Channel adjustment in the Wadbilliga River following fires and floods, Tuross Catchment, NSW

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Key points

- Coupled fire-flood events drove rapid channel adjustment and expansion in the Wadbilliga River.
- Loss of riparian vegetation and increased sediment supply increased runoff, discharge, stream power and erosion potential.
- Channel widening and localised anabranching occurred and some floodplain surfaces were stripped.
- Geomorphic processes leading to post-fire channel instability have significant implications for hazard assessment and river management.

Abstract

Bushfires are landscape-scale disturbances that trigger secondary hydrological, geomorphological and biogeochemical responses, particularly when followed by major rainfall and flood events. Widespread hillslope erosion and debris flows are known to occur after fires and floods, causing water quality issues downstream, but the geomorphic responses of rivers to flood pulses and elevated sediment supply following fires are relatively poorly understood. The Wadbilliga River and its catchment, a major tributary of the Tuross River on the south coast of New South Wales (NSW), were severely burned in the Badja fire during the 'Black Summer' of 2019/20. Analysis of satellite imagery and UAV-derived digital elevation models, combined with field surveys and sampling, allowed investigation of the dramatic response of the Wadbilliga River to the bushfire and subsequent flooding from 2020-2022. Significant erosion and channel expansion occurred and in several reaches the previously single-thread river developed an anabranching or wandering gravel bed planform where sections of the floodplain were stripped and reworked. These changes are associated with increased runoff and sediment supply from hillslopes and upstream, elevated stream power, and reduced hydraulic roughness following riparian vegetation loss. The findings highlight the sensitivity of bed and bank stability in post-fire environments and demonstrate how coupled disturbances can rapidly alter channel morphology and connectivity. Improved understanding of these processes is important for hazard assessment, post-fire recovery planning, and river and wetland management in fire-prone landscapes.

Keywords

Avulsion, channel expansion, geomorphology, stream power, river management

Introduction

Bushfires and floods are common disturbances in Australian catchments that have widespread effects on catchment and ecosystem processes. Removal of vegetation, changes to soil structure and reduced infiltration capacity can lead to increased runoff and erosion during subsequent rainfall events. Where high-intensity rainfall follows fire, these changes can generate large sediment pulses and elevated discharge, with impacts that extend from hillslopes to river channels and downstream receiving environments.

This was the case during the 'Black Summer' bushfires of 2019/20, when ~55,000 km^2 of land and ~23,300 km of stream length burned in the coastal catchments of New South Wales (NSW), approximately 30 % of these catchments (Fryirs et al., 2022). The fires were followed by heavy rainfall events and major floods in 2020, 2021 and 2022, triggering hillslope erosion and marked declines in river and estuarine water quality (NSW DCCEEW, 2024). These impacts were part of a cascade of hazards with compounding impacts on the NSW coast, as drought conditions paved the way for severe and widespread bushfires, and bushfires cleared vegetation and exposed soils for the rainfall, runoff and floods (Kemter et al., 2021).

Much of the existing work on post-fire geomorphic response has focused on hillslope processes, including rilling, gullying and debris flows (McGuire et al., 2024). These processes are important sources of sediment and can affect geomorphology, water quality and aquatic ecosystems downstream (Lybeck et al., 2024). However, the response of river channels to post-fire conditions, particularly where large flood events occur soon after burning, is less well documented. Rivers integrate catchment-scale changes in water and sediment supply, thereby potentially providing an important record of disturbance response. In some cases, increased discharge and sediment supply may lead to channel aggradation, while in others, elevated stream power and reduced bank resistance may promote erosion and channel expansion.

This study examines channel response in the Wadbilliga River following the 2019/20 'Black Summer' bushfires and subsequent flooding from 2020 to 2022. The Wadbilliga River provides an opportunity to assess channel adjustment in a largely forested coastal catchment that experienced extensive burning followed by high-magnitude flow events. We investigate patterns of channel planform change and expansion and identify the processes driving these adjustments using a combination of remote sensing, elevation data analysis, and field observations. We discuss the importance of understanding the impacts of coupled fire-flood events in the context of post-fire river recovery and management.

Study area and methods

Catchment setting and sites

The Wadbilliga River is a major tributary of the Tuross River on the south coast of NSW (Figure 1). The catchment is characterised by steep, forested terrain in its upper reaches, transitioning to lower gradient valleys downstream. The river flows through a mix of confined and partly-confined valley settings, with sections of alluvial floodplain interspersed with bedrock-controlled reaches. Mean annual rainfall across the catchment is ~931 mm, generally evenly distributed throughout the year, and sandstone is the dominant lithology (DPI, 2016). Vegetation across the catchment is dominated by native forest, with dense riparian vegetation along much of the river corridor.

The Wadbilliga and broader Tuross catchments were extensively impacted by the Badja fire during the 2019/20 bushfires, which burned approximately 315,500 ha between December 2019 and March 2020. Large areas of both catchments experienced severe to extreme fire severity, including widespread canopy removal and burning of riparian vegetation. Following the fires, several major rainfall and flood events in the period 2020-2022 generated extensive debris flow activity on hillslopes, sediment supply to channels, and sediment transport and erosion with significant water quality impacts in the river and estuary (NSW DCCEEW, 2024). These coupled fire-flood disturbances provide an important context for examining geomorphic response and channel adjustment within the Wadbilliga River. The study reach and focus sites are located on the middle Wadbilliga River in a partly-confined valley setting where the channel has low-moderate sinuosity, with discontinuous floodplain pockets set between bedrock valley margins (Figure 1).

Desktop and field methods

Satellite imagery was sourced from Google Earth and used to assess channel morphology. Pre-fire imagery from 2011 provided a baseline for channel planform and width, while post-fire imagery from

2021 and 2023 were used to identify areas of planform change, channel expansion, bank erosion and floodplain disturbance. Hydrology data was sourced from NSW Water Insights (WaterNSW, 2026).

Two unmanned aerial vehicle (UAV) photogrammetry surveys were undertaken at highly impacted focus sites on the Wadbilliga River in May 2023. The photos were processed using ODX version 3.7.3 and Pix4D version 4.10.1. An orthomosaic of the site photos were compiled in addition to developing a dense point cloud and digital terrain model (DTM) of the channel for each of the surveys. Cross-sections extracted from the high-resolution DTMs were used to support interpretations of channel morphology and geomorphic processes.

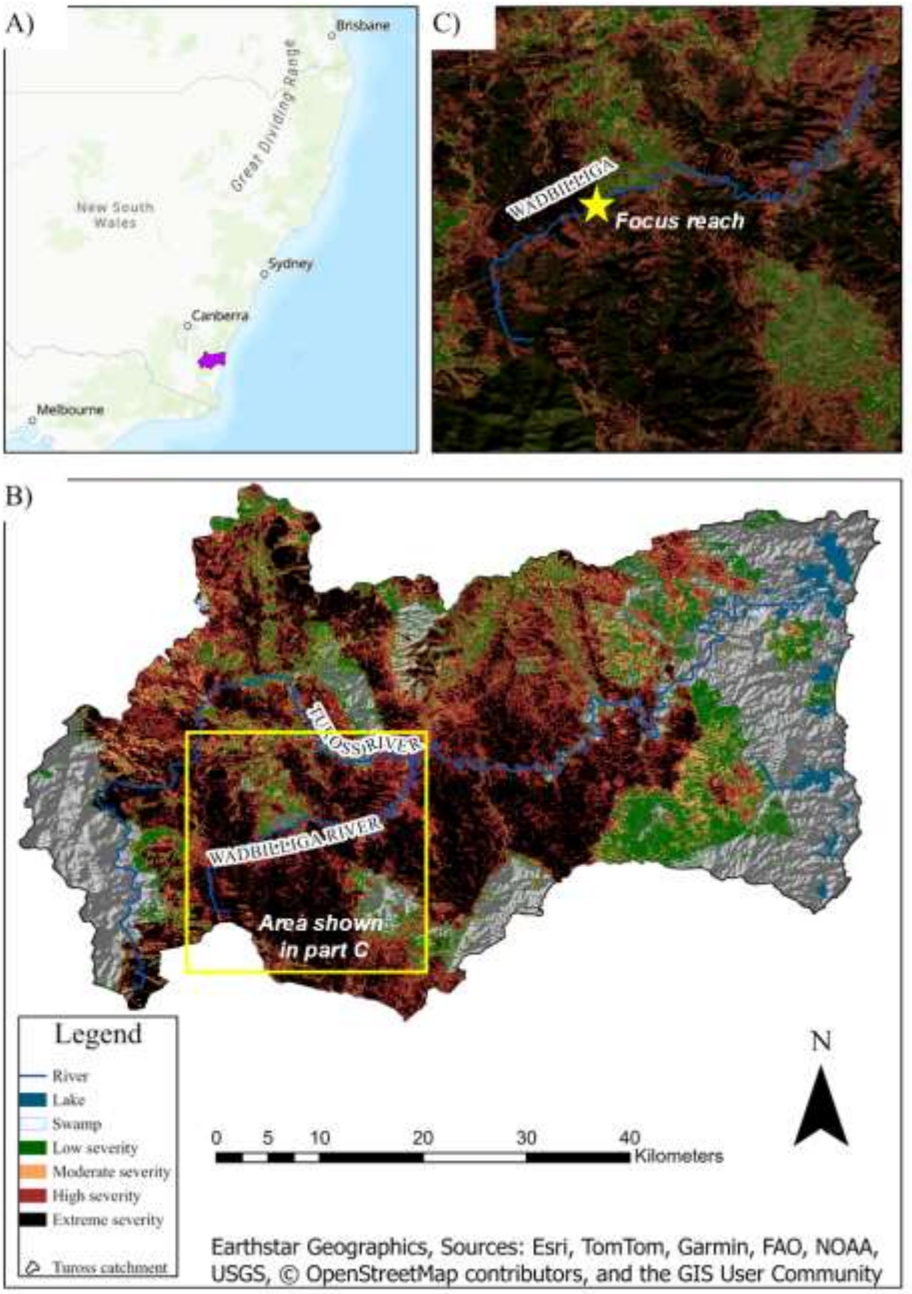

Figure 1 Map of the Tuross catchment and the fire extent and severity model (FESM) for the 2019/2020 Black Summer bushfires. A) Location of the Tuross catchment in relation to NSW. B) The Tuross catchment, Tuross River and major tributaries overlain with 2019/2020 FESM. C) Focus reach and sites. Data sources: FESM from SEED (https://www.seed.nsw.gov.au/, last accessed 13/5/2026) and surface hydrology from Geoscience Australia (https://www.ga.gov.au/, last accessed 13/5/2026)

Field assessments were undertaken at selected sites to ground-truth observations from remote sensing and DTM analysis. This included observations of geomorphic units, channel width, bank condition, evidence of erosion processes (e.g. undercutting, bank collapse), substrate type and debris. Aspects of floodplain condition, including stripping of surface sediments and vegetation, were also recorded.

Results and discussion

River conditions and planform adjustment

Prior to the 2019/20 bushfires, vegetation in the Wadbilliga catchment and throughout the riparian corridor was very dense, providing significant roughness at the channel margins and on the floodplain, with roots armouring the banks in places. Following the fires, tracts of vegetation were removed from the hillslopes and the riparian zone, leading to exposed soils and sediments when the drought broke via a series of short but intense rainfall and runoff events in the first half of 2020 (Figures 2 and 3). There was a significant period of river adjustment between March 2020 and December 2022 when changes in channel planform, arrangement and size occurred.

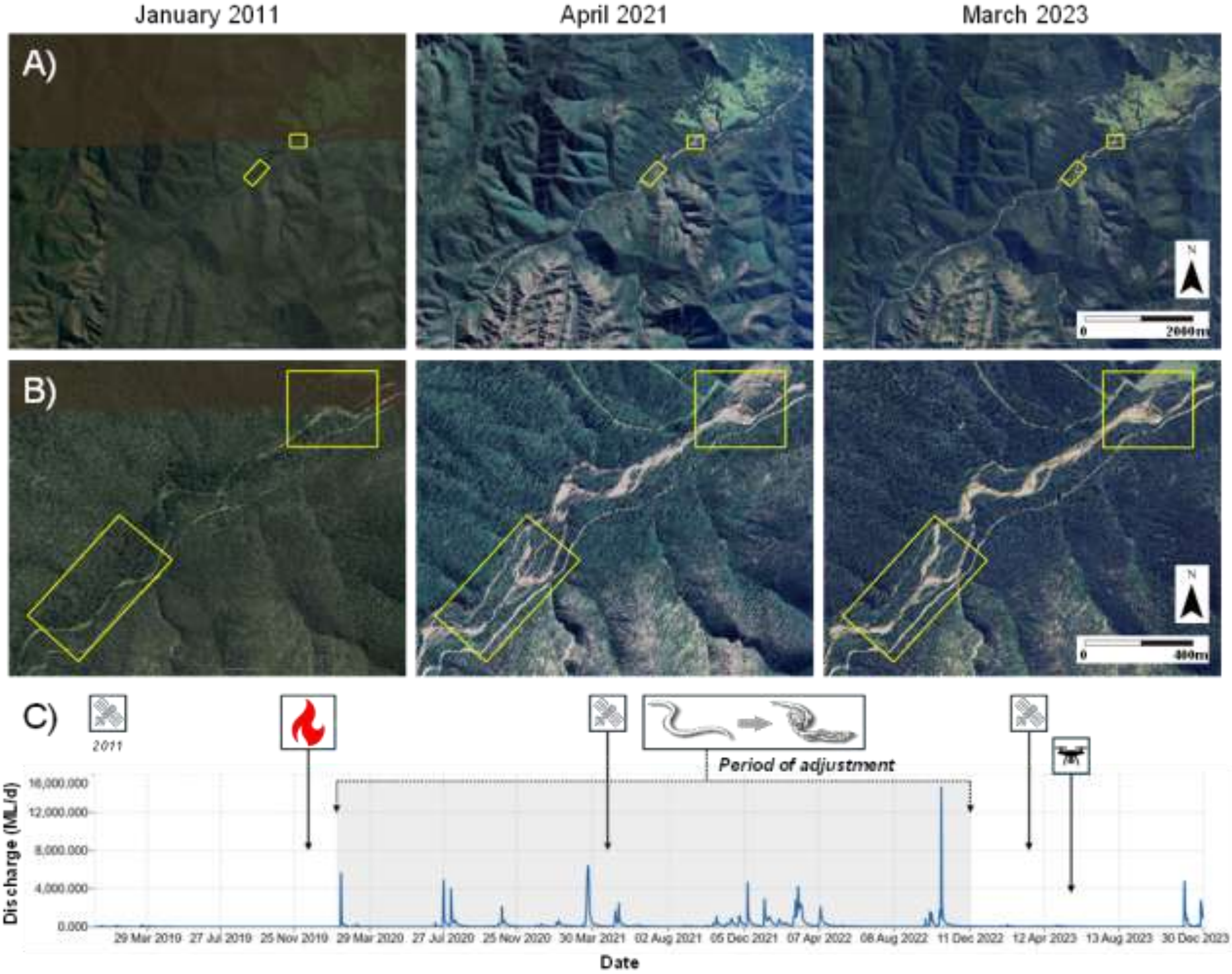

Figure 2 Satellite imagery showing the Wadbilliga River before (2011) and after (2021, 2023) the 2019-20 Black Summer bushfires and subsequent floods. A) The middle reach of the river. B) The two focus sites within the middle reach. C) Discharge record for the Wadbilliga River at Wadbilliga (gauge 218007) showing the dry period leading up to the bushfires (red flame), and the subsequent floods and period of channel adjustment from 2020 to 2022. The timing of satellite image acquisition (from part A) and UAV surveys are also shown. Imagery from Google Earth, and flow data from NSW WaterInsights (https://waterinsights.waternsw.com.au, last accessed 13/5/2026)

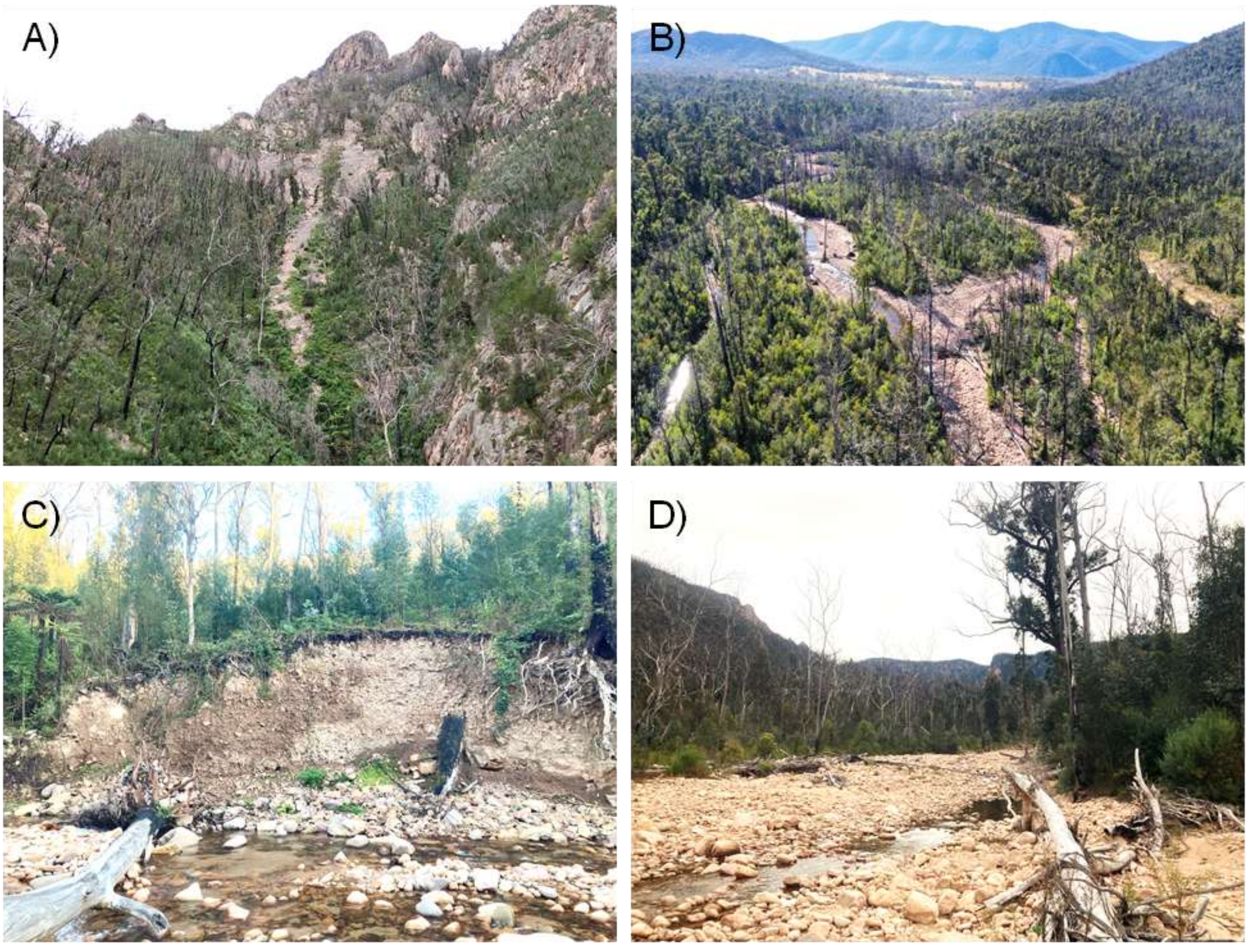

Figure 3 Site photographs from the Wadbilliga River and catchment. A) Burned hillslope with bare rock and debris flows. B) Middle reach of the Wadbilliga River with burned riparian corridor and disturbed channel. C) Severe bank erosion and exposure of cobble and boulder bed in the middle reach of the river. D) Cobble and gravel bars and large woody debris in the expanded channel

Satellite imagery and field observations indicate that significant post-fire channel adjustment via avulsion and expansion occurred in 2020 and 2021 along sections of the Wadbilliga River (Figures 2 and 3). Planform adjustment occurred where previously single-thread channels developed multiple flow paths, with new channels forming across adjacent floodplain surfaces. These sections of river exhibited characteristics of anabranching and/or braiding, with flow divided around islands and/or bars and through several channels during high flow conditions. At our two focus sites, channel bed sediment ranged from small boulders to gravel and sand, and most of the larger material was sitting on or near bedrock; our interpretation is that this boulder and cobble lag from a previous high energy flow regime has been liberated from the base of the floodplain.

Planet imagery also provides a useful insights into the channel adjustments experienced by the Wadbilliga River during the years following the fires and floods, and a visual summary of these images is available online (see Larkin, 2023; https://www.planet.com/stories/wadbilliga-r-pre-and-post-2019-20-bushfires-m1ko2faVg).

Channel enlargement and floodplain stripping

In addition to channel planform changes, channel widening was also evident in both confined and partly-confined reaches, where banks composed of unconsolidated sediments were susceptible to erosion. In these areas, channel width increased substantially compared to pre-fire conditions, with erosion occurring along one or both banks (Figure 4). In more confined, bedrock-controlled sections, channel expansion was less pronounced, although localised bank erosion was still observed and occasionally bedrock was exposed at the bed. This suggests that valley confinement and substrate play an important role in controlling the extent of channel adjustment and expansion.

Field observations and DTM analysis indicate that some of these morphological changes were associated with bank erosion, while others were due to stripping of floodplain sediments and vegetation (Figure 4). In some locations, floodplain surfaces were eroded to form new flow paths, effectively incorporating previously inactive areas into the active channel network. This resulted in floodplain pockets being reduced to slightly higher elevations than the pre-existing (and now further scoured) channel bed, meaning that in future only relatively small changes in water level or flow direction will activate the new channels. At both the Wadbilliga upper and lower sites, bank erosion and bed lowering of the single-thread channel greatly increased channel capacity, as did the formation of new avulsion channels (Figure 4). The width of the single channel at the upper site ranged from ~6 to ~39 m, while at the lower site it ranged from ~79 to ~89 m (Table 1 and Figure 5). In contrast, where the branching occurred, including some areas of floodplain stripping, channel width dramatically increased to ~141 m and ~122 m at the upper and lower sites, respectively. In places, channel depths exceeded ~5 m.

Overall, channel adjustment due to avulsion, expansion and floodplain stripping were not uniform along the river, but occurred in discrete reaches associated with local changes in valley setting, sediment storage/supply, or flow/energy concentration. These patterns indicate that while catchment-scale disturbances set the overall conditions for fluvial adjustment and change, local controls determine where and how that change is expressed.

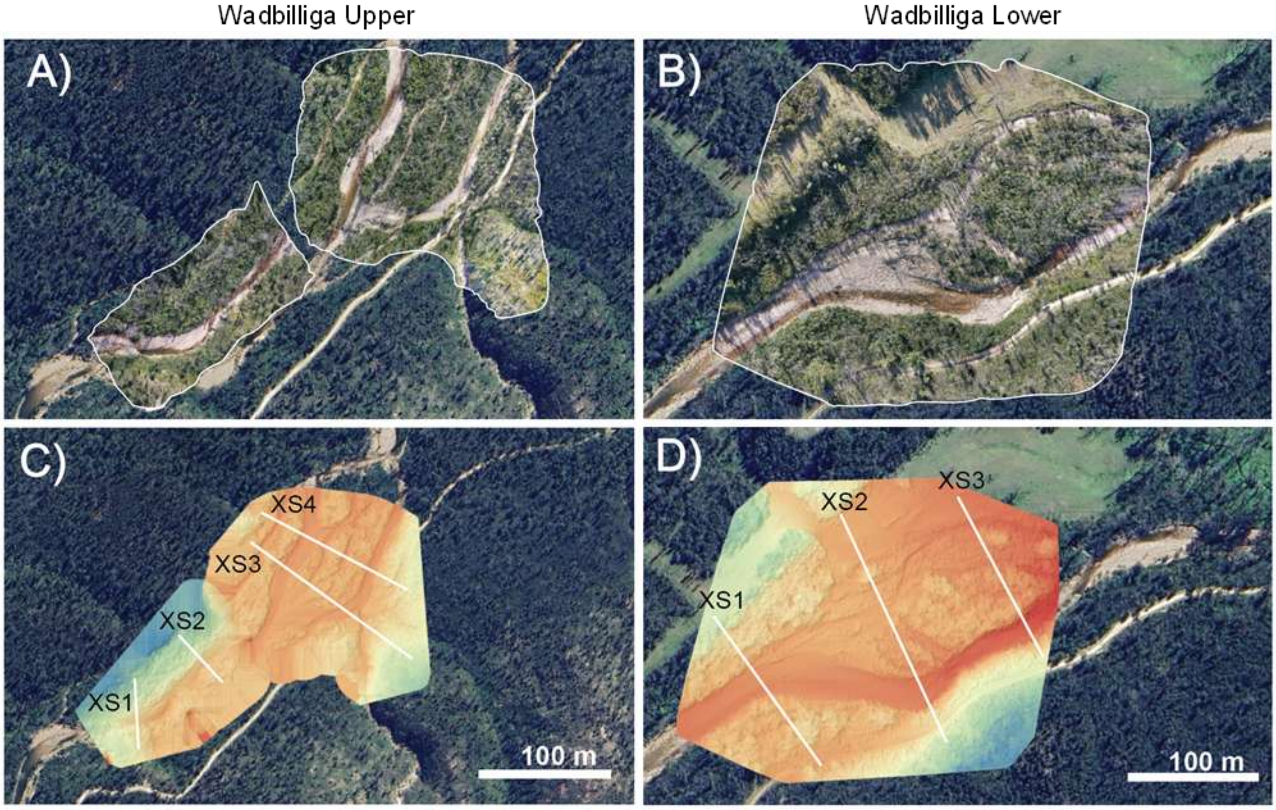

Figure 4 A) and B) UAV-derived orthophotos for the upper and lower Wadbilliga focus sites in 2023. C) and D) UAV-derived DTMs for the focus sites in 2023, with cross sections

Table 1 Estimates of channel metrics from the UAV-derived DTMs at the focus sites

Reach	Cross Section ID	Channel Area (m^2)	Channel Width (m)	Channel Depth (m)	Channel Width:Depth
Wadbilliga Upper	XS1	68.13	38.87	1.75	22.17
	XS2	85.52	29.99	2.85	10.52
	XS3	40.84	6.19	6.60	0.94
	XS4	348.27	141.00	2.47	57.08
Wadbilliga Lower	XS1	89.16	29.41	3.03	9.70
	XS2	639.15	122.25	5.23	23.38
	XS3	79.03	33.30	2.37	14.03

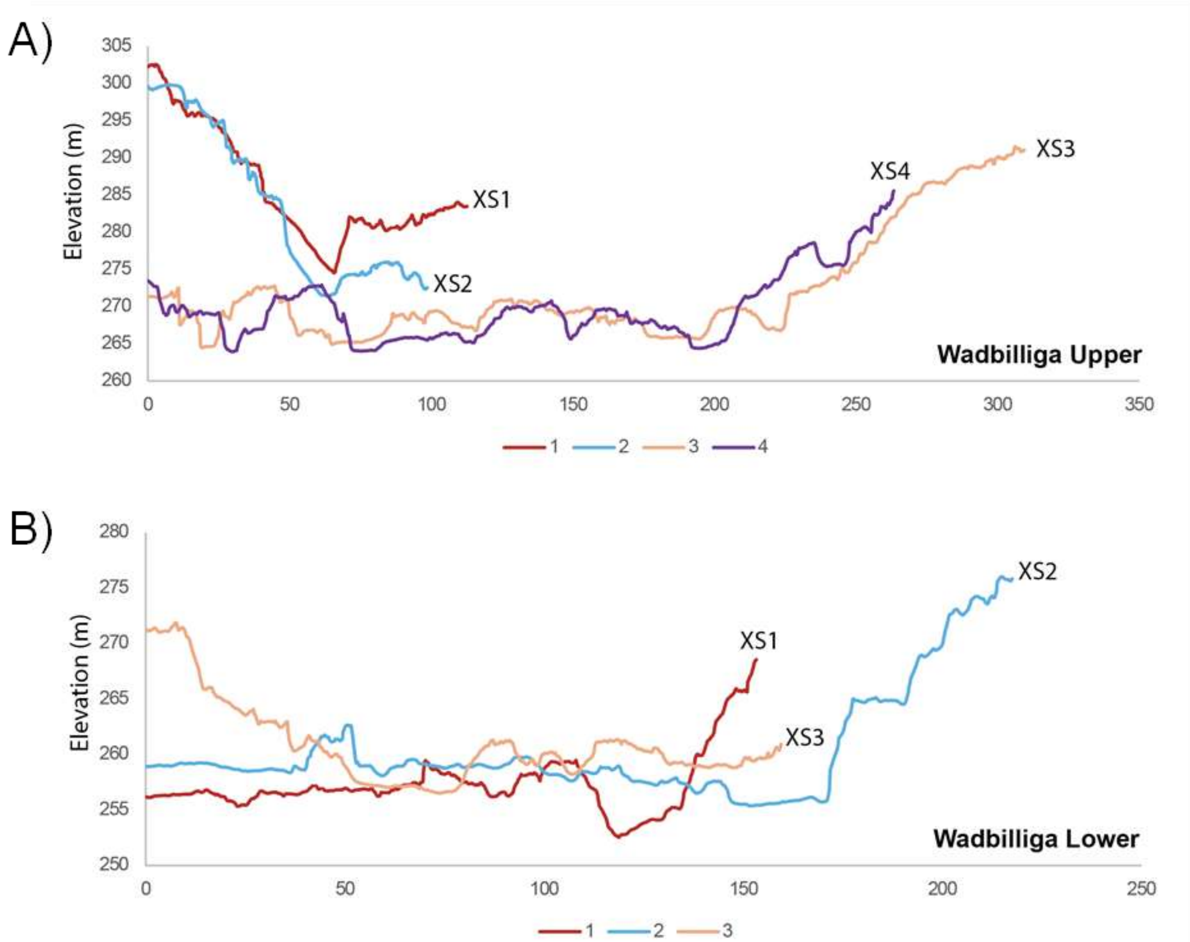

Figure 5 Channel cross-sections extracted from the UAV-derived DTMs. A) Wadbilliga upper site. B) Wadbilliga lower site

Interaction of geomorphic processes

The observed channel changes can be explained by the interaction of several processes associated with the fire-flood sequence. Following the fires, loss of vegetation across the catchment would reduce interception and increase runoff, contributing to higher peak discharge during rainfall events. At the same time, burning of riparian vegetation would reduce hydraulic roughness and bank strength, making the channels more vulnerable to erosion at their margins and within the bed. Increased sediment supply from hillslopes, including fine and coarse material mobilised during rainfall events, would have contributed to changes in channel bed conditions and sediment transport dynamics. In some cases, this may have led to temporary aggradation, while in others it may have increased abrasion and erosion of channel boundaries. Under these conditions, flows with higher stream power would persist and thresholds for bank stability would be exceeded in the Wadbilliga River, resulting in rapid channel widening and, in some cases, the initiation of new flow paths across the floodplain.

The development of an anabranching planform reflects this combination of high flow energy and reduced resistance due to vegetation loss. Once established, these new channels may persist or evolve depending on subsequent flow conditions and sediment dynamics. Currently, they are reminiscent of wandering gravel-bed rivers usually found in steeper, wetter environments with excess sediment supply, such as the South Island of New Zealand (e.g. Williams, 2017) and the United Kingdom (e.g. Fuller et al., 2003). Further work is required to assess whether the sedimentary structures revealed by bank erosion, channel adjustment and floodplain stripping in the Wadbilliga River provide evidence for bar-growth sequences dominated by lateral accretion as in other wandering gravel-bed rivers (see Rice et al., 2009). Or perhaps the Wadbilliga River has a greater mix of vertical and lateral accretion as in mixed alluvial and bedrock-controlled anabranching rivers (see Tooth and McCarthy, 2004). Judging by the pre-fire state of the river, it is fair to say that a braided form dominated by vertical accretion is probably not the norm for this river.

Sediment observations indicate that material from hillslopes was effectively transferred to the channel network following the fires. The presence of poorly sorted sediments and coarse material in the channel suggests high-energy transport conditions during flood events. Increased connectivity between hillslopes and channels following vegetation loss likely facilitated this transfer, raising important questions about dominant post-fire sediment sources and whether connectivity assessment and management of 'switches' should be considered in the context of post-fire river recovery (see Fryirs et al., 2025). These interactions highlight the importance of considering both water and sediment fluxes when assessing post-fire channel response. Changes in one component can influence the behaviour of the other, leading to complex and spatially variable outcomes. It is also important to recognise that other gravel-bed rivers did not exhibit significant geomorphic responses to the 2019/20 fires and floods (Lybeck et al., 2024).

Relevance to management

The channel changes observed in the Wadbilliga River have implications for river management in fire-prone catchments. Rapid channel expansion and planform adjustment can affect infrastructure, land use and ecological values. Increased erosion may lead to sediment delivery downstream, affecting water quality and aquatic habitats. The NSW Bushfire Inquiry (Owens and Kane, 2020) recognised the need for better long-term ecosystem and land management research, including interactions between fire and hydrological change, but it did not substantially address how burnt catchments respond geomorphically when large rainfall and flood events follow soon after fire. Following from our study, identification of reaches that are susceptible to post-fire channel change will be important for risk assessment and prioritisation of management actions. Factors such as valley setting, substrate and floodplain characteristics can be used to identify areas where channel expansion and/or avulsion are more likely to occur. Monitoring channel conditions following fire events is also important, for example, repeated surveys to help track changes over time and assess whether channels stabilise or continue to adjust. In some cases, intervention may be required to manage erosion or protect key assets, although such actions should be considered carefully in the context of natural recovery processes.

Conclusion

Channel adjustment by avulsion and expansion occurred along sections of the Wadbilliga River following the 2019/20 fires and subsequent flood events from 2020 to 2022. Widening was driven by bank erosion, with the greatest changes occurring in the less-confined alluvial reaches. In some locations, floodplain stripping led to the development of multiple flow paths and localised anabranching and/or braided planforms. The findings highlight the sensitivity of river bed and bank stability in post-fire environments and demonstrate how coupled disturbances can rapidly alter channel morphology and connectivity. Improved understanding of these processes is important for hazard assessment, post-fire recovery planning, and river and wetland management in fire-prone landscapes.

Acknowledgements

The authors acknowledge the Brinja-Yuin people of the Yuin Nation, the Traditional Custodians of the lands and waters of the Tuross River catchment where field data collection took place, and the Wallamattagal people of the Dharug Nation, the Traditional Custodians of the unceded land where Macquarie University stands and where this research paper was prepared. We pay our respects to their Elders past and present, and extend this respect to all First Nations people. We recognise their deep, continuous history and their enduring scientific and ecological knowledge systems of these environments. We thank NPWS for facilitating access to the field sites. Macquarie University undergraduate students provided field assistance, and C.H. received a PhD scholarship from Macquarie University and project top-up funding from DCCEEW. We also thank Lukman Soboyejo for insights and suggestions during the peer-review phase.

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