope and sediment distribution, producing markedly different flows and morphological changes than those observed between 2001 and 2005. For example, the Belham River responded to the relatively smaller flows on the 21st May by channel form change cutting deep and narrow channels.

Implications for hazard assessment and management: Although low in sediment concentration compared to many lahars, flows in the BRV are capable of significant infrastructure damage because they are difficult to predict; often rapid, locally erosive, and transport large sediment loads including boulders and other debris. A needs assessment of the various agencies responsible for managing the risk associated with the lahar activity was conducted in December 2007. Clear understandings of *both* the long term impacts and the likely inundation, scour and siltation behavior of individual flow events are necessary. The former is essential to aid long term policy decisions relating to investment and the latter in providing day-to-day warnings for the local population. Differing agencies retain different priorities with this information and a 'one-size-fits-all' hazards assessment is unlikely to be beneficial.Thus key priorities in our ongoing analysis of lahars are the modelling of individual flows (both typical and extreme) and elucidation of the conditions that lead to exceptional flows and the longevity of impact.

References: [1] Barclay, J et al. (2007) *JGeolSoc (Lond), 164,* 815-827. [2] Alexander. J et al. (submitted)