Ecological Engineering 36 (2010) 292–304

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

The role of riparian trees in maintaining riverbank stability: A review of Australian experience and practice

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ARTICLE INFO

Article history:
Received 31 August 2008
Received in revised form 21 April 2009
Accepted 24 April 2009

Keywords:
Root-reinforcement
Root-Area-Ratio
Rooting depth
Riverbank stability analysis
Slope stability
Eucalypts

ABSTRACT

Riverside vegetation is a significant factor influencing the occurrence and progress of streambed and riverbank erosion. Recent riparian management practice in Australia has focussed on re-establishing or maintaining native riparian vegetation in order to control or prevent erosion as well as regenerate or preserve the complex variety of in-stream and riverside habitats. This work presents an integrated review of field and experimental studies conducted in eastern Australia that evaluate native vegetation's role in mass failure of riverbanks. Several results of these studies have general application and include the following: (1) The presence of riparian forest on riverbanks significantly reduces the likelihood of erosion by mass failure due to reinforcement of riverbank soils by tree roots and this reduced likelihood of mass failure enables a narrower channel cross-section than would otherwise be the case for many Australian coastal streams. (2) A number of Australian tree species have apparently evolved roots that seek the permanent, summer water table in order to survive prolonged dry spells, these root systems are particularly effective in mass failure mitigation due to rooting depths that are commonly greater than 5 m and are sometimes well in excess of 20 m. (3) The so-called "Root-Area-Ratio method" of calculating the shear strength of root-reinforced soil using root tensile strength data and Waldron's [Waldron, L.J., 1977. The shear resistance of root-permeated homogenous and stratified soil. J. Soil Sci. Soc. Am. 41, 843–849] and Wu et al.'s [Wu, T.H., McKinnell, W.P., Swanston, D.N., 1979. Strength of tree roots and landslides on Prince of Wales Island, Alaska. Can. Geotech. J. 16, 19–33] simple root model leads to significant overestimation of the actual root-reinforcement due to (a) breakage or pull-out of roots that taper and narrow beneath the shear plane such that individual roots do not achieve the tensile strength calculated on the basis of root diameter at the shear plane; and/or (b) the fact that the soil mass fails progressively along the length of potential shear plane rather instantaneously across the entire shear plane.

1. Introduction

There has been a complete reversal in the approaches applied to the management of the in-stream woody debris and riparian vegetation present in Australian rivers over the past few decades. In the 1970s, it was commonly the case that government policy and funding encouraged the removal of trees and woody debris from streams to increase stream-flow velocity during floods so that flood-peak heights were reduced (Brooks et al., 2006; Erskine and Green, 2000). The aims were to protect buildings and infrastructure from inundation and to minimise disruption to public services, private business and transport networks. In many parts of the country, particularly in eastern Australia (e.g. Bega, Hunter, Nepean, Thurra, and Lockyer Creek), river channels were cleared of large woody debris and riverbank trees were cut down to reduce channel roughness. Prior to direct government involvement, unregulated farming practices had effectively achieved the same result on many streams (Rutherfurd, 2000; Brooks and Brierley, 1997).

During the 1980s and early 1990s it was increasingly recognised that the removal of in-stream debris and riverbank trees in combination with increased runoff due to catchment clearing had caused significant channel incision and widening (Brooks and Brierley, 2000; Brooks et al., 2006) with the consequent loss of agricultural and recreational land and the potential loss of roads, bridges and buildings (Docker and Hubble, 2008). It was also recognised that the mobilisation of sediment from the channel and banks had led to water quality reduction and that the removal of woody debris had effectively destroyed the in-stream, micro-habitats necessary for the survival of riverine fauna (Brooks et al., 2006).

By the late-1980s the degradation of these riverine environments, the reduction in the resilience and diversity of their biota, and the "dramatic homogenisation of in-stream habitat and

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doi:10.1016/j.ecoleng.2009.04.006

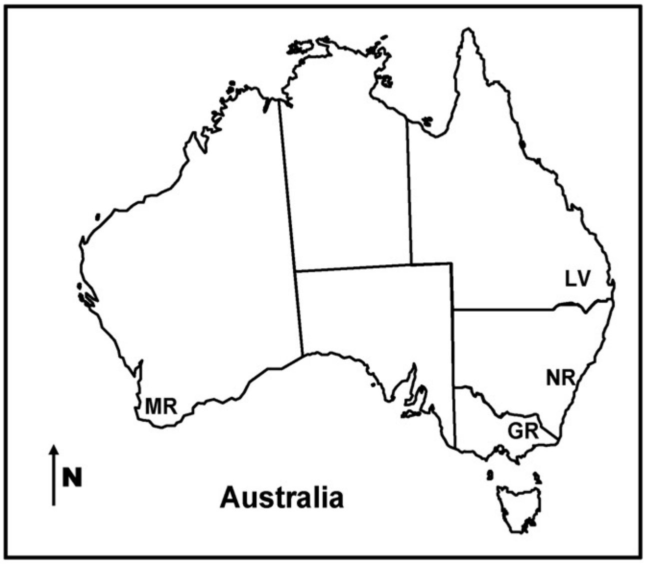

Fig. 1. Map of Australia showing the general location of specific sites referred to in the text. LV—Lochyer Valley, South-east Queensland; NR—Nepean River, central coastal New South Wales; GR—Goulburn River, north-eastern Victoria; MR—Margaret River, south-western Western Australia.

ecosystems" (Brooks et al., 2006) was recognised to have been detrimental. From the early 1990s, Australian state governments established Catchment Management Trusts which were made responsible for restoring anthropogenically damaged streams and improving river health. In contrast to previous practice, these publically funded bodies mobilised community groups and set about replanting riparian vegetation and re-establishing in-stream woody debris. These activities were recognised to be necessary actions required for ensuring the long-term viability of riverine ecosystems (Lovett and Price, 2007) and the re-establishment of riverbank trees is now a major component of Australian public spending on the repair of riverine ecosystems (Brooks and Lake, 2007).

This paper reviews some of the studies that justified this reversal in attitude and the adoption of the riparian tree replanting as a key objective of river management by Australian Government agencies (Fig. 1 locates the study sites). Brooks et al. (2006) provide an excellent account of the re-establishment of large woody debris in the Australian context and reviews past and present practices and their consequences which will not be repeated here. Instead, this review focuses on the asked-and-answered questions which established why it is that Australian riparian trees and their root systems increase riverbank stability and potentially reduce the volume of sediment supplied to river channels generated by slumps and other types of large-scale mass failure. The investigations of the role of root-reinforcement in the prevention or mitigation of bank failure reviewed here were largely inspired by the seminal works on the soil reinforcement by roots undertaken by Wu, Waldron and Dakessian (Wu, 1976; Waldron, 1977; Waldron and Dakessian, 1981) and the pioneering work of Endo and Tsurata (1969). The success of the studies is founded on these earlier works.

2. Does the presence of riparian trees reduce or prevent riverbank failure?

Several studies have directly addressed this question in the Australian context (Hubble and Hull, 1996; Abernethy and Rutherfurd, 1998, 2001; Docker and Hubble, 2001; Hubble, 2001, 2004). They have demonstrated that forested banks and banks with well-established, closely spaced trees are not generally prone to bank failures, while adjacent and nearby banks that have been cleared of trees but presenting similar slopes and soils generally do experience bank failures (Fig. 2). Although, these detailed studies established this relationship for two rivers in particular, the Latrobe in Victoria and the Hawkesbury–Nepean in New South Wales, it is accepted that these findings have more general application (Rutherfurd, 2007) with several other studies (Huang and Nanson, 1997; Brooks and Brierley, 2000; Wasson and Wasson, 2000) demonstrating that streams presenting a dense native riparian forest tend to be narrower than streams that do not present trees or those streams that present only a few trees on their banks—the

Fig. 2. Aerial photographs of the Nepean River taken in 1961 and 1965; downstream flow is indicated by an arrow, and is towards the top of the page. Comparison of the images indicates prominent bank failure features developed on the previously devegetated right-hand bank which is on the inside of the meander bend. This contrasts with the absence of bank failure features on the vegetated left-hand bank located on the outside of the meander bend. This contrast in behaviour was demonstrated to be due to the absence of root-reinforcement of the bank soils (right bank) by Hubble (2003, see Fig. 3).