Riparian setbacks: Summary of the science

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Introduction

Riparian setbacks have been promoted as a standard best practice tool for water quality and freshwater habitat restoration. The purpose of this paper is to review and summarise the published research on the range of functions provided by riparian setbacks and their effectiveness as a tool to support Northland Regional Council's (NRC) freshwater plan change. This includes the potential contribution riparian setbacks can make towards achieving:

1. Freshwater objectives and target attribute states (and timeframes) set in the freshwater plan change,
2. Te Mana o te Wai (TMotW) hierarchy of obligations set out in Clause 1.3(5) of the National Policy Statement for Freshwater management 2020 (NPS-FM), that prioritises:

(a) first, the health and well-being of water bodies and freshwater ecosystems

(b) second, the health needs of people (such as drinking water)

(c) third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

This paper summarises key literature reviews in New Zealand (Collier et al.,1995; Parkyn et al., 2003; Parkyn, 2004; Quinn, 2005; McKergow et al., 2016; Basher et al., 2016; McDowell et al., 2017; Baillie 2020; Fenemor and Samarasinghe 2020, and references therein) and the review undertaken by Ballinger (2019).

Aspects within this paper's scope

- All freshwater bodies, but noting that most of the literature focuses on stream and rivers.
- All land uses, but noting that most of the literature focuses firstly on agriculture, and secondly, on plantation forests.

Aspects outside this paper's scope

- Details on riparian planting designs. Rather, the focus is on regulatory minimum riparian setback distances to inform the freshwater plan change. Specific designs are better addressed at the local catchment and farm level taking into account the waterbody type, site-specific conditions and pressures and riparian functional objectives (e.g., https://www.nrc.govt.nz/media/cyjbyxfg/nrccleanstreamsguide2018.pdf). Hence riparian designs have been referred to in a high-level context only.
- Riparian setbacks from the coastal marine area given the focus of the plan change is freshwater.

What are riparian zones?

The riparian zone (Figure 1) is the land that extends along a stream, lake or wetland. It is the interface between terrestrial and aquatic ecosystems.

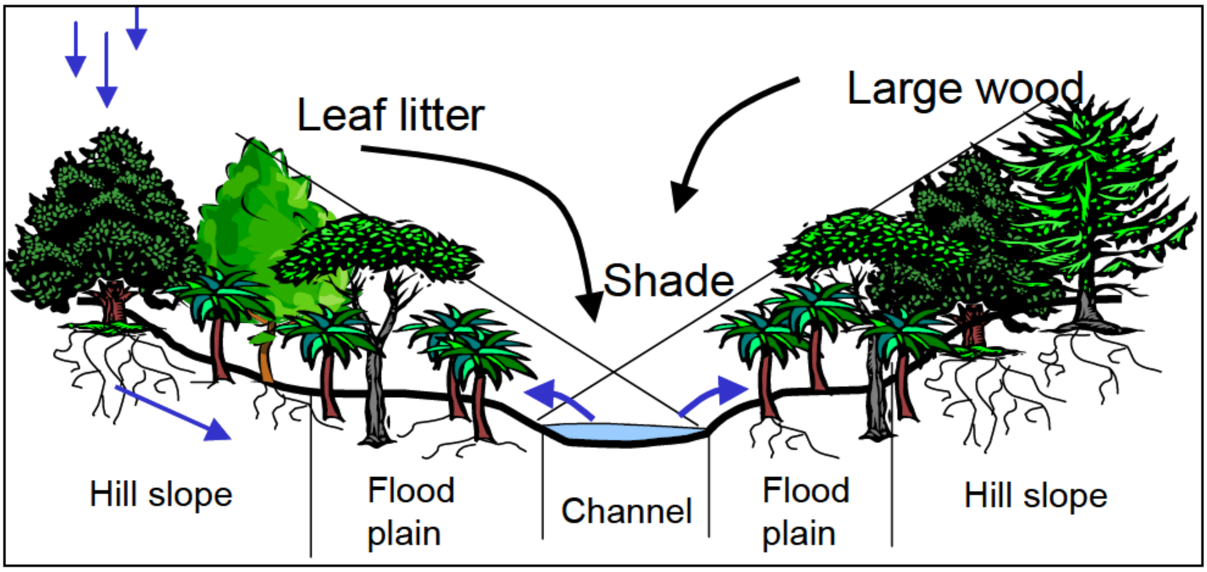

Figure 1: The riparian zone is the land beside the stream that interacts with (1) runoff from hillslopes and (2) stream water when this overflows into the floodplain. The vegetated riparian zone can affect the stream by intercepting runoff, and thereby improving water quality, by providing shade, leaf matter and wood, and stabilising stream banks (Parkyn, 2004).

Riparian composition

Riparian composition can take various forms, depending on the outcomes or objectives that you want to achieve, as summarised by Parkyn (2004) below:

- **Multi-tier system**: a combination of buffers where native forest trees may be used beside the stream to enhance ecological function and biodiversity; a buffer of production trees may occur outside of that; and the outer edge beside agricultural land would be a grass filter strip (example in Figure 2).
- **Forested or planted native trees**: a buffer of native trees to return ecological function to the stream and provide water-quality benefits.
- **Grass Filter Strips**: Fenced strip of rank paddock grasses to filter nutrients and sediment.
- **Headwater or riparian wetlands**: Fenced wetlands as hotspots for nutrient removal.
- **Rotational grazing**: Filter strips with varied stock grazing practices, such as occasional light grazing by sheep.
- **Production trees or plants**: a buffer of forestry trees left unharvested along stream banks, or production trees that are planted in riparian zones for selective harvesting with minimal disturbance (e.g., Tasmanian blackwoods). Plants such as flax for weaving, or fruit and nut trees, or high value native tree species that can be selectively harvested, may also provide ecological function and a mechanism to remove nutrients such as phosphorus from the riparian zone.

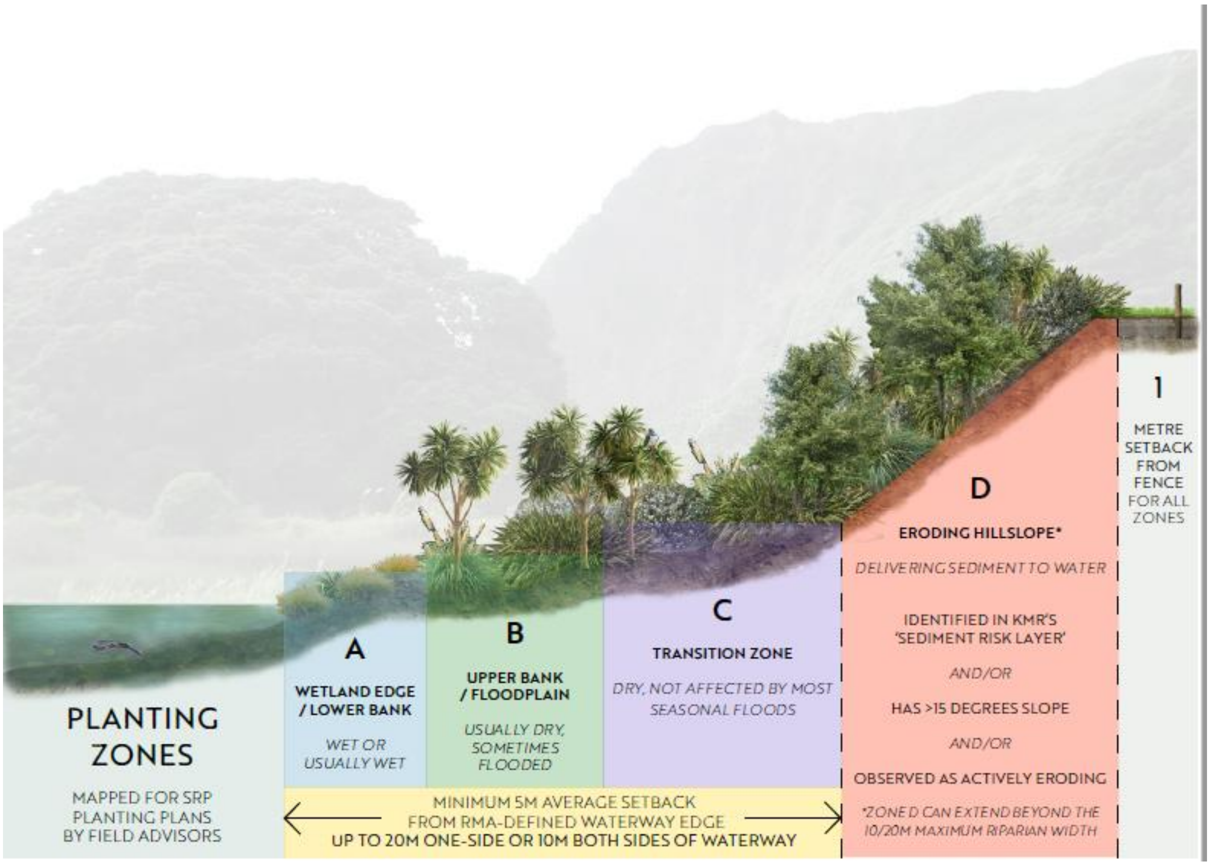

Figure 2: A simplified zonation of riparian planting areas to assist site-specific selection (Kaipara Moana Remediation Planting Guide, https://kmr.org.nz/wp-content/uploads/2023/02/KMR-Planting-Guide-Feb-2023.pdf

Key riparian functions and setback effectiveness

In the context of the freshwater plan change, the primary function of riparian zones is their contribution to maintaining, improving or restoring the health and well-being of water bodies and freshwater ecosystems (TMotW hierarchy priority 1). They are also one of the key tools for managing 'diffuse' source contaminants or runoff from land – the management of diffuse-source contaminants is one of the biggest challenges for water quality in Northland. When it comes to their filtering capacity, riparian zones can be viewed as the last line of defence for attenuating contaminants such as nitrogen, phosphorus, sediment and *E. coli*/faeces before they enter a waterbody and should not be relied on as the primary tool for managing contaminants. Instead, the management of some contaminants is better addressed at their source e.g., planting of highly erodible land to reduce sediment.

Some generalisations on riparian function effectiveness follow below:

- Riparian setbacks are just one option in a range of mitigations available to achieve freshwater outcomes such as improved water quality.

- The wider the riparian setback along/around the waterbody, the more functions it will be able to provide (Figures 3 and 4).
- Wider riparian setbacks are more effective as slope gradient and length increase, clay content in the surrounding catchment increases, and soil drainage decreases.
- The length of the riparian zone is just as important as the width.
- The influence of riparian zones on waterbodies tends to decrease as the waterbody increases in size or width.
- Hence benefits at the catchment scale are maximised by starting in the headwaters first, and working downstream, targeting the protection, enhancement and establishment of riparian setbacks, providing cumulative benefits to larger/wider downstream waterbodies.
- It can take years or even decades for riparian zones to provide effective benefits.

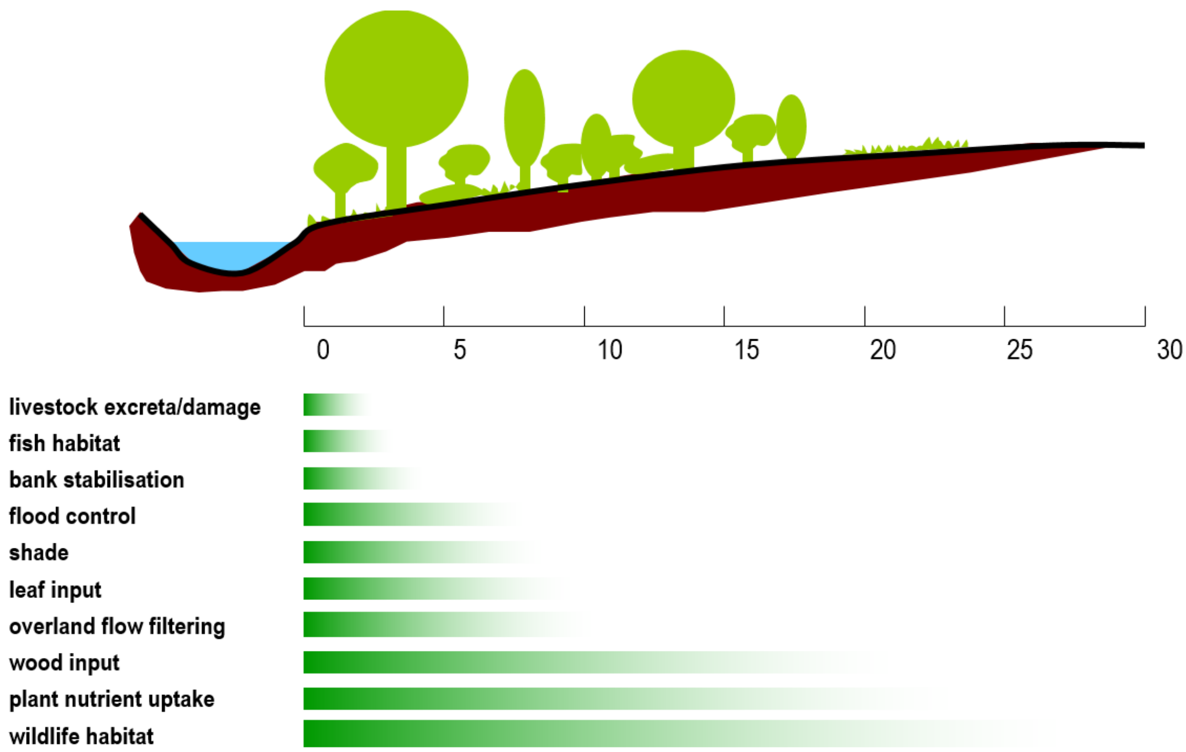

Figure 3: In a presentation to NRC in 2012, John Quinn from NIWA included this slide based on work by Dosskey et al. (1997), showing the riparian widths required to be effective at providing a range of functions.

Freshwater ecosystem health and function

Prior to the arrival of humans, most of New Zealand was covered in forest, so many of our freshwater ecosystems are adapted to environments associated with cool, shady, forested conditions. Therefore, re-establishing riparian setbacks in native vegetation is a key mitigation for improving freshwater ecosystem health and function.

Establishment of native riparian vegetation supports the re-establishment of forested stream food webs, based on organic inputs from terrestrial invertebrates, leaf litter and woody debris, and essential sources of carbon (energy), particularly in smaller headwater streams. This in turn contributes to habitat diversity and a transformation of invertebrate and fish communities from those associated with pasture to those associated with forests, thus improving freshwater biodiversity. Fish and invertebrate populations are influenced directly by the presence of riparian vegetation at many life-cycle stages – as a food source, habitat, oviposition sites and refugia from predators and floods (e.g., Parkyn and Collier 2004; Jowett et al., 2009; Hickford and Schiel 2011; Greenwood et al., 2012).

A primary function of riparian vegetation is the re-establishment of shade, which reduces the amount of light reaching the stream. Shade has the effect of limiting the extremes of daily variation in water temperature (especially maximum temperatures), and where riparian zones are wide enough (>10m), also air temperatures, both of which are necessary to support freshwater invertebrates both in juvenile and adult forms (Quinn et al., 1994). Cooler water temperatures can improve levels of dissolved oxygen, pH, and assist in reducing nuisance algal and plant growth, thus benefiting invertebrate and fish communities (Quinn et al., 1994). However, the influence of shade declines as the stream width or waterbody size increases.

Improvements in freshwater ecosystem health and function can be maximised by focusing riparian restoration efforts in headwater areas, as they contain the highest density of streams and respond more rapidly to riparian restoration efforts than the larger streams and rivers. Some 77% of streams (by length) in Northland are in headwater areas. The aim is to achieve canopy closure over the stream and to re-establish connectivity between isolated patches of riparian vegetation to increase their length, providing source areas for re-colonising degraded areas downstream as well as improved migratory corridors for native fish. Parkyn suggested time frames of years to decades, and a minimum of 10m riparian setbacks, to support ecosystem function.

Mediating the impacts of clearcut harvesting to the stream edge

Riparian setback distances to protect freshwater ecosystem health and function primarily focus on agricultural land. Streams and rivers in mature plantation forests tend to have similar water quality and freshwater biodiversity characteristics to native forests, but clear-fell harvesting, particularly up to the stream edge, can cause freshwater bodies' ecosystems to become like those of agricultural land. Retention of riparian setbacks along stream edges can mediate the impacts of harvesting. Setback distances ranging from 5m to 30m assist in maintaining stream shade, water temperature and channel bank stability, reducing excessive algal growth and inputs of logging slash and sediment, and minimising impacts on fish and invertebrate communities (Baillie 2020).

Channel bank stability

Stock exclusion and riparian planting are two key mitigations for improving channel bank stability. Root systems of riparian vegetation can assist in stabilising stream banks up to depths of 0.5 to 1.5m and will be most effective in stabilising banks in smaller streams (up to 10m wide) and banks less than 2m in height. A 5m setback is considered a minimum, but 10m is preferable depending on the species.

Hughes (2016) and Basher et al. (2016) both point out that lowland riparian management should aim to prevent scour (e.g., wider setback for streams to broaden naturally to reduce bank profile or slope, accompanied by deeper-rooted native or exotic trees for greater mechanical strength of banks) (Stephens, 2019 pers. comm., 18 February).

Recommended setbacks in Fenemor & Samarasinghe (2020) ranged from 2-5m (for pre-existing, well established native vegetation), to 15m.

Contaminant filtering

Contaminants such as nitrogen, phosphorus, sediment and *E. coli* are best managed by intercepting them at critical source areas within the catchment. Improved land management practices to reduce contaminant loads entering riparian zones will assist in extending their longevity and effectiveness. Riparian zones are the last line of defence, and their ability to attenuate incoming contaminants will depend on the:

- quantity, composition and timing of in-coming contaminants loads;
- riparian width;
- vegetation composition and structure e.g., grass strips are more effective at filtering sediment and particulate forms of nitrogen and phosphorus, whereas forested buffers are more effective at removing soluble forms of nitrogen;
- ability of the vegetation to retard surface flows and to filter contaminants;
- soil structure and infiltration rates;
- denitrification properties;
- catchment slope length and steepness.

Hence, riparian widths to effectively manage contaminants vary widely.

Within the riparian zone, contaminants can be managed by:

(a) eliminating direct inputs into the riparian area by restricting the direct use of land beside the waterbody e.g., stock exclusion to remove faecal inputs; or

(b) filtering contaminants and sediments from overland and subsurface flow, by increasing the infiltration into soil, intercepting particulates, and removing soluble nutrients by plant uptake and denitrification. The mechanisms of contaminant removal in riparian zones differ according to the characteristics of the hydrology, soils, and vegetation, as well as the mode of transport to streams.

Catchment modelling by McDowell et al. (2017) showed that contaminate loads from low-order small streams (<1m wide, 30cm deep) accounted for an average of 77% of the national load. Many of these streams are currently exempt from the Stock Exclusion Regulations and fencing regulations under NRC's Proposed Regional Plan (e.g., typically beef cattle do not have to be excluded from hill country[1] streams / rivers). This means that if stock exclusion is not required in these areas some other form of mitigation would need to be applied to substantially reduce contaminant loads, e.g., targeted afforestation and wetland restoration. While targeting headwaters may be logistically challenging, it will have significant water quality and habitat benefits (McKergow et al., 2016). The Waikato River Authority (2010) report eloquently states:

> *"fix the veins that feed the awa [river, stream] and you will fix the awa itself".*

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[1] Hill country is land with an average slope of 15 degrees or more and these areas are mapped in the Regional Plan: https://www.nrc.govt.nz/your-council/about-us/council-projects/new-regional-plan/regional-plan-maps/

Across the literature, optimal riparian widths to remove a high proportion of incoming contaminants varied from 5 to 10 m at the lower end and up to 30 m or more at the higher end, with associated increases in contaminant removal efficiencies.

Attenuating flood flows

The vegetation within riparian zones increases land surface roughness, slowing down and retaining floodwaters as well as associated sediment and debris. Water held in storage can be gradually released or can provide recharge to ground water, particularly in flatter areas in the catchment. These zones can contribute to reducing peak flows in small-to-moderate flood events but are less effective in reducing the power of large flood events. However, riparian zones can be part of a larger strategy to move away from engineered flood management to more natural flood management schemes. We were unable to locate any information on the effectiveness of different riparian widths in mediating flood flow — rather it was the type of vegetation present that appeared to be more important.

Recreational, cultural, aesthetic and landscape values

There will be areas in a catchment or wider landscape where the re-establishment of forested riparian areas will support many of the freshwater values in the NPS-FM, e.g. human contact (e.g., swimming), mahinga kai, drinking water supply, natural form and character, and wai tapu sites. They will also improve the general aesthetics of the wider landscape. However, we were unable to find any information on the effectiveness of different riparian widths on these values.

However, attaining these benefits is reliant on good riparian buffer design, implementation, and maintenance. Riparian planting is an expensive exercise and usually implemented over a number of years. Plantings are at risk of failing if they are not properly maintained in the first few years of establishment and unmanaged riparian zones can provide pathways for the spread of weeds and pests.

Managing land use activity

Riparian zones / setbacks from waterways are also commonly used to control the scale of land disturbance activity (such as earthworks and vegetation clearance) near waterbodies. Limiting the scale of disturbance in riparian areas reduces the risk of sediment from earthworks entering waterbodies or impacts of reduced shade, temperature regulation and habitat loss from vegetation clearance. The Proposed Regional Plan for Northland currently applies a 10metre setback for the purposes of managing vegetation clearance and earthworks in the riparian margins of freshwater bodies. Setbacks are also commonly applied to discharges of contaminants to land (such as wastewater) to limit the risk of the contaminants entering waterbodies – these tend to vary in width depending on the nature of the discharge and the sensitivity of the waterbody.

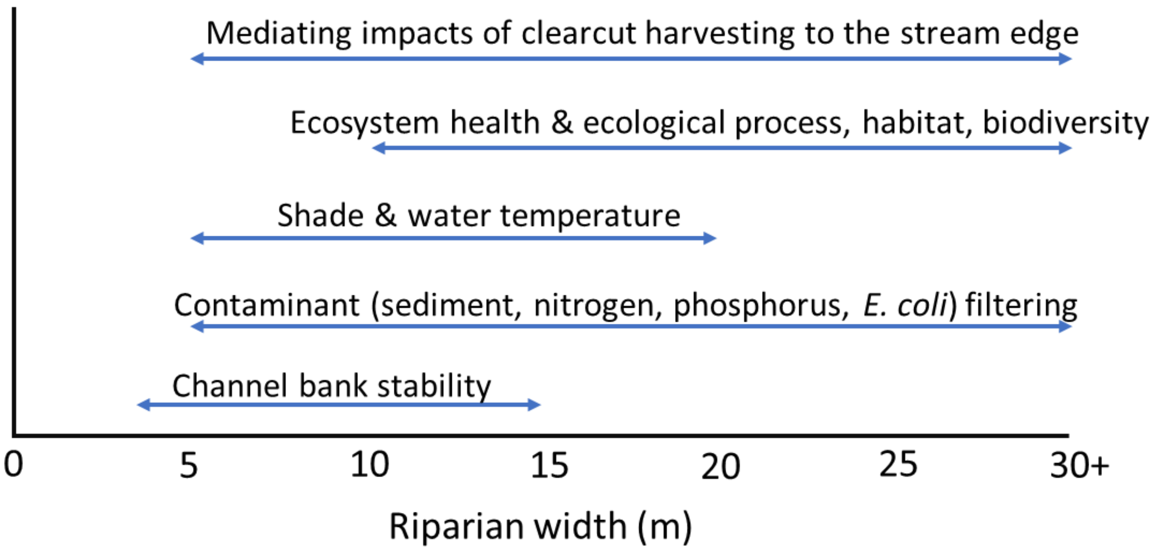

Figure 4: Effectiveness of riparian widths in providing a range of functions. Primarily based on information in Fenemor and Samarasinghe (2020)[2], and references therein; and Baillie (2020).

Considerations for proposed minimum setback widths for Northland

There is no "magic width" that will be able to address the multitude of impacts from land use on riparian zones (Parkyn et al., 2000), as riparian designs (including width) are very site-specific, and the riparian zone may not alleviate the problems in all cases. Many authors stress the importance of identifying runoff source areas, soil characteristics, topography, vegetation, and regional weather before implementing riparian management (Barling and Moore 1994, Collier et al., 1995). However, there is merit in establishing a minimum riparian setback width to support freshwater ecosystem health and function as required under the NPS-FM TMotW hierarchy of obligations and a standard minimum width is more easily implemented by land users and then monitored. The following points need to be considered when identifying minimum riparian widths for Northland in the freshwater plan change process:

- The recommended minimum width of riparian zones depends on the outcomes sought. For the purpose of the freshwater plan change, the focus is on:
    - Improving freshwater ecosystem health and ecological processes (shade, temperature, health etc.).
    - Decreasing sediment (bankside erosion and overland runoff).

[2] The effectiveness of different setback distances in achieving various riparian functions varies widely in the literature. We have drawn mainly from Fenemor and Samrasinghe (2020) when developing this diagram, as their review focused mainly on New Zealand literature.

    - Decreasing faecal bacteria (overland runoff).
    - While smaller riparian widths can be effective at filtering sediment and bacteria, wider zones are required to remove soluble nutrient (N and P) and protect ecological functioning.
- Riparian widths should provide for the most ‘sensitive’ value/outcome and reflect the TMoTW hierarchy – namely they should set to protect the health and well-being of the waterbody and its ecosystems, not just their capacity to filter contaminants.
- Any setback rules should apply as a minimum recognising that riparian setback widths would ideally provide for the variability of Northland’s terrain, drainage, land uses, and sensitivity of freshwater bodies.
- Research has identified that approximately 77% of the contaminant load in lowland rivers originates from upstream sources. Therefore, we need to target action in headwater/hill country areas.
- Riparian setbacks are one of the key tools for managing ‘diffuse’ source contaminants or runoff from land – the management of diffuse-source contaminants is one of the biggest challenges for water quality in Northland.

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