The challenges of implementing nature-based solutions (NbS) in reach-scale river management in NSW

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Key points

- Eastern NSW experienced severe 'climate whiplash' between 2019 and 2025 (drought, bushfire, repeated major flooding), creating both the need for and significant obstacles to implementing nature-based solutions (NbS) in river management.
- Drawing on 40 NbS project sites across the Hunter, Greater Sydney and North Coast regions, this paper identifies six key implementation challenges: reactive/short-term funding, community perception, stakeholder risk tolerance, limited industry and landholder capacity, site suitability constraints, and nature-based timescales.
- Hybrid structures combining engineered log jams and rock elements were the most commonly implemented NbS type (70% of sites), reflecting the difficulty of delivering 'pure' nature-based approaches in high-energy, asset-adjacent settings.
- Key recommendations include whole-of-catchment planning, prioritising lower-risk 'low-hanging fruit' sites over high-profile asset protection, establishing large woody debris stockpiles, ensuring funded post-construction maintenance, and streamlining NbS approval pathways for private landholders.

Abstract

Nature-based solutions (NbS) are considered an important tool in establishing resilient fluvial corridors, with research suggesting they will be integral to upscaling efforts from the local to catchment scale. While nature-based methods are frequently cited as a more sustainable alternative to conventional practices, there is little research examining the challenges and practicalities of implementing this approach in the current NSW context. Building on our long history of working in catchment management, we examine and present the real-world challenges we have experienced in implementing NbS during a period of 'climate whiplash' in eastern NSW from 2019 to 2025. From this examination, we outline some of the key challenges to nature-based catchment management such as lacking industry and landholder capacity, understanding of where NbS can be effective, nature-based timescales, reactive/short-term funding models, community perception and stakeholder risk tolerance. This examination offers lessons and suggestions to increase or support the implementation of NbS, help focus attention on areas for future research, and inform pathways forward in establishing resilient fluvial corridors in our changing climate.

Keywords

Nature-based solutions, climate whiplash, river management implementation, on-ground works

Introduction

From 2019 to 2025, fires, floods and periods of drought across eastern Australia have highlighted the vulnerability of rivers to changing climate extremes (Fryirs et al 2023). Nature-based solutions (NbS) are considered an important tool for establishing resilient fluvial corridors that can more readily adapt to and recover from a changing climate (Christopher et al 2024; Fryirs et al 2023; Zhu et al 2023). Research suggests that while upfront costs can be comparable to grey infrastructure, NbS tend to be more cost-effective in the long-term due to lower maintenance costs and their environmental co-benefits (Santos, 2025).

For the first time, the NSW Government has released a State Disaster Mitigation Plan (SDMP) that specifically points to NbS as having a critical role in reducing natural hazard risk (NSW Reconstruction Authority, 2024). The Australian and NSW Government have adopted the International Union for Conservation of Nature (IUCN) definition of NbS as:

'actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature.'

However, there is a lack of clarity in the literature on what constitutes best practice NbS in river management in an Australian context (Morris et al 2024), which based on this broad IUCN definition, could vary from catchment scale revegetation to rock revetment coupled with native revegetation.

As outlined by Russell et al. 2023, NbS have been embedded in Australian river management practice since the early 90's, with a shift in best practice through time towards revegetation and 'soft engineering' techniques that mimic nature at the reach or catchment scale. However, there is still a lack of guidelines, research and technical specifications for designing, implementing and managing these approaches in the current NSW context and into the long term (Christopher et al 2024; Morris et al 2024; Santos, 2025; Zhu et al 2023). In this paper, we examine and present the real-world challenges we have experienced as an on-ground government agency in implementing NbS during a period of 'climate whiplash' in eastern NSW from 2019 to 2025. We then provide key lessons and suggestions to increase or support the implementation of NbS, help focus attention on areas for future research, and inform pathways forward in establishing resilient fluvial corridors in our changing climate.

Organisation context

The Soil Conservation Service (SCS) was established in 1938 to meet the challenge of increasing soil erosion in NSW. SCS is a commercial agency within the NSW Department of Primary Industries and Regional Development (DPIRD) and has implemented numerous river management programs and schemes since 1938. SCS has evolved to manage large-scale infrastructure and rehabilitation projects from the design phase through to the construction phase throughout NSW. SCS also fulfills disaster management responsibilities by supporting agencies such as Local Government Agencies, Public Works, Local Land Services and the NSW Reconstruction Authority during and in the recovery stages of natural disasters. This often involves working with public and private landholders to implement best practice environmental management on ground.

Climate context

This paper has been prepared in the context of implementing NbS in a fluvial setting in the Hunter, Greater Sydney and North Coast regions of NSW throughout 2019-2025. During this period, Eastern NSW experienced extensive climatic variability with rapid shifts between drought, fire and flooding. The period began with extreme heat and drought in 2019, culminating in the catastrophic 2019–20 Black Summer bushfires. This was followed by a rapid shift to a prolonged wet period from 2020 to 2022, resulting in severe flooding events across the Hunter, Greater Sydney and North Coast regions resulting in widescale fluvial geomorphic change in these river systems. Conditions then transitioned in 2023 to a warmer period, increasing bushfire risk, before becoming more variable during 2024–2025, with record rainfall and Tropical Cyclone Alfred resulting in multiple high magnitude flood events throughout eastern NSW particularly in the mid-north coast region.

Methods

We have compiled a summary of the key challenges and lessons learnt in the context of implementing NbS at 40 case study sites in the Hunter, Greater Sydney and North Coast regions throughout 2019-2025. SCS was requested and engaged to undertake works by government agencies at the reviewed sites on both public and private land. The majority (78%) of the river rehabilitation sites were disaster-recovery projects with priority sites selected through an extensive desktop asset risk multi-criteria analysis and prioritisation process undertaken by Alluvium in 2023 that considered proximity to environmental, agricultural and cultural heritage assets as well as ecological connectivity, recovery potential and existing vegetation cover metrics. Out of these sites, SCS then selected sites to construct on ground based on constructability and funding timeframes. Other sites (23%) were chosen strategically by the client as part of broader catchment erosion and rehabilitation effort to improve water quality and protect important agricultural and ecological assets downstream. Site designs were prepared by SCS are well as multiple other private consultancies including Alluvium, Fruition, Tallowood, Northern River Catchment Management and Wolf Peak.

A summary of the key characteristics of each site is outlined in Figure 1 to 3 with the Riverstyles spatial dataset (NSW DCCEEW, 2023) used as a key indicator of river behaviour for each site. It should be noted that all sites had multiple rehabilitation aims and included enhancing aquatic habitat features where possible and increasing native riparian vegetation cover, however, the main geomorphic rehabilitation aim was assigned to each site. Works at all sites included revegetation with native species and stock exclusion fencing. The main NbS type was assigned per site with the Hybrid category including works with large wood elements (i.e. ELJs, timber piles and roots balls) as well as rockwork (i.e. rock key in, groynes or revetment). Sites classified as Urban Creek Rehabilitation, included reaches where sandstone rockwork, benches and batters were constructed to mimic natural geomorphic processes.

Site summary

Case study sites assessed are located primarily within the Norther Rivers area and the Hunter/Central Rivers area, with the Hunter River (*n* = 9) and Manning River (*n* = 7) catchments hosting the most sites. Across the 12 catchments assessed, most sites were in mid-catchment areas (60 %), and were primarily classified as partly confined, planform-controlled river systems (63 %) (Figure 1) (NSW DCCEEW, 2023). This result reflects the reaches within a catchment that are most susceptible to geomorphic changes due to increased energy (compared to laterally unconfined areas), and the presence of erodible alluvium sediments (compared to confined reaches). Majority of sites were in geomorphically moderate (50 %) to poor (43 %) condition before rehabilitation, with the large proportion classified as having a moderate recovery potential (58 %) (Figure 2) (NSW DCCEEW, 2023). Furthermore, management priority classification ranged across the sites assessed, with majority classified as a medium priority (43 %) (Figure 2) (NSW DCCEEW, 2023).

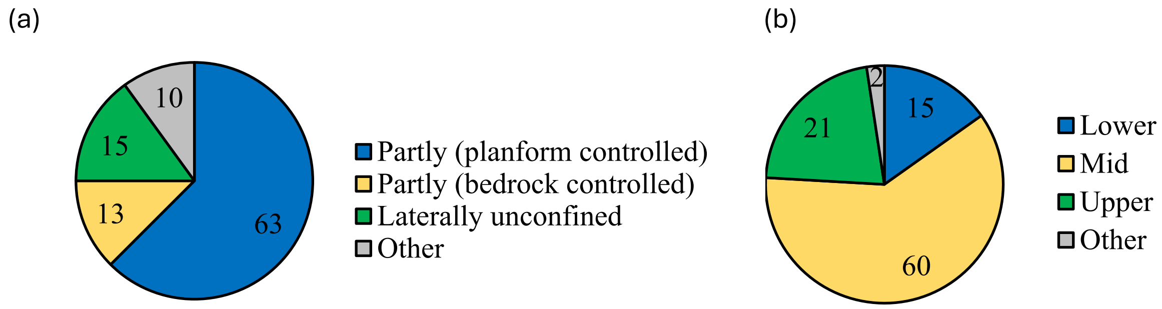

Figure 1 General location of sites assessed, including (a) river confinement type (NSW DCCEEW, 2023), and (b) general catchment location. Data labels are presented percentages with total sample size n = 40

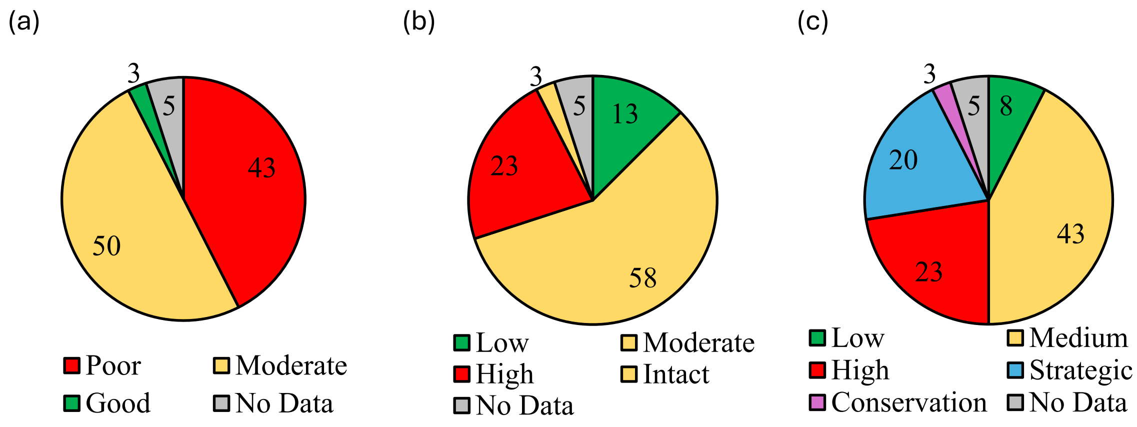

Figure 2 Geomorphic classifications for sites including; (a) geomorphic condition, (b) recovery potential, and (c) priority for management (NSW DCCEEW, 2023). Data labels are presented percentages with total sample size n = 40

The major rehabilitation aim across the sites was to address lateral meander migration (45 %), with majority of the remaining sites falling into the following categories; mitigating incision and bed lowering (23 %), halting lateral river erosion (15 %), and promoting vegetation establishment to minimise bank retreat (10 %) (Figure 3a). In conjunction with the rehabilitation aims, majority of the NbS used were hybrid structures (70 %) (Figure 3b). The scale of rehabilitation for each project was inherently dependent on the scale of the issue being addressed, and therefore, results are highly variable, with an average project length of ~300 m (SD±205), and an average revegetation area of ~13,080 m^2 (SD±12,677) (Figure 4).

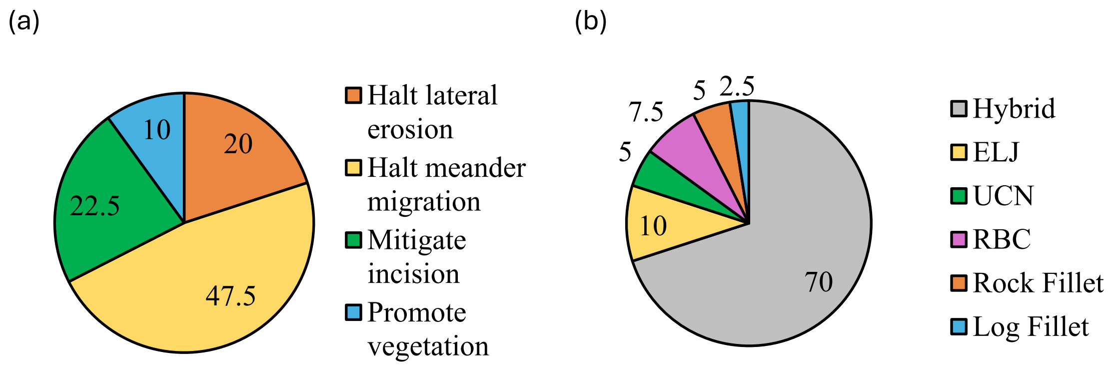

Figure 3 Distribution of (a) rehabilitation aims, and (b) nature-based-solutions used. Data labels are presented percentages with total sample size n = 40. Acronyms in Figure (b) are as follows; ELJ: Engineered Log jams; UCN: Urban Creek Naturalisation; and RBC: Rock Bed Control

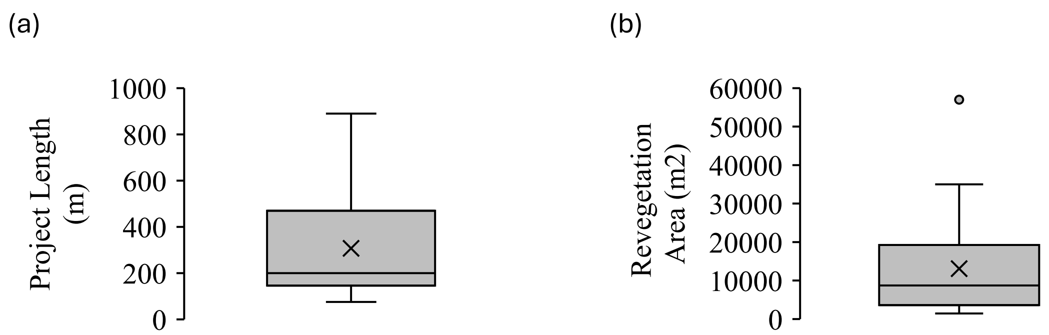

Figure 4 Box and whisker plots displaying the distribution across sites assessed of (a) project lengths (m), and (b) revegetation area (m^2)

Key challenges

Reactive/short-term funding models

Funding for NbS projects is most commonly occurring in a reactive post-flood asset protection context, which results in short-term funding models of typically 1-2 years in duration. This funding timeframe is insufficient for the implementation of best-practice NbS due to the time required fto fulfill the full project life cycle. The project lifecycle for NbS projects often includes team development, site identification, site prioritisation, site selection, investigation, design, approvals, construction planning, material procurement, construction, and maintenance. Further, short term reactive decision making is more likely to result in 'squeaky wheel' or high-exposure project implementation to protect small-scale assets rather than prioritising strategic reach- or catchment-scale projects.

Challenges that are specific to NbS compared to conventional asset protection works include material procurement and post-construction maintenance. NbS often utilise large quantities of large woody debris (LWD), tubestock and erosion and sediment control (ERSED) products, which can be difficult to source at short notice (especially LWD and tubestock). LWD usually requires large stockpiling sites, while tubestock may require up to 6 months lead time for supply. The increase in demand for these items following natural disasters (ERSED products) is another challenge.

Further, post-construction maintenance of NbS is often critical due to the establishment of deep-rooted vegetation and increased vegetation roughness being key design elements to strengthen riverbank materials and slow flow velocity. Successful native revegetation requires consistent post-installation maintenance programs of at least 12 months for watering (subject to weather conditions), weed control, pest animal control, infill planting, and post-flood replacement until established (2-5 years). Many NbS 'failures' are the result of floods occurring within the 12-month post-construction period prior to vegetation establishing sufficiently to provide critical bank stability and flow resistance.

Community perception

Despite three decades of NbS being implemented by river management practitioners, there is still a long road ahead for community education and planning approval pathways that enable these practices. NbS often require a large land footprint due to their reliance on stable bank gradients (<1V:2.5H) and re-establishing native riparian vegetation corridors. As such, convincing landholders to 'give up' or 'lose' land for NbS when neighbours upstream or downstream are still reclaiming land or rock armouring at 1V:2H with no riparian corridor is a nearly impossible feat without well-informed and educated landholders who buy into the environmental benefits of NbS.

The uptake of NbS by private landholders is also heavily reliant on planning approval pathways being streamlined and assistance provided to ensure the implementation of NbS is the easier option for riverbank protection compared to hard engineering or unapproved land reclamation activities. Currently, planning approval pathways require private landholders to submit extensive and costly development applications to undertake major NbS works, which can make adoption inhibitive. Without supporting landholders to gain rapid planning approval for NbS, the implementation of poor-practice river works will continue to set a false precedent of acceptable river works for future flood events.

Stakeholder risk tolerance and the implementation of NbS where most effective

NbS usually involve experimental methods and carry an inherent risk of 'failure' (i.e. readjustment of materials and river position over time) that is not typically tolerated when committing to conventional river management methods such as rock riprap. Out of the 40 study sites, 67.5% of sites were constructed to mitigate the lateral migration of rivers (Figure 3) with a focus on works in the lower (15%) to mid (60%) catchment in partly confined, planform-controlled river systems (63 %). These river settings carry a higher risk of failure due to high velocity flows and inherent susceptibility to geomorphic change and are therefore not typically suitable for 'pure' NbS without a longer project timeframe and a trial-and-error mindset. This is reflected in the review of sites, whereby NbS that are perceived as being less likely to adjust during flood events, such as hybrid rock groynes or the inclusion of rock key-ins, are preferred by stakeholders at 70% of sites.

Lacking industry and landholder capacity

The implementation of NbS in a fluvial setting requires both an understanding of complex fluvial geomorphic processes and the implementation of on-ground construction techniques in sensitive environments. The pressure of short-term funding cycles and loss of “river knowledge” within agencies exposed the lack of capacity in NSW in both the practical geomorphic design skillset and on ground availability of suitable local contractors/plant. This resulted in the need to upskill contractors and remove some sites from construction priority lists that were not practical for construction.

An effective NbS site also needs landholder buy-in for decadal timeframes and long-term funding support to be effective which can be a challenge with an aging population. Successful sites have passionate landholders who give a lot of their time and energy to ‘look’ after their riparian corridor. Effective NbS also requires the landholder to be onboard with the resulting geomorphic change and “messy river” that forms as a result. In the context of bushfire risk, this can be challenging as a revegetated riparian corridor potentially leads to a greater bushfire risk.

Nature-based timescale

The intention of most local-scale NbS (i.e. ELJs) is to afford enough stability for vegetation or other natural processes to take hold and add roughness/stability to the waterway (Brooks et al 2003). Previous investigations utilising ELJs coupled with native revegetation suggested ELJs within a mid-catchment sand bed stream can last up to 25 years plus and at this timescale vegetation starts to play a more important role in the stability of the waterway (Hughes et al 2024; Daley & Brooks, 2013). It is known that it takes 5+ years for effective vegetation establishment with considerable maintenance effort, however, due to variable climatic conditions during the study period timeframe does not provide the window of stability to support softer or more natural approaches, hence leading to a preference for hybrid (70%) or more “heavily engineered” approaches.

During the study period, climate variability was a significant challenge during construction with drought, fire and multiple high magnitude flood events changing catchment/site conditions throughout the works. This often led to reactive design changes from softer to hybrid approaches halfway through construction at some sites.

Recommendations

Plan ahead

Creating NSW wide Catchment Management Plans (CMP) or updating existing historical plans (such as Rivercare Plans) will allow for whole-of-catchment prioritisation to occur which can be utilised in a post-flood emergency setting and alleviate the ‘reinventing the wheel’ effect that is commonly seen in river management in NSW. Plans could include where to allow ‘Room for the River’ (Zevenbergen, 2015), where NbS are most suitable and where more engineered solutions are required or allowed within the catchment. CMP will reduce the patchwork of band aid solutions that commonly occur and assist with implementing meaningful and strategic reach or catchment-scale works. CMP will promote more on-ground action rather than repeated prioritisation studies and could follow a similar framework to the implementation of Coastal Management Plans in NSW.

The establishment of native revegetation as a critical design element needs to be included in project risk assessments prior to committing to NbS designs. Project funding needs to reflect the lead time for sourcing or growing tubestock (up to 6 months+) and the 2-5 year timeframe for effective vegetation establishment.

Less ‘perfection’, more action

If stakeholders want to implement NbS, site selection should reflect both the project’s risk tolerance and the funding available. Projects with low risk tolerance are generally better suited to lower stream order, mid- to upper-catchment locations with lower stream power, no immediate high-value assets, and relatively stable channel planform (i.e. active incision, widening and lateral migration are absent). Where works must be undertaken in higher-risk settings, achieving a low-risk outcome will usually require greater investment in smaller-scale hybrid designs. Site selection should therefore be driven by risk tolerance and available funding, rather than by pre-selecting high-risk sites and then attempting to deliver time limited funded works with a high likelihood of poor outcomes. For example, where funding is limited by time or budget and risk tolerance is low, a lower stream order upper-catchment reach may be more appropriate, as less intensive NbS such as revegetation or LWD structures can often deliver greater benefit over a longer length of river.

The implementation of less intensive NbS at lower risk sites over a larger scale will provide greater outcomes for river management overall even if a portion of works are seen as a 'failure'. Investing large budgets and materials into small-scale, intensive projects on a 10-100 m scale that are designed for high magnitude floods is not achieving meaningful benefits to improving catchment resilience. We should be allowing high-risk sites to run their course (managed retreat) if there are no critical assets that need to be protected and look towards the 'low hanging fruit' sites that can have a meaningful benefit to catchment resilience.

LWD stockpiles

LWD stockpiles should be established as materials become available from land clearing activities such as new transport infrastructure and housing developments. LWD should be harvested by contractors to meet the specifications needed for NbS to maximise the environmental outcomes of repurposing intact LWD, compared to chipping or burning. SCS implemented statewide pre-construction LWD stockpiling campaign during a 2023-2026 river rehabilitation program, which ensured material availability and greatly expedited construction programs. LWD stockpiling occurred on public land (e.g. travelling stock routes, water utility operational land, road corridors) and private land (e.g. development projects). SCS also provided LWD technical specifications to Transport for NSW early in the project timeline to ensure this could be written into land clearing contracts.

Site stewardship – on-going maintenance and monitoring

NbS projects must be planned around sites and designs that allow for at least 1 year, or ideally 3+ years of site maintenance to ensure riparian vegetation is established and structures are functioning as intended. As such, if landholders or land managers are not supportive of in-kind or funded site maintenance then alternative sites should be selected. Similarly, if the initial project investment is not sufficient for both the design and on-going maintenance, then a scaled-back design, alternative design or additional funding source should be considered. On-going maintenance should be supported by monitoring to document the efficacy of NbS and help to fill existing design and implementation knowledge gaps.

Community outreach

Community awareness of acceptable river behaviour, particularly in a post-flood context, needs to improve to enable broad-scale NbS implementation. Investment into community outreach programs will help debunk many inhibiting beliefs surrounding river behaviour, such as all erosion being 'bad', riparian canopy causing bank failure, and that rock-based erosion management is best. Likewise, education of landholders about permitted and unpermitted river works will shift the expectations of landholders who seek poor-practice or unpermitted works such as riverbank reclamation or hard-engineered structures.

Rapid approval pathways

Streamlined approval pathways for best-practice NbS are needed to support broader landholder uptake and reduce unregulated riverbank management. Without simpler approvals, landholders are likely to view NbS as too difficult, assume they can only be delivered by government, or continue using unpermitted works instead of taking responsibility for riverbank management. This will need a strong definition for best practice NbS in a catchment management context to ensure best practice is maintained and undertaken in the right place.

Conclusion

It is widely known that NbS have an important role to play in establishing resilient fluvial corridors in NSW; however, upscaling their successful implementation from the local scale to the catchment scale is constrained by practical challenges including short-term funding models, community perception, stakeholder risk tolerance, limited industry and landholder capacity, site suitability constraints, and the long timeframes required for natural processes to establish. A review of 40 river works project sites delivered by SCS during a period of climate variability from 2019 to 2025 demonstrates that although a preference for 'softer' NbS is evident at the onset of river rehabilitation programs, overall, river works are more commonly occurring in mid to lower catchment areas in partly confined, high energy fluvial settings resulting in a preference for hybrid approaches. While these project sites successfully achieved their rehabilitation objectives, to support the broader adoption of NbS, investment is needed in strategic catchment planning and research to ensure NbS are occurring in the most effective locations in the catchment. By addressing these challenges and prioritising lower-risk opportunities, NbS can move from isolated projects to a scalable approach for improving river resilience in a changing climate.

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