Resilience-based triage for post-disaster recovery: The Cyclone Jasper case study

Lyndsay Charlton[1], Misko Ivezich[2], Ian D. Rutherfurd[3], Isabelle Flook[2] and Kirstie Fryirs[4]

1 Alluvium, Brisbane, QLD, 4006. Email: lyndsay.charlton@alluvium.com

2 Alluvium, Byron Bay, NSW, 2481

3 Alluvium, Melbourne, VIC, 3002

4 School of Natural Sciences, Macquarie University, Wallumattagal campus, North Ryde, NSW, 2109

Key points

- Contemporary river management recognises that rivers can be both values to be protected and sources of threat, requiring prioritisation approaches that balance conservation and risk reduction.
- However, flood recovery and river rehabilitation investment is often dominated by reactive responses to visible erosion, infrastructure risk, and downstream impacts.
- The river resilience framework provides a resilience-based triage approach that integrates recovery potential, connectivity, geomorphic threats, and ecosystem service outcomes into investment decisions.
- The Tropical Cyclone Jasper riverine recovery project demonstrates how this framework can be applied to direct disaster recovery funding towards strategic, long-term catchment resilience rather than isolated erosion repair.

Abstract

Triage approaches in river management prioritise investment and effort in these complex physical and social systems. Such triage is increasingly required as climate change intensifies flood disturbance, geomorphic instability, and pressure on riverine ecosystems across Australia, requiring more investment decisions. This paper examines the practical realities of river management triage through recent Australian rehabilitation and flood recovery programs. Modern triage approaches emphasise values. Streams represent 'intrinsic' biodiversity and conservation values, as well as a bundle of human values, which are often represented as ecosystem services. Streams can also threaten many values, usually by erosion, deposition, or poor water quality. While the broadly-based conservation-based approach is widely accepted in theory, contemporary investment patterns often revert to narrowly defined and reactive post-disaster responses that focus on visible erosion threats.

This paper describes the application of an integrated, resilience-based triage in the Tropical Cyclone Jasper Disaster Recovery Funding Arrangements (DRFA) riverine recovery project across 12 Far North Queensland catchments. The project applied a spatially explicit prioritisation framework integrating river condition, recovery potential, geomorphic threats, connectivity, and ecosystem services to strategically target rehabilitation investment. This paper argues that increasing climatic disturbance will require river management approaches that move beyond reactive erosion repair toward integrated resilience-based triage frameworks capable of addressing the multiple, connected values and threats operating across catchments. The Jasper project illustrates how resilience frameworks can be translated into transparent, repeatable investment decisions at catchment scale using disaster recovery funding.

Keywords

River resilience, disaster recovery, prioritisation, triage, river management

Introduction

River management triage emerged from conservation biology as a way of prioritising limited environmental management resources across degraded systems and competing objectives (Bottrill et al., 2008; Wilson et al., 2007). Within river management, triage is increasingly used to determine where rehabilitation, protection, or intervention should occur across catchments experiencing widespread degradation, erosion, and increasing climatic disturbance.

Contemporary approaches emphasise values. Priority is given to protecting streams (reaches, corridors or catchments) in good-condition and with high recovery-potential (Rutherfurd et al., 2000; Brierley and Fryirs, 2005; Agnew and Fryirs, 2022). This underpins process-based approaches such as the River Styles Framework and corridors of river recovery, which emphasise working with river recovery processes and protecting connected resilient corridors (Fryirs et al., 2018). Priority is also given to reaches of river that threaten other values, including infrastructure, agricultural land, downstream ecosystems, or communities (DCCEEW, 2024; Queensland Government, 2024). Under this approach, investment is commonly directed toward actively unstable or highly eroding reaches that threaten assets or values. Hence rivers can be both valued themselves, as well as threats.

These approaches were combined in the river resilience framework initially developed through the Southeast Queensland Strategic River Resilience Works program (Alluvium, 2025a), which draws on River Styles, Corridors of River Recovery and recent resilience theory (Agnew & Fryirs, 2022; Wohl et al., 2024; Curtis & Lefroy, 2010) to integrate river condition, geomorphic threats, ecosystem services, recovery potential, and long-term adaptive capacity within a single prioritisation framework (Alluvium, 2025a; Wohl et al., 2024). In this paper we describe some recent examples of triage in river investment programs, then describe the triage approach developed for this program, and describe how it was applied.

Recent Australian triage experience

Dominant investment patterns

Although conservation-based triage principles are well established within river rehabilitation literature, recent Australian river management investment has been dominated by erosion risk, infrastructure protection, and downstream impacts. Across many contemporary programs, prioritisation is strongly influenced by visible geomorphic instability, recent flood damage, sediment generation, and threats to external assets or ecosystem services. Disaster recovery funding has reinforced this pattern because major river rehabilitation investment increasingly occurs through post-flood recovery mechanisms. As a result, investment is often reactive, targeting sites exhibiting recent geomorphic adjustment or posing immediate risks to infrastructure, agricultural land, or communities (QRA, 2024; NSW Local Land Services, 2024).

Examples from major Australian programs

The Australian Government's Reef Trust and associated Great Barrier Reef programs provide a clear example of threat-based triage. These programs prioritise streambank erosion, gully erosion, and sediment delivery because fine sediment is recognised as a major threat to reef ecosystems (DCCEEW, 2024; Reef Water Quality Scientific Consensus Statement, 2022). Prioritisation therefore focuses on sediment-producing reaches rather than intrinsically high-condition river systems.

Similarly, the NSW Targeted Riverbank Rehabilitation Project following the 2021–2022 floods largely targeted erosion hotspots, focusing on stabilisation of actively eroding banks and protection of adjacent infrastructure and land (NSW Local Land Services, 2024). As with many flood recovery programs, prioritisation was strongly influenced by visible damage and immediate risk exposure.

On the other hand, programs in Southeast Queensland such as the Resilient Rivers Initiative (RRI) increasingly incorporate resilience-focused concepts such as connectivity, recovery potential, and adaptive capacity (SEQ Mayors, 2025). The RRI frames river management around improving the capacity of waterways to absorb disturbance while continuing to provide ecosystem services.

Implications

Many contemporary Australian river management programs prioritise the threat that rivers pose, targeting the areas that generate the greatest sediment loads, erosion hazards, or downstream threats. While this can reduce immediate threats, prioritisation based solely on visible erosion or recent flood damage may not align with longer-term catchment resilience objectives.

There are also important political and institutional dimensions shaping investment patterns. Schweizer et al. (2022) argue that environmental triage decisions are influenced not only by science, but also by competing social demands, governance systems, institutional constraints, and political pressures. Consequently, visible damage and risks to infrastructure or communities often attract stronger investment responses than proactive protection of intact or recovering river corridors. This creates a structural bias toward reactive investment in many flood recovery programs. While these responses are often necessary, they can reinforce repeated cycles of erosion repair without improving long-term catchment resilience.

Under increasing climatic disturbance, governments will increasingly face difficult decisions regarding which river corridors, ecosystem services, and assets can realistically be protected or restored. This highlights the need for triage frameworks that are transparent, spatially strategic, and capable of integrating ecological values, geomorphic threats, social priorities, and long-term adaptive capacity.

A resilience-based triage approach

Framework overview and structure

Drawing on several published approaches Alluvium (2025a) developed a reach-scale prioritisation framework to improve river resilience through strategic investment in rehabilitation and recovery processes. Developed initially for Southeast Queensland (SEQ) waterways, the framework is broadly applicable to river systems experiencing increasing flood disturbance and climatic variability.

The framework distinguishes between river resilience and river health. A resilient river is defined as one that can “absorb and adapt to pressures and threats that arise from natural or anthropogenic disturbances, enabling it to continue providing ecosystem services and values indicative of good condition” (Alluvium, 2025a; Wohl et al., 2024). Healthy river systems are defined as those capable of providing ecosystem services collectively valued by society, rather than systems restored to pre-European condition (Alluvium, 2025a). Healthy systems are often more resilient to disturbance, although degraded systems can also display resilience where they repeatedly recover to an already degraded state. Rather than focusing solely on erosion repair or isolated asset protection, the framework seeks to maintain the processes and structures that enable river corridors to absorb disturbance, recover naturally, and sustain ecosystem services over time. The approach builds on River Styles and corridors of river recovery concepts that emphasise working with geomorphic recovery processes and strategic catchment connectivity (Agnew and Fryirs, 2022; Alluvium, 2025a).

The framework is structured around three questions: what biophysical characteristics contribute to river resilience; how can these characteristics be maintained or enhanced; and where should management interventions occur? It focuses on the three key characteristics underpinning river resilience: three-dimensional connectivity, spatial heterogeneity, and physical and ecological integrity (Wohl et al., 2024). The effectiveness of management therefore depends not only on the intervention itself, but also on where it is applied within the river network.

Prioritisation logic

The framework’s reach-scale prioritisation approach builds on the principles of the prioritisation protocol outlined in Agnew and Fryirs (2022), which aims to take advantage of natural river recovery and establishing and connecting river corridors through catchments. As with the approach outlined by

Agnew and Fryirs (2022) (and the River Styles Framework more broadly) the resilience framework classifies reaches into three broad categories based on river condition, recovery trajectory, and geomorphic behaviour: protection, recovery and high threat or strategic reaches (Alluvium, 2025a).

Unlike traditional threat-based rehabilitation programs, the framework does not assume that actively unstable reaches should automatically receive highest priority. Instead, prioritisation depends on recovery potential, connectivity, downstream consequences, strategic importance, and long-term resilience benefit, building on the prioritisation principles first proposed by Rutherfurd et al. (1999).

The prioritisation logic is summarised in Figure 1 (Alluvium, 2025a) and shifts river management away from reactive erosion repair toward strategic investment in connected resilient corridors, recovery trajectories, and long-term adaptive capacity under increasing climatic disturbance.

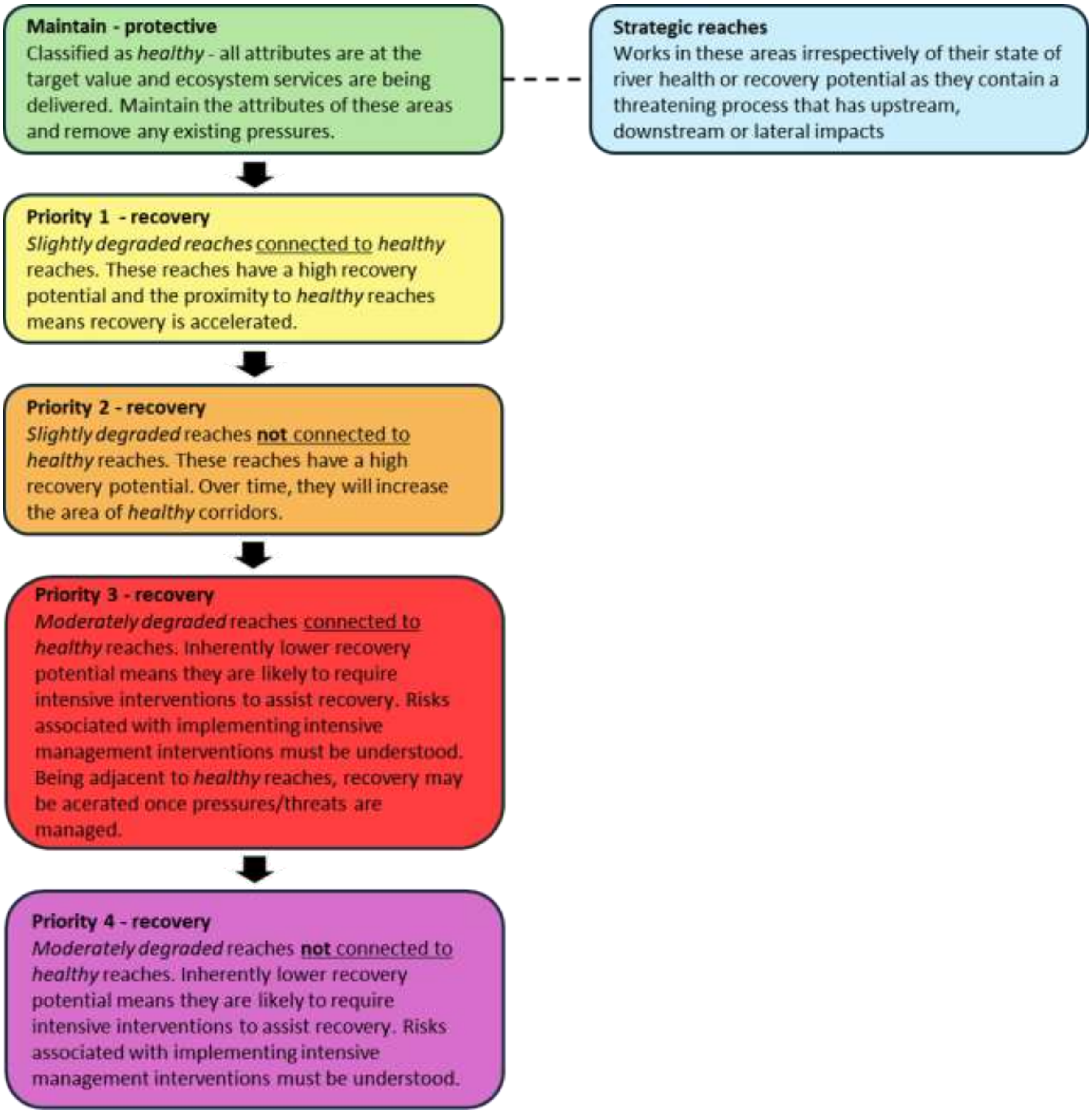

Figure 1 Prioritisation approach for implementing on-ground reach-scale rehabilitation works to increase the resilience of waterways to flooding (Alluvium, 2025a)

Case study: Cyclone Jasper riverine recovery prioritisation

Project context

Tropical Cyclone (TC) Jasper produced extreme rainfall and flooding across Far North Queensland (FNQ) in December 2023, resulting in widespread geomorphic adjustment, landslides, channel erosion, sediment mobilisation, and impacts to agricultural land and riverine ecosystems across 12 catchments (Alluvium, 2025b). As with many recent flood events in Australia, the recovery process created a significant opportunity for large-scale river rehabilitation investment through disaster recovery funding. In response, the Queensland Reconstruction Authority funded a large-scale river recovery program under the Disaster Recovery Funding Arrangements (DRFA) to identify strategic rehabilitation opportunities that would improve the long-term resilience of river systems to future flood events (Alluvium, 2025b).

Rather than adopting the conventional post-disaster approach of repairing individual erosion sites, the project sought to apply the river resilience framework (Alluvium, 2025a) to prioritise investment at the catchment scale. The objective was to direct rehabilitation efforts toward locations where interventions would maximise long-term river resilience, ecosystem service delivery and recovery potential, while reducing future flood risk (Alluvium, 2025b). The project progressed through the following stages (Figure 2).

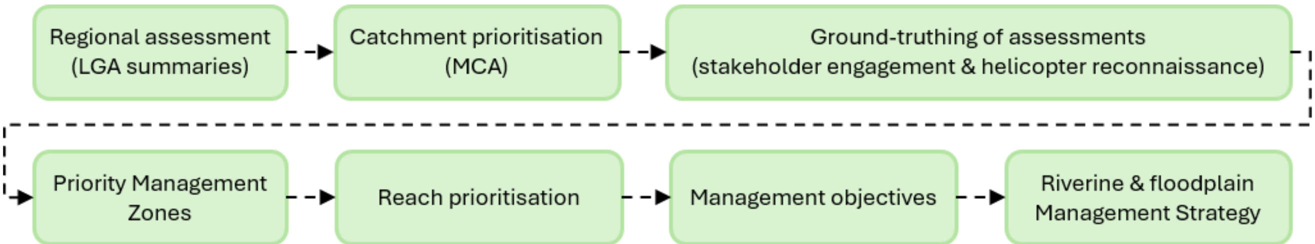

Figure 2 Prioritisation approach for implementing on-ground reach-scale rehabilitation works to increase the resilience of waterways to flooding

Regional screening and catchment-scale prioritisation

The first stage involved development of desktop summaries for each activated Local Government Area (LGA). These summarised regional geomorphic setting, distribution of environmental values, rainfall and streamflow impacts associated with TC Jasper, and the catchments most affected within each region. This regional screening provided a consistent understanding of flood impacts across the study area and identified candidate catchments for more detailed assessment (Alluvium, 2025b).

A catchment-scale multi-criteria assessment (MCA) was then undertaken to prioritise catchments for investment. The MCA comprised three assessment criteria: average catchment rainfall during TC Jasper, peak rainfall intensity during the event, and the degree of hydraulic and ecological connectivity between flood-affected waterways and downstream high-value environmental assets. Each criterion was assigned a score from 1 to 4, with scores summed to produce an overall catchment priority ranking. This provided a transparent, repeatable and evidence-based method for identifying the twelve highest-priority catchments for detailed assessment (Alluvium, 2025b). Importantly, catchments were prioritised not simply according to flood damage, but according to the potential for rehabilitation investment to deliver strategic catchment-scale resilience outcomes.

Priority Management Zones and reach prioritisation

Detailed geomorphic assessments were undertaken within each priority catchment to delineate Priority Management Zones (PMZs). Rather than assessing waterways as isolated erosion sites, PMZs grouped river corridors based on geomorphic behaviour, flood impacts, ecosystem services, cultural values and functions, recovery potential and ongoing threat processes. This enabled rehabilitation priorities to be evaluated within the broader functioning of connected river corridors and catchments rather than as individual damaged locations (Alluvium, 2025b).

Within each PMZ, waterways were further classified into five reach priority classes based on river condition, riparian integrity, geomorphic stability, recovery potential, longitudinal connectivity and strategic importance within the river network. The resulting priorities and typical management responses are summarised in Table 1.

Table 1 Generalised reach priority classes used in the Jasper resilience framework (Alluvium, 2025b)

Reach priority	Typical characteristics	Primary management response
Priority 1	Intact, connected, good-condition corridors.	Protect and maintain existing resilience.
Priority 2	Slightly degraded, connected reaches with high recovery potential.	Expand resilient corridors through revegetation and riparian enhancement.
Priority 3	Slightly degraded or recoverable reaches with moderate connectivity.	Targeted rehabilitation to improve recovery trajectories.
Priority 4	Moderately degraded reaches associated with strategic geomorphic threats.	Targeted intervention where broader resilience benefits are achieved.
Priority 5	Highly degraded, disconnected reaches with low recovery potential.	Intensive rehabilitation only where justified by strategic risk reduction or protection of adjacent high-value corridors.

Reaches in good condition with intact and connected riparian corridors were generally assigned Priority 1 status, with management focused on protection and maintenance (Figure 3). Slightly degraded reaches connected to intact corridors and exhibiting strong recovery potential were typically assigned Priority 2 or 3 status, where interventions such as revegetation, infill planting, weed management, riparian buffer expansion, and targeted stabilisation works could strategically expand resilient corridors and improve connectivity (Alluvium, 2025b).

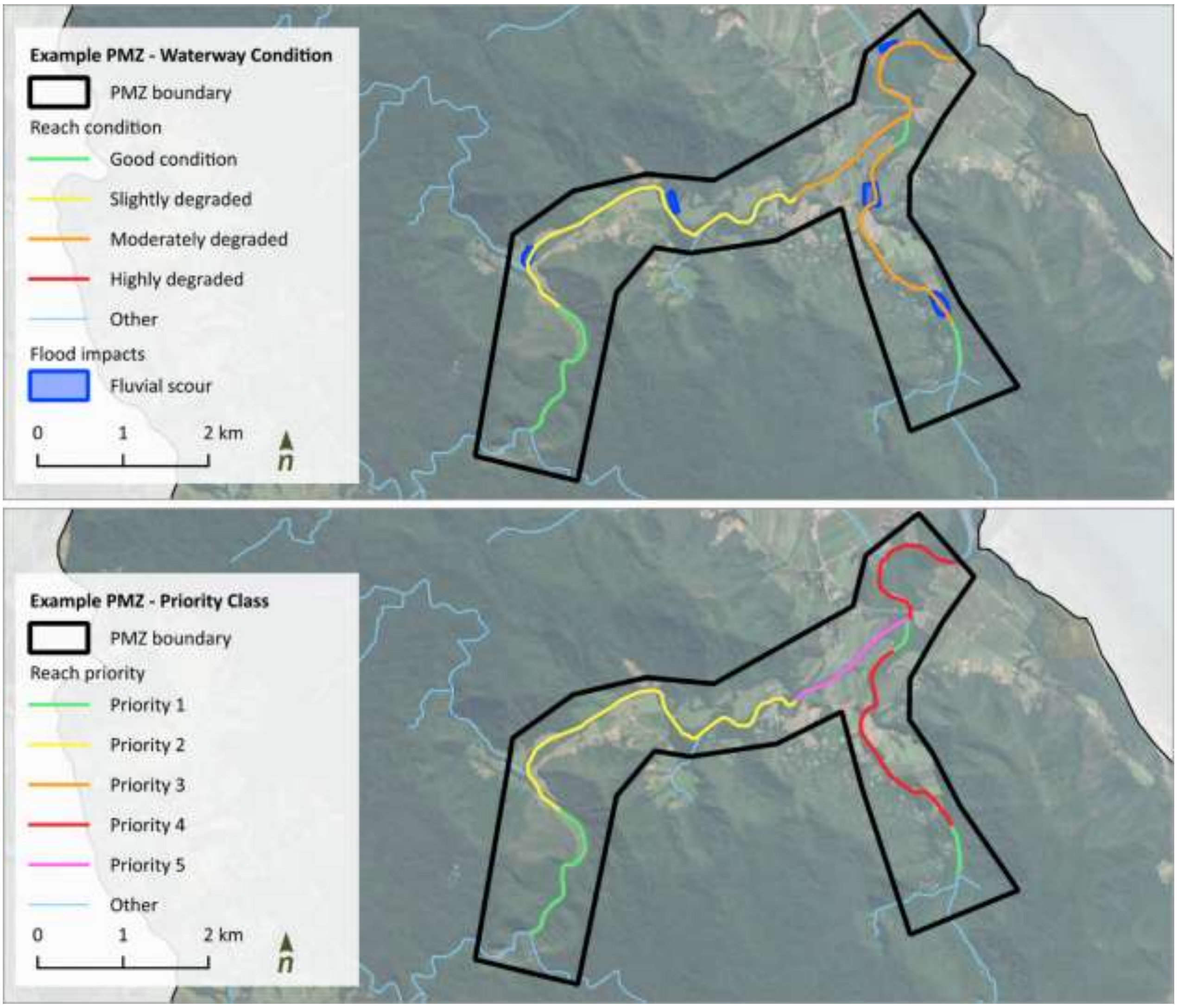

Figure 3 Example reach prioritisation output within an identified PMZ (Alluvium, 2025b)

Unlike traditional flood recovery programs, actively eroding reaches were not automatically assigned the highest rehabilitation priority. Instead, investment decisions reflected recovery potential, connectivity, downstream consequences, strategic corridor function and expected long-term resilience benefits. For example, slightly degraded reaches connected to intact upstream and downstream riparian corridors were frequently assigned Priority 2 because relatively modest interventions (e.g. revegetation, weed management and riparian buffer expansion) could substantially strengthen connected resilient corridors. Conversely, highly degraded reaches exhibiting comparable erosion severity but isolated from resilient river networks were commonly assigned Priority 5 because rehabilitation would require substantially greater investment while delivering comparatively limited catchment-scale resilience benefits (Alluvium, 2025b).

Management and rehabilitation planning

Reach priorities informed the selection of appropriate management actions within each reach, through five broad management objectives that linked resilience characteristics with practical on-ground interventions (Alluvium, 2025b):

- Increase **hydraulic roughness** of the channel to help slow flow velocity through flood conveyance zones.
- Reduce **bed and bank erosion** occurring at rates above natural background rates.

- Reduce **nutrient and sediment loads** entering waterways from adjacent land and encourage nutrient cycling processes for nutrient removal (also achieved by objective 2).
- Improve the physical **aquatic habitat** for native instream biota.
- Improve **riparian habitat** quality and **longitudinal connectivity** through structurally diverse native vegetation communities in riparian corridors.

These objectives were implemented through combinations of riparian revegetation, weed management, stock exclusion, riparian buffer establishment, engineered bank stabilisation, large wood installation and other nature-based rehabilitation measures selected according to local geomorphic processes and management priorities (Alluvium, 2025b). When the five management objectives are achieved, a river corridor is more likely to maintain a self-adjusting regime of processes, functions, and set of feedback mechanisms that sustain and/or improve river ecosystem health and, therefore, allow that corridor to better absorb the impacts of flood events.

Benefits compared to previous flood recovery programs in Australia

The Jasper project differed substantially from many previous flood recovery programs in Australia, which have typically prioritised highly visible erosion damage, infrastructure threats, and emergency stabilisation works following major flood events (QRA, 2024; NSW Local Land Services, 2024). Traditional recovery programs have generally prioritised sites exhibiting active instability or posing threats to assets and infrastructure.

Application of the river resilience framework through the Jasper project demonstrated that resilience-based triage can produce substantially different investment priorities from conventional post-disaster recovery programs. Across the twelve priority catchments, the framework was applied to produce a hierarchy of catchment priorities, PMZs, reach-scale priority classes and site-specific rehabilitation recommendations directly linked to river condition, geomorphic behaviour, recovery potential and ecosystem service outcomes (Alluvium, 2025b). Rather than prioritising sites solely on the basis of recent erosion, interventions were assessed according to their contribution to maintaining or expanding resilient river corridors and supporting long-term adaptive capacity under future flood disturbance. This represented a significant shift from reactive erosion repair toward strategic resilience building.

A key expected benefit of the approach is the potential for more cost-effective investment by directing resources toward reaches where interventions were most likely to generate durable catchment-scale outcomes. Recent optimisation analyses using Marxan demonstrate that prioritising connected corridors of river recovery can deliver substantially greater rehabilitation outcomes per dollar invested than conventional site-based approaches, providing an economic rationale for resilience-based triage alongside its ecological and geomorphic advantages (Agnew et al., 2024). Resilience-based prioritisation can improve rehabilitation benefit: cost ratios, reduce future rehabilitation expenditure, and generate broader ecosystem service benefits across river networks (Agnew et al., 2024). This also reduces the likelihood of repeated investment in highly unstable or disconnected reaches with limited long-term recovery potential.

Conclusions

Climate change is expected to increase the frequency and intensity of major flood events across many Australian catchments, resulting in greater geomorphic disturbance, erosion, sediment mobilisation, infrastructure damage, and pressure on riverine ecosystems (SEQ Mayors, 2025). Under these conditions, an increasing proportion of river rehabilitation and environmental management investment is likely to occur through disaster recovery and resilience funding mechanisms rather than through traditional long-term conservation programs. This has significant implications for how river management priorities are determined and how triage principles are applied.

Historically, disaster recovery funding has predominantly supported reactive threat-based responses focused on repairing visible erosion damage, stabilising actively degrading reaches, and protecting infrastructure and adjacent assets (QRA, 2024; NSW Local Land Services, 2024). While these responses remain important, reactive approaches alone are unlikely to provide sustainable long-term outcomes under increasing climatic disturbance. At the same time, purely conservation-focused triage approaches are unlikely to adequately address the complex interaction between river condition, geomorphic hazards, ecosystem services, infrastructure exposure, and community risk across catchments. Both approaches are required.

The river resilience framework (Alluvium, 2025a) – a resilience-based triage approach – provides a pathway for addressing these challenges by integrating river condition, recovery potential, connectivity, ecosystem services, and geomorphic threat processes within a single prioritisation framework. The framework seeks to direct investment toward locations where intervention can most effectively maintain long-term adaptive capacity and catchment-scale resilience under future disturbance regimes.

The application of the river resilience framework through the TC Jasper riverine recovery project demonstrates how disaster recovery funding can be used not only to target flood damage, but also to strategically enhance long-term river resilience and ecosystem service provision across catchments. This represents a significant shift in river management philosophy from attempting to resist geomorphic adjustment everywhere toward building the adaptive capacity and long-term resilience of river systems through strategic, process-based investment.

Acknowledgements

The authors would like to acknowledge assistance provided through the jointly funded Commonwealth-state Disaster Recovery Funding Arrangements (DRFA).

References

Agnew, D., & Fryirs, K. (2022). Identifying corridors of river recovery in coastal NSW Australia, for use in river management decision support and prioritisation systems. *PLoS ONE* 17(6): e0270285. https://doi.org/10.1371/journal.pone.0270285

Agnew, D., Fryirs, K. & Leishman, M.R. (2024). Cost-benefit analysis of working with recovery in river management using Marxan. *Frontiers in Environmental Science*, 12:1425668. https://doi.org/10.3389/fenvs.2024.1425668

Alluvium. (2025a). *SEQ Strategic River Resilience Works.* Report prepared by Alluvium Consulting Australia for the Council of Mayors SEQ.

Alluvium. (2025b). *DRFA TC Jasper Environmental Investigation Riverine and floodplain management strategy.* Report prepared by Alluvium Consulting Australia for the Department of the Environment, Tourism, Science and Innovation, Queensland.

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C., Game, E. T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., Pressey, R. L., Walker, S., Wilson, K. A., & Possingham, H. P. (2008). Is conservation triage just smart decision making? *Trends in Ecology & Evolution,* 23(12), 649–654. https://doi.org/10.1016/j.tree.2008.07.007

Brierley, G. J. & Fryirs, K. A. (2005). *Geomorphology and river management: Applications of the River Styles Framework*. Blackwell Publishing. https://download.e-bookshelf.de/download/0000/5790/16/L-G-0000579016-0015290102.pdf

Curtis, A. L. & Lefroy, E. C. (2010). Beyond threat-and asset-based approaches to natural resource management in Australia. *Australasian Journal of Environmental Management*, 17(3), 134-141. https://doi.org/10.1080/14486563.2010.9725260

Department of Climate Change, Energy, the Environment and Water (DCCEEW). (2024). *Repairing land to improve reef water quality*. Australian Government. https://www.dcceew.gov.au/about/news/repairing-land-to-improve-reef-water-quality

Department of Climate Change, Energy, the Environment and Water (DCCEEW). (2024). *Reef Trust programs*. Australian Government. https://www.dcceew.gov.au/parks-heritage/great-barrier-reef/protecting/our-investments/reef-trust/programs

Fryirs, K.A., Brierley, G.J., Hancock, F., Cohen, T.J., Brooks, A.P., Reinfelds, I., Cook, N. & Raine, A. (2018). Tracking geomorphic recovery in process-based river management. *Land Degradation & Development*, 29(9), 3221-3244. https://doi.org/10.1002/ldr.2984

New South Wales Local Land Services. (2024). *Riverbank rehabilitation program*. NSW Government. https://www.nsw.gov.au/departments-and-agencies/local-land-services/projects/riverbank-rehabilitation

Queensland Government. (2024). *Reef protection: Streambank erosion management*. Queensland Government. https://www.qld.gov.au/environment/agriculture/sustainable-farming/reef/streambank

Queensland Reconstruction Authority (QRA). (2024). *Disaster Recovery Funding Arrangements (DRFA) efficiencies*. Queensland Government. https://www.qra.qld.gov.au/DRFA-efficiencies

Reef Water Quality Scientific Consensus Statement. (2022). *Question 7.1 evidence summary*. https://reefwqconsensus.com.au/wp-content/uploads/2024/06/2022-SCS-Q7.1_Evidence-Summary_Final.pdf

Rutherfurd, I., Jerie, K. & Marsh, N. (2000). *A rehabilitation manual for Australian streams* (Vols. 1–2). Cooperative Research Centre for Catchment Hydrology.

Rutherfurd, I. D., Jerie, K., Walker, M. & Marsh, N. (1999). "Don't raise the Titanic: How to set priorities for stream rehabilitation". *Second Australian Stream Management Conference*, Adelaide, South Australia.

Schweizer, V., Colloff, M.J. & Pittock, J. (2022). The Dammed and the Saved: a Conservation Triage Framework for Wetlands under Climate Change in the Murray–Darling Basin, Australia. *Environmental Management,* 70, 549–564. https://doi.org/10.1007/s00267-022-01692-x

SEQ Mayors. (2025). *Resilient Rivers Initiative: SEQ waterways and wetlands investment strategy*. Council of Mayors SEQ. https://seqmayors.qld.gov.au/wp-content/uploads/2025/01/Resilient-Rivers-Initiative_SEQ-Waterways-and-Wetlands-Investment-Strategy-2.pdf

Wilson, K.A., Underwood, E.C., Morrison, S.A., Klausmeyer, K.R., Murdoch, W.W., et al. (2007). Conserving Biodiversity Efficiently: What to Do, Where, and When. *PLoS Biology,* 5(9): e223. https://doi.org/10.1371/journal.pbio.0050223

Wohl, E., Fryirs, K., Grabowski, R., Morrison, R.R. & Sear, D. (2024). Enhancing the natural absorbing capacity of rivers to restore their resilience. *BioScience*, 74, 782-796. https://doi.org/10.1093/biosci/biae090