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River response to European settlement in the subtropical Brisbane River, Australia

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ABSTRACT

The response of river channels to land cover and land use changes in large areas of the tropics and subtropics is poorly documented. Arable agriculture and grazing was introduced to the subtropical catchment of the Brisbane River, Australia, by European settlers in the 1840s. This study examines subsequent changes to the morphology, sediments and vegetation of the Brisbane River in relation to the major drivers of channel change. Documentary evidence from pioneers, paintings, newspapers,maps, surveys, photographs, and instrumental flow records suggests that within 20 years of the introduction of sheep grazing, compaction and degradation of catchment soils and surface drainage produced a shift from perennial to seasonally ephemeral flow and channel incision in minor tributary valleys. The main channel remained stable until the 1850s in the Estuary, and until the 1890s in the middle reaches, where bank erosion increased average channel widths by 18%. Compared to rivers in temperate areas, the Brisbane River has been relatively resilient to changes in land use and land cover. Rates of lateral channel migration have been low since at least 1885, and the level of the channel bed has been stable since 1894. It is shown that the present-day compound channel is a pre-European form with dimensions adjusted to floods with decadal return periods. Increases in sediment supply associated with the incision of tributary streams and later, from widening of the main channel, is consistent with regional evidence for the predominance of channel erosion. This implies an ongoing channel adjustment to changes associated with European land use change.

1. Introduction

In temperate Australia and North America channel responses to changes in land use have been well documented. In general, rivers metamorphosed from low-energy, sinuous, stable channels into deeper, wider, and straighter channels transporting a larger, coarser sediment load (Brooks and Brierley, 1997; Prosser et al., 2001; Olley and Wasson, 2003; Brierley et al., 2005; Knox, 2006). These responses have variously been ascribed to secular changes in rainfall (e.g. Erskine and Warner, 1998), reduced bank resistance from degraded riparian forests (Brooks et al., 2003; Brierley et al., 2005), and altered hydrological regimes following forest clearance (Brooks and Brierley, 1997; Kirkup et al., 1998). So far, little of this work has extended into subtropical and tropical river systems.

In the last three decades, agricultural development in the tropics has intensified worldwide, leading to high rates of deforestation, deteriorating riverine ecosystems and degraded water supplies (Phalan et al., 2013; James and Marcus, 2006). As the consequent impacts to channel systems from flooding and sediment pollution begins to be more fully appreciated, a greater understanding of fluvial response and sensitivity to shifts in land use and climate is urgently needed (Gregory, 2006; Bradshaw et al., 2007; Meyfroidt and Lambin, 2011). Compared to temperate systems, tropical rivers have highly seasonal flow, a larger flood range, high sediment yields, and a higher proportion of suspended to bed sediment load. It is therefore not appropriate to translate river response models developed from temperate areas into the lower latitudes (Latrubesse et al., 2005; Thomas, 2006; Sinha et al., 2012).

Rivers in southeast Queensland experience a subtropical, wet-and-dry climate with streamflow dominated by tropical weather systems. Studies of floodplain and marine sedimentation suggest that widespread clearing, logging and farming by the first European settlers from the 1840s produced substantial increases in catchment erosion with increased rates of sedimentation in floodplains and estuaries (Hughes et al., 2009, 2010 Morelli et al., 2012; Saxton et al., 2012; Olley et al., 2015). Empirical measurements and models suggest that river sediment loads increased between 2 and 14 times following the arrival of Europeans (Neil et al., 2002; Hughes et al., 2010; Kroon et al., 2012). Studies using fallout radionuclide

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concentrations in fluvial sediment have shown that most sediment is generated from the channel network with a relatively minor contribution from hillslopes (Wallbrink, 2004; Hughes et al., 2009; Olley et al., 2013). This pattern of increased sediment loads and erosion of the channel network is similar to that reported in more temperate regions (Olley and Wasson 2003), so it might be expected that subtropical channels will have experienced similar changes to those in the more temperate regions. However, this contrasts with a recent historical reconstruction of channel change in the Brisbane Basin which points to overall channel stability in the face of large floods and land use change (Fryirs et al., 2015).

Here, we use qualitative and quantitative documentary evidence combined with instrumental records to examine channel changes in the Brisbane River from the time of the first European explorers (1820s) to the present day. Firstly, we assess whether the rivers are in their natural state or have been altered markedly by anthropogenic change. Secondly, we examine the strength of the evidence for major changes with respect to the major drivers of channel change, namely, catchment hydrology, riparian forests, and secular climate change. Finally, we resolve the discrepancy between apparent channel stability and increased sediment loads and the predominance of channel erosion.

2. Regional setting

The Brisbane River, in southeast Queensland, drains 13,500 km^2 and discharges into Moreton Bay, which has Ramsar-listed seagrass, mangrove and saltmarsh communities (Fig. 1). Moreton Bay is a semi-enclosed estuarine embayment, which is sensitive to inputs of sediments and nutrients derived from the catchments. The health of these Ramsar-listed communities is currently threatened by increased sediment inputs (Neil et al., 2002; Coates-Marnane et al., submitted). These sediments are primarily derived from channel erosion in the Brisbane River catchment (Douglas et al., 2003; Olley et al., 2013).

The study area encompasses 40 km of the Brisbane River Valley between Northbrook and the tidal reaches below Mount Crosby, hereafter referred to as “the Estuary” (Fig. 1). Much of the catchment is underlain by Palaeozoic metasediments with erodible, duplex soils, with smaller areas underlain by Tertiary basaltic intrusions featuring fertile structured and massive earths (Stevens, 1990). Ranges over 1000 m in elevation occur along the Brisbane’s western and southern divide. The channel bed slope averages 1 in 3700 (0.00027).

The Brisbane catchment experiences a subtropical climate with a summer rainfall maximum and an annual precipitation of

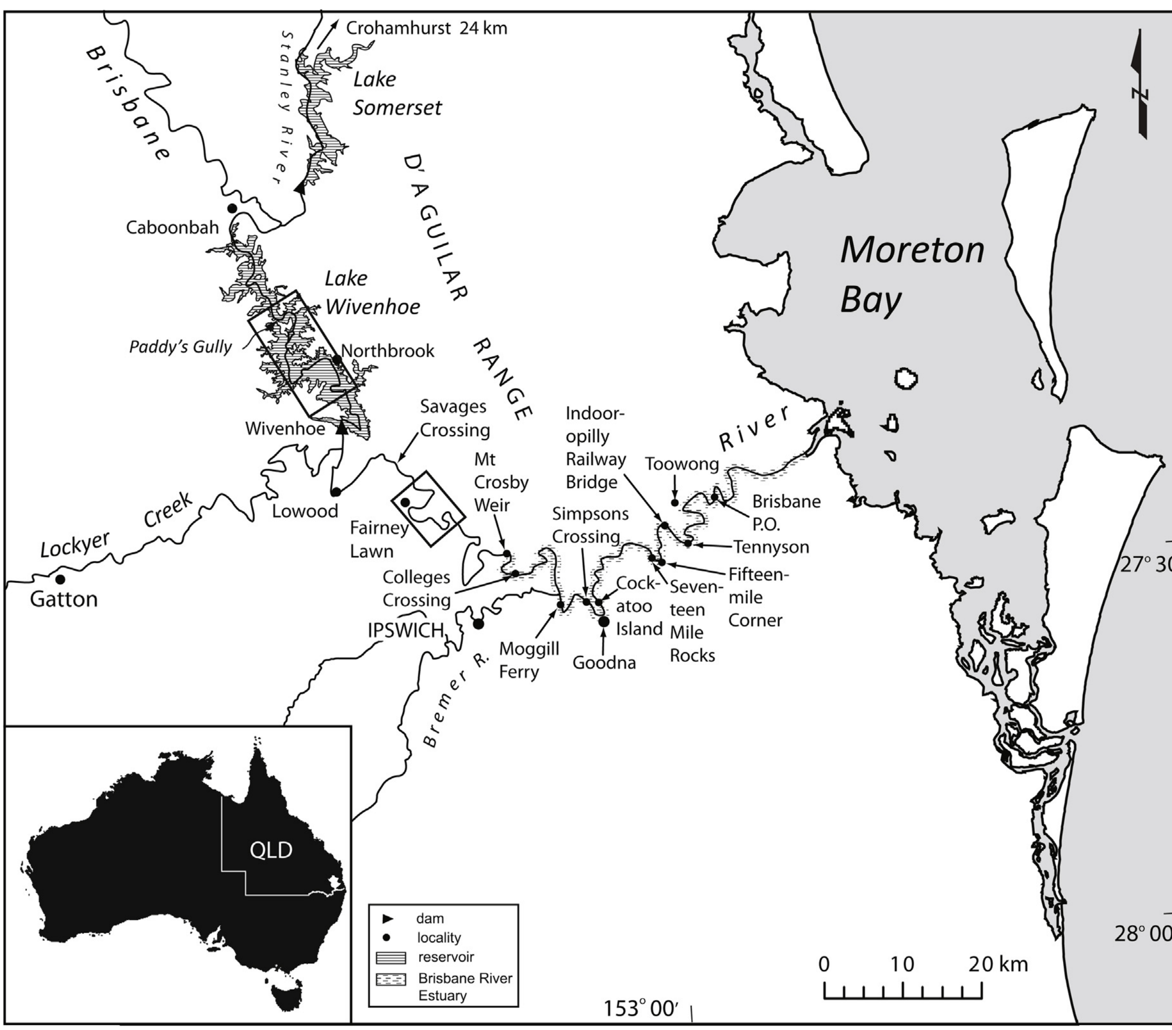

Fig. 1. The Brisbane River catchment in southeast Queensland (inset), showing the study reach upstream from Mt. Crosby Weir, and major hydrographic stations at the Brisbane Port Office (P.O.), Savages Crossing, Lowood, and Mt. Crosby. The precise locations of Eight-mile Point and Nine-mile Corner could not be established. Northbrook and Fairney Lawn reaches (boxed) are shown in more detail in Fig. 7.