THE REGENERATIVE POWER OF WATER

Nature Repair in the Sydney Catchment Area

A report prepared by Mulloon Institute for WaterNSW

This publication has been produced by Mulloon Institute and was commissioned by WaterNSW.

ISBN: 978-0-6483635-3-8

Authors: Laura Fisher, Peter Hazell, Erin Healy, Mitch Lennon, Chris Inskeep & Jack Smart.

Cover design: Tilda Joy

Digital illustrations: Tilda Joy

Watercolour illustrations: Kim Williams

This publication would not have been possible without the vision and guidance of Stuart Naylor, Catchment Program Coordinator at WaterNSW. The authors sincerely thank him for his support, and pay tribute to his long-standing dedication to communities caring for landscapes and waterways in NSW.

Photos are courtesy Mulloon Institute unless credited otherwise in the captions.

This book has been printed on recycled paper.

Mulloon Institute is a not-for-profit research, education and advocacy organisation. Its mission is to actively demonstrate, validate and share landscape rehydration, restoration, and regenerative practices to create sustainable and resilient agricultural and environmental systems now and into the future.

The Institute demonstrates innovative land management approaches that create healthier landscapes more resilient to climatic extremes, rebuild soil fertility, fix more carbon in the landscape, restore lost biodiversity and improve water quality and availability. We work collaboratively across Australia with landholders, community groups, First Nations custodians, scientists and government.

WaterNSW is a state-owned corporation and one of the main government agencies tasked with managing water in NSW. WaterNSW operates the state's dams, capturing and storing water, and then supplying it ready for distribution – for the environment, agriculture, industry and the community. With 41 major dams and hundreds of waterways across the state, WaterNSW plays a vital role at the source of the state's water, delivering two thirds of all water used in NSW.

This publication is the outcome of a new partnership, formed in 2025, between Mulloon Institute and WaterNSW. A key focus of this partnership is the establishment of a new Water Stewardship Program in the Sydney catchment area. This community-oriented initiative will fund innovative landscape-scale projects that restore local water cycles and enhance water quality, water security and catchment health. The pilot phase of this program has been generously supported by The Ian Potter Foundation.

Further information about the program, including funding guidelines, can be found here: www.mullooninstitute.org/water-stewardship-program

Mulloon Institute and WaterNSW acknowledge Aboriginal and Torres Strait Islander peoples as the First Australians and Traditional Custodians of the lands and waters where we live, learn and work.

WaterNSW preface

This report has been commissioned by WaterNSW to uplift the understanding, regeneration and management of our waterways and landscapes. WaterNSW is responsible for safeguarding the health of the Sydney catchment area and its drinking water supply. For 25 years, together with partners, WaterNSW have supported landholders to nurture healthy waterways by fencing and managing stock, treating erosion and revegetation. Now, observation and evaluation has led to the recognition that waterway management is shifting and expanding. We cannot regenerate degraded landscapes without a much deeper consideration of water.

Mulloon Institute has been fostering understanding of water in the landscape through its catchment scale project, the Mulloon Rehydration Initiative (MRI), located within the Sydney catchment area, and rehydration projects across Australia. The 2022 Sydney Catchment Audit recommended that WaterNSW's rural programs support and increase regenerative agriculture and landscape rehydration. This report is one of many steps being taken by WaterNSW and Mulloon Institute to respond to that recommendation. It supports a course of action that is in the interests of healthy catchments, water security, and water quality.

Stuart Naylor, WaterNSW

Mulloon Institute preface

Mulloon Institute was established in 2011 by the late Tony Coote and his wife Toni Coote. Tony's deep concern for Australia's food and water security, coupled with his recognition of water's critical role in landscape restoration, led to the creation of the Institute. Tony was also inspired by his relationship with Yuin Elder Uncle Max Dulumunmun Harrison from whom he learnt that nature is the greatest teacher. Together they imagined a future where there was more culturally attuned water management across Australia. Over time, the Institute has gained significant interest and engagement from farmers, First Nations groups, and rural communities for its approach to rehydrating degraded landscapes, resulting in demonstration projects around the country.

At the heart of the Institute is a project that is unique in the world: the Mulloon Rehydration Initiative, located in the Sydney Drinking Water Catchment in the Southern Tablelands region of NSW. It involves 23 landholders and has repaired 50km of Mulloon Creek, a highly degraded former chain-of-ponds system. Scientifically benchmarked and subject to extensive monitoring, in less than ten years this project has radically improved the condition of the creek and the adjacent land, benefiting native species, landholders and the quality of water that leaves the catchment. Awarded the Biodiversity Prize at both the 2024 NSW and the 2025 National Banksia Sustainability Awards, it highlights the power of a cooperative, landscape-scale approach. The project showcases a set of strategies that can be applied not only across Australia but also globally, offering a viable nature-based solution for nature repair and climate change resilience.

The success of the Mulloon Rehydration Initiative rests in its community-centred approach, and this informs all the Institute's activities. We foster a culture of trust and collaboration, working directly with communities to understand the challenges they face around water. Together we are building the knowledge and capacity to create a future in which land managers are empowered to act in the face of climate change, safeguard water resources through improved stewardship practices, and restore productive, biodiverse landscapes.

Carolyn Hall, CEO

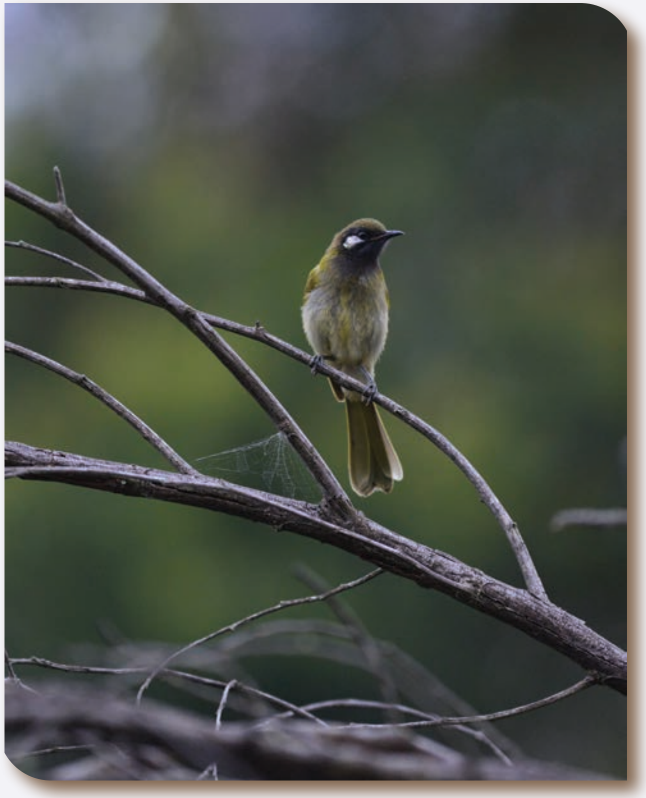


Photo by Antony Mulhall

Contents

Chapter 1: Introduction & Context

1.1 Introduction

To achieve nature repair, we need resilient landscapes that can withstand climate extremes. For landscapes to be resilient, they must be functional. A functional landscape is able to retain and cycle water, carbon, minerals and nutrients, and meet social, cultural and spiritual needs.

Waterway and landscape management practices are evolving. The wetlands, chain of ponds systems, waterways and floodplains of the Sydney catchment area are now eroded and incised, and the small water cycles on which they depend are broken. For the last 30 years, WaterNSW has pursued catchment health by increasing riparian vegetation, using fencing to limit stock access to waterways, treating gully and streambank erosion and supporting farmers to implement sustainable grazing practices. These strategies have often achieved great results and land rehabilitation. However, they have tended not to embrace the full hydrological picture. By working at the site or property-scale and thus often addressing issues in an ad hoc way, they have been unable to take an integrated, landscape-scale approach. Now that land managers, communities, water utilities and government agencies are increasingly challenged by climate change and the degraded condition of waterways, a deeper consideration of the role water plays is needed. This publication is designed to meet this need. It aims to provide clear information about how we can harness the regenerative power of water to achieve multiple benefits.

The strategies presented here extend and enhance existing waterway and landscape rehabilitation and restoration. They draw on the work of Mulloon Institute, and a range of proven methods the Institute defines as 'landscape rehydration'.

Landscape rehydration

Landscape rehydration is a method of restoring the natural movement, storage and cycling of water in degraded landscapes. It first involves identifying the causes of hydrological dysfunction at any given location and situating the landscape in its catchment context. From there it works to recover landscape function in the most efficient way possible. A landscape rehydration project might include changes to agricultural land management, altering farm infrastructure and/or installing physical interventions in the landscape – known as "natural infrastructure". Such projects incorporate a series of steps that include landscape assessment, mapping, planning, design, implementation and monitoring. They also involve building the capacity of land managers to integrate landscape rehydration principles into their long-term management, and where possible, community engagement to extend learning and benefits more widely.

"Natural infrastructure can include both natural features and engineered structures that mimic or promote natural processes over time.' Structures made from soil, rock, logs, brush and vegetation 'are used to intercept and alter the flow of water. In this way, natural infrastructure slows and stores water in the landscape to reduce downstream flood peaks and remove nutrients and other pollutants."

Environmental Defense Fund, 2020.

What might this look like in practical terms? It may include the construction of contour structures on slopes to reduce run-off and encourage infiltration, and accompanying plantings. Brush packs and permeable rock structures may be built to heal erosion gullies and earthen structures may be employed on the mid-slopes to divert flows from gullies and redistribute them over alluvial features. The use of fencing to limit stock access to rocky outcrops and swampy areas is encouraged to support biodiversity and drive improvements to water quality. Where fencing and new watering points are coupled with revised grazing regimes, recovery of floodplain landscapes and grasslands can occur quickly.

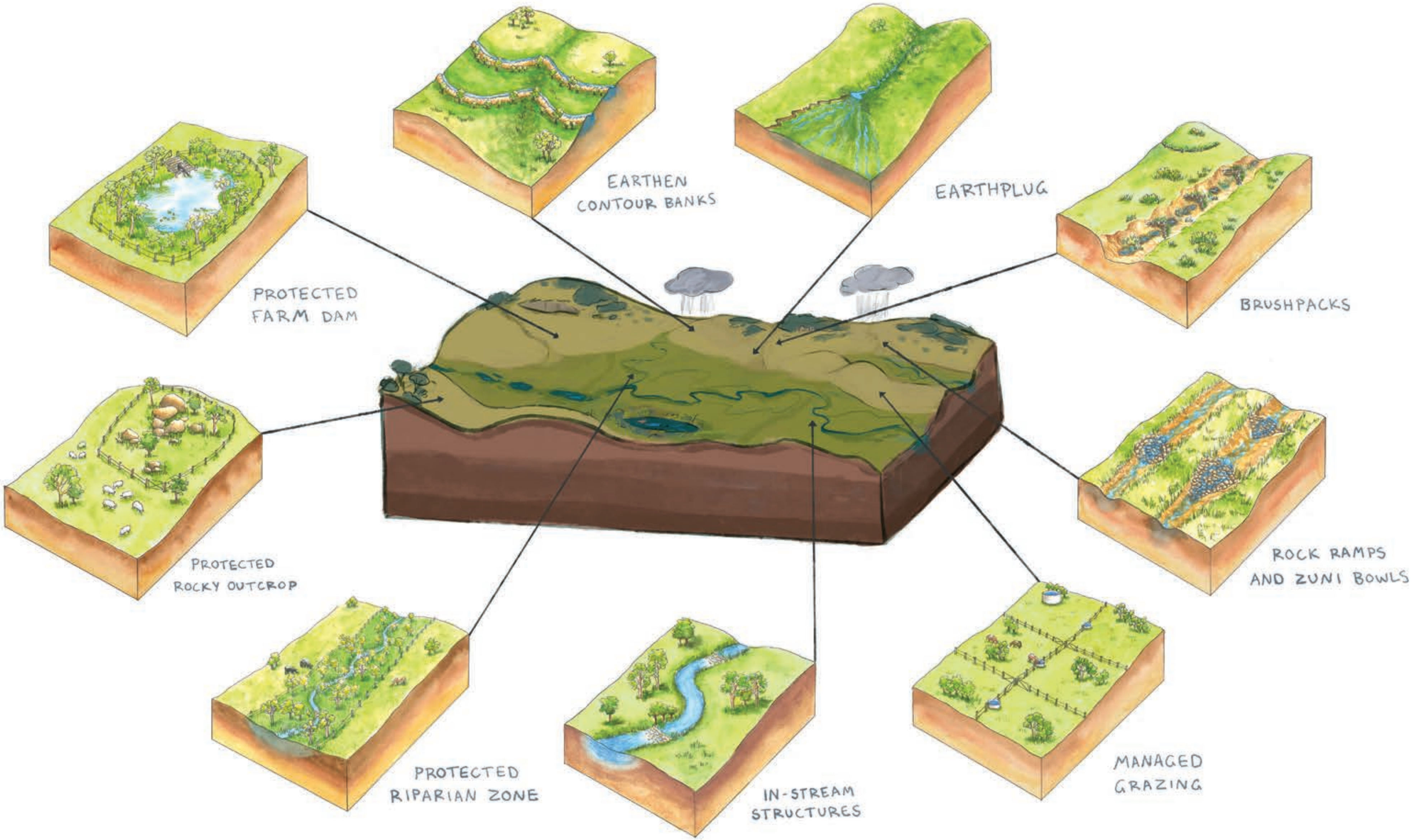
Down in the creek lines where streams are incised, riparian areas can be fenced, and carefully designed and engineered in-stream structures may be employed. These structures de-energise flows, facilitate sediment capture and the return of aquatic plants, leading to banks being stabilised and the bed level of the stream being raised.

In summary, all the actions that form the landscape rehydration "toolkit" encourage water to slow down, infiltrate, pond, meander, drop sediment, cycle, form microclimates and cool the land surface (Figure 1). They are all designed to support plant growth and restore biodiversity above and below ground. They can be applied incrementally in very cost-effective ways or expanded to multi-property projects that quickly achieve dramatic benefits across vast areas.

Landscape rehydration can make a significant contribution to WaterNSW's catchment health objectives, because it leverages the full array of functions that water has within landscapes. It is attuned to water's intricate relationship with all of life's biological and chemical processes and its high heat buffering capacity. It is also attuned to the vital role of the small water cycle in linking plants, soil and the atmosphere, and in moderating local climate. At the same time, it incorporates practices proven to enhance geomorphic condition of waterways, minimise erosion, preserve soil moisture and enhance vegetation coverage across the landscape. Furthermore, landscape rehydration incorporates the social and cultural dimensions of water stewardship and care for Country, fostering the community skills and cooperative relationships needed to safeguard catchment health in the face of climate change. In essence, it provides practical, achievable ways to reinstate water's proper role in maintaining the resilience of the entire landscape system.

Figure 1: Landscape Rehydration Toolkit, illustrations by Tilda Joy and Kim Williams.

The Landscape Rehydration Toolkit



How this publication is structured

We begin with an at-a-glance snapshot of the landscapes of the Sydney catchment area, drawing attention particularly to agricultural land use. Following this, in Chapter 2, we summarise how those landscapes have been transformed since colonisation and, in many instances, have lost hydrological function. Chapter 3 then introduces scientific principles and landscape concepts that are foundational to landscape rehydration: catchment-scale thinking, landscape function, landscape resilience and the importance of a Country-centred approach.

Chapter 4 documents how landscape rehydration projects are implemented at small and large scales and varying degrees of complexity. It provides a series of fact sheets that describe the hydrological features to be found across the Sydney catchment area, each of which manage water in a different way. These fact sheets highlight typical indicators of degradation in each case, and opportunities for repair and regeneration. This chapter then outlines a four-part framework for evaluating, prioritising and planning projects, and describes the community engagement process. It concludes with a workflow chart that incorporates all the stages of a large-scale landscape rehydration project.

Chapter 4 provides an overview of the current legal context for landscape rehydration projects. While much can be done without encountering regulation, there are scenarios in which projects need approval from government agencies responsible for waterways. This chapter clarifies these triggers and the current approvals pathway.

Finally, Chapter 5 presents six case studies of landscape rehydration projects. These range from small gully restoration projects to catchment-scale projects, and illustrate how they can involve single landholders, communities of practice, First Nations groups, Landcare groups, councils and many other stakeholders.

A note on science and style

To be as accessible and useful as possible, this publication uses imagery, fact sheets and case studies to present information, and is light on scientific references. However, the landscape rehydration principles and methods presented here draw extensively on scientific research, its evidence and its applications in the field.

Relevant literature includes (*footnotes provide some example literature*):

- Geomorphological studies of the characteristics and transformation of the catchment landscapes of South-eastern Australia.[1]
- Empirical studies of comparable restoration projects in disturbed landscapes that attest to significant beneficial outcomes, including those that have quantified the ecohydrological benefits of natural infrastructure projects, and studies affiliated with the field of 'function-led' ecological restoration.[2]
- Manuals, guidelines and other literature published by scientific organisations and experienced practitioners who lead and monitor similar projects.[3]
- Natural Resource Management publications and related literature that demonstrate the merits of socio-ecological and systems-approaches to nature repair.[4]
- Scholarship about Country-centred approaches to landscape and water, and ways to enable First Nations-led projects and increased economic opportunities.[5]

---

1 *Brierley & Fryirs (2005), Hazell et al (2003), Williams, R.T (2018), Eyles (1977), Prosser (1991), Prosser et al (1994).*

2 *Liu & Hiller, (2016), Martyn et al (2022), Nichols et al (2012), Norman et al; (2016), Norman (2020), Norman et al (2022), Silverman et. al (2018), Tongway & Ludwig (1996, 2004, 2011), Wikenson et al (2022).*

3 *Apfelbaum & Hanley (2010, 2012), Lancaster & Marshall (2013), Sustainable Farms, Wheaton et al (2019), Wilkerson et al (2022), Zeedyk & Clothier (2009).*

4 *Chapin et al (2009), Folke (2010), Commonland (2021), Tongway/Ludwig, Cross & Ampt (2017).*

5 *Abdila (2020), McKnight (2015), Janke et al (2021), Moggridge (2020), Moggridge et al (2022), First Nations Portfolio (2024).*

- Seminal hydrobiological science, soil science and climate science that highlights the role of terrestrial water cycling, coupled with biodiversity, in moderating the earth's temperature and supporting local precipitation events (including concerns about the climatic effects of land clearing and bare earth around the globe).[6]

A companion publication has been drafted to synthesize this research and is forthcoming.

6 *Ripl (2003), Pokorný et al (2010). Trenberth (2011), Ellison et.al (2017)*

1.2 The Sydney catchment area

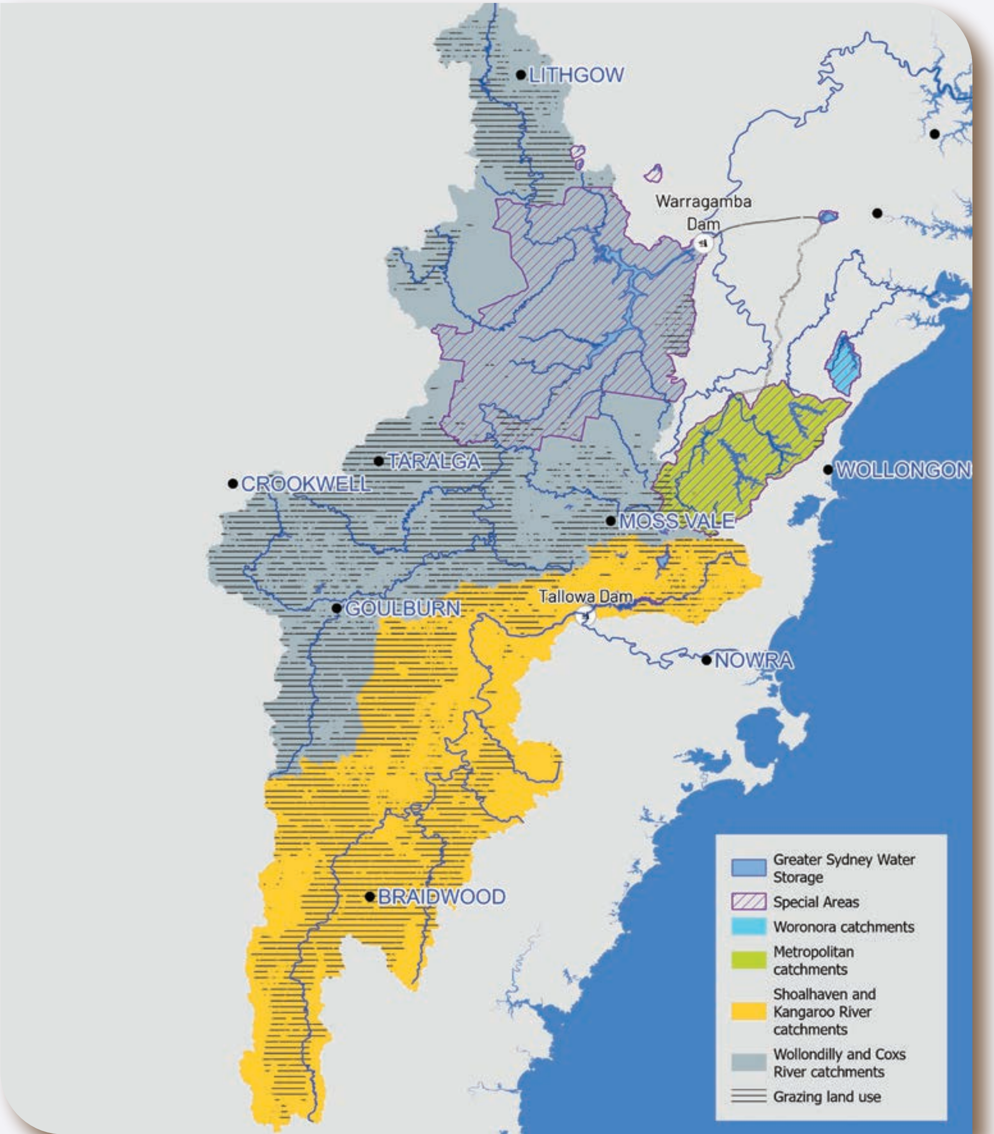


Figure 2: Sydney's drinking water catchments and grazing land use areas

Figure 3: The custodial lands within which the Sydney catchment area is situated.

Key Facts:

- The land area of Sydney's drinking water catchment is 16,000 km^2.
- 40% of this land is agricultural.
- This agricultural land includes 21,000 km of waterways.
- There are about 19,000 properties within the catchment that are fully or partly used for grazing. Of these, about 200 properties are over 500 hectares in size, with many being under 100 hectares (WaterNSW, 2024).

The health of the Catchment was most recently audited in 2022 (Eco Logical Australia, 2023). 'Climate-driven events' like floods, bushfires and heatwaves were acknowledged as key drivers of declining catchment health. Among the most concerning areas in the catchment were:

- agricultural properties with poor land management practices and poorly managed waterways (e.g., no native riparian vegetation, uncontrolled stock access, erosion).
- watercourses in poor condition with moderate or low recovery potential.
- wetlands that have been degraded and are deteriorating.

About 2,000 grazing properties were identified by WaterNSW as a high risk to water quality (Ecological Australia 2023, 21). Most of these properties are located on the NSW Southern Tablelands.

Recommendation eight of the Audit proposed that WaterNSW 'Increase regenerative agriculture in the Catchment through refinements to WaterNSW rural programs'. This recommendation echoed one of the objectives of WaterNSW's Source Water Protection Strategy 2040, which has set the goal of '1000 landholders managing healthy waterways and regenerative grazing practices' (WaterNSW, 2020). To achieve this goal, the audit recommended that 'rural program protocols are adjusted to provide funding for projects that feature regenerative agriculture and/or landscape rehydration' (Ecological Australia 2023, 297). This publication aims to contribute to WaterNSW's strategic efforts to meet this target.

The Sydney Drinking water catchments are situated in the custodial lands of several First Nations groups. These are illustrated in the map in Figure 3, which is derived from the AIATSIS map of Indigenous Australia (1996) and also acknowledges Ngambri traditional ownership of the Canberra area (Gore 2023).

Chapter 2: The Catchment Landscape: then and now

"It was at the Pack Inn, and afterwards at Lockyers Farm that I first observed those highly characteristic Chain of Ponds, which would deserve a geological examination of months as they are a phenomenon not to be found, to my knowledge, in any other Chapter of the world. They are commonly round or oval basins of from 20 to 200 feet in diameter or length, excavated or sunk in the superficies of an alluvial soil, which is commonly of a rich kind, fed by subterraneous springs; often, indeed generally, very deep and not at all to be confounded with waterholes owing their origin to the accumulation of atmospheric water."

An account made by Polish Naturalist Dr John Lhotsky, of his observations while staying at the Pack Inn, by the banks of the Wollondilly River (1835:25). Lhotsky also noted that the ponds were deep, clear and cool, with mist rising off them each morning, despite the prevailing hot weather.

2.1 A transformed landscape

The first-person accounts of the European explorers, pastoralists and surveyors provide us with a compelling record of how the landscapes of the Sydney Drinking Water Catchment looked and functioned at the time of colonisation. For example, in February 1822, explorer William Kearns was the first European to find the Southern end of the extensive Weereewaa Valley, through which the Molonglo River runs. He described the country as 'the finest plain we ever saw'. He noted that the river was a 'chain of connected ponds' running from the southern end of the plains before taking a course through the range of hills (Throsby, 1822). This was the Molonglo River flowing through the Carwoola floodplain.

There are many other descriptions of broad low-relief valleys that were thinly treed on the slopes, with grassy valley floors containing chains of ponds. These valleys were filled with deep, layered sediments which, later evidence has revealed, have eroded and refilled many times over many millions of years. Geomorphically, these are known as 'cut and fill' landscapes. They are very fertile, yet inherently fragile. The water in the rivers and ponds was always described as being clear. The chains of ponds were often deep, with no or only a poorly defined channel linking them. They maintained plenty of water during extended dry periods.

Figure 4: Google Earth image of Fosdykes Creek chain of ponds, Mongarlowe River Catchment

Figure 5: Detail of Figure 4.

Figure 6: Pond in Orroral Valley, Tharwa

Figure 7: An intact valley floor, Orroral Valley, Tharwa

Later analysis suggests that streams with catchments of greater than 1000 km^2 had continuous channels, whereas the smaller catchments contained less distinct, 'discontinous' channels (Prosser 1991). These were more likely to contain chains of ponds, or contained no surface water bodies at all, yet were consistently grassy and green. Figures 4, 5, 6 and 7 provide us with glimpse of what these landscapes looked like – they are rare examples of currently intact, hydrologically functional chains of ponds.

Ponds and wetlands were filled with Phragmites, Cumbungi, Eleocharis and Schoenoplectus, as well as many types of rushes and floating water plants. There was abundant wildlife: including fish, eels, crayfish, and platypus in the rivers, ducks, geese and swans in the wetlands, as well as emus, brolga, Wonga pigeons, plains turkeys, quails, kangaroos and wallabies. Many accounts observed that the floodplain soils were soft and spongy, making travelling by horseback difficult. The soils away from the floodplains were often described as light but friable. We can assume from these accounts that water was retained and cycled in the landscape – in the soils, aquifers, ponds, atmosphere and living systems.[7] The mosaic-like management of these landscapes by the first Australians for many thousands of years through burning had supported this local water cycling.

Floods moved slowly and spread out across the extensive floodplains. This allowed water to soak into the ground, and sediment to catch on the vegetation and deposit, thus continually building soil.

Figure 8: Darrunda Wajaar Ranger Luana Furgeson conducting a cultural burn in Gumbaynggirr Country.

7 *Johnston & Brierley (2006); Rivers of Carbon (2019).*

Figure 9: Incised floodplain and channelised stream near Bungendore.

The way these fertile, yet fragile landscapes functioned quickly changed once pastoralism spread across the catchment. Rapid soil erosion commenced in the early decades of the 19th century and a landscape which had never seen hard-hooved animals before was suddenly overrun with them. By 1830 there was almost two million Merino sheep in the colony, and by 1890 there were nearly 100 million sheep and ten million head of cattle. The elements that optimised hydration of the landscape in the harsh Southern Tablelands climate were the very things that the livestock, and later, plagues of rabbits, impacted the most.

Incised streamlines and erosion gullies spread across the catchment (see Figure 9). This process effectively pulled the plug on the valleys causing the soil to drain out, along with the carbon, nutrients and moisture it contained. Soil carbon loss and soil compaction had a dramatic effect on the landscape's hydrology. As agriculture expanded and industrialised in the 20th century, livestock, tree-clearing and intensive farming practices continued to disrupt the delicate balance maintained for thousands of years in the catchment. While the region's climate had always been variable and harsh, now these cycles of wet and dry had more severe impacts. Chains of ponds were replaced by deep gullies and previously clear streams became turbid (see Figures 10 and 11). Soil compaction and vegetation loss led to increased runoff, severe flooding, further degrading the landscape and limiting its ability to retain water.

Figure 10: Channelised stream with turbid water.

Figure 11: A substantial gully system in a floodplain landscape.

Most catchment landscapes now have much reduced vegetation cover, minimal topsoil and incised valley floors. The ubiquity of these features over many generations means there is poor understanding of what healthy landscapes and waterways should look like and how they should function. Misunderstanding and misclassification of the discontinuous watercourses that once dominated South-East landscapes (and indeed most of Australia) continues to impede conservation efforts to repair these natural systems and improve the productivity of agricultural landscapes.[8]

Whereas rainfall once filtered into the landscape and moved slowly through the catchment within soils, swamps and aquifers, now it largely runs over the surface of the land and through channelised streams. Similarly, where floodwaters were previously tempered and dispersed by dense vegetation and intact valley floors with chains of ponds, they now move rapidly and destructively through catchments (see Figure 12).

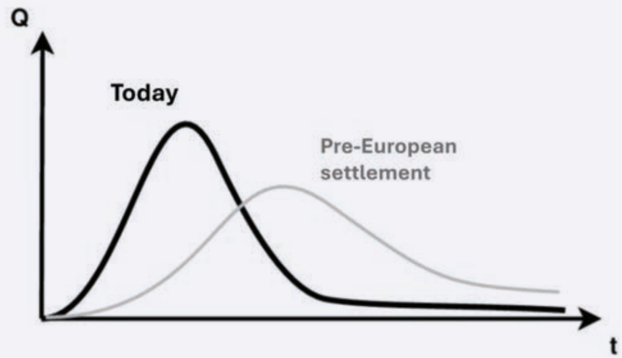


Figure 12: A simulated catchment hydrograph (Q = flow; t = time). It illustrates that prior to colonization, water flowed slowly through the catchment after a rain event, whereas today those flows tend to peak with greater intensity and subside quickly.

8 Williams (2018) notes that 'In Australia, fluvial systems with discontinuity of flow and/or channel make up 50–70% of the channel network in Australia' (147). He also notes that the Water Management Act 2000 (NSW) includes no definition of a watercourse, whereas all other States have legislative definitions of watercourses or waterways that include discontinuity with words like 'intermittent' (153, see also Mactaggart et al, 2008, Thwaites & Brooke, 2021).

2.2 Comparison of an intact and incised floodplain: Burrumbowlie Swamp & Manar Creek

As previously described, most valley floors in the Sydney catchment area have become incised. These channelised landscapes are now so widespread, it can be difficult to imagine their former appearance or function. In this section we provide a comparison of the characteristics of an intact floodplain landscape (Burrumbowlie Swamp in the lower reaches of Boro Creek, a tributary of the upper Shoalhaven catchment), and an incised valley floor of similar size in the same region (Manar Creek. See Figure 13 for locations). Burrumbowlie Swamp and Manar Creek would once have been quite similar - both systems are classified as 'laterally unconfined' (open floodplains) with sand or fine grain beds.[9]

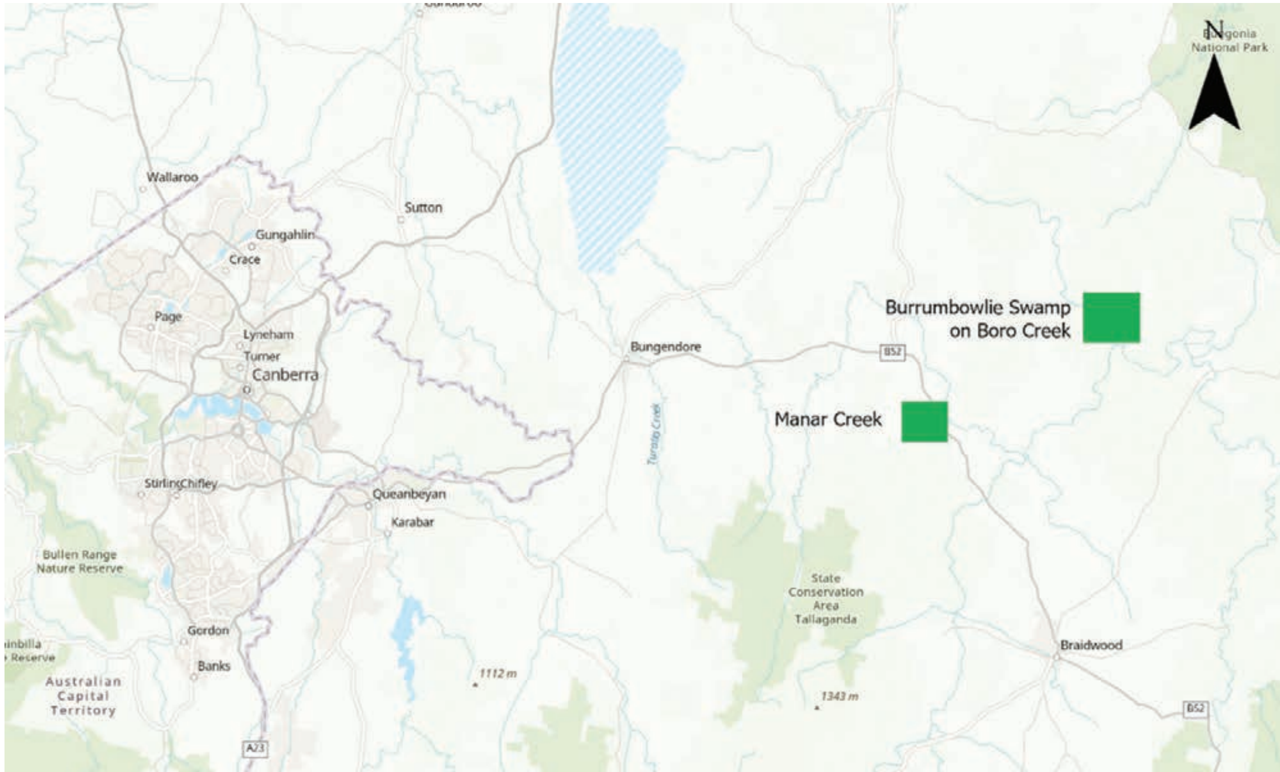


Figure 13: Location of Burrumbowlie Swamp and Manar Creek

9 This classification is derived from NSW River Styles portal. The River Styles mapping tool can be found here: https://trade.maps.arcgis.com/apps/webappviewer/index.html?id=25d05de7453d4b0eb54783f84d319f0c

Figure 14 shows us that Burrumbowlie Swamp remains a 'discontinuous' watercourse. The varied greens show that wetland plants are present and that there are large swampy areas with saturated soils. Ponds of water are visible, some of which are quite large and up to five metres deep. Generally, ponds in this context are "windows" on the underlying groundwater. The visible surface water is only a small percentage of the total connected reservoir of water that lies beneath. Such systems act as giant sponges, having the capacity to slow floodwaters, as well as absorb and retain a percentage of its peak flow, which it can store for prolonged periods, slowly releasing it over time and maintaining a hydrated system downstream during dry times. An important but little understood feature of these landscapes is the hyporheic zone. This zone is situated between stream channel and the floodplain groundwater. Water flows in both directions within it, carrying micro-organisms, gasses and dissolved substances, enabling water filtration and many other important ecological functions.

In contrast, Figure 15 shows that Manar Creek is now a single, narrow, continuous channel with low sinuosity (which means it has limited meanders, causing water to often flow in a straight line). The bed of the stream has lowered by two to three metres. The impact of clearing, draining and cultivation is clearly visible in the land adjacent to the creek line and within the broader catchment. Runoff from rainfall drains quickly into creeks and rapidly funnels out of the catchment.

"The most obvious effect of channel incision is the physical conversion from a discontinuous watercourse to a continuous channel. This converts a system of permanent, lentic waterbodies [still or slow-moving water] into an ephemeral and essentially lotic [running water] system. As discontinuous gullies lengthen in an upstream direction, each pond that is encountered becomes part of the incised channel and loses the capacity to retain water."

Hazell et. al. 2003, 309.

The schematics in Figures 16 and 17 illustrate in profile how an intact valley floor like Burrumbowlie Swamp compares with an incised valley floor like Manar Creek. These provide a reference point for Figure 19, which illustrates the difference in the elevation profiles of Burrumbowlie Swamp and Manar Creek. Each line shows the undulations of the land across a 200 metre cross-section of the two sites.

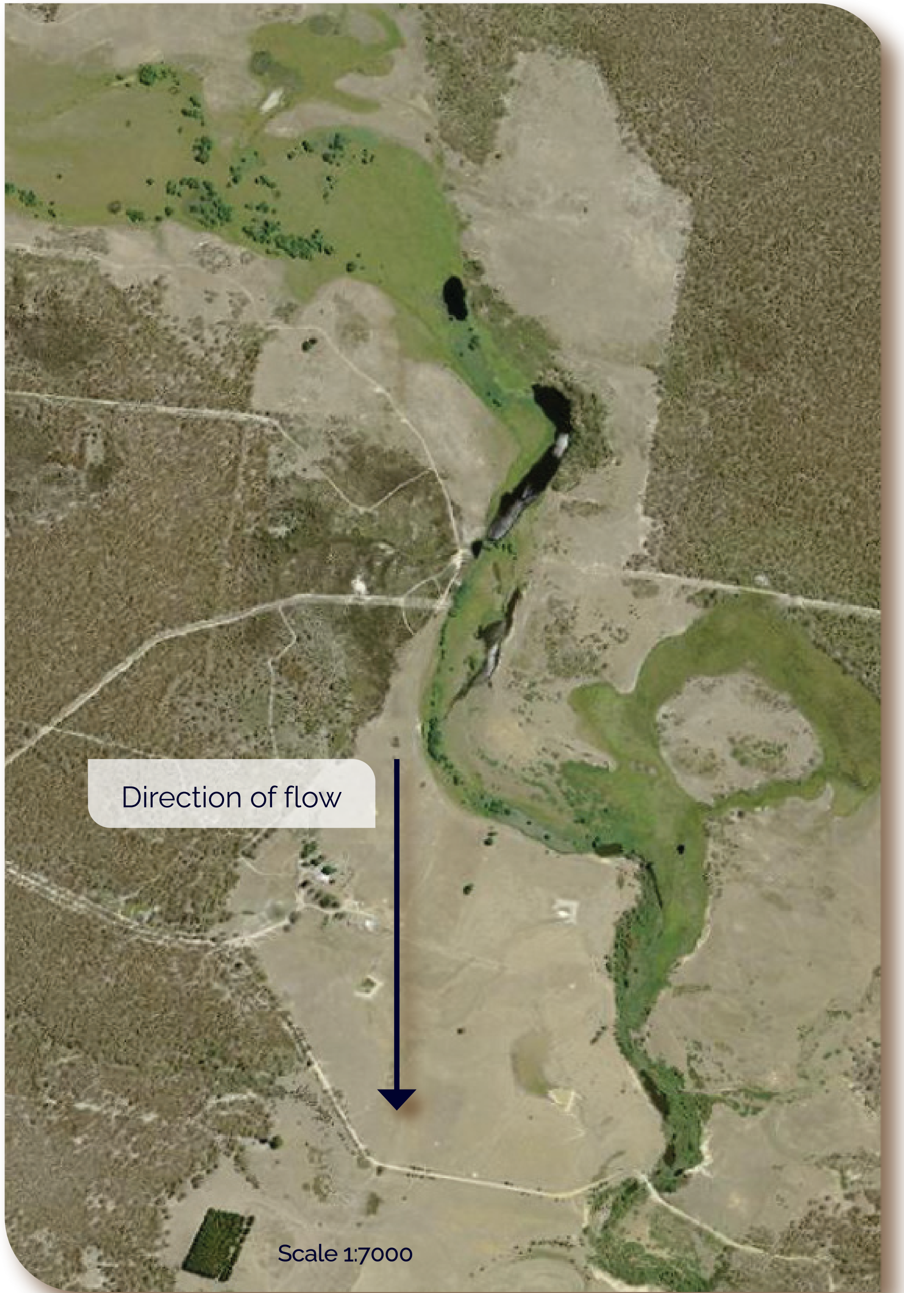


Figure 14: Satellite image of Burrumbowlie Swamp

Figure 15: Satellite image of Manar Creek

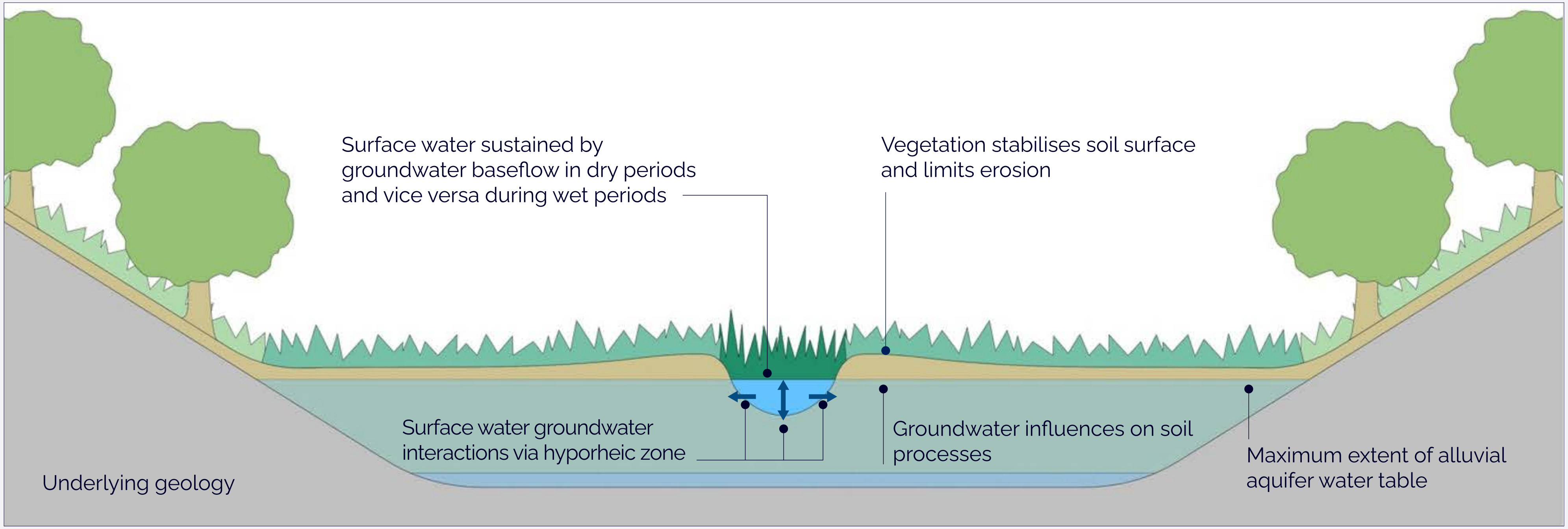


Figure 16: Intact valley floor diagram

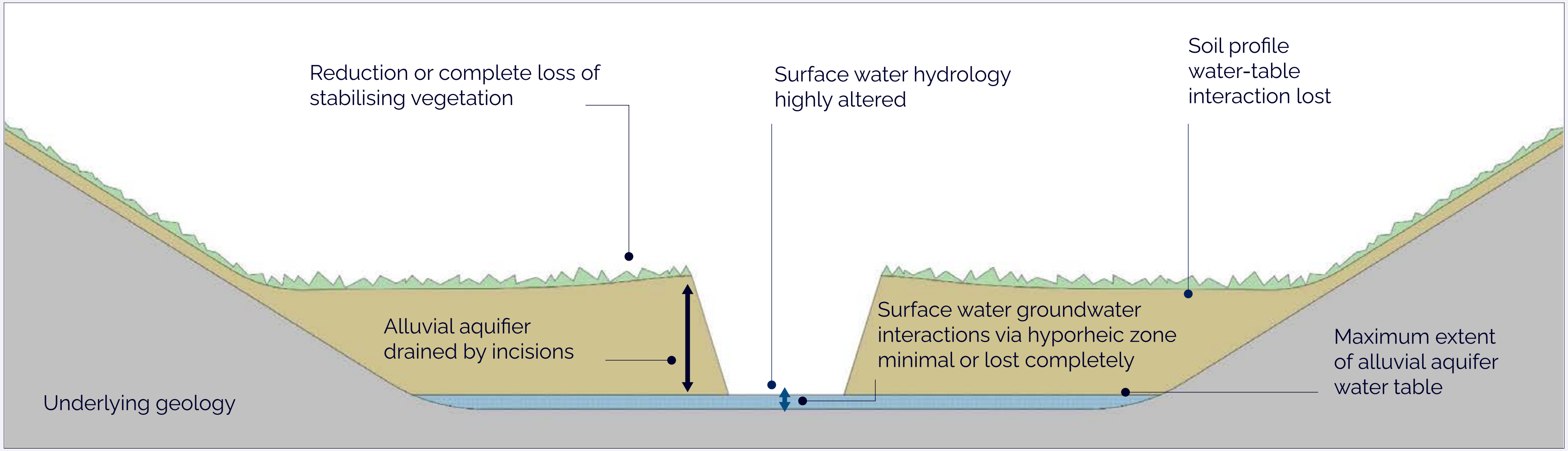
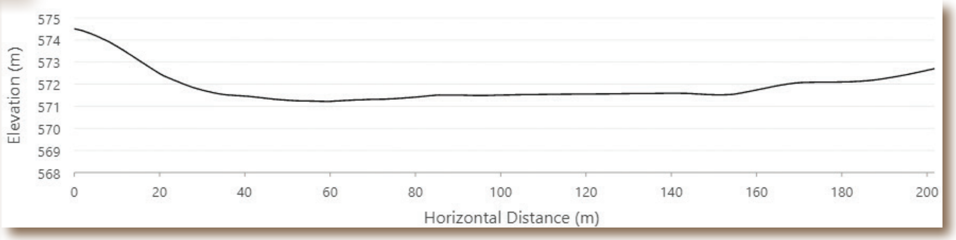
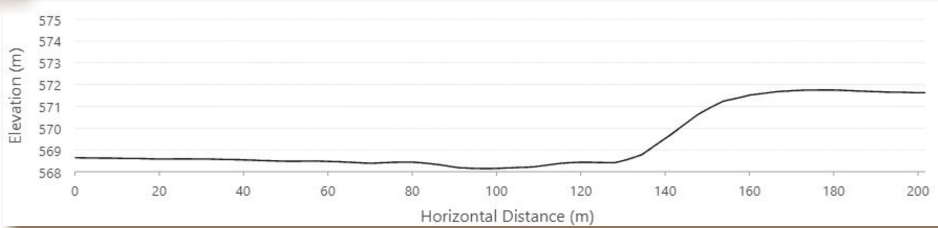


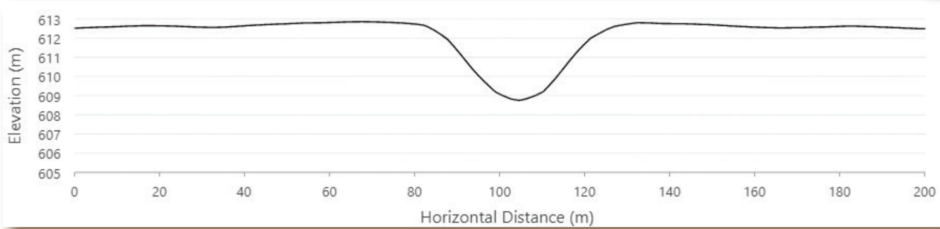
Figure 17: Incised valley floor diagram



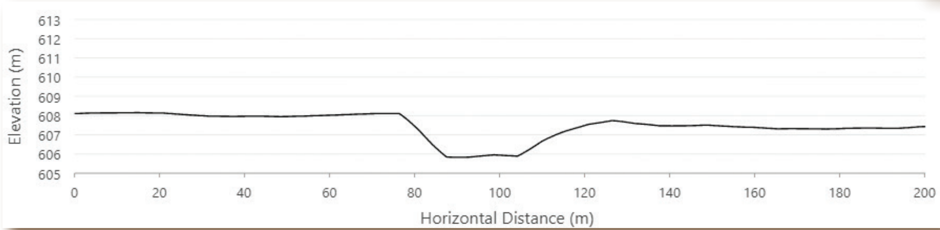
Burrumbowlie Swamp up-stream cross section,



Burrumbowlie Swamp down-stream cross section,



Manar Creek up-stream cross section



Manar Creek down-stream cross section

Figures 18 and 19: Comparisons of elevation profiles at cross-sections of Burrumbowlie Swamp (left) and Manar Creek (right).

Boro Creek, and several other tributaries of the Shoalhaven River, are installed with gauges that measure stream flow. This provides further data with which to compare how these waterways manage water. In 1999, the NSW Healthy Rivers Commission undertook a flow duration analysis of all gauged tributaries of the Shoalhaven River. It found that the flow duration curve for Boro Creek was noticeably different from the curves for other sites (see Figures 20 and 21).

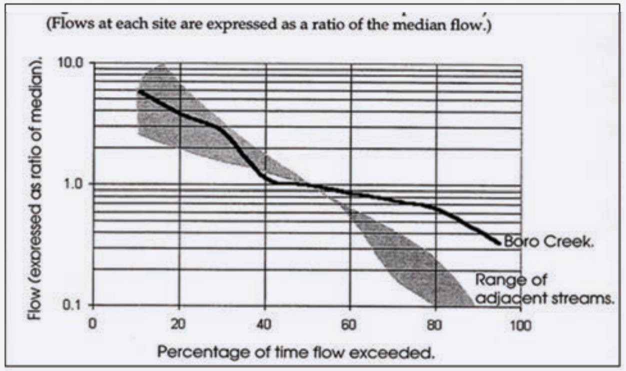


Figure 20: Graph from NSW Healthy Rivers Commission report (1999) comparing the flow duration curves for Boro Creek and several adjacent streams in the Shoalhaven catchment.

The flatter gradient of Boro Creek, at the gauging station downstream of Burrumbowlie Swamp, indicates that low flows were being maintained when other streams were drying out. The shape of the curve also indicates that Boro Creek experienced a reduced number of medium to high flows compared to the other streams. The Commission concluded that 'the different flow duration characteristics of the Boro Creek gauging site are the result of the delaying effect the Burrumbowlie wetland has on median flows. Median flows are temporarily stored and released slowly over time, providing reliable flows over a long period' (Healthy Rivers Commission of NSW, 1999).

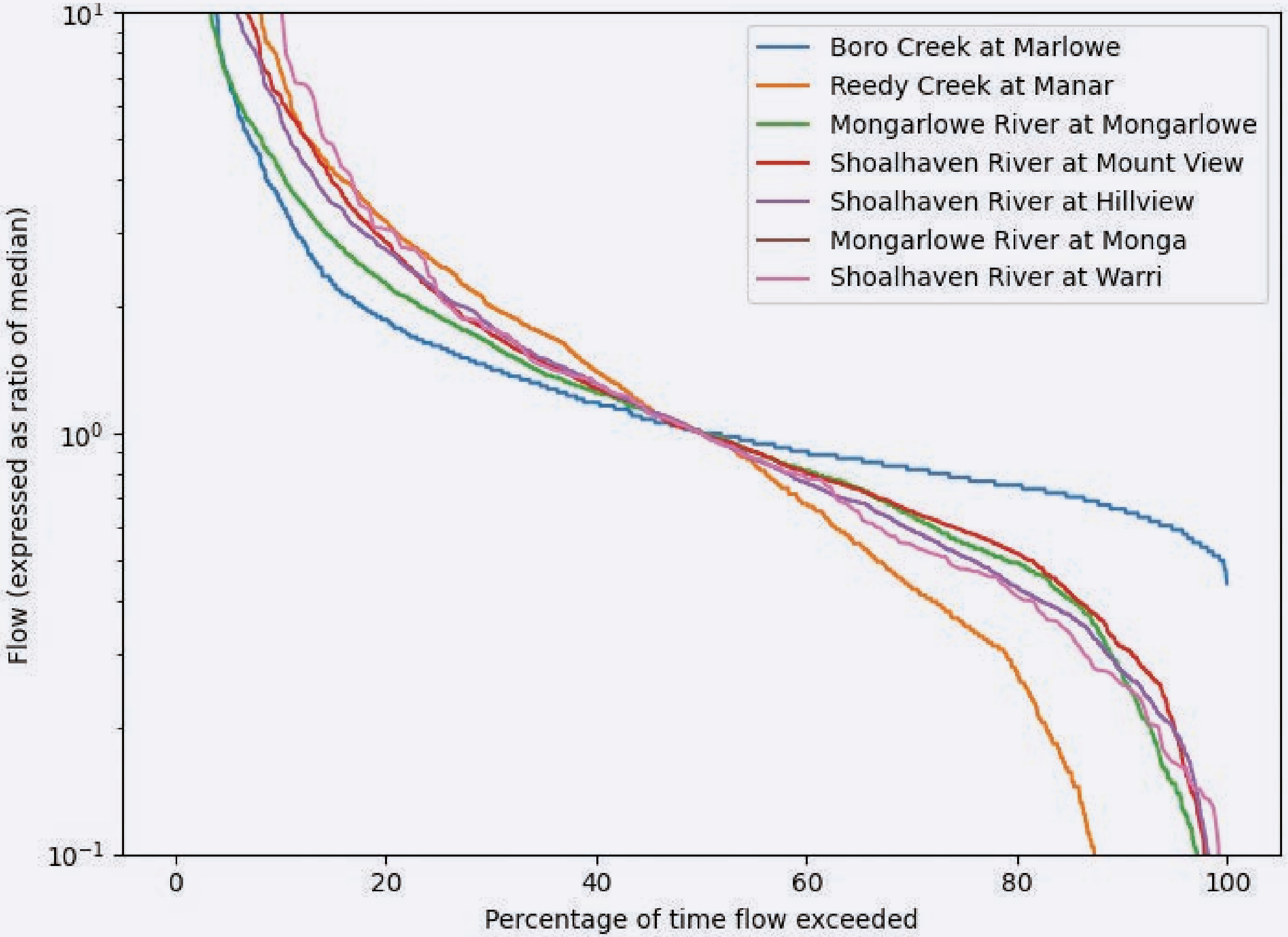


Figure 21: Flow duration curve of Upper Shoalhaven tributaries between 1990 and 1999, with data sourced from Water NSW WaterInsights portal (indicating trends over a similar period to the data illustrated in the 1999 Healthy Rivers Commission report).

More recent data sourced from the WaterInsights portal (WaterNSW 2024) from these same gauging stations, show that Boro Creek's distinctive flow characteristics persist to this day. Figure 22 compares how the flow over time at each stream gauge varies from the median flow. Flatter curves - such as Boro Creek's in this case (shown in blue) - indicate steady and consistent flows, while steeper gradient curves indicate that higher flows are more frequent and lower flows are less frequent i.e. the system is drying out more quickly.

Manar Creek flows into Reedy Creek just upstream of the Reedy Creek gauge (shown in orange in the graph). If the Manar Creek flow regime was like that of Burrumbowlie Swamp, the duration curves would have a similar profile: a low gradient curve throughout the centre of the graph. Although the upper catchment of Reedy Creek also needs to be considered, it can be assumed from the steeper gradient in the graph that the incised valley floor at Manar Creek does not allow for the storage of large amounts of water in the floodplain. This makes Manar Creek more dependent on regular rainfall to remain hydrated, which reduces its resilience.

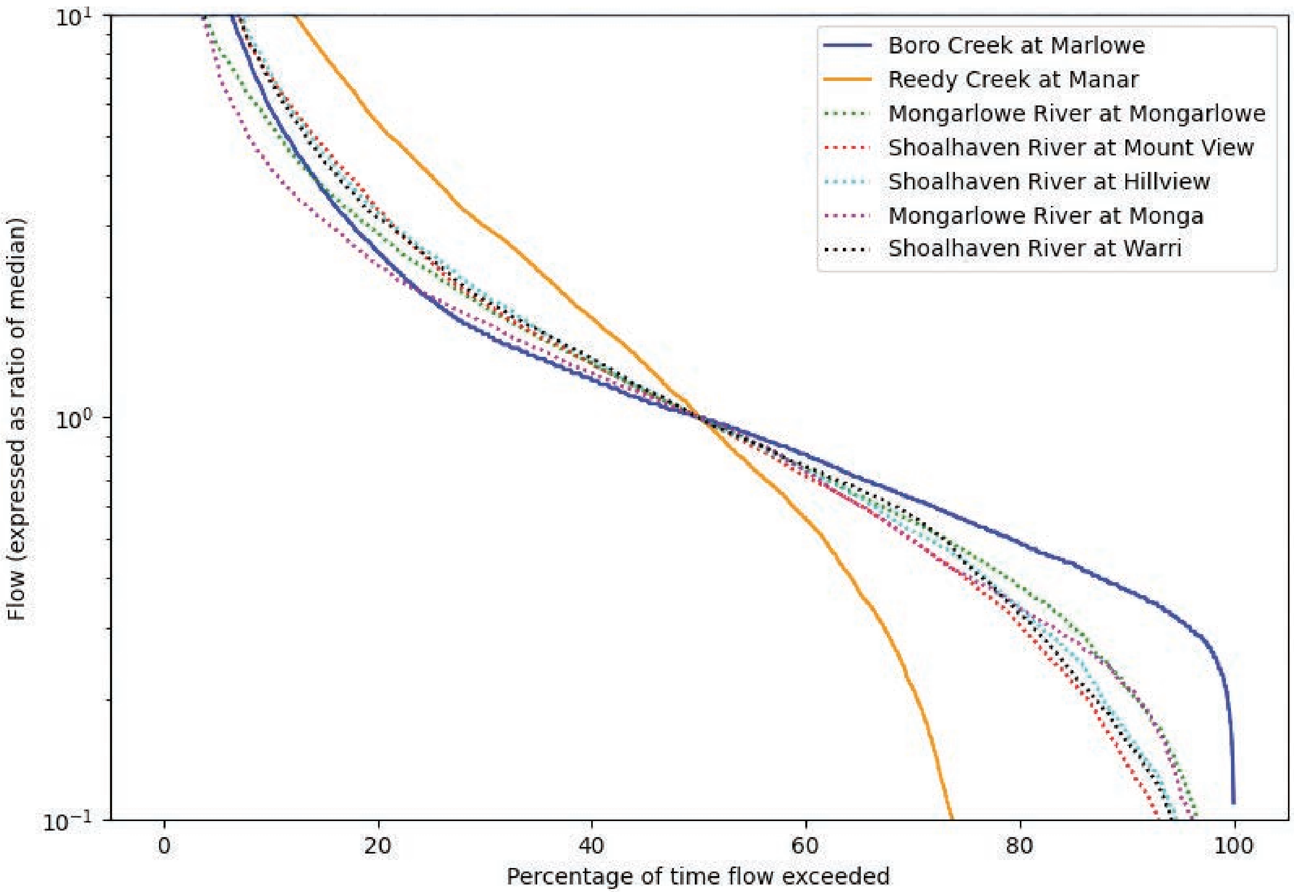


Figure 22: Flow duration curves of Upper Shoalhaven tributaries (1990 - 2024).

The different characteristics of Burrumbowlie Swamp and Manar Creek are also illustrated in Figures 23 and 24. These are infrared aerial images taken on 28 January 2014, the hottest, driest month on record for this area. The average maximum temperature for the month was 30˚C (3˚C above the long-term median), and on that day it was 34.5˚C. Rainfall for the month was 4 mm (48 mm below the long-term median). The previous month (December 2013) only recorded 22 mm rainfall.

In infrared aerial imagery, red tones represent vigorously growing vegetation, or 'greenness'. These images show that Manar Creek only displays greenness in the small treed areas in the creek corridor, whereas Burrumbowlie Swamp is maintaining a significant level of greenness despite the punishing conditions. The data tells us that:

- the valley floor is well hydrated
- the vegetation within the floodplain pocket is green and actively photosynthesising
- the floodplain pocket is much cooler than the surrounding landscape because of the high transpiration rate associated with the photosynthesising vegetation
- the temperature of the ponds is cool and close to the temperature of the underlying groundwater because they are both connected, which reduces evaporation
- dense vegetation in and around the ponds buffer wind, reducing evaporation
- the humidity close to the surface is higher than the surrounding landscape, and green leaf surface area is high, which reduces evaporation, and facilitates condensation and dew formation at night
- all of these processes minimise evaporation and drying of the land surface, protecting the landscape from extreme conditions
- these processes also moderate extreme climatic variations by supporting the maintenance of diverse, green, actively growing vegetation and its associated fauna.

These are all indications that the landscape is functional, something on which we elaborate in Chapter 3.

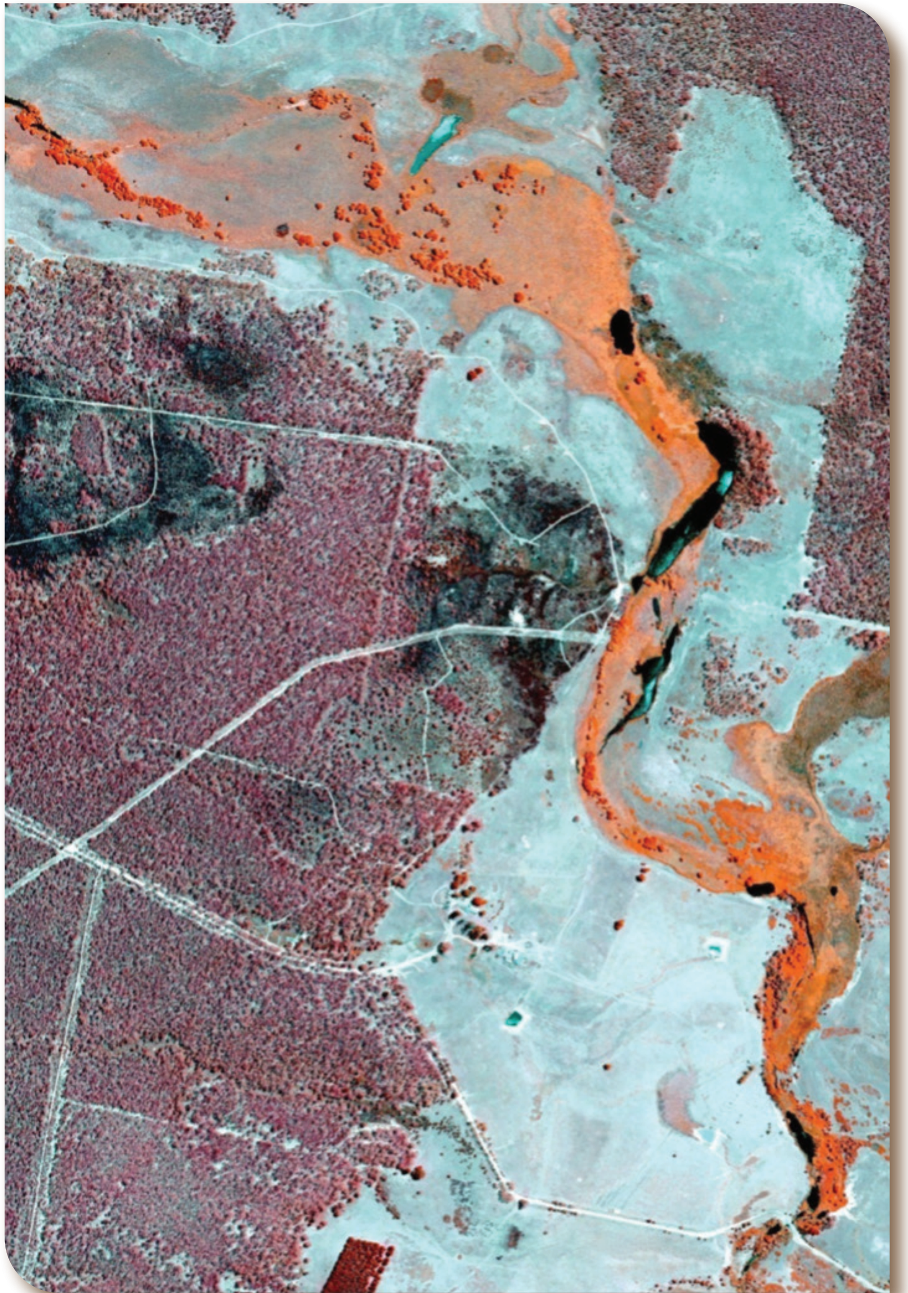


Figure 23: Infrared aerial image of Burrumbowlie Swamp, January 2014. The red colour indicates greenness. The black shapes are ponds of surface water.

Figure 24: Infrared aerial image of Manar Creek, January 2014.

Chapter 3: Landscape Rehydration fundamentals

3.1 A function-led approach

Landscape rehydration is about re-establishing natural processes in degraded landscapes so that every rain event drives improvements in landscape health and resilience. It focuses on natural processes that are well-understood by science and promotes principles and methods applicable to any landscape. Core to the approach is the recognition that a landscape is a complex and dynamic system, always adapting and never static. That system comprises various interconnected elements, each with a vital role to play sustaining the system. This is where the concept of 'landscape function' comes to the fore.

> *"High levels of dissolved nutrients and suspended particulates [in streams] indicate that the watershed is "leaky" and is not conserving soil and nutrients very well... The healthiest ecosystems are frugal, or tight, meaning they retain soil and nutrients."*
>
> Apfelbaum & Haney, 2010. 20-21.

Landscape function refers to the capacity of a landscape to retain and cycle resources, including water, carbon, nutrients, soil and biodiversity. It also refers to a landscape's capacity to capture and dissipate energy, and to meet the material, cultural and spiritual needs of its human inhabitants. These functions are vital to the survival of complex life. Landscape function is related to a landscape's resilience, which is its ability to resist or bounce back from shocks such as droughts, fires and floods. Restoration practitioners who adopt a function-led approach work from the standpoint that restoration is not 'about returning damaged lands to some notional "pristine" state; it is about repairing landscapes to an acceptable level of functionality' (Tongway & Ludwig, 2011. xix). Such an approach involves identifying where and why natural processes aren't functioning properly and taking strategic steps to repair and enhance them. In this publication we refer often to hydrological functions, which are the processes and interactions that govern the movement, distribution, and quality of water within the environment, including on the surface of the land, in the soil and underlying rocks, in the atmosphere, and in relation to living things.

'Catchment-scale' thinking is fundamental to this approach. To address the hydrological health of a system it is necessary to define its boundaries, and for landscape rehydration it is the catchment – an area of land where water flows to a common outlet - that constitutes this boundary. In saying this, catchments exist at multiple scales, as do the hydrological functions that sustain them (This is elaborated on page 59, The Hydrological Landscape).

> *"Functioning ecosystems cool themselves; they use solar energy for self-organisation and export entropy to the atmosphere as heat. These energy transformations are achieved by water and plants in the activity of evapotranspiration."*
>
> Pokorny et al, 2010. 333.

Functional landscapes have a high capacity to:

- capture and cycle water, carbon and nutrients
- dissipate the forces that can damage landscapes, such as the sun's heat, and high-energy flows of water
- provide habitats for populations of plants, animals and micro-organisms
- sustain people by providing their material, cultural and spiritual needs.
- bounce back from shocks such as droughts, heatwaves, floods and wildfires.

Dysfunctional landscapes have:

- impaired capacities to maintain fundamental processes and leak vital natural resources
- limited capacity to bounce back from shocks
- a tendency to spiral downwards at an accelerating sometimes dramatic, rate
- limited capacity to support the thriving of communities of people and animals.

Derived from Tongway & Ludwig, 2011.

3.2 Repairing landscape systems, healing Country

In foregrounding a 'systems-approach' to landscape function, landscape rehydration is not promoting something new but is rather connecting with ways of relating to landscape that are ancient and enduring on the Australian content. Indigenous perspectives on Country are deeply holistic. Of foundational importance is the interconnectedness of all living things, symbiotic relationships between the tangible and the intangible, and reciprocity between people and Country (McKnight, 2015, Moggridge et al. 2022).

Landscape rehydration aims to be compatible with a Country-centred approach to healing landscapes, and to work alongside First Nations knowledge and practice. It acknowledges the social challenges of doing this in agricultural contexts but aims to take positive steps in a respectful and collaborative spirit. It aims to be part of a landscape management culture in which First Nations-led projects on Country become more commonplace, and community and cultural values enliven our understanding of landscape health and nature repair.

This approach entails acknowledging that all nature repair projects are social projects. Many social systems overlap with and shape landscape systems, for example the agricultural economy, the local community and various governing jurisdictions.

Figure 25: Scar Tree and Water Ceremony at Coorongooba, Glen Davis, Wiradjuri Country, led by Dabee Wiradjuri elder Peter Swain. Photo by Alex Wisser.

Figure 26: Scar Tree and Water Ceremony at Coorongooba. Photo by Alex Wisser.

> *"Caring for Country is holistic, with the physical interconnected with the social, the cultural and the spiritual. Sustainable environmental practices are embedded in our culture through traditional hunting, harvesting, and managing plants and animals. Our cultural expressions reflect our symbiotic relationship with Country. Our stories are evidence of the countless generations of interaction with and nurturing of Country, and we continue to speak, sing and to enact our connections... , the health of the land, water, sky and people are deeply interconnected. If Country is sick, our people are sick. Healing Country means healing ourselves."*
>
> Janke et al, 2021, 10 -11.

When landscape rehydration projects are scoped and planned, the cultural and emotive meanings of landscapes, the economic drivers of land use, and the concerns of various stakeholders are all factored in.

> ***"Seeing Country teaches people how to hear with their eyes and to be 'regenerative learners'... respect, responsibilities, reciprocity and relationships will develop if Country is at the core of decisions made in respectful relationship."***
>
> **McKnight, 2015, 14-16**

Adopting this kind of integrated approach to nature repair and landscape resilience focuses our attention on various cycles and flows that are dynamically in play in every landscape system. Specifically, practitioners of landscape rehydration are attentive to:

- flows of energy from the sun that drive photosynthesis but can also heat up and dry out landscapes
- flows of gravitational energy impelling water and everything it carries – sediment, organic matter, nutrients – downhill. These flows drive processes of erosion and deposition that can both degrade and rehabilitate landscapes
- the water cycle, which moderates local climate by managing the colossal energy of the sun through transpiration (cooling) and condensation (warming)
- the carbon and nutrient cycles, in which plants photosynthesise – and other organisms metabolise – the food they need to survive, and distribute it around the ecosystem through their movements, sustaining a constantly regenerating web of life
- the flows of social, cultural and economic capital and meaning that shape a landscape, including agricultural land management, stewardship practices and so on.

When they are assessing landscape condition, landscape rehydration practitioners seek out the indicators of these flows and cycles – where are they occurring? Where are beneficial flows disrupted, broken or vulnerable? How can our actions catalyse and/or complement nature's own regenerative mechanisms?

3.3 Tracking the trajectory of a landscape

Embarking on nature repair with landscape rehydration strategies requires us to assess where a landscape system sits on a continuum between functional and dysfunctional, and to interpret the shocks, drivers and feedback loops that are pushing that landscape in a positive or negative direction.

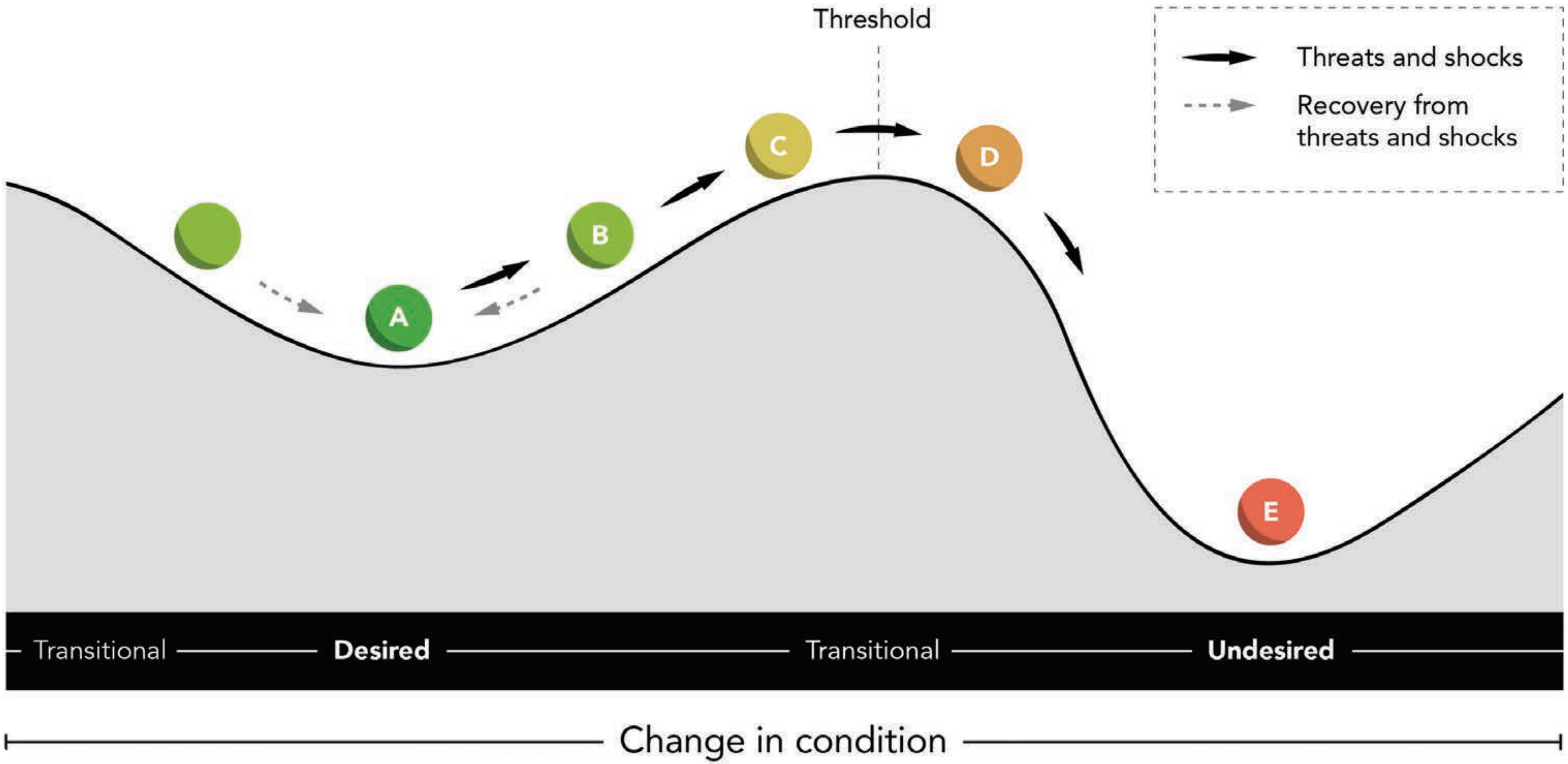


Figure 27: Systems resilience diagram (adapted from SELLS 2014, p. 33).

Figure 27 presents an illustration of this. The ball – the system – is sitting within a desired condition state (A). When it is subjected to a shock it is pushed towards a different condition state (B). If the ball is resilient to shocks, it will settle back into a desired condition state (A) when the shock passes. If the ball is not resilient to shocks, it will be pushed towards a threshold (C). Continued shocks could see the ball transition beyond the threshold (D) and tip into a completely different, undesired, condition state (E). The function-led approach mapped out in this publication focuses on helping landscapes to default to state (A) despite negative impacts, and even progress to a more biodiverse and hydrated state over time.

Figure 28: Headcuts migrating upslope

Landscape trajectory is not linear and can change rapidly. A small patch of bare earth caused by cattle movement can become an erosion gully after a rain event, with a headcut advancing up-slope that over time becomes substantial (see Figure 28). A series of shocks, such as a drought, followed by bushfires and/or floods, can dramatically change the condition and trajectory of a landscape. What may have appeared as a healthy, functional ecosystem yesterday, may today be a burnt out and eroding wasteland. A landscape's ability to resist and to bounce back from shocks is a test of its resilience.

Drivers also influence landscape condition in both positive and negative directions. A driver could be a new grazing regime, a new road, or a neighbour's decision to regenerate a riparian area upstream.[10] By addressing the core issues that affect how a landscape functions, landscape rehydration aims to create buffers for the impacts of shocks and negative drivers and use nature-based solutions to drive positive change (see Figure 29).

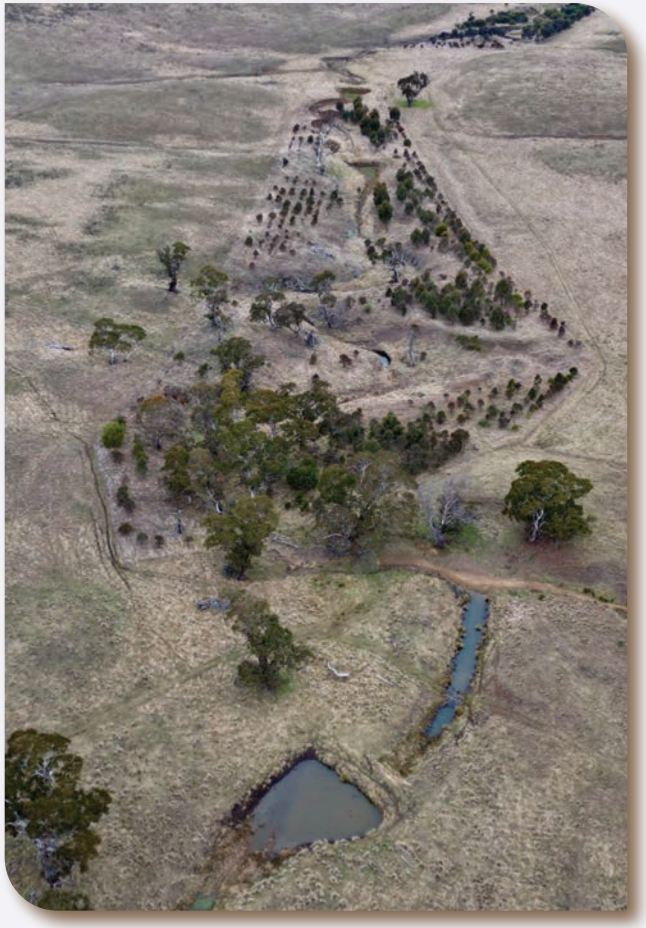


Figure 29: A formerly incised stream with active erosion that has been repaired with natural infrastructure and improved land management in the Monaro region. The scar of the incision is still clearly visible, however the site is regenerating due to plantings, a grazing regime that maintains 100% groundcover, and a series of ponds. Photo by Charlie Maslin.

10 *For relevant examples of drivers, see Peel and Hazell et. al (2022), p. 36.*

3.4 Plants: Landscape Rehydration's heroes

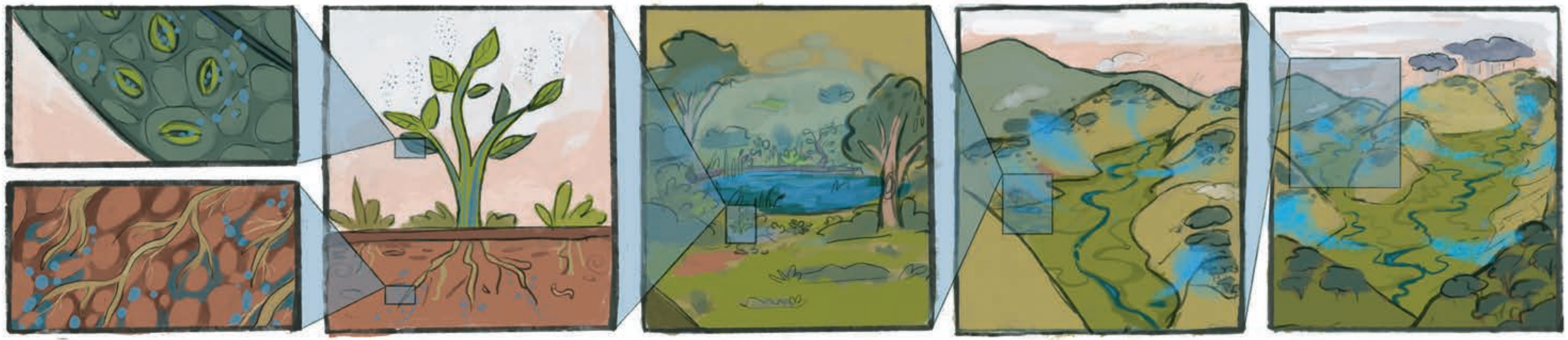


Figure 30: Scales of the small water cycle. Illustration by Tilda Joy.

All landscape rehydration projects are ultimately about increasing plant cover and diversity, because plants – having been on the earth for 460–500 million years – are fundamental to all the functional flows and cycles listed above. Plants provide shade, shelter, habitat, food and many other functions, however landscape rehydration focuses on two additional functions that are sometimes underestimated in ecological restoration.

The first of these is the role plants play in driving and tempering the small water cycle, and in moderating temperature extremes. During the day, plants respond to the onslaught of solar energy by transpiring enormous volumes of water into the atmosphere. Like a giant evaporative air conditioner, this vapour also absorbs enormous quantities of heat, which cools the surrounding environment. At night, under cooler conditions, that vapour condenses again into dew on the leaves of plants, and releases heat, which also moderates the nighttime temperature. This hydrating cycle works at multiple scales, from tiny microclimates to large catchment areas (see Figure 30). Simultaneously, plants are capturing carbon and converting it into sugars to drive the food chain and emitting oxygen which provides us with a breathable atmosphere.

The second function of plants that is a primary focus for landscape rehydration is their role in diffusing the power of water as it moves through a catchment. The flood tragedies unfolding globally attest to the power of moving water to erode and destroy. In the long run, it is only plants, building soil, feeding its microorganisms, holding the soil together, and providing friction through complex surface features, that can prevent this and indeed rebuild landscapes that are resilient to forceful flows.

> ***"Areas with an even cover of vegetation, with sufficient evaporable water, have more predictable weather events than do damaged areas without proper vegetation cover."***
>
> **Ripl, 2003, 1925**

3.5 An integrated approach to catchment health

Landscape rehydration projects require thoughtful decision-making when it comes to site selection, allocation of resources and sequence to ensure that the restoration of landscape function remains the foremost objective. While plant recovery is always prioritised, in certain circumstances degradation may be so severe that structural interventions, involving natural infrastructure, are necessary to stabilize a given landscape and support the rebuilding of its natural function and resilience. However, natural infrastructure is never treated as solely an engineered solution that makes other land management alterations redundant. It is always necessary to contextualise natural infrastructure solutions within an integrated vision of landscape repair and resilience. For example, while an incised stream may need structural intervention to prevent the streambed and banks from eroding further (see Figure 31), the efficacy of that intervention will still depend on effective management of riparian, floodplain and up-slope areas to diffuse the energy of water that enters the stream from the surrounding landscape.

To navigate these decisions, practitioners adopt a 'catchment-scale' or 'landscape-scale' vantage point to plot the problem/solution pathway, and work with a well-tested guiding framework for decision-making that prioritises plant recovery (see page 64). This ensures that practitioners and land managers together evaluate how different parts of the 'landscape mosaic' influence each other, and where positive and negative drivers exist that will support or constrain a nature-repair project.

These principles are shared via capacity-building events and relationships, which also support land managers to continue to make adaptive decisions for the long-term resilience of the landscape. Figure 32 is an example of a property plan in which fencing, revegetation and new watering points were an integral part of a rehydration project that included several in-stream structures. This successful project is documented in the Lorrina case study on page 110.

Figure 31: A channelised stream in which it is clear there is nothing to prevent the streambed from lowering further if high energy flows move through the catchment.

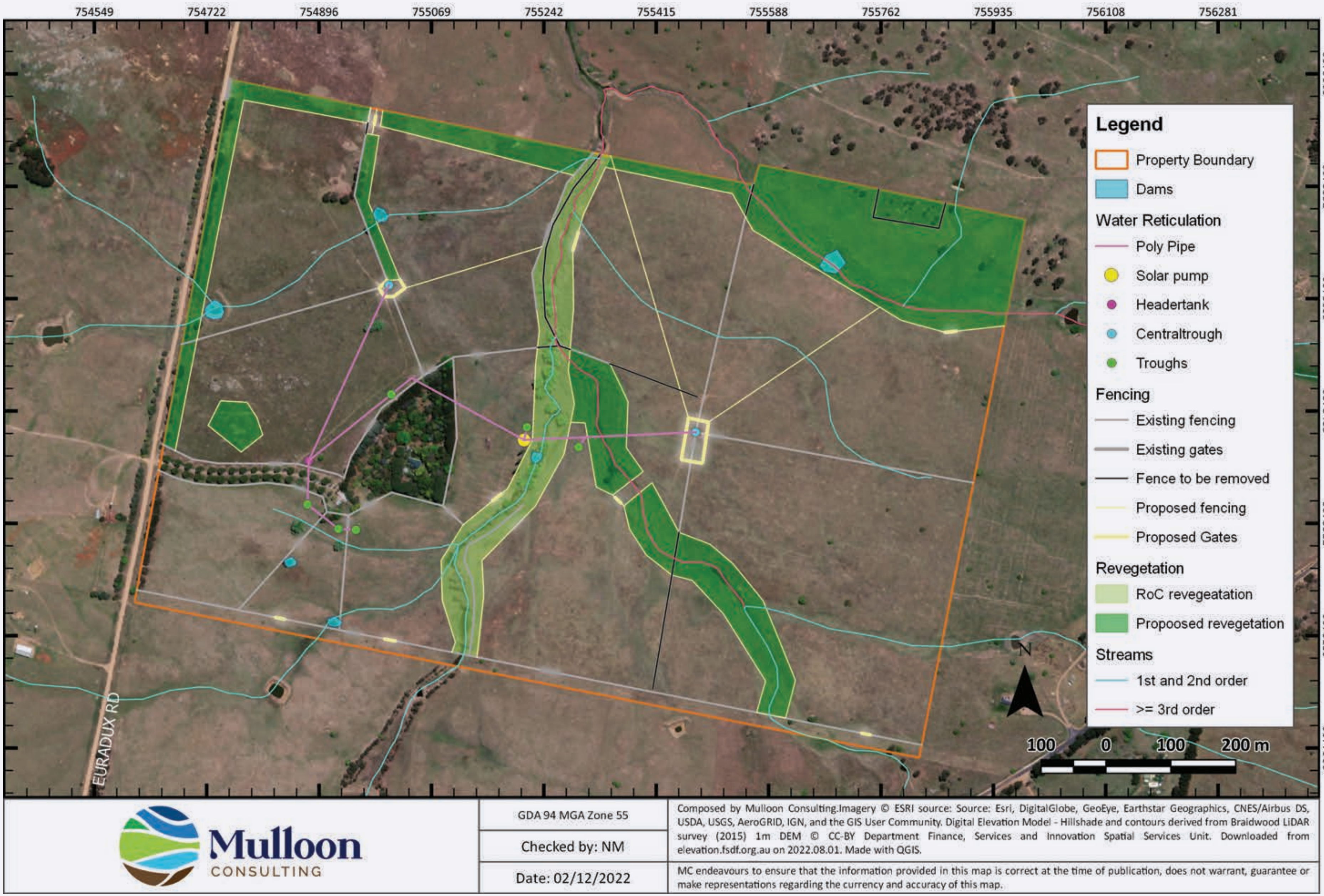


Figure 32: A whole-of-landscape plan was created for the Lorrina landscape rehydration project (see case study on page 110).

Figure 33: Healthy aquatic vegetation captures and filters sediment, stores carbon and diffuses the energy of fast flowing water.

Figure 34: Observing flow patterns in miniature at a landscape rehydration workshop.

Figure 35: A gully that is regenerating thanks to the use of natural infrastructure, plantings and natural regrowth. See the Wamboin case study for more detail (page 106).

It is now possible to summarise how landscape rehydration principles and practices address WaterNSW's catchment health objectives, specifically, how they drive improvements in water quality, water security and overall ecological health. The table on page 43 synthesizes information that is elaborated in detail in the remaining sections of the publication. Here its purpose is to be a snapshot and scene setter; to highlight the array of benefits that can be achieved when landscape rehydration is incorporated into nature repair.

Water Quality	Water Security	Overall Ecological health
Increased groundcover and riparian vegetation intercepts and de-energises flowing water, reducing the quantity of sediment and pollutants that enters streams. Plant roots keep streambanks stable and also prevent sediment from entering the stream.	Increasing amounts of vegetation cover, and green leaf surface area, promotes the water cycle – transpiration and condensation – at multiple scales. This helps balance a catchment's water requirements, driving greater climate and drought resilience.	Reduced streambank erosion and sediment movement improves ecosystem health and habitat in waterways. For example, clear water increases light penetration, improving instream photosynthesis, which increases oxygen levels and availability of benthic food. Reduced scour of the stream bed (due to slower flows) means invertebrates aren't dislodged and spawning cycles aren't disrupted.
Fencing and grazing management protects streams and other water bodies from pollutants.	Increased vegetation cover provides shade, cooling, and wind protection to the land surface and to water bodies. This reduces evaporation rates, increases soil infiltration, and moderates temperature fluctuations.	Re-establishing the functional connection between streams and floodplains improves the complexity and vigour of in-stream, riparian and floodplain vegetation communities. It also improves the ecological function of sub-surface areas such as the hyporheic zone.
Natural infrastructure within erosion gullies slows down flow and creates conditions for plant recovery and sediment capture. This reduces the amount of sediment and pollutants that reach our waterways.	Slower water movement through catchments increases infiltration rates, increasing the volume of water stored in soils and aquifers. Wetlands and swampy areas also stay saturated for longer periods.	More stable stream forms, ponds, and more complex stream structure increases and improves habitat for fish, macroinvertebrates and other aquatic animals. Natural features that can return include pool and riffle sequences, woody debris, snags and logs.
Natural infrastructure in degraded streams, coupled with increased riparian and instream vegetation, reduces stream power, thus reducing streambank and bed erosion. This allows complex stream structure and habitat to re-emerge, which helps to filter out sediments, pathogens and other pollutants.	Natural infrastructure helps to improve base flows and reduce peak flows. This helps intermittent streams to flow for longer, which increases water availability and drought resilience.	Agricultural production and ecological regeneration are in greater synergy, which drives improvements in biodiversity. Healthier vegetation in all areas of the landscape increases photosynthesis, leading to greater carbon storage in soils, wetlands and waterways.

Chapter 4: Landscape Rehydration in Practice

4.1 Introducing the Hydrological Landscape

Practitioners of landscape rehydration perceive a catchment landscape as a mosaic of hydrological features. Like the human body, the structure of a catchment is not random. From the ridgelines down to the valley floor, every feature has a function that has been established through the interaction of ecosystems, water, climate and underlying geology over millennia. Hydrology-focused nature repair projects aim to re-establish functional connections between land and water and between soil, plants and atmosphere in situations where they have been disrupted or broken. This includes addressing the causes of soil erosion, creating long-term improvements in vegetation condition, enhancing biodiversity, regenerating waterways, and reactivating local water cycling.

In this section, we start with the catchment as the primary landscape unit and then identify six features that can be found throughout the Sydney catchment area:

- ephemeral drainage lines / natural gullies
- streams
- alluvial fans
- wetlands
- river floodplains and floodplain pocket systems
- swampy meadows and chain-of-ponds.

These are each depicted in Figure 36. Knowing the function of each of these is vital to assessing how well the water, nutrients and carbon are cycling through any landscape. This also equips us to interpret how well the landscape is dissipating the energy of the sun, or of water under the power of gravity. These fact sheets have been designed to support project planning, to ensure they are informed by landscape-scale thinking and enhance nature's own healing processes. They also provide the context for the Regenerative Strategies outlined in sections 4.3 and 4.4. Restoring hydrological features to their pre-settlement state may not be feasible, however by supporting them to regain function we can set them on a positive trajectory towards vastly improved resilience. Doing so will yield many co-benefits, including improved water quality and availability, and greater tolerance of climate extremes.

***Hydrological functions** are the processes and interactions that govern the movement, distribution, and quality of water within the environment, including on the surface of the land, in the soil and underlying rocks, in the atmosphere, and in relation to living things.*

4.2 Hydrological Features Factsheets

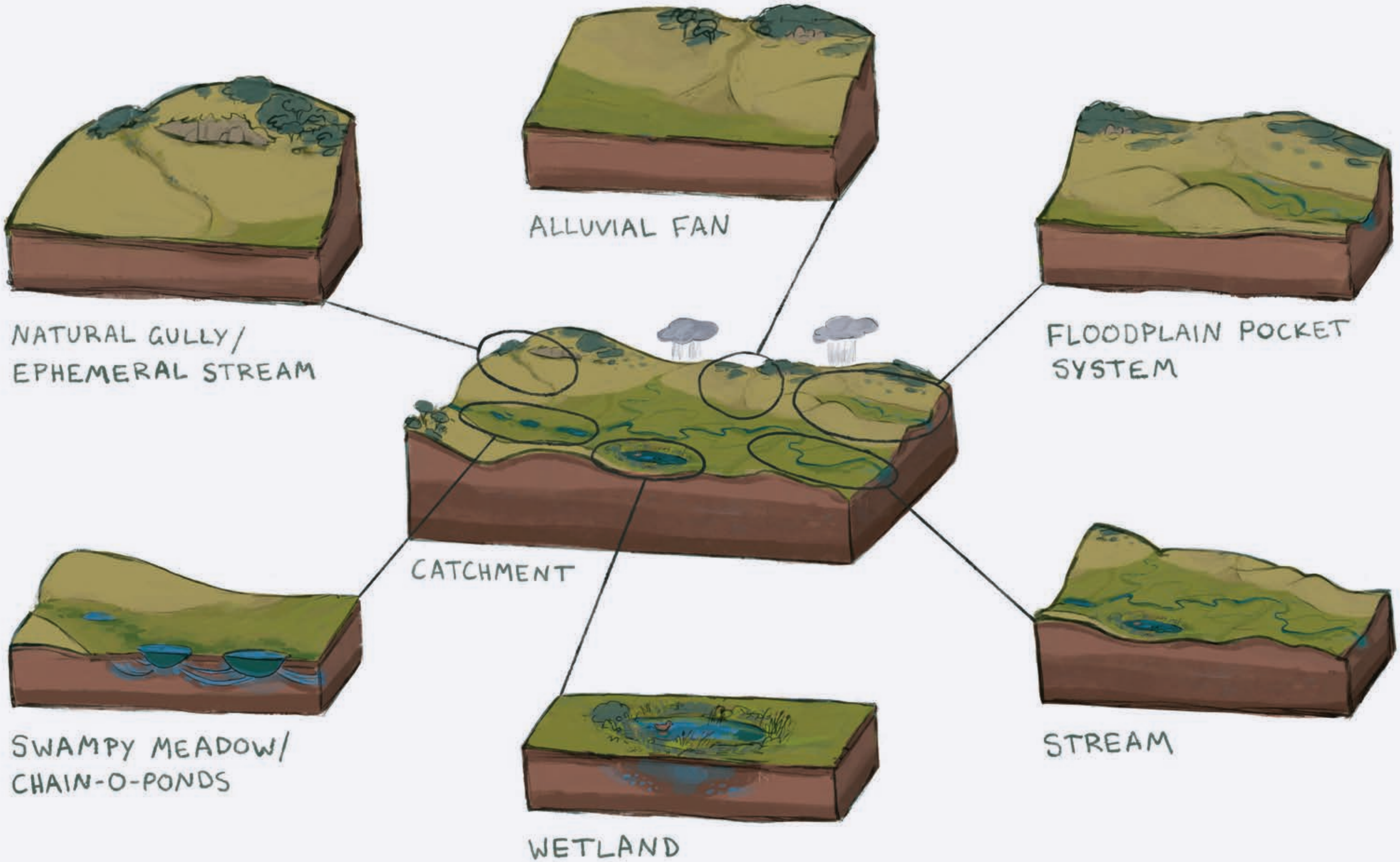
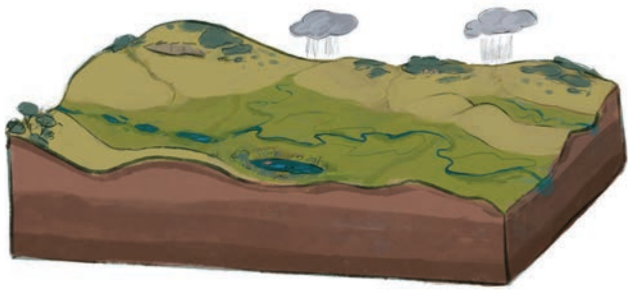


Figure 36: Hydrological features of the Sydney catchment area. Illustration by Tilda Joy

Catchments



A water catchment is an area of land in which all rainfall, streamflow and groundwater flows to a common outlet, such as a river, lake or ocean bay. They are usually made up of several 'sub-catchments'. These are smaller, more localised catchments where water flows into a smaller tributary or stream, before eventually flowing beyond. For example, Bungonia Creek is a sub-catchment of the larger Shoalhaven River catchment.

A note on scale: A catchment can exist at any scale. It can be as large as the Murray–Darling Basin or as small as a suburban backyard. Therefore, catchment processes are applicable at any scale.

What is the hydrological function of a catchment?

A catchment collects water from rainfall, dew, surface runoff, and groundwater flow, and stores it in various forms such as soil moisture, groundwater, and surface water bodies (such as streams, ponds and wetlands). Healthy catchments regulate water movement through the landscape (through vegetation, soils and hydrological features), attenuating peak flows during heavy rainfall and maintaining base flows during dry periods. Additionally, natural processes within the catchment improve water quality by filtering out pollutants and sediments, and by recycling nutrients. Importantly, healthy catchments also maintain an active small/daily water cycle, which can also moderate its microclimate and improve water quality.

It is useful to see catchments as containing inter-connected source and depositional zones. Source zones tend to be in the upper parts of a catchment – ridges and steeper slopes, while depositional zones tend to be in the lower parts of the catchment – gentler slopes and alluvial features such as fans and floodplains.

The hydrological processes of each zone are intricately linked to the different vegetation communities and habitats to be found there. In a healthy catchment, water, nutrients, and carbon effectively cycle between source and deposition zones and vice versa. Because these zones in a catchment can directly influence one another, land regeneration strategies are best addressed from a whole-of-catchment perspective.

What are indicators of healthy catchments?

- Clean, clear water exiting the catchment.
- Rich biodiversity filling multiple niches above, on, and below the surface.
- Stable ridgelines and slopes: Steep upper-catchment slopes are well vegetated with minimal bare ground or visible erosion.
- High surface roughness: features such as vegetation create friction and slow and spread surface flows.
- Stable riverbanks: well-vegetated stream edges aren't eroding.
- Stable, generally low energy flow regimes: waterways that maintain a steady flow. The power of water is diffused by hydrological features within the catchment, reducing flood peaks, extending base flows during dry times, and creating deposition rather than erosion.
- Functional small water cycle: substantial plant cover is maintained across the catchment that maximises transpiration during the day and dew formation at night. Land surface temperatures are moderated, and there is frequent, localised precipitation.
- Solar energy is efficiently transforming into

biomass and latent heat.

- Healthy soils: stable, permeable soils, high in organic carbon, that support plant growth and resist erosion.
- Effective water filtration: 100% groundcover, multi-layered vegetation communities, healthy wetlands and riparian zones filter pollutants to improve water quality.

What are some indicators of an unhealthy catchment?

- Pollution and poor water quality.
- Erosion, resulting in loss of nutrients, carbon and water retention capacity.
- Disrupted or unnatural flow patterns (extreme flood peaks, extended periods of no flow).
- Water sheeting off the surface during rainfall events.
- Low surface water and/or groundwater availability.
- Poor and disconnected vegetation cover.
- Poor soil health – compacted soil, acidity, salinity, water logging, poor or no infiltration.
- Low biodiversity.
- Invasive species – lots of weeds and feral animals.
- Landscapes cannot manage solar energy and therefore dry out.

How can we regenerate catchments?

Approaches to restoring catchment health should be holistic, combining ecological objectives, sustainable land use practices, and community engagement. This requires collaboration between stakeholders working at the property, sub-catchment and catchment scale. This holistic approach ensures the long-term health and resilience of the catchment.

What are the signs of positive change?

Ecology

- Restoration of diverse connected and functional habitats throughout the catchment (wetlands, riparian areas, ponds, grasslands, woodlands, forests).
- Mosaic of diverse, well-structured vegetation from instream to hilltop habitats is sufficiently connected to enable long-term species survival.
- Diverse and abundant wildlife.
- Stable populations of rare and threatened species.

Hydrology

- Restored instream pools and aggrading flowlines.
- Reduction of flood peaks and sustained flows following significant rainfall events.
- Well-connected flowline and floodplain.
- Hydrated floodplain with high vegetation cover and greenness.
- Improved water quality.
- Lowered shear stress from high flows.
- Stabilised riverbanks (no erosion).
- Functional connection between surface water and groundwater is re-established.

Land Use

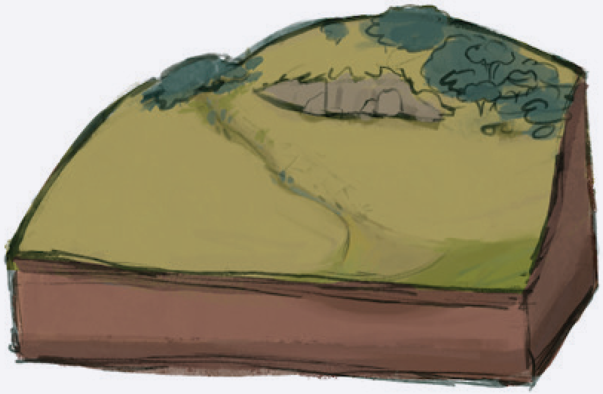
- Low impact and regenerative agricultural practices are becoming more widespread.
- Enhanced soil health.
- Substantial revegetation occurring (increased ground cover).

Social

- First Nations-led activities are supported, and plants, animals, materials that underpin cultural practices valued by First Nation people are present.
- Land stewardship knowledge is widely shared across multiple generations and the impact of land use practices is well understood.
- Sustained support by the wider community and its markets for adaptive and sustainable management and a willingness to pay for a range of ecosystem services.
- Sustained support for on-ground research, knowledge sharing and community cohesion.
- Improved traceability of regeneratively produced food and fibre, increasing market confidence.

Figure 37: A catchment landscape

Natural gullies / Ephemeral streams



A natural gully is a landform with steep sides created by running water. Natural gullies usually exist in steeper upper (source zone) areas of the catchment in concentrated points of water flow. Their shape is usually determined by the underlying bedrock. Natural gullies are also sometimes ephemeral streams where water flows after significant rainfall. This means they are often unnamed watercourses and thus can be undervalued.

Although gullies are often a natural hydrological feature, flowlines in intact upper catchment areas can have no discernible channel form, other than the natural topography of the surrounding landscape (for example, see Figure 38). When healthy, these flowlines are usually well-vegetated and have small catchment areas, which means they can dissipate and manage the erosive forces of surface flows. The vegetation acts to protect the ground surface and spread water across a larger area.

What is their hydrological function?

Natural gullies interact with the slopes that feed them to manage and slow the movement of surface water, as well as the movement and deposition of sediment. If well vegetated, which creates surface roughness, they can manage runoff and help prevent soil erosion. As they are hydrated more frequently and for longer periods than the surrounding landscape, they can host microhabitats and microclimates. This means they can be important sites of biodiversity.

Figure 38: A well-vegetated natural gully

What are indicators of a healthy natural gully?

- Stable banks: well-vegetated gully edges that have not eroded.
- Clean, clear water.
- Rich biodiversity: presence of diverse plant and animal species.
- High surface roughness.
- High levels of organic matter.
- Riparian vegetation: abundant native plants.
- Minimal erosion: little to no active soil erosion or sediment deposition.
- Healthy soil: stable, porous soil that supports vegetation growth, resists erosion and allows infiltration.

What are indicators of a degraded or unhealthy gully?

- Sparse vegetation within and surrounding the gully resulting in low surface roughness, and greater heating of land surface by solar energy.
- Disrupted or unnaturally fast flow patterns.
- Incised channel (deep, steep and narrow).
- Eroded banks (collapsing gully edges).
- Polluted and poor water quality.
- Reduced biodiversity.
- Invasive species.

Figure 39: A deep gully that is still actively eroding

What are some common risks to consider?

- Low ground cover.
- Concentrated runoff.
- Low channel roughness.
- Exposed and unstable soils.
- High runoff into gully.

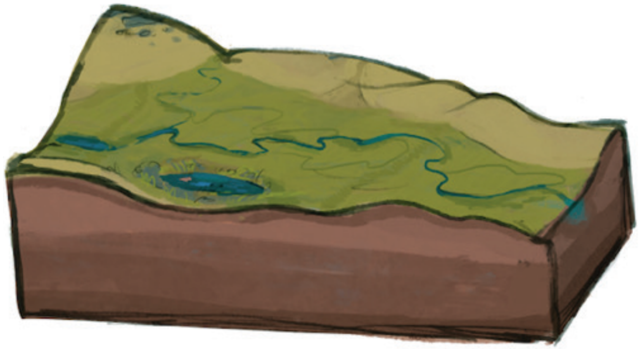
Figure 40: An erosion gully in which a rock weir has just been installed. The weir will slow flood flows, prevent further erosion and start to rebuild the gully floor by causing ponding and deposition.

What are the signs of positive change?

- Stabilized bed and banks.
- Improved water quality.
- Greater moisture retention.
- Increased vegetation and shift towards more sensitive species such as ferns.
- Biodiversity recovery.
- Reduced flow peaks and flow is moving more slowly.
- Increasing organic matter on the surface.
- Moderated microclimate (cooler, increasing dew formation and moisture retention).
- Soil becoming more friable and porous allowing greater infiltration.

Figure 41: A deep erosion gully that has healed and regained hydrological function, with aquatic vegetation taking advantage of ponded water.

Streams, creeks & rivers



A stream is a body of water, at least some parts of which are flowing. It can be classified as *perennial* (flowing year-round), *intermittent* (flowing seasonally or during certain times of the year), or *ephemeral* (flowing only briefly after rain events). Creeks and rivers are generally perennial flowing streams and are typically found in mid (transitional zone) and lower (depositional zone) catchment areas.

Although creeks and rivers are often natural hydrological features, it is common within the Australian context for single linear channels to flow through former intact chain-of-ponds, swampy meadows and braided channel floodplain environments (see fact sheets on 81-84). In such cases, these streams are a sign of degradation and loss of former hydrological function.

What is the hydrological function of a stream?

Streams play an important role in the water cycle, receiving and holding water and sediments from the surrounding landscape and moving excess flow into estuaries and finally the ocean. They also provide essential ecosystem services within a landscape, including water filtration, flood mitigation, nutrient cycling, temperature buffering and habitat for wildlife.

What are some indicators of a healthy stream?

- Clear, clean water.
- Rich biodiversity: presence of diverse plant and animal species.
- Stable bed and banks: well-vegetated and erosion-resistant stream edges.
- Stable flow regimes: waterways maintain a steady flow and water is diffused through ponds, floodplain features and sub-surface flows, reducing flood peaks and extending baseflows during dry times.
- Abundant and diverse riparian and instream vegetation that is also represented by endemic species with multiple zones and layers.
- Varied habitat for wildlife: mixture of shallow pools, deep pools, rock riffles and a diversity of aquatic vegetation layers and assemblages.
- Stable water temperature ranges for aquatic life.

What are some indicators of a degraded or unhealthy stream?

- Poor water quality, pollutants.
- Incised channel (deep, narrow and confined stream).

Figure 42: An eroded reach of Mulloon Creek, incised through to bedrock. Picture taken in 2015. To see how it has recovered following in-stream works implemented in 2018, see the 'Westview diary' on page 137.

- Eroded banks.
- Excessive sedimentation (water carrying sediment).
- Sparse vegetation.
- Disrupted or unnatural (for example - flashy) flow patterns.
- Reduced biodiversity.
- Habitat loss.

What are some common risks to consider?

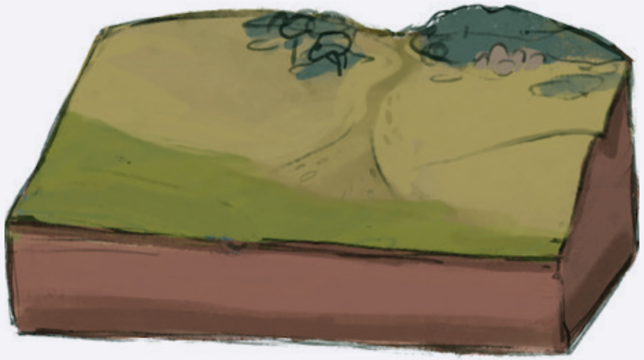
- Insufficient vegetation around the stream.
- Overgrazing.
- Agricultural runoff.
- Urban development.
- Poor irrigation practices.
- Poor waste management.
- Channelisation: altering of natural stream channels, disrupting flow and habitat.

What are the signs of positive change?

- Improved water quality.
- Stabilised bed and banks.
- Increased biodiversity.
- Restored flow patterns (e.g. restoring floodplain flows, increased periods of healthy/stable flows, reducing flood peaks and no flow periods).
- Increased stream bed heights.
- Improved productivity (agricultural and/or ecological) of surrounding landscape.
- Healthy and diverse plant assemblage.
- Enhanced habitat.

Figure 43: White-necked Heron, Mulloon Creek. Photo by Antony Mullhall

Alluvial Fans



ALLUVIAL FAN

An alluvial fan is a fan-shaped deposit of sediment formed where water flowing over the land's surface slows down and spreads out. They can be found where a confined valley transitions into a larger, less confined valley or plain. They can form at any scale, from the base of small valleys and natural gullies to large open watersheds such as the Murray–Darling basin. These formations are common in any landscape but are more obvious at the margins of mountain ranges.

What is the function of an alluvial fan?

Alluvial fans spread water across a wide, sloping, convex fan shaped area during a rainfall event. This reduces the energy of flowing water, causing sediment and litter to drop out and rest on the land surface. This depositional process creates fertile soil for vegetation.

What are indicators of a healthy alluvial fan?

- Vegetation cover that stabilises the soil, increases surface roughness and encourages deposition of sediments and organic matter.
- Spreading surface flow: water moving slowly over the land surface, spreading out and infiltrating into the soil.
- Biodiversity: a variety of plant and animal species indicating a balanced ecosystem.
- Deep friable, well-structured, biologically active soils that readily infiltrate surface flows.

What are indicators of a degraded or unhealthy alluvial fan?

- Sparse vegetation.
- Reduced fertility.
- Hard compacted surface.
- Lots of weeds.
- Channel incision and erosion gullies resulting in disconnection of surface flows from adjacent alluvial fan.
- Disrupted or unnatural flow patterns (e.g. water does not spread across the alluvial fan due to minimal vegetation, soil degradation and/or gully erosion).

What are common risks to consider

- Low groundcover.
- Low vegetation.
- Post-fire susceptibility.
- Intensive agricultural practices on the alluvial fan and/or in the upstream catchment area).
- Placement of farm infrastructure.
- Vulnerable areas up-slope from the fan.
- Headcut formation downstream or along alluvial fan.

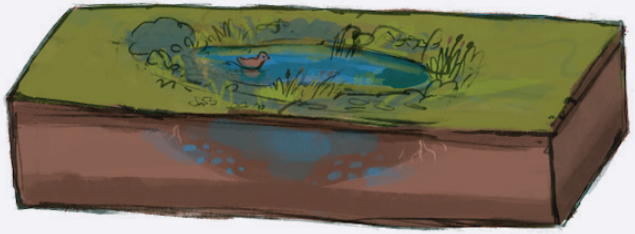
What are the signs of positive change?

- Little evidence of water lying on the surface during rainfall events meaning greater infiltration.
- Spreading and slow movement of any surface flows.
- Deposition of sediment, especially organics.
- Increased vegetation cover.
- Improved biodiversity.

Figure 44: Alluvial fans are often subtle, and therefore under acknowledged as important hydrological features where nature repair can be achieved.

Figure 45: This image shows a series of valleys with fans at their base. An erosion gully has cut through one of them, likely the result of stock accessing the dam.

Wetlands



A wetland is an area where water saturates the soil either permanently or temporarily (e.g. in the case of ephemeral, intermittent or seasonal wetlands), creating distinct ecosystems. There are various types of wetlands, including perched wetlands, peatlands, groundwater-controlled wetlands, surface water-controlled wetlands, and floodplain wetlands.

What is the hydrological function of a wetland?

Wetlands play a crucial role in groundwater recharge, allowing water to seep into the ground and replenish aquifers. Wetlands also act as natural water purifiers, filtering out pollutants and sediments from the water. As they are cool and humid areas, they manage the sun's heat in ways that benefit the wider landscape and serve as refuges for wildlife during dry times. Additionally, they help to mitigate flooding by absorbing excess rainfall and reducing the speed and volume of runoff. Wetlands are also natural carbon sinks.

What are indicators of a healthy wetland?

- Hydrophytic vegetation: presence of water-loving plants like cattails, sedges, and rushes.
- Hydric soils: soils that are saturated with water, often dark and rich in organic matter.
- Consistent water levels: areas are regularly saturated or inundated, maintaining a stable water table (this is more relevant to permanent surface-water controlled wetlands or groundwater-controlled wetlands).
- Natural water flow: Attenuated water flow that moderates energy, reduces erosion and increases the cycling of water and nutrients.
- Rich biodiversity: presence of diverse plant and animal species.
- Minimal erosion: stable soils resistant to degradation

What are indicators of a wetland being degraded or unhealthy?

- Sparse vegetation.
- Invasive species.
- Pollution.
- Altered hydrology causing them to dry out.
- Erosion and sedimentation.
- Reduced biodiversity.

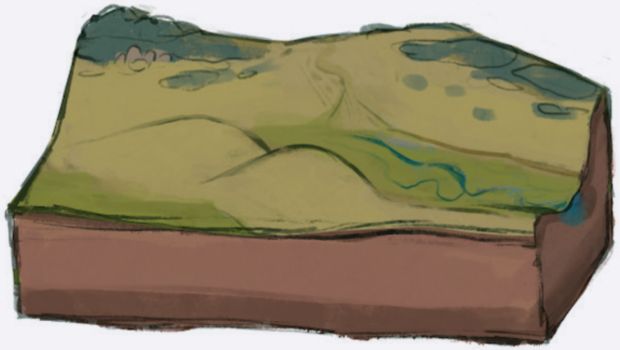
What are common risks to consider?

- Drainage and diversion of water from wetland areas.
- Overgrazing.
- Unstable soils.
- Pollution.
- Invasive species.
- Land clearing.
- Wildfires.
- Peat extraction.

What are the signs of positive change?

- Increased wetland vegetation (abundance and diversity).
- Improved water quality.
- Stable water levels and/or restored hydrological regime.
- Enhanced biodiversity.
- Reduced erosion.
- Natural water flow.

River floodplain & floodplain pocket systems



A river floodplain is a flat or gently sloping area adjacent to a river or creek, formed by the stream's sediment deposits and subject to periodic flooding. Floodplain pockets are similar, however they are typically found in upland valleys. They are characterised by fertile soils that support dense vegetation like grasses, sedges, and rushes.

What is the hydrological function of a floodplain or floodplain pocket?

These are depositional parts of the landscape which play an important role in capturing and cycling carbon and other nutrients. These areas are closely connected to the underlying groundwater. They act as natural sponges that absorb floodwaters, and then slowly release them, thereby maintaining moisture levels and supporting diverse ecosystems.

What are indicators of a healthy floodplain?

- Hydrological connectivity: there are natural surface and sub-surface connections between the river and its floodplain (both laterally and longitudinally), allowing for regular flooding and exchange of nutrients.
- Natural stream form: there is a meandering main channel interlinking with secondary and tertiary flow paths that are braided or have a chain-of-ponds structure.
- Diverse vegetation.
- Stable soil and banks.
- Water quality: clear, clean water with low levels of pollutants and sediments.
- Rich biodiversity.
- Groundwater recharge: effective infiltration of water into the ground, replenishing aquifers.

Figure 46: A pond in a healthy floodplain system.

What are indicators of a floodplain being degraded or unhealthy?

- Single, continuous, linear channel.
- Severe incision resulting in stream surface water levels well below the adjacent floodplain surface.
- Erosion of floodplain sediments.
- Poor water quality.
- Loss of vegetation.
- Reduced biodiversity.
- Disconnected hydrology from floodplain.

What are common risks to consider?

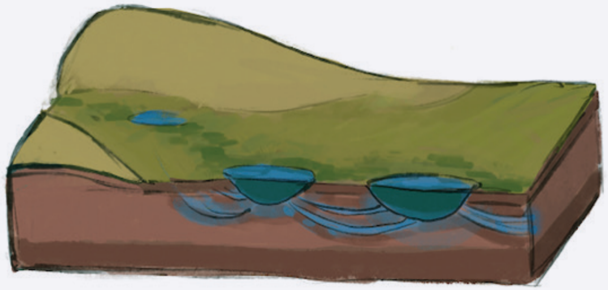
- Placement of farm infrastructure.
- Intensive agricultural practices.
- Pollution.
- Water drainage, extraction or diversion.
- Feral animals.

What are the signs of positive change?

- Improved water quality.
- Stabilised bed and banks.
- Enhanced downstream flows.
- Reduced high flow peaks.
- Extended baseflow periods.
- Reduced cease-to-flow events.
- Increased biodiversity.
- Healthy vegetation.
- Enhanced habitat.
- Ponds maintain their level during dry periods.
- Increased greenness of floodplain vegetation.

Figure 47: A floodplain in which an incision has formed, and the damaging effects of grazing are visible

Swampy Meadows and Chain-of-Pond Systems



SWAMPY MEADOW / CHAIN-O-PONDS

A swampy meadow is an ecosystem characterised by often wet soils and diverse vegetation such as sedges and grasses. They are similar to floodplain systems, however in a natural state they don't feature a continuous channel. Swampy meadows are often found in upland valleys. In some swampy meadows a chain of ponds system may also be present. Such systems can comprise multiple deep pools bounded with areas that are periodically inundated.

What is the hydrological function of swampy meadow/chain-of-ponds systems?

Swampy meadows and chain-of-pond systems are generally grassland environments that effectively retain and cycle moisture. They support diverse plant and animal communities and are important for water filtration. These systems slow and spread water flows, reducing flood peaks. They retain water during dry periods, which supports aquatic habitats such as ponds and wetlands.

Swampy meadows represent areas of substantial water retention, most of which is sub-surface. As such, they can also buffer the sun's heat and maintaining stable land surface temperatures. Additionally, the surface water in chain-of-ponds systems is often closely connected to the adjacent groundwater table, supporting surface and sub-surface flows (both laterally and longitudinally).

Figure 48: Pond at Baarlijan, Mongarlowe River Catchment

What are indicators of a healthy system?

- Mosaic of wet and dry grasslands, ponds and wetlands.
- Discontinuous or subtle braided channels: the presence of multiple, interconnected channels that are not continuous but rather spread out, diverge and converge.
- Hydrological connectivity: ponds are connected by natural surface and sub-surface channels during high-flow events, allowing surface and sub surface flows between them.
- Diverse, well-structured, mainly grassland, wetland and pond vegetation: a variety of native aquatic plants thrive, supporting a balanced ecosystem.
- Ponds generally maintain high water levels, even during dry periods.
- Clear water: water in the ponds is generally clear, indicating low levels of pollutants and sediments.
- Stable pond banks: minimal erosion and well-vegetated banks help maintain the structure of the ponds.
- Rich biodiversity: high levels of biodiversity, including various fish, amphibians, and invertebrates.
- Effective groundwater recharge: ponds contribute to groundwater recharge, maintaining local water tables.

What are indicators of a swampy meadow being degraded or unhealthy?

- A single continuous channel.
- Severe erosion.
- Lowering bed level.
- Lowered surface water level.
- Lowered groundwater levels.
- Water is of poor quality.
- Loss of vegetation.
- Reduced biodiversity.
- Impaired groundwater recharge.

What are common risks to consider?

- Water drainage, extraction or diversion.
- Land clearing.
- Placement of farm infrastructure.
- Invasive species.
- Feral animals.
- Stock grazing.
- Pollution.

What are signs of positive change?

- Reformation of distinct ponds.
- Restored surface water and groundwater levels.
- Stable pond banks.
- Improved water quality.
- Increased native vegetation.
- Enhanced biodiversity.
- Effective groundwater recharge.

Figure 49: Google Earth image of Baarlijan chain of ponds, Mongarlowe River Catchment

Figure 50: An incised swampy meadow

4.3 What is the most suitable landscape rehydration strategy?

Four planning principles

Landscape rehydration projects require considered planning and prioritisation. Mulloon Institute staff work with a decision-making framework to select strategies tailored to local settings and conditions. This framework is built on four key principles that align directly with WaterNSW's goals to improve catchment health, water security and water quality for the Sydney drinking water catchments. These principles are:

1. Grow more plants.
2. Protect and enhance intact features.
3. Halt active erosion.
4. Rebuild and regenerate degraded waterways.

The following pages expand on these principles, providing a short rationale and highlighting associated strategies. A series of fact sheets complement the principles. These provide brief summaries of natural infrastructure solutions that may sometimes be applicable.

Figure 51: A series of rock weirs being installed in an erosion gully at a landscape rehydration skills event.

1. Grow more plants.

Enhance plant cover to increase water retention and cycling, and to improve water quality from runoff, improve soil condition, reduce erosion, strengthen biodiversity and moderate the microclimate.

Decisions and strategies:

- Fencing waterways.
- Managing or excluding stock.
- Establishing alternative watering points for stock.
- Increasing groundcover.
- Selecting areas for revegetation to promote biodiversity recovery, such as rocky outcrops, farm dams and riparian zones.

Rationale:

Plants play a pivotal role in the local water cycle. They intercept and increase the infiltration of surface flows, store water in the soil and cycle it into the atmosphere through transpiration, which also cools the surrounding air mass. This process reduces surface runoff and erosion, transitioning landscapes from degrading to regenerating systems. Increasing and enhancing plant cover not only improves water retention and cycling but also integrates with carbon and nutrient cycles, providing essential ecosystem services and promoting biodiversity.

2. Protect and enhance intact features.

Protect existing water features like wetlands, natural gullies and chain-of-ponds systems, and work to expand these areas to improve the movement, storage and cycling of water and waterway/ landscape function.

Decisions and strategies:

- Fencing waterways.
- Managing or excluding stock.
- Revegetation and encouraging regeneration of bare ground or degraded areas.
- Stabilising active erosion such as head-cuts and deepening gullies.
- Re-establishing aquatic vegetation to reduce evaporation, enhance microclimates and improve water quality.
- Implementing natural infrastructure solutions such as;
  - contour structures.
  - earthen structures.
  - low-risk brush and rock structures.
  - rock armouring structures.
  - in-stream structures such as log-sill and rock weirs.

Rationale:

Intact water and riparian features like swampy meadows and wetlands are vital components of a functioning landscape. Farm dams, especially when built within a waterway, can also be important water and habitat features. These features contain regularly saturated soils and have cooler microclimates than the surrounding landscape. They support diverse and dense vegetation including grasses, sedges and rushes, enhance water filtration, and promote groundwater recharge. They also regulate flows, maintain baseflows and provide a buffer to both flood and drought.

Figure 52: A fenced riparian area and pond, with stock access limited through managed grazing. Toowoomba River Catchment. Photo by Grant Forsdick.

Figure 53: A waterway with a recently completed rock weir, behind which a new pond has formed. New riparian fencing to exclude stock, and new plantings are contributing to the regeneration of the site. Emerging plant communities are visible on the structure, banks and in the pond. See Lorrina case study, page 110.

3. Halt active erosion.

Manage active erosion processes such as head-cut migration and channel incision to prevent accelerated soil loss and support the regeneration of waterway functions.

Figure 54: A North East Wiradjuri Company team prepare to install brushpacks in an erosion gully.

Decisions and strategies:

- Implementing conservation earthworks.
- Management of stock (limit access to degrading areas).
- Altered land management of erosion sites and remediation areas.
- Implementing natural infrastructure solutions such as:
  - › contour structures.
  - › earthen structures.
  - › low-risk brush and rock structures.
  - › rock armouring structures.
  - › in-stream structures such as log-sill and rock weirs.

Rationale:

Accelerated erosion, often caused by long periods of overstocking and loss of vegetation, is a primary reason landscapes lose their soil, and lose their capacity to cycle water, nutrients and carbon effectively. If left untreated, even small areas of erosion can develop into significant sites of accelerating landscape degradation following a rain event. There are many forms of erosion, such as head-cut migration, bank wall collapse, channel deepening, and sheet and rill erosion.

Figure 55: Brushpacks being installed in a large erosion gully. Photo by Grow Love Project

4. Rebuild and regenerate degraded waterways.

Stabilise and rehabilitate degraded waterways through interventions that slow water flow, reinstate hydrological functions, capture sediment and rebuild habitat. Adapt land management to support regeneration of riparian and aquatic vegetation.

Decisions and strategies:

- Re-establish hydrological connectivity.
- Manage stock pressures and threats.
- Provide waterways with space, de-energise flows, capture mobilised sediment and encourage natural regeneration.
- Implementing natural infrastructure solutions such as:
    - › low-risk brush and rock structures.
    - › rock armouring structures.
    - › in-stream structures such as log-sill and rock weirs.

Rationale:

Degradation of waterways is the result of a wide spectrum of interrelated causes at different stages of progression: diminished groundcover and vegetation, accelerated erosion, head-cut advancement, incised waterways, diminished hydrological functions, vanishing hydrological features, uncontrolled stock access and overgrazing.

In degraded waterways and landscapes the objective is to build, repair, and conserve natural and functional waterway conditions important to the local setting. The repair recreates the functions and values that support the health and regeneration of the waterway and landscape, including vegetation structure and diversity, soil and bank stability, as well as improved water quality and microclimate.

Figure 56: Two log-sill weirs, one year after construction. See the Lorrina case study, page 110.

4.4 Natural Infrastructure Strategies

Contour structures

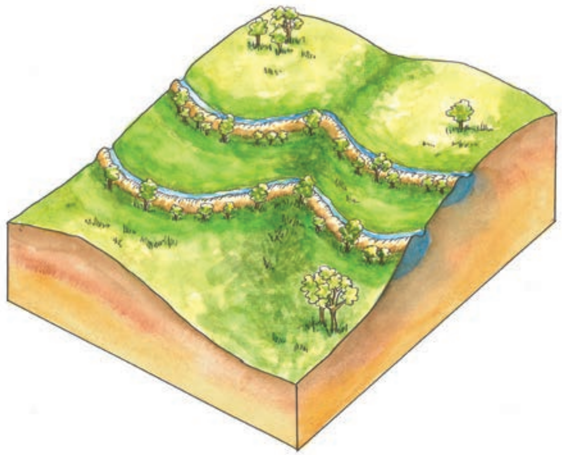


Figure 57: A freshly built contour that has captured rainfall.

What is their purpose?

To encourage infiltration and to intercept and redirect surface flows away from a hillslope or spillway before water can concentrate and cause erosion. Contours can be used to convey and spread water to typically dry parts of the landscape, such as ridgelines or reconnect degraded waterways (incised channels) to larger floodplain systems.

Common names:

- Level contour banks.
- Graded contour banks.

Figure 58: A well-established contour. Photo by Grow Love Project.

Suitable sites:

- Hillslopes.
- Scalded flats.

How are they constructed?

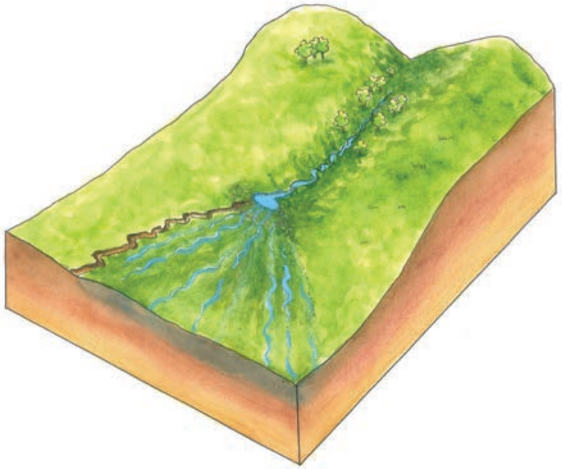
An earthen channel is cut into a hillslope at a consistent depth and elevation along the contour line, with a spoil bank constructed on the downhill side. A spoil bank acts as a spillway, providing safe drainage for surplus water in high-flow events. Contour structures typically take two forms: a graded (sloping) contour bank, where gravity will drain intercepted flows to one area; and a level contour bank, where the head pressure of water will move it along the level channel.

Figure 60: Two rows of contours were built on this hilltop in 2017, and tubestock trees planted below contour soon after. This photo was taken in 2020.

Figure 59: One of three hilltop ponds that form part of the contour project seen in Figures 60 and 61. These ponds are now providing food, shelter, habitat, cooling and subsurface hydration of the hilltop.

Figure 61: The same site as Figure 60, showing ponds and tree growth 3 years after contours were first dug.

Earthen structures



What is their purpose?

The structures are designed to plug and pond surface flows down eroded and incised channels, such as gullies, and safely re-direct overflows to spread across alluvial landscapes such as fans, floodplains or wetlands.

Common names:

- Earthen berm.
- 'Plug and pond' approach.

Suitable sites:

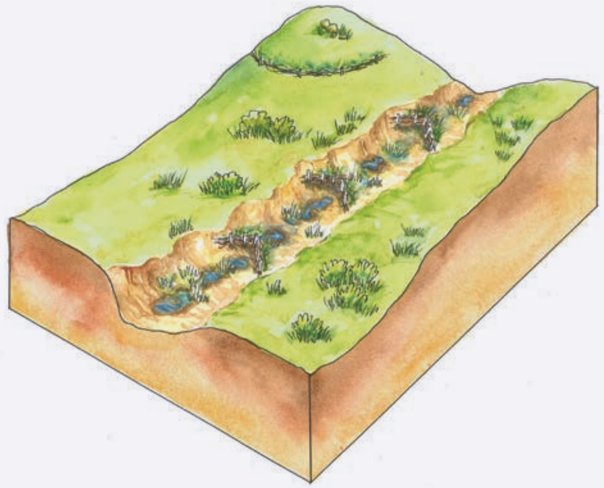
- Alluvial fans.
- Floodplains pockets.
- Swampy meadows / chain of ponds.
- Wetlands.

How are they constructed?

An earth berm is a mound constructed across the width of an eroded or incised channel, with an appropriately sized spillway. A spillway is a drainage outlet that allows for the safe passage of surplus water.

Figure 62: Google Earth image of an earthen berm installed in an erosion gully, with water pooling behind.

Low-risk structures made from brush and rock



What is their purpose?

To be permeable and semi-permeable structures that intercept surface flow and catch mobilised sediment and debris such as brush, leaf litter and seeds

Common names:

- Small rock weirs.
- Brush pack weirs.
- Pin weirs.
- Brush contours.
- Brush matting.

Suitable sites:

- Ephemeral streams.
- Gullies.
- Headcuts.
- Scalds.
- Hillslopes.

How are they constructed?

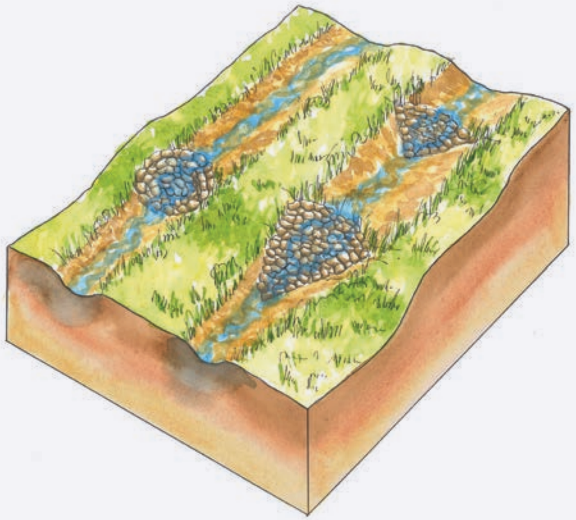
In the case of brush structures, brush cuttings from trees and shrubs are bundled, woven or laid down and pinned into the bed and banks of gullies, or spread on contour on slopes and scalds. Semi-permeable weirs constructed from earth and rock are shaped to the curvature of gullies. Brush-like materials can also be applied as a mulch or compost to bare and scalded soils.

Figure 63: A brushpack being installed in an erosion gully.

Figure 64: A brushpack positioned on contour above a dam that has been in place for over a year.

Figure 65: Plants can be seen growing within and on the uphill side of the brushpack, taking advantage of the increased litter, water ponding and water infiltration.

Rock armouring structures



What is their purpose?

To slow, dissipate and safely divert or direct surface flows along a waterway. These structures are utilised in areas where the hydraulic force or energy of water has greater potential to cause erosion, such as at a knickpoint or headcut.

Common names:

- Rock ramp.
- Brush ramp.
- Rock groyne.
- Rock baffle.

Suitable sites:

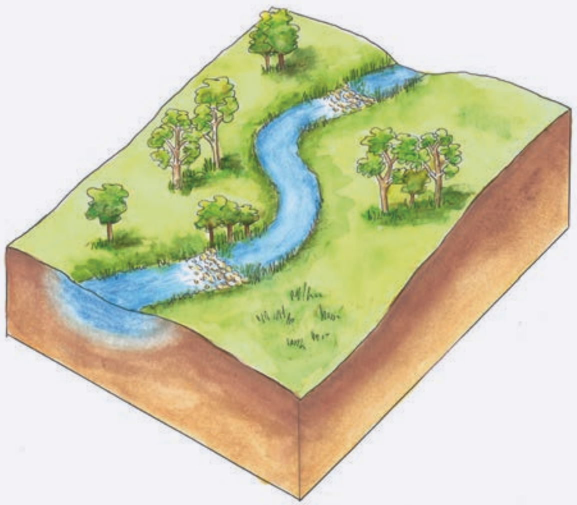
- Perennial streams.
- Intermittent streams.
- Ephemeral streams.
- Gullies.
- Head cuts.

How are they constructed?

A grade control structure is constructed from earth and/or rock in an open channel where there is a steep drop in the flow path of surface water.

Figures 66a and b: Rock armouring structures being installed in erosion gully. Photo by Maddison O'Brien.

In-stream structures



What is their purpose?

In-stream structures are designed to slow the flow of water by reducing the grade (slope) of the waterway. Structures effectively raise the bed level of the channel. This reduces the velocity of the streamflow, which in turn causes sediment to drop on the stream bed. Over time, this de-energising and depositional process improves the quality of the water in the stream, raises the bed level further and creates the conditions for enhanced aquatic and riparian habitats.

Common names:

Rock weir, log-sill and rock weir, leaky weir.

Suitable sites:

- Perennial streams.
- Intermittent streams.

How are they constructed?

A semipermeable structure made from natural materials such as logs, earth and rock is embedded into the bed and banks of a waterway. Each structure has a graded downstream rock ramp and a V-notch cross sectional profile ensuring water flows over the structure. This protects the banks and allows for fish passage. These structures are typically designed and constructed in a series. The Westview Diary (page 179) provides a 6-year photographic record of an in-stream structure where it has transformed a reach of Mulloon Creek.

Figure 67: A log-sill and rock weir.

4.5 A note on Community Engagement & Capacity Building

All nature repair projects are social projects. Landscape rehydration begins when people who want to heal degraded landscapes decide to reach out to others for solutions and support. This step might be taken by an individual landholder or group of landholders, a Landcare, First Nations or grower group, or representatives of a corporation or government agency. Each type of engagement establishes different social and cultural parameters for the project. Responding both sensitively and strategically to these parameters is essential, otherwise projects will falter. As land relationships are so subjective, people often bring very different assumptions and expectations to a new project. If these are left unearthed, things tend to unravel as soon as challenges arise. It is thus essential to find ways to create a shared understanding of land condition and trajectory, priorities, risks and time frames for projects.

Tackling landscape degradation tends to be both daunting and empowering for those involved. Even gaining a fresh understanding of the issues that cause degradation, and invisible processes (like energy flows, soil biology and the hydrological cycle) can prompt striking shifts in perspective on a landscape, even those known intimately. As with any new skill or learning journey, a supportive social environment that 'meets people where they are' is key. To create this supportive environment, landscape rehydration practitioners take for granted that some form of capacity-building with land managers and community needs to occur, whether informally through conversations and site visits, or through coordinated events.

Figure 68: photo by Alex Wisser

Expert presentations and field days can raise awareness of land management topics, however they usually achieve very little where capacity-building is concerned. To support land managers to apply new knowledge in their own context, landscape rehydration has been developed around an ethos of deep community engagement. This involves working closely with trusted organisations and networks as much as possible and facilitating experiential learning programs in local community contexts. These involve active landscape observation, mapping, models, surveying, monitoring and "boots on ground" days where low-risk projects are completed collaboratively. Some activities are co-designed and co-delivered with First Nations educators to foreground cultural understandings of Country. Creative tools and activities are used to demystify scientific concepts, spur the imagination and enable participants to work through decision-making steps amongst understanding peers. Mentoring programs bring experienced landscape planners into the journey of planning, designing and implementing a project.

Climate change adaptation

The learning programs described above aim to serve a further goal of landscape rehydration: to nurture the social ecosystem required for climate change adaptation and resilience. As noted in Chapters 1 and 2, dysfunctional landscapes are not only failing to provide ecosystem services and clean water, they are also hazardous to local communities by contributing to the severity of natural disasters. Climate change mitigation and resilience depends on cooperation and resource-sharing across regional Australia to transform how catchment landscapes are managed: between landholders, utility companies, local councils, emergency services, conservation groups, philanthropists and many other networks and entities. Every landscape rehydration project is an opportunity to build this community connectivity and capacity.

The following section outlines the typical workflow of a landscape rehydration project. Capacity-building can fit into any stage of this workflow. The more it can be incorporated so that diverse people are able to observe, participate, gain skills and support each other, the better. To read about example projects in which capacity-building has been built into on-ground projects, see the Case Studies in Chapter 6.

Image by Alex Wisser

4.6 Landscape Rehydration Project Workflow

Landscape rehydration projects follow a sequence of steps, from initial inquiry, site assessment, detailed design, through to implementation, construction and monitoring. These steps are elaborated in the following pages. Unless otherwise noted, the steps outlined here are the responsibility of the landscape rehydration consultancy / project coordination team.

Stage 1: Preliminary Steps

1.1	**Initial inquiry**	A land manager reaches out for guidance on water management on their property.
1.2	**Desktop review**	A review to compile the following information: The property location and size. Catchment. First Nations Country. Key landscape features: geology, soils, vegetation, threats and limitations (e.g. salinity). Relevant regulatory requirements.
1.3	**First conversations**	The land manager and project coordinator discuss: Historic and existing land management, production context. Social context of the project (relationships with neighbouring properties, relevant community connections, potential support from local Council, Local Land Services, Landcare). Basic water stewardship and land restoration principles, priorities and practices.
1.4	**Stakeholder engagement**	Relevant stakeholders are contacted to gain input on the project and see if there are potential cooperative relationships.

Stage 2: Initial Site Assessment

2.1	**Site visit 1**	This visit involves: Examining priority areas. Assessing the condition of landscape features. Discussing property vision and goals with the land manager. Determining key opportunities, limitations and risks for project scope. Diving deeper into landscape rehydration principles and practice. Evaluating the suitability of sites for landscape rehydration strategies.
2.2	**Initial site report**	This report contains: Landscape assessment (soils, geology, geomorphology, biology, and terrain), threats, issues and limitations. Hydrological assessment (catchment mapping, flood frequency analysis). Recommendations for suitable landscape rehydration strategies. Conceptual design (property scale).
2.3	**Circulate report**	This step involves collecting feedback on the Report from key stakeholders where possible.

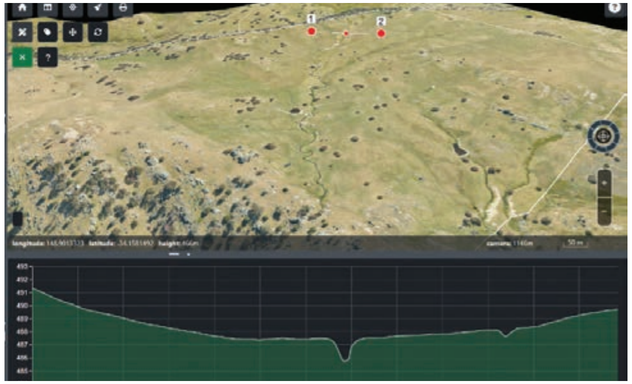


Figure 69: Conducting a landscape assessment with Agronomeye digital twin software.

Stage 3: Detailed Design Assessment – in the case of larger-scale natural infrastructure solutions being selected.

3.1	**Design survey (site visit 2)**	A second site visit to: Collect survey data (longitudinal profile and cross-sections) of the waterway sites. Determine the location of in-stream structures and other potential interventions. Capture photos and descriptions of structure sites.
3.2	**Design development stage**	This step involves preparing: A hydraulic analysis and condition report, including modelling of hydraulics pre-and-post intervention. design calculations, specifications and CAD drawings.
3.3	**Integration of sustainable land management**	This design and planning step involves identifying if/how the following can be integrated into the project: Revegetation. Fencing infrastructure. Reticulated water system. Grazing management.
3.4	**Constructability and safety**	The project design is reviewed from an engineering and safety perspective to clarify site conditions, access and construction requirements.
3.5	**Detailed design report**	A written report is prepared that details: Project background and scope. Hydraulic analysis and pre-and-post hydraulic condition report. Detailed structure designs. Vegetation management plan (VMP), erosion and sediment control plan (ESCP). Site monitoring plan. Structure maintenance plan. Information about relevant regulatory approvals. (see section 5.2).

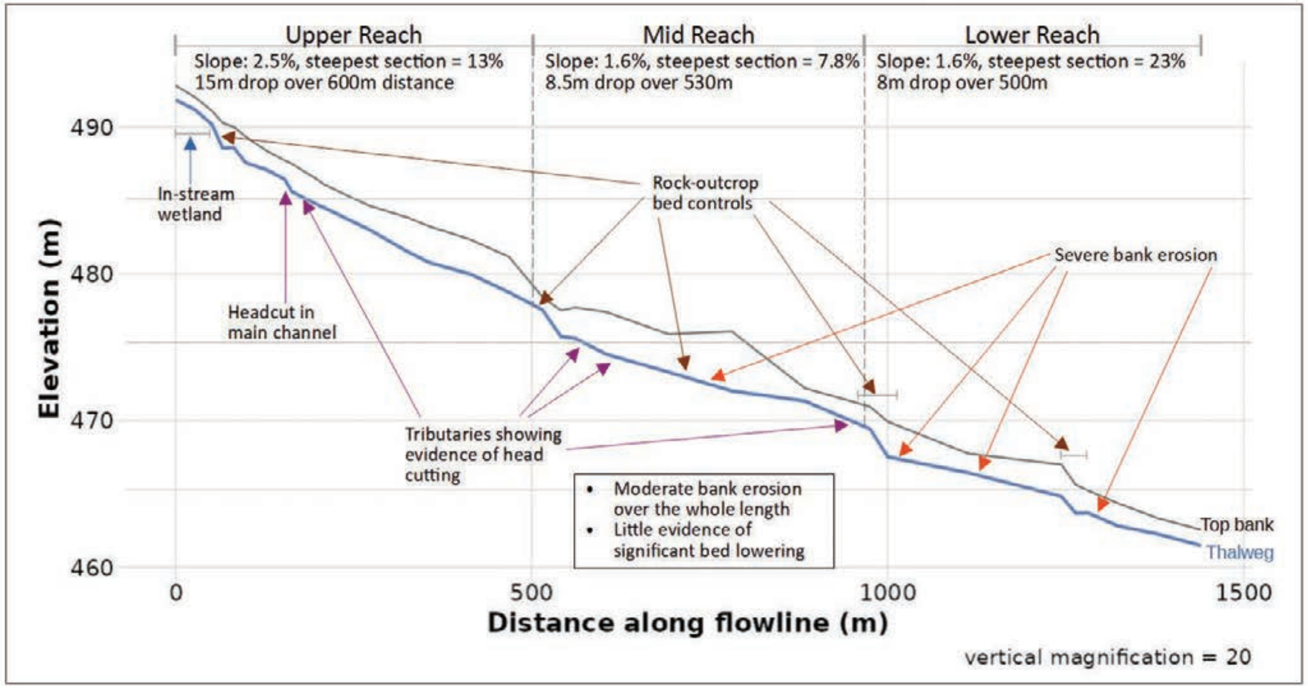


Figure 70: A graph displaying a long section view of a creek site and identifying key features and characteristics.

L4 Long Section Detail A-A
(Example V-notch log weir long-section)

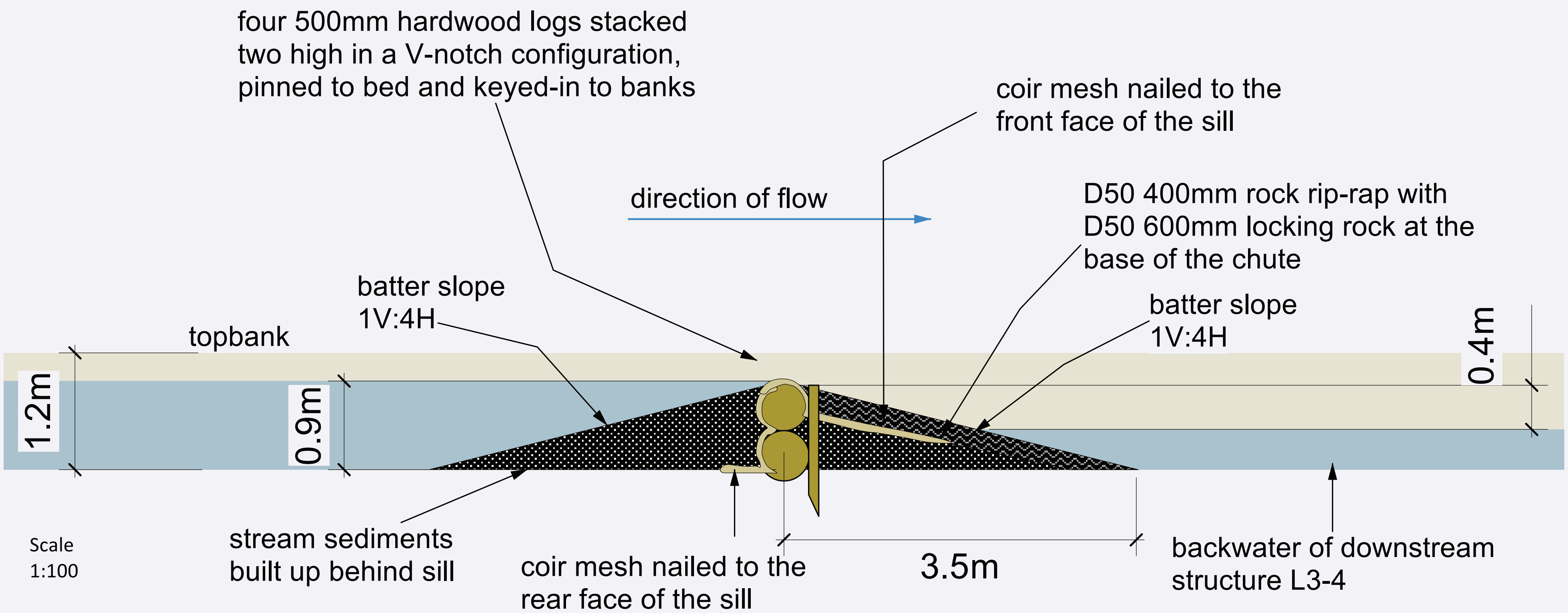


Figure 71: Planning diagram for an in-stream structure.

Stage 4: Construction Planning, Oversight and monitoring

4.1	**Pre-construction**	A project management process to ensure the safety and success of the project during the construction period. Includes: Construction site plan (construction schedule and approach, site access, stockpile sites, etc.). Costings report. Project management (liaison with client and sub-contractors). Landholder agreement.
4.2	**Construction steps**	A construction oversight process comprising: Construction meeting (WHS, Machine Safety). Site set-out. Material delivery and machinery mobilisation . Site preparation (e.g. VMP, ESCP). Construction. Site rehabilitation (in line with VMP).
4.3	**Post-construction steps**	A meeting with land managers to discuss the following, ensuring they are confident to implement the monitoring plan and any maintenance if required: Ongoing rehabilitation requirements. Monitoring points and activities identified. Monitoring program clarified. Maintenance expectations and responsibilities provided.

Project Monitoring

A range of indicators can be monitored to assess the impact and success of landscape rehydration projects across different hydrological features. They include:

- water quality (e.g. pH, turbidity, nutrient levels, pollutants)
- hydrology (stream flow, groundwater, flood intensities)
- geomorphic condition (stream shape, stability and sediment transport)
- riparian vegetation
- aquatic/pond vegetation
- biodiversity (diversity and abundance of invertebrates, fish, birds etc.)
- soil health
- ground cover.

Common methods for assessment include:

- photo-point monitoring
- drone imagery
- satellite NDVI (Normalised Difference Vegetation Index)
- Structure Health Scorecards (SHS)
- Riparian and aquatic vegetation assessments (e.g. RARC - Rapid Assessment of Riparian Condition)
- Landscape Function Assessment (LFA)
- Ephemeral Drainage Line Assessment (EDA).

A **structure health scorecard** is a monitoring tool created by Mulloon Institute to assess the condition of in-stream structures, such as log-sill and rock weirs, over time. It monitors three aspects of the structure: structure integrity, structure function and the health of the vegetation that grows on and around the structure. The scorecard system was developed to:

- quickly identify targets for repair and maintenance
- track the establishment of vegetation in the vicinity of the structure
- be consistent across sites and through time.

Figure 72: Using a transect to monitor changes to landscape function.

Chapter 5: The Regulatory Environment

5.1 The current legal context in NSW

While most of the strategies outlined in Chapter 3 can be implemented at the discretion of the land manager or project coordinator, some projects designed to regenerate waterways are subject to regulation. If a project includes a proposal to install in-stream structures in streams that – according to the Strahler Stream Order system – are characterised as 3rd order or above, this will trigger the need for government agency assessment and approval. The point at which a project falls into this category is outlined in the Figure 73 on the following page.

Since March 2023, the NSW Government has had in place a planning pathway in the *State Environmental Planning Policy (Transport and Infrastructure*) ISEPP for Landscape Rehydration Infrastructure (LRI) (DPE, 2023). In this context, Landscape Rehydration Infrastructure works are defined as "works involving placing permeable structures on the bed of a stream to reduce erosion and maintain or restore flows for ecological purposes, not including works designed to impound water or impede the passage of fish."

Such projects can be developed without consent from local Council so long as they occur in:

- Zone RU1 Primary Production
- Zone RU2 Rural Landscape
- Zone RU4 Primary Production Small Lots

At the time of writing, it is mandatory for project coordinators to seek approval from Department of Climate Change, Energy, the Environment and Water (DEECCW). Concurrence may also be required from NSW Fisheries and NSW Crown Lands for these projects, by submitting a Controlled Activity Approval application. All applications must include a review of environmental factors (REF). The process by which project proposals are assessed is outlined in the publication: Landscape Rehydration Infrastructure Works – approvals and procedures (2023). For ease of reference, a table outlining the water-related responsibilities of various government agencies can be found on page 97–99 and a summary of the process for gaining approval for Landscape Rehydration Infrastructure is provided on page 100–102.

Currently, where Landscape Rehydration Infrastructure is considered 'impoundment', a water supply works approval is required from WaterNSW, putting Landscape Rehydration Infrastructure proposals on an alternative approval pathway.

Where projects are endorsed and supervised by WaterNSW, they may be exempt from controlled activity approval requirements. However, those projects will still need comprehensive due diligence and respond to Fisheries and Crown Land requirements.

5.2 Under what circumstances does a landscape rehydration project require government approval?

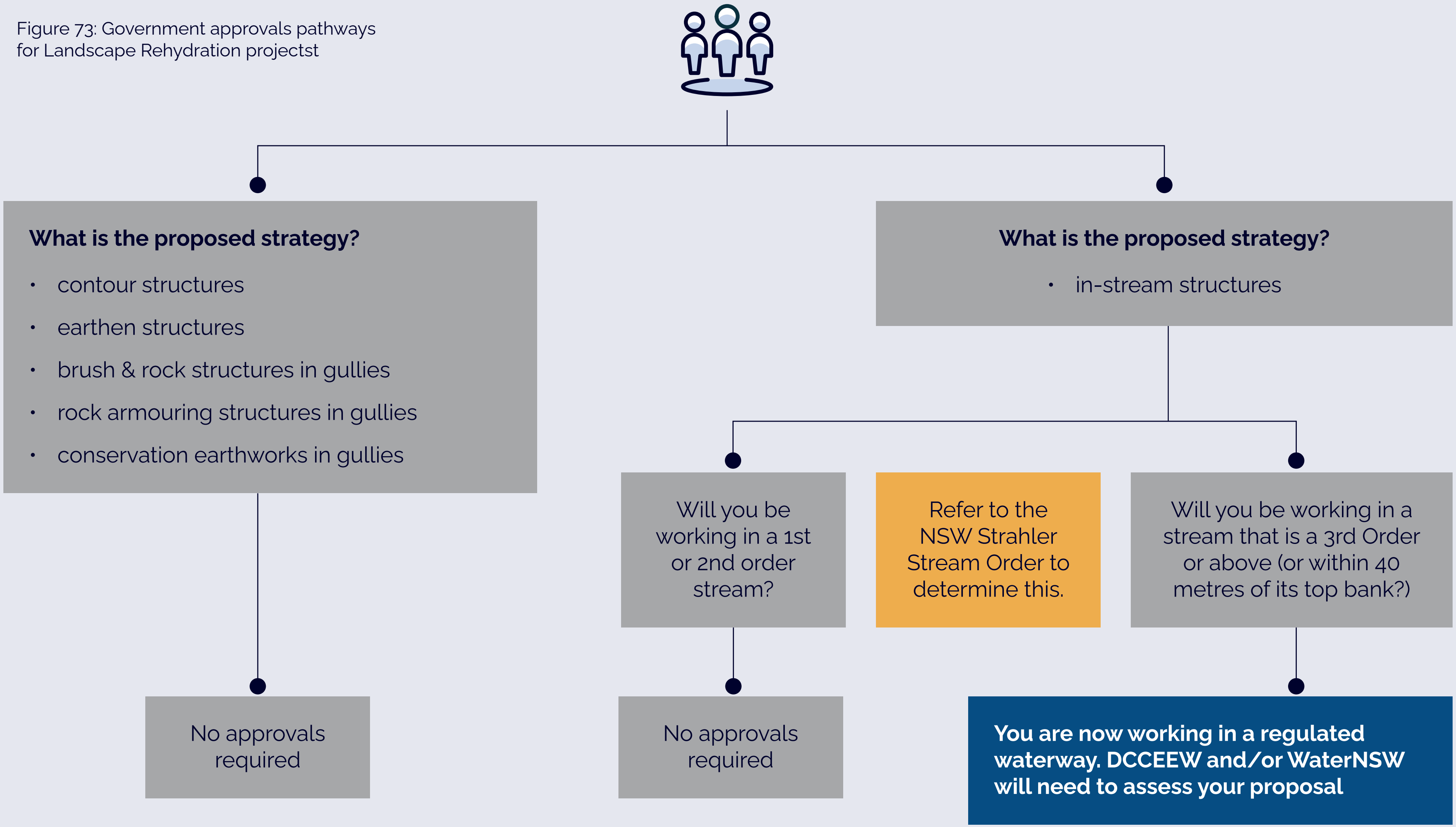


Figure 73: Government approvals pathways for Landscape Rehydration projectst

5.3 Key consultation and approvals requirements in NSW

(The information below may be subject to change, however it is accurate in July 2025). Acronyms are explained on page 102.

	Relevant legislation	Agency	Consultation required?	Approval or licensing required?	Requirements
1	**Water Management Act 2000**	DCCEEW and/or Water NSW	Yes – prior to submission of application to determine relevant approval pathway and provide preliminary feedback on project documentation	Yes (if a regulated stream or watercourse), requiring either: - CAA through DCCEEW - WSWA through WaterNSW	Both the CAA and WSWA applications require submission of key project documentation, supporting studies (if required) and lodgement fee: - REF - Detailed structure designs - Site descriptions - Hydraulic modelling - Vegetation Management Plans - Site Management Plan - Other supporting studies if relevant (refer below)
2	**Water Management Act 2000**	WaterNSW	Yes – consultation recommended prior to lodgement to determine if licencing or water use consideration apply	Possibly	In addition to a CAA or WSWA this may include a separate application for a Water Access Licence or water use if required.

	Relevant legislation	Agency	Consultation required?	Approval or licensing required?	Requirements
3	**Crown Land Management Act 2016**	NSW Crown Lands	Yes – only if project partly or fully on Crown Land	Possibly: - If fully on Crown Land a Crown Lands Licence is required (in lieu of CAA). - If partly on Crown Land, landowners consent (LDC) is required - CAA through DCCEEW - Crown Lands Short Term Environmental License	Crown Land Licence of landowners consent (if required)
4	**Biodiversity Conservation Act 2016 -**	DCCEEW - BCD	Possibly - if SIS or BDAR is triggered.	If SIS or BDAR is required, this will be assessed by DCCEEW-BCD as part of the approval process.	If Test of Significance determines there's likely to be a significant impact, then an SIS or BDAR will need to be prepared.
5	**National Parks and Wildlife Service Act 1974**	Heritage NSW	Possibly	Possibly - An Aboriginal Heritage Impact Permit (AHIP) is required if project will harm aboriginal objects or places	Need to demonstrate due diligence in accordance with the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales. Includes searching the Aboriginal Heritage Information Management System (AHIMS) and if required undertaking a cultural heritage assessment.
6	**Fisheries Management Act 1994 -**	NSW DPIR Fisheries	Yes	Yes - undertaken concurrently with relevant approval process.	Requires consideration of impact to aquatic biodiversity and fish passage, including: - Assessment of significance, and - Structure designs to meet best practice requirements for fish passage.

	Relevant legislation	Agency	Consultation required?	Approval or licensing required?	Requirements
7	**Environmental Protection and Biodiversity Conservation Act 1999**	Department of Environment (National)	Possibly	Possibly - if EPBC listed ecological communities or species are likely to be significantly impacted.	Assessment of impacts to EPBC listed ecological communities and species to be undertaken as part of Biodiversity assessments in item 5 to determine if the impacts will be significant and the project needs to be referred under the EPBC Act.
8	**Heritage Act 1977**	Heritage NSW	Possibly	Possibly - if the site is listed on the State Heritage Register	Requires preparation of a Heritage Impact Statement
10	**National Parks and Wildlife Service Act 1974**	NSW National Parks and Wildlife Service	Possibly	Possibly - authorisation required only if the site is on land acquired or reserved under the National Parks and Wildlife Act 1974	
11	**Aboriginal Land Rights Act 1983**	Aboriginal Affairs NSW	Possibly - if site has a Native Title or Aboriginal land claim	Possibly - if site has a Native Title or Aboriginal land claim	REF needs to identify if the site has a Native Title or Aboriginal land claim and resultant procedures that will be followed, requiring an online search of the Register of Native Title claims.

5.4 Current approvals process for in-stream structures

For further information on these steps, please see the DPE publication: Landscape Rehydration Infrastructure Works – Approvals and Procedures (2023).

Before commencing – determine if the proposal is located along a regulated waterway (or within 40m of the banks of a regulated waterway). Within NSW a regulated waterway is determined using the NSW Strahler Stream order (streams that are 3rd order and above are regulated).

(The information below was accurate in July 2025, but may be subject to change). Acronyms are explained on page 102.

Order	Summary	Additional notes
1	**Confirm if the proposal meets the definition of landscape rehydration infrastructure.**	Landscape rehydration infrastructure works means works involving placing permeable structures on the bed of a stream to reduce erosion and maintain or restore flows for ecological purposes, not including works designed to impound water or impede the passage of fish. See Section 2.165A of the T&I SEPP.
2	**Confirm the zoning of the land.**	LRI permitted to be constructed as development without local government consent in the following zones; RU1, RU2 and RU4.
3	**Ensure the proposal is not for extraction purposes nor for impoundment to facilitate water extraction.**	Any proposal designed for extraction purposes or for impoundment to facilitate water extraction is not landscape rehydration infrastructure. See the Water Management Act 2000.
4	**If your landscape rehydration infrastructure meets the definition and is in the correct zone – go to Step 6.**	This means your proposal can be assessed without the need for a development application (i.e. Part 5 planning pathway is allowed).

Order	Summary	Additional notes
5	**If your proposal does not meet Steps 1 to 3 then you cannot proceed under Part 5 planning pathway – Ask your local Council.**	If development without consent is not permitted (i.e. Part 5 planning pathway), consultation with local council is required. The proposal may require a development application or it may be prohibited.
6	**Prepare a Review of Environmental Factors (REF).**	The REF outlines the environmental impacts of your proposal and any steps that you will take to protect the environment and manage impacts. State agencies use this to assess your application.
7	**Determine which mandatory approval pathway applies.**	Landscape Rehydration Infrastructure may currently be assessed for approval through three pathways: - Crown Land License from DPHI - Crown Lands (where development is located all on Crown Land. - Controlled Activity Approval from DCCEEW (where development is located either partly on Crown Land or not located on Crown Land), or; - Water Supply Works Approval from WaterNSW (where development is located either partly on Crown Land or not located on Crown Land and works deemed to impound water).
8	**Determine what additional licences or permits might be required.**	Terrestrial Biodiversity consideration in accordance with Biodiversity Conservation Act (2016). Requires a Test of Significance, and if the significant effect is likely, REF must be accompanied by an SIS or BDAR. Aquatic Biodiversity and Fish Passage considerations under the Fish Management Act. Requires an assessment of significance, and if the significant effect is likely, REF must be accompanied by a SIS. Also requires consultation with DPI Fisheries to demonstrate appropriateness of designs for fish passage. Aboriginal Heritage Impact Permit. If you are proposing works or an activity that may cause harm to Aboriginal cultural heritage, you need an Aboriginal Heritage Impact Permit (AHIP) before the work can take place. Other additional licences or permits to be considered: - State Heritage (an approval is required under the Heritage Act 1977 if the site is listed on the State Heritage Register) - National Parks (if the site is on land acquired or reserved under the National Parks and Wildlife Act 1974) - EPBC Act - Native Title and Aboriginal land claims

Order	Summary	Additional notes
9	**Apply for relevant approval.**	Prepare and submit application for relevant approval, either: - Crown Lands Licence through DPHI - Crown Lands - Controlled Activity Approval through DCCEEW - Water Supply Works Approval through WaterNSW
10	**Determination**	The determining authority advising if the activity can or cannot proceed and if any mitigating measures are required.
11	**Implementation**	Construction may not proceed until the approval to proceed has been granted by the determining authority and any mitigating measures (if required) have been implemented.

BCT: Biodiversity Conservation Trust

BDAR: Biodiversity Development Assessment Report

CAA: Controlled Activity Approval

DCCEEW: NSW Department of Climate Change, Energy, the Environment and Water

DPHI: Department of Planning, Housing and Infrastructure

EPBC: Environmental Protection and Biodiversity Conservation Act

REF: Review of Environmental Factors

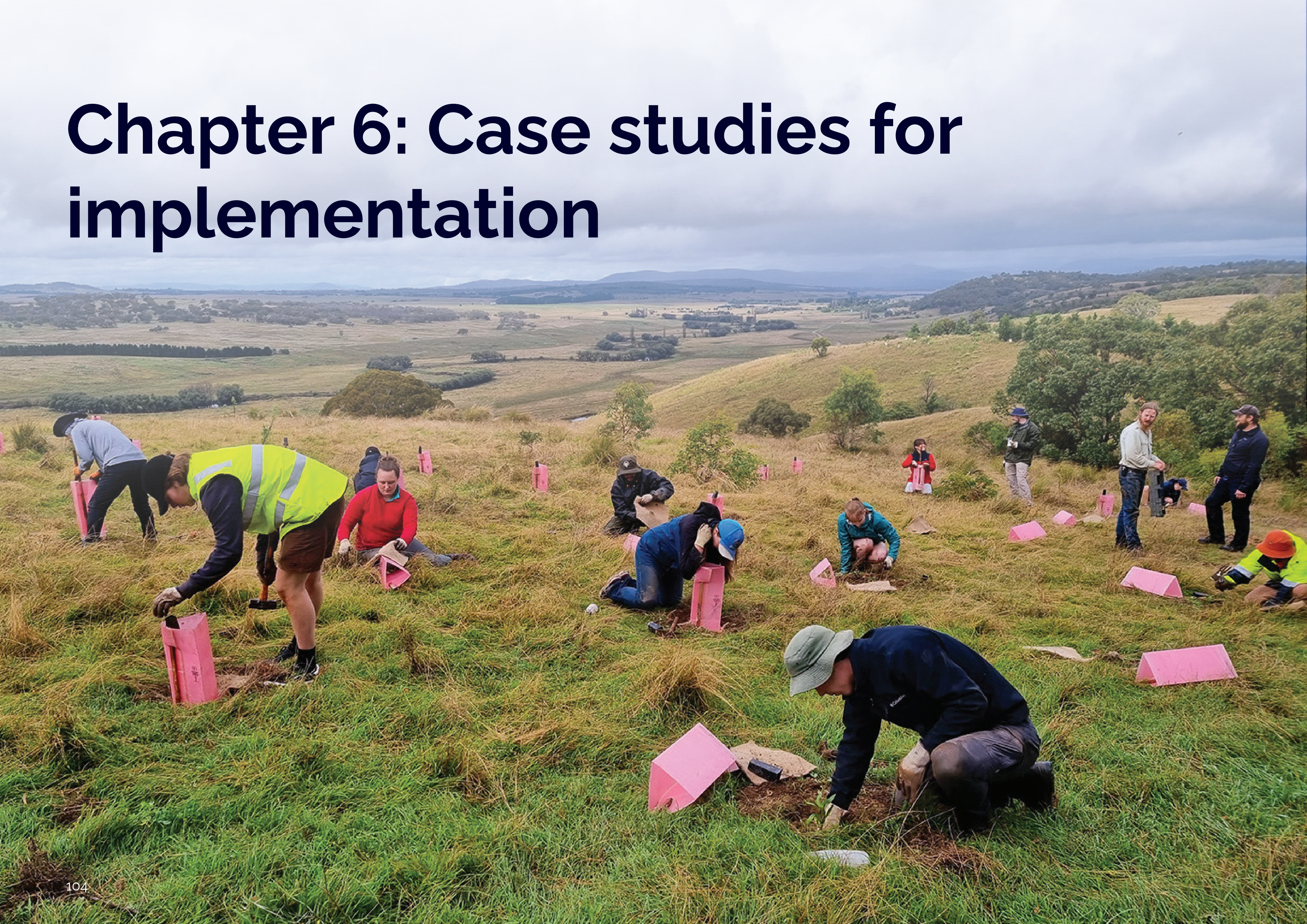
SIS: Species Impact Statement

T & I SEPP: Transport and Infrastructure State Environmental Planning Policy

WSWA: Water Supply Works Approval

Photo by Antony Mulhall

Chapter 6: Case studies for implementation



6.1 Introduction

This section provides several case studies of landscape rehydration projects. They illustrate different scales, and different combinations of on-ground action, land management, capacity-building and community engagement.

Landscape rehydration is sometimes viewed as a purely technical practice focused on delivering on-ground outcomes. These case studies demonstrate that it is in fact a holistic endeavour that it is deeply invested in community participation and up-skilling. Here we see Landcare members, First Nations groups, conservation organisations, Councils and landholders and their families working together, and many more stakeholder groups committed to water stewardship and climate adaptation could potentially be added to this list.

These case studies have been presented to highlight the range of benefits the projects seek to achieve, including production, ecological, aesthetic, skills-based, cultural and community benefits. They also highlight common constraints and parameters, for example different funding scenarios and legal considerations.

Figure 74: Minyumi Rangers Bootcamp (p. 118-121)

6.2 Wamboin

Project Location
Wamboin, NSW

Country
Ngunnawal

Size (HA)
16

Land Use context
Lifestyle property managed for wildlife habitat and conservation

Participants / organisations
Landholder

Funding Sources
Self-funded

Project date
2018-2021

Scale
Property-scale

Figure 75: Project site during construction in 2021

Figure 76: Project site in 2023.

What problems was the project seeking to address?

The landscape has experienced the effects of widespread degradation and erosion caused by clearing and overgrazing of the property. Due to the nature of the sodic soils and peak flow rates, severely incised gullies have formed. Concentrated flows continue the cycle of erosion and damage to the landscape and surrounding infrastructure.

What factors shaped the project's establishment and scope?

Mulloon Institute was engaged to analyse the property, design interventions and construct landscape rehydration features as previous attempts to slow the flow of water on the property had failed. The landholders' main objectives were to:

- improve landscape and ecosystem function through landscape rehydration
- improve aesthetic values of the landscape.

The site assessment found that the main priorities of the project were:

- revegetation to ensure adequate ground cover across the property
- install instream structures that capture sediment and filter high flows.

As this was a self-funded project, capacity-building was essential to ensure that landscape rehydration techniques could continue to be implemented by the landholder after the initial in-stream structures were completed.

What actions were taken?

The on-ground works used both materials obtained on site and imported rock. They included;

- battering of steep banks (to allow for revegetation)
- construction of rock ramps.

Revegetation works were vital to reduce runoff before it has a chance to cause further erosion. These works included:

- trees, shrubs and grasses planted along banks and in riparian zone
- disturbed vegetation transplanted back into creek
- casuarina trees and grasses planted in erosion zone
- education on longer term revegetation strategies.

What has the outcome been?

The property has seen a huge increase in the population and diversity of plants and animals inhabiting the landscape, particularly birds and kangaroos. The vegetation on the banks has increased to approximately 70% groundcover, the first time any groundcover on the banks has been seen for close to 20 years. Multiple high rainfall events have occurred since completion. These have left little to no damage in the system, but have rather driven improvements to multiple issues across the landscape.

The landholders have continued to revegetate the property and have now planted hundreds of plants across erosion zones and provided connectivity between the riparian area and other landscape features. They have also created a tradition of planting trees with family and friends whenever they have an event on the property, allowing for the continuation of learning and sharing within the community.

Key Lessons:

- Planning, and an analysis of the whole landscape system is critical to ensure success of landscape rehydration interventions
- Capacity-building can be highly empowering for landholders
- Benefits can be seen on a property-scale, however, catchment scale will allow greater benefits to be seen by the wider community.

Figure 77: Project site in 2020

Figure 78: Project site in 2023

6.3 Lorrina

Project Location
Lorrina - Braidwood NSW

Country
Walbanga

Size (HA)
102

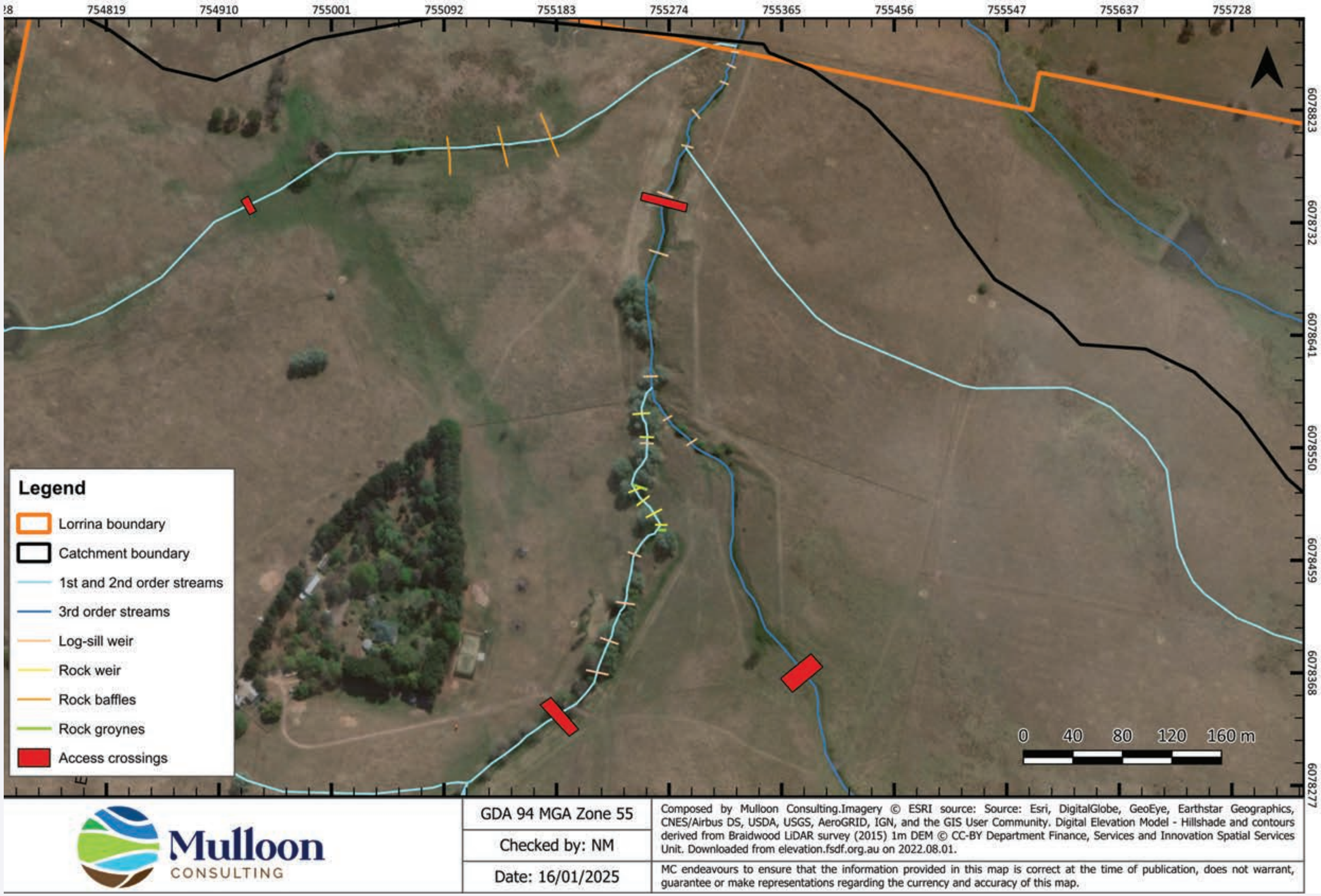
Land Use context
Livestock grazing

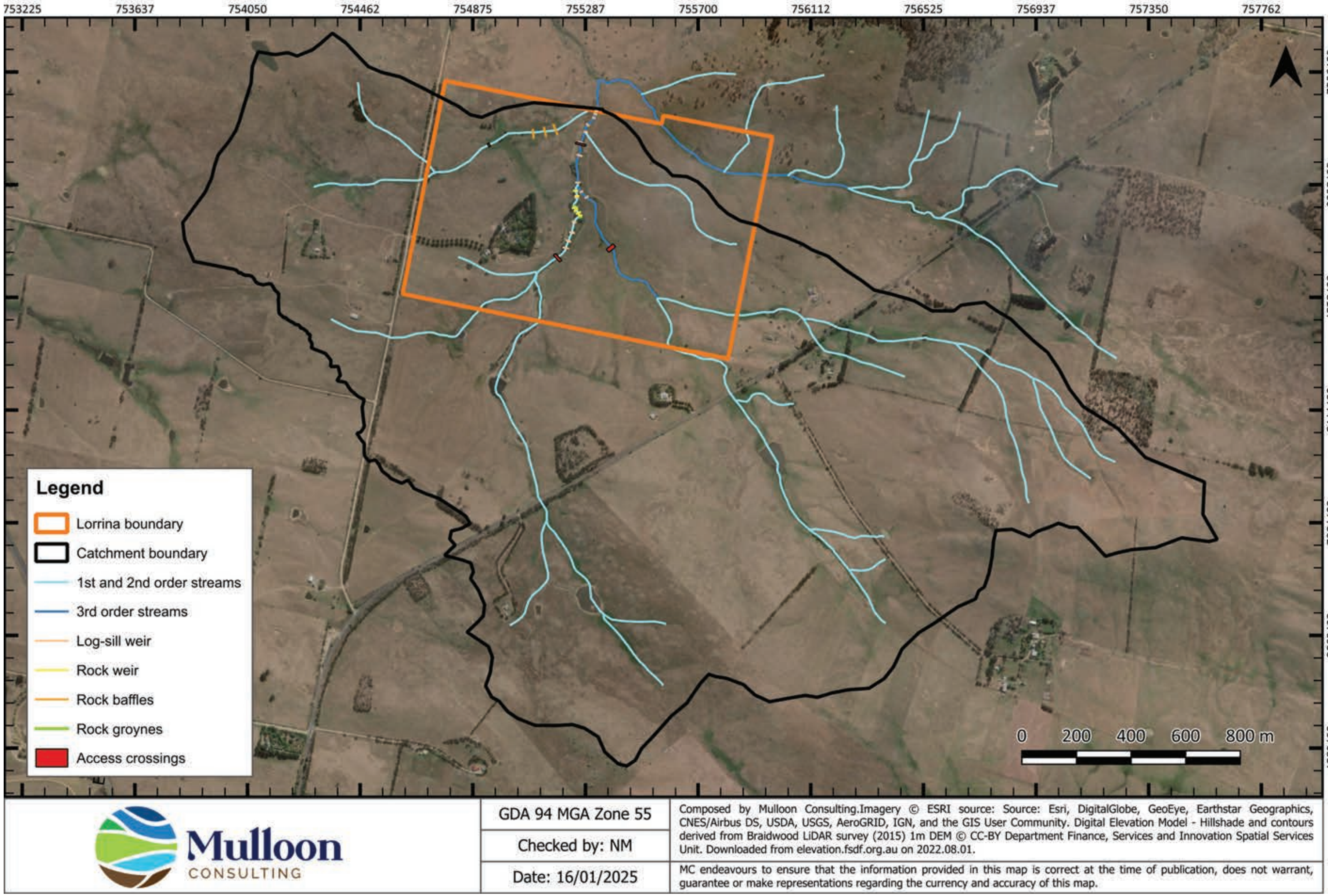
Participants / organisations
Justine Isemonger and
Andrew Bullock

Funding Sources
Self-funded and
Rivers of Carbon grant

Project Date
May 2021-2024

Scale
Property–scale




753225
753637
754050
754462
754875
755287
755700
756112
756525
756937
757350
757762
6079012
6078600
6078187
6077775
6077362
6076950
6076537
Legend
Lorrina boundary
Catchment boundary
1st and 2nd order streams
3rd order streams
Log-sill weir
Rock weir
Rock baffles
Rock groynes
Access crossings
0 200 400 600 800 m
Mulloon CONSULTING
GDA 94 MGA Zone 55
Checked by: NM
Date: 16/01/2025
Composed by Mulloon Consulting.Imagery © ESRI source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Digital Elevation Model - Hillshade and contours derived from Braidwood LiDAR survey (2015) 1m DEM © CC-BY Department Finance, Services and Innovation Spatial Services Unit. Downloaded from elevation.fsdf.org.au on 2022.08.01.
MC endeavours to ensure that the information provided in this map is correct at the time of publication, does not warrant, guarantee or make representations regarding the currency and accuracy of this map.

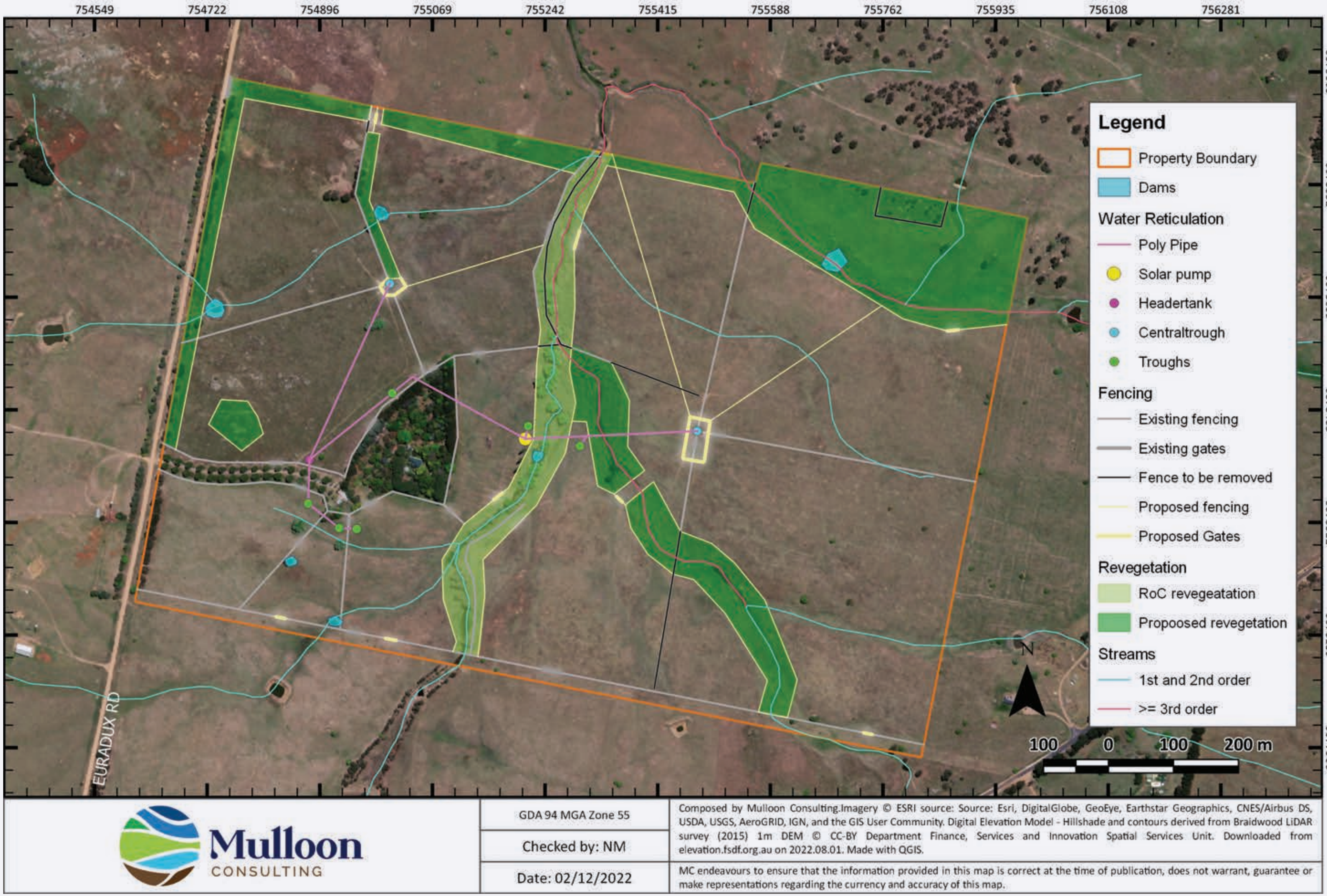


Figure 79: A whole-of-landscape plan was created for Lorrina. RoC in the key refers to Rivers of Carbon.

What problems was the project seeking to address?

The clearing and overgrazing of land in the Southern Tablelands over the past 200 years has led to widespread degradation through biodiversity loss, a decline in soil health and the incision of natural flowlines. Although Lorrina was only suffering from minor areas of erosion, the lack of trees and trampling of the creek line by stock was negatively affecting the small water cycle and water quality on the property. Although there was one enduring pond that seemed to be spring fed, Brushy Hill Creek was otherwise an intermittent stream and sometimes ran dry. The landowners were keen to see if they could increase the permanence of the creek.

What factors shaped the project's establishment and scope?

The landowners purchased the property in early 2021 and immediately embarked on a suite of projects to regenerate the property and redesign its infrastructure so that they could manage it more sustainably. They had an expert biodiversity assessment conducted, Justine attended a whole of farm planning workshop with Local Land Services, and applied for funding from the Rivers of Carbon – Source Water Linkages program, to support their aspirations to regenerate Brushy Hill Creek. The landowners also contracted Mulloon Institute to develop a farm plan and to design and construct in-stream interventions. They wanted a plan that would support:

> *"Working towards restoration of the riparian area, revegetating parts of the paddocks with shelterbelts and paddock trees, improving the soil fertility and carbon in the pastures, rehabilitating the dams (and possibly adding a couple more) and providing better access and infrastructure around the farm, all ultimately to help in regenerating the landscape while engaging in more sustainable grazing practices."*
>
> (Isemonger/ Mulloon correspondence, Nov. 2021).

A detailed landscape rehydration plan was produced that reflected an integrated approach to water, erosion, creek health, grazing, vegetation recovery and access management (see figures 79 and 81 that featured in that report). Regulations meant that the works could only occur within 1st and 2nd order streams on the property. The landowners began to implement the plan in 2022. Most of the activities were self-funded with the exception of the budget that came from their successful Rivers of Carbon grant.

What actions were taken?

- Using local Braidwood contractors, the landowners installed creek fencing, troughs and tanks to supply water to paddocks for cattle that formerly had unrestricted access to the creek.
- Paddock fencing was redesigned to increase the number of paddocks and centralise troughs (to minimise piping and plumbing costs), thus reducing grazing pressure from set stocking.
- Earthbanks and contours were installed to slow water and discharge it out onto paddocks to reinstate overland flow patterns.
- Water reticulation: Two solar pumps were installed to improve the efficiency of the pumping system – one from the creek to a header tank supplying the western half of the property and another from a rear dam to a header tank supplying the eastern half of the property - thus making water supply for stock more reliable.
- Revegetation: Using contractors and a tubestock supplier recommended by Australian River Restoration Centre (who managed the Rivers of Carbon project), the landowners planted 900 native species tubestock in the riparian area.
- Future revegetation: In addition to the riparian plantings, various trees and shrubs will be planted around the paddock bounds and elsewhere to restore the small water cycle, increase biodiversity, provide shade

Figure 80a: Prior to construction, September 2022 (Spring).

Figure 80b: June 2023 (Winter)

Figure 80c: December 2023 (Summer)

and bird habitats, provide wind shelter and improve aesthetic values.

In-stream structures

- Log-sill with rock ramp weirs were constructed to raise the water level along Brushy Hill Creek and in turn stabilise eroding banks. These structures also facilitate water capture in the landscape to extend pasture growth and support riparian vegetation.
- Rock weirs of a smaller scale were installed to manage the head drop between the log-and-sill weir structures. These act as a series of riffles to slow water movement and create pools.
- Rock groynes were installed to divert flows away from an active headcut and back into the meander channel. This will greatly reduce flow velocity and consequently erosion.
- Rock baffles were installed to trap sediment, aid rehydration and restore the creek's ability to recharge the surrounding floodplain.
- Access crossings: three existing crossings were upgraded, and one new temporary crossing surface installed. These will be upgraded pending approval to work in the regulated section of the stream.

What has been the outcome?

Monitoring of the project site by Mulloon Institute has been ongoing since May 2023. Water quality has improved and vegetation has flourished, with most banks and structures achieving 100% ground cover. An increase in the population and diversity of aquatic plant species has helped to stabilise the structures while also providing roughness to the hydraulic system, sediment capture and habitat for a diverse range of wildlife. The in-stream structures have raised the water level in the creek between 0.5 – 1m, creating a sequence of ponds and riffles and rehydrating the surrounding landscape.

There has also been a very noticeable increase in water quality and availability. The landholder has observed an obvious improvement in both water clarity and odour, with the water used for stock watering, garden irrigation and some household purposes. Creek flows have persisted through periods of low rainfall. With the removal of grazing pressure from the riparian zone, some woody weeds (mainly poplars) have thrived and are currently being controlled manually.

Figure 80d: May 2024 (Autumn)

Figure 80e: December 2024 (Summer)

Figure 80f: June 2025 (Winter)

"Despite the very dry spring we had, the creek retained water downstream of the interventions and the ponded areas quickly refilled with the recent rain and are holding that water well.

We pump from the creek to the stock water system, garden irrigation system and to flush one of the toilets at the house and the improvement in water quality is significant. We have not had it tested, but the improvement in water clarity and odour is obvious (February 2025)."

Justine Isomonger - Landholder

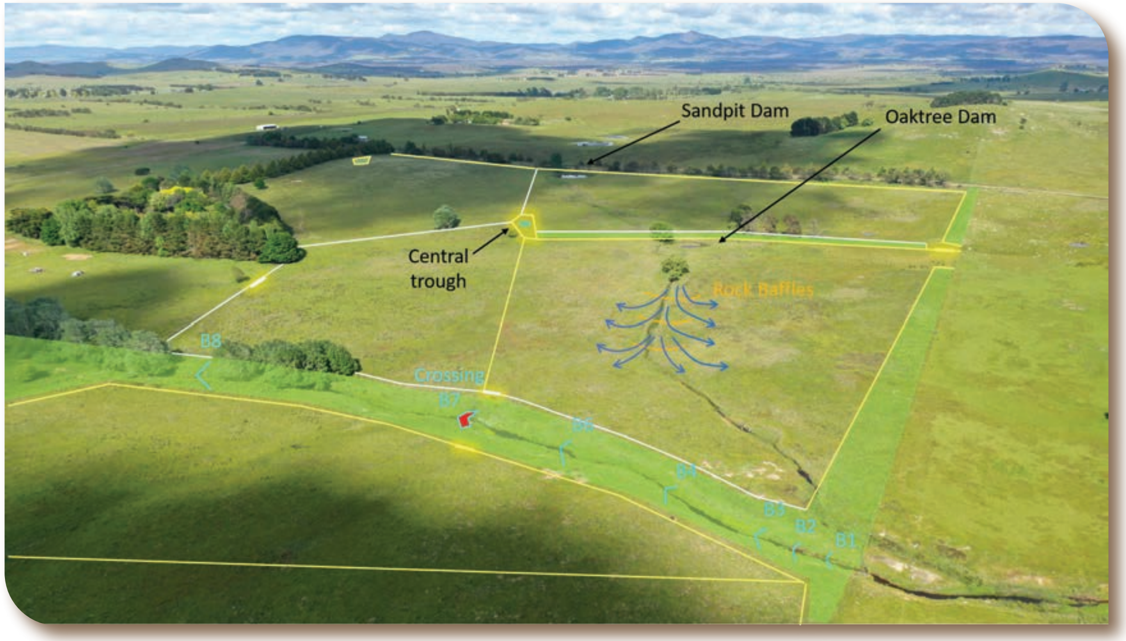


Figure 81 Drone imagery of the western paddocks of Lorrina, showing proposed location of in-stream structures (B1–B8), rock baffles (orange) and estimated flow diversion (blue arrows), existing fencing (grey), proposed fencing (yellow), gates (glowing yellow) and revegetation areas (green shading).

Figure 82a: April 2023 (Autumn)

Figure 82b: December 2023 (Summer)

Figure 82c: May 2024 (Autumn)

Figure 82d: December 2024 (Summer)

Figure 82e: June 2025 (Winter)

Figure 83: Detail of Figure 82d

6.4 Minyumai Indigenous Protected Area

Project Location
Minyumai Indigenous Protected Area - Evans Head, NSW

Country
Bundjalang

Size (HA)
2,163ha property, 550 ha catchment area of Setaria Flat

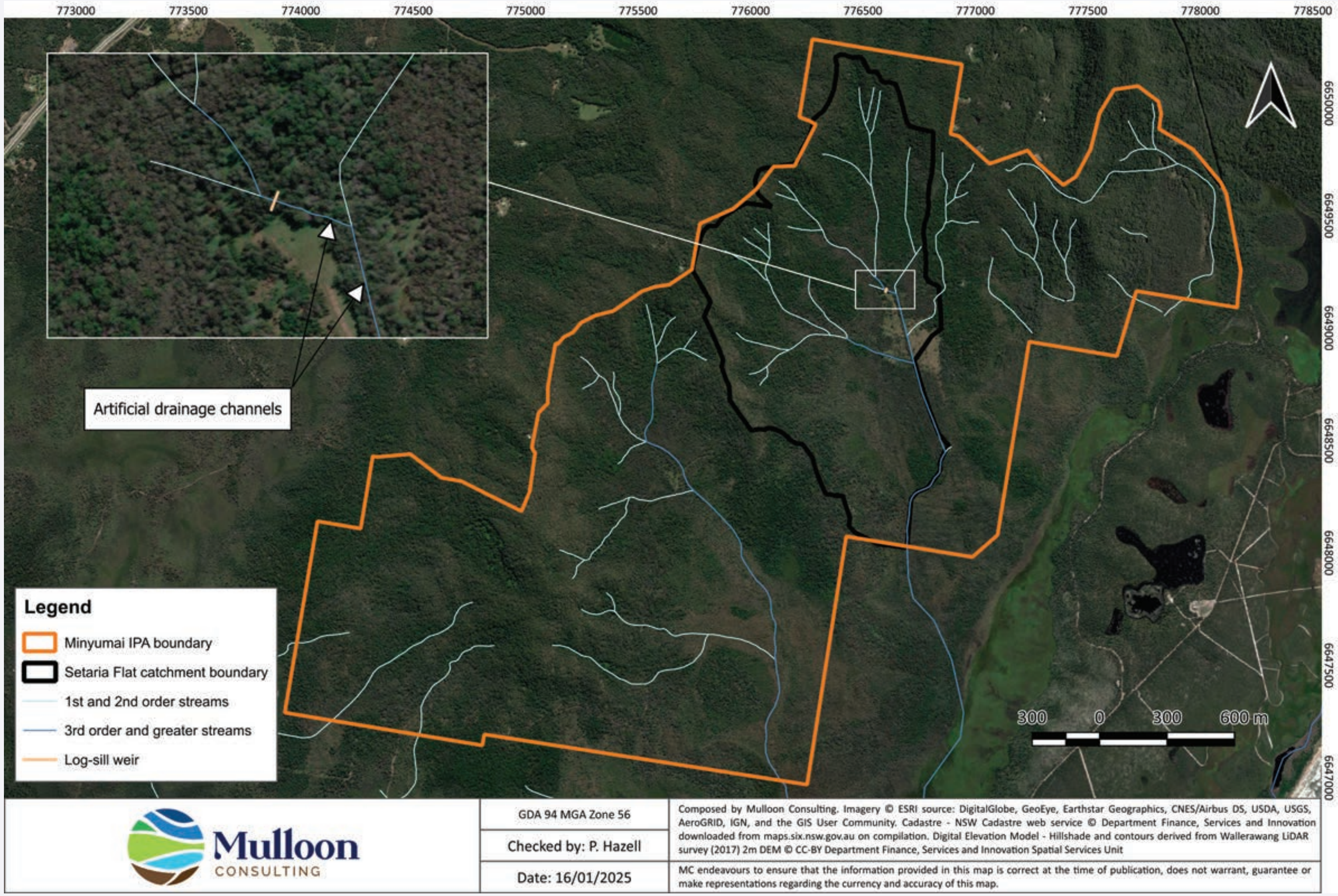
Land Use Context
Indigenous Protected Area

Participants / Organisations
Minyumai Land Holding Aboriginal Corporation (MLHAC), Jagun Alliance, Nature Glenelg Trust (NGT)

Funding Sources
Jointly funded through the Australian Government's Future Drought Fund, Jagun Alliance Aboriginal Corporation, Nature Glenelg Trust and Minyumai IPA.

Project Date
2024

Project Scale
Property–scale project in Community of Practice context



What problems was the project seeking to address?

The Minyumai Indigenous Protected Area (IPA) was established in 2011 after a history of logging, clearing and draining of the natural wetlands for grazing dating back to the 1970s. The drainage channels, which were cut into the floodplain to make it more suitable for grazing, now threaten areas of swamp forest in the IPA, due to the damage caused by increased velocity of surface flows and significant erosion.

What factors shaped the project's establishment and scope?

Figure 84: An active headcut in one of the drainage channels

NSW Environment Trust funding was secured by Nature Glenelg Trust (NGT) to address the impacts of historic drainage on the floodplain and to plan and implement hydrological restoration works over a three-year period. Mulloon Institute provided technical designs, however regulatory constraints have slowed the delivery of this aspect of the project. In the interim, NGT saw the opportunity to work with Jagun Alliance to build the capacity of the local Ranger groups through an adapted Mulloon Institute Bootcamp program, which would also enable NGT staff to gain further skills to support future on-ground works.

The bootcamp aimed to build water stewardship skills and facilitate hands-on learning, including the ability to identify and address erosion hazards such as active headcuts and high velocity flowlines, both of which are present across the IPA. The Jagun Alliance led aspects of the bootcamp to situate the activities in a Bundjalung cultural context. A particular focus area of the project was Setaria Flat, a floodplain wetland complex that was heavily cleared with multiple drainage channels constructed for agriculture prior to 1971.

What actions were taken?

Multiple locations were identified by the group as having potential for small-scale landscape rehydration techniques to be implemented. Participants worked together and used field observations with the knowledge shared in the Bootcamp to select the appropriate techniques using materials obtained from site. The construction works included:

- in-stream log-sill structure
- pin weirs
- brush pack weirs.

What has been the outcome?

Consultation and design work has been ongoing since 2022, culminating in the delivery of the bootcamp in 2024. Water was flowing strongly during the bootcamp as there had been regular rainfall leading up to and during the event. This meant there was immediate evidence of the positive effects the works had including:

- raising the stream level by approximately 30cm with the log-sill structure allowing some spill back out onto the floodplain
- sediment capture and reduced flow velocity through the pin weirs and brush packs.

In addition to the environmental gains, there was also an opportunity to share and interweave cultural and scientific principles by using a Country-centred approach to hydrological restoration.

Lessons learnt?

- It is possible to build simple yet effective structures using locally available materials which can make an immediate impact on flow velocity and sediment capture
- Foregrounding the cultural importance of water to sustaining Country is highly empowering and inspiring
- Engaging practitioners and specialists in up-skilling means they can continue supporting landholders and community with future projects.

Figure 85: Brushpack weir

"On behalf of the Minyumai Land Holding Aboriginal Corporation Board, Elders, and members, we would like to thank Mulloon Institute for their expertise, and enthusiasm over the course of their landscape rehydration training. This course has given our rangers the skills and confidence to construct small, affordable 'flow-through' structures in the man-made drainage lines using surrounding natural materials. This will go a long way to realising our old people's vision of restoring the wetland on the Minyumai IPA by filling in the drainage lines that were dug when it was managed as a cattle farm."

Maitland Wilson – MLHAC Chairperson

"As a wetland and watercourse restoration practitioner it was inspiring to participate in a landscape rehydration bootcamp run by Mulloon Institute. There is always more to learn and the practical skills taught have expanded our tool kit when it comes to identifying and repairing the damage. Mulloon tailored the training so it best aligned with the issues most relevant to the Traditional Owners we are working with and their country and the result was highly engaging."

Ben Taylor – Nature Glenelg Trust

"I feel confident finding the locations for structures because of learning how landscapes are formed and change. I would more confidently be able to do this in my local area."

Kavitha Chinathamby – Jagun Alliance

Figure 86: Senior Ranger Maitland Wilson with brushpack weir

6.5 Urandangie

Project Location
Urandangie – Guyra, NSW

Country
Kamilaroi

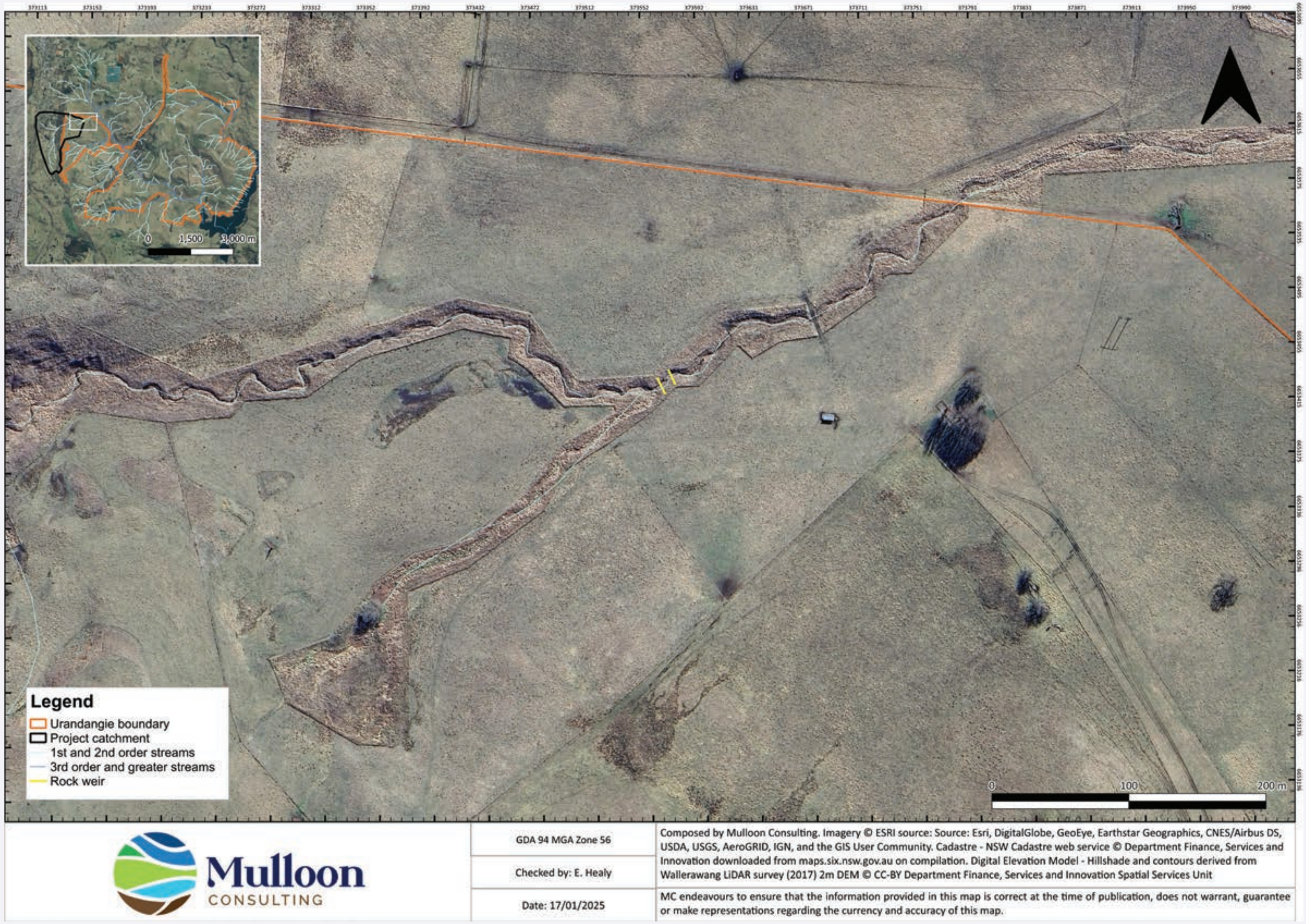
Size (HA)
1850

Land Use context
Grazing – mixed beef, sheep and goat enterprise

Participants / organisations
Bill & Jaqui Perrottet (Landholder), Simon Brown (Farm Manager), Southern New England Landcare, Armidale Regional Council

Funding Sources
NSW Environment Trust Education Grant, Armidale Regional Council

Project Scale
Property-scale project in landscape scale context



What problems was the project seeking to address?

Urandangie is situated in the upstream catchment of Malpas dam, which is the main reservoir for supplying drinking water to the Armidale region. The property has been heavily cleared and has suffered significant soil erosion. The flowline treated during the Bootcamp was an active headcut advancing into productive land upslope, while also negatively impacting the water quality flowing downstream into Malpas dam.

What factors shaped the project's establishment and scope?

The landholder had previously implemented some landscape rehydration interventions, including brush packs and fencing off gullies, and was interested in continuing to improve the hydrological cycle on their property. Armidale Regional Council had reached out to Mulloon Institute with the idea of supporting capacity-building in the region around landscape rehydration. Urandangie was selected as a site for a 3-day Bootcamp in late 2023, hosting 25 people from the region including fellow landholders, Landcare staff and the local council. The intent of the program was to 'learn by doing', involving mapping, observation, planning, design and implementation. The participants worked together to identify key locations and used both field and desktop observations to select the appropriate interventions and sites.

The Bootcamp resulted in:

- Two 'flow over' rock ramps using material sourced from the property.
- Transplanting of disturbed vegetation back into the flowline.
- Vegetation planting in and around structure.

Following the bootcamp, the landholder installed more structures, bringing the total number to seven.

What has the outcome been?

Monitoring of the site in May 2024, six months after the bootcamp, showed that vegetation has completely covered the rock structure, stabilising it and capturing sediment during any flow-over event. Water was also pooling upstream of each structure, retaining water in the landscape for longer periods. The success of the structures in both a dry gully and more permanent watercourse has provided the landholder with confidence to continue further implementation across the property.

The social outcomes of the project have provided landholders and educators in the wider community with the confidence to further support and implement these practices on their own properties. Participants in the Bootcamp have been back to visit the site to check how it has progressed, building on the relationships established during the learning program.

> ***"Southern New England Landcare has greatly valued its collaborative relationship with the Mulloon Institute, particularly through our joint delivery of the 3-Day Bootcamp in September 2023 and the follow-up site visit in May 2024.... The combination of theory and on-ground work allowed participants to gain a deeper understanding of natural processes and the positive impact that well-designed interventions can have on landscape function. The collaborative atmosphere and expert guidance from the Mulloon team fostered a strong sense of shared learning among attendees.***
>
> ***Seeing tangible improvements [at the site visit in May] and discussing the landholder's additional rehydration efforts on another gully... provided a space to reflect on successes, challenges, and opportunities for future work in similar landscapes"***
>
> **Elizabeth Rosser – SNEL Coordinator**

Figure 87: Project site A under construction during bootcamp, October 2023.

Figure 88: Project site A, May 2024.

Figure 89: Project site B, October 2023.

Figure 90: Project site B, May 2024 (project site A in foreground).

6.6 Swan Brook

Project Location
Swan Brook Catchment, Yarrawa Park, Inverell, NSW

Country
Kamilaroi

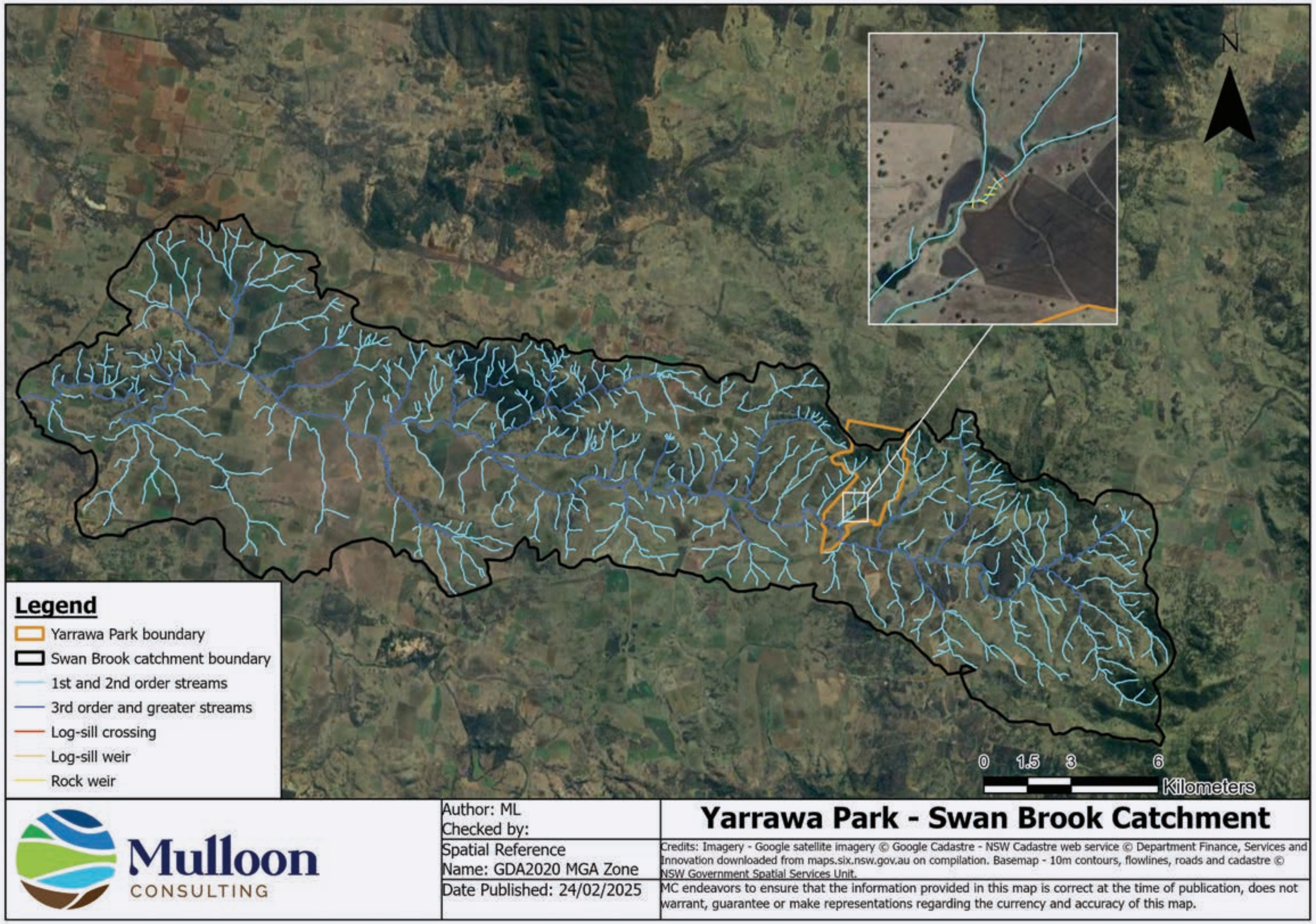
Size (HA)
Swan Brook (30,000) Codie Law - Yarrawa Park (722)

Land Use context
Livestock and cropping, Livestock grazing and stock horse breeding

Participants / organisations
Northern Tablelands Local Land Services, Gwydir Macintyre Resources Management Committee (GWYMAC), Swan Vale Landcare, various landholders.

Funding sources
Levins Family Foundation, LLS, Future Drought Fund (Aus Gov)

Project Scale
Property–scale project in both sub-catchment and Community of Practice context



What problems was the project seeking to address?

The Swan Brook catchment has been slowly degrading through decades of cultivation, clearing for grazing and alluvial mining. This all came to a head under drought conditions between late 2019 and early 2021 when the Swan Brook stopped flowing for a period of 12 months, the first time this had occurred in living memory. Landholders had also identified sheet erosion across paddocks, active gully erosion and a lack of water holding capacity in their soils as indicators that something needed to be done to improve the health of their catchment.

What factors shaped the project's establishment and scope?

Two farmers in the catchment, Glenn Morris and Johannes Meier, had already implemented water-focused strategies on their properties Billabong and Danthonia (see Figures 91 and 92). The evident benefits provided valuable examples for landholders in the region of what could be achieved. Responding to local appetite for more knowledge and skills, and with the Mulloon Rehydration Initiative as a reference case of a catchment-scale project (see case study on page 131), the representative bodies engaged Mulloon Institute to hold a landscape rehydration workshop to introduce the concept to the community. Following this event, a scoping report (funded by the Levins Family Foundation) was produced in 2021 that provided a detailed case for a catchment-scale project.[11] While there was strong motivation to pursue such a project, and considerable efforts made to find funding, it has not progressed. The fact that Swan Brook is classified as a 5th order stream in the area identified as suitable for in-stream structures also means that the project would be subject to an extended approvals process under the current regulatory regime (see page 137).

Figure 91: contour with spillway on Billabong. Photo by Glenn Morris.

Figure 92: a rehydrated landscape at Danthonia. Photo by Grow Love Project.

In 2023 grant funding obtained from the Future Drought Fund enabled Mulloon Institute to establish the Community of Practice Project (CoPP), a skills-oriented program that focuses on low-risk natural infrastructure and farm-system solutions proven to retain more water in the landscape. Swan Brook was selected as one of five communities around Australia to take part. This enabled the landholders and organisations to continue collaborating for the benefit of the catchment, but with an emphasis on capacity-building, altered land management and solving problems in the tributaries and gullies that flowed into Swan Brook.

The program incorporated a field-day, 2-day Bootcamp, an extended mentoring program in which landholders were supported to design, plan and implement a project, and a 'Boots on Ground' day in which participants all took part in building a natural infrastructure project. It has been highly

11 *This report can be viewed at https://www.catchmenttwin.org/s/Swan-Brook-Scoping-report.pdf*

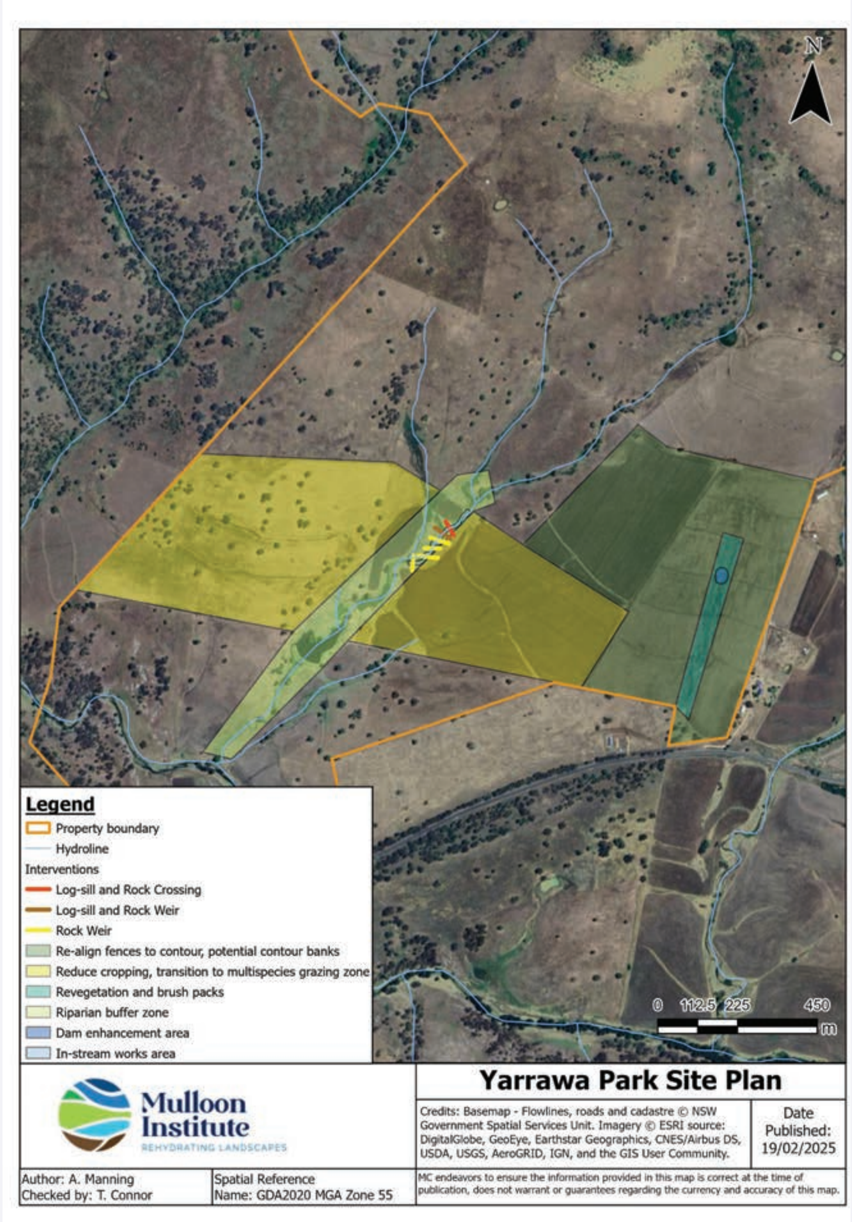
successful, with 90 farmers and NRM professionals participating in the community events in the Swan Brook, and by mid-2025, nine farmers had completed restoration works on their properties. The CoPP also involved a 4-day Professionals Intensive Course that provided NRM professionals with some tools and strategies to support their local communities implement these solutions.[12]

What actions were taken?

Here we focus on one of these nine farmers, grazier Codie Law. With mentoring from a Mulloon Institute landscape planner, Law established a property and project vision for the 722 ha property Yarrawa Park. Some of the major issues identified were:

- Large amounts of runoff from cultivated paddocks causing sheet erosion.
- Failure of graded banks and dams due to high runoff and active headcuts.
- Aim to increase water retention and improve water quality.

One of the key issues identified on the property was the poor quality and sheer volume of water running off cultivated paddocks adjacent to the flowline. Working with the decision-making framework (see section 4.3, page 64) it became clear that this area wasn't suited to cultivation and that multiple benefits could be achieved if a permanent multi-species pasture could be established there.



12 Soils for Life has produced a valuable set of landscape rehydration case studies, podcasts and videos that provide further insight into this Community of Practice project. These can be found at www.soilsforlife.org.au/landscape-rehydration

The goal that emerged from the mentoring program was:

To protect, enhance and restore the riparian area along the front paddock gully with a series of in-stream structures, exclusion fencing and revegetation. The goal is to provide a buffer reserve between cultivated paddocks and the waterway, as well as slowing and retaining more water within the waterway during flood events and to help prevent erosion.

Yarrawa Park was selected as a suitable property for the 'Boots on Ground' day, which was attended by 39 participants. Several structures that featured in the project plan were installed in a gully, including:

- log-sill and rock weir
- brush weirs
- pin weir
- coir log weir.

Reeds were also transplanted to encourage wetland species to take root in those treated areas.

Decision-making framework	Yarrawa Park Project Plan
1. Grow more plants	Establish permanent multi-species pasture in adjacent paddocks
2. Protect and expand intact features	Install exclusion fencing and revegetate
3. Halt active erosion	Implement natural infrastructure solutions
4. Rebuild and regenerate degraded waterways	Implement natural infrastructure solutions

Figure 93: Log-sill and rock weir being constructed during the bootcamp. Photo by Grow Love Project.

What has the outcome been?

The project exemplifies the benefits accrued when socially supportive processes are incorporated into nature repair projects. Learning in a collaborative environment and directly participating in projects, even very small ones, makes a real difference for people who might otherwise feel reticent to try solutions themselves. Feedback and testimonials attest to the fact that the Community of Practice program has had a significant positive impact in the Swan Brook region with respect to the uplift of knowledge, skills and enthusiasm for tackling achievable projects. Local land managers, supported by the local Landcare Coordinators and LLS staff, continue to share ideas and solutions and stage events to support transformational work at the property scale around the catchment.

"The work that we've done today has really demonstrated just how simple it is…you know, you can make a lot of change just with a handful of people and half a day on the ground."

Farmer Emma Ratajczyk, 'Boots on Ground Day' participant.

"I originally assumed that if you held more water on, say, my farm, then the next person wouldn't get it. It's actually the opposite, that the more you hold it in, the more it hydrates here and then the slower the water will flow down the Swan Brook and then everybody gets access to more water."

Codie Law

"Having that expertise to get those one-on-ones, to work on the landholders' plans together, I think that's the exciting part. Seven out of our original ten landowners all now have property plans that they can work on, know their next steps. Without having that Community of Practice or that funding, I think we'd still be chasing our tails."

Lee Thompson, CEO and Landcare coordinator for the Gwydir and Macintyre Resources Management Committee (GWYMAC).

"Having 10% of the catchment area already under rehydration and sustainable agricultural practices has allowed landholders to observe and compare landscapes and learn from neighbours."

Andrew Walsh, Northern Tablelands Local Land Services.

6.7 Mulloon Rehydration Initiative

Project Location
Mulloon Creek Catchment, Bungendore NSW

Country
Ngunnawal

Size (HA)
23,000 – 50 kms of creek

Land Use context
Livestock grazing (predominantly)

Participants / organisations
23 landholders

Funding Sources
Multiple external funding sources including Australian Government, NSW Government and philanthropy

Project scale
Catchment-scale project

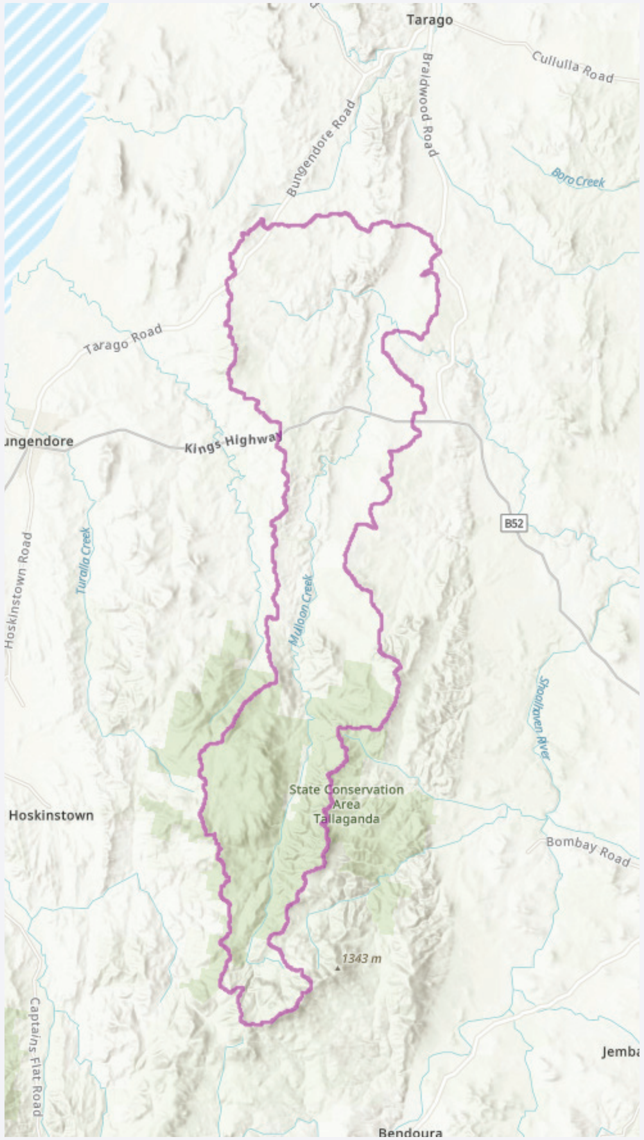


Figure 94: The Mulloon Catchment, with in-stream structures depicted. Detailed information about the Mulloon Rehydration Initiative, including the monitoring array can be viewed at the Mulloon Interactive Web Map (2025).

What problems was the project seeking to address?

The degradation of the Mulloon Creek floodplain after 200 years of agriculture, forestry and mining reached a point of acute crisis during the Millennium Drought (2001–2009). The deep and chronic erosion of creeks and gullies has lowered the water-table, dried up wetlands and dramatically reduced the water holding capacity of the soils. In 2005, Tony Coote, owner of Mulloon Creek Natural Farms, became interested in the in-stream structures – or 'leaky weirs' - being tested at the time by Peter Andrews as a strategy to reinstate slower flows. He invited Peter to do an experimental project on the stretch of Mulloon Creek that ran through his farm.

What factors shaped the project's establishment and scope?

In the early 2000s there was strong interest in the potential of Natural Sequence Farming among scientists and NRM professionals in CSIRO and other Australian Government departments. Peter Hazell, a Government NRM facilitator for the ACT and former Upper Shoalhaven Landcare Coordinator, was tasked with investigating how Natural Sequence Farming and other strategies for healing broken water cycles might be demonstrated. Hazell, who had a keen interest in water cycle science and chain-of-ponds ecosystems, began facilitating gatherings involving Peter Andrews, landholders, scientists, community and government representatives. At the assurance that the concept had the backing of Tony Coote's neighbours and the wider community, the Catchment Management Authority agreed to be the lead applicant on a funding bid to establish a pilot project on a 2.4 km stretch of Mulloon Creek, which was successful.

The first few years of the project saw numerous structures installed in Mulloon Creek. However, there were funding limitations and other obstacles that arose due to its experimental nature and Peter Andrews' style of working. In 2011, Tony Coote and his wife Toni decided to found the Mulloon Institute, and sought to expand the project. The idea was initially met with some mistrust and skepticism in the community. By this point Peter Hazell had left the public service, and Tony invited him to play a larger role. Through extensive community engagement, Hazell managed to gain support for a 'catchment-scale' project that could involve many other Mulloon Creek landholders and achieve greater benefits. One of the conditions of the landholders' support was that the project be properly monitored.

In 2014, a grant from the Vincent Fairfax Family Foundation enabled the Mulloon Rehydration Initiative (MRI) to begin, with over 20 landholders involved. Peter Hazell, now Principal Landscape Planner at the Institute, took responsibility for its planning and implementation. In the subsequent years, grants from NSW Environment Trust and the National Landcare Program enabled over 60 in-stream structures to be built and a comprehensive monitoring program to be established. With the support of a Science Advisory Committee, the monitoring program was designed to capture the effects of landscape rehydration interventions on the ecology and farm productivity of the landscapes within the Mulloon catchment.Considerable revegetation has occurred, as well as land management alterations that complement the in-stream works, such as fencing and the construction of contour banks on slopes. The design, planning and engineering of the in-stream structures was to a highly rigorous standard that now provides a template for the work Mulloon Institute does around the country.

Similarly, Hazell's dedication to bringing community, NRM and agricultural sector stakeholders 'into the tent' to cooperatively pursue catchment health outcomes continues to shape the Institute's approach to projects and partnerships.

In 2024 the Mulloon Rehydration Initiative was awarded the Biodiversity Award at the NSW Banksia Sustainability Awards and in 2025 it went on to win the National Biodiversity Award.

"The aim of the weirs is to correct the physical structure and function of the system. Rapid revegetation is critical in stabilising and transforming the system into one that is aggrading and not eroding. All sites are fenced to exclude livestock and revegetation uses a diversity of native trees, shrubs and rushes."

Peel & Hazell et al, 2022, 30.

Figure 95: Mulloon Creek, August 2020, with floodwaters receding. Multiple in-stream structures attenuated the high flows, and caused water to safely overbank and spill across the floodplain. As a result, water reached secondary and tertiary channels, extending the hydrating footprint of the flood, and tonnes of nutrient-rich sediment were deposited across the floodplain.

What has the outcome been?

Extensive monitoring data has been collected to understand the effect of landscape rehydration interventions on the ecology and farm productivity of the landscapes within the Mulloon catchment. Some of the key outcomes include:

Creek Flow

- Downstream flow has increased, water held within system.
- Multiple overbank events, including during a 1 in 100 year flood, with minimal erosion.
- Improved water quality across all parameters.

Soils and Vegetation

- Increased organic matter content.
- Increased levels of productivity for grazing.
- Increased soil fertility.
- A key productivity measure, Total Standing Dry Matter (TSDM) on the floodplain has, in some cases, doubled since the instream works, possibly due to the increased frequency of over-bank events.

Biodiversity

- Riparian and instream plant assemblages and species richness have shown a significant improvement, providing complex habitat and moderation of high stream flows.
- Increase in population and species richness of aquatic invertebrates and frogs.
- Increase in population of endemic Mountain galaxias fish species while significant reduction in numbers of the exotic Eastern gambusia, indicating an ecosystem aligning with natural conditions.
- High bird numbers with over 80 species recorded, including 12 rare or endangered species such as the Scarlet Robin and Azure Kingfisher.
- Rakali are returning and platypus have been seen for the first time in decades.

Figure 96: Yellow-spotted Bell Frog, being monitored with a radio tracker, Mulloon Creek.

Social

- A more connected catchment community equipped with the skills to repair their landscapes.
- Delivery of extensive educational programs for land managers, university students, schools and community groups.
- Capacity and confidence of landholders to continue implementing landscape rehydration techniques on their properties.

"It's not everywhere you'll see a heap of landowners work together to get something like this done. You probably couldn't do it on your own anyhow I don't think, it takes a few people to get together to do it."

John West – Mulloon Creek landholder.

"You can see the creek levels, the water levels have come up. The moisture has been absorbed up into the sand here and so we've started to get a lot of plant cover, the changes are quite significant."

Andrew Robinson – Mulloon Creek manager.

"The one lovely benefit that happened very quickly was the increase in birdlife here. It's been so noticeable. It was almost instant… There's a lot more green vegetation in this area, there's more water kept in behind the v-notched weirs"

Sue Tuisk – Mulloon Creek landholder.

Figure 97: A pond on Sandhills Creek with a swampy meadow immediately downstream, through which the stream naturally takes a braided flow path. In the context of the MRI, land management has been adapted to ensure that this intact and highly functional hydrological feature is protected.

Westview Diary

The following pages feature a photo diary of a single in-stream structure on Mulloon Creek that was installed in 2018 at Westview. The diary tells the story of how the condition of the site, and its function and resilience, has changed over time.

Figure 98: View of Mulloon Creek, looking South. Circles indicate where in-stream structures are located. The 'Westview Diary' tells the story of the structure in the foreground.

Figure 99a: August 2015

Westview site, prior to construction.

Figure 99b: October 2018

Prior to construction

The creek is laterally unconfined and incised through to bedrock. It is a single continuous channel flanked by sandy point bars and terraces which have had the fine floodplain sediments stripped away.

Riparian vegetation at this site is poor in density and diversity. Stream condition is poor. The banks both upstream and downstream of the site are poorly vegetated and show signs of recent erosion.

The hydraulic modelling for this structure anticipated there would be a significant reduction in the total stream power once the structure was installed. This is because the proposed structure would reduce the average stream gradient (slope), spread the flow over a greater cross-sectional area of the channel, and associated riparian fencing and revegetation will increase surface roughness.

Figure 99c: November 2018

Construction at Westview. The structure raised the site 700 mm above the existing streambed using a combination of hardwood log-sill and an imported rock baffle.

2 x 400 mm hardwood logs were pinned to the bed using 200 mm diameter hardwood uprights and keyed into each bank. 650 mm granite boulders were keyed downstream of the sill and upstream of an existing bedrock bar to create a rock baffle and to lock in the rock and sediments immediately below the sill.

Figure 99d: December 2018

Undermine protection was achieved using knitted brush mattressing and Poa tussock mulch (900gsm coir mesh can also be used).

The downstream side of the sill was filled with rock and gravel to create a ramp. Streambed gravel was placed against the upstream side of the structure, into which Typha and Phragmites were transplanted. For scour protection on the flanks, a 200 mm deep rip rap apron was installed on the downstream side (where bedrock is absent), extending to one metre above the low flow channel on both flanks.

This image shows that stock exclusion fencing has been installed to manage livestock access.

The banks and bed above, below and on the in-stream structure were extensively planted with native vegetation comprising reeds, sedges, shrubs and trees.

Figure 99e: December 2018.

This image shows a flow over the structure soon after construction.

The width of the stream has been greatly increased under baseflow conditions.

Figure 99f: February 2019

This image shows the growth of the millet that was planted as a cover crop to provide rapid stability for the rock ramp. This plant burns off with the first frost.

Figure 99g: March 2020

By the following spring, native perennial wetland vegetation has taken over, including species such as Cumbungi, Eleocharis, Carex and Phragmites.

Figure 99h: December 2020

Plants are well established and distinct plant zones are emerging, such as riparian sedges, littoral zone reeds, and floating water plants. Plants have colonised the instream works as well as the pond zone and the banks.

Plants as above plus Umbrella Sedge, Marsh Wort, Milfoil and Juncus. Less weed species also evident compared to above. The vegetation is slowing stream flow, filtering sediments and nutrients, improving water quality, moderating the micro-climate, improving the water cycle and creating a more complex ecosystem.

Figure 99i: January 2025

Vegetation in each zone has become more established, increasing habitat complexity and acting to de-energise high flows. Vegetation is armouring the leaky weir structure as well as the banks and bed of the stream. Floating water plants have spread right across the pond also de-energizing and filtering flows.

Schoenoplectus is emerging amongst the Cumbungi and Phragmites is becoming more abundant. Carex is extending across the structure. Riparian shrubs and trees planted in 2018 are now well established.

Figure 100: January 2025

View of the pond from above. Flow is right to left. Note the reed bed extends the whole way across the stream above the structure. The reed bed extends more than two metres into the zone pond behind the structure.

This helps to armour the structure from high flows. In the deeper parts of the pond, Milfoil and Marshwort are the dominant plants.

Figure 101: January 2025

View from above the structure looking downstream. It demonstrates another important role that reeds play, which is in filtering organic matter from high flows. Note that significant material has been caught up in the reed bed that extends across the stream on the upstream side of the structure.

This process captures carbon and nutrients, enabling both to be processed and recycled through the food chain. It is also an important process for building the bed of the stream.

Figure 102: Close-up view of the reed bed looking upstream from the ramp of the structure. It demonstrates the energy dissipating effect of the reed bed. The flow is being split by hundreds of stems, creating friction and turbulence, slowing and filtering the flow before it descends over the structure.

In very high flows, the reeds will lay down over the structure, further armouring it against the water's energy. In this case, in a functioning system, the organic matter will be caught in the riparian vegetation or be deposited on the floodplain.

References

AAEE (2020) *A Palette of Possibilities for environmental action projects*. Australian Association for Environmental Education – NSW Chapter. https://aaeensw.org.au/wp-content/uploads/2020/03/paletteofpossibilitiesv1compact-208.pdf

Abdilla, A. (2020) 'Learning from Country centred knowledge systems', Whyte Lecture, Monash University, https://www.monash.edu/it/whyte-fund/whyte-lecture/learning-from-country-centred-knowledge-systems

AIATSIS (1996) AIATSIS Map of Indigenous Australia https://aiatsis.gov.au/explore/map-indigenous-australia

Apfelbaum, Steven & Haney, Alan. (2010). *Restoring Ecological Health to Your Land*. Island Press, Washington.

Apfelbaum, Steven & Haney, Alan. (2012). *The Restoring Ecological Health to your Land Workbook*, Island Press, Washington.

Bernacchi CJ, VanLoocke A. Terrestrial ecosystems in a changing environment: a dominant role for water. *Annu Rev Plant Biol.* 2015;66:599-622. doi: 10.1146/annurev-arplant-043014-114834. Epub 2015 Jan 22. PMID: 25621516.

Brierley, G J, and K A Fryirs. 2005. *Geomorphology and River Management: Applications of the River Styles Framework.* Oxford: Blackwell Publishing.

Chapin, Stuart F, Gary P Kofinas, and Carl Folke. 2009. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World.* Springer.

Cross, R., & Ampt, P. (2017). Exploring Agroecological Sustainability: Unearthing Innovators and Documenting a Community of Practice in Southeast Australia. *Society & Natural Resources,* 30(5), 585–600. https://doi.org/10.1080/08941920.2016.1230915

Commonland (2021) The Four Returns Framework for Landscape Restoration *https://commonland.com/wp-content/uploads/2021/08/4-Returns-Framework-For-Landscape-Restoration.pdf*

Conner, T., Fisher, L., Hazell, P., Healy, E. & Walsh, A. (2024) 'Land Restoration and Water Stewardship with the Swan Brook Community of Practice' *11th Australian Stream Management Conference Proceedings.* https://asnevents.s3.amazonaws.com/Abstrakt-FullPaper/103097/Connor_et_al_Swan_Brook_CoP_FINAL.pdf

Eco Logical Australia (2023). *Sydney Drinking Water Catchment Audit 2019-2022*. Prepared for the NSW Minister for Water. https://www.waternsw.com.au/__data/assets/pdf_file/0007/239344/Drinking-Water-Catchment-Audit-2022-Main-Report.pdf

Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., van Noordwijk, M., Creed, I. F., Pokorny, J., Gaveau, D., Spracklen, D. V., Tobella, A. B., Ilstedt, U., Teuling, A. J., Gebrehiwot, S. G., Sands, D. C., Muys, B., Verbist, B., ... Sullivan, C. A. (2017). Trees, forests and water: Cool insights for a hot world. *Global environmental change: human and policy dimensions, 43*, 51-61. https://doi.org/10.1016/j.gloenvcha.2017.01.002

Environmental Defense Fund (2020) 'Multiple Benefits of Natural Infrastructure in Agricultural Landscapes' Fact Sheet, https://www.edf.org/sites/default/files/content/Benefits-Natural-Infrastructure-Agricultural-Landscapes.pdf

Eyles, R J. 1977. "Changes in drainage networks since 1820, Southern tablelands, NSW, Australia." *Geographer* 13: 377-387.

First Nations Portfolio (2024) *Murru waaruu (On Track)* Economic Development Seminar Series Outcomes Report, First Nations Portfolio, ANU.

Folke, C, S Carpenter, B Walker, M Scheffer, T Chapin, and J Rockström. 2010. 'Resilience thinking: integrating resilience, adaptability and transformability.' Ecology and Society 15 (4).

Gies, E. (2022) *Water always Wins: Thriving in an Age of Drought and Deluge,* Head of Zues, London.

Gore, C. (2023) 'ACT government apologises to Canberra's Ngambri people for failing to recognise them as traditional custodians'. ABC News, 27 April 2023. https://www.abc.net.au/news/2023-04-27/act-government-apologises-to-ngambri-over-indigenous-protocol/102274536

Hazell, D., Osborne, W., & Lindenmayer, D. (2003). Impact of post-European stream change on frog habitat: Southeastern Australia. *Biodiversity and Conservation, 12*(2), 301-320. https://doi.org/10.1023/A:1021999518939

Healthy Rivers Commission of NSW. 1999. *Independent inquiry into the Shoalhaven river system*. Sydney.

Janke T, Cumpston Z, Hill R, Woodward E, Harkness P & von Gavel S & Morrison J (2021). *Australia state of the environment 2021: Indigenous*, independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra, DOI: 10.26194/3JDV-NH67.

Johnston, P, and G Brierley. 2006. "Late Quaternary river evolution of floodplain pockets along Mulloon Creek, New South Wales, Australia ." *The Holocene* 16 (5): 661-674.

Lancaster, B., & Marshall, J. (2013). *Rainwater harvesting for drylands and beyond*. Second ed. Tucson, AZ, Rainsource Press.

Lhotsky, John. 1835. *A journey from Sydney to the Australian Alps undertaken in the months of January, February and March, 1834*. Sydney: Innes.

Liu, J. D, Hiller, B. (2016) 'A Continuing Inquiry into Ecosystem Restoration: Examples from China's Loess Plateau and Locations Worldwide and Their Emerging Implications' in I. Chabay, M. Frick, J. Helgeson (eds), *Land Restoration: Reclaiming Landscapes for a Sustainable Future*, Academic Press, pp. 361-379.

Martyn, T. E., Barberán, A., Blankinship, J. C., Miller, M., Yang, B., Kline, A., & Gornish, E. S. (2022). Rock structures improve seedling establishment, litter catchment, fungal richness, and soil moisture in the first year after installation. *Environmental Management,* 70(1), 134-145. Available at: https://doi.org/10.1007/s00267-022-01651-6.

Moggridge, B. J. (2020) 'Aboriginal people and groundwater', *Proceedings of The Royal Society of Queensland* Vol. 126, pp. 11-27 Great Artesian Basin Springs Special Edition, www.royalsocietyqld.org/2020-springs-special-issue-vol-126/

Moggridge, B.J., Thompson, R.M. & Radoll, P. (2022) 'Indigenous research methodologies in water management: learning from Australia and New Zealand for application on Kamilaroi country'. *Wetlands Ecol Manage* 30, 853–868. https://doi.org/10.1007/s11273-022-09866-4

Mulloon Institute (2022) *Mulloon Rehydration Initiative* Case Study https://static1.squarespace.com/static/5600deebe4b07aebe017c6d2/t/61ef923fb62e0a0c746a5d5d/1643090566154/2021+Case+study+-+MRI.pdf

Mulloon Interactive Web Map (2025) https://arcg.is/0jmPGe0

Nichols, Mary & McReynolds, Kimberly & Reed, C. (2012) 'Short-term soil moisture response to low-tech erosion control structures in a semiarid rangeland'. *CATENA*. 98. 104–109. 10.1016/j.catena.2012.06.010.

Norman, L, F Brinkerhoff, E Gwilliam, D. P Guertin, J Callegary, D Goodrich, P Nagler, and F Gray. 2016. 'Hydrologic Response of Streams Restored with Check Dams in the Chricahua Mountains, Arizona.' *River Research and Applications* 32: 519-527.

Norman, L. M. (2020). 'Ecosystem Services of Riparian Restoration: A Review of Rock Detention Structures in the Madrean Archipelago Ecoregion'. *Air Soil Water* Res. 13 doi:10.1177/1178622120946337

Norman, L., R. Lal, E. Wohl, E. Fairfax, A. C. Gellis, M. M. Pollock (2022) 'Natural infrastructure in dryland streams (NIDS) can establish regenerative wetland sinks that reverse desertification and strengthen climate resilience' *Science of the Total Environment* 849, 157738. https://doi.org/10.1016/j.scitotenv.2022.157738

Mactaggart, B., Bauer, J., Goldney, D., Rawson, A., 2008. 'Problems in naming and defining the swampy meadow—An Australian perspective'. *Journal of Environmental Management*, 87(3), 461473. https://dx.doi.org/10.1016/j.jenvman.2007.01.030

McKnight, Anthony (2015). 'Mingadhuga Mingayung: Respecting Country through Mother Mountain's stories to share her cultural voice in Western academic structures'. *University of Wollongong* Journal contribution. https://hdl.handle.net/10779/uow.27737289.v1

Peel, L., Hazell, P., Bernardi, T., Dovers, S., Freudenberger, D., Hall, C., Hazell, D., Jehne, W., Moore, L. and Nairn, G. (2022), 'The Mulloon Rehydration Initiative: The project's establishment and monitoring framework' *Ecol Manag Restor*, 23: 25-42. https://doi.org/10.1111/emr.12549

Pokorný, Jan & Brom, Jakub & Cermák, Jan & Hesslerová, Petra & Huryna, Hanna & Nadezhdina, Nadia & Rejšková, Alžběta. (2010). 'Solar energy dissipation and temperature control by water and plants'. *International Journal of Water*. 5. 311-336. 10.1504/IJW.2010.038726.

Prosser, I. 1991. 'A Comparison of Past and Present Episodes of Gully Erosion at Wangrah Creek, Southern Tablelands, New South Wales.' *Australian Geographical Studies* 29 (1): 139-154.

Prosser, I., J Chappell, and R Gillespie. 1994. 'Holocene valley aggradation and gully erosion in headwater catchments, south-eastern highlands of Australia. *Earth Surface Processes and Landforms* 19 (5): 465-480.

Ripl W. 'Water: the bloodstream of the biosphere'. *Philosophical Transactions, R Soc Lond B Biol Sci.* 2003 Dec 29;358(1440):1921-34. doi: 10.1098/rstb.2003.1378

Rivers of Carbon (2019) 'Buffers, sponges and moderators – managing swampy meadows, wetlands and chains-of-ponds' Technical Note, https://riversofcarbon.org.au/our-projects/rivers-carbon-source-water-linkages/buffers-sponges-moderators-managing-swampy-meadows-wetlands-chains-ponds/

SELLS (2014) *South East Catchment Action Plan, South East Local Land Services* https://www.lls.nsw.gov.au/__data/assets/pdf_file/0009/752832/South-East-CAP.pdf

Silverman, N.L., Allred, B.W., Donnelly, J.P., Chapman, T.B., Maestas, J.D., Wheaton, J.M., White, J. and Naugle, D.E. (2019), 'Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands'. *Restor Ecol*, 27: 269-278. https://doi.org/10.1111/rec.12869

Sustainable Farms (2020) *Ten ways to improve the natural assets on a farm*, Fenner School of Environment & Society, Australian National University, Canberra.

Soils for Life (2019) Mulloon Creek Catchment – Case Study https://soilsforlife.org.au/mulloon-creek-catchment-this-is-the-story-about-a-creek/

Soils for Life (2025) 'Community-led Landscape Rehydration: Building drought resilience on a community and catchment scale' – Case Study, https://soilsforlife.org.au/community-led-landscape-rehydration/

Throsby, C. 1822. "Papers of Charles Throsby, including various journals of exploration, 1822-1826." *Empire Studies. Australia Colonial Life And Settlement_Part2_Reel34_Vol2*. Compiled by Adam Matthew Digital. Marlborough, Wiltshire : Adam Matthew Digital, February.

Tongway, D. & Ludwig, J. (1996) 'Rehabilitation of Semiarid Landscapes in Australia. I. Restoring Productive Soil Patches' *Restoration Ecology* 4(4), 388-397.

Tongway, D.J. & Ludwig, J.A. (2011) *Restoring Disturbed Landscapes – Putting Principles into Practice*. Island Press, Washington, Covelo.

Tongway, D. & N. Hindley (2004) *Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes*. CSIRO, Canberra. https://www.researchgate.net/profile/David-Tongway-2/publication/238748160_Landscape_Function_Analysis_Procedures_for_Monitoring_and_Assessing_Landscapes_-_with_Special_Reference_to_Minesites_and_Rangelands/links/0deec52c915ae0139e000000/Landscape-Function-Analysis-Procedures-for-Monitoring-and-Assessing-Landscapes-with-Special-Reference-to-Minesites-and-Rangelands.pdf

Trenberth, Kevin (2011) 'Water Cycles and Climate Change.' *In Global Environmental Change.* Springer.

Thwaites, R. & Brookes, A. (2021) 'A gully is not a stream channel. How do we tell the difference and why does it matter?' *10th Australian Stream Management Conference*, August 2021, https://asnevents.s3.amazonaws.com/Abstrakt-FullPaper/74446/10ASM+paper_Thwaites_FULL_PAPER_FINAL.pdf

WaterNSW (2020). *Source Water Protection Strategy: Sydney drinking water catchment 2040*. Sydney: WaterNSW.

WaterNSW (2024a). *Managing the Catchment* https://www.waternsw.com.au/water-services/catchment-protection/management

WaterNSW (2024b) WaterInsights Portal, Upper Shoalhaven Tributaries, https://waterinsights.waternsw.com.au/18876-upper-shoalhaven-tributaries-/updates

Wheaton J.M., Bennett S.N., Bouwes, N., Maestas J.D. and Shahverdian S.M. (Editors). (2019) *Low-Tech Process- Based Restoration of Riverscapes: Design Manual. Version 1.0.* Utah State University Restoration Consortium. Logan, UT. Available at: http://lowtechpbr.restoration.usu.edu/manual

Williams, R. T. (2018). *The hydrogeomorphic structure, function and evolution of chainsofponds: implications for recognition of these discontinuous watercourses in river management*. Macquarie University. Thesis. https://doi.org/10.25949/19443353.v1

Wilkinson S, Hairsine PB, Bartley R, Brooks A, Pietsch T, Hawdon A, Shepherd R. (2022) Gully and Stream Bank Toolbox. *A technical guide for gully and stream bank erosion control programs in Great Barrier Reef catchments*. 3rd Edition. Commonwealth of Australia.

Zeedyk, B. and Clothier, V. (2009) *Let the Water Do the Work: Induced Meandering, an Evolving Method for Restoring Incised Channels*, Island Press, Washington D.C.


Mulloon Institute
For environment, farming and society
Rehydrating landscapes

The Mulloon team sincerely thanks all the land owners and managers, community groups, partner organisations and neighbours who have been part of the journey so far - many of whom feature in these pages. Your dedication to the care of our landscapes inspires and motivates us every day.

We know this community of water stewardship champions will continue to grow, and we look forward to working together for many years to come!

PO Box 126, Bungendore NSW 2621 Australia
info@mullooninstitute.org | mullooninstitute.org