Managing East Coast Landscapes

A Community Forum organised by Ranell Nikora (Te Whāinga),
Lois Easton (Waimatā Catchment Restoration Group),
Murry Cave (Gisborne District Council) and Gary Brierley (The University of Auckland)

ANZGG
AUSTRALIAN & NEW ZEALAND GEOMORPHOLOGY GROUP

Introduction

Geomorphologists (landscape scientists) have long had a special interest in the landscapes of the East Coast of Aotearoa. Hillslopes, rivers and coastal systems have global renown, as dramatically adjusting landscapes of the region have some of the highest rates of sediment generation and movement per unit area in the world. For decades these landscapes have been the subject of ground-breaking research and countless field trips.

While the East Coast is something of a geomorphologist's dream, to others those dreams have become nightmares, as lived realities of flooding, erosion, and sedimentation issues wreak havoc.

The Australian New Zealand Geomorphology Group (ANZGG) is holding its biannual conference at Lawson Field Theatre in Gisborne from 12-16 February 2024. The theme of the conference is: **Geomorphic Disturbance and Recovery**. Details of the conference can be found at www.anzgg2024.com

As part of this year's conference, ANZGG has worked with local groups in the Gisborne region to organise a community forum to highlight local, national and international work that has been undertaken to look after the landscapes and ecosystems of the East Coast region.

This is the latest in a long list of conferences and workshops in the region. What have we learnt? How well have we responded to the lessons from Cyclone Bola (1988)? How can we best use knowledge to inform management applications in scoping and enacting better futures?

This event aims to provide a constructive, generative environment in which to share, learn and listen. Discussion will focus on what's possible going forward in locally-owned approaches to river and landscape recovery.

Presentations will include:

a) Murry Cave (Gisborne District Council): Local responses and management actions following Cyclone Gabrielle
b) Gary Brierley (The University of Auckland): Managing at source and at scale for the five major catchments on the East Coast – lessons not learnt from Cyclone Bola
c) Jon Tunnicliffe (The University of Auckland): Managing gravel extraction on the East Coast
d) Kirstie Fryirs (Macquarie University, Australia): Sharing lessons learnt from recent Natural Flood Management experiences in Eastern Australia

Presentations will be followed by an interactive discussion session co-ordinated by Ranell Nikora.

Managing the landscapes of Tairāwhiti, Aotearoa New Zealand

Aims and Aspirations for the Community Forum

- Reflective, constructive, big-picture discussion on where we're at, where we'd like to be, and what we need to do to get there.
- Recovery and sustainability: What does it look like, how does it work?
- Fit for purpose, catchment-specific management plans that manage at source and at scale.

Issues/Perspectives to be considered

- It's about all of us … discussions with regional key stakeholders … Role of mana whenua in addressing in-your-face concerns for Te Mana o te Wai Kaupapa, Catchment Planning, Recovery planning post Cyclone Gabrielle, River health.
- All decision-making should be made with the Taiao being the centre. At the end of the day, impacts on the Taiao directly impact people - financially, socially, mentally.
- Process of getting there and maintenance (upkeep, active learning) … Decision-making processes that hear and act upon local voices through multiple kōrero … Inclusion, not permission! How can we all work better together across each level within every sector locally, regionally and nationally?
- Wilful disregard of the lessons and recommendations from Cyclone Bola (1988)
- Taking stock: What is currently happening and under way in the region? How we can be more efficient in what we do that requires a collective approach? What lessons have we have learnt from responses to Cyclone Gabrielle? Have we taken time to reflect on the number of issues and concerns that impacted during the cyclone and are impacted still to this day?
- Capacity and realities (managing expectations) … Lack of coherence in response to overwhelming impacts of Cyclone Gabrielle … Beyond response (reactive actions) to proactive, precautionary, pre-emptive actions.
- Working with recovery: Planning and Action …
- It's not just about carbon, it's about keeping soil on hills, out of the waterways.
- Sense that 'answers are in-hand' … need for change in practice through locally grounded applications, monitoring to test their viability.
- Need to restore wetlands to mitigate impacts of climate change … policies to incentivise land owners to restore them.
- Maximising potential/uptake of research: Are researchers merely seeking to meet their own outcomes, or do they truly want to be part of the community in deriving and enacting long term solutions?
- Socialising the messages – information sharing, living and updated database.
- Longevity – an ongoing commitment, not a project: Concern for what we do after Jobs for Nature and recent funding dries up … Reflections upon where we have come from in the last 5 years – from having so few aware of the issues to now having a small army in our region that are not only aware of the issues but know what the solutions are and how to achieve them. But how do we sustain this? Resources are needed to maintain the momentum to keep progressing … grants, contracts, relations to external (experienced, knowledgeable) experts - sharing opinions, knowledge, proposed solutions.

Managing at Source and at Scale: The use of geomorphic river stories to support rehabilitation of Anthropocene riverscapes in the East Coast Region of Aotearoa New Zealand

Compiled by Jacqui McCord

The Waipaoa, Waimatā, Hikuwai, Waiapu and Mōtū catchments have unique geomorphic stories, with profound variability in river diversity, contemporary processes (sediment sources, and connection from hillslopes to the streams) and future pathways of river evolution. These insights inform management applications that work with the river on a catchment scale. The steep topography, weak lithology and recurrent high intensity storms, have primed the land for deep weathering which generates high sediment yields, transforming the rivers. In relation to their size, rivers on the East Coast deliver some of the highest sediment yields to the ocean on the planet.

River	Geomorphic River Story
Waipaoa	Globally significant example of an overloaded channel with exceedingly high sediment flux that is prone to profound, rapid and recurrent geomorphic adjustment, reflected in marked transition from rapidly aggrading bedload to aggrading suspended load dominated river along its length. Gully mass movement complexes and landslips induce rapid fan and valley floor aggradation. Sediment stores are readily reworked. High connectivity from the Mountains to the Sea
Waimatā	Terraces constrain the river creating a flume-like chute that readily conveys fine-grained sediments (and forestry logs) from the mountains to the sea
Hikuwai	Excessive fine-grained sediment flux (and forestry logs) readily conveyed within a slot-like channel from the mountains to the sea
Waiapu	This river has two sides: the Mata is in sediment deficit and incising, while the Tapuaeroa is unruly and unpredictable, reflecting rapid overload of sediment from gully mass movement complexes. A globally significant example of a river subject to significant sediment flux and dramatic geomorphic adjustment (aggradation).
Mōtū	High accommodation space has created opportunity to store large volumes of sediment on valley floors in the upper catchment, separated from the coast by a gorge. Terraces buffer hillslope sediment inputs to the channel in the upper catchment. Reworking of valley floor sediments by incision (headcut erosion) and channel expansion of the laterally migrating river is the dominant sediment source.

Fit-for-purpose rehabilitation strategies build on catchment specific understandings and use process-based strategies to inform management programmes that work with the river on a catchment scale. They take account of both the hillslopes which deliver sediment to the river and the river that reworks and transports it.

The legacy of over a century of intensive and widespread catchment erosion has overloaded river systems on the East Coast. Whole-system recovery is a very long-term prospect. Even if all erosion ceased today, river bed aggradation will continue for decades or even centuries to come as the vast amount of sediment on the valley floor is repeatedly reworked, mobilised and delivered downstream. Such understandings help to determine what is realistically achievable in terms of river rehabilitation.

River	Evolution Trajectory	Recommended Management Actions
Waipaoa	Dynamically adjusting rivers are subject to rapid rates and high volumes of sediment input from hillslope movement. Fans and bed materials on the valley floor are recurrently reworked. Poor condition rivers with limited recovery potential over next 50-100 years.	Revegetation of areas prone to gullying and surface erosion. Continued use of targeted reafforestation and native regeneration of erosion-prone land. Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.
Waimatā	High sediment flux (fine-grained sediments, logs), but limited and localised changes to geomorphic structure and function in recent decades. Shallow landslides, earthflows and occasional mud volcanoes are primary sediment inputs. Large volumes of fine-grained sediments are temporarily trapped and recurrently reworked along channel banks. Poor condition rivers with moderate recovery prospects over next 50-100 years.	Reafforestation in headwaters and prioritised revegetation of riparian margins. Native reversion where production forestry marginal or risk of slash.
Hikuwai	Dynamic river with significant sediment flux but limited indication of notable change in geomorphic structure and function in recent decades. Active hillslope failures feed the river, with significant re-storage and reworking of fine-grained sediments along banks in mid-lower course reaches. Poor condition rivers with limited recovery prospects over next 50-100 years.	Reafforestation in headwaters and prioritised revegetation of riparian margins. Retire areas of production forest on highly connected slopes to allow reversion of indigenous vegetation to mitigate slash mobilisation.
Waiapu	Indication that bed levels are stabilising or slightly degrading in upstream reaches, but aggradation will continue for centuries in downstream reaches. Gully mass movement complexes are dominant sediment source. Poor condition rivers with limited recovery prospects over next 50-100 years.	Revegetation of areas prone to gully-mass movement activity. Catchment-wide reafforestation Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.
Mōtū	Incision and lateral channel expansion have increased sediment inputs and flux in meandering reaches in recent decades. Moderate to poor condition rivers with moderate recovery potential over next 50-100 years.	Bed control structures, increased wood loading and riparian vegetation management is the key priority to increase channel roughness and dissipate stream powers, reducing potential for bed degradation and channel expansion.

Full Paper Reference

Fuller IC, Brierley GJ, Tunnicliffe J, Marden M, McCord J, Rosser B, Hikuroa D, Harvey K, Stevens E and Thomas M (2023), Managing at source and at scale: The use of geomorphic river stories to support rehabilitation of Anthropocene riverscapes in the East Coast Region of Aotearoa New Zealand.

Geomorphologically-informed river management practices in Aotearoa New Zealand

Compiled by Gary Brierley

Respect diversity: Know your catchment

- Recognize, respect and work with links to Mātauranga Māori … Te Mana o te Wai, rivers as living, indivisible entities, place-based, catchment-specific applications, agency (rights) of the river, mana, mauri, ora …
- Frame management practices in relation to the type of river under consideration – its character and behaviour – what it looks like and how it adjusts
- Each river has its own story to tell: Geography and History matter

Process-based applications/solutions

- Develop and apply Nature-based Solutions … Work with the river, not against it. Don't fight the river – the river fights back … Eventually it wins
- Determine where the river get its sediments from
- Address problems for the channel bed before the banks
- Analyse the range of variability - mix of formative processes (erosion, deposition) that creates the patterns of landforms (morphodynamics – process-form interactions – dynamic physical habitat mosaic)
- Appraise magnitude-frequency relations and the role of extreme events
- Channels and floodplains tell different stories – get your head out of the channel
- Rivers create their own roughness, left to their own devices, they are really good at using their own energy

Measure river condition

- Compare like with like … Use process-based measures to appraise and monitor river condition (health, ora) in ways that reflect the character and behaviour of the type of river under consideration
- Carefully consider what to measure where, when, how and why, and what to measure against (good/healthy reference condition – expectations of a good condition river)

Interpret evolutionary trajectory to determine what is realistically achievable

- Develop proactive, not reactive, plans and practices - precautionary and pre-emptive approaches
- Derive and work towards a coherent vision at the catchment scale – fit-for-purpose plans and applications (geomorphic river stories)
- Analyse connectivity relationships: From the Mountains to the Sea … tributary-trunk stream relationships
- Describe, explain, predict … Use geomorphic understandings and modelling applications to relate contemporary character and behaviour to evolutionary trajectory to appraise the range of prospective river futures (moving targets for management)
- Appraise cumulative impacts – relate contemporary sediment flux/pulses to system responses to past disturbance events (legacy effects, landscape memory, path dependencies) to determine what is realistically achievable into the future

Management principles

- Work with the river as it is, not fanciful ideas of what it used to be (myths of a lost paradise)
- Manage at source and at scale
- Work with river recovery (self-healing practices), recognizing that condition assessment is key to analysis of recovery
- Target and prioritize actions that work with the river; strategically address threatening processes
- Get the best bang for the buck: Use cost effective practices that minimise opportunity costs ... stop making the same mistakes
- Apply a conservation ethos - Look after the good bits ... before they become a problem
- Don't fight the site, don't transfer problems elsewhere - minimize negative off-site and legacy effects (give careful consideration to treatment response)
- Carefully consider the range of options: Active and passive practices (including the do nothing option) – hard versus soft engineering practices ... Role of maintenance (weed management) ... when/where can the river be left alone to look after itself
- Prioritise space to move (erodible corridor) interventions ... managed retreat, wetland conservation/rehabilitation
- Adaptive learning: Monitoring and a living database (making the most of real-time monitoring)
- Learn effectively: Transfer understandings and management applications in a meaningful (informed, evidence-based) manner
- Beyond management: Living generatively with living rivers ... Listen to the river and learn from it

Selected readings

Brierley, G., & Fryirs, K. (2022). Truths of the Riverscape: Moving beyond command-and-control to geomorphologically informed nature-based river management. Geoscience Letters, 9(1), 14.

Brierley, G. J., Hikuroa, D., Fuller, I. C., Tunnicliffe, J., Allen, K., Brasington, J., ... & Measures, R. (2023). Reanimating the strangled rivers of Aotearoa New Zealand. Wiley Interdisciplinary Reviews: Water, 10(2), e1624.

Brierley, G., Fuller, I., Williams, G., Hikuroa, D., & Tilley, A. (2022). Re-imagining wild rivers in Aotearoa New Zealand. Land, 11(8), 1272.

Brierley, G., Tadaki, M., Hikuroa, D., Blue, B., Šunde, C., Tunnicliffe, J., & Salmond, A. (2019). A geomorphic perspective on the rights of the river in Aotearoa New Zealand. River Research and Applications, 35(10), 1640-1651.

Declining landscape resilience and land use sustainability in response to land use change and climate-related influences in Tairāwhiti: What do we know and what needs to change?

Mike Marden, formerly at Landcare Research

This research has been undertaken by Landcare Research over several decades and supported by the Foundation for Research Science and Technology.

In geomorphically active landscapes such as Tairāwhiti, geologic, tectonic and climatic factors have had a significant influence on the magnitude and frequency of erosion processes that include shallow landslides, large scale rotational slumps, earthflow, and gully erosion. The use of multitemporal mapping from orthophotographs has provided the opportunity to quantify rates of erosion and sediment supply to the drainage network following rapid and widespread clearance of the indigenous forest cover and during an ~80-100-year period of pastoralism. To slow the rate of erosion and reduce the volume of sediment delivered to streams, significant areas of land have been planting of exotic tree species (predominantly Pinus radiata). In addition, substantial areas of shrubland have been retired to allow passive (natural) reversion and/or the planting of indigenous plant species (assisted reversion) aimed at speeding up the recovery process. Since the 1990's, increasing areas of exotic forest have been clear felled and during which there have been a spate of severe storms.

The documentation of landscape responses to the removal of the indigenous forest cover, to the re-establishment of exotic forest and to clear fell harvesting across two geologic terrains, each with contrasting lithologies and tectonic histories, during a period of increased frequency and severity of storm events, has provided valuable insights into:

- temporal changes in areas affected by shallow landslides, earthflows, and gullies following deforestation by early settlers.
- the influence of plant species choice (indigenous and exotic), planting densities, rates of plant survival, differences in canopy growth and in the development of an effective soil-root reinforcement system as key determinants of the time required to restore slope stability to parts of the landscape affected by shallow landslides, earthflows, and in rehabilitating gullies.
- site-specific factors that contribute to successes and failures of different erosion control strategies employed to mitigate different erosion processes.
- temporal changes in annual sediment generation rates and total volumes following reforestation of shallow landslides, earthflows, and gullies.
- the influence of forests on rainfall interception and transpiration in reducing the duration of periods of high soil moisture content when slopes are at their most vulnerable.
- the influence of increased soil moisture contents during a 5-8-year post-harvest period (period of vulnerability) in contributing to an increase in landslide occurrence following clear fell harvesting.
- the effect of sediment derived from different land uses on water quality and stream health in different geologic terrains.
- the influence of different types of erosion in depleting soil Carbon stocks.

Journal Articles

Marden, M., Rowan, D., & Watson, A. (2023). Effect of changes in forest water balance and inferred root reinforcement on landslide occurrence and sediment generation following Pinus radiata harvest on Tertiary terrain, eastern North Island, New Zealand. New Zealand Journal of Forestry Science, 53.

Phillips, C., Bloomberg, M., Marden, M., & Lambie, S. (2023). Tree root research in New Zealand: a retrospective 'review' with emphasis on soil reinforcement for soil conservation and wind firmness. New Zealand Journal of Forestry Science, 53.

Marden, M., & Seymour, A. (2022). Effectiveness of vegetative mitigation strategies in the restoration of fluvial and fluvio-mass movement gully complexes over 60 years, East Coast region, North Island, New Zealand. New Zealand Journal of Forestry Science, 52.

Marden, M., Lambie, S., & Phillips, C. (2020). Potential effectiveness of low-density plantings of mānuka (Leptospermum scoparium) as an erosion mitigation strategy in steeplands, northern Hawke's Bay, New Zealand. New Zealand Journal of Forestry Science, 50:10.

Marden, M., Lambie, S., & Rowan, D. (2018). Root system attributes of 12 juvenile indigenous early-colonising shrub and tree species with potential for mitigating erosion in New Zealand. New Zealand Journal of Forestry Science, 48:11.

Marden, M., Lambie, S., & Phillips, C. (2018). Biomass and root attributes of eight of New Zealand's most common indigenous evergreen conifer and broadleaved forest species during the first 5 years of establishment. New Zealand Journal of Forestry Science, 48(1), 1-26.

Phillips, C., Marden, M., & Basher, L. R. (2018). Geomorphology and forest management in New Zealand's erodible steeplands: An overview. Geomorphology, 307, 107-121.

Marden, M; Rowan, D; Lambie, S. (2016). Root development and whole-tree allometry of juvenile trees of five seed-lots of Pinus radiata D. Don: implications for forest establishment on erosion-prone terrain, Easy Coast region, North Island, New Zealand. New Zealand Journal of Forestry Science, 46:24.

Marden, M, Basher, L, Phillips, C. (2015). Should detailed terrain stability or erosion susceptibility mapping be mandatory in erodible steeplands? New Zealand Journal of Forestry, 59, 4, 32-42.

Marden, M., Herzig, A., & Basher, L. (2014). Erosion process contribution to sediment yield before and after the establishment of exotic forest: Waipaoa catchment, New Zealand. Geomorphology, 226, 162-174.

Marden, M. (2012). Effectiveness of reforestation in erosion mitigation and implications for future sediment yields, East Coast catchments, New Zealand: A review. New Zealand Geographer, 68(1), 24-35.

Marden, M., Arnold, G., Seymour, A., & Hambling, R. (2012). History and distribution of steepland gullies in response to land use change, East Coast Region, North Island, New Zealand. Geomorphology, 153, 81-90.

Marden, M., Herzig, A., & Arnold, G. (2011). Gully degradation, stabilisation and effectiveness of reforestation in reducing gully-derived sediment, East Coast region, North Island, New Zealand. Journal of Hydrology (New Zealand), 50(1), 19-36.

Marden, M., Phillips, C. J., & Rowan, D. (2008). Recurrent displacement of a forested earthflow and implications for forest management, East Coast Region, New Zealand. IAHS publication, 325, 491.

Parkyn, S., Davies-Colley, R., Scarsbrook, M., Halliday, J., Nagels, J, Marden, M., Rowan, D. (2006). Pine afforestation and stream health: a comparison of land-use in two soft rock catchments, East Cape, New Zealand. New Zealand Natural Sciences 31, 113-135.

Marden, M., Arnold, G., Gomez, B., & Rowan, D. (2005). Pre-and post-reforestation gully development in Mangatu Forest, East Coast, North Island, New Zealand. *River Research and Applications*, *21*(7), 757-771.

Marden, M. (2004). Future-proofing erosion-prone hill country against soil degradation during large storm events: have past lessons been heeded?' (Professional paper). *New Zealand Journal of Forestry*, 49 (3), 11-16.

Landslides and mud volcanoes in the Gisborne region

Collaborative research co-ordinated by GDC and Martin Brook (The University of Auckland)

Gisborne's weak, clay-rich soils and weathered rocks, forming steep hillslopes, means the area can be prone to landsliding. Most often the landslides are triggered by rainfall, but occasionally by earthquakes. Even in their natural state, without any deforestation or road cuttings, Gisborne's slopes can be prone to failing if the soils become saturated enough. A further issue is the seasonal drying and wetting of soils. Gisborne's clay-rich soils show high "shrink and swell" properties, meaning there is a natural annual cycle of wetting (swelling) and drying (shrinking). This can cause a progressive weakening of the soils over years and decades, called "strain-softening" (a bit like taking a steel fork and bending it back and forth). The soil is then more prone to failure when a large rainfall event occurs.

Rainfall "thresholds" are also important to consider. These are the rainfall totals – measured across either 24, 48 or 72 hour intervals – that can initiate landslides on a given hillslope. But using rainfall forecasts to predict landslides oversimplifies the issue because the prevailing ("antecedent") soil moisture conditions are also important. Soils (and rock) are made of solids (the grains), water, and air which creates "pore" spaces. If it's been a very wet few weeks preceding a storm event, water increases within the soil pores ("porewater"), creating an increase in pressure. This lowers the strength of the soil, meaning less rainfall may be required to trigger landslides. Therefore, monitoring to see if hillslopes are moving, and any changing groundwater conditions within the soils, is important. Our work uses a combination of site investigation, laboratory testing of the material properties, and importantly, satellite radar ("InSAR") to track mm-scale movements of hillslopes across large areas to examine these, and related issues. This research has involved several postgraduate students and Gisborne District Council staff and has been funded by the EQC. Some new EQC funding extends the research until 2026.

Journal articles

Cook, M. E., Brook, M. S., Tunnicliffe, J., Cave, M., & Gulick, N. P. (2022). Preliminary investigation of emerging suburban landsliding in Gisborne, New Zealand. Quarterly Journal of Engineering Geology and Hydrogeology, 55(3), qjegh2021-087.

Cook, M. E., Brook, M. S., Hamling, I. J., Cave, M., Tunnicliffe, J. F., Holley, R., & Alama, D. J. (2022). Engineering geomorphological and InSAR investigation of an urban landslide, Gisborne, New Zealand. Landslides, 19(10), 2423-2437.

Cook, M., Brook, M., Cave, M., Wolter, A., & Rosser, B. (2022). November 2021 rainfall-triggered landslides in Gisborne/Tairāwhiti: field reconnaissance and insights from InSAR monitoring. New Zealand Geomechanics, 104, 46-57.

Cook, M. E., Brook, M. S., Hamling, I. J., Cave, M., Tunnicliffe, J. F., & Holley, R. (2023). Investigating slow-moving shallow soil landslides using Sentinel-1 InSAR data in Gisborne, New Zealand. Landslides, 20(2), 427-446.

Cook, M., Brook, M., & Cave, M. (2023). Interferometric Synthetic Aperture Radar (InSAR) and field-based observations of rainfall-triggered landslides from the November 2021 storm, Gisborne/Tairāwhiti, New Zealand. New Zealand Geographer, 9, 138-152.

Leighton, A., Brook, M. S., Cave, M., Rowe, M. C., Stanley, A., & Tunnicliffe, J. F. (2022). Engineering geomorphological reconnaissance of the December 2018 Waimata Valley mud volcano eruption, Gisborne, New Zealand. Quarterly Journal of Engineering Geology and Hydrogeology, 55(4), qjegh2021-149.

McGovern, S., Brook, M. S., & Cave, M. (2021). Geomorphology and triggering mechanism of a river-damming block slide: February 2018 Mangapoike landslide, New Zealand. Landslides, 18(3), 1087-1095.

Recent GNS Science projects in Tairāwhiti

Compiled by Brenda Rosser

Geonet landslide responses

GeoNet landslide responses, funded through the GeoNet Project, have been carried out following numerous extreme weather events in the last few years. The most significant of these were Cyclone Gabrielle, in February 2023 (see below), Cyclone Hale in January 2023, June 2023 storm, March 2022 storm, June and November 2021 storms. The responses included carrying out rapid airborne reconnaissance of landslide impacted areas to identify immediate risks to people and infrastructure and to identify the main areas of landslide impacts. Significant landslides investigated include Te Arai landslide, Whareongaonga, Waiorongomai landslide dam and the Mangahauini (Tokomaru Bay) landslide dam.

The cumulative effect of multiple extreme weather events in quick succession are starting to be seen in Tairāwhiti and we are documenting and investigating these with the data gathered from the Geonet landslide responses and ongoing work following Cyclone Gabrielle.

Cyclone Gabrielle Landslide Response and Recovery (ongoing)

Funded by MBIE through SSIF, the aim of this work is to support NEMA in the national emergency response and recovery to/from landslides triggered by Cyclone Gabrielle (February 2023) in the upper North Island of New Zealand. It was identified by NEMA, the Councils and lifeline infrastructure providers that the landslides triggered by this event needed to be mapped accurately, and more work needed to be done to help inform the ongoing response and recovery phases of work. The main outcome of this work is that NEMA, Councils and lifeline infrastructure providers know – with a good level of spatial and positional accuracy – where landslides triggered by Cyclone Gabrielle have occurred, and where future landslides could occur in other rain events, which may pose a risk to life and/or lifeline infrastructure. This project is due to end June 30, 2024.

The project includes several components:

1) **Response:** Forecasting and rapid identification of landslides and damaged ground that could pose a risk to life and lifeline infrastructure:
    a. Impact forecasting – providing landslide and landslide impact forecasts on residential buildings, state highways and railway lines, during the passage of Cyclone Gabrielle.
    b. Helicopter reconnaissance – carry out rapid airborne reconnaissance of landslide impacted regions (Northland, Auckland, Coromandel, Tairawhiti, Hawkes Bay and Tararua regions), to: i) identify main areas of landslide impacts, and ii) to help LINZ clearly define the area of interest for the acquisition of remotely sensed data from a variety of sensors (eg. satellite imagery, LiDAR, aerial photography).

2) **Remote sensing:** In association with LINZ, identify and procure pre- and post-event satellite imagery, covering the main areas impacted by landslides triggered by Cyclone Gabrielle. Using the imagery, create a series of derivative 'automated' products to help focus and assist the landslide mapping.

3) **Landslide mapping and modelling:** Carry out manual mapping of the landslides triggered by Cyclone Gabrielle, and to use the results of the mapping to investigate the accuracy of the landslide

forecast algorithms used to carry out the impact forecasts in 1) above, and to retrain them using the mapped landslide distribution.

a. Landslide inventory: Produce a high-quality inventory of landslides triggered by Cyclone Gabrielle.
b. Landslide susceptibility modelling: Investigate the efficacy/accuracy of the landslide forecasts provided in 1) above, using the mapped landslide inventory from this event (from 3) a.) Explore the regional-scale controls on the landslide distribution triggered by this event, and retrain the landslide susceptibility forecast algorithms using the landslides in this inventory, along with those in several already existing landslide inventories triggered by other historical events in the region.

4) **Tokomaru Bay landslide dam** (located in the Mangahauini River inland from Tokomaru Bay): Carry out field-based mapping and UAV lidar surveys of the landslide and dam, and investigate the landslide and dam and potential impacts wrt., downstream areas affected if it were to reform and breach in the future. Provide Gisborne District Council with hazard advice relating to the landslide and dam.

Waingake landslide hazard assessment for forest management options (ongoing)

GNS Science, working with University of Canterbury (UC) Forestry School, are currently undertaking a landslide hazard assessment and forest management options for the Castletons forestry block, Waingake, Gisborne. Castletons forestry block in the Waingake water supply catchment and is identified as highly erodible land. GDC is seeking advice and options to help manage the risk of landslides (and woody debris) which could impact assets and/or the receiving environment if the block is harvested. This work is funded through Envirolink, and due to end April 15, 2024.

Future Risk Planning through the Visualisation of Forestry Harvesting Cycles (ongoing)

GNS Science is working with GeoInsight Limited (project Lead) on a National Science Challenge funded Project "Future Risk Planning through the Visualisation of Forestry Harvesting Cycles". GNS is co-leading, with University of Canterbury's School of Forestry, the landscape erosion susceptibility (and sediment generation) components of the project. The objective of this project is to create an integrated visualisation tool of the most significant landscape hazards associated with forestry-related activities, on a catchment-by-catchment basis, across different points in time. It is intended that this information could be used to support proactive discussions and actions to influence adverse outcomes related to forest harvest activities in the short, medium, and long term. A baseline prototype demonstrating what could be possible has been developed by GeoInsight (https://remotehq.co.nz/) and currently illustrates forestry harvesting cycles across Te Tauihu (Tasman, Nelson, and Marlborough districts). The aim of the project is to widen the geographic extent of the visualisation tool to include Te Matau-a-Māui (Hawkes Bay) and Tairāwhiti (Gisborne) regions. A flyer for the project can be found here: https://share.gns.cri.nz/SZ7CZACWG746/Catchment_Planning_through_Forestry_Harvesting_Cycles.pdf.html

Recent Publications:

Rosser BJ, Jones KE. (2022). Application of LiDAR differencing to assess sediment load in the upper Waipaoa River, 2005 to 2019. Lower Hutt (NZ): GNS Science. 55 p. Consultancy Report 2021/102.

Rosser BJ, Ashraf S. (2022). Rapid landslide and flooding assessment of Gisborne Storm, 23–27 March 2022. GNS Science Letter Report No: CR 2022/75 LR. 12p.

Wolter A, Rosser BJ, Cave M, Morgenstern R, Farr J, Massey CI. 2023. Mangahauini / Tokomaru Bay landslide dam: initial scientific observations, survey results and breach inundation modelling. Lower Hutt (NZ): GNS Science. 21 p. (GNS Science report; 2023/11). doi:10.21420/SENN-CB35.

Leith K, et al. (2024). Ex Tropical Cyclone Gabrielle (12-16 February 2023): Landslide Inventory for North Island New Zealand, Version 1.0. GNS Science Report No. 2023/28. ISBN: 978-1-99-105831-7. (in review).

Leith K et al. in prep. Capturing the impact of over 800,000 landslides triggered by Cyclone Gabrielle in the North Island of New Zealand. Manuscript in prep. For submission to Science.

Wolter A, Lin SL, Hamling I, Cao Y. (2023). Makorori Landslide Complex Assessment. Letter Report No: CR 2023/74 LR. GNS Science, Lower Hutt.

Massey, C. et al., (2024). Cyclone Gabrielle landslides. Poster presented at ANZGG Conference, Gisborne, February 2024

National Science Challenges (2024). Catchment planning through the visualisation of forestry harvesting cycles. Poster presented at ANZGG Conference, Gisborne, February 2024.

Catchment-scale monitoring of river change to support a gravel management plan, Waiapu River, Aotearoa New Zealand.

Collaborative research coordinated by Jon Tunnicliffe and Ian Fuller, compiled by Jacqui McCord

As a result of rapid rates of rock formation, sediment generation and sediment conveyance, the East Coast (Tairāwhiti) region of Aotearoa New Zealand hassome of the highest rates of sediment flux per unit area in the world. Landscape connectivity is exceptionally high. Hillslopes are well connected to valley floors and sediments are readily flushed from the mountains to the sea. Tectonic processes create loosely consolidated and highly erodible rocks. Uplifted mountains create steep hillslopes that readily fall down (especially when forest cover is removed, and during cyclonic storms). These dynamically adjusting and rapidly evolving landscapes present a geomorphological laboratory to study how human activities have impacted upon sediment flux, quantifying differing sediment sources and rates of erosion, reworking and deposition which drives forms and timeframes of river adjustment. Cumulative impacts set the evolutionary trajectory of the river, as deposits from earlier phases of disturbance are reworked (i.e., legacy sediments). These insights, in turn, are critical considerations in determining sustainable rates of gravel extraction. Removal of gravel in the wrong place, and at the wrong quantity, can change the balance of sediment in the system and alter how a river operates. Collaborative research examines associated implications for the mana, mauri and ora of the river.

LiDAR difference mapping was undertaken on the Waiapu Catchment to show the cumulative amount of aggradation and degradation along the river between the 2019 and 2022 surveys. The general trend from the differencing indicated:

- The Tapuaeroa River is strongly responding to a relatively intense regime of landsliding and gullying, leading to sediment buildup in the river.
- The Mata River shows remarkably consistent sediment deficit to equilibrium trends along relatively long reaches, suggesting that sediment derived from the hillslopes is effectively moved through the system over tens of river kilometres.
- In the Waiapu River, the more highly populated and accessible reaches are likely well-supplied by the Tapuaeroa, but movement of material is episodic based on flood events, and sections vary between surplus and deficit.

On-going removal of coarse-grained gravelpresents the potential for cascading effects that create significant issues now and into the future. The LiDAR differencing indicates areas where gravel extraction should be avoided due to the cumulative sediment deficit.

To minimise the impact of the stream from gravel extraction, extraction rates should be less than the natural sediment flux, averaged over years. Where extraction rates are equal to or exceed the natural sediment inputs, the gravel extraction works can start to remove the sediment reserves in the floodplain. Monitoring is essential to understand system evolution, helping to identify reaches that could sustain some extraction without changing the essential morphodynamic feedbacks.

Selected Journal articles - Erosion and sedimentation research on the East Coast

Tunnicliffe, J., Brierley, G., Fuller, I. C., Leenman, A., Marden, M., & Peacock, D. (2018). Reaction and relaxation in a coarse-grained fluvial system following catchment-wide disturbance. Geomorphology, 307, 50-64.

Fuller, I. C., Strohmaier, F., McColl, S. T., Tunnicliffe, J., & Marden, M. (2020). Badass gully morphodynamics and sediment generation in Waipaoa Catchment, New Zealand. Earth Surface Processes and Landforms, 45(15), 3917-3930.

Leenman, A., & Tunnicliffe, J. (2020). Tributary-junction fans as buffers in the sediment cascade: a multi-decadal study. Earth Surface Processes and Landforms, 45(2), 265-279.

Poeppl, R. E., Fryirs, K. A., Tunnicliffe, J., & Brierley, G. J. (2020). Managing sediment (dis) connectivity in fluvial systems. Science of the Total Environment, 736, 139627.

Leenman, A., & Tunnicliffe, J. (2018). Genesis of a major gully mass-wasting complex, and implications for valley filling, East Cape, New Zealand. Bulletin, 130(7-8), 1121-1130.

Marden, M., Fuller, I. C., Herzig, A., & Betts, H. D. (2018). Badass gullies: Fluvio-mass-movement gully complexes in New Zealand's East Coast region, and potential for remediation. Geomorphology, 307, 12-23.

Phillips, C., Marden, M., & Basher, L. R. (2018). Geomorphology and forest management in New Zealand's erodible steeplands: An overview. Geomorphology, 307, 107-121.

Fuller, I. C., & Marden, M. (2011). Slope–channel coupling in steepland terrain: A field-based conceptual model from the Tarndale gully and fan, Waipaoa catchment, New Zealand. Geomorphology, 128(3-4), 105-115.

Fuller, I. C., & Marden, M. (2010). Rapid channel response to variability in sediment supply: Cutting and filling of the Tarndale Fan, Waipaoa catchment, New Zealand. Marine Geology, 270(1-4), 45-54.

Let the River Speak

Marsden Project co-ordinated by Anne Salmond, Dan Hikuroa, Billie Lythberg and Gary Brierley. Summary compiled by Megan Thomas.

In te ao Māori, rivers are beings in their own right, more ancient and powerful than people. Working with the Waimata Catchment at Gisborne as a case study, this project draws on thinking across different 'worlds' (ways of being), knowledge traditions and disciplines to understand the life of a particular river through time, as a living community of plants, animals and people. This work conducts a river ethnography that expresses the multiple voices of the river. Related to this project, an MSc thesis by Danielle Cairns analysed socio-cultural relationships to the Waimatā River through questionnaires and interviews with participants living/ working in the catchment. Results showed that personal interactions with the river and mental and physical wellbeing declined as perceived river condition worsened. Follow-up work completed in an MSc thesis by Elliot Stevens examined the role of storytelling as expressions of local knowledge that can be incorporated into catchment management plans. Interviewees reflected upon their passion for the river, but also their concerns for river health, ancestral relations, and the everyday usability of the river. Ongoing PhD thesis work by Megan Thomas questions notions of the Anthropocene as a human-dominated world … in whose interests? Separating people from nature disconnects people from the river, failing to conceptualise a river as a living, connected and indivisible entity. From a biophysical perspective, an MSc thesis by Jazmine Burgess examined hydrological responses to differing land cover scenarios to better inform farm and catchment planning initiatives for the Waimatā River.

Selected references

Salmond, A., Brierley, G., & Hikuroa, D. (2019). Let the rivers speak: Thinking about waterways in Aotearoa New Zealand. Policy Quarterly, 15(3).

Salmond, A., Brierley, G., Hikuroa, D., & Lythberg, B. (2022). Tai Timu, Tai Pari, the ebb and flow of the tides: working with the Waimatā from the Mountains to the Sea. New Zealand Journal of Marine and Freshwater Research, 56(3), 430-446.

Hikuroa, D., Brierley, G., Tadaki, M., Blue, B., & Salmond, A. (2021). Restoring sociocultural relationships with rivers: Experiments in fluvial pluralism. River restoration: Political, social, and economic perspectives, 66-88.

Thomas, M., Lythberg, B., Hikuroa, D. & Brierley, G. (subm). Problematizing the Anthropocene: Geographic perspectives upon the riverscapes of Waimatā Catchment, Aotearoa New Zealand. Under review.

Stevens, E., Brierley, G. & Hikuroa, D. (subm). Storytelling to support river knowledge and management. Under review.

Cairns, D., Boswijk, G., & Brierley, G. (subm). River restoration as a socio-cultural process: A case study from the Waimatā Catchment, Aotearoa New Zealand. Under review.

Natural Flood Management and uptake of the River Styles Framework in New South Wales, Australia

Summary of research co-ordinated by Kirstie Fryirs, Macquarie University

All rivers are products of the balance of impelling and resisting forces. This reflects the energy of flowing water (stream power, shear stress) relative to the roughness that creates frictional resistance and energy loos through interactions with flow. Resistance is largely determined by the slope/gradient that is set by the sinuosity of the channel, the number of channels (surface area) and the amount, type and distribution of riparian vegetation and wood along the valley floor.

Dry conditions during the millennium drought in coastal New South Wales meant there were few geomorphologically effective (i.e., erosive) floods at that time. At the same time, reduced land use pressure resulted in an increase in the extent and density of riparian vegetation cover. The air photograph record indicates that this 'regreening' trend has been ongoing for several decades (since the 1980s). When big floods hit the region following the millennium drought, the enhanced roughness of the valley floor decreased the downstream rate of flood conveyance relative to previous flood events, reducing the extent and rate of erosion along channel margins. The pattern of response varied notably from catchment to catchment.

The systematic, state-wide River Styles database in NSW now provides a resource base that helps to unravel catchment-by-catchment variability (see www.riverstyles.com for details). This information base now informs local, catchment, regional and state-wide decision-making. This includes selection of appropriate measures (balance of passive and active restoration interventions) in carefully prioritised plans that facilitate river recovery. Whenever practicable, self-healing measures work with the river, helping the river to help itself. A conservation ethos looks after remnant (good condition and high ecological value) reaches first, then targeted actions strategically address threatening processes are treated second. Then, nature-based rehabilitation is used to enhance river recovery in a cost-effective approach to proactive river management.

Selective journal papers

Fryirs, K., Zhang, N., Ralph, T. J., & Arash, A. M. (2023). Natural flood management: Lessons and opportunities from the catastrophic 2021–2022 floods in eastern Australia. Earth Surface Proc & Land, 48(9), 1649-1664.

Cohen, T. J., Suesse, T., Reinfelds, I., Zhang, N., Fryirs, K., & Chisholm, L. (2022). The re-greening of east coast Australian rivers: An unprecedented riparian transformation. Sci of The Total Env, 810, 151309.

Zhang, N., & Fryirs, K. (2023). Trends in post-1950 riparian vegetation recovery in coastal catchments of NSW Australia: Implications for remote sensing analysis, forecasting and river management. Earth Surface Proc & Land.

Arash, A. M., Fryirs, K., & Ralph, T. J. (2023). Detection of decadal time-series changes in flow hydrology in eastern Australia: Considerations for river recovery and flood management. Earth Surface Proc & Land, 48(15), 3251-3272.

Fryirs, K., Hancock, F., Healey, M., Mould, S., Dobbs, L., Riches, M., ... & Brierley, G. (2021). Things we can do now that we could not do before: Developing and using a cross-scalar, state-wide database to support geomorphologically-informed river management. PloS One, 16(1), e0244719.

Fryirs, K. A., Wheaton, J. M., Bizzi, S., Williams, R., & Brierley, G. J. (2019). To plug-in or not to plug-in? Geomorphic analysis of rivers using the River Styles Framework in an era of big data acquisition and automation. Wiley Interdisciplinary Reviews: Water, 6(5), e1372.

Fryirs, K. A., Brierley, G. J., & Dixon, T. (2019). Engaging with research impact assessment for an environmental science case study. Nature Communications, 10(1), 4542.

0

Just another storm?
Or the power of antecedent conditions

March 2015 **Ex TC Pam**. Regional Severe
April 2017 **Ex TC Debbie & Cook Severe** Uawa, Tokomaru, Waipaoa
June 2018 Queen's Birthday **Very Severe** Uawa (4-5th) 11th-12th Waipaoa
Nov. 2021 **Gisborne Very Severe** flooding and landslides
March 2022 **Regional Very Severe** Tokomaru & Anaura Bay Flooding

Jan 2023 8th **R&V Storm** City short duration high intensity
Jan 2023 11-13th **Ex TC Hale Very Severe**
Feb 2023 11th-13th **Ex TC Gabrielle Very Severe**
Feb 2023 27-28th **Son of Gabrielle** City short duration high intensity
June 2023 26th **Regional Very Severe**
September 2023 26th **Regional South** Severe. Tiniroto Landslide Dam
October 2023 30-31st **Ex TC Lola. Severe**. Tolaga North

Gisborne District Council | Maximum daily rainfalls in Gabrielle (594mm). Less than the 990mm in March 2022

1

The response

10 days advanced warning.

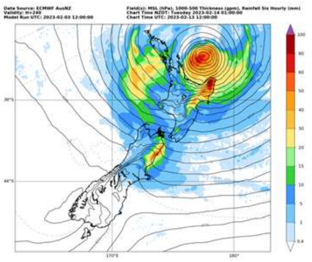
Support mobilised early

No event can ever be perfectly managed; %$# will happen.

(learn from it, get over it, move on)

The recovery process is hard

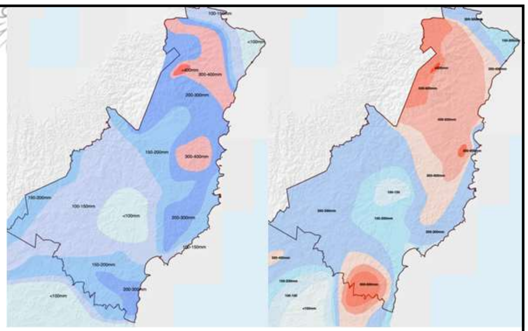
We are still in response mode



Gisborne District Council | 5 October 2021 | 2

2

Cyclones Hale and Gabrielle were very different storms



Cyclone Hale January 2023 Cyclone Gabrielle February 2023

Gisborne District Council | 5 October 2021 | 3

3

Impacts

Communication networks

(whoever was it who thought it was a good idea to load critical infrastructure to the undersides of bridges? Don't do it again!!)

Water supply pipeline

Roads and Bridges

Landslide dams

Housing

Marae and Whenua Maori land

1 fatality many close calls

Gisborne District Council | | 4

4

Water Supply Pipeline

9 Breaks

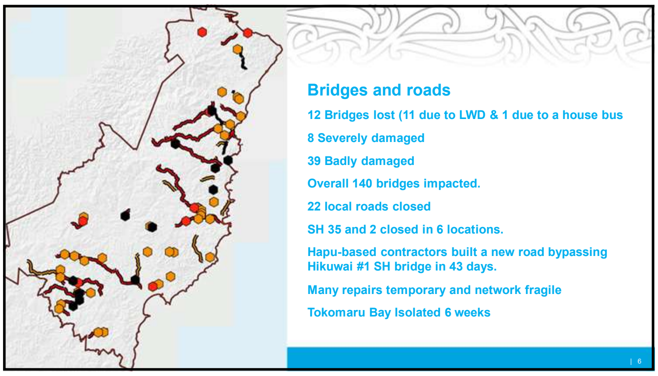
Most breaks the result of pine logs

45 days to get water flowing again (but much more to do)

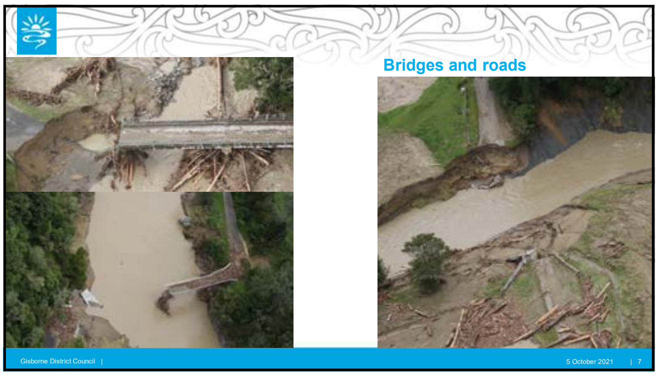
Backup Waipaoa water treatment plant intake smothered by mud

Gisborne District Council | | 5

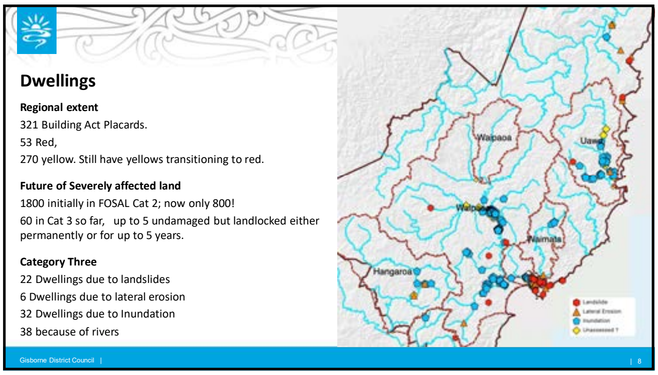
5


Bridges and roads
12 Bridges lost (11 due to LWD & 1 due to a house bus
8 Severely damaged
39 Badly damaged
Overall 140 bridges impacted.
22 local roads closed
SH 35 and 2 closed in 6 locations.
Hapu-based contractors built a new road bypassing Hikuwai #1 SH bridge in 43 days.
Many repairs temporary and network fragile
Tokomaru Bay Isolated 6 weeks
| 6

6


Bridges and roads
Gisborne District Council |
5 October 2021 | 7

7


Dwellings
Regional extent
321 Building Act Placards.
53 Red,
270 yellow. Still have yellows transitioning to red.
Future of Severely affected land
1800 initially in FOSAL Cat 2; now only 800!
60 in Cat 3 so far, up to 5 undamaged but landlocked either permanently or for up to 5 years.
Category Three
22 Dwellings due to landslides
6 Dwellings due to lateral erosion
32 Dwellings due to Inundation
38 because of rivers
Waipaoa
Uawa
Waimata
Hangaroa
Gisborne District Council |
| 8

8


Landslide affected Dwellings
Gisborne District Council |
| 9

9


Rural Inundation of dwellings
Gisborne District Council |
| 10

10


Inundation of dwellings in Gisborne City
Gisborne District Council |
| 11

11

Lateral erosion of dwellings in Gisborne City

Gisborne District Council | | 12

12

Marae

4 Marae severely inundated Category 3
1 Marae flooded Category 2 p
2 in Waipaoa
2 at Uawa

Gisborne District Council | | 13

13

Future of Severely Affected land (FOSAL)

In some ways the category 3 properties are easy as there is finality

For Category 2P Inundation its also relatively straight forward as there is some funding for lifting dwellings…..but

No funding for dwellings that can't be economically lift (ie those with concrete floors)

The funding has been focussed on flood inundation and little or no consideration has been given to properties affected by landslide or lateral erosion, or for those properties where construction methods makes lifting uneconomic, or where water velocities or woody debris makes lifting a dwelling not an option.

We have a large number of 2P landslide affected dwellings that may ultimately become Category 3 because there is no funding to mitigate landslide risk.

Gisborne District Council | | 14

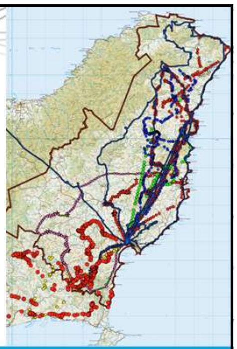
14

A few closing thoughts

Intelligence is critical
- Get a clear picture as fast as possible
- Don't wait for Satellite imagery acquire regional aerial imagery asap.

Learn from past mistakes
- After Bola large areas of pine were planted as the solution. No thought as to impact of harvest.
- A legacy of LWD will be the elephant in the room for many years.

National recognition of regional issues
- Advisors need to understand the scale of the issues & understand the human cost
- Insurers, Govt Agencies Councils need to work closely
- We need to rethink the EQC/Insurer process. Insurers are motivated to minimise their liabilities but EQC has a social licence; has that licence expired?
- We need to rethink land damage pay outs. Paying out the lesser of the cost of mitigation or the land value merely transfers the liability to future generations.
- We need to address managed retreat



Gisborne District Council | | 15

15

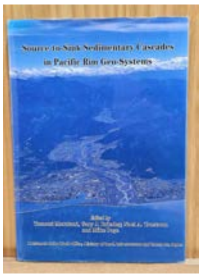
Thank you

Gisborne District Council | | 16

16

Geomorphic river stories: Geography & History Matter

Context - Parallels and contrasts with Japan



Fuller, I. C., Brierley, G. J., Tunnicliffe, J., Marden, M., McCord, J., Rosser, B., ... & Thomas, M. (2023). Managing at source and at scale: The use of geomorphic river stories to support rehabilitation of Anthropocene riverscapes in the East Coast Region of Aotearoa New Zealand. *Frontiers in Environmental Science*, *11*, 1162099.

Lessons from Cyclone Bola (and Gabrielle)

1

Geomorphic river stories

Where does the river get its sediment from?

How readily are sediments conveyed from the Mountains to the Sea?

How long does it take to rework sediments from past disturbance events (legacy sediments)?

What is realistically achievable into the future?

2

Condition and recovery

What is a healthy river?

Perception of flooding, erosion, sedimentation

What does recovery look like: Nature-based Solutions that work with the river?

- Waiapu
- Uawa/Hikuwai
- Waimatā
- Waipaoa
- Mōtū

Are 'solutions' locally-owned – designed and implemented?

3

Cyclone Gabrielle: Reactive response or proactive recovery?

Are responses catchment-specific, fit-for-purpose?

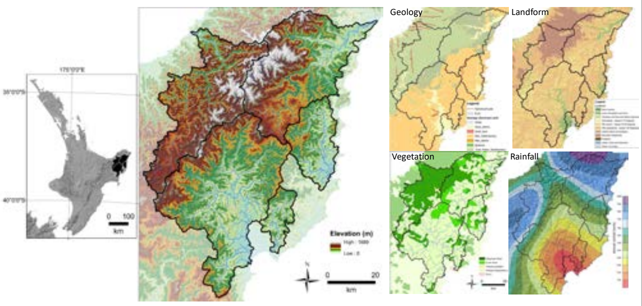
Do they apply Nature-based Solutions that work with the river?

Relations to mātauranga Māori: Mana, mauri, ora … the river as a living, indivisible entity that operates from the Mountains to the Sea

What does recovery/sustainability look like?

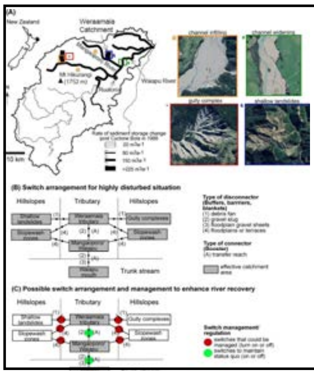
4

River stories from the East Coast (Fuller et al., 2023)

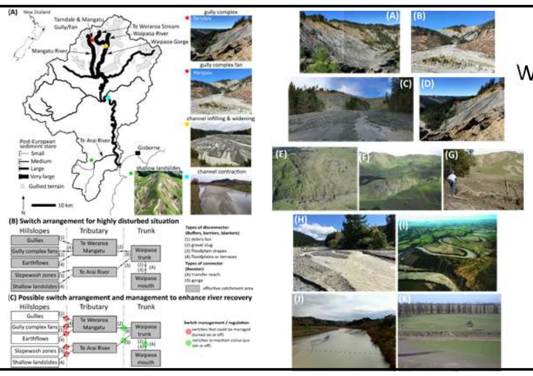


5

Waiapu



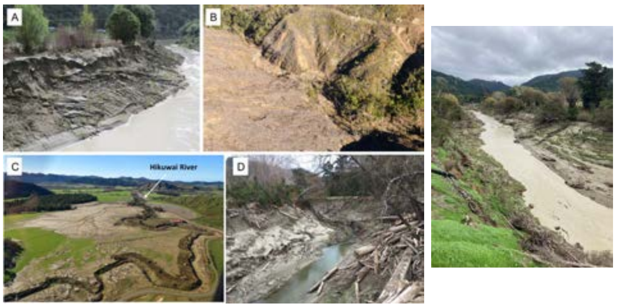
6



Waipaoa

7

Uawa/Hikuwai

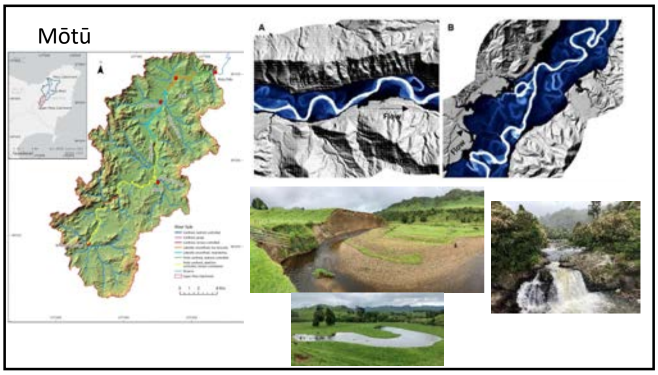


8

Waimatā

9

Mōtū



10

River stories from the East Coast: Summary

River	Story
Waiapu	The Mata is in sediment deficit and incising, while the Tapuaeroa is unruly and unpredictable, reflecting rapid overload of sediment from gully mass movement complexes. A globally significant example of a river subject to significant sediment flux and dramatic geomorphic adjustment (aggradation).
Hikuwai	Excessive fine-grained sediment flux (and forestry logs) readily conveyed within a slot-like channel from the Mountains to the Sea
Waimatā	Terrace-constrained flume-like chute that readily conveys fine-grained sediments (and forestry logs) from the Mountains to the Sea
Waipaoa	Globally significant example of an overloaded channel with exceedingly high sediment flux that is prone to profound, rapid and recurrent geomorphic adjustment, reflected in marked transition from rapidly aggrading bedload to aggrading suspended load dominated river along its length. Gully mass movement complexes and landslips induce rapid fan and valley floor aggradation. Sediment stores are readily reworked. High connectivity from the Mountains to the Sea
Mōtū	High accommodation space has created opportunity to store large volumes of sediment on valley floors in the upper catchment, separated from the coast by a gorge. Terraces buffer hillslope sediment inputs to the channel in the upper catchment. Reworking of valley floor sediments by incision (headcut erosion) and channel expansion of the laterally migrating river is the dominant sediment source.

11

Waiapu futures

Respect Diversity	Process Regime	Evolutionary trajectory	Management actions
Gravel-bed braided river with complex physical habitat mosaic	Sensitive, rapidly-aggrading (overloaded) rivers with high hillslope-valley floor, tributary-trunk stream and upstream-downstream connectivity	Indication that bed levels are stabilising or slightly degrading in upstream reaches, but aggradation will continue for centuries in downstream reaches. Gully mass movement complexes are dominant sediment source. Poor condition rivers with limited recovery prospects over next 50-100 years.	Revegetation of areas prone to gully-mass movement activity. Catchment-wide reafforestation Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.

12

Waipaoa futures

Respect Diversity	Process Regime	Evolutionary trajectory	Management actions
Gravel-bed braided river with complex physical habitat mosaic in upper-middle reaches transitioning to single channel, which is initially sinuous before becoming a straightened low sinuosity and suspended load river with reduced habitat diversity in lower reaches (constrained by stopbanks)	Sensitive, dynamically-adjusting rivers. Pronounced hillslope-valley floor connectivity creates overloaded, aggrading rivers in headwaters. High longitudinal connectivity promotes rapid floodplain aggradation in lower reaches, where stopbanks now limit capacity for lateral adjustment.	Dynamically adjusting rivers are subject to rapid rates and high volumes of sediment input (sometimes extreme). Significant, recurrent reworking of fans and bed materials. Decadal aggradation rates may have diminished (upstream incision), but sediment flux remains exceedingly high. Gully mass movement complexes and pervasive landslips generate extreme sediment loads. Poor condition rivers with limited recovery potential over next 50-100 years.	Revegetation of areas prone to gullying and surface erosion (earthflows and landslides). Continued use of targeted reafforestation and native regeneration of erosion-prone land. Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.


13

Hikuwai futures

Respect Diversity	Process Regime	Evolutionary trajectory	Management actions
Relatively homogeneous fine-grained suspended-load channel	Highly connected from the Mountains to the Sea. High hillslope-valley floor connectivity in headwaters, but significant buffering by terraces and broad floodplain downstream. Slot-like channels in lower reaches have limited channel-floodplain connectivity and are not prone to lateral adjustment, but large volumes of fine-grained sediment are stored and reworked along channel	Dynamic river with significant sediment flux but limited indication of notable change in geomorphic structure and function in recent decades. Active hillslope failures feed the river, with significant re-storage and reworking of fine-grained sediments along banks in mid-lower course reaches. Poor condition rivers with limited recovery prospects over next 50-100 years.	Reafforestation in headwaters and prioritised revegetation of riparian margins. Retire areas of production forest on highly connected slopes to allow reversion of indigenous vegetation to mitigate slash mobilisation.



14

Waimatā futures

Respect Diversity	Process Regime	Evolutionary trajectory	Management actions
Relatively homogeneous channel dominated by fine-grained sediments	Terrace-constrained flume-like channel with high longitudinal connectivity but limited channel-floodplain connectivity. Large volumes of fine-grained sediment are stored and reworked along channel banks.	High sediment flux (fine-grained sediments, logs), but limited and localised changes to geomorphic structure and function in recent decades (transfer reaches). Shallow landslides, incremental inputs from earthflows and occasional mud volcanoes are primary sediment inputs, but large volumes of fine-grained sediments are temporarily trapped and recurrently reworked along channel banks. Poor condition rivers with moderate recovery prospects over next 50-100 years (sediment inputs and forms/rates of geomorphic adjustment are less pronounced than other rivers in the region).	Reafforestation in headwaters and prioritised revegetation of riparian margins. Native reversion where production forestry marginal or risk of slash.


15

Mōtū futures

Respect Diversity	Process Regime	Evolutionary trajectory	Management actions
High sediment storage in wide upland valley, with falls demarcating transition to gorge and narrow valley to the coast. Upper catchment has active mixed load meandering sand-bed river with pool-riffle sequences and oxbow lakes	Upper catchment is a moderately sensitive river subject to incision and lateral channel expansion (high channel-floodplain connectivity). Terraces buffer sediment input. High longitudinal connectivity, with limited accommodation space downstream of the gorge.	Incision and lateral channel expansion have increased sediment inputs and flux in meandering reaches in recent decades. Moderate to poor condition rivers with moderate recovery potential over next 50-100 years.	Bed control structures, increased wood loading and riparian vegetation management is the key priority to increase channel roughness and dissipate stream powers, reducing potential for bed degradation and channel expansion. Although warranted, reafforestation will reduce flow inputs but have limited impacts on the sediment regime.

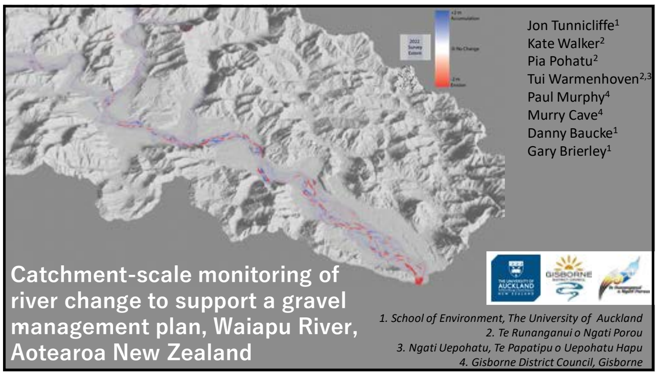
16

Summary

Geomorphologically-informed river management…

- Respects diversity: river type, capacity to adjust, different scales of space & time
- Works with processes (e.g. bank erosion, bed erosion)
- Is proactive and precautionary to improve river condition (do no harm)
- Applies a conservation ethos, strategically addressing threats to river condition / character / state – what is realistically achievable – where, how, priorities…
- Must be founded on understanding river (hi)stories
- Plans for the future (monitoring, data collection & analysis, adapting strategies…)

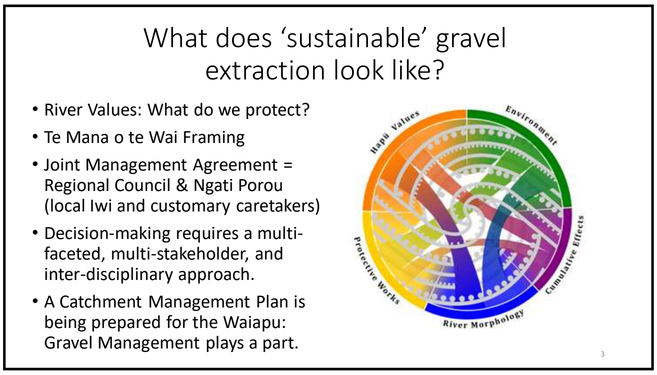
17


Jon Tunnicliffe[1]
Kate Walker[2]
Pia Pohatu[2]
Tui Warmenhoven[2,3]
Paul Murphy[4]
Murry Cave[4]
Danny Baucke[1]
Gary Brierley[1]
Catchment-scale monitoring of river change to support a gravel management plan, Waiapu River, Aotearoa New Zealand
1. School of Environment, The University of Auckland
2. Te Runanganui o Ngati Porou
3. Ngati Uepohatu, Te Papatipu o Uepohatu Hapu
4. Gisborne District Council, Gisborne

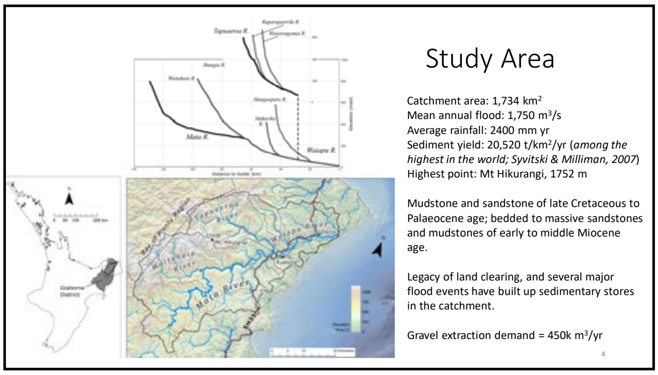
1


Ko Hikurangi te maunga
Ko Waiapu te awa
Ko Ngati Porou te iwi

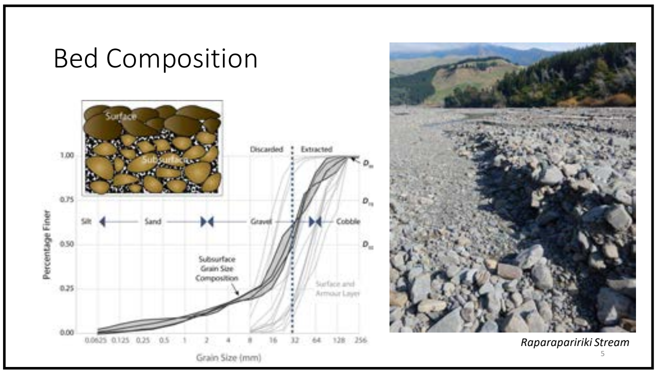
2


What does 'sustainable' gravel extraction look like?
• River Values: What do we protect?
• Te Mana o te Wai Framing
• Joint Management Agreement = Regional Council & Ngati Porou (local Iwi and customary caretakers)
• Decision-making requires a multi-faceted, multi-stakeholder, and inter-disciplinary approach.
• A Catchment Management Plan is being prepared for the Waiapu: Gravel Management plays a part.
Hapu Values
Environment
Cumulative Effects
River Morphology
Protective Works
3

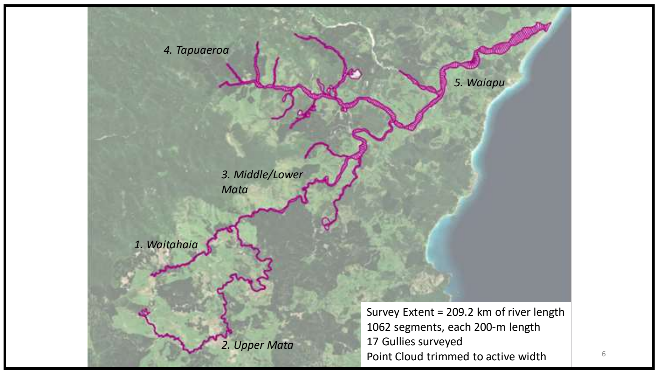
3


Study Area
Catchment area: 1,734 km²
Mean annual flood: 1,750 m³/s
Average rainfall: 2400 mm yr
Sediment yield: 20,520 t/km²/yr (among the highest in the world; Syvitski & Milliman, 2007)
Highest point: Mt Hikurangi, 1752 m
Mudstone and sandstone of late Cretaceous to Palaeocene age; bedded to massive sandstones and mudstones of early to middle Miocene age.
Legacy of land clearing, and several major flood events have built up sedimentary stores in the catchment.
Gravel extraction demand = 450k m³/yr
4

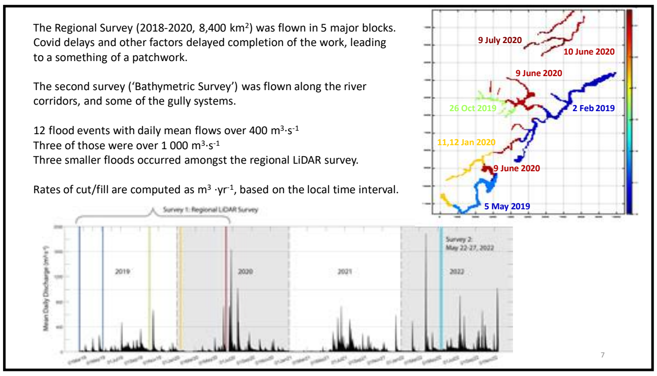
4


Bed Composition
Surface
Subsurface
Discarded
Extracted
Silt
Sand
Gravel
Cobble
Subsurface Grain Size Composition
Surface and Armour Layer
Percentage Finer
Grain Size (mm)
Raparapaririki Stream
5

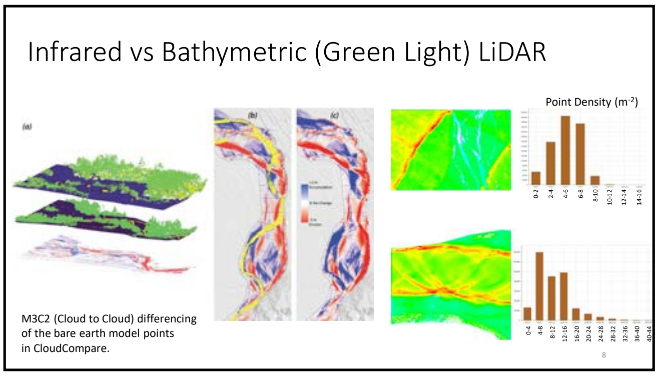
5


4. Tapuaeroa
5. Waiapu
3. Middle/Lower Mata
1. Waitahaia
2. Upper Mata
Survey Extent = 209.2 km of river length
1062 segments, each 200-m length
17 Gullies surveyed
Point Cloud trimmed to active width
6

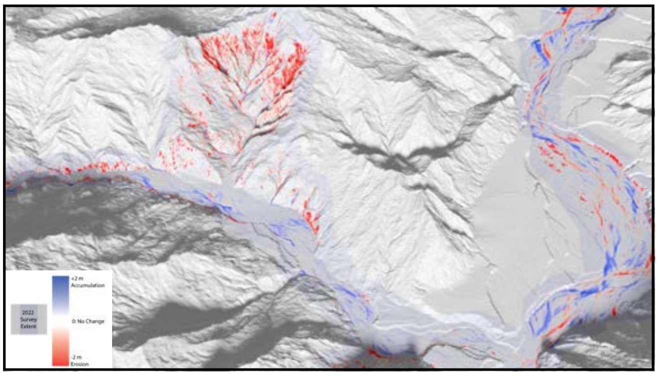
6


The Regional Survey (2018-2020, 8,400 km²) was flown in 5 major blocks. Covid delays and other factors delayed completion of the work, leading to a something of a patchwork.
The second survey ('Bathymetric Survey') was flown along the river corridors, and some of the gully systems.
12 flood events with daily mean flows over 400 m³·s⁻¹
Three of those were over 1 000 m³·s⁻¹
Three smaller floods occurred amongst the regional LiDAR survey.
Rates of cut/fill are computed as m³ ·yr⁻¹, based on the local time interval.
9 July 2020
10 June 2020
9 June 2020
26 Oct 2019
2 Feb 2019
11,12 Jan 2020
9 June 2020
5 May 2019
Survey 1: Regional LiDAR Survey
Survey 2: May 22-27, 2022
2019
2020
2021
2022
Mean Daily Discharge (m³s⁻¹)
7

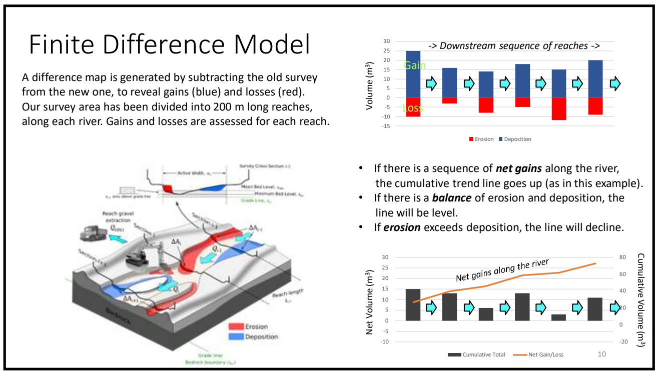
7


Infrared vs Bathymetric (Green Light) LiDAR
Point Density (m⁻²)
(a)
(b)
(c)
M3C2 (Cloud to Cloud) differencing of the bare earth model points in CloudCompare.
8

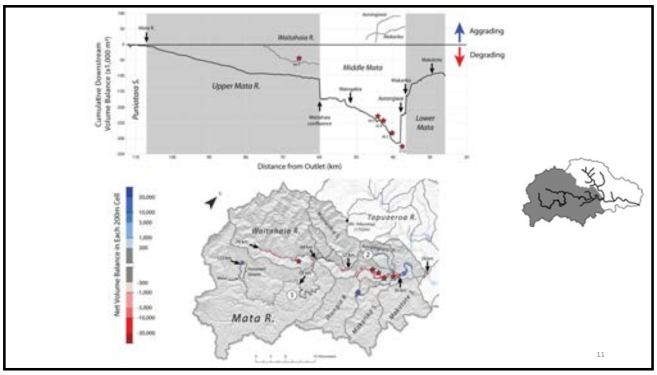
8


2022 Survey Extent
+2 m Accumulation
0: No Change
-2 m Erosion

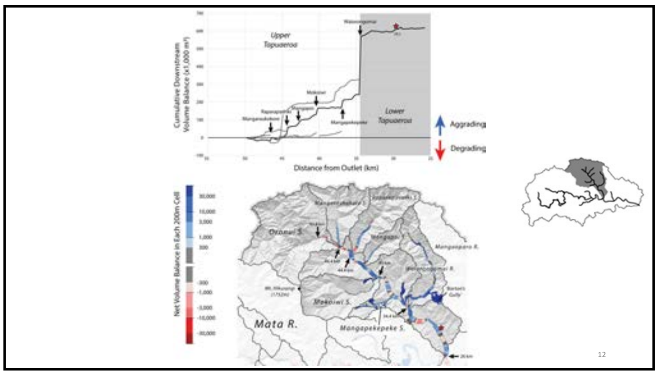
9


Finite Difference Model
A difference map is generated by subtracting the old survey from the new one, to reveal gains (blue) and losses (red). Our survey area has been divided into 200 m long reaches, along each river. Gains and losses are assessed for each reach.
-> Downstream sequence of reaches ->
Volume (m³)
Gain
Loss
Erosion
Deposition
If there is a sequence of net gains along the river, the cumulative trend line goes up (as in this example).
If there is a balance of erosion and deposition, the line will be level.
If erosion exceeds deposition, the line will decline.
Net gains along the river
Net Volume (m³)
Cumulative Volume (m³)
Cumulative Total
Net Gain/Loss
Erosion
Deposition
10

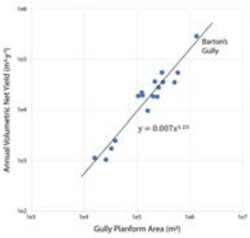
10


Aggrading
Degrading
Upper Mata R.
Middle Mata
Lower Mata
Waitahaia R.
Distance from Outlet (km)
Cumulative Downstream Volume Balance (x1,000 m³)
Net Volume Balance in Each 200m Cell
Waitahaia R.
Tapuaeroa R.
Mata R.
11

11


Upper Tapuaeroa
Lower Tapuaeroa
Aggrading
Degrading
Distance from Outlet (km)
Cumulative Downstream Volume Balance (x1,000 m³)
Net Volume Balance in Each 200m Cell
Mata R.
12

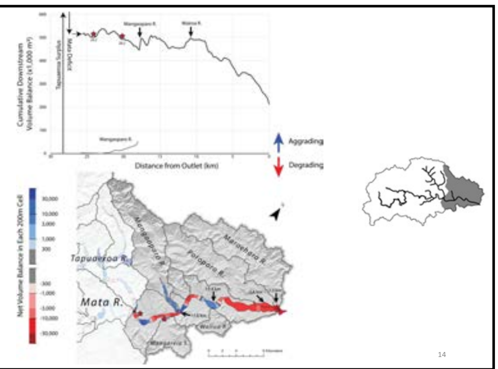
12



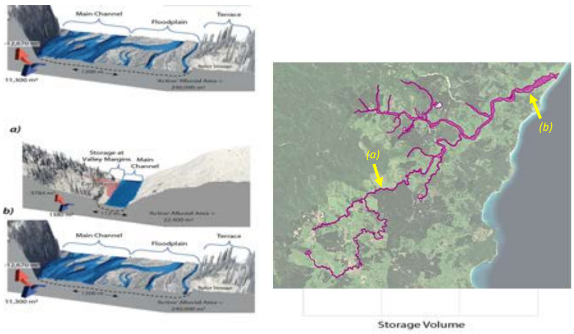
At just over 1 km in width, Barton's Gully is the largest gully complex in New Zealand; it shows a next export of over half a million m^3 of sediment in the interval between surveys (2.88 *x* 10^5 m^3·yr^{-1}).

With a combined area of 4.5 km^2, the 17 surveyed gullies contribute 6.4 x 10^5 m^3 of sediment to the river annually.

13



14



15

Scale Questions

16

17

Additional [Geomorphic] Concerns:

- Multiple sites of extraction
- Annual variability in supply
- Supply of competent, >32mm fractions
- Operating 'footprint' and selective hunting for coarse fractions
- Habitat diversity, distribution
- Groundwater, hyporheic pathways
- 'Headwater', <= 3rd order streams
- Water, air quality (fine sediment issues)

18

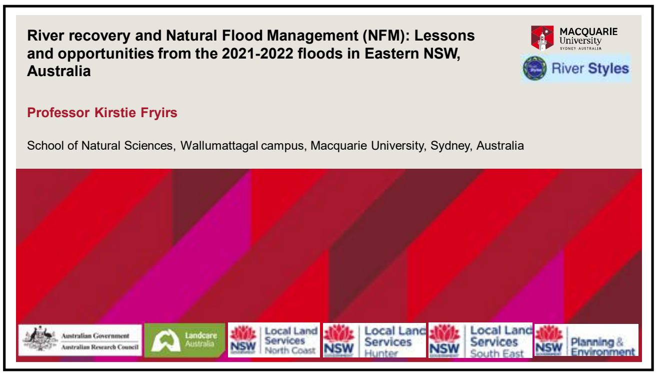
Conclusions (so far..)

- We now have a catchment-scale ***baseline of bed material transfer***. The picture may be imperfect, but this will continue to improve with future surveys.
- The ***Mata River*** shows systematic downstream losses, upstream of Makarika Stream. There is a concentration of extraction operations here that should be reconsidered.
- The ***Tapuaeroa***, by contrast, has both high flux rates and considerable storage (these are related..). Any extraction work should consider how best to preserve sites of cultural importance, and the potential for habitat diversity and connectivity.
- There is a relationship between flux and storage: ***aggrading, transport-limited systems*** should be key criteria for gravel removal.
- Continued monitoring will reveal any changes in longitudinal changes to the equilibrium state of sediment transfers. Bed texture should also be monitored for compositional changes.
- The development of braids and a complex and dynamic river environment reflect the continued renewal of ***the mana of the river***: while its form is dynamic, the river is in balance with sediment supply.

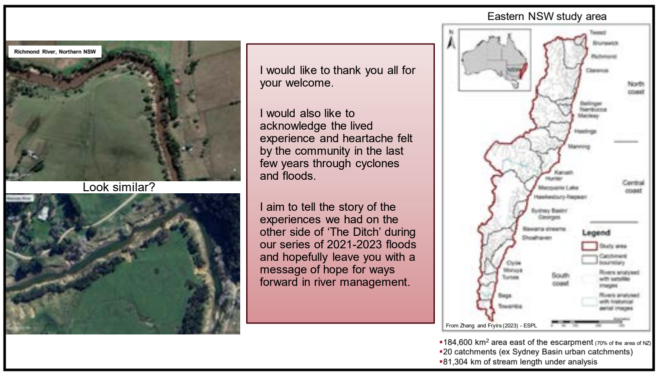
19

19

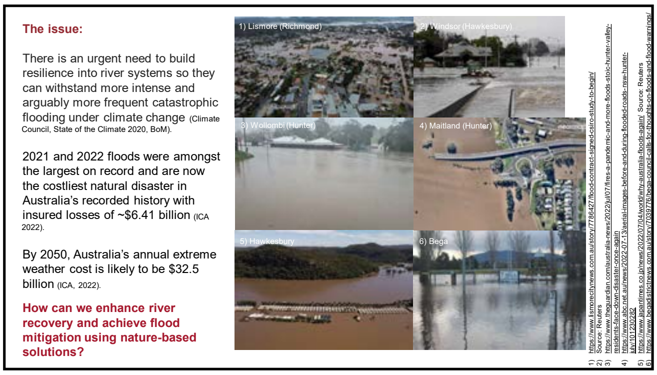
20


River recovery and Natural Flood Management (NFM): Lessons and opportunities from the 2021-2022 floods in Eastern NSW, Australia
MACQUARIE University SYDNEY·AUSTRALIA
River Styles
Professor Kirstie Fryirs
School of Natural Sciences, Wallumattagal campus, Macquarie University, Sydney, Australia
Australian Government Australian Research Council
Landcare Australia
NSW Local Land Services North Coast
NSW Local Land Services Hunter
NSW Local Land Services South East
NSW Planning & Environment

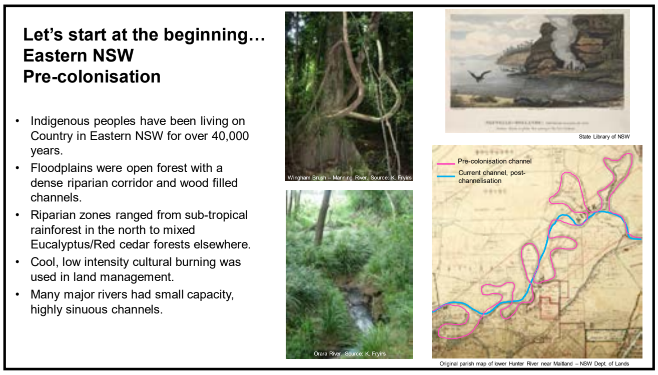
1


Richmond River, Northern NSW
Look similar?
I would like to thank you all for your welcome.
I would also like to acknowledge the lived experience and heartache felt by the community in the last few years through cyclones and floods.
I aim to tell the story of the experiences we had on the other side of 'The Ditch' during our series of 2021-2023 floods and hopefully leave you with a message of hope for ways forward in river management.
Eastern NSW study area
North coast
Central coast
South coast
Legend
From Zhang and Fryirs (2023) - ESPL
▪184,600 km² area east of the escarpment (70% of the area of NZ)
▪20 catchments (ex Sydney Basin urban catchments)
▪81,304 km of stream length under analysis

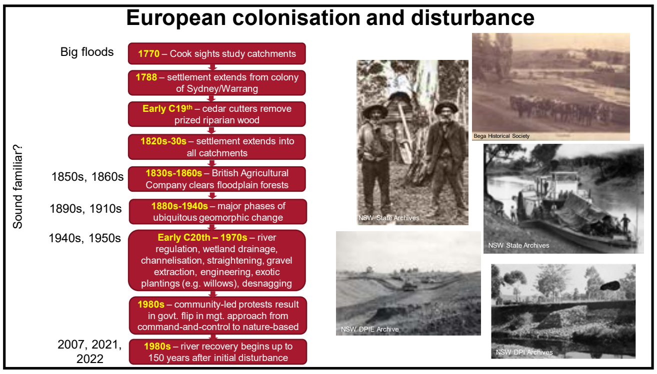
2


The issue:
There is an urgent need to build resilience into river systems so they can withstand more intense and arguably more frequent catastrophic flooding under climate change (Climate Council, State of the Climate 2020, BoM).
2021 and 2022 floods were amongst the largest on record and are now the costliest natural disaster in Australia's recorded history with insured losses of ~$6.41 billion (ICA 2022).
By 2050, Australia's annual extreme weather cost is likely to be $32.5 billion (ICA, 2022).
How can we enhance river recovery and achieve flood mitigation using nature-based solutions?
1) Lismore (Richmond)
2) Windsor (Hawkesbury)
3) Wollombi (Hunter)
4) Maitland (Hunter)
5) Hawkesbury
6) Bega
1) https://www.lismorecitynews.com.au/story/7786427/flood-contract-signed-csiro-study-to-begin/
2) Source: Reuters
3) https://www.theguardian.com/australia-news/2022/jul/07/fires-a-pandemic-and-more-floods-stoic-hunter-valley-residents-face-down-disaster-once-again
4) https://www.abc.net.au/news/2022-07-13/aerial-images-before-and-during-flooded-roads-nsw-hunter-july/101230282
5) https://www.japantimes.co.jp/news/2022/07/04/world/why-australia-floods-again/ Source: Reuters
6) https://www.begadistrictnews.com.au/story/7039776/bega-council-calls-for-thoughts-on-floods-and-flood-warnings/

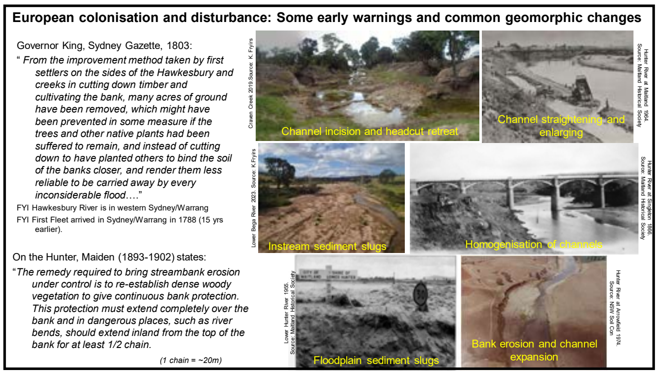
3


Let's start at the beginning…
Eastern NSW
Pre-colonisation
• Indigenous peoples have been living on Country in Eastern NSW for over 40,000 years.
• Floodplains were open forest with a dense riparian corridor and wood filled channels.
• Riparian zones ranged from sub-tropical rainforest in the north to mixed Eucalyptus/Red cedar forests elsewhere.
• Cool, low intensity cultural burning was used in land management.
• Many major rivers had small capacity, highly sinuous channels.
Wingham Brush – Manning River. Source: K. Fryirs
Orara River. Source: K. Fryirs
State Library of NSW
Pre-colonisation channel
Current channel, post-channelisation
Original parish map of lower Hunter River near Maitland – NSW Dept. of Lands

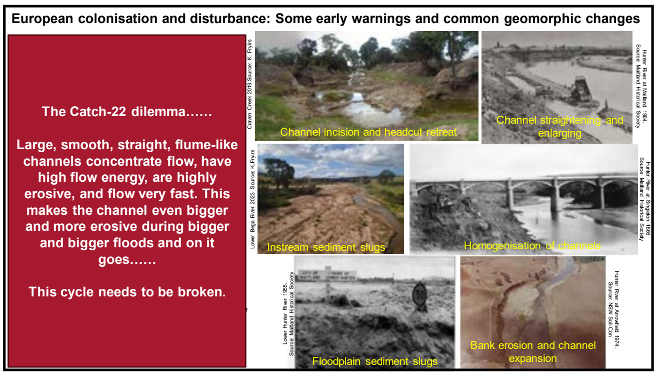
4


European colonisation and disturbance
Big floods
1770 – Cook sights study catchments
1788 – settlement extends from colony of Sydney/Warrang
Early C19th – cedar cutters remove prized riparian wood
1820s-30s – settlement extends into all catchments
1850s, 1860s
1830s-1860s – British Agricultural Company clears floodplain forests
1890s, 1910s
1880s-1940s – major phases of ubiquitous geomorphic change
1940s, 1950s
Early C20th – 1970s – river regulation, wetland drainage, channelisation, straightening, gravel extraction, engineering, exotic plantings (e.g. willows), desnagging
1980s – community-led protests result in govt. flip in mgt. approach from command-and-control to nature-based
2007, 2021, 2022
1980s – river recovery begins up to 150 years after initial disturbance
Sound familiar?
Bega Historical Society
NSW State Archives
NSW State Archives
NSW DPIE Archive
NSW DPI Archives

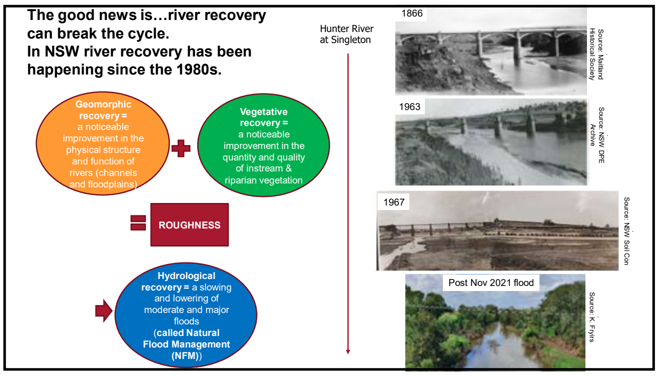
5


European colonisation and disturbance: Some early warnings and common geomorphic changes
Governor King, Sydney Gazette, 1803:
" From the improvement method taken by first settlers on the sides of the Hawkesbury and creeks in cutting down timber and cultivating the bank, many acres of ground have been removed, which might have been prevented in some measure if the trees and other native plants had been suffered to remain, and instead of cutting down to have planted others to bind the soil of the banks closer, and render them less reliable to be carried away by every inconsiderable flood…."
FYI Hawkesbury River is in western Sydney/Warrang
FYI First Fleet arrived in Sydney/Warrang in 1788 (15 yrs earlier).
On the Hunter, Maiden (1893-1902) states:
"The remedy required to bring streambank erosion under control is to re-establish dense woody vegetation to give continuous bank protection. This protection must extend completely over the bank and in dangerous places, such as river bends, should extend inland from the top of the bank for at least 1/2 chain.
(1 chain = ~20m)
Craven Creek 2019.Source: K. Fryirs
Channel incision and headcut retreat
Hunter River at Maitland 1964. Source: Maitland Historical Society
Channel straightening and enlarging
Lower Bega River 2023. Source: K.Fryirs
Instream sediment slugs
Hunter River at Singleton 1866. Source: Maitland Historical Society
Homogenisation of channels
Lower Hunter River 1955. Source: Maitland Historical Society
Floodplain sediment slugs
Hunter River at Arrowfield 1974. Source: NSW Soil Con
Bank erosion and channel expansion

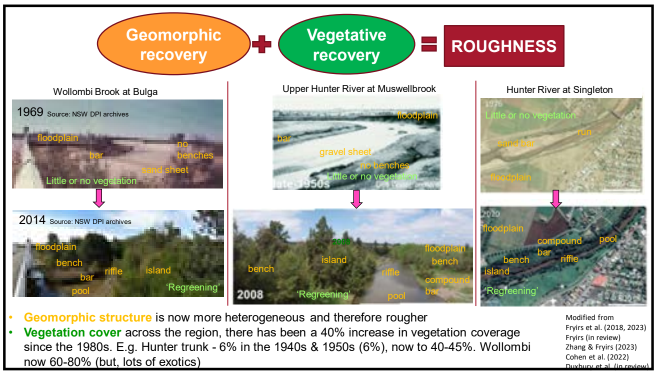
6


European colonisation and disturbance: Some early warnings and common geomorphic changes
The Catch-22 dilemma……
Large, smooth, straight, flume-like channels concentrate flow, have high flow energy, are highly erosive, and flow very fast. This makes the channel even bigger and more erosive during bigger and bigger floods and on it goes……
This cycle needs to be broken.
Channel incision and headcut retreat
Channel straightening and enlarging
Instream sediment slugs
Homogenisation of channels
Floodplain sediment slugs
Bank erosion and channel expansion

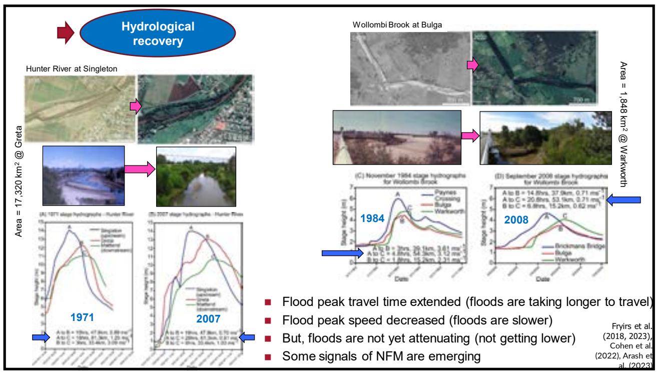
7


The good news is…river recovery can break the cycle.
In NSW river recovery has been happening since the 1980s.
Geomorphic recovery = a noticeable improvement in the physical structure and function of rivers (channels and floodplains)
Vegetative recovery = a noticeable improvement in the quantity and quality of instream & riparian vegetation
ROUGHNESS
Hydrological recovery = a slowing and lowering of moderate and major floods (called Natural Flood Management (NFM))
Hunter River at Singleton
1866
1963
1967
Post Nov 2021 flood

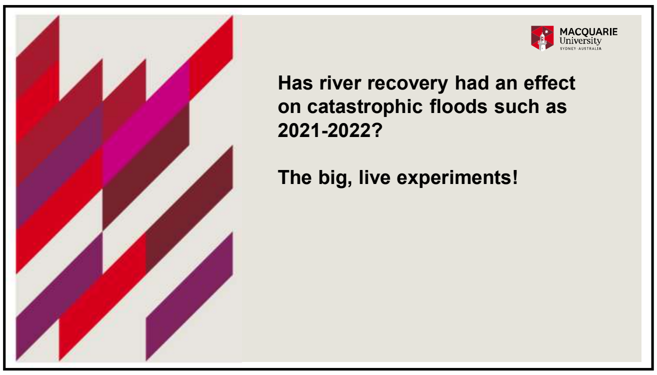
8


Geomorphic recovery
Vegetative recovery
ROUGHNESS
Wollombi Brook at Bulga
Upper Hunter River at Muswellbrook
Hunter River at Singleton
1969
2014
2008
Geomorphic structure is now more heterogeneous and therefore rougher
Vegetation cover across the region, there has been a 40% increase in vegetation coverage since the 1980s. E.g. Hunter trunk - 6% in the 1940s & 1950s (6%), now to 40-45%. Wollombi now 60-80% (but, lots of exotics)

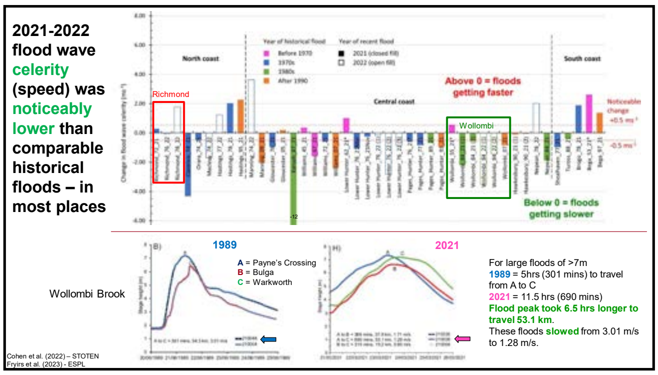
9


Hydrological recovery
Hunter River at Singleton
Wollombi Brook at Bulga
1971
2007
1984
2008
Flood peak travel time extended (floods are taking longer to travel)
Flood peak speed decreased (floods are slower)
But, floods are not yet attenuating (not getting lower)
Some signals of NFM are emerging

10

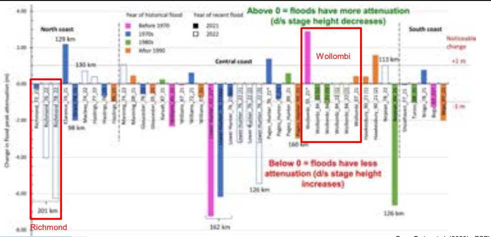

MACQUARIE University
Has river recovery had an effect on catastrophic floods such as 2021-2022?
The big, live experiments!

11


2021-2022 flood wave celerity (speed) was noticeably lower than comparable historical floods – in most places
Above 0 = floods getting faster
Below 0 = floods getting slower
Wollombi Brook
1989
2021
For large floods of >7m
1989 = 5hrs (301 mins) to travel from A to C
2021 = 11.5 hrs (690 mins)
Flood peak took 6.5 hrs longer to travel 53.1 km.
These floods slowed from 3.01 m/s to 1.28 m/s.

12

2021-2022 flood wave attenuation was noticeably worse than comparable historical floods – in most places



From Fryirs et al. (2023) - ESPL

Wollombi at Bulga-Warkworth

~11.7 m stage height.
July 2022 – valley wide flood.

Largest flood on record at this gauge.

Take home messages:
- Floods are generally getting slower but not lower.
- There is still work to be done to achieve NFM, but there are great foundations from which to work.

13

Generic lessons and opportunities to take away…..

What needs to be done now? Using river recovery as a nature-based management and flood mitigation tool.

14

1. Let the river do the work…..just help it along.

2022 NSW GOVERNMENT INDEPENDENT INQUIRY INTO THE FLOODS

Recommendation 20 – Floodplains as an asset (pg 30)
- consider "**floodplains as an asset**" including "**letting watercourses largely flow naturally rather than implementing engineering barriers such as flood levees and mitigation schemes to stop floods**"
- reconsider land use planning and all development on floodplains.

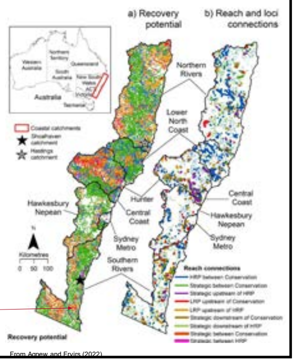
Recommendation 27 – Environment (pg 36)
- specifies the need to "**develop an Indigenous led cultural landscape restoration strategy**….**for nature-based flood mitigation and adaptation which would see large-scale native revegetation and wetland restoration**", starting in the Northern Rivers region.

15

2. Value-add on any geomorphic, vegetative and hydrological recovery that is already happening.
3. Work locally, but dramatically up-scale.

- **Build landscape-scale corridors of river recovery** to build resilience and enhance mitigation – work in reach connections that are already recovering first. (see Agnew and Fryirs, 2022)
- **Dramatically improve the co-ordination of participatory actions** at the local scale, and **upscale** them to corridor and catchment-scales (Fryirs et al. 2021).
- In Eastern NSW, of >87,000 km stream length, 4,500 km could be immediately prioritised for rehabilitation to build corridors of river recovery.

Candelo Creek Landcare Association. Source: K. Fryirs



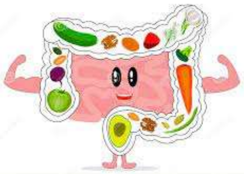
From Agnew and Fryirs (2022)

16

4. Continue to enhance recovery using nature-based solutions.

- Use all the roughness tools you have in your toolbox.
- Increase bank and bench strength using **ground cover** – fantastic stabiliser.
- Enhance in-stream and riparian (floodplain and channel bank) **roughness.** Slows floods down and reduces their erosiveness.
- **Lock up sediment** at source.
- Improve the condition of **floodplains** and floodplain **wetlands** and allow them to act as natural **flood detention basins.**
- Undertake **weed management** and replacement of vegetation to improve biodiversity value.
- Utilise the naturally occurring **seedbank.**
- **Flood mitigation and river recovery** is a catchment-scale, cumulative exercise and every reach counts towards a **corridor.**

"Get the roughness back in to the river"
(its like fibre in the gut!)



17

Concluding remarks

- We need to work with the river, not against it. Rivers naturally need space to move, erode and flood.
- Where recovery is happening, we need to work further to enhance it and build resilience. We may then have a chance of mitigating future natural disasters.
- We need to up-scale in a coordinated and strategic manner and use all the nature-based tools we have in the toolkit.
- We need to stay the course, but work more urgently……..as an industry, as scientists, and as communities in collaboration with all levels of government and Indigenous peoples.

Hunter River community forum 2023. Source: K. Fryirs

18


Thank you!
Wollombi @ Broke (K. Fryirs)
Feb 2021
Wollombi @ Broke (K. Fryirs)
Aug 2022

19