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Late Holocene upper bounds of flood magnitudes and twentieth century large floods in the ungauged, hyperarid alluvial Nahal Arava, Israel

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Abstract

The impact of large twentieth century floods on the riparian vegetation and channel morphology of the relatively wide anabranching and braided Nahal Arava, southern Israel, was documented as part of developing tools to (a) identify recent large floods, (b) determine these flood's respective magnitudes in alluvial ungauged streams, and (c) determine long-term upper bounds to flood stages and magnitudes. Along most of its course Nahal Paran, a major tributary that impacts the morphology, floods and sediments of Nahal Arava at the study reach, is a coarse-gravel, braided ephemeral stream. Downstream of the Arava–Paran confluence, aeolian and fluvial sand delivered from eastern Arava valley alters the channel morphology. The sand has accreted up to 2.5 m above the distinct current channels, facilitating the recording of large floods. This sand enhances the establishment of denser riparian vegetation (mainly *Tamarix nilotica* and *Haloxylon persicum*) that interacts with floods and affects stream morphology. A temporal association was found between specific floods recorded upstream and tree-ring ages of re-growth of flood-damaged tamarix trees (‘Sigafoos trees’) in the past 30 years. This association can be utilized for developing a twentieth century flood chronology in hyperarid ungauged basins in the region. The minimum magnitude of the largest flood that covered the entire channel width, estimated from flood deposits, is approximately 1700–1800 m^3s^{-1}. This is a larger magnitude than the largest gauged flood of 1150 m^3s^{-1} that occurred in 1970 about 30 km upstream in Nahal Paran. Our estimation agrees with flood magnitude estimated from the regional envelope curve of the largest floods. Based on Holocene alluvial stratigraphy and OSL dating in the study reach we also conclude that flood stages did not reach the late Holocene (~2.2 ka) surface and therefore we estimate a non-exceedance upper bound of ~2000 m^3s^{-1} flood magnitudes for Nahal Arava during that interval. This study

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indicates that in unfavorable areas the combination of hydrology, fluvial morphology and botanic evidence can increase our understanding of ungauged basins and give information crucial for hydrology planning.

Keywords: Negev desert; Arava valley; Flood; Paleofloods; Tree ring; Alluvial stratigraphy; Arid

1. Introduction

Very few streams are monitored in hyperarid environments and when volume and/or peak discharge data are needed, the current practice is usually based either on rainfall–runoff modeling or regional empirical or statistical analyses, usually with scant data. These analyses rely at best on very little useful and sometimes untestable indirect estimation. The problem is exacerbated in ungauged regions with only alluvial reaches. However, much information on floods can be derived from geomorphic-and botanic-based flood hydrology studies of specific reaches of ungauged streams (e.g., Baker et al., 1988; House et al., 2002). Here we provide support to claims frequently put forward by field-oriented fluvial geomorphologists that geomorphology should be part of any hydrologic analysis; more so when the hydrology is based on scarce data. In the case presented here we show the strength of such an integrative procedure, particularly in hyperarid regions.

Alluvial reaches usually impose difficulties on gathering information on occurrences and magnitudes of past floods, but the vast experience and knowledge in fluvial geomorphology can assist in resolving specific hydrologic problems. Although results may not be as accurate as those provided by applying paleoflood hydrology methodologies in bedrock canyons (Baker et al., 1988), we show here that indirect geomorphic and hydrologic methods assisted by botanical information yield relatively high-quality and useful information. Our results indicate that gathering data from multiple sources augments flood geomorphology research and particularly adds to specific and regional flood patterns so needed by the practitioners. These results can be easily incorporated in any hydrological practice.

In the hyperarid ephemeral streams in the Negev desert and the Arava valley, geomorphology-based flood hydrology and paleoflood studies were used for the following: flood risk and water resources analyses; generating regional envelope curves; extending the systematic flood series and for estimating transmission losses (Polack, 1980; Ben-Zvi, 1988a,b; Greenbaum and Schick, 1997; Greenbaum and Enzel, 1998; Greenbaum et al., 1998, 2000, 2001, 2002, 2006; Meirovich et al., 1998; Shentsis et al., 1998a,b, 1999). These studies substantially improved our knowledge and demonstrated how powerful hydro-geomorphic studies are in generating scientifically-based concrete data and understanding of magnitude and frequency of past floods in hyperarid environments. However, the geomorphology and hydrology research communities frequently face the need for detecting occurrences and (at least) the relative magnitudes of large floods in alluvial reaches and fluvial environments where the search for proper methodologies is needed.

We explored methodologies to reconstruct even short historic flood chronologies and faced the understanding that data are rare at all temporal scales but, that flood magnitudes of even the last few decades provide crucial if only partial information (e.g., House et al., 2002). Riparian trees (mostly *Tamarix nilotica*) are abundant along many of the wadi channels of the Near East deserts. Therefore, we made an effort to test their applicability to hydrological studies. We decided to explore these botanic methodologies specifically because we recognize and are aware of the problems associated with these braided and hence shifting channels in wide alluvial reaches.

This research integrates different methodologies: we use available upstream gauged data (Shentsis et al., 1999), regional estimations of maximum regional floods (Greenbaum, 1996; Greenbaum and Schick, 1997; Greenbaum and Enzel, 1998; Meirovich et al., 1998; Greenbaum et al., 2001) and paleofloods (Greenbaum, 1996; Greenbaum and Schick, 1997; Greenbaum and Enzel, 1998; Greenbaum et al., 1998, 2000, 2001, 2002, 2006) to test results on flood magnitudes and relative frequencies and their potential upper bounds from a downstream alluvial reach. We also use (a) Holocene to modern alluvial stratigraphy and numerical dating of abandoned terraces and floodplains in determining both recent flood stages and geomorphic evidence for non-exceedance stages over longer periods, (b) tree ring chronologies of flood damaged riparian trees indicative of flood stages and occurrences, and (c) topographic surveys and hydraulic calculations in flood magnitude estimations.

2. The study reach

Nahal Arava forms an axial stream along the northern Arava valley, where several tributaries join and flow into