

Controls on recent channel narrowing and incision in Canyon de Chelly National Monument, Arizona.

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Abstract. Cycles of stream channel incision and aggradation in the southern Colorado Plateau have been identified throughout the past several thousand years (Leopold, 1976; Graf, 1983). Debates as to the cause of the transitions between aggrading and incising systems have centered on climate change (Hereford, 1984; Graf et al., 1991); internal thresholds that trigger the cycles independent of climate or land use (Schumm and Hadley, 1957; Patton and Schumm, 1981; Patton and Boison, 1986;); and land use impacts, which include grazing, increased density of unpaved roads, groundwater pumping, and invasion of exotic plant species (Graf, 1987; Allred and Schmidt, 1999; Gellis et al., 2004). Canyon de Chelly National Monument, located on the Navajo Reservation in northeastern Arizona, has experienced recent increases in channel narrowing and incision comparable to other drainages within the southern Colorado Plateau. Canyon de Chelly (1,236 km²) is an ephemeral, sand-bedded channel. Air photographs from 1935 show the channel throughout the canyon as braided with sparse vegetation. Since that time, the channel has narrowed to a single-thread, meandering channel with an average bed gradient that ranges between 0.0037 and 0.0046. This channel response coincides with the presence of tamarisk and Russian olive, exotic plant species that have become widespread along riparian areas within the arid and semi-arid regions of North America (Tickner et al., 2001). Evidence from a detailed longitudinal profile of the streambed, coupled with an analysis of historical aerial photographs that span a 75 year period (1935-2010) (Cadol, 2007), indicates that widespread establishment of exotic and native plants in the 1980's exacerbated the most recent channel narrowing and incision in parts of the monument, specifically the lower 13 km of the canyon. In this lower section, the channel has incised as much as 8 m and the average width:depth values is 6. In the middle and upper portions of the canyon, vegetation and channel narrowing are less closely coupled, and incision is limited to the middle portion of the canyon. The upper portion of the canyon is the least incised with an average width:depth value of 13. The variability in the longitudinal profile and degree of incision is the result of a suite of conditions that likely cause portions of the stream to locally become more vulnerable to incision, such as specific timing and type of vegetation establishment, the presence of in-channel structures, streambed substrate, longitudinal position, historic grazing, and vehicular traffic within the canyon. The pattern of incision within the canyon is consistent with the conceptual model of discontinuous gullying, which is an expression of complex response commonly seen in semi-arid landscapes (Schumm and Hadley, 1957).