Geophysical Research Abstracts
Vol. 12, EGU2010-11320, 2010
EGU General Assembly 2010

Controls on flow width in aggrading alluvial systems and implications for alluvial fan evolution and environmental reconstruction

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Alluvial fans are dynamic landforms, the evolution of which is controlled by both external environmental forcing (climate, tectonics and base level change) and internal process-form feedbacks. The latter include changes in flow configuration and width, driven by aggradation and degradation, which may in turn promote changes in sediment transport capacity. Recent numerical modelling indicates that such feedbacks may lead to dramatic and persistent fan entrenchment in the absence of external forcing. However, the parameterisation of flow width within such models is untested to date and is subject to considerable uncertainty. Here we consider this problem and its implications in two ways. (1) We present results from a physical modelling study of flow width dynamics on an aggrading fan in which spatial and temporal patterns of fan inundation are monitored continuously using analysis of digital vertical photography. Observed flow widths are compared with results from a simple theoretical model developed for non-equilibrium (aggradational) conditions. Results demonstrate that the theoretical model is capable of capturing the first-order characteristics of width adjustment over the course of the experiment, and indicate that flow width is a function of fan aggradation rate. This illustrates that models of alluvial flow width derived for equilibrium conditions may have limited utility in non-equilibrium situations, despite their widespread use to date. (2) We then apply this model to simulate post-glacial fan entrenchment in the Avoca Valley, New Zealand. This is carried out by conducting a series of c. 80000 numerical simulations of fan formation, within a Monte Carlo framework, in order to evaluate the potential for reconstructing past environmental conditions by matching simulated and observed fan morphologies. Our results indicate that simulations based on a wide range of model boundary conditions are able to reproduce the observed fan characteristics. Such equifinal behaviour is a product of an imposed limit on fan progradation and associated autogenic feedbacks, which drive flow narrowing and fan entrenchment even in the absence of external changes in water or sediment supply. We find little evidence that the majority of preserved fan terraces that formed post-entrenchment did so during periods of higher than average discharge or sediment supply to the fan apex, or that evidence for significant changes in sediment supply associated with major climate shifts are likely to be preserved in the current fan morphology. These results have significant implications for the use of numerical models to assist interpretation of alluvial landforms in the context of past environment change.