The way of the rivers: geomorphic recovery under different land use patterns and catchment management activities in adjacent river catchments

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Key Points

- Rivers of similar geomorphic character may be assessed for recovery trends
- Geomorphic recovery is complex and may be affected by local factors
- Geomorphic recovery potential is an important tool to decision support in NSW rivers

Abstract

Examining geomorphic factors driving and hindering river recovery is important to designing reach to catchment scale river management programs. Additionally, multi-decadal social and land use history provides important context for projecting future recovery pathways. It also informs catchment managers of perceived and actual threats to river recovery. Combined consideration of geomorphic and social drivers adds to standard hydraulic, channel form and sediment transport analysis, informing our understanding of interactions between flow and physical form to enhance ecological health and understand limits to human activities that promote or hinder recovery.

Part of the NSW River Styles project is to understand relationships between rivers of similar geomorphic character and the key differences that result in different recovery outcomes. Comparisons of recovery trajectories between similar rivers with significant differences in land use and management history highlight important considerations for developing river rehabilitation projects. This paper reviews literature over five decades of river management programs in two adjacent coastal rivers, Wollombi Brook and Macdonald River, combined with mapping of existing geomorphic condition to inform future management priorities.

Keywords

Geomorphic recovery, land use patterns

Introduction

The majority of rivers in south-eastern Australia have undergone significant adjustment since European occupation (Hoyle et al. 2008, Erskine and Webb 2003, Rutherfurd 1996). Assessment of the extent and severity of riverine degradation and consequential impairment of recovery occupies much of Australian geomorphic literature (Fryirs et al. 2009). Understanding by what processes rivers have become degraded, and how they might recover, are fundamental requirements for science-informed river management.

In addition to identifying geomorphic processes, analysing long term land use history provides important context for projecting future geomorphic recovery trajectories. Along with standard hydraulic, channel form and sediment transport analysis, social and land use history can contribute to development of decision support systems that recognise land management risks, ongoing threats and priorities for intervention (Fryirs et al. 2021). Thinking in terms of recovery trajectories – or the pathways via which a river may recover or degrade – can help to prioritise reaches for monitoring and rehabilitation based on proximity to a threshold for change and the presence of recovery processes and/or threats. Using River Styles data, these trajectories have been conceptualized in River Recovery Diagrams (e.g. Brierley and Fryirs 2016) to support decision making.

However, social and agency funding pressures lend to a ‘set and forget’ state for river channel management (Downs and Kondolf 2002, Brierley and Fryirs 2008). Selecting priority rivers and the most cost-effective actions has not occurred consistently. Evaluation, monitoring and consolidation of the most effective options and review of recovery trajectories and priorities must occur. As more than twenty years is needed to evaluate future state and recovery potential (Erskine and Chalmers 2009, Mould and Fryirs 2018), review of channel condition and geomorphic recovery requires long term commitment from government and community to demonstrate effectiveness.

Agencies in NSW Government have agreed on prioritising actions to enhance geomorphic recovery using a combined framework of geomorphic vulnerability, riparian vegetation condition and socio-economic values. Central to this work is the NSW Department of Planning, Industry and Environment – Water Division's state-wide geomorphic assessment and mapping database using the River Styles framework (Brierley and Fryirs 2005). The River Styles Framework provides a coherent and structured basis for describing and comparing the geomorphic character of rivers, assessing condition, inferring their potential to recover and applying this information to develop catchment-scale river management priorities (Fryirs et al. 2021). This database underpins key government activities and has assisted a wide range of river management programs, including Hunter Central Rivers Local Land Services' efforts to identify priority sites for its Area 15 asset program under the Hunter Valley Flood Mitigation program (Jenny Weingott, Gavin Farley, LLS pers comm).

This paper draws on recent updates to the NSW River Styles database, along with historical information, to make comparison between two adjacent river systems in coastal New South Wales. We compare the rivers' geomorphic character, condition and recovery potential, situated in their different land use histories. Findings highlight how key similarities and differences create different possibilities for river recovery. This paper then suggests priorities for future rehabilitation, using science and history as a basis for sustainable river management.

Case study: comparing Wollombi Brook and Macdonald River

Catchment character and hydrology

Wollombi Brook is a tributary to the Hunter River in coastal New South Wales. The Macdonald River is an adjacent sub-catchment draining to the Hawkesbury River. The two rivers have similar catchment areas (Wollombi Brook 1850 km^2, Macdonald River 1845 km^2), geology and comparable rainfall and rainfall/runoff relationships (Erskine and Melville 1983, Erskine 1996, Rustomji 2008, Chalmers et al. 2012). Both rivers are partly confined, sand bedded River Styles as shown in Figure 1. Wollombi Brook has long-term gauging records (112 years) compared to the very limited flow record of the Macdonald River (approximately 40 years). Rivers in coastal New South Wales and tributaries such as Wollombi Brook have been intensely analysed for changes in recovery pathways from catastrophic degradation towards a more intact state (Erskine 2008, Erskine and Melville 2008, Erskine and Chalmers 2009, Chalmers et al. 2013, Kemp et al. 2017), making them useful for comparison.

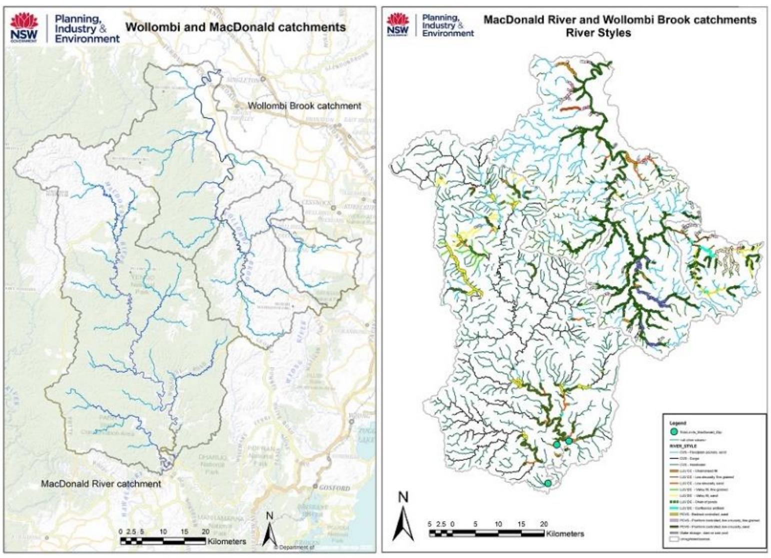

Figure 1. Macdonald River and Wollombi Brook catchments, showing mapped River Styles associated with each river network (Hancock 2014, 2021).

Land use and management history

Land use changes influenced channel response to flood events in both river systems. It is useful to compare geomorphic character, river condition and drivers towards or away from recovery, situated in their different land use histories. This comparison highlights how key similarities and differences create different possibilities for river recovery. The decline in dairying in both catchments affected the density of land occupation and vegetation recovery in both rivers (Mould and Fryirs 2018, Erskine and Chalmers 2009). Both catchments have experienced significant land use change as low-density weekender, tree changers and farm-stay and holiday accommodation grew to become significant land uses in both the Macdonald River and Wollombi Brook catchments over the past thirty years. Tributaries to Wollombi Brook have remained under grazing pressure to the present, whereas tributaries to the Macdonald River were set to reduced stocking rates from the early 1950s and are largely used now for low-intensity grazing and depasturing (Erskine 1986) This led to significant 'passive' recovery in the Macdonald River catchment due to unintentional removal of pressures on river banks and riparian zone (Mould and Fryirs 2018).

Wollombi Brook forms part of the river engineering scheme of the Hunter Valley Flood Mitigation Act, where approximately $3.8M was spent on 182 river training work sites between 1956-85 (Erskine and Chalmers 2009). Twenty elevated rock bed control weirs and other structures in Wollombi Brook, Congewai Creek and six tributaries were constructed between 1982-98 (J. Weingott, G. Farley, Hunter LLS pers comm). The Macdonald River, by contrast, lacked any concerted river management program until after 2000 (Mould and Fryirs 2018) and river management has been largely passive rehabilitation, focusing on riparian fencing, weed management and native plantings.

The large proportion of moderate condition reaches in Wollombi Brook contrasts with generally poor condition in lower Macdonald River. Extensive rehabilitation works projects in Wollombi Brook are complemented by passive rehabilitation management following long term community engagement by Hunter Central Rivers LLS (Mahoney and Whitehead 1994, Erskine and Chalmers 1996, Kemp et al. 2017). Rehabilitation projects, relying on fencing, weed removal and replanting in the Macdonald River catchment may see recovery occur in a similar way to Wollombi Brook. The consequences to geomorphic condition from rehabilitation programs is shown in Figure 2 in the recovery potential mapping conducted by NSW Department of Industry and Environment – Water Division.

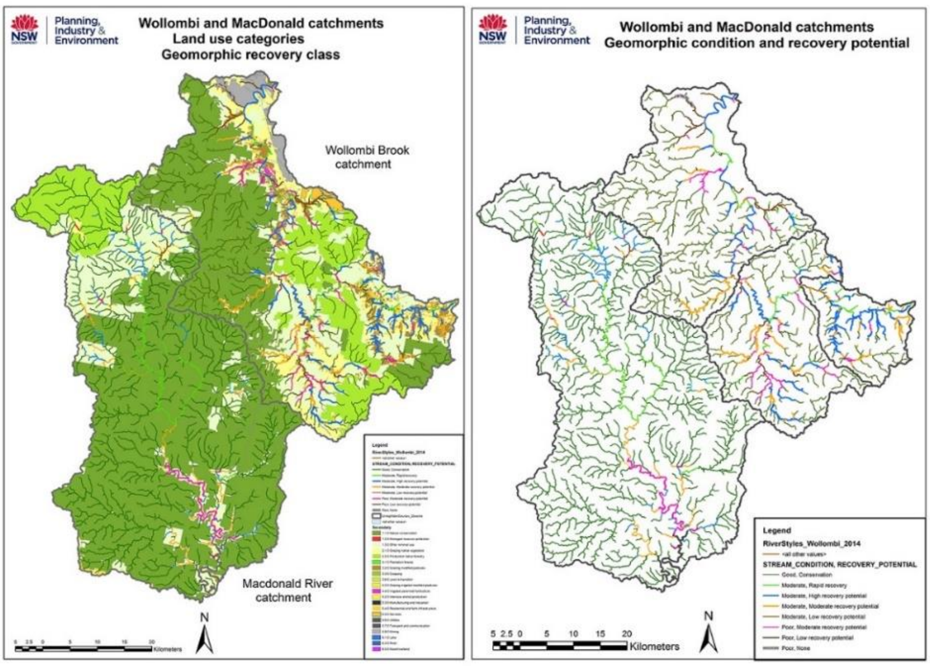

Figure 2. Land use mapping (DPI agricultural land use survey 2012 – NSW DPIE 2012) and geomorphic recovery potential for Wollombi Brook and the Macdonald River (Hancock, 2014, Hancock and Mould 2021).

Channel network configuration and flood responses

Historic catastrophic channel impacts occurred in both Wollombi Brook and Macdonald River catchments since European occupation. These have been analysed in depth in both the Macdonald River (Erskine 1986, Rustomji 2008, Mould and Fryirs 2018) and Wollombi Brook and tributaries (Erskine 1994, Erskine 2008, Erskine and Chalmers 2009, Kemp et al. 2017). Channel degradation, including alternating sections of bed incision and excess sedimentation (in the form of sand slugs), destruction of bars and benches and floodplain stripping occurred in Congewai Creek and Upper and Lower Wollombi Brook and a number of tributaries (Mahony 1994, Erskine 2008). The main channel of the lower Macdonald River's lower reaches experienced significant channel alteration, including meander cutoffs and bed incision, destruction of bars and benches, but with lower levels of floodplain stripping as channel outbreaks did not occur to the same extent as in Wollombi Brook (Erskine 1986, Rustomji 2007, Mould and Fryirs).

Tributary responses differed significantly. Both rivers were sensitized to flood energy, and catastrophic alterations in channel shape, width and depth commenced in the late 19th century, peaking during a series of large flood events between 1949 to 1955. Tributaries to Wollombi Brook were extensively channelised and trapped valley fills scoured and partly destroyed (Erskine 1994, Erskine 2008, Erskine and Chalmers 2009). Channel sand slugs were equally sourced from the main channel and destroyed tributary fills. However, existing sand slugs within Wollombi Brook are now entirely sourced from tributary inputs, such as Dairy Arm and Stockyard Creek (Figure 3). Tributaries to the Macdonald River remain largely intact with only two exhibiting significant channelisation. Trapped tributary valley fills store large volumes of sediment that would form new, pervasive sand slugs in the main river if sand storage were eroded and mobilised.

A. Sand slug migration from Wollombi Brook tributary (Dairy Arm)

B Forced pool on Wollombi Brook ~3km downstream Dairy Arm sand slug inut

C. Sand slug migration along Macdonald River (Mogo Ck junction)

D. Moderate recovery site on Macdonald River (Piggyback bridge)

Figure 3 Localised sand slug inputs from tributaries (Dairy Arm) to Wollombi Brook and extensive slug affected reaches of the Macdonald River

The most distinctive differences are between the upper and lower sections of both river systems. The upper section of Wollombi Brook (above Congewai Ck junction) remains in poor to moderate condition and with moderate recovery potential. The lower section is in moderate to near-intact condition. The majority of lower Wollombi Brook has high recovery potential.

The upper section of the Macdonald River is largely in moderate condition, and nearly half of the main three rivers have high recovery potential. The mid-section, falling within the Macdonald River gorge, is in near intact condition, while the Macdonald River from below the gorge to the junction with the Hawkesbury River is largely in poor condition with short lengths in moderate condition.

The gorges that separate the upper and lower sections of both rivers have low sensitivity to adjustment and did not attract European agricultural use. These sections remain in relatively good condition, though they act as high energy conduits, flushing sand slugs from the upper to lower catchment in both rivers (Hancock 2014).

Discussion: threats and prioritisation for the future

The two rivers assessed face different recovery trajectories and future threats. Wollombi Brook is undergoing high rates of recovery following completion of installation of constructed bed controls and enhanced passive rehabilitation projects over the past twenty years. The lower half of Wollombi Brook has significantly lower flood celerity and increased resilience to flood energy due to channel narrowing and revegetation (Kemp et al. 2017). Similar transitions have occurred in Congewai Creek and sections of Upper Wollombi Brook where Local Land Services has formed land use agreements with landholders for passive recovery management of kilometre-scale river lengths (J Weingott pers comm). Geomorphic recovery in Wollombi Brook is particularly complex due to the hard-engineered structures that constrain the channel vertically and laterally. The most rapid recovery is occurring through and downstream of the Paynes Crossing gorge to the junction with the Hunter River. Ongoing threats to channel integrity and complexity in Wollombi Brook, requiring ongoing management are sourced from tributaries that remain in relatively poor condition and transmit large volumes of sand into the main channel.

The Macdonald River is undergoing recovery within the upstream half since the last major flood in 2007. River management practices have focussed on passive rehabilitation; fencing, stock exclusion or restriction, revegetation and weed suppression. The Macdonald River below the Macdonald gorge continues to transport very large volumes of mobilized sand slugs. The intrusion of multiple sand slugs continues to the tidal limit that has moved downstream several kilometers due to bed aggradation (Rustomji 2008). Channel forms remain simplified, dominated by sand plumes in the low flow channel. However, bench rebuilding is occurring along section of the river above the tidal limit where undisturbed ground cover remains intact, and the low-flow channel is becoming better defined with formation of pools (Mould and Fryirs 2018). Active threats include migration of sand slugs into recovering sections of the river and flood disruption of fencing, revegetation and rehabilitation works before consolidation of recovered features occurs.

The most significant difference between the two rivers lies in the differences in tributary/trunk sediment regimes. Wollombi Brook will likely experience ongoing intrusion of sediment slugs sourced from tributaries that continue to smother channel features for some distance below the junction with the main channel. Hunter Central Rivers is targetting tributaries for further rehabilitation (Weingott, pers comm.). The Macdonald River feature numerous relatively intact trapped tributaries compared to accumulated sand slugs from the outlet of the Macdonald gorge.

Most current river management actions in the lower half of the Macdonald River focus on fencing out livestock, replanting and weed control rather than on bed stabilisation. The Macdonald River requires a prioritisation scheme to guide actions to arrest mobilized sand slugs and rebuild trapped sand into in-channel benches.

Prioritising the most beneficial and cost-effective techniques should be a major focus for agencies responsible for river management. Sediment management, including arresting and trapping mobilized sediment slugs, remains the highest single priority in both catchments. A range of techniques are available to minimise sediment source release and trap sediment to rebuild geomorphic units such as benches (Erskine et al. 2010, Sims and Rutherfurd 2017). These may be suitable for slug affected rivers such as the Macdonald River and Wollombi Brook. Trial installation of large woody debris structures designed to trap mobilised sand waves and scour downstream sand to form and deepen pools (Hughes et al. 2014) should be considered as an effective means to stabilise mobile sand and enhance sand trapping in both catchments. Continued fencing, revegetation and monitoring of sand trapping and bench rebuilding should be a focus for reaches affected by historic channel expansion and sand slug migration. Other techniques applied to rivers in Victoria and elsewhere in New South Wales should be evaluated for use in both catchments.

Conclusions

All rivers across New South Wales require assessments for erosion hazard, threats to channel geomorphic condition and cost-effective options for river rehabilitation. Comparisons between similar river types in different condition classes will yield valuable insights to probable recovery trajectories, necessary timeframes to reach a recovered state (Brierley and Fryirs 2008, Brierley et al. 2013, Bartley and Rutherfurd 2004) and guide necessary funding priorities to remediate impacted rivers. The Wollombi and Macdonald case study demonstrates how rivers with similar geomorphic characteristics, but different histories, produce varying possibilities for river recovery. The case demonstrates the importance of understanding the drivers of change, be they physical or human, so that rehabilitation efforts can be targeted to the type of river, its threats and its existing recovery processes (if present). Using scientific information like that contained in the River Styles database, along with an understanding of history, can provide a sound basis for sustainable river management.

Acknowledgments

Jenny Weingott and Gavin Farley provided records of structural works and rehabilitation projects in Wollombi Brook funded by Hunter Central Rivers Local Land Services. Rory Williams provided thoughtful comments on the initial manuscript. The NSW River Styles project is funded by the NSW government and the state-wide database was developed in partnership between NSW Department of Planning, Industry and Environment – Water Division, NSW Department of Regional Services and Macquarie University.

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