Roseberry Creek

Catchment Rehydration Feasibility Report

2021

Roseberry Creek

Project Aims and Objectives

- Aim: To apply The Mulloon Institute's approach to riparian restoration, erosion management, habitat restoration and water management.
- Objectives: To complete a feasibility study for the Roseberry catchment to serve as a guide for the direction and scope of future catchment scale landscape rehydration works.

Please note

This feasibility report has been scoped based upon the information requested by the Border Ranges –Richmond Valley Landcare Network (BRRVLN); with the intent to better understand a potential landscape rehydration approach in the Roseberry Creek catchment. This report is an overview and cannot make specific recommendations for on-ground activities as this would require further on-ground reconnaissance to understand the catchment and provide recommendations.

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Document Control

Document Reference	Roseberry Creek Catchment Rehydration Feasibility Report 2021
Project	Roseberry Creek
Document Type	Draft
Author	A Dunne, B McAlister and P Irish

Revision History

Date	Version	Name	Comments
10.12.21	Ver 1	A. Dunne & B. McAlister	Draft
21/12/21 22/01/2022	Ver 2	P. Hazell & N. McColl	Review draft
22/12/21 24/01/2022	Ver 3	C. Hall	Final review draft report
5/02/2022	Ver 4	G. Tinning	Review of draft report
7/2/22	Ver 5	A. Dunne & N. McColl	Final PDF

Document Approval

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1 Introduction

1.1 Project Background

The Border Ranges–Richmond Valley Landcare Network (BRRVLN) engaged the Mulloon Institute (TMI) to present a workshop to Landcare members in the Roseberry catchment in February 2021. Peter Hazell and Sam Skeat presented the workshop and visited properties in the area. Following on from the workshop, Gavin Tinning (BRRVLN Project Officer) approached TMI to complete a feasibility study on the catchment with the lens of landscape rehydration and land management practices. The catchment is currently engaging with the NSW Soil Conservation Services and alternative land management practices, with a longer-term goal to create demonstrations for a diversity of approaches in addressing land management concerns.

1.2 What is Landscape Rehydration?

Landscape rehydration is the act of restoring a range of biophysical processes that have been disrupted in a degraded landscape to improve the way that landscape functions, with a particular emphasis on the water cycle. The biophysical processes that affect how landscapes function are interrelated and include the capture of energy (solar and other forms), retention and use of water, and cycling of nutrients[1]. These processes drive biological productivity and are therefore critical to sustaining agricultural productivity.

Some features of hydrated, functional landscapes include high levels of vegetative groundcover, healthy, water-receptive soils, clean surface water flows, stable stream forms and high levels of primary productivity. Water moves through a hydrated landscape more slowly. The volume stored in soils and vegetation is greater. Stream pulse events are moderated, reducing the erosive energy of flows and increasing the permanency of streams (

Figure 1).

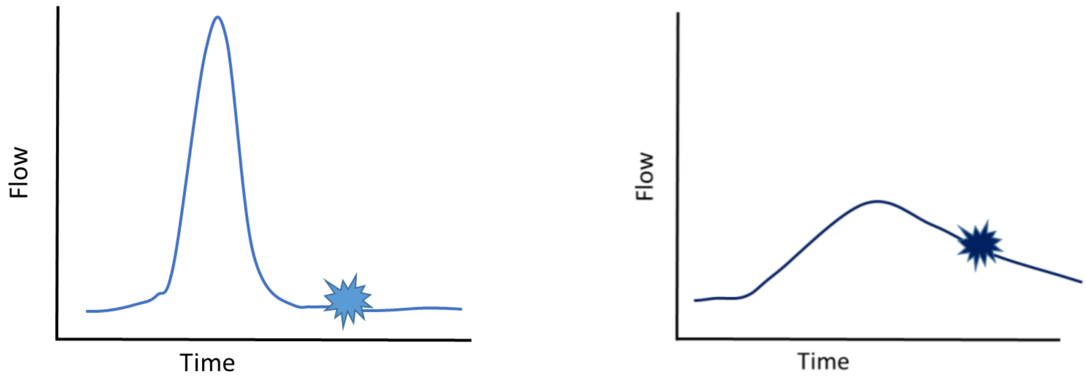

Figure 1: Conceptual flow duration curve for a degraded (left) and restored (right) stream after a rainfall event. A restored stream tends to have a lower peak flow and a higher baseflow than a degraded stream.

A range of techniques are used to achieve landscape rehydration, including installing erosion control structures, changing vegetation management (e.g., rotational grazing, revegetation, cover cropping) and installing leaky rock and/or log structures in incised stream channels to begin to restore a more natural flow regime. The principles used to understand and restore landscape function are the same

[1] Tongway, D and Ludwig, J. (2011) *Restoring disturbed landscapes: Putting principles into practice*. Island Press, Washington, USA.

for all landscapes, but the physical interventions are unique to each situation in which they are applied.

1.3 Aims and objectives

BRRVLN has requested that the feasibility study include the following elements and that the report is practical to inform future on ground works within the catchment. This report follows the delivery of a landscape rehydration workshop for BRRVLN by TMI in February 2021.

- catchment layers
- identification of suitable options for landscape rehydration
- identification of stream order for the Roseberry catchment
- information on navigating the relationship between leaky weirs and harvestable water rights
- potential permits are required for construction.

2 Catchment Description

2.1 Catchment context

Location:	Scenic Rim: Northern Eastern New South Wales
Catchment:	Roseberry Creek catchment – 4,850 ha
Council:	Kyogle
Zoning:	Ru1, Primary Production
Development Approval (DA) required?	Leaky weirs and creek crossings are considered environmental protection works. In the Kyogle Local Environmental Plan 2012[2]; environmental protection works are permitted without consent
Controlled Activity Approval (CAA) required?	Unless undertaken for and on behalf of a determining authority, under Part 5 of the EP&A Act 1979, all works in a 3rd order stream or above require a CAA, as defined by the Water Management Act 2000[3]. For more information, see: https://www.industry.nsw.gov.au/water/licensing-trade/approvals/controlled-activities

The Roseberry Creek Catchment is a tributary of the Richmond River; the catchment is depicted in Figure 2. The following sections describe the catchment, including climate, landform, geology, soils, stream order, vegetation and historical context.

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2 Kyogle Local Environmental Plan 2012 (2013 EPI 25). Kyogle Local Environmental Plan - NSW Legislation https://legislation.nsw.gov.au/view/html/inforce/current/epi-2013-0025#pt

3 Water Management Act (2000) New South Wales Government. https://legislation.nsw.gov.au/view/pdf/asmade/act-2000-92

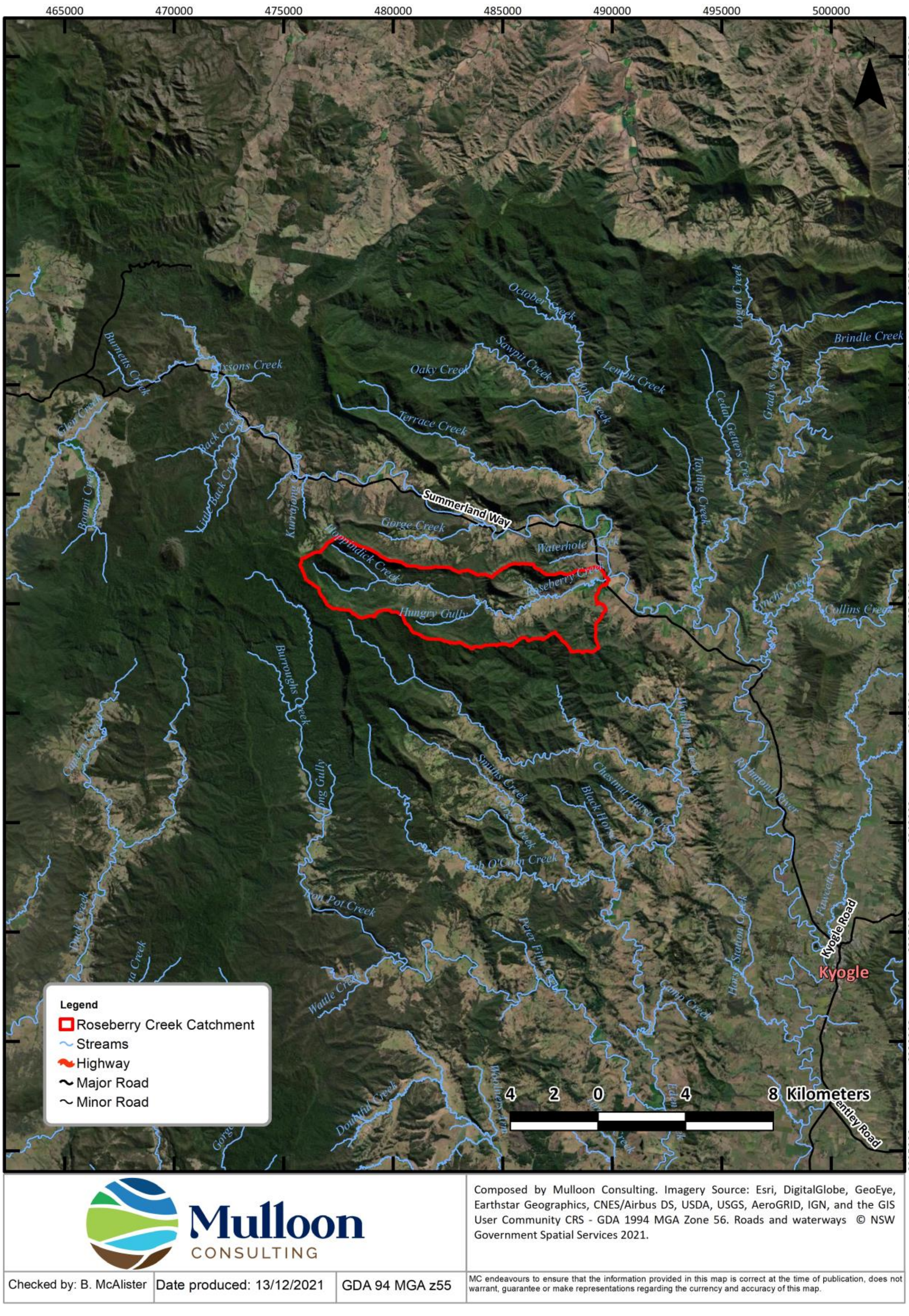

Figure 2. The position of Roseberry catchment within the Richmond River valley and with the regional town of Kyogle, with roads and waterways included.

2.2 Climate

The Roseberry catchment area generally experiences warm, humid and wet summers, with winters that are short, cool and mostly clear. The median annual rainfall is 1199 mm[4] (see Figure 3). The annual median maximum temperature is 22.5°C and the median minimum temperature is 12.7°C[5] Figure 4). The temperature typically varies between 6°C and 30°C.

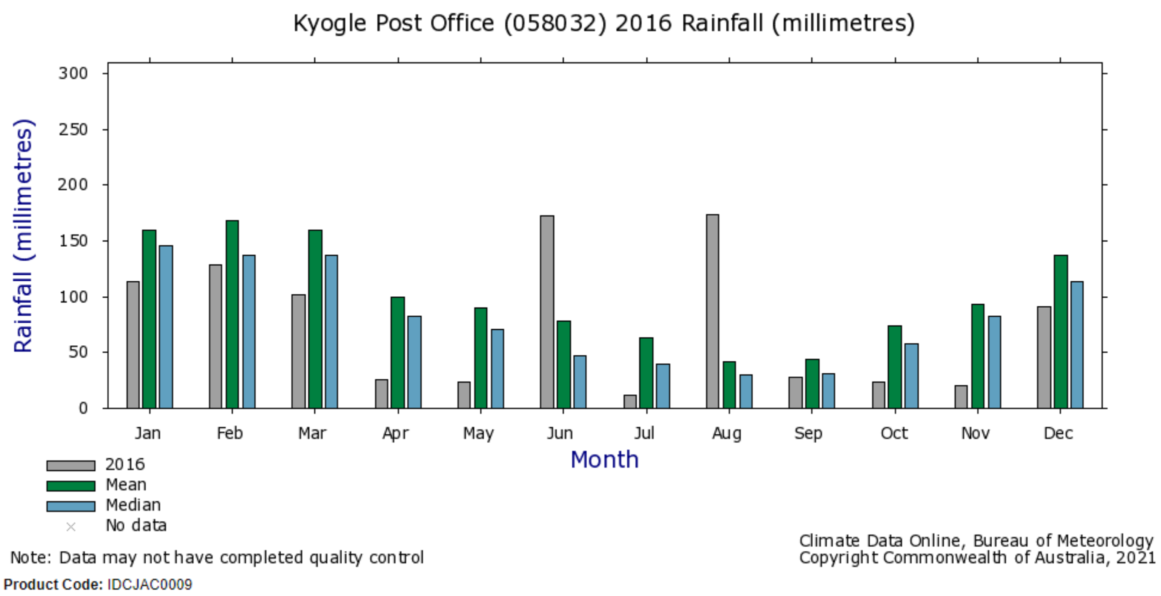

Figure 3. The 2016, and monthly mean and median rainfall for the Kyogle post office.

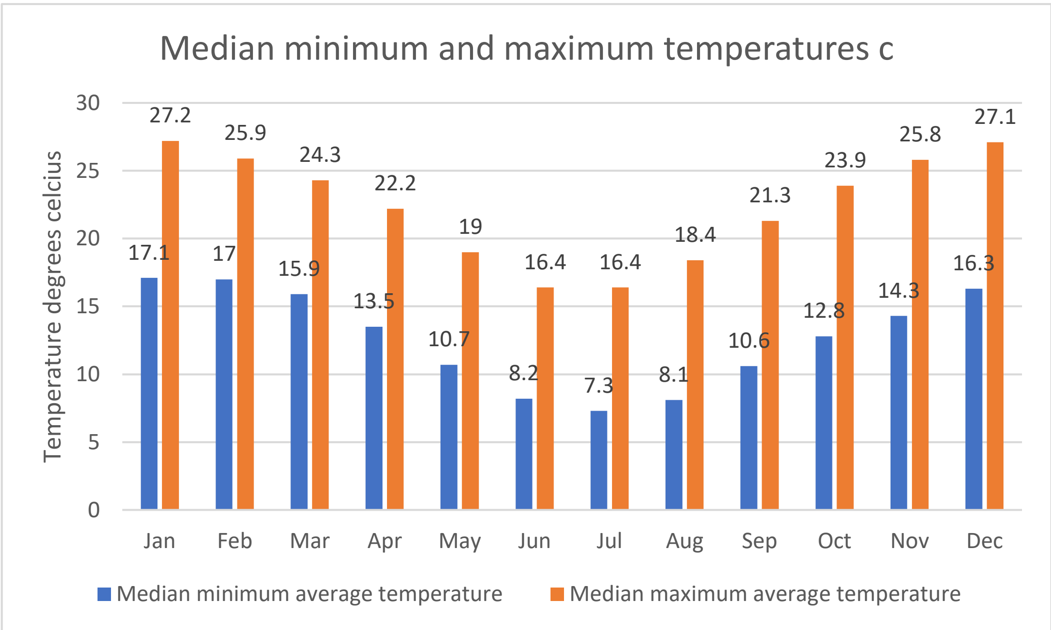

Figure 4. Median minimum and maximum temperatures for Roseberry creek from 1970–2021, taken from the Tabulam weather station, BOM.

4 BOM (2021) Bureau of Meteorology. Climate data online.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_stn_num=058032

5 BOM (2021) Bureau of Meteorology. Monthly mean temperature
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=36&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=057095

The rainfall data has been taken from the Kyogle post office, 24 km from Roseberry Creek. It has the greatest length of observations available, from 1908–2017. Rainfall data is therefore an indicator of the rainfall within the Roseberry catchment. Likewise, temperature data is from the Tabulam station office,48.5 km from Roseberry Creek. Temperature information is also presented as an indicator.

Australia's land areas have warmed by 1.4°C from 1910–2020, this is combined with annual temperature changes above natural variabilities[6]. Since 2005, Australia has recorded the four hottest years on record; 2019, 2013, 2005 and 2020 respectively. This is evident in the recent drought occurring across large parts of NSW from 2017–2020. In 2019 the conditions were drier and hotter than any other recorded drought in NSW in the past 120 years[7].

As a tributary of the Richmond River, the downstream impacts of Roseberry Creek have been noted in two recent reports focusing on the Northern Rivers. While the reports do not focus on Roseberry, they are a good indicator for the wider catchment challenges and opportunities. The reports are the "*Northern Rivers Watershed Initiative*" by the Rous County council[8] and the "*Review into the implementation of nature-based solutions for flood risk management"* by the Lismore Floodplain management committee[9]. Key themes of the reports are the role of hydrological cycles, biodiversity and agricultural land management in mitigating the impacts of climate change; including shifts in rainfall patterns, bushfires increased flood events and damage to infrastructure and property.

Current predictions of climate change impacts are based on the number of greenhouse gasses released in a set period and the mitigating actions taken. Commonly these are referred to as 1.5°C, 2°C and 4°C warming scenarios. Under all scenarios for future climate prediction, in Australia heat extremes will continue to increase and cold extremes decrease. Southeastern Australia may drop by up to 20% of its annual rainfall in some areas. The frequency of extreme fire days and fire seasons will continue to increase. Heavy rainfall and river floods are projected to increase. Heatwaves, droughts and floods are projected to increase. Marine warming events will increase as will rising sea levels and ocean acidification[10]. Sand and dust storms from the interior will be more common. It is not clear if sand and dust storms will impact the Northern Rivers[6].

2.3 Historical catchment description

2.3.1 Aboriginal Heritage

Before the European colonisation of Australia, "*the Richmond valley was occupied by the Gidabal and Galibal people a dialectic subgroup of the Bundjalung Language*"[11]. It is reported that fire was used in the area as a management tool for woody species and trees along with a tool to cycle nutrients and energy in a landscape. This is consistent with practices set out by modern interpretations of aboriginal land management[12 13].

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6 Zhai, V. P., A. Connors, L. Pean, C. Berger, S. Caud, N. Chen, Y. Goldfarb, L. Gomis, M. Huang, M. Leitzell, K. Lonnoy, E. Matthews, R. Maycock, T. Waterfield, T. Yelekci, O. Yu, R And Zhou, B. 2021. Ipcc, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press Intergovernmental Panel on Climate Change

7 Bureau of Meteorology (2021) BOM temp record continent Australian 12-monthly mean temperature anomalies since 1911 (bom.gov.au)

8 Rous County Council, 2019, Northern Rivers Watershed Initiative: Discussion Paper, February 2019.

9 Kirby, M (2021) A review into the implementation of nature-based solutions for flood risk management. Report prepared for the Lismore Floodplain Management Committee.

10 IPCC (2021) Regional Factsheet: Australia. IPCC fact sheet PowerPoint Presentation (ipcc.ch)

11 Lennon, J. 2002a. Report on regional history and landscape context for the Githabul Native Title Claim, northern NSW. Unpublished report for State Forests of NSW.

12 Gammage, B. (2012) The Biggest Estate on Earth: How Aboriginals Made Australia. Allen & Unwin.

13 Pascoe, B. 2014, Dark Emu: black seeds: agriculture or accident? / Bruce Pascoe Magabala Books Broome, Western Australia

Sacred sites in the area are often associated with the many mountain tops and by extension the forests[10]. This information is reported to come from the *Githabul* people at Mulli which is on the other side of the Toonumbar National Park from Roseberry Creek approximately 50 km via the current road. Surveys conducted in the 1990s returned 66 sites of stone artifacts and two rock shelters in the Richmond Range[10]. The shire wide Aboriginal Cultural Heritage mapping project completed in 2012[14] found four sites of significance in the Roseberry catchment. A map of the rough site location is available in Appendix 1: Roseberry Creek Aboriginal cultural heritage mapping and Appendix 2: Description of the Aboriginal cultural heritage sites in the Roseberry catchment

Kyogle Council Aboriginal Community Advisory Committee, in consultation with Local Aboriginal Land Councils have produced the 2012 Shire Wide Aboriginal Cultural Heritage Mapping Project, which can be found at this link: 2012 Shire Wide Aboriginal Cultural Heritage Mapping Project

holds the site number descriptors.

2.3.2 Colonial Heritage

In 1828 Captain Henry Rous is reported to have discovered and explored the Richmond River and its estuaries. The area was untouched by Europeans for the next two years until the drought in the south drove settlers into the New England tablelands with the overflow settling in the Richmond and Clarence valleys [15]. Drought may have been a primary driver for expansion onto the area, but timber soon became a staple part of the economy. The cutting and milling of cedar was a significant industry by the late 1830s. The region exported 624,500 feet of cedar in 1945 which was two-thirds of Australia's total exports[16]. Small coastal schooners began to trade with the region following the visit of surveyor James Burnett of Brisbane in 1843. In the early 1940s, the first grazing stations were gazetted with the largest grazing station, *Casino,* at a size of 30,000 ha. Other stations upriver were named *Wiangaree, Roseberry and Unumgar*[17]. These stations are representative of localities existing in the region today.

The Wooroowoolgen company sold the area of modern-day Roseberry to George Sparkes in 1854 who was a previous manager for the company. Following the passing of the Robertson land act in 1861, selectors began to purchase parcels of land in the region. This marks the end of the larger stations as they were broken down into smaller parcels. Increased intensity of settlements is likely to have further driven the killing and dispossession of the local Aboriginal people. By 1918, six timber mills were operating in the upper Richmond valley region (Martin, 1988).

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14 Gall, T. 2012 Shire wide aboriginal cultural heritage mapping project. Converge heritage and community pty ltd. Accessed: https://drive.google.com/file/d/1gg9tbaj8Te9Lac2M3KPd1lGgom8e_W_F/view

15 Lennon, J. 2002b. Long Creek: from logging to World Heritage, in Dargavel, J., Gaughwin, D. and Libbis, B. (ed.) Australia's Ever-Changing Forests V, proceedings of the Fifth National Conference on Australian Forest History (Canberra: Centre for Resource and Environmental Studies, ANU, in association with the Australian Forest History Society Inc.), 274–288.

16 Daley, L. T. 1966. Men and a River: Richmond River District 1825-1895 (Carlton: Melbourne University Press).

17 Martin, G. 1988. Places in the Bush: A History of Kyogle to 1988 (Kyogle: Kyogle Shire Council).

3 Hydrology

3.1 Catchment context

Roseberry Creek is a tributary of the Richmond River, which is the main water supply for Kyogle and other regions. The total area of the Roseberry Creek catchment is 4,850 ha and, as stated above in the climate section, the mean annual rainfall is 1,199 mm.

First-order streams are the starting point for water moving through the landscape. When two first-order streams meet, they join to become a second-order stream. When two second-order streams meet, they form a third-order stream. Most of Roseberry Creek is a third-order stream according to the NSW 1:100K topographic maps. (Figure 5 on page 7) shows the stream orders for the Roseberry Creek catchment.

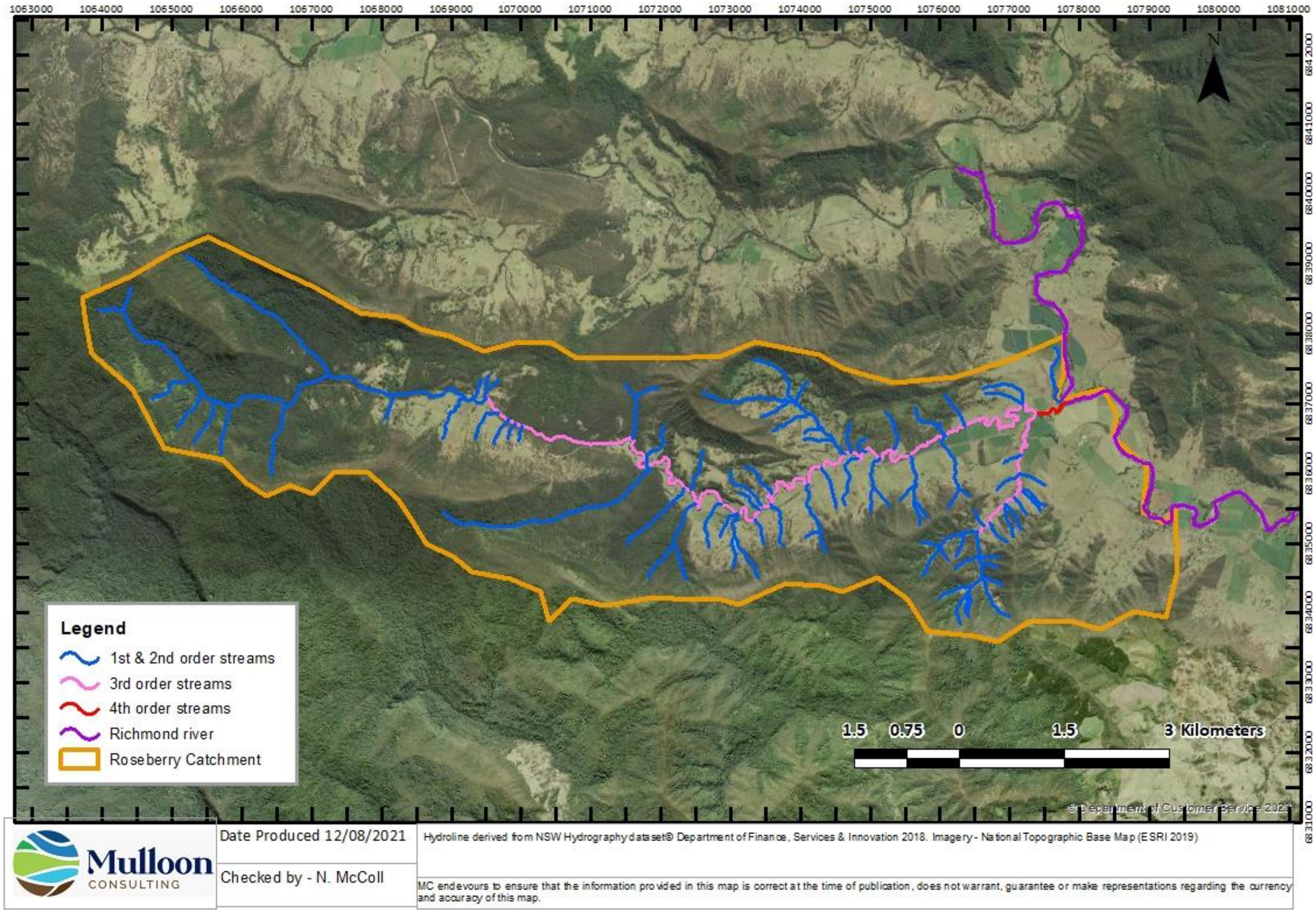

Figure 5. The stream orders of the Roseberry catchment

3.2 Total catchment yield per annum

An estimate of average annual catchment yield was prepared as an indicator of the volume of flow expected from Roseberry Creek in an average year. Only a small proportion of rainfall runs off into streams. This proportion increases as annual rainfall increases. Annual runoff can be calculated in the following way:

$$\text{Catchment yield} = \frac{A \times R \times YC}{10{,}000}$$

Where A = catchment area (Hectares)

R = average annual rainfall (mm)

YC = yield co-efficient (see Figure 75)

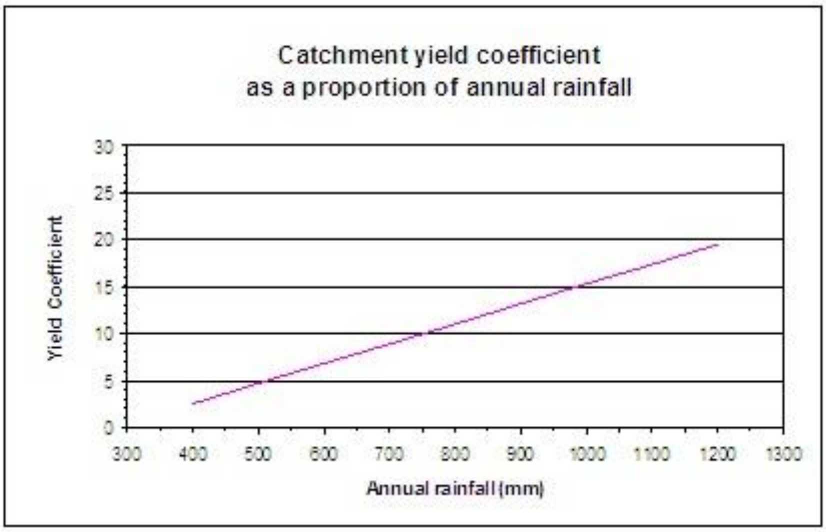

Figure 6. Catchment yield co-efficient as a proportion to annual rainfall (from the Agriculture Victoria website[18])

YC can also be influenced by soil properties and type of groundcover to give an adjusted catchment yield (see Figure 7. Adjusted catchment yield with soil and ground cover factors.).

18 Agriculture Victoria. (2018, May 16). Determining Catchment Yield for Planning Farm Dams. https://calculator.agriculture.vic.gov.au/fwcalc/information/determining-catchment-yield-for-planning-farm-dams

Adjusted Catchment Yield (megalitres) = SF x GF x LF		
SF = Soil factors		
Highly permeable soils	(sandy)	x 0.3
Permeable soils	(loamy)	x 0.6
Medium textured soils	(clay loam - light clay)	x 1.0
Heavy textured soils	(medium - heavy clay)	x 1.3
GF = Groundcover factors		
Annual pasture cover		x 1.0
Perennial pasture cover		x 0.5
Timbered or forested cover		x 0.5

Figure 7. Adjusted catchment yield with soil and ground cover factors.

Therefore, assuming the soils are heavy textured, and the groundcover is forested with patches of perennial pasture, annual catchment yield for the case study catchment is as follows:

Catchment yield = $\frac{4850 \text{ (ha)} \times 1{,}200 \text{ (annual rainfall)} \times 20 \text{ (YC)}}{10{,}000}$

= 11,640 ML per annum

Adjusted catchment yield = 11,640 ML x 1.3 (SF) x 0.5 (GF)

= 7,566 ML per annum

3.3 Regional Flood Frequency Estimation (RFFE)

RFFE is a web-based tool that provides a probability estimate that a given event will exceed known annual event thresholds (see arr-software.org). The estimations are calculated using data from nearby BOM weather stations and stream gauges. The data is presented as an Annual Exceedance Probability (AEP). For example, a 50% AEP is equivalent to a 1 in the 2-year event. A 2% AEP is equivalent to a 1 in 50-year event. Figure 8 below depicts the AEP for the case study catchment.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	25.5	11.1	59.0
20	57.5	25.6	131
10	88.7	36.0	218
5	127	46.0	350
2	193	59.3	620
1	254	69.0	920

Figure 8. Predicts a 50% probability of at least one event exceeding 25.5m^3/s within two years.

3.4 Summary of catchment hydrology

In summary, catchment yield can indicate the total volume of water that is likely to discharge from the case study catchment on an annual basis = 7,566 ML. The RFFE gives an indication of the rate of discharge for any given event, for example, 50% AEP = 25.5 m^3/s. It should be noted that the spread of the upper and lower confidence limits is very wide for Roseberry Creek. This seems to reflect the wide range of natural values for nearby catchments.

These figures can change as the characteristics of the catchment change – such as improving groundcover and soil properties. The figures can also be coupled with water quality data to quantify nutrient, and sediment loads that may be washed from the catchment.

3.5 Landform

Roseberry Creek rises on the steep slopes of Toonumbar National Park. It descends, running east, to join the Richmond River. The lower reaches of Roseberry Creek are flanked by floodplain pockets. The Richmond River is flanked by substantial floodplains where it meets Roseberry Creek. The River Styles database describes the lower reaches of Roseberry Creek as being partly confined, planform controlled, low sinuosity, discontinuous floodplain [with a] gravel bed. Along with reaches of bedrock margin-controlled gorges, parts of the upper reaches are described as being confined, bedrock margin-controlled, occasional floodplain pockets [with a] sand bed.

The northern edge of the catchment is defined by an east to west ridge originating in the Toonnumbar National Park. Primary ridges tend east to west with secondary ridges oriented southeast to northwest or southwest to northeast.

Most of the catchment is characterised by moderate or steep slopes. Approximately three-quarters of the catchment is on slopes steeper than 10% with flats localised around the Roseberry Creek channel. A finer scale delineation of landform would consider parent material and so define some separate units for the sandstone outcrops within the catchment, however, on the assumption that a great majority of the catchment is formed from basalt, it can be broken into three broad landscape units with associated processes:

- Steep slopes – mostly steeper than 10%, though there are significant areas with gentler slopes. These areas are defined by the soil being formed colluvial or *in-situ*.
- Alluvial fans – areas of fluvial deposition with slopes less than 10%. The deposition processes give rise to convex land shapes. Soils are alluvially derived but sometimes coarser than those of the alluvial flats.
- Alluvial flats – areas associated with streams and formed by alluvial deposition. Slopes are less than 2%. This unit comprises floodplain pockets adjacent to Roseberry Creek and some of its larger tributaries as well as terrace deposits.

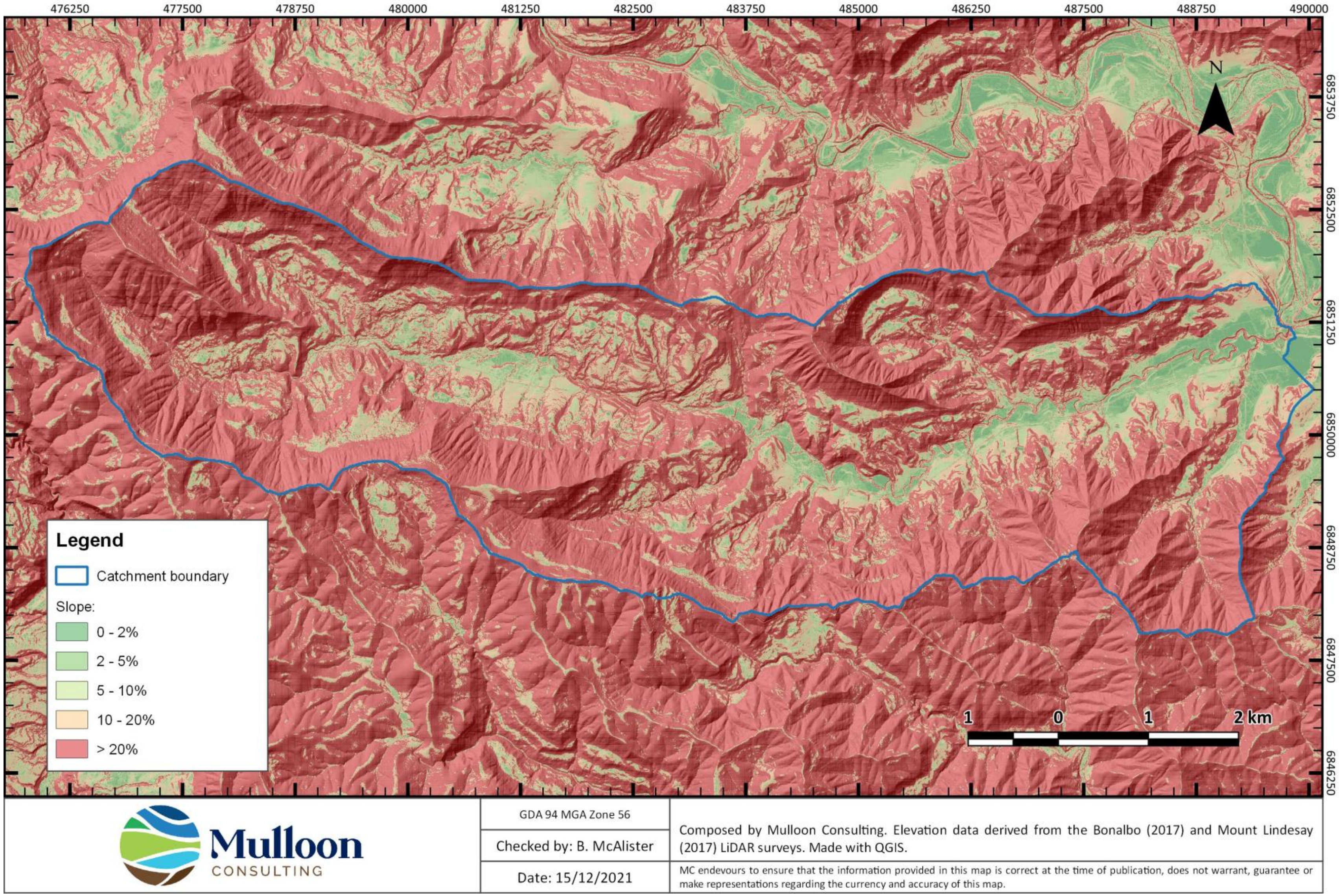

Figure 9. Roseberry Creek landform.

3.6 Geology

The geology of the Roseberry Creek catchment is dominated by the basalts extruded by the Tweed Volcano during the Miocene (~23 Ma)[19]. The Tweed Volcano is the dominant feature of the Northern Rivers region with its caldera recognised as the largest erosional caldera in the southern hemisphere. Mount Warning is a volcanic plug that stands at the location of the peak of the former Tweed Volcano.

Basalt is formed by lava flowing over the land surface before hardening into rock – as is happening in parts of Hawaii today. At the time of the Tweed Volcano's eruption, the area around Roseberry Creek was a sandstone landscape[20]. Outcrops of sandstone are also present within the Roseberry Creek catchment. These may have been exposed by erosion of the overlying basalt or, perhaps, were never buried by lava flows.

The sandstone of the Roseberry Creek catchment was originally laid down during the Jurassic (up to ~166Ma)[19]. The sandstone was deposited by rivers; it is likely that Kyogle was very close to the coast during the Jurassic with the deposition of sand being similar to the processes we observe at the mouths of sandy rivers such as the Burdekin River near Ayr, Queensland.

The following are descriptions of geological units taken from the *Seamless Geology of NSW* dataset[19] and depicted in Figure 10.

Quaternary Alluvium – deposited up until the present day – unconsolidated grey to brown to beige humic (±)micaceous silty clay, quartz-(±)lithic silt, fine- to medium-grained quartz-rich to quartz-lithic sand, polymictic pebble to cobble gravel (as sporadic lenses); sporadic palaeosol horizons.

Kyogle Basalt – deposited up until 23 million years ago – hawaiite, minor alkali olivine basalt, basanite, and rare tholeiitic volcanic rocks. Most hawaiites at the base of the sequence approach mugearite in composition (dark green).

Marburg Sandstone – deposited up until 166 million years ago – fine to coarse-grained, thin- to very thick-bedded, cross-bedded, quartzose to lithofeldspathic sandstone, interbedded with polymictic pebble and minor cobble conglomerate, siltstone and claystone; minor coal and basalt, fossil wood ferruginous oolite.

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19 Duggan, M, B., Mason, D, R. (1978) Definition card for Kyogle Basalt. Australian Government Geoscience Australia.http://dbforms.ga.gov.au/pls/www/geodx.strat_units.def?strno=25142&stratname=Kyogle%20Basalt

20 Colquhoun, G., Hughes, K. S., Deyssing, L., Ballard, J. C., Phillips, G., Troedson, A. L., Folkes, C. B., & Fitzherbert, J. A. (2018). New South Wales Seamless Geology Dataset (version 1, version 1) [Geological Map]. Geological Survey of New South Wales, NSW Department of Planning and Environment. search.geoscience.nsw.gov.au/product/9232

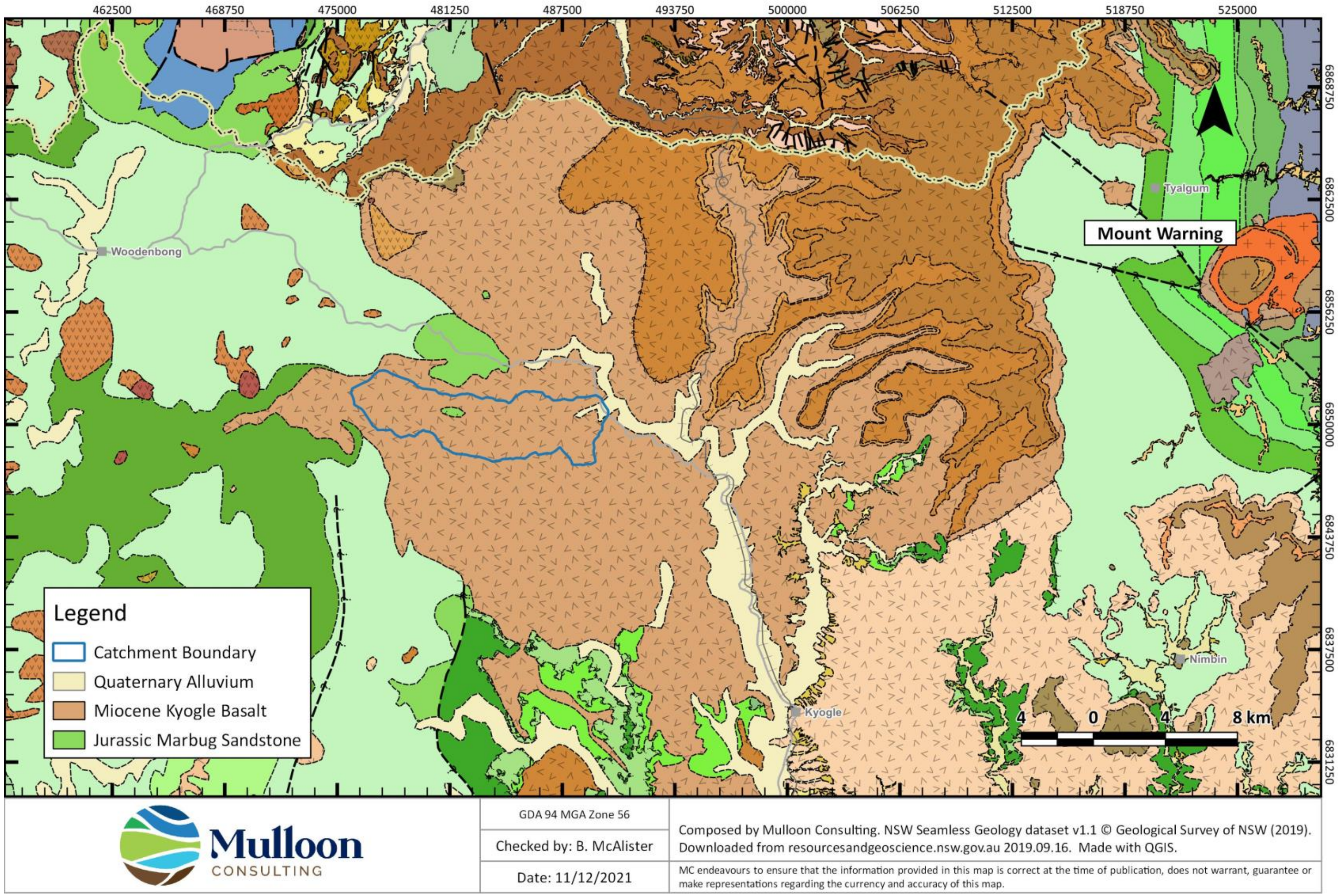

Figure 10. The geology of the Roseberry catchment is dominated by Kyogle Basalt from the eruption of Mount Warning.

3.7 Soils

There is no soil-landscape mapping that covers the Roseberry Creek catchment however, as discussed above in the landform section, the catchment is relatively uniform with basalts dominating most of the area and sandstone outcrops making up a small part. As such, the soils of Roseberry Creek are primarily basalt derived and will vary somewhat as per the land classifications defined above in the landform section. Chocolate soils and alluvial black earth are expected to predominate with areas of podzolic soils in parts.

It should be noted that some alluvial soils derived from basalt are highly erodible. Care will need to be taken to assess erosion risks before modifying patterns of flow on basalt-derived alluvial units.

3.8 Vegetation

The Roseberry Catchment is 4850 ha. 73.5% is forested (3565 ha) and the remaining area is mostly cleared pasture (1285 ha). Historical imagery of the catchment shows there was a similar vegetation cover in 1962 and this did not appear to be young regrowth. It is unclear to what extent the catchment was cleared following settlement and what the impact of changes in fire management has been. There are 20 different vegetation communities recorded through the NSW Office of Environment and Heritage Vegetation mapping. This is displayed in

Figure 11. Many of the vegetation communities are similar and can be classified as five larger communities listed below[21]:

Open Shrubby Brush box Tallowwood is characterised by tall open forests on the eastern side of the great escarpment north of the Nymboida river and found on ranges north of the Clarence.

Northern ranges dry Tallowwood is a tall forest with a mixed canopy often containing Tallowwood (*Eucalyptus microcorys*). This community can be associated with exposed sloped and is found throughout the northern rivers.

Sub-tropical and warm temperate rainforests are often found in medium to high rainfall areas with fertile soils. Communities prefer plateaus and high mountain gullies along escarpments.

Escarpment redgum as the name suggests is found on escarpments, with a distribution from the Chandlers Creek in Victoria to the McPherson Range on the New South Wales and Queensland border.

Costal flooded gum is characterised by very tall to extremely tall forests that are open and moist. Often found in sheltered valleys, creek flats, or benches.

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21 Australian Government Department of Agriculture, Water and the Environment. Northern Rivers Appendix 11: Vegetation formation classes and communities. Microsoft Word - App 11 Vegetation formations_12Apr10 (awe.gov.au)

3.8.1 Biodiversity

New South Wales currently lists six bird species and four plant species in the Scenic Rim region as critically endangered[22]. These species are listed in Table 1, below. It is not known whether these species are present in the Roseberry catchment.

Table 1. Critically endangered species of the New South Wales Scenic Rim. Source: NSW Environment Threatened species 2021.

Scientific Name	Common Name	Kingdom	Status
Cyclopsitta diophthalma coxeni	Coxen's Fig-Parrot	Anamalia	Critically Endangered
Erythrotriorchis radiatus	Red Goshawk	Anamalia	Critically Endangered
Esacus magnirostris	Beach Stone-curlew	Anamalia	Critically Endangered
Turnix melanogaster	Black-breasted Buttonquail	Anamalia	Critically Endangered
Anthochaera phrygia	Regent Honeyeater	Anamalia	Critically Endangered
Calyptorhynchus banksii	Red-tailed Black-Cockatoo (coastal subspecies)	Anamalia	Critically Endangered
Lenwebbia sp. Main Range	Lenwebbia sp. Main Range	Plantae	Critically Endangered
Rhodamnia rubescens	Scrub Turpentine	Plantae	Critically Endangered
Rhodomyrtus psidioides	Native Guava	Plantae	Critically Endangered
Rhodamnia maideniana	Smooth Scrub Turpentine	Plantae	Critically Endangered

22 NSW environment (2021) Threatened Species: https://www.environment.nsw.gov.au/threatenedSpeciesApp/cmaSearchResults.aspx?SubCmaId=370

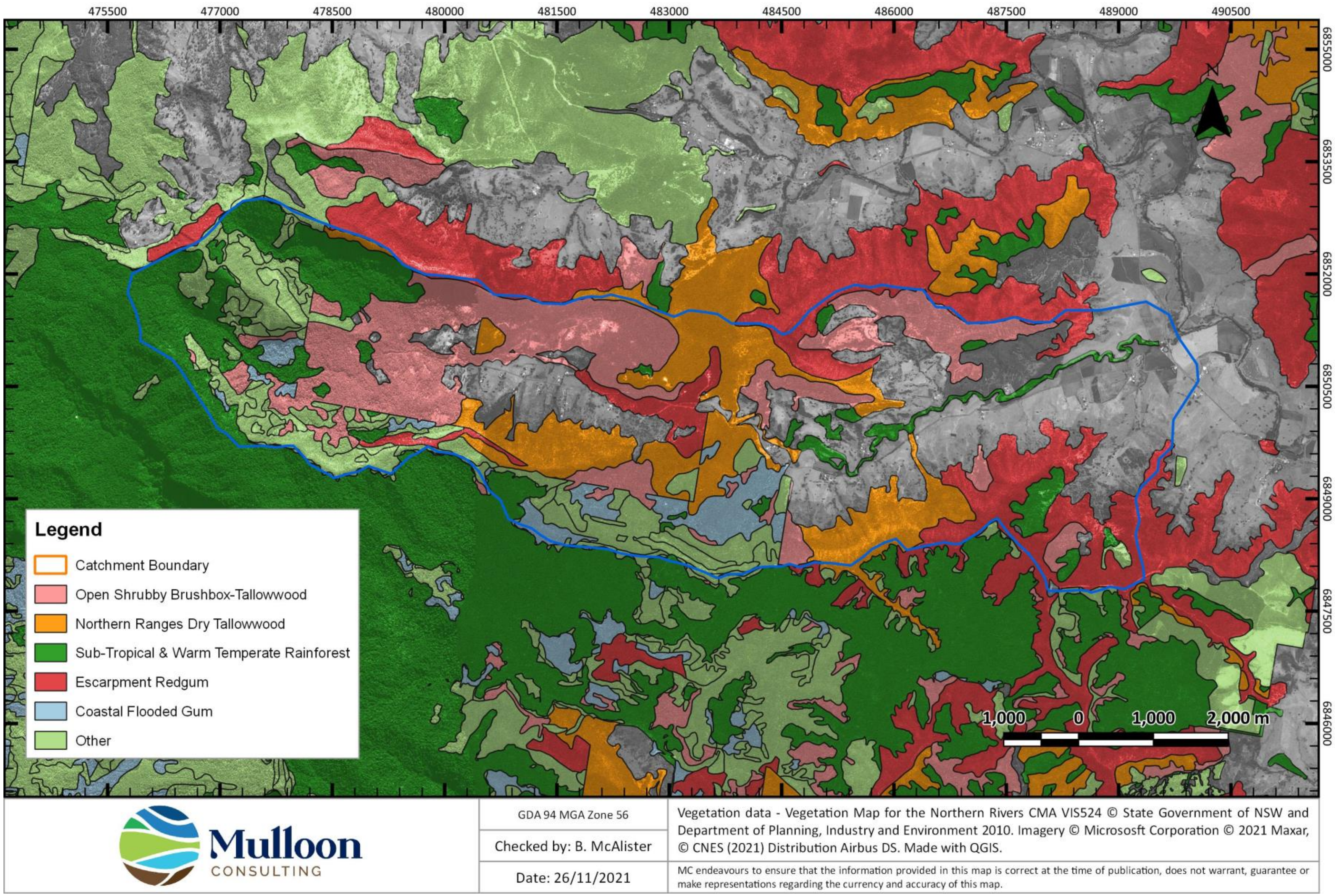

Figure 11. The Roseberry Creek vegetation communities; with the open shrubby Brushbox–Tallowood community the most common.

4 Landscape Function

4.1 Energy Conversion

4.1.1 Solar Energy

Most of the solar energy reaching the Earth's surface is converted into either latent or sensible heat, depending on the character of the surface (Figure 12). Dry, bare soils with little vegetation cover will generate more sensible heat and increase the surface temperature. A hydrated surface with high vegetation cover will capture more of the solar energy and dissipate it as latent heat through evapotranspiration, generating much less sensible heat and creating a cooler environment.

Ground that is periodically bare through the cropping cycle, and more heavily grazed pastures with less ground cover, will be less efficient at capturing and dissipating solar energy compared with ground that is permanently covered with healthy vegetation.

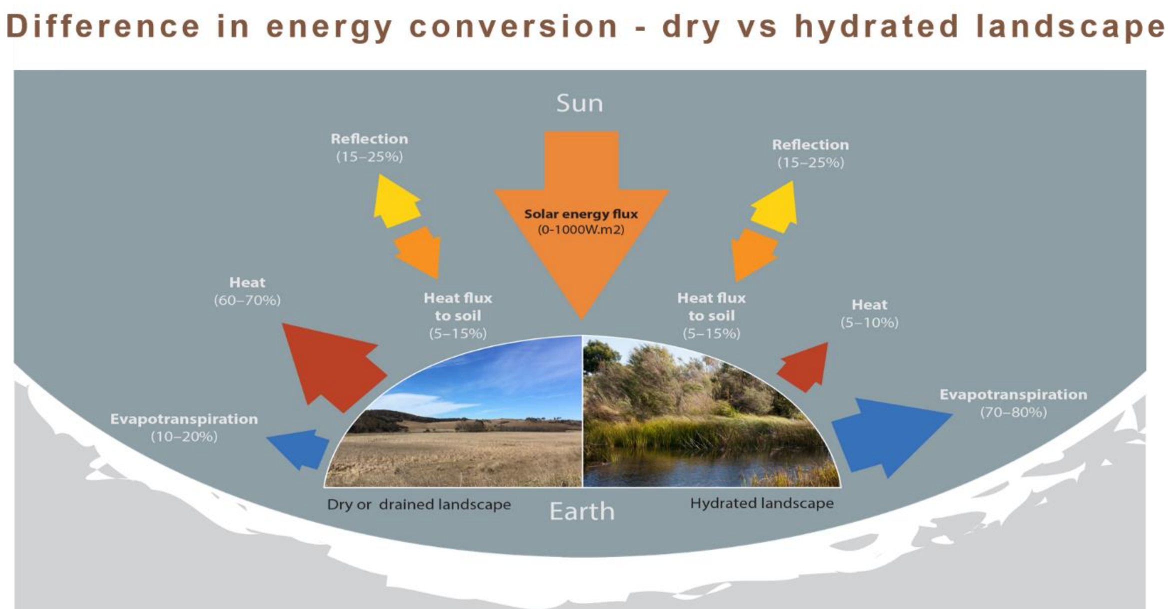

Figure 12. Comparison of solar energy conversion between a dry and a hydrated landscape. Adapted from Pokorney at al. (2010)[23])

4.1.2 Water Flow

The steep slopes in many parts of the catchment mean that surface water from large rainfall events flows relatively quickly downslope unless there is sufficient "roughness" (ground cover vegetation and water-receptive soil) at the surface to slow it down. This means the erosive power of water is building energy in the steeper parts of the catchment which adds additional pressure on the lower-lying areas which is commonly where agriculture is practiced. If agricultural management does not cultivate ground cover, the erosive force of the water may cause degradation and erosion.

The native forest and woodland vegetation on the slopes intercept raindrops before they reach the ground and release them slowly, which dissipates potentially erosive energy. This benefits the soils in

23 Pokorney, J., Brom, J., Cermak, J. and Hesslerova, P., Huryna, H., Nadezhdina, N. and Rejskova, A. (2010) Solar energy dissipation and temperature control by water and plants. International Journal of Water, 5(4), 311-336

some of the steeper slopes in the catchment. Infiltration of surface water into the soil can be higher in woodland/forest compared to pastures or crop paddocks, and so wooded areas reduce the amount of water flowing off slopes during and after large rainfall events[24].

One hundred and eighty years of post-settlement agricultural management and the clearing of native forests have contributed to reducing the catchment system's natural capacity to dissipate energy. A consequence is the increased erosive force of water. This erosive force has caused deep incision and simplification of Roseberry Creek. As the channel has incised it has reduced the capacity to slow water and dissipate the energy of that flow.

Landscapes such as lower Roseberry Creek are known as cut and fill landscapes. The stream has cyclically cut through the floodplain sediments and filled back up several times over the millennia. Without intervention, the creek will repair itself again, though this will take many human lifetimes. Interventions at strategic locations along Roseberry Creek and its tributaries can fast track the natural process of rebuilding the creek and floodplain function.

4.2 Retention use and cycling of water and nutrients

4.2.1 Water

The retention of water in the landscape (notwithstanding the effect of slope) is largely dependent on the type of vegetation present and the characteristics of the soils. Tall vegetation intercepts raindrops and releases them slowly to the ground, reducing surface flow and increasing potential infiltration during a given rainfall event. The high ground cover protects soils from solar radiation and wind evaporation and therefore improves water retention. Soils with a porous structure and high carbon levels retain more water than compacted soils with low carbon levels. Soils with a higher clay content hold more water than those with less clay, all other things being equal[25].

In the Roseberry catchment, water retention will be most efficient in areas with more permanent ground cover and some woodland patches. Areas where the ground is bare for long periods, as well as heavily grazed and unrested pastures, will retain water less efficiently and have higher runoff after rain. The historical lowering and simplification of the Roseberry channel have it flowing faster and retaining less water in streambed and floodplain sediments.

Efficient water use and cycling depend on managing pastures and soils to be receptive to rainfall and then achieving good utilisation of pastures and available soil moisture for crops. Areas with permanently high ground cover levels and where pastures are grazed before plants flower (except when flowering is desired) will use and cycle water more efficiently than areas where soils are compacted and pastures over-or under-grazed. Water use and cycling in crop fields are most efficient when the near-permanent ground cover can be maintained, assuming rainfall is sufficient to enable year-round plant growth and acceptable yields.

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24 Eldridge, D. and Freudenberger, D. (2005) Ecosystem wicks: Woodland trees enhance water infiltration in a fragmented agricultural landscape in eastern Australia. Austral Ecology, 30(3), 336-347.

25 McLaren, R. and Cameron, K. (2012) Soil science: Sustainable production and environmental protection (2nd edition). Oxford University Press, Melbourne, Australia.

4.2.2 Nutrients

Nutrient retention, use, and cycling are likely to vary significantly between enterprise types in the catchment. Cropping systems that include a regular pasture or cover crop phase will manage nutrients more efficiently than cropping-only systems because soil carbon and microbial activity will increase during the non-crop phase and stabilise soil nutrients at risk of leaching or washing away with wind- or water-eroded topsoil.

The most nutrient-efficient systems in the catchment are likely to be grazing systems with permanent high ground cover levels and planned to graze, in which biomass is well utilised, manure is readily decomposed, topsoil erosion is minimal, and the vast bulk of nutrients removed from the system are in the bodies of the animals. Mixed farming systems that apply fertiliser judiciously, minimise fallow periods, and have minimal topsoil erosion will also use and cycle nutrients efficiently.

As evident in the recent Rous report[6] and the Lismore Flood Management Report[726] erosion and the management of waterways for flood mitigation and water availability are high priorities. These reports do not focus on the Roseberry catchment, however, they are indicators for the wider region's land management impacts on waterways. As much of this area is under agricultural production or has been previously cleared, nutrient loss through land management practices is likely.

4.3 Biological productivity

Vegetation in the form of grasses, trees, and shrubs drives energy flow and transformation through the landscape from photosynthesis to nutrient cycling. Landscape rehydration works focus on the relationship between land management of vegetation and the function of hydrological cycles. Plants have been key in the creation of the Australian landscape. Acknowledgment of this fact and integration of plants is essential when working with a whole landscape approach.

Plants are often cultivated or managed in an agricultural setting to produce food or fiber. Management of agricultural enterprises to leverage the capacity of plants to heal the landscape requires further investigation from an individual landholder perspective in the Roseberry Creek catchment. This individual approach is required to understand the management goals of each enterprise and to tailor an approach that supports a business to be ecologically, socially, and economically successful.

4.4 Biodiversity

An important measure of landscape function is the ability of a landscape to support populations of plants, animals, and microorganisms. Biodiversity is a broad term used to describe differences in species, family, genus, genetic diversity, and the interactions amongst them. Diversity in nature could be termed resilience as each ecological role or niche is filled by multiple species, as one is removed or damaged another may fill its place. In the current context, diversity is often viewed through a production lens where diversity in a tree plantation, crop of grazing pasture may be limited. From a landscape lens, diversity may then represent the total capacity of species to exist within a landscape.

Compared to 1788, diversity in Australian production landscapes is generally much diminished. This is often represented by the lack of knowledge or awareness of the species present in a landscape from

6 Rous County Council, 2019, Northern Rivers Watershed Initiative: Discussion Paper, February 2019.

7 Kirby, M (2021) A review into the implementation of nature-based solutions for flood risk management. Report prepared for the Lismore Floodplain Management Committee.

grasses, trees, birds, insects, fungi and microorganisms. Microbes make up most of the species diversity in the landscape and are critical to agricultural production because of their role in carbon sequestration and soil nutrient cycling. Beneficial soil microorganisms thrive when there is a near-permanent ground cover of actively growing plants.

Limited species-specific information is available within the Roseberry Creek catchment, which indicates the current need for greater resources for landholders in identifying, cataloguing, and working with a variety of species.

4.5. Sustaining people in the landscape

A final measure of landscape function is the ability of the landscape to meet the material, social and spiritual needs of its inhabitants, without degradation of the landscape. While humans may visibly degrade a landscape and its natural functions, we often miss the cyclical impacts of these actions on ourselves. Essentially there is a link between the health of a landscape's function and the capacity of ecological and social systems. Understanding the dynamics between the Roseberry Creek landscape function and its capacity to sustain people requires surveys or interviews with the landholders. A detailed survey of landholders is not within the scope of this report.

5 Opportunities for landscape rehydration

The analysis of landscape function in Roseberry Creek catchment identified that degradation since European settlement has affected some aspects of landscape function which can be targeted with on-ground measures.

Evidence from locals who have lived in the area for a long time is that the bed of Roseberry Creek has been changing through time. Sediment has been accumulating in some areas while NSW Soil Conservation Service has recently done work stabilising bank erosion in other areas. Improved hydrology resulting from rehydration of the Roseberry Creek catchment will help to stabilise the channel geomorphology of Roseberry Creek by slowing large flows and providing a more reliable baseflow to support vigorous riparian vegetation.

Efforts should be made to plan for the conservation of valuable wetland features within the catchment. The greatest rehydration gains can be made by increasing the water banking capacity of degraded wetlands higher in the catchment. The measures that should be considered for landscape rehydration within the Roseberry Creek catchment are:

- conservation of existing chain of ponds systems
- gully stabilisation
- revegetation of in-stream wetlands
- bush regeneration
- construction of landscape rehydration structures, such as leaky weirs and contours
- grazing management including in riparian areas
- planting and fencing of riparian corridors.

5.1 Conservation of intact valley floors

The highest priority of the Roseberry Creek catchment should be to identify and describe intact valley floors where pre-European hydrology has remained relatively unaltered. Plans should be put in place to prevent gully erosion while efforts can be made to stabilise active erosion that is threatening otherwise intact valley floors.

Intact (un-incised) valley floors on the mid slopes of the catchment hold water within their sediments for slow discharge during dry periods. An intact valley floor also has a hydrating effect on the surrounding slopes as the effective hydraulic gradient is lowered by the high-water table within the gully. Through the process of gully incision, the deep soils of the valley floor and their associated water storage, are stripped away. Furthermore, gully erosion increases the hydraulic gradient on the surrounding slopes causing them to be drained.

The Roseberry Creek catchment includes examples of degraded and relatively intact valley floors including chain-of-ponds systems (Figure 13) and, on steeper slopes swampy meadows.

Figure 13. An intact chain of ponds system at Rukenglen in the Roseberry Creek catchment

Conservation of these intact systems requires, above all, awareness of their needs and understanding of their significant role in the catchment's hydrology. Care should be taken that management and future development do not compromise these precious intact systems. Two very common threats to these systems are a modification to allow passage by vehicles and poor grazing management. In both cases, farm planning can negate these threats at very little cost.

5.2 Gully stabilisation

As outlined above, intact valley floors are very beneficial to catchment hydrology. Stabilisation of active gully erosion in the smaller tributaries of Roseberry Creek should be a priority rehydration measure. The techniques used for treating erosion gullies depend on several factors including the size of the gully, the steepness of the slope, the upstream catchment area, and the materials available.

Figure 14. Steep vertical banks adjacent to an active headcut indicate that this gully, located on a tributary to Roseberry Creek, is unstable.

Active erosion head cuts (see Figure 14) are usually stabilised by reshaping and installing rock, but smaller head cuts can be treated by hand using logs and brush. Steep gully walls are generally battered to facilitate vegetation establishment, but this is often not necessary if walls are stable. Contour banks can be installed across a gully to divert and spread water across the slope or to a dam. Gabions, or rock baskets, installed across a gully can be used to catch sediment and slow water flow. Each gully must be assessed on its merits to determine which stabilisation techniques are most appropriate.

Figure 15. A rock flume was constructed to stabilise a headcut.

In some instances, it may be possible to rehydrate an incised former swampy meadow by the plug-and-pond method[27]. This method is applicable where an incised, but formerly discontinuous, a minor stream is flanked by flats. In this case earth dams constructed at intervals in the stream raise the water table and restore the stream to its former hydrology. The short *Film Buffers Sponges and Moderators*[28] include a good introduction to this approach to restoration.

27 Zeedyk, W., & Vrooman, S. (2017). The Plug and Pond Treatment: Restoring Sheetflow to High Elevation Slope Wetlands in New Mexico. Stream Dynamics. https://streamdynamics.us/resource/plug-and-pond-treatment-restoring-sheetflow-high-elevation-slope-wetlands-new-mexico

28 Wilson, C. (2018, May 28). Buffers, sponges and moderators: Managing swampy meadows, wetlands and chains of ponds. Rivers of Carbon. http://riversofcarbon.org.au/our-projects/rivers-carbon-source-water-linkages/buffers-sponges-moderators-managing-swampy-meadows-wetlands-chains-ponds/

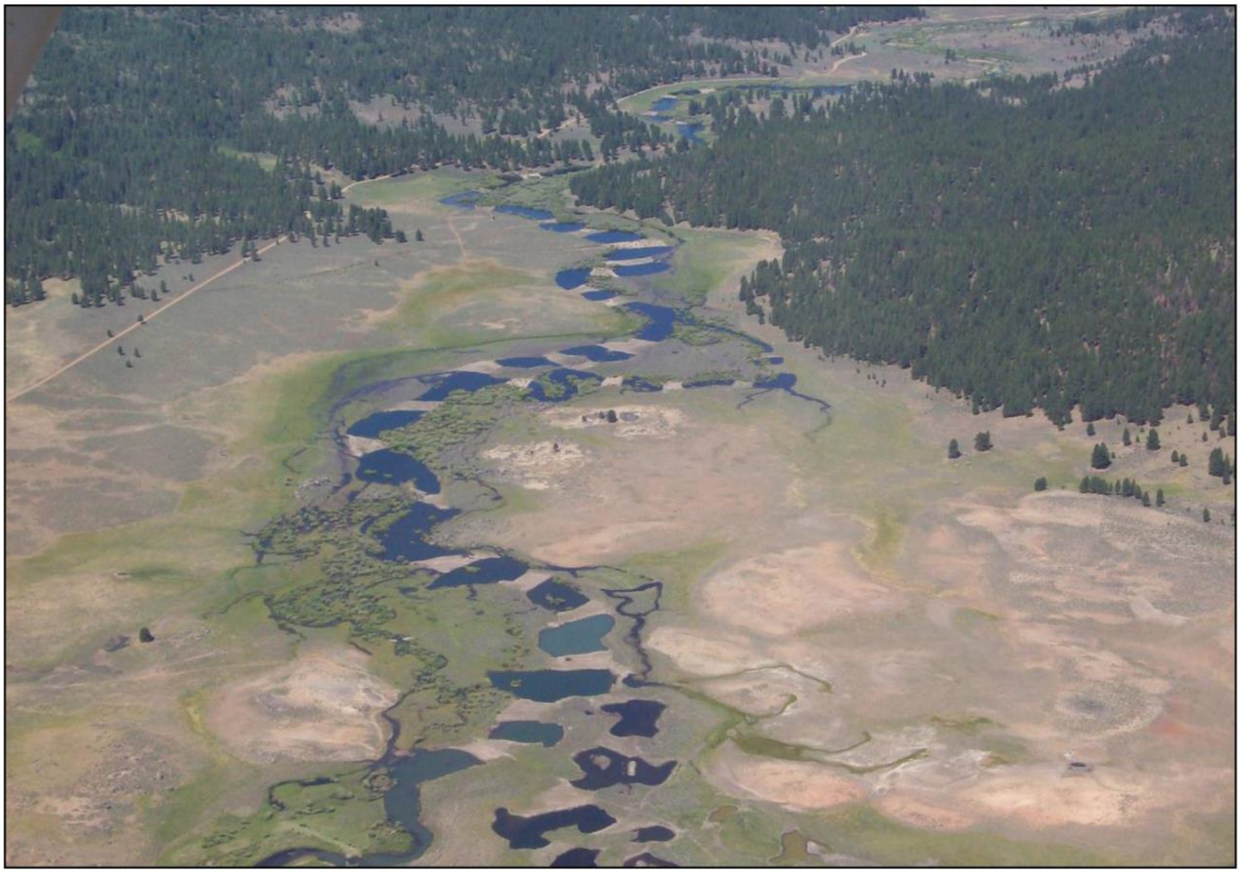

Figure 16. The plug and pond were employed to restore this valley floor in the United States (Photo: Jim Wilcox | adapted from Zeedyk 2017).

Generally, livestock should be excluded from recovering gullies for a period to avoid soil disturbance and to allow groundcover and woody vegetation to establish. Once soils have stabilised and vegetation is established, it may be safe to occasionally graze stock in these areas for short periods to utilise feed.

A detailed survey of erosion gullies could not be undertaken as part of this scoping study, but gullies should be assessed and prioritised for treatment on each participating property as part of any future landscape rehydration work.

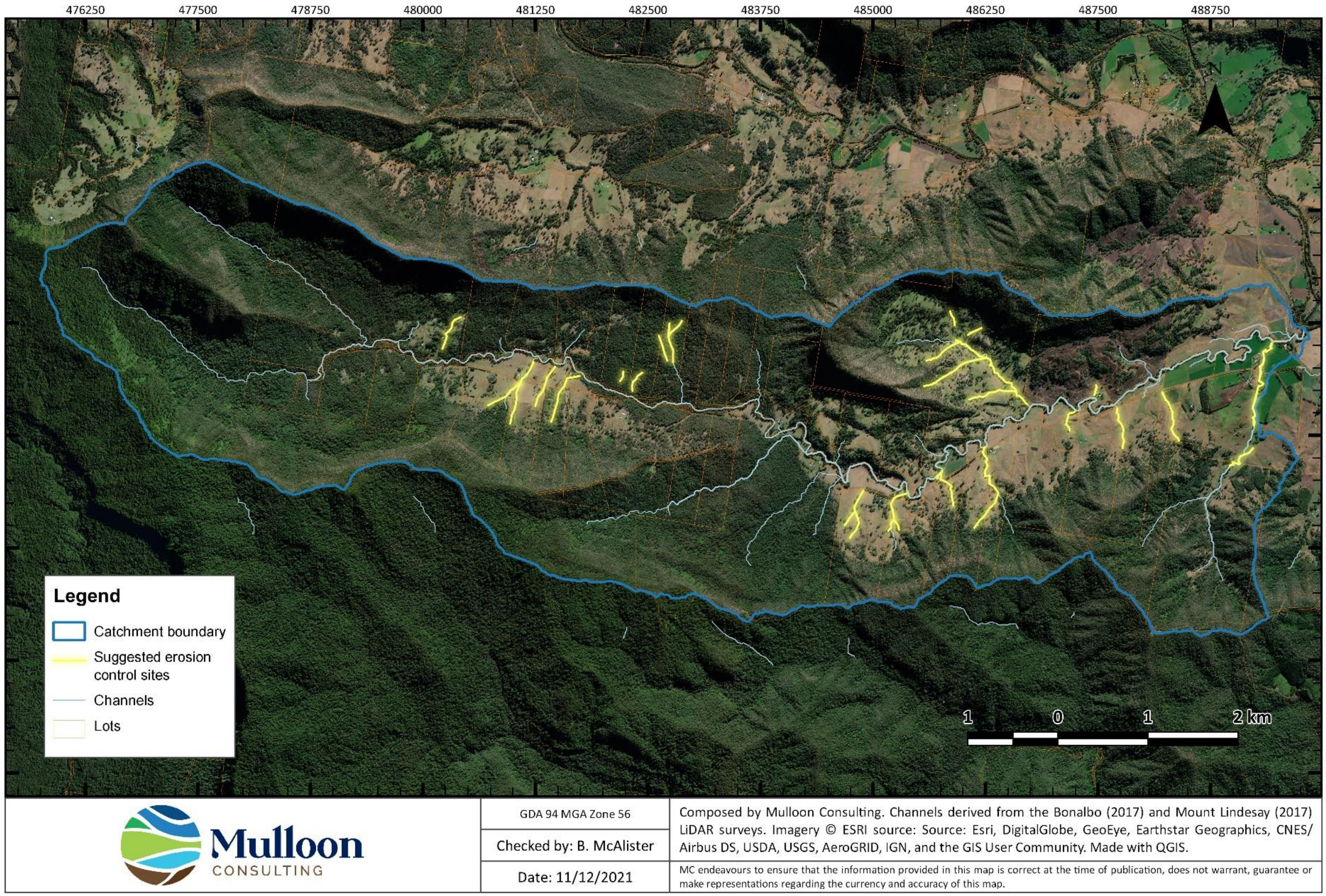

Figure 17. Stream reaches identified from available elevation data as potentially unstable.

5.3 Revegetation of in-stream wetlands

Beyond conservation and stabilisation of gullies, some stable but historically degraded gullies can be revegetated to great effect. The instream wetlands that can be created in gullies have been shown to have significant sediment-trapping capacity[29]. Instream wetlands improve the stability of the channel giving it greater resilience to erosion while causing the bed of the stream to aggrade by trapping sediment. Instream wetlands can be viewed as the repair process that reverses gully erosion.

Intervention to promote instream wetlands can often be as simple as changing the grazing regime on the valley floor. Often the seed bank of the valley floor contains sufficient wetland species to regenerate itself under the right conditions. Rest from grazing is necessary for the establishment and maintenance of wetlands. Fencing of drainage lines so that the valley floor can be treated as a separate management unit is often the key intervention necessary to encourage instream wetlands. The natural regeneration that results from resting a valley floor from grazing is sometimes very rapid. Wetland plants such as *Typha* sp. And *Phragmites australis* are capable of taking over a valley floor in as little as two wet growing seasons making regeneration of instream wetlands perhaps the fastest impact that can be made to rehydrate a catchment.

Figure 18. This instream wetland spread to cover the floor of the channel within two seasons of a change in the grazing regime.

29 Zierholz, C., Prosser, I. P., Fogarty, P. J., & Rustomji, P. (2001). In-stream wetlands and their significance for channel filling and the catchment sediment budget, Jugiong Creek, New South Wales. Geomorphology, 38(3–4), 221–235.

Beyond management of grazing, the establishment of instream wetlands can be assisted by the installation of simple hand-made interventions such as log and brush weirs, brush mattresses, and pin weirs. These interventions are intended to augment natural steps in the stream and by trapping a small amount of moisture, sediment and seed create a bridgehead for the establishment of wetland plants that can then proliferate throughout the channel. These small-scale interventions promote the establishment of wetlands in minor tributaries in a similar way to how leaky weirs promote the establishment of wetlands in larger streams (see section 5.4 below).

Figure 19. Freshly constructed log and brush weirs temporarily detain flow and collect sediment and nutrients through a steeper section of the valley floor.

Translocation of wetland plants from lower down in the catchment to restored areas higher upslope is also a technique that may help to accelerate restoration of instream wetlands in the Roseberry catchment.

5.4 Bush regeneration

As stated above in the vegetation section, the Roseberry Creek catchment is dominated by forest. Because of the high proportion of the catchment under forest, any change to the state of the forest is likely to have a great effect on the catchment's hydrology. It is quite likely that the changes that have been observed by BRRVLN in the Roseberry Creek catchment have been driven by changes to the catchment's forests.

Forests are unmatched in their capacity as moderators of the water cycle. Their soft soils and deep litter layers are optimal for slowing and infiltrating overland flows of water. Also, by a process termed 'interception' forests temporarily store rainwater in their canopy, effectively reducing the intensity of storms. Healthy forests moderate the hydrology of a catchment by capturing and infiltrating water and slowing flash floods.

The historic operations of the timber industry modified the forests of the Roseberry Creek valley, and, likely, the forests have not had time to recover to full health. Observation by locals indicates that mature trees of some species are very rare notably tallowwood, flooded gum and blackbutt. Red cedar and rosewood that were formerly present have been all but lost from the valley.

With changes in land use, the proportion of the catchment that is forested has been increasing. Historic aerial imagery shows that the extent of the forest has been expanding since the mid-twentieth century while observation by long-term residents indicates that the density of the understory has increased. Some areas of flooded gum forest are affected by dieback.

Forest age[30], and in particular, fire regimes[31], can have dramatic effects on the hydrology of forest systems. Further gathering of evidence about historic changes to Roseberry Creek catchment's forests is strongly recommended. On-ground observation of the geomorphic condition of flowlines within the forested part of the catchment could provide clear evidence of change or instability. Depending on the findings of a closer investigation, changing fire regimes, perhaps concerning local indigenous cool burning knowledge, could be an important restoration activity within the catchment. Thinning of dense regrowth might also be recommended to allow large mature trees to develop in areas currently dominated by saplings.

Figure 20. Cool burning of undergrowth in the Mulloon Creek catchment as part of a workshop on indigenous burning practices.

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30 Cornish, P. M., & Vertessy, R. A. (2001). Forest age-induced changes in evapotranspiration and water yield in a eucalypt forest. Journal of Hydrology, 242(1), 43–63. https://doi.org/10.1016/S0022-1694(00)00384-X

31 Cawson, J. G., Sheridan, G. J., Smith, H. G., Lane, P. N. J., Cawson, J. G., Sheridan, G. J., Smith, H. G., & Lane, P. N. J. (2012). Surface runoff and erosion after prescribed burning and the effect of different fire regimes in forests and shrublands: A review. International Journal of Wildland Fire, 21(7), 857–872. https://doi.org/10.1071/WF11160

5.5 Construction of Leaky weirs

As discussed above, the geomorphology of the Roseberry Creek channel is currently unstable. Observations by BRRVLN indicate that a series of leaky weir structures could be installed in the Roseberry Creek channel to begin to restore a more natural flow regime by moderating the intensity and extending the duration of storm flows, which would increase the permanency of water in the creek.

Leaky weirs are low, porous structures made from rock and/or logs that span the stream channel below the top-of-bank height (see Figure 21 and Figure 22). Leaky weirs create an upstream pool while also allowing a constant flow over and through the structure while ever the stream is flowing. They are best installed in a series, where the pool created by one leaky weir extends upstream to the base of the next structure in the series, creating a chain of ponds.

Figure 21. Leaky weir and crossing under construction on Mulloon Creek at "Duralla", February 2020.

Figure 22. Completed leaky weir and crossing on Mulloon Creek at "Duralla", March 2020.

Leaky weirs are strategically located within a stream to take advantage of stream steps, secondary channel exits or re-entries, and/or a constriction, and each of these features can coincide. Importantly, leaky weirs generally have the effect of enhancing existing pools in the stream.

Installation of leaky weirs will also increase the frequency of overbank flows, the extent of which depends on their height with the top of the stream bank. Overbank flows dissipate the energy of storm flows and should result in deposition, rather than erosion, of sediment. Modeling of changes to surface water flows should be undertaken as part of the leaky weir planning, design, and approval process to mitigate risks and to ensure that expected changes will be compatible with existing and future land uses. Stream crossings also need to be considered when designing leaky weirs and can be easily incorporated into the structures themselves.

Within the Roseberry Creek catchment, leaky weirs would be most suited to the main branch of Roseberry Creek along reaches where the channel has incised through well below alluvial flats (see Figure 23). Further on-ground investigation of the stream's geomorphology and the history of its change is required before determining whether, and to what extent, leaky weirs are appropriate for the restoration of Roseberry Creek.

Because of their impact on the frequency and extent of floods, a leaky weir project needs to include all stakeholders along the affected reaches. The alluvial flats within the Roseberry Creek catchment are divided amongst many landholders and a consensus must be reached about the goals of the project before pursuing leaky weirs further.

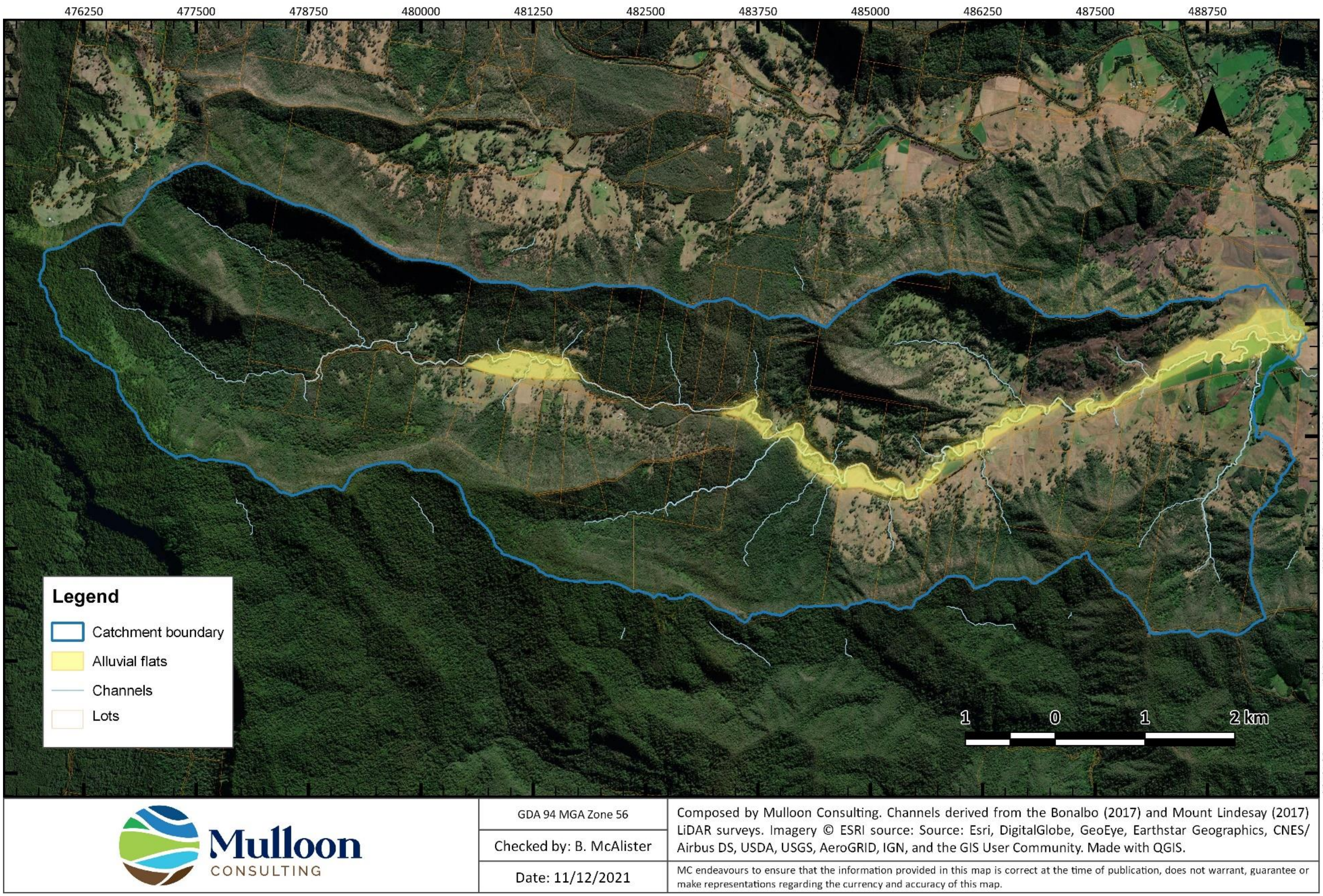

Figure 23. Locations of alluvial flats along Roseberry Creek where leaky weirs could have a substantial impact on landscape function.

5.6 Grazing management

Unlike forests at Roseberry Creek, pastures comprise a relatively small part of the total catchment area. Because of this, and because pasture is mostly located downstream in the catchment, changes to the management of these areas will have a relatively small impact on the overall health of the catchment.

As with forests, the hydrology of pastures can vary markedly depending on management[32]. Dense and vigorous pastures slow overland flows and infiltrate water at a greater rate than areas of poor pasture. When done well, rotational grazing of pastures can maintain a denser sward more often. This and improvements to soil structure and biota occasioned by the periodic resting of paddocks promote greater infiltration rates of rotationally grazed paddocks[33].

5.7 Contour banks

Earth contour banks have been employed by the Mulloon Institute on the upper slopes of landscapes with poor infiltration rates to spread concentrated flows of water and encourage infiltration over a wider area. When properly managed, contour banks can also be used to spread fertility through the landscape (Figure 24). By spreading flows and detaining a small amount of water, contour banks can increase the amount of water captured by infiltration. Contour banks could be constructed above the floodplain on cleared gentle slopes where infiltration is limited. Contour banks are intended to imitate the hydrological effect of forest litter – construction of contour banks under a forest canopy would not be expected to have a significant effect. See Figure 25 for possible locations of contours.

Figure 24. Contour bank retains water and has been planted out and fenced.

32 Döbert, T. F., Bork, E. W., Apfelbaum, S., Carlyle, C. N., Chang, S. X., Khatri-Chhetri, U., Silva Sobrinho, L., Thompson, R., & Boyce, M. S. (2021). Adaptive multi-paddock grazing improves water infiltration in Canadian grassland soils. Geoderma, 401, 115314. https://doi.org/10.1016/j.geoderma.2021.115314

33 Ampt, P., & Doornbos, S. (2011). Communities in Landscapes Project Benchmark Study of Innovators [Report]. University of Sydney.

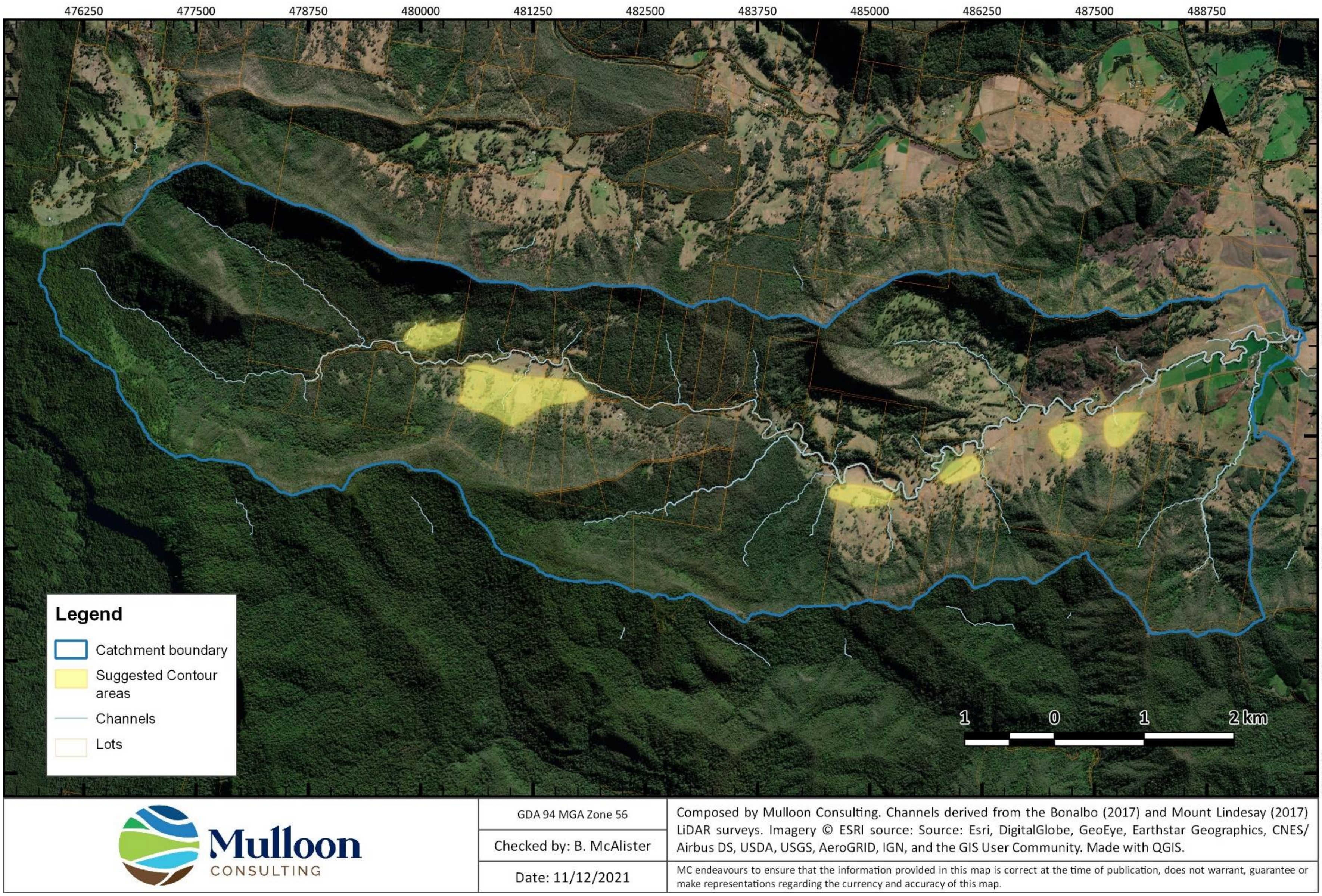

Figure 25. Areas where digital data suggests that construction of contours could be considered.

6 Regulatory context

6.1 Harvestable rights

Harvestable rights refer to the legal capacity of landholders to capture and store water on a property. In New South Wales there are different rules based on the location of the catchment. The Roseberry catchment sits within the coastal catchments meaning that only 30% of the annual rainfall can be captured on the property without prior approvals; provided it is built on non-permanent minor streams, hillsides, and gullies. This refers to capture through dams and non-permanent water sources[34]. Whether regulatory approval is required for harvestable rights will then depend upon the planned landscape rehydration works for the catchment. Some of the techniques of stream restoration proposed under the Gully Stabilisation heading in Section 4, will impound water and so need to take account of harvestable rights regulations. For other works, it may be necessary to apply for regulatory approval which is addressed in the following section.

6.2 Recommendations for obtaining permits for instream works

There are a variety of potential regulatory requirements which may be triggered in New South Wales when undertaking Landscape Rehydration activities. The extent of approvals required is dependent upon the specific works to be undertaken. Examples of potential regulatory requirements is set out below. Further advice on obtaining permits can be provided once the scope and intended works to be carried out on the ground are known. Commonly permits are triggered once working in a 3rd order stream, though regulations can be triggered without this. New South Wales is in the process of changing legislation and incorporating Landscape Rehydration works under the NSW State Environmental Planning Policy Infrastructure, which may impact this approvals process. If the change occurs it will streamline parts of the current process.

Table 2. Examples of potential regulatory requirements that may be triggered when undertaking landscape rehydration activities.

Requirement	Governing ACT
Controlled Activity Approval (CAA)	Water Management Act 2000
Crown Lands License	Crown Lands Management Act 2016
Water Access License	Water Management Act 2000
Concurrence from the Environment Agency Head for a Species Impact Statement (SIS) or Biodiversity Development Assessment Report (BDAR)	Biodiversity Conservation Act 2016
Threatened Species License	Biodiversity Conservation Act 2016
S199 approval	Fisheries Management Act 1994
Aboriginal Heritage Impact Permit (AHIP)	National Parks and Wildlife Act 1974
S57(1) approval	Heritage Act 1977
EPBC approval	Commonwealth Environment Protection and Biodiversity Conservation Act 1999

[34] NSW Department of planning, Industry, and the Environment: https://www.industry.nsw.gov.au/water/licensing-trade/landholder-rights/harvestable-rights-dams/increase

7 Monitoring

Monitoring and evaluation of progress are the basis for continuous improvement and underpin the management planning process. Monitoring is required to determine if management objectives are being met and whether the measures are effective.

Monitoring and evaluation can be implemented in effective low-cost ways that build capacity and local knowledge at the same time. On the other extreme are more technical approaches to monitoring, which may involve the installation of scientific instruments that use telemetry to communicate data. With the current understanding of the catchment and plans, there are a variety of low-cost effective solutions that could be implemented for monitoring. Monitoring plans often aim to:

- assist in demonstrating accountability to stakeholders and show that funds have been allocated, used wisely, and have resulted in desired outcomes
- help to leverage any ongoing support for actions and for any further funding that may be required
- track whether the management actions that are implemented have been effective or not
- can help to determine whether any small adjustments or significant changes may be required to ensure success.

An integrated monitoring plan for the Roseberry catchment that aims to monitor and evaluate the outputs and outcomes of the catchment scale landscape rehydration project will be an important tool to facilitate adaptive management. Once the scope and intention for on-ground works are confirmed a monitoring plan can be built to meet the needs of the project and landholders.

8 Next Steps

This report lays a foundation for the next steps in the rehydration of the Roseberry catchment. How this occurs depends upon what is important to the community. Table 3 outlines the steps forward for a catchment scale project. The steps outlined are focussed on intervention in a regulated part of the stream, if the preference is to focus on an unregulated part of the stream (stream order two or lower) and or to focus on interventions and management outside of the stream, the steps forward will be slightly different. The next stage would involve a workshop to discuss this report with landholders and stakeholders in the region with a focus on what a catchment scale project may look like and what commitments are required. The Mulloon Institutes' experience around Australia in catchment-scale projects has found that landholder and stakeholder engagement at the beginning of a project is integral for its success.

Table 3. Outline of the steps for a catchment scale rehydration project at Roseberry Creek NSW

Stage	Outcome	Timing
Stage 1 – Scoping Report	Completion of a scoping report of the Roseberry Catchment to build a foundation for a whole catchment project	January 2022
Stage 2 – Workshop	A workshop with Roseberry catchment landholders and other stakeholders to discuss what a whole catchment project may look like from the scoping report. Identify shared values, training opportunities and funding options. Ground truth the Scoping Report.	March to April 2022

	Opportunity to construct a demonstration site.	
Stage 3 – Stakeholder engagement and capacity building program	Engagement with landholders and stakeholders. Relationship building. Education and capacity building activities.	Ongoing
Stage 4 – Undertake modelling of the Roseberry Creek catchment	Development of a hydraulic/hydrological model to: - inform the planning, design and construction of instream structures - support landholder's conceptualisation and visualisation to the catchment hydrology. - inform the regulatory approvals process.	May to July 2022
Stage 5 – Land Holder Visits	Identify property-specific actions. Explain landscape rehydration strategies. Document concerns and management issues.	Post June 2022
Stage 6 – Detailed Planning Design and Government approvals	Fully costed rehydration master plan for the catchment with detailed designs for each intervention. Integrated research and monitoring plan completed. Mandatory assessments completed (eg CAA Controlled Activity Approval NSW DPI Office of Water) Approval documentation and license applications completed and submitted to relevant agencies.	2022–2023
Stage 7 – On-ground implementation	Monitoring benchmarks established. Contractors engaged. Materials ordered and delivered to site. Interventions built. Revegetation works.	Dependant on any necessary approvals – 2023
Stage 8 – Ongoing management, monitoring and capacity building.	Controlled Activity Approvals generally run for two years, allowing for any major modifications and routine maintenance to occur while interventions stabilise. Management and maintenance of structures is always necessary and should be seen as part of the broader catchment management. More maintenance is required early while vegetation is established, structures are generally robust to high flows. Ongoing monitoring based on the integrated monitoring plan	2023–2024

Appendix 1: Roseberry Creek Aboriginal cultural heritage mapping

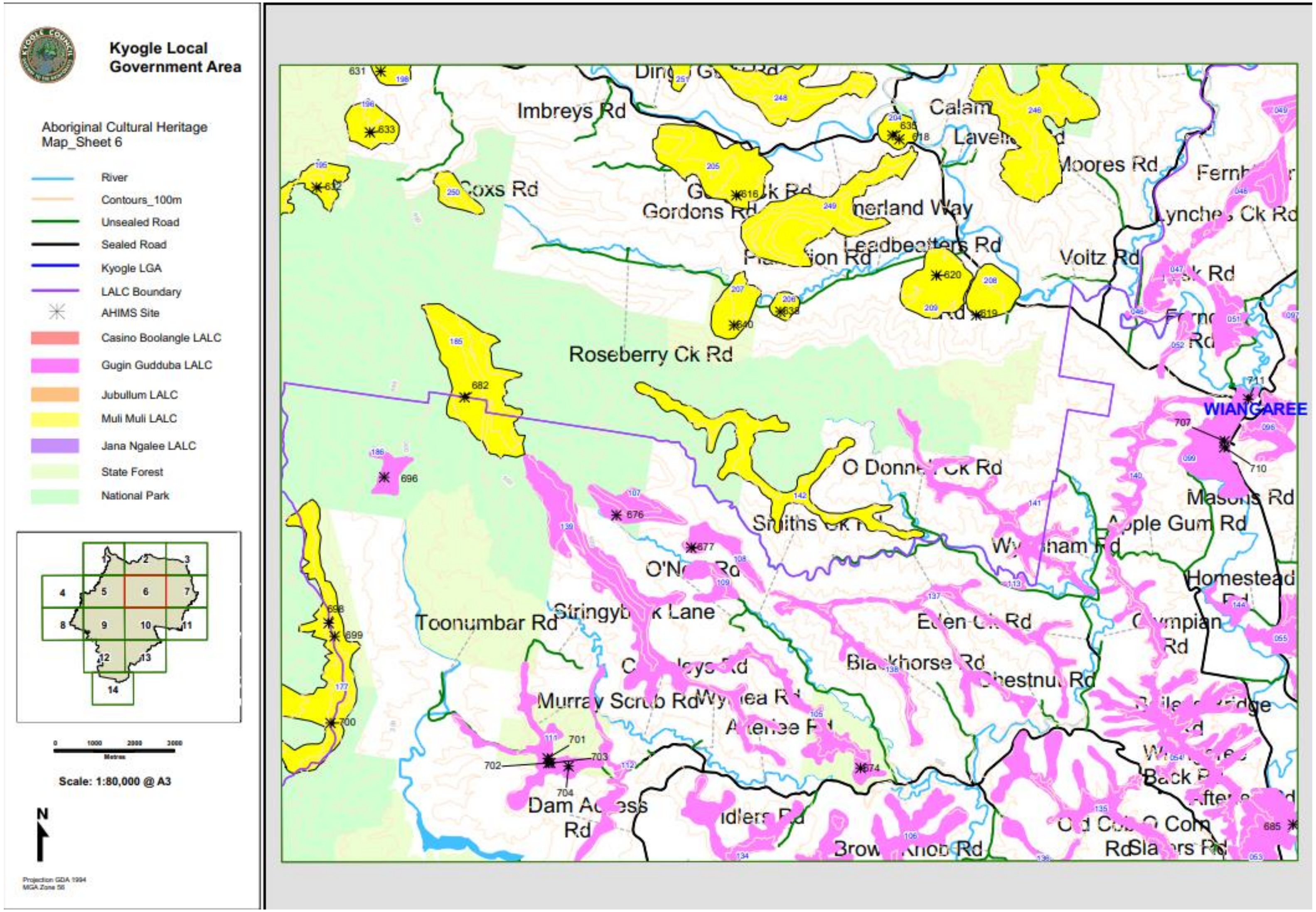

Figure 26: Map of the identified Aboriginal cultural heritage sites for Roseberry Creek identified in the 2012 report.

Appendix 2: Description of the Aboriginal cultural heritage sites in the Roseberry catchment

Kyogle Council Aboriginal Community Advisory Committee, in consultation with Local Aboriginal Land Councils have produced the 2012 Shire Wide Aboriginal Cultural Heritage Mapping Project, which can be found at this link: 2012 Shire Wide Aboriginal Cultural Heritage Mapping Project

Table 4. Description of Aboriginal cultural heritage sites from the 2012 report.

Kyogle LGA AHIMS Sites

ID (tab file)	site_id	site_name	asrtypes
616	03-3-0001	Grevillea	Burial/s
617	03-3-0002	Urbenville The Apple Tree Jurraveel (Jubabelkn)	Natural Mythological (Ritual)
618	03-3-0003	Imersom The Bull Rat Jurraveel (Jubabelkn)	Natural Mythological (Ritual)
619	03-3-0005	Roseberry 1	Bora/Ceremonial
620	03-3-0006	Roseberry 2	Burial/s
621	03-3-0007	Gibbumni, The Moon Rock	Natural Mythological (Ritual)
622	03-3-0008	The Wattle Grub Jurraveel (Jubabelkn)	Natural Mythological (Ritual)
623	03-3-0009	The Kangaroo Juraveel (Jubabelkn)	Natural Mythological (Ritual)
624	03-3-0010	Boomi Juraveel Leech Site (Jubabelkn)	Natural Mythological (Ritual)
625	03-3-0011	Edinburgh Castle, The Bull's Head Mountain	Natural Mythological (Ritual)
626	03-3-0012	Woodenbong Aboriginal Burials	Burial/s, Contact, Mission
627	03-3-0013	Mt Lindesay Jalgumbum	Natural Mythological (Ritual)
628	03-3-0014	Glennies Chair	Natural Mythological (Ritual)
629	03-3-0016	Cedar Getters Creek 1	Burial/s
630	03-3-0017	Cedar Getters Creek 2	Natural Mythological (Ritual), Water Hole/Well
631	03-3-0018	Gabai Increase Site	Natural Mythological (Ritual)
632	03-3-0019	Goya Bay Mountain	Natural Mythological (Ritual)
633	03-3-0020	Moogime Jurraveel Unumgar (Jubabelkn)	Natural Mythological (Ritual)
634	03-3-0021	Gidthumandu Wombindani Unumgar	Natural Mythological (Ritual)
635	03-3-0022	Burbi Burbi Grevillea	Natural Mythological (Ritual)
636	03-3-0023	Upper Duck Creek 1 Woodenbong	Open Camp Site
637	03-3-0024	Upper Duck Creek 2 Woodenbong	Axe Grinding Groove
638	03-3-0025	Aboriginal Burial	Burial/s
639	03-3-0026	Hills Road 1-1	Isolated Find
640	03-3-0027	Short Cut 1	Isolated Find
641	03-3-0029	Mount Lindsay 1	Open Camp Site
642	03-3-0030	Sandy Hill 1	Open Camp Site
643	03-3-0032	Duck Hole 3	Open Camp Site
644	03-3-0033	Duck Hole 2	Open Camp Site
645	03-3-0034	Duck Hole 1	Open Camp Site
646	03-3-0036	Mount Lindesay 3	Open Camp Site
647	03-3-0037	Boomi Creek Engraved Circle BCEC	Rock Engraving, Water Hole/Well
648	03-3-0038	Camp Ridge	Open Camp Site
649	03-3-0039	Boomi Creek Bora Ground	Bora/Ceremonial
650	03-3-0040	Boyle's # 2	Open Camp Site
651	03-3-0041	Boyle's # 3	Open Camp Site
652	03-3-0042	Boyle's # 4	Isolated Find
653	03-3-0043	Castle Spur Road 3	None
654	03-3-0044	Castle Spur Road 2	None
655	03-3-0045	Castle Spur Road 1	None
656	03-3-0046	Goodamun Kangaroo Footprint 1	None
657	03-3-0047	Goodamun Kangaroo Footprint 2	None
658	03-3-0048	Goodamun Kangaroo Footprint 3	None
659	03-3-0049	Goodamun Dreaming Kangaroo Site	None
660	03-5-0014	Iverson's Plantation Burial	Burial/s
661	03-5-0015	Theresa Creek	Burial/s
662	03-5-0020	Pocupar Road 2	None
663	03-5-0021	Pocupar Road 1	None
664	03-6-0002	Dyraaba Dyraaba Central 1	Burial/s
665	03-6-0003	Dyraaba Dyraaba Central 2	Burial/s
666	03-6-0004	Dyraaba Creek Dyraaba 1	Shelter with Art
667	03-6-0005	Dyraaba Creek Dyraaba 2	Shelter with Art
668	03-6-0006	Dyraaba Creek Dyraaba 3	Axe Grinding Groove, Shelter with Art, Shelter with Deposit
669	03-6-0007	Dyraaba Arm	Rock Engraving
670	03-6-0008	Tabulam Njimbun Cave	Natural Mythological (Ritual)
671	03-6-0009	Tabulam 1	Burial/s
672	03-6-0012	Old Mission Cave	Shelter with Art
673	03-6-0015	Wyangarie	Bora/Ceremonial
674	03-6-0016	Corn O'Cob Creek Kyogle	Bora/Ceremonial
675	03-6-0017	Tabulam 2	Ochre Quarry
676	03-6-0018	Smith's Creek Kyogle 1	Rock Engraving
677	03-6-0019	Smith's Creek Kyogle 2	Burial/s
678	03-6-0020	Sandy Creek 01	Bora/Ceremonial
679	03-6-0022	Dyraaba Central Dyraaba	Shelter with Deposit
680	03-6-0023	Dyraaba Arm Dyraaba	Shelter with Deposit
681	03-6-0024	Jarubirani, The Three Sisters Rocks	Natural Mythological (Ritual)
682	03-6-0025	The Murray Scrub Toonumbar State Forest	Open Camp Site
683	03-6-0026	Bonalbo Gorges Creek	Natural Mythological (Ritual)
684	03-6-0027	Pigman Creek.#1 Doubtful Creek Mummulgum	Open Camp Site
685	03-6-0029	Canoe Tree	Scarred Tree
686	03-6-0030	Mummulgum Rock Shelter	Shelter with Midden
687	03-6-0036	Camp Forest Road Rock Shelter	Shelter with Deposit
688	03-6-0037	Sugar Loaf FT1-1	Open Camp Site
689	03-6-0038	Sugar Loaf FT1-3	Open Camp Site
690	03-6-0039	Gorge Creek 1-1	Open Camp Site

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