Waikato Regional Council Technical Report 2024/04

Riparian characteristics of pastoral waterways in the Waikato Region, 2002-2022

www.waikatoregion.govt.nz
ISSN 2230-4363 (Online)

Prepared by: T. Norris, H. Jones (Waikato Regional Council), and M. Kimberley (Environmental Statistics Ltd)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

Publication: March 2025

Document #:28642621

Peer reviewed by:		
Brandan Goeller (NIWA)	Date	Dec 2024

Approved for release by:		
Mike Scarsbrook	Date	March 2025

Acknowledgements

We wish to acknowledge the outstanding contribution of the wider project team to the 2022 riparian characteristics survey. Many thanks to: Dan Borman for assistance with setting up the GIS layers for site selection; Richard Glass for designing the Survey123 forms and assisting with data management throughout the course of the survey; all those involved in the field data collection (Liam Houghton, Kerry Jones, Isabel Mans, and Cassidy Chaytor); and Claire Kotze for assisting with coordination of the project. Many thanks to Andrew Hoffmann for creating the maps required for field work and landowners' letters, and to Cecilia Raynel for preparing letters that were sent out to landowners. Finally, we would like to thank all the landowners who granted us access to sites via their property. This survey could not have been successfully completed without the assistance and cooperation of all those involved.

Table of Contents

Figures

Tables

Executive summary

The Regional Riparian Characteristics Survey aims to assess the state and trend of key riparian attributes (including fencing, vegetation, buffer width, waterway crossings, and stream-bank erosion) at various sites within pastoral land across the Waikato region. The first survey was undertaken in 2002 and was subsequently repeated at approximately 5-year intervals in 2007, 2012, 2017, and 2022. This report presents the findings from the most recent survey, conducted during the summer and autumn of 2022/23, hereafter referred to as the '2022 survey'. In addition to presenting the current state of riparian margins across the region, this report also examines changes in key variables such as fencing and vegetation over the past 5, 10, 15, and 20-year monitoring periods. In 2022, data was collected from 430 waterway sites, comprising 223 sites within dairy farms and 207 sites within drystock farms. Survey results were evaluated in the context of stock exclusion regulations, as outlined in the Action for Healthy Waterways package (2020 'Decisions on the National Direction for Freshwater' document[1]) and the Waikato Regional Council's Proposed Plan Change 1 decisions version document (Schedule C[2]). A comprehensive review of the current survey design was conducted, and recommendations made to improve the monitoring framework for future cycles of the survey.

Across surveyed sites in the Waikato region, the proportion of bank length fenced has increased considerably over the past two decades from 29% in 2002 to 58% in 2022, with an average annual increase of about 1.5% of bank length per year. Overall, in 2022, the total proportion of bank length in pastoral land effectively fenced was 58%, with 42% remaining unprotected from stock access. With the conclusion of the Sustainable Dairying Water Accord in 2018 and the completion of most fencing along waterways on dairy farms, there is now a need to shift focus towards encouraging, supporting, and facilitating the fencing of unprotected stretches of waterways on drystock farms across the region. The strong correlation between the amount of effective fencing and observed stock access confirms that the proportion of bank length effectively fenced is a good indicator of stock exclusion.

Consistent with previous surveys, non-woody vegetation dominated riparian margins in pastoral land across the region in 2022, occupying approximately 73% of bank length and was dominated by grass and weed species (64% of surveyed bank length). A combination of woody and non-woody species within riparian margins is important because riparian buffers with mixed vegetation (including woody species) provide a wide range of benefits. These benefits include filtering sediment and nutrients from surface runoff, removing dissolved nutrients from shallow groundwater, enhancing biodiversity, providing leaf litter and woody debris essential for aquatic food webs and habitats, stabilising stream banks, and shading streams to regulate water temperature and control the growth of in-stream plants. While the total coverage of woody species across riparian margins was relatively low (27% of surveyed bank length) in 2022, the coverage of woody native species increased by 6% over the past 20 years (2002 to 2022), most likely in response to riparian restoration efforts. Results indicate that continued effort is required to encourage the restoration of woody riparian vegetation in the region. Approximately 60% of the riparian margins across the region were considered narrow (< 5 m) in 2022. In general, wider buffer zones are associated with greater benefits for stream health, providing more habitat for indigenous vegetation establishment and providing greater filtering capacity for nutrient attenuation.

[1] Ministry for the Environment 2020a. Action for healthy waterways – Decisions on the national direction for freshwater: An at-a glance summary. Wellington: Ministry for the Environment.

[2] Waikato Regional Council 2020. Proposed Waikato Regional Plan Change 1: Waikato and Waipā River Catchments. Decisions version (volume 2 of 2). Waikato Regional Council Policy Series 2020/02. Hamilton, Waikato Regional Council

In line with previous surveys, most waterway crossings (83%) across the Waikato region were categorised as culverts in 2022, with the remaining crossing being categorised as either bridges (14%) or fords (3%). There were no differences in the total number of crossings per km of stream length between dairy and drystock. However, there were more fords observed across drystock farms (9%) compared to dairy (< 1%). Drystock farms more often occur in remote hill-country areas, where fords are more likely to be used to cross waterways in difficult to access areas. The low number of streambed crossings across dairy farms confirms the findings from the final Sustainable Dairying Water Accord progress report (DairyNZ). The report highlighted that 99.8% of regular stock crossing points on dairy farms were either bridged or culverted to exclude dairy cows.

The proportion of banks affected by streambank erosion across the region was approximately 9% in 2022. This was nearly double that observed in 2002 (5.3%), similar to that observed in 2012 (10.5%), but less than that observed in 2007 (21.4%) and 2017 (17.3%). Overall, the total erosion measured in 2022 was low compared to the previous 2017 survey. This reduction could be attributed to unusually high river flows during the 2022/23 field season, which may have masked bank erosion. Large differences in erosion measures between surveys have occurred previously (e.g. 2002–2007 and 2012–2017) and it is noted that the assessment of stream-bank erosion is somewhat subjective, making comparisons over time less reliable than, for example, changes in fencing or stock access. Furthermore, the magnitude and frequency of storm events prior to the survey along with flow levels at the time of the survey is likely to influence the amount of stream bank erosion observed from year to year. The extent of bank erosion recorded in a particular year can be affected by several factors, including the vegetation cover present during the survey, the frequency and severity of storm events prior to the survey, and high river levels at the time of the survey that might obscure evidence of erosion. Riparian disturbance is the sum of total streambank erosion and pugging disturbance caused by livestock treading. About 10% of the surveyed bank length in 2022 was disturbed, with 1% of this being due to pugging disturbance caused by livestock treading. The decrease in the incidence of pugging (> 50% of the riparian margin) over the past 10 years indicates that riparian fencing efforts are resulting in measurable reductions in soil disturbance.

Over the past two decades (2002 to 2022), the mean proportion of bank length effectively fenced has significantly increased by 49% from 44% to 88% for dairy and by 17% from 17% to 36% for drystock farms. The emphasis placed on improving stock exclusion on dairy farms by the Dairying and Clean Streams Accord appears to have had a positive impact on the amount of riparian fencing observed at dairy sites in the Waikato region, particularly between 2012 and 2017. However, the 2022 estimate of Accord site waterways with complete stock exclusion is considerably lower (52%) than the 98% reported in the final Sustainable Dairying Water Accord summary report (DairyNZ, 2018). This discrepancy highlights the need for continued efforts in the dairy sector to achieve full stock exclusion from waterways. Results also suggest that there is a continued need to focus riparian fencing efforts toward drystock land uses.

Of the eight management zones in the Waikato region, sites surveyed in the Upper Waikato and Waihou-Piako management zones had the highest proportion of bank length effectively fenced (81% and 85%, respectively), substantially higher than those in the Lower Waikato, Waipā, and West Coast management zones (54%, 66%, and 20%, respectively). The Upper Waikato and Waihou-Piako zones also had the lowest amount of total stock access (19% and 15%, respectively). Apart from the Lake Taupō zone, the Upper Waikato and Waihou-Piako had the lowest amount of streambank erosion (4% and 6%, respectively). The Lake Taupō zone stood out as having the highest proportion of ‘wide’ (> 5 m) riparian buffers and lowest incidence of stream bank erosion (1% of surveyed bank length). Significant efforts have been made by WRC and its predecessors to encourage fencing of waterways in the Waihou-Piako, Upper Waikato, and Lake Taupō management zones through historic soil conservation initiatives and adherence to Method 4.3.5.3 of the Waikato Regional Plan. Method 4.3.5.3 mandates the exclusion of livestock from mapped portions of high-priority water bodies, including specific sections of the Waihou River and all tributaries flowing into Lake Taupō. The high proportion of bank length effectively fenced in the Waihou-Piako zone in 2022 (85%) is consistent with efforts undertaken through the Dairying and Clean Streams Accord process in this predominantly dairy catchment. Consistent with previous surveys, the West Coast management zone exhibited the lowest proportion of bank length with effective fencing (20%) and no stock access (19%). The West Coast clearly stands out as the management zone that could benefit most from future riparian fencing efforts.

The average proportion of bank length effectively fenced was largest for drains (89%), reflecting the relative ease with which these features can be fenced (often straight, linear features located on flat land) and their location on predominantly dairy enterprises. Small to medium streams (classified as stream orders 1 to 3) exhibited the lowest percentage of effectively fenced bank lengths, with values ranging from 47% to 63%. In comparison, larger waterways (stream orders 4 to 6) had a higher proportion of effective fencing, ranging from 72% to 82%. Given that lower order streams often contribute the most to contaminant loads in agricultural catchments, it may be necessary to explore alternative strategies for reducing these loads, especially in situations where excluding livestock from waterways is either impractical or not required under regulatory frameworks.

Stream bank erosion was most prevalent at medium to large waterways, ranging from 22 – 31%, and relatively low for small to medium waterways (< 15%), despite high levels of stock access. This finding is consistent with the 2012 riparian survey results and seems to suggest that undercutting of stream banks is largely unaffected by the grazing of riparian margins. For riparian vegetation, drains stood out as having the lowest coverage of woody vegetation (8% of surveyed bank length) and the lowest proportion of buffer widths > 5 m (5% of surveyed bank length). Consistent with previous surveys, findings from the 2022 survey suggest that future riparian restoration efforts should be targeted towards small and medium sized waterways where stock access remains high, and coverage of woody vegetation is generally low.

An evaluation of the 2022 survey results in the context of national stock exclusion regulations found that 93% of surveyed bank length in low slope (< 5˚) dairy land was effectively fenced, whereas drystock enterprises had only 65% to 67% of bank length effectively fenced. On non-low slope (> 5˚) land, about 90% of waterways on dairy farms were effectively fenced, compared to 60% for high intensity drystock systems. Given that the national stock exclusion regulations came into effect in July 2023 for dairy cattle, the analysis demonstrates that a small proportion of bank length across the region (7% on low slope and 10% on non-low slope land) does not comply with current regulations. Over the past 5 years (2017 to 2022), the annual increase in the proportion of bank length with effective fencing across the region has slowed to 0.2% per annum. The apparent slowdown in the average annual increase in effective fencing suggests that further effort is required to achieve complete stock exclusion along the remaining unfenced waterways on dairy farms. For intensive drystock operations, 33-35% of streambanks on low slope land and 40% on non-low slope land did not comply with stock exclusion regulations. This highlights the need for substantial work across the region to meet the July 2025 deadline. According to the 'setback' provisions within the Stock Exclusion Regulations 2020, a 3-metre buffer is mandated only for new fencing. Although 15-20% of fencing on low slope dairy land had a setback greater than 3 meters in 2022, this is largely irrelevant since only new fencing must adhere to the 3 m setback requirement. Drystock enterprises exhibited a significantly higher proportion (54%) of existing fencing on low-slope land with a setback of 3 metres or more. However, all new fencing (required along 33-35% of streambanks on low-slope land and 40% on non-low slope land) will require a minimum setback of 3 m.

Analysis was undertaken to evaluate the 2022 stock exclusion survey results against the Proposed PC1 requirements as outlined in Schedule C of the 2020 decisions version document (Waikato Regional Council, 2020). Overall, 80% of the bank length along rivers and streams (Strahler order 1 – 6) on low slope land (< 15˚) was effectively fenced across qualifying management zones (Upper Waikato, Central Waikato, Lower Waikato, and Waipā). For narrow drains (< 2 m), 90% of the bank length was effectively fenced compared to 70% for wide drains

(> 2 m). On non-low slope land (> 15˚), 88% of the surveyed bank length was effectively fenced, however, there were only a small number of rivers and streams across intensively managed land uses (n=15). Of the streams and rivers on low slope land with existing fencing, approximately 50% had a setback distance of at least 3 m. For narrow drains (< 2 m wide) on low slope land, 65% of existing fencing had a setback distance of at least 1 m; while for wide drains (> 2 m wide), 88% of fencing was associated with a buffer width of at least 3 m. Streams and rivers on high-intensity, non-low slope land had 63% of existing fencing with a setback distance of at least 3 metres. Overall, the results indicate that fencing of narrow drains (< 2 m) in PC1 zones is largely complete, with approximately 9% of bank length remaining unfenced or ineffectively fenced. Compared to drains, a greater percentage of bank length remains unfenced across qualifying streams and rivers (20%), particularity in the Central Waikato (41%) and Lower Waikato (30%) management zones.

The WRC regional riparian survey provides robust estimates of riparian characteristics across the region on a 5-year cycle. Estimates of key variables (e.g. percentage of effectively fenced bank length and the percentage of vegetation types) are provided with good precision and are reported from subsamples surveyed throughout the entire region as well as for specific domains of interest, including land use types, management zones, and stream orders. We recommend maintaining the current design with minimal changes in future survey cycles to ensure consistency in the survey approach. Minor adjustments in the number of sample units assessed per stratum could be adopted to reduce the sampling effort in over-represented strata and increase sample numbers in under-represented strata, without compromising the precision of state and trend estimates. While resource intensive, the current field-based approach remains the best approach for quantifying riparian characteristics across the region and it is envisaged the current methodology will remain in place for the foreseeable future. Additional survey methods such as remote sensing, machine learning technologies and drone footage are being considered as potential options to support the current methodology.

1 Introduction

1.1 Riparian margins: a general introduction

Riparian margins are best described as the transitional zone between terrestrial and aquatic ecosystems or, more simply, as zones of direct interaction between land and water (McKergow et al., 2016; Pusey and Arthington, 2003; Gregory et al., 1991). Riparian margins provide several key ecosystem functions including filtering of contaminants from runoff, increasing soil infiltration of soluble pollutants, sediment trapping, stream bank stabilisation, flood attenuation, and maintenance of in-stream biodiversity (Renouf and Harding, 2015; Parkyn, 2005; Norris et al., 2020). Riparian vegetation helps regulate stream water temperature and nuisance growth of in-stream plants via stream shading (Burrell et al., 2014; Davies-Colley et al., 2023). The functionality of these margins for supporting water quality and ecological health may, however, be compromised through clearance of native vegetation and re-development of surrounding land for intensive land uses (McKergow et al., 2016; Hughes et al., 2012). Increases in diffuse contaminant transfers and unrestricted stock access in and around waterways may lead to a wide range of inter-related adverse effects, including disturbance of streambanks, streambeds and riparian vegetation, and the deposition of animal excreta directly into the waterway (McKergow et al., 2016; Neale et al., 2009; Monaghan et al., 2021; Wilcock et al., 2013). The result is a deterioration of water quality and ecological health through nutrient enrichment (e.g. nitrogen and phosphorous), pathogen inputs (e.g. as evidenced by the faecal indicator bacteria *Escherichia coli, E.Coli*), increased sedimentation and general disturbance of the aquatic ecosystem (Norris, 2020; Quinn, 2016; Davies-Colley et al., 2009). As such, enhanced riparian management and restoration are recognised as key strategies to mitigate the impact of land use activities on waterways (Monaghan et al., 2021; Collins et al., 2012; Lind et al., 2019; Renouf and Harding, 2015; Parkyn et al., 2005).

In pastoral farming, an important first step for riparian management is fencing off riparian margins to prevent stock access to the waterway and the use of well-designed and controlled waterway crossing structures such as bridges and culverts (Parklyn and Davies Colley, 2003). Much of the science used to inform policy for the improvement of water quality has highlighted the efficacy of riparian fencing to reduce direct input of faecal contaminants into waterways and mitigate bank erosion by preventing stock from accessing the stream bank (Ministry for the Environment, 2022; McDowell et al., 2020; McKergow et al., 2016). Protection of the riparian margin with fencing also promotes the establishment of riparian vegetation, which provides a wide range of ecosystem services. These include nutrient filtration, removal of dissolved nutrients from shallow groundwater, biodiversity enhancement, subsidies of leaf litter and woody debris that are important for aquatic food webs and habitat, stream bank stabilisation, reduced water velocity, enhanced infiltration in undisturbed areas, and stream shading that regulates stream water temperature and nuisance growth of in-stream plants. (Langer et al., 2008).

In New Zealand, riparian restoration recommendations emphasise planting a combination of woody (e.g. manuka and lemonwood) and non-woody (e.g. sedges and flaxes) vegetation types and the inclusion of a grass or sedge-covered buffer between the planted vegetation and the fence for optimal results (DairyNZ, 2014; Waikato Regional Council, 2004). Woody vegetation provides organic matter in the form of wood and leaves, which is an essential source of carbon for in-stream biota. In addition, woody material can provide structure and habitat for invertebrates and fish (McKergow et al. 2016). Over the long term, the root systems of large trees provide structural support to streambanks, reducing the extent of streambank erosion. For example, in New Zealand, there has been a strong emphasis on the use of poplars (*Populus spp*.) and willows (*Salix spp.*) for protection of eroding stream banks (Langer et al., 2008). It is noted, however, that few studies in New Zealand have quantifiably linked tree-based riparian vegetation to reductions in streambank erosion due to the short-time scales and semiquantitative nature of most studies (Hughes, 2015). Non-woody vegetation types (e.g. sedges and rushes) provide effective shade and temperature regulation in narrow (< 2 m) channels and can provide an important spawning ground for native fish species such as Inanga (*Galaxias maculatus*). Additionally, non-woody grasses and wetland species play a critical role in filtering sediment and sediment-associated contaminants (particulate phosphorus and nitrogen) via interception of surface water (McKergow et al., 2016; Fenemor and Samarasinghe, 2020). Nitrate in near-surface ground water can be reduced via denitrification pathways where flows pass through wetlands or seepage areas within the riparian margin (Fenemor and Samarasinghe, 2020).

Riparian buffer width is defined as the distance from the edge of a waterway to a production area, which may include fenced off livestock or the edge of a cultivated field (Fenemor and Samarasinghe, 2020). The width of vegetation buffer in riparian margins varies depending on specific contextual factors (e.g. size of the stream, surrounding land use or slope of the surrounding land) and is often a compromise between maintaining productive land use and maximising the ecosystem services provided by the riparian margin (McKergow et al., 2016). A recent review by Fenemor and Samarasinghe (2020) focussed on a range of New Zealand studies to assess riparian margins, and the setback width required to achieve a range of ecosystem responses. These ecosystem responses included, amongst other factors, reduction in nutrient via overland flow, improved channel and bank stability, attenuation of flood flows, and increased freshwater ecosystem health. The study concluded that although setback width is an important factor, it represents only one of multiple factors to be considered when designing interventions aimed at achieving the specified functional objectives within a given catchment. In general, wider buffer zones are associated with greater benefits for stream health (Fenemor et al. 2020). For instance, Parkyn et al. (2000) identified a 10-metre threshold for successful indigenous vegetation establishment, while narrower buffer widths provide fewer long-term benefits to both aquatic and terrestrial ecosystems and require ongoing weed management. Other studies, such as Death (2018), have demonstrated that effective setbacks can vary from 5 metres for bank stabilisation and stream shading to over 50 metres for enhancing biodiversity. In the Waikato region, when planting is undertaken, riparian margins are typically wider (> 5 m) and consist of a mix of native species, such as sedges (*Carex* species), flax (*Phormium tenax*), cabbage tree (*Cordyline australis*), and various native shrubs (Norris et al., 2020; McKergow et al., 2016). However, overall buffers are typically less than 5 m, with previous regional riparian surveys (Norris et al., 2020) indicating that the majority (54%) of stream length had < 5 m wide buffers.

1.2 Riparian restoration and protection: regional and national initiatives

Regional Councils are tasked with the integrated management of New Zealand's natural and physical resources under the Resource Management Act (Resource Management Act, 1991). Over recent decades, regional authorities have emphasized the restoration and management of riparian margins as a crucial strategy for enhancing water quality in their respective regions. Waikato Regional Council (WRC) for example has actively promoted fencing and planting along riparian margins through the Clean Streams project (2002 – 2010), Project Watershed (2002 – current) and through implementation of zone and catchment plans (e.g. Waipā Catchment Plan, 2014) and funding schemes within priority catchments (Norris, et al., 2022). Additionally, WRC has developed a comprehensive set of guidelines to assist landowners to manage their riparian margins (Waikato Regional Council, 2004). The Waikato River Authority (WRA), through the Waikato River Cleanup Trust, has also provided significant funding for a range of water quality enhancement actions, including riparian restoration, in the Waikato and Waipā River catchments since its establishment in 2011. Alongside regional council programmes, there have been several industry-led initiatives, most notably the Dairying and Clean Streams Accord (2002 – 2012) (Fonterra et al., 2003), which later transitioned into the Sustainable Dairying Water Accord (2013 – 2018) (DairyNZ, 2018). This cross-sector initiative aimed to improve New

Zealand's water quality outcomes while improving dairy farm performance through the adoption of good management practice. Several key objectives were set during establishment of the programme, and related to five key areas: riparian management, nutrient management, effluent management, water use management, and conversions (DairyNZ, 2015). In terms of riparian and waterway management, the following objectives were set:

- exclusion of dairy cattle from qualifying waterways (wider than "a stride" and deeper than "ankle depth"), all lakes and significant wetlands (exclusion from 100% of the length of waterways on dairy farms by 31 May 2017,
- use of bridges or culverts for regular waterway crossings (100% of crossings to be bridges or culverted by 31 May 2018) and
- preparation of riparian management plans to identify future areas for riparian planting (100% of dairy farms to have a plan by 31 May 2020 and all planting to be completed by 31 May 2030).

In 2018, and at the conclusion of the Dairying and Clean Streams initiative, the objectives were reported to have largely been met for the 11,079 farms that were assessed as part of the audit process (DairyNZ, 2018). A total of 7,629 dairy farms were purported to have accord waterways measuring 24,249 km in total, with 98.3% of these being protected from stock. Additionally, dairy companies identified 36,393 regular stock crossing points, of which 99.8% were bridged or culverted to exclude dairy cattle (DairyNZ, 2018). The WRC regional riparian survey provides an important evidence base to assess the findings of the final Sustainable Dairying Water Accord report (DairyNZ, 2018). Following the conclusion of the Dairying and Clean Streams Accord, the 'Dairying Tomorrow' strategy was developed to build on previous initiatives and to focus on 'continuous improvement on-farm through the widescale adoption of Farm Environmental Plans and good farming practice targeted at the water quality and climate change problems we are working to solve' (Dairy tomorrow, 2022).

Since 2018, several national and regional programs have been launched to encourage riparian restoration across the country. One such initiative was the 'shovel ready project', established in response to Covid-19 to stimulate the construction and environmental industries and economy, be of public or regional benefit and create jobs (WRC, 2025). Waikato Regional Council put forward several environmental proposals to fast-track projects focused on protecting and enhancing water quality, biodiversity, soils and coastal areas, and to protect communities from flooding. Council would ultimately receive funding for over 20 hard structure and environmental projects totalling about $29 million. 'Shovel ready funding' was made available via several central government agencies including Ministry of Business, Innovation and Employment – MBIE (Jobs for Nature), Te Uru Rākau and Ministry for the Environment (MfE). As of July 2024, shovel ready projects resulted in 270 km's of fencing in the Waikato region, of which 166 km's was along streams and waterways. In total 1,684,543 plants were planted, with over 800,000 mixed natives being planted along riparian margins. Key riparian restoration projects funded by 'shovel ready' included the Piako River green corridor, Upper Waiomou habitat enhancement project, Manaia River restoration project, and Clean Streams 2020 (WRC, 2025). By the end of 2024, 16 of the 20 'shovel ready' projects in the Waikato region were closed out, with the 4 remaining projects being handed over to the existing business as usual structures for oversight (WRC, 2024).

The One billion trees planting programme was established in 2018 by Te Uru Rākau - New Zealand Forest Service within MPI – to support landowners to grow both native and exotic trees. The programme provides direct landowner grants through the Provincial Growth Fund to establish trees on land and commit to maintaining the planting project for a minimum period of 10 years (Horizons Regional Council, 2018). Landowners can apply directly for funding to support planting and fencing of riparian margins providing the planted area is greater than one hectare for indigenous species and five hectares for mixed plantings. As of 2024, about $2.76 million was provided in the form of landowner grants in the Waikato Region, equating to 716, 000 native plants and 41,000 exotic plants (Te Uru Rākau, 2024). However, it is unclear as to what proportion of these plants were established in riparian margins. In addition to direct landowner grants, the One billion trees programme has supported a range of riparian restoration partnership programmes with community groups, research providers, and regional councils. For example, the Manaia River Catchment Restoration Programme in the Waikato Region was a partnership between two Coromandel iwi, WRC and Te Uru Rākau. The project received $790, 000 of funding to support riparian planting (39,000 native seedlings) and fencing (6.6 kms). Another example is the Ngāti Hauā Mahi Trust partnership with WRC and landowners in the Karāpiro and Mangaonua Catchments. Overall, the programme received 638, 000 from Te Uru Rākau (One billion trees programme) to support riparian restoration efforts, land retirement and wetland restoration (WRC, 2025). In total, WRC received $800,000 of funding from the One billion trees programme to support a range of gully, riparian and wetland restoration projects across the region. The One billion trees initiative will continue until 2028 for grants that have already been approved (Te Uru Rākau, 2025).

Given the increase in available funding for riparian restoration efforts over recent years, there has arisen a need to record, and document completed works to date. While centrally and regionally funded riparian restoration initiatives are recorded and reported on, the extent of efforts that are funded by individual landowners and community groups are often underreported. Freshwater farm plans are one mechanism by which on-farm mitigation actions such as riparian management can be documented and tracked. However, the rollout of freshwater farm plans has been paused under the current government until improvements in the system are finalised (Ministry for Primary Industries, 2025). Another tool to capture nationwide information about what restorative or protective actions are occurring where and to what extent is the 'Actions for Healthy Waterways' module on Land Air Water Aotearoa (LAWA) platform. The module provides a register of actions relating to stock exclusion, riparian planting, erosion control, wetland protection and restoration, and farm plans (LAWA, 2025). Assuming the register is widely used, there is potential to better understand the benefits of collective actions on water quality and the scale of effort still required to meet freshwater objectives. In the absence of a region-wide inventory of riparian restoration efforts, the regional characteristics survey provides important data to assess the current state of our riparian margins and the changes in key attributes such as fencing and stock access over time. Further work is required to link riparian metrics assed in the survey to region-wide water quality trends.

1.3 Riparian restoration and protection: policy frameworks

The implementation of mandatory stock exclusion rules outlined in national policy documents and council plans is expected to further enhance riparian restoration and protection. In the Waikato region, the proposed Regional Plan Change 1 (PC1), which covers all land in the Waikato and Waipā River catchments, highlights stock exclusion from waterbodies as a key approach to reduce contaminant losses from pastoral land (WRC, 2020). The proposed Plan Change 1 has been notified and is currently going through the Environment Court appeals process (WRC, 2024). According to the PC1 regulations, farmed cattle, horses, deer, and pigs must be excluded from water bodies on land with a slope of up to 15 degrees. Additionally, if the slope exceeds 15 degrees, stock units should not exceed 18 per grazed hectare in any paddock adjoining the water body. In terms of setback distances, new fencing must be located at a distance of at least 3 m from the edge of any wetland listed in Table 3.7.7 of the Waikato Regional Plan; at least 3 m from the out edge of the bed for all other bodies; and 1 m from the edge of a drain, except for cases where the bank-to-bank width is less than 2 m. Waterbodies, include wetlands (as defined by the RMA), with an area of 50 m² or more, lakes, and any river or drain that flows permanently or intermittently and is wider than one meter from bank to bank. Rules also exist with regards to stock crossing structures which must be in place to prevent direct stock access to waterbodies, unless stock are being supervised and actively driven across a waterbody, at a location identified for this purpose in a Farm Environment Plan.

A similar set of regulations are outlined in the Action for Healthy Waterways package. It mandates stock exclusion from wetlands, lakes, and rivers wider than one metre (bank-to-bank), while smaller waterbodies (those less than 1 metre) will be managed through freshwater farm plans (FW-FPs). Dairy cattle and pigs were required to be excluded from lakes and rivers by 1 July 2023, regardless of slope. The same rule applies to dairy support cattle, with regulations coming into effect on 1 July 2025. For beef cattle, stock exclusion regulations apply to all qualifying water bodies (i.e. those wider than 1 m) on low slope land, defined by MfE as pastoral areas with a local slope of less than or equal to 5 degrees and an elevation of less than 500 m above sea level (Ministry for the Environment, 2022). For hill-country pasture (i.e. areas with slopes of greater than 5 degrees), stock exclusion applies to all dairy cattle and pigs but only for deer and beef cattle where intensive farming practices are undertaken, including: fodder-cropping, break-feeding or grazing on irrigated pasture. A minimum setback distance of 3 m is required for all new fencing, and existing permanent fences can remain in place, even where setback distance is less than 3 m.

1.4 Regional riparian characteristics survey: overview and rationale

The Waikato region has more than 16,000 km of streams and rivers which provide a wide range of social, economic, and ecosystem services including water supply, electricity generation, waste treatment, flood control, recreational values, and habitat for aquatic plants and animals (WRC, 2024). Over the past 50 years, regional councils and their predecessors have overseen the management and allocation of freshwater across their respective regions. Over time, the focus has shifted from directly regulating discharges into, and takes from, regional water bodies through to recognising the need to manage the surrounding catchment area to achieve community and iwi expectations for freshwater quality (WRC, 2017).

Riparian management is an important tool to help achieve water quality outcomes, and as such, there have been several regional and national initiatives aimed at enhancing riparian restoration and management. In 2002, the first regional riparian characteristics survey was undertaken to quantify the amount of fencing, vegetation, and erosion along drains, streams, and rivers in pastoral land (Hill and Kelly, 2002). Since 2002, the survey has been repeated at approximately 5-year intervals (2007, 2012, 2017, and 2022) to allow for a consistent, quantitative evaluation of key riparian characteristics (such as fencing, vegetation, and stream-bank erosion) and changes in these attributes over time. The surveys also enable the examination of differences between land use types, management zones, and stream orders in terms of both state and change over time. Despite being time-consuming and resource-intensive, field observation was chosen as the best method for gathering the data needed for a thorough assessment of state and trend (Hill & Kelly, 2002).

In this report we present findings from the most recent regional riparian characteristics survey, carried out during the summer/autumn period of 2022/2023 (referred to henceforth as the '2022 survey'). Previous surveys were undertaken in 2002, 2007, 2012, and 2017. The aims of this report are to:

- describe the state of key riparian characteristics (fencing, vegetation, buffer width, waterway crossings, and stream-bank erosion) of pastoral waterways as observed during the 2022 survey for the Waikato region. Fencing, vegetation, and stream-bank erosion are described by land use type (dairy and drystock), by management zone, and by stream order,
- across the surveyed sites, describe the changes in riparian fencing, vegetation, and stream-bank erosion over the previous 5, 10, 15, and 20-year periods (using the 2002, 2007, 2012, 2017, and 2022 survey data) for the entire Waikato region, by land use type (dairy and drystock), by management zone, and by stream order,
- evaluate the 2022 stock exclusion data against regulations outlined under the Action for Healthy Waterways Package (Ministry for the Environment, 2020a) and Plan Change 1 (Waikato Regional Council, 2020),

- examine the association between fencing and streambank erosion, and
- review the survey design and recommend changes for future surveys if required.

2 Methods and materials

The regional riparian characteristics survey involves the observation of the state of key riparian attributes including fencing, vegetation, buffer width, waterway crossings, and stream-bank erosion at sites on pastoral land across the Waikato region. The survey was first undertaken in 2002, and has been repeated four times, at approximately 5-year intervals, in 2007, 2012, 2017, and most recently in 2022. Consistent with previous surveys, the 2022 survey was undertaken during the summer/autumn period spanning two calendar years (i.e., 2022/23) and is henceforth referred to as the '2022 survey'. The combined datasets derived from the surveys undertaken to date provide observations of key riparian characteristics at five points in time (2002, 2007, 2012, 2017, and 2022) spanning a period of 20 years in total.

The following sections provide an overview of the methodology used for the 2022 survey, including selection of sampling units, field data collection, and the data analysis undertaken. To maintain comparability across the different survey periods and allow for comparison of trends in the riparian attributes surveyed, the 2002 survey method was followed, but with slight modifications in each survey. A brief overview of the original 2002 survey is provided in each sub-section, with further details provided on implemented design modifications over subsequent survey years.

2.1 Survey design

The original (2002) regional riparian characteristics survey utilised a stratified random sampling design. The rationale for this stratification is provided in Hill and Kelly (2002) and stemmed from preliminary methodology development work undertaken in the Upper Waipā (Hill, 2001). Stratification of a variable population seeks to subdivide the population into meaningful sub-populations (i.e. strata) and then randomly sample from each stratum to reduce variance for the purpose of providing more precise estimates and increasing the efficiency of sampling (Frampton, 2009). In the original 2002 survey design, the population of riparian margins across the Waikato region was stratified by management zone, land use, and stream order with approximately equal sample numbers within each stratum. In 2007 and in subsequent surveys, the allocation of samples was based on a proportional basis to improve the representation of sites across previously under or overrepresented strata. Individual strata, along with site selection criteria and determination of sample sizes, are discussed in detail below.

2.1.1 Management zones

Management zones are sub-regional areas defined largely based on physiographic boundaries of major catchments or parts of major catchments (e.g. Upper Waikato, Lower Waikato, etc.) within the region with some adjustments to align political and management-related boundaries. Management zones provide a convenient basis for the subdivision of the region into areas of similar physiographic and management conditions and enable the examination of sub-regional differences in riparian characteristics. At the time of the 2002 survey, the Waikato region was subdivided by nine management zones (Hill and Kelly, 2002). Changes to management zone boundaries occurred during the 2002 survey and again prior to the time of the 2007 survey (Storey, 2010). In association with the boundary changes, the number of zones was reduced from nine to eight. The zone boundaries at the time of the 2022 survey were the same as those at the time of the 2007 survey. Current management zone boundaries, together with the 2022 sample site locations, are shown in Figure 1.

The eight management zones subdividing the Waikato region at the time of the 2022 survey were (1) Coromandel, (2) Waipā, (3) West Coast, (4) Central Waikato, (5) Waihou-Piako, (6) Lake

Taupō, (7) Lower Waikato, and (8) Upper Waikato. Zones are described in more detail by the respective zone management plans (WRC, 2025).)

Information relating to land use and stock density for each of the eight management zones is presented in Appendix 1 (Table A1-1) to aid in the characterisation of zones. Land use information was extracted by combing information from LCDB 5.1 and Agribase^{TM}. Pasture is the dominant land use across all zones, except for the Coromandel and Lake Taupō management zones, where indigenous forest was the dominant land use. As a proportion of land area within respective zones, the Lake Taupō and West Coast zones have the highest coverage of commercial forestry. In terms of stocking rate, the Lake Taupō and West Coast zones have the lowest median pastoral stock density (stock units/ha), while the Waipā and Waihou-Piako have the highest median pastoral stock density values (Table A1-2).

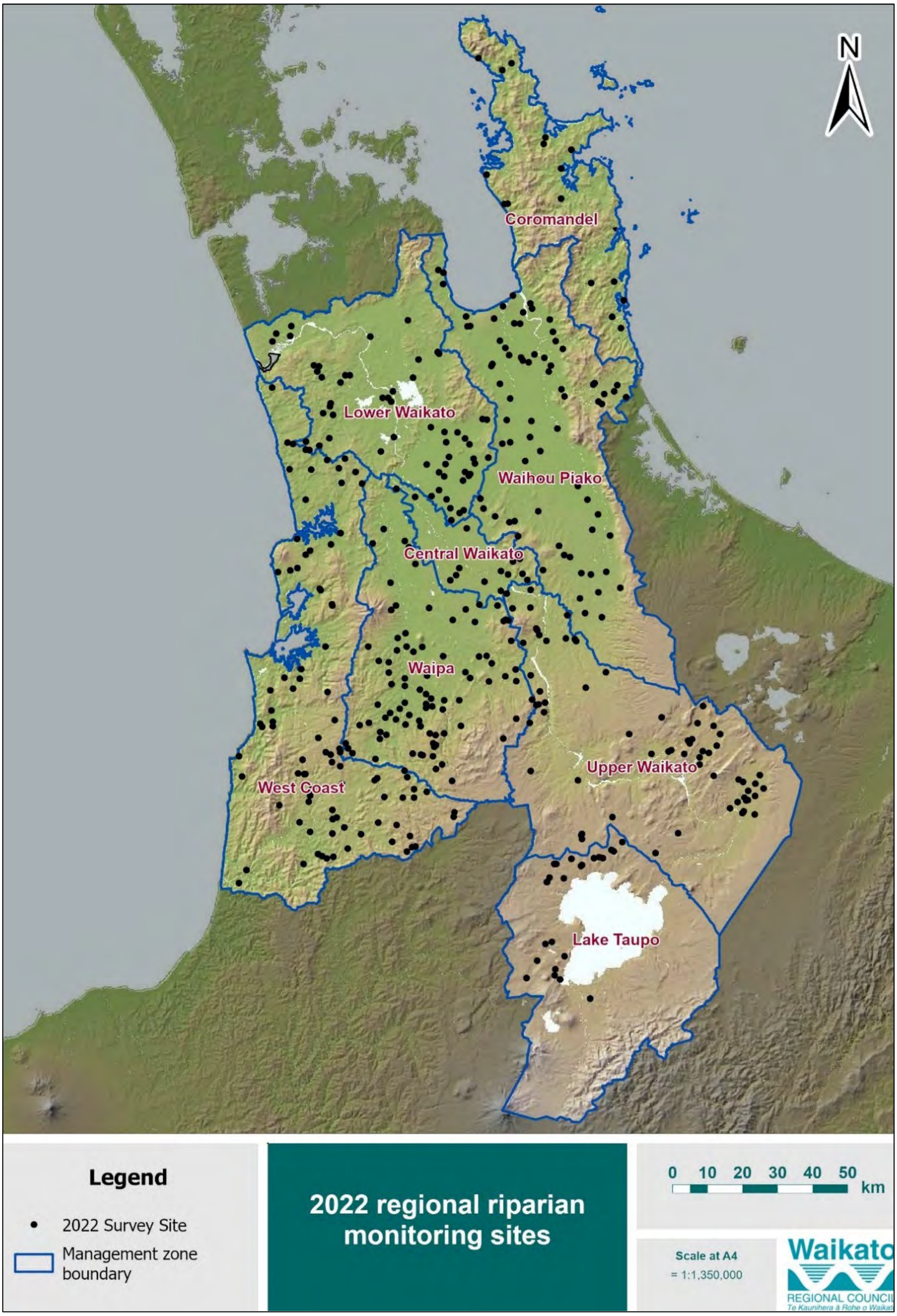


Figure 1. Map showing sample site locations and Catchment Management zone boundaries for the 2022 survey. Management zone boundaries were extracted from the WRC "RACS – Management Boundaries" layer[1]. Location data for riparian monitoring sites is held in the WRC ArcGIS server[2].

[1] https://liveapps.wairc.govt.nz:8443/ords/live/f?p=135:12:7740648927731::NO::P12_METADATA_ID:1073

[2] https://services.arcgis.com/2bzQ0Ix3iO7MItUa/arcgis/rest/services/RCSCatchment/FeatureServer

2.1.2 Land use type

Consistent with previous riparian surveys, the 2022 survey categorised land use into two broad groups, these being dairy and drystock. In the original 2002 survey design (Hill and Kelly 2002), Land Use Capability (LUC) classes were used to define dairy (LUC 1-4) and drystock (LUC 5-8) land for the purpose of site selection. This was because there was no other spatial land use information available at the time. The premise behind the LUC – land use approach was that dairy farms tend to occur on flat to gently rolling land whereas drystock farms typically occur on rolling to steep land. The 2002 survey design sought to allocate a similar number of sites to LUC defined dairy and drystock farms. However, the observed land use at the time of the survey may have differed to the land use predicted by LUC. In the 2007, 2012, 2017, and 2022 surveys, the Agribase™ database was used to define land uses at newly selected (i.e., replacement) sites. Agribase™ is a database owned and maintained by Assure Quality that contains information on land use activities (e.g. land use, stock class, and stocking rates) for approximately 144, 500 properties across New Zealand (Assure Quality, 2024). Previously sampled sites were assumed to have the same land use type as previously assessed until confirmed at the time of resampling. A change in land use from either dairy or drystock to some other land use (e.g. from drystock to forestry) at a given site, would result in that site being excluded from the analysis of survey data.

2.1.3 Stream order

Stream order is a measure of stream or river size, based on the degree of branching in a river network (LAWA, 2024), and was described using the Strahler system of ranking channels. The Strahler system assigns a number from 1 – 7 to a waterway based on the number and size of upstream tributaries contributing flow to a given segment of waterway. The larger the stream order (Strahler) number, the larger the stream or river (Figure 2). Drains were differentiated from other waterways for the purpose of the survey by assigning a stream order designation of zero (Hill and Kelly, 2002). Based on the bank to bank width, drains were further separated into narrow (< 2 m) and wide (> 2 m) drain classes for analysing stock exclusion results with respect to Plan Change 1 regulations (Waikato Regional Council, 2020).

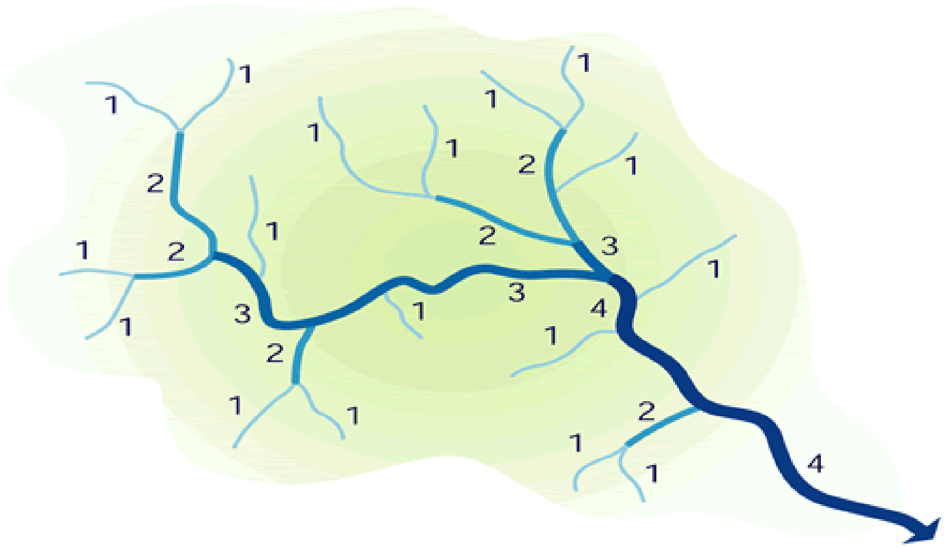


Figure 2. Schematic showing the concept of stream order (Strahler order), with stream order increasing further down the catchment as stream/river size increases (figure obtained from The Federal Interagency Stream Restoration Working Group, 2001).

2.2 Sample site selection and sample sizes

In line with the previous 2017 survey, each sampling unit (i.e., site) consisted of an approximately 500 m long segment of waterway. Both banks along each stream/river segment were assessed, meaning a total bank length of approximately 1 km was assessed at each site.

The use of the 500 m stream length for each sampling unit was consistent with the 2017 survey approach but differed to the 1 km stream length used in the 2002, 2007 and 2012 surveys. An ad hoc analysis of the 2012 dataset (Jones et al., 2016) found that there was minimal loss in precision for key variables under a 500 m sampling regime compared to the 1000 m sampling method. Providing the overall sample size (i.e., number of sites) was increased by ~30, the statistical power to detect changes in key attributes was maintained. The exception was for fords (stream crossing variable), where reducing the surveyed stream length resulted in less precision and a large increase in sample size (~ 180) was required to maintain statistical power. However, the practical benefits of reducing sample length were deemed more important than the reduction in precision for one variable overall, and hence the new sampling approach was adopted for the 2017 and 2022 surveys. Benefits of the revised sampling approach included significant time and cost savings associated with a 50% reduction in survey length and requirement for fewer landowner contacts (i.e., fewer property boundaries crossed by shorter sample lengths).

The number of sampling sites analysed from each survey year and the year that sites were first selected is summarised in Table 1. The first survey in 2002 consisted of 373 sampling units. In the 2007 survey, 89 of the original sites were excluded due to insufficient stream length, and only 284 existing sites were sampled along with 13 new sites added from under-represented strata. In the 2012 survey, 312 new sites from the previous two surveys were reassessed and 70 new sites added. In 2017, a large number (153) of new sites were selected for implementation of the modified sampling regime (i.e. 500 m stream length opposed to 1000 m) along with 279 previously sampled sites. In the 2022 survey, 397 sampling units from previous surveys were surveyed, and 33 new sites were added to replace existing locations that were inaccessible. A core set of approximately 249 to 299 of the original 2002 sites were included in each subsequent survey. New sites were randomly selected from Geographic Information System (GIS) derived tables, which used information extracted from LCDB 5.1, NZLRI (New Zealand Land Resource Inventory), zone data and AgriBase™. In all surveys, a small proportion of sites (< 5% of the total number of surveyed sites) were excluded from the dataset due to the land use type being different to either dairy or drystock.

Table 1. Number of sampling sites used in each survey year.

Survey year	Number of units used in a survey					
	Units selected in 2002	Units selected in 2007	Units selected in 2012	Units selected in 2017	Units selected in 2022	All units
2002	373					373
2007	284	13				297
2012	299	13	70			382
2017	263	4	12	153		432
2022	249	4	11	133	33	430

The total number of sites used within each stratum (i.e. combination of management zone, farm type, and stream order) is shown in Appendix 2 (Table A2-1). Management zone boundaries changed following the 2002 survey and again in 2012 and the information in Table A2-1 is based on current zone boundaries. Furthermore, the farm type associated with each site was defined using the information associated with the year each survey was undertaken.

Under the original 2002 sampling methodology (Hill, 2001), a total of three samples were randomly selected from each stratum (defined by combinations of management zone, farm type, and stream order), although sample sizes were increased in the most common strata to account for strata combinations that did not actually exist. The sampling numbers in Table A2-1 indicate that the actual number of samples per stratum varied greatly. For example, the management boundaries for the Lake Taupō, Lower Waikato, and West Coast zones have not changed, yet the number of samples per stratum varied between 0 and 19 (2002 – 2012).

A key assumption of stratified random sampling is that samples are randomly selected from within respective strata, and sample numbers are weighted depending on the relative size of each stratum. The advantage of such an approach is that it provides more precise estimates of subpopulation parameters (e.g. fencing along first order streams within drystock). Typically, strata with zero samples are excluded from analyses to satisfy the requirements of probabilistic sampling. As is evident in Table A2-1, several smaller strata (e.g., 5th order rivers on dairy farms in the West Coast Zone) had zero samples. To meet the requirements of stratified random sampling, some strata were redefined by aggregating some stream orders within each management zone and farm type to ensure that strata had at least one sample. Strata information (including those that were redefined) are shown in Appendix 3 (Table A3-1).

It is recognised that the strata used for the most recent 2022 survey differed from the strata used in the original 2002 survey. Firstly, current management zone boundaries were used to define strata, but sites selected in 2002 were sampled using the 2002 management zone boundaries. A key assumption in stratified random sampling is that all units from the same stratum have the same inclusion probability and this assumption would not be met for units from different 2002 management zones within 2022 strata. However, the effect in this case is deemed negligible since inclusion probabilities of sites did not vary greatly between survey years. Secondly, for some strata, stream orders were combined to avoid strata with zero observations. The effect of this is also negligible as the number of aggregated strata (and sites within) were relatively small.

When designating a sampling unit to a given stratum, the farm type at the time the sample was selected was used. This was to ensure that the inclusion probability of the unit at the time it was selected was correctly calculated. This created difficulties in calculating population stream length in a stratum when samples were selected in different years because estimated stream length within each land use changed over time. The solution implemented in the analysis was to average the selection year of samples within each stratum and use the closest available stream length year to determine the stream length of the stratum (Table A3-1). An important assumption of stratified random sampling is that randomly selected samples from within strata are representative of those within sub-populations. Therefore, inference can be made about particular groups within the population based on sample estimates. Due to the difference in the way that samples were designated during past surveys, we recognise that there was a small imbalance in the distribution of samples across some strata. This imbalance arose from resampling previously sampled sites, which could not be abandoned due to the value of historical data, or due to resource constraints limiting the number of sites we could sample. Except for a small number of strata, such as first order streams on drystock sites, the sample numbers within most strata corresponded well with the population numbers (Table A3-1). A key recommendation from this report is to adjust sample numbers across strata to ensure that the distribution of samples in future surveys better reflect the size of sub-populations (see section 4.6)

2.3 Field data collection

2.3.1 Approach and equipment

The overall approach to field data collection has remained constant since commencement of the regional riparian survey characteristics survey in 2002. However, field equipment and procedures were improved and refined over successive surveys as data capture technologies have advanced and as our experience with the approach has grown. The biggest change in this regard occurred between the 2002 and 2007 surveys. During the 2002 survey, field observations were recorded manually on pre-printed sheets and the spatial location of changes in characteristics along the length of the sample site were determined using a hand-held GPS device (Hill and Kelly, 2002). In subsequent surveys, field observations were recorded digitally using computers with in-built GPS for the simultaneous recording of the spatial location at which the changes in characteristics occurred. Trimble Nomad® devices were used in the 2007 survey whereas Trimble Juno® devices were used in the 2012 and 2017 surveys. In 2022, the same overall approach was employed but using an upgraded Trimble TDC 600 device along with Survey123 to record observations. The TDC 600 provided an improved user interface (touch screen) with a higher specification GPS to improve the efficiency and accuracy of data collection.

After locating the pre-determined start point at the sample site using the Trimble device, the necessary general site observations were undertaken and recorded. Field staff then proceeded to walk the length of the survey site (approximately 500 m), adjacent to the waterway, making observations of riparian characteristics on both banks. One survey form was completed per site, with one field technician making observations and the other recording data using the Survey123 form. Two separate field teams, each consisting of two field technicians, conducted riparian assessments across the region over a seven-month sampling period (December 2022 – June 2023). To ensure consistency in data collection between the two field teams, field training was conducted prior to the commencement of the survey. Additionally, a 'quick guide' reference document was provided to field staff to minimize differences in the interpretation of riparian attributes. All data was quality-checked before analysis (section 2.4) using ArcGIS Pro to eliminate any erroneous points collected during the field surveys.

Due to fencing and/or deep stream channels, most assessments were made from one bank only. Changes in characteristics from those observed at the start point were recorded together with the spatial location of that change. The resulting stream segment information allowed for the length and proportion of total stream length or bank length with certain characteristics (e.g. effective fencing) to be calculated (Figure 3). The spatial location of any substantial change in the direction of the waterway was also recorded to ensure the shape of the track-log being generated by the survey observations conformed to the shape of the waterway (Storey, 2010). In the 2012, 2017, and 2022 surveys, observations made at the start point were repeated at the middle and end points for selected characteristics (i.e. 'point' characteristics).

The diagram presented in Figure 3 illustrates the concepts of stream length, bank length, and fencing configuration. Stream length and bank length are central to the presentation of the survey results as most characteristics are reported as a proportion of stream length or bank length.

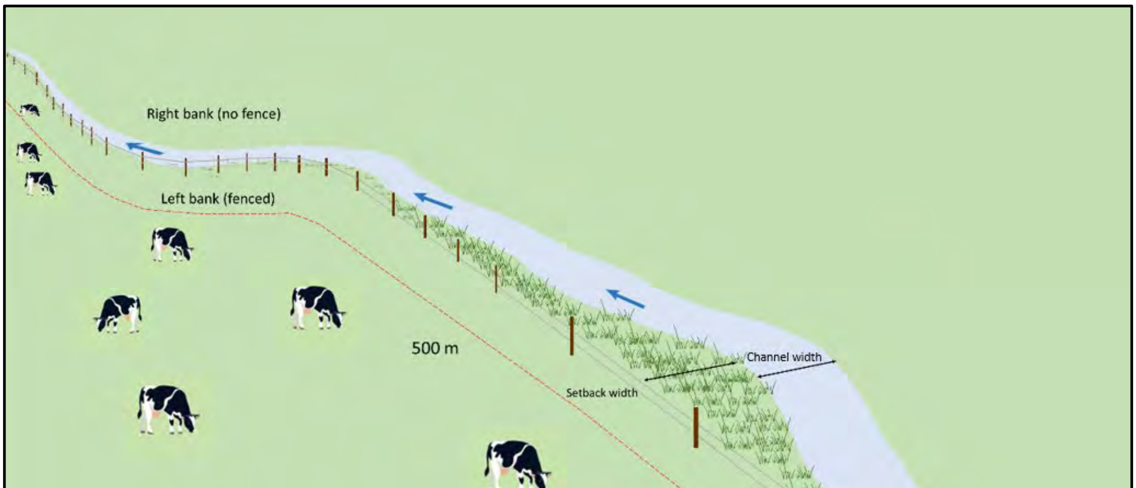


Figure 3. A stylised example of stream reach that illustrates the concepts of stream length, bank length, and fencing configuration. Bank width and setback width concepts are included for reference. Note that channel width was based on the distance between the terrestrially vegetated areas on the margins.

In the example given in Figure 3, total stream length is 500 m (illustrated by the red line). Total bank length is the sum of the total stream length along both banks. In this case, total bank length is 1000 m (500 m + 500 m, or 2 x 500 m). The amount of bank fenced is 500 m which equates to 50% of total bank length (500 m / 1000 m x 100). The fencing in this example is configured as follows: 0 m (0%) of stream length is fenced on both banks; 500 m (100%) is fenced on one bank only; and 0 m (0%) of stream length is fenced on neither bank.

The Trimble TDC 600 devices used in the 2022 survey ran Survey123 and this was used in the collection of the field data via the use of pre-designed 'forms' in which options to describe a particular characteristic were provided in the form of drop-down menus. At each sample site, survey staff recorded their observations using four pre-designed forms: (1) general site characteristics form, (2) true right continuous characteristics form, (3) true left continuous characteristics form, and (4) point characteristics form. Each form comprised multiple drop-down menus from which the appropriate category that best described a particular characteristic could be selected.

2.3.2 Characteristics observed

Key characteristics describing riparian fencing and vegetation have remained largely unchanged since the original 2002 survey. However, over time, some minor changes to naming terms have been implemented to improve clarity of reporting and efficiency of data collection. For example, for the 2017 and subsequent surveys, vegetation category names for 'pastoral grasses' and 'grasses/sedges' were changed to 'grass and weeds' and 'flax/sedge/rush' respectively (Table 2) while the 'bridge with culvert' category under the stream crossing type was included under 'culvert'.

As in previous surveys, the characteristics observed during the 2022 survey were grouped into three broad categories: (1) general site characteristics, (2) continuous characteristics, and (3) point characteristics. Characteristics in each group are described below.

General site characteristics help to describe the nature of, and conditions at, the sample site. These included site metadata (site identification number, date observed, and observer), site status (new or resampled), general land use (e.g. dairy or drystock), specific land use directly adjacent to each bank along the waterway (e.g. maize cropping, planted forest, sheep grazing, etc.) and whether or not the waterway qualified as a Sustainable Dairying Water Accord waterway (i.e. wider than 1 m, more than ankle deep and permanently flowing).

Continuous characteristics are those attributes that have potential to vary spatially along the length of a waterway, on either bank, or can be measured in terms of waterway segment length. Key continuous characteristics observed for both banks along the length of each sample site are presented in Table 2 and includes the nature and status of the riparian fencing, vegetation type, and stream-bank erosion present at a site. Since the 2017 survey, land use was recorded as a continuous characteristic. This allowed more subtle changes in land use not recorded under the general land use assessment to be captured, for example, where a cropping paddock was present along a surveyed stretch within a dairy farm.

Point characteristics are those that occur, or are best described, at a specific location along the length of the waterway. Consistent with the 2012 and 2017 surveys, two broad categories of point characteristics were observed: (1) those observed at the three designated locations (i.e. start, middle, and end points) and (2) those observed anywhere along the length of the sample site (co-incident with the occurrence of these features — i.e. occurrence-based). Key point characteristics observed during the 2022 survey are listed in Table 3 (designated locations) and Table 4 (occurrence-based). At each site, we assessed bank height, slope, and stock access at the start, middle, and end points. Additionally, we documented obstructions and waterway crossings where they occurred. Stream channel type, channel width, and aquatic vegetation were also noted at these same points.

Photographs documenting the waterway and adjacent riparian margins were taken at the start, middle and end point at each site. If any significant or unusual features were observed during the survey (such as waterway crossings or obstructions), they were also documented through photographs.

Table 2. Key continuous characteristics observed during the 2022 survey.

Characteristic	Category	Description
Land use	Dairy	Dairy (platform)
	Drystock	Dairy support Beef Sheep Sheep & beef Deer Goats Horses Llamas/alpacas Pigs
	Forestry	Planted forestry
	Other	Poultry Manuka honey Other
Fence type	No fence	There is no fence present.
	Electric	Fence present has at least one wire that is electrified.
	Wire	Fence present is predominantly of wire construction.
	Wood	Fence present is predominantly of wood construction.
	Deer	Fence present is designed for deer (mesh and > 2 m in height).
	Mesh	Fence present is of mesh construction.
	Other	Fence present is of some other design, material, or construction.
Fence status	Effective, permanent	The fence is permanently in place, with large concrete or wooden posts.
	Ineffective, permanent	The fence is permanently in place, with large concrete or wooden posts.
	Effective, temporary	The fence is easily removed; posts may be waratahs, standards, or
	Ineffective, temporary	The fence is easily removed; posts may be waratahs, standards, or
Vegetation type	Woody native	Predominance of native trees/shrubs.
	Woody exotic willow	Predominance of willow (deciduous exotic) species.
	Woody exotic other	Predominance of deciduous exotic (non-native) tree and shrub species
	Woody exotic other	Predominance of evergreen exotic (non-native) tree and shrub species.
	Grass and weeds	Predominance of low (< 1 m) pastoral grass and/or herbaceous weed
	Flax/sedge/rush	Predominance of (mainly indigenous) flax, sedge and rush species. Species
Vegetation structure	Forest	Tall dense vegetation, trees close together.
	Treeland	> 3 m high, widely spaced trees with grass in between.
	Scrub	Low stature vegetation (< 3 m) and close together.
	Shrubland	Low stature (< 3 m), widely spaced, grass in between.
	Grasses	Grass including small, low-lying weeds < 1 m in height.
	Wetland	Raupo/sedges.
Vegetation management	Planted and managed	The riparian vegetation has been intentionally planted and is being
	Planted and	The riparian vegetation has been intentionally planted but is not being
	Planted and grazed	The riparian vegetation has been intentionally planted but is periodically
	Unplanted and	The riparian vegetation has not been intentionally planted but is being
	Unplanted and un-	The riparian vegetation has not been intentionally planted and is not
	Unplanted and grazed	The riparian vegetation has not been intentionally planted and is
Average width of riparian margin	< 2 m	Up to 2 m.
	2 – 5 m	Between 2 and 5 m.
	5 – 10 m	Between 5 and 10 m.
	> 10 m	Greater than 10 m.
Stream-bank erosion type	No erosion	No erosion present.
	Recent	Likely to add sediment to the waterway when in flood.
	Active	Adding sediment to the waterway at the present time.
	Pugging (> 50%)	Soil trampled by livestock across more than 50% of the stream-bank area.
	Pugging (< 50%)	Soil trampled by livestock across less than 50% of the stream-bank area.

Table 3. **Key point characteristics observed at designated locations at each sample site during the 2022 survey.**

Characteristic	Category	Description
Location	Start point	Locate the start-point of the survey.
	Middle point	Locate the middle-point of the survey.
	End point	Locate the end point of the survey.
Bank slope	Slope value recorded (°)	Measure the slope of the stream bank using a clinometer.
Bank height†	< 1 m	Bank height is less than 1 m.
	1 – 9 m	Bank height is between 1 and 9 m (selected to the nearest metre).
	> 9 m	Bank height is more than 9 m.
Stock access type	None	No evidence for livestock access to the waterway or riparian margin is observed.
	Past	Some evidence for livestock access to the waterway or riparian margin at some time in the past is observed (e.g. pugged soil, grazed/browsed vegetation, trampled/broken vegetation, animal tracks and dung).
	Recent	Evidence for recent livestock access to the waterway or riparian margin is clearly observed (e.g. recently pugged soil, grazed/browsed vegetation, trampled/broken vegetation; fresh animal tracks and dung).
	Current	Livestock are observed in the waterway or riparian margin at time of survey.

† Estimated height from stream bed to bank top.

Table 4. **Key occurrence-based point characteristics observed during the 2022 survey.**

Characteristic	Category	Description
Obstruction type†	Non-living debris	Dead wood, plastic, metal, fencing materials, etc in the stream flow.
	Willows	Willows in the stream flow.
	Other live vegetation	Living vegetation (other than willows) in the stream flow.
	Dams	Dam structures including small farm dams, concrete walls stopping flow, etc.
	Weir	A structure across the width of the waterway that alters the flow and level of the water.
	Side entry	Side entries are tributary streams, drains or pipes (including tile drains) that flow into the mainstream course.
Stream crossing type	Culvert	Pipes channelling the stream water, usually associated with a stream crossing (e.g. road, track or constructed crossing).
	Constructed ford	Constructed area of controlled and regular animal or vehicle crossings through the water.
	Streambed ford	Area of regular animal or vehicle crossings through the water across the streambed.
	Bridge ≤ 10 m	Bridge 10 m or less in length.
	Bridge > 10 m	Bridge greater than 10 m in length.

† An obstruction was defined to be an object or structure that blocked 50% or more of the width of the waterway.

2.3.3 Data extraction and processing

In the previous two riparian surveys (2012 and 2017), Trimble Juno® devices were utilised, with GPS points being corrected to improve the accuracy of locational data to within a range of 2 – 5 m. The same overall approach was employed during the 2007 survey, except that a Juno Nomad device was used for data collection. In the 2022 survey, field data was collected using Trimble© TDC 600 devices. These devices offered an enhanced user interface, streamlining data collection. Notably, the GPS accuracy ranged between 2 – 5 m, eliminating the need for post-processing corrections. Riparian characteristics data (and associated GPS points) were collected using pre-designed forms within the Survey123 application (Appendix 5). At the end of each day, data was uploaded onto ArcGIS online and photographs were uploaded onto the WRC server at the end of each week.

The raw field data, in the form of database files containing sets of individual observations of riparian characteristics, each associated with the spatial location of the observation, were subject to an extraction process (automated using R based computer scripts). Segment lengths were calculated for each observation and 'chainage' (cumulative lengths) at each site sampled. After extracting the data, statistical analyses (described in the section below) were undertaken. The automated data extraction process was employed for all surveys except in 2002, where segment lengths for continuous characteristics were manually recorded and calculated.

2.4 Data analysis

2.4.1 Methods for estimating population parameters

The focus of the riparian survey on estimating ratios and percentages sets it apart from most surveys, which typically aim to sample populations using totals or averages. It would certainly be possible to calculate population totals from the riparian survey, but the predominant interest was on estimating ratios. For example, the survey could be used to estimate the total bank length fenced across the region, but it was of far greater interest to estimate the percentage bank length fenced rather than the total. Table 5 provides examples of typical ratios that were estimated using the survey data. When calculating a ratio, the first step is to calculate its numerator and denominator for each site and is achieved by summing the bank lengths of each characteristic within a sampling unit. The analysis was undertaken using a purpose-built script within R (R Core Team, 2023).

Table 5. Example of ratio variables estimated in the survey

Variable	Numerator	Denominator
Proportion bank length effectively fenced	Bank length effectively fenced	Total bank length
Proportion bank length effectively fenced in dairy farms	Bank length effectively fenced where land use is dairy	Total bank length where land use is dairy
Proportion bank length effectively fenced for stream order 0	Bank length effectively fenced where stream order is 0	Total bank length where stream order is 0
Number of fords per kilometre stream length	Number of fords	Total stream length

In addition to estimating ratios for the 2022 survey, estimates for previous surveys were also calculated. These estimates differ somewhat to previously reported values because the analysis methods used in the current study varied slightly from those used in earlier analyses. For example, the analysis of the 2012 data (Jones et al., 2016), strata were defined using the 2012 land use classes. In the 2017 analysis (Norris e al., 2020), sampling units were assigned to strata using land use at the time the sampling unit was selected, ensuring that inclusion probabilities were more accurately determined. In the 2022 survey, the same approach was used as for the 2017 survey except that some strata were redefined due to minor changes in sample numbers within respective strata. The results in the current report provide the best estimates for each measurement year.

While standard texts like Cochran (1977) and Särndal et al. (1993) discuss methods for estimating ratios in stratified random surveys, they do not specifically address how to estimate changes in ratios over time. However, Särndal et al. (1993) outlines a general approach for estimating functions of survey variables within stratified random sampling, which can be adapted to analyse changes in ratios. Using this approach, we derived equations to estimate differences in ratios over time, along with their corresponding 95% confidence intervals.

2.4.2 Estimation of a ratio

We use the following notation:

y_{hi} is the numerator in the i^{th} sampling unit in the h^{th} stratum

x_{hi} is the denominator in the i^{th} sampling unit in the h^{th} stratum

n_h is the number of sampling units in the h^{th} stratum

N_h is the number of units in the population in the h^{th} stratum

H is the number of strata

For simplicity and to retain compatibility with earlier surveys, we assumed each sampling unit was 1 km long when calculating Nh. Therefore, when the denominator is bank length, Nh equals the total stream length within the stratum.

The following quantities are calculated:

$f_h = n_h/N_h$, the sampling fraction in the stratum h

$y_h = \sum_{i=1}^{n_h} y_{hi}$, the sum of y in stratum h

$x_h = \sum_{i=1}^{n_h} x_{hi}$, the sum of x in stratum h

$s_{yh}^2 = \left(\sum y_{hi}^2 - (\sum y_{hi})^2/n_h\right)/(n_h - 1)$, the variance of y in stratum h

$s_{xh}^2 = \left(\sum x_{hi}^2 - (\sum x_{hi})^2/n_h\right)/(n_h - 1)$, the variance of x in stratum h

$s_{yxh} = (\sum y_{hi}x_{hi} - (\sum y_{hi})(\sum x_{hi})/n_h)/(n_h - 1)$, the covariance between x & y

The estimator of the ratio is:

$$(1) \quad R = \sum_{h=1}^{H} (N_h y_h/n_h) \Big/ \sum_{h=1}^{H} (N_h x_h/n_h)$$

The estimated variance of R is:

$$(2) \quad V(R) = \frac{\sum_h \left[N_h^2(1 - f_h)\left(s_{yh}^2 - 2Rs_{yxh} + R^2 s_{xh}^2\right)/n_h\right]}{\left(\sum_h (N_h x_h/n_h)\right)^2}$$

A 95% confidence interval for R is calculated by multiplying the square root of the variance by a t-value with degrees of freedom being the number of units with non-zero denominator minus the number of strata. Estimates for sub-populations within the stratified design (e.g. management zone or land use type) were calculated using equation (1), but with summations over the sub-population rather than the total population. Tests of significance between subpopulations were performed using least significant difference (LSD) tests, with each pair-wise comparison tested by a t-statistic:

(3) t = (Mean1-Mean2)/√(Var1+Var2)).

The pairwise comparison was undertaken in R (R Core Team, 2023) using the ‘multicompLetters’ package. The P value was calculated using the t-statistic and degrees of freedom, with results reported as significant at $P < 0.05$.

2.4.3 Estimation of change in ratio over time

In this section we describe how the change in ratio over time is estimated (e.g. the change in proportion of bank length effectively fenced between 2017 and 2022). The first step is to calculate the ratios for times 1 and 2 using Equation (1). These are referred to as R_1 and R_2 respectively. The difference between ratios is the required estimator:

(4) $R_{diff} = R_2 - R_1$

Since R_{diff} is a function of population totals, its variance can be calculated using the Taylor linearisation technique as described by Särndal et al. (1993). The method’s application poses challenges due to varying sampling units between surveys. Specifically, some units were measured at both points in time (time 1 and time 2), while others were measured only at one point in time. Prior to the 2017 survey (Norris et al., 2020), estimates of change over time were based on units measured in both years. However, for the last two surveys (2017 and 2022), all measurements were used in the calculation of R_{diff} to maximise the available information from the survey and improve change over time estimates.

In the formula for the variance of R_{diff} which is given below, the numerator and denominator at time 1 are denoted by $y1$ and $x1$ respectively. At time 2 they are denoted by $y2$ and $x2$. The number of units in the population is denoted by N. The number of units sampled at time 1 is n_1 and n_2 at time 2. The number of units measured only at time 1 is n_{11}, the number measured only at time 2 is n_{22}, and the number measured both times is n_{12}. The bar notation is used to denote means (e.g. $\overline{y1}$ is the mean of y1), and s^2 is used to denote variances (e.g. s^2y1 is the variance of $y1$) and s is used to denote covariances (e.g. $sy1y2$ is the covariance between $y1$ and $y2$). Subscripts are used to indicate the units over which means and variances are calculated within a stratum. The subscript ‘1’ indicates all units in the stratum at time 1, ‘2’ indicates all units at time 2, ‘11’ indicates units measured only at time 1, ‘22’ indicates units measured only at time 2, and ‘12’ indicates units measured both times. For example, s^2y1_{11} is the variance of $y1$ in units measured only at time 1, while $sy1x2_{12}$ is the covariance between $y1$ and $x2$ in units measured at both times. All summations are over strata (i.e. h=1,…,H) although subscripts h are not shown for clarity. The formula for the variance of R_{diff} derived using the Taylor linearization technique is as follows:

$$
\begin{aligned}
V(R_{diff}) = {} & \frac{\sum(N^2 n_{11} s^2 y1_{11}/n_1^2)}{(\sum N\overline{x1}_1)^2} + \frac{(\sum N\overline{y1}_1)^2 \sum(N^2 n_{11} s^2 x1_{11}/n_1^2)}{(\sum N\overline{x1}_1)^4} - 2\frac{(\sum N\overline{y1}_1)\sum(N^2 n_{11} sy1x1_{11}/n_1^2)}{(\sum N\overline{x1}_1)^3} \\
& + \frac{\sum(N^2 n_{22} s^2 y2_{22}/n_2^2)}{(\sum N\overline{x2}_2)^2} + \frac{(\sum N\overline{y2}_2)^2 \sum(N^2 n_{22} s^2 x2_{22}/n_2^2)}{(\sum N\overline{x2}_2)^4} - 2\frac{(\sum N\overline{y2}_2)\sum(N^2 n_{22} sy2x2_{22}/n_2^2)}{(\sum N\bar{x}2_2)^3} + \\
& + \frac{\sum(N^2 n_{12} s^2 y1_{12}/n_1^2)}{(\sum N\overline{x1}_1)^2} + \frac{(\sum N\overline{y1}_1)^2 \sum(N^2 n_{12} s^2 x1_{12}/n_1^2)}{(\sum N\overline{x1}_1)^4} - 2\frac{(\sum N\overline{y1}_1)\sum(N^2 n_{12} sy1x1_{12}/n_2^2)}{(\sum N\overline{x1}_1)^3} + \\
& + \frac{\sum(N^2 n_{12} s^2 y2_{12}/n_2^2)}{(\sum N\overline{x2}_2)^2} + \frac{(\sum N\overline{y2}_2)^2 \sum(N^2 n_{12} s^2 x2_{12}/n_2^2)}{(\sum N\overline{x2}_2)^4} - 2\frac{(\sum N\overline{y2}_2)\sum(N^2 n_{12} sy2x2_{12}/n_2^2)}{(\sum N\overline{x2}_2)^3} + \\
& + 2\frac{(\sum N\overline{y1}_1)\sum(N^2 n_{12} sy2x1_{12}/(n_1 n_2))}{(\sum N\overline{x1}_1)^2(\sum N\overline{x2}_2)} + 2\frac{(\sum N\overline{y2}_2)\sum(N^2 n_{12} sy1x2_{12}/(n_1 n_2))}{(\sum N\overline{x1}_1)(\sum N\overline{x2}_2)^2} - \\
& - 2\frac{\sum(N^2 n_{12} sy1y2_{12}/(n_1 n_2))}{(\sum N\overline{x1}_1)(\sum N\overline{x2}_2)} - 2\frac{(\sum N\overline{y1}_1)(\sum N\overline{y2}_2)\sum(N^2 n_{12} sx1x2_{12}/(n_1 n_2))}{(\sum N\overline{x1}_1)^2(\sum N\overline{x2}_2)^2}
\end{aligned}
$$

Tests of significance of change over time were obtained using t-statistics t = Difference/√(Variance of difference). The P value was calculated using the t-statistics from the T-distribution, with differences being reported as significant at $P < 0.05$.

2.4.4 Factors associated with stream-bank erosion

In 2022, factors contributing to stream bank erosion were examined using linear regression analysis with the R 'lm' function. The focus was on identifying the drivers of stream bank erosion, so the stratified survey design was not considered. Four dependent variables were analysed: active erosion, active or recent erosion, disturbed soil (active or recent erosion or more than 50% pugging), and any signs of erosion or disturbance (active or recent erosion or any level of pugging). These variables were measured as percentages of bank length at each sample site. The independent variables included the percentage of effectively fenced bank length and the percentage of bank length with woody vegetation.

Tests of significance for the coefficients (intercept and dependent variable of interest) were calculated using t statistics, with t = coefficient value/standard error. The P value was calculated using the t-statistics from the T-distribution, with coefficients reported as significant at $P < 0.05$.

3 Results and discussion

The following subsections present and discuss the riparian characteristics survey results in relation to riparian fencing, stock access and exclusion, riparian vegetation, riparian buffer width, waterway crossings, and streambank erosion. The state (as at the time of the 2022 survey) is described for each of these factors. Change over time (i.e. over the past 5, 10, 15, and 20-year periods) is examined for riparian fencing, stock access, riparian vegetation, and stream-bank erosion. Information presented in these subsections follow the same general structure involving a description of the overall (region-wide) status, status by land use type, status by management zone, and status by stream order. A summary of key results is provided at the end of each subsection and average values presented in the graphs are provided in Appendix 4. Additional subsections describing the 2022 survey results in relation to drivers of stream-bank erosion and regulatory requirements as outlined in the Action for Healthy Waterways package (Ministry for the Environment 2020a) and the 2020 Proposed Plan Change 1 decisions version document (Schedule C; Waikato Regional Council, 2020) are also included. The report concludes with an evaluation of the current survey design.

3.1 Riparian fencing

3.1.1 State

Of the sampled waterways across the Waikato Region in 2022, 58% of the surveyed bank length was effectively fenced (Figure 4). Effective fencing was defined as that which is sufficient to prevent stock access to the waterway and is adjacent to riparian margins. The remainder of the bank length (42%) was either not fenced at all or was ineffectively fenced.

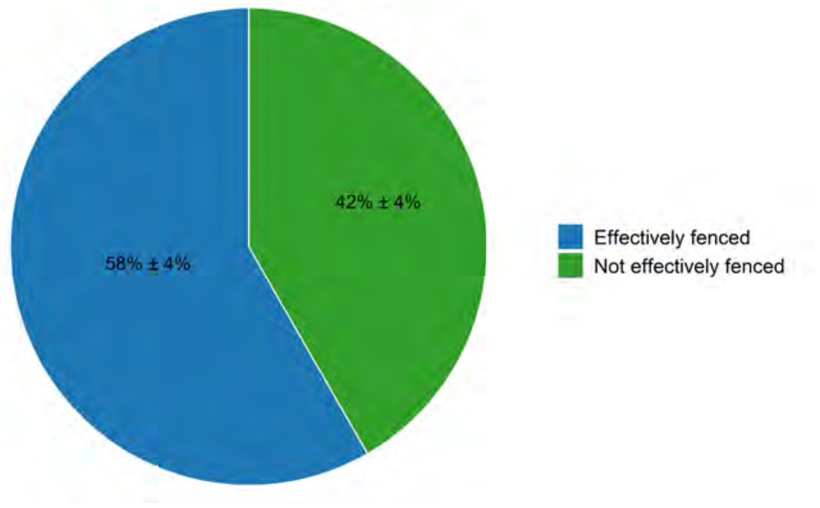


Figure 4. **Average proportion of bank length effectively fenced and not effectively fenced across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

Most fencing was observed as effective permanent (57%), with effective temporary fencing accounting for only 2% of the surveyed bank length across the region (Table 6). Temporary fencing was defined as fencing that could be moved or removed with relative ease. Most of the bank length that was not effectively fenced was found to be completely unfenced, with ineffective fencing accounting for only 2% of bank length. These results suggest that where fencing has been installed, it is predominantly fit for purpose (i.e. effective at excluding stock) and is a relatively permanent fixture.

Table 6. **Average proportion of bank length occupied by each fence status type across the Waikato region in 2022.**

	Fencing status type	Proportion of bank length (%)	
		Average	95%CI†
Effectively fenced	Effective permanent	56.8	3.7
	Effective temporary	1.5	0.8
Not effectively fenced	Ineffective	2.3	0.7
	Unfenced	39.4	3.9

† 95% confidence interval about the average

The configuration of effective riparian fencing across the region in 2022 was also examined in terms of the average proportions of stream length effectively fenced on either one bank, both banks, or neither bank (Figure 5). About half (51%) of the stream length across the region in 2022 was effectively fenced on both banks with a relatively small proportion of stream length (14%) fenced on only one bank. Effective fencing was absent on both banks for the remaining 35% of streambank. Effective fencing on both banks is required for complete exclusion of stock from the waterway.

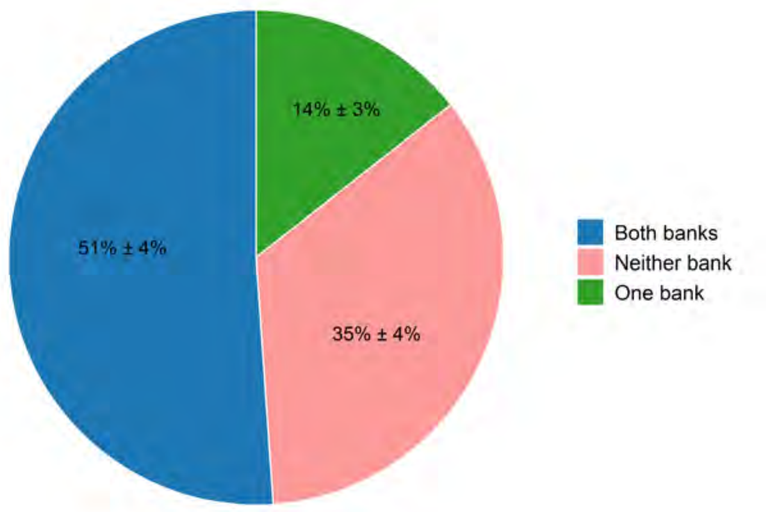


Figure 5. **Average proportion of stream length effectively fenced on one bank, both banks, and neither bank across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

Consistent with previous regional riparian surveys, there were clear differences in the proportion and configuration of effective riparian fencing between dairy and drystock land uses (Figure 6). The average proportion of bank length effectively fenced was significantly greater for dairy (88%) compared to drystock (36%) ($t = 15.9$, $P < 0.0001$). Similarly, the proportion of stream length effectively fenced on both banks was significantly greater for dairy (81%) compared to drystock (29%) ($t = 14$, $P < 0.0001$), and a significantly higher proportion of stream length was unfenced on both banks for drystock (57%) compared to dairy (5%) ($t = 15$, $P < 0.0001$). The proportion of streambank that was effectively fenced on one bank (and not the other) was similar between land uses. The observed differences in fencing proportion and configuration between dairy and drystock is generally consistent with dairy farms being located on flatter land, making fencing more cost effective. Additionally, the dairy industries active promotion of waterway fencing through the Dairy and Clean Streams Accord (active from 2003 to 2012) and the relative financial strength of the dairy industry has contributed to these results. The Clean Streams Accord was superseded by the Dairying Water Accord (DairyNZ, 2015).

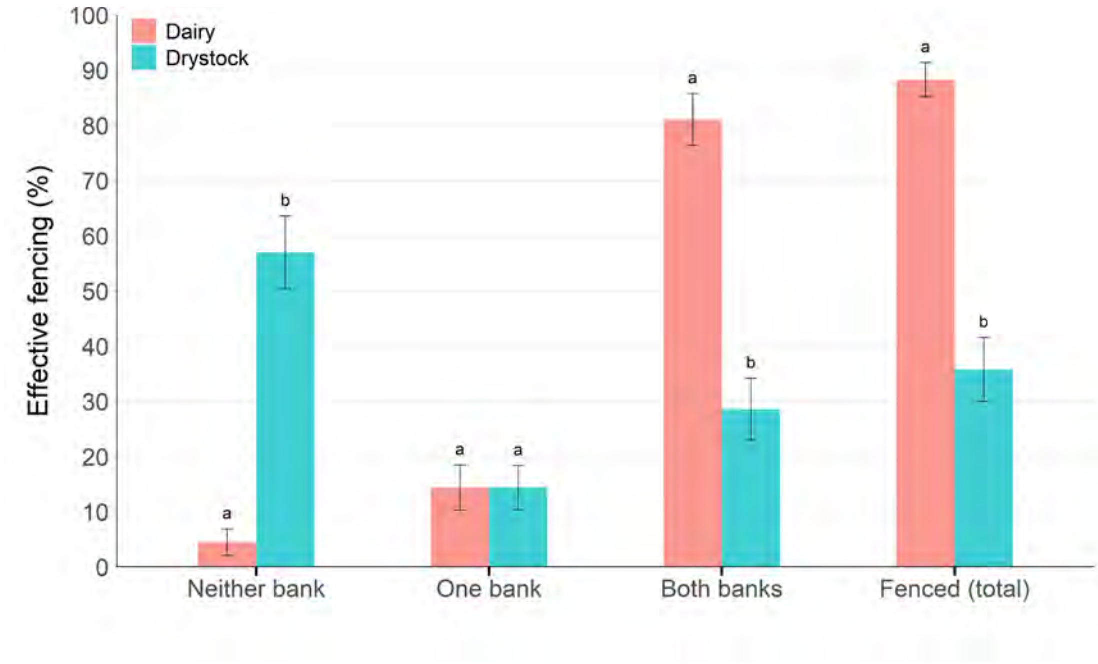


Figure 6. **Average proportion of bank length effectively fenced (total) and average proportion of stream length effectively fenced on one bank, both banks, and neither bank within land use types across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

The average proportion of surveyed bank length effectively fenced for each management zone in 2022 is presented in Figure 7 with raw data contained in Appendix 4 (Table A4-1). The proportion of bank length effectively fenced was comparable between the Central Waikato, Coromandel, Lake Taupō, and Waipā management zones, ranging from 59% to 79%. The Upper Waikato and Waihou-Piako management zones had the highest proportion of bank length effectively fenced with values of 81% and 85%, respectively. Pairwise analysis revealed that the proportion of bank length effectively fenced was significantly higher (P < 0.05) in the Upper Waikato and Waihou-Piako zones compared to the Lower Waikato, Waipā, and West Coast management zones (54%, 66% and 20%, respectively) (Figure 7). The West Coast management zone had the lowest proportion of bank length effectively fenced (20%) compared to all other zones, with the differences being statistically significant (Figure 7). The hilly and often steep terrain, combined with the prevalence of drystock farms, is likely to have contributed to the relatively limited extent of fencing in the West Coast management zone. In contrast, significant efforts have been made by WRC and its predecessors to encourage fencing of waterways in the Waihou-Piako, Upper Waikato, and Lake Taupō management zones through historic soil conservation initiatives (Waikato Regional Council, 1998b; Palmer, 2004) and adherence to Method 4.3.5.3 of the Waikato Regional Plan, which mandates the exclusion of livestock from mapped portions of high-priority water bodies, including specific sections of the Waihou River and all tributaries flowing into Lake Taupō.

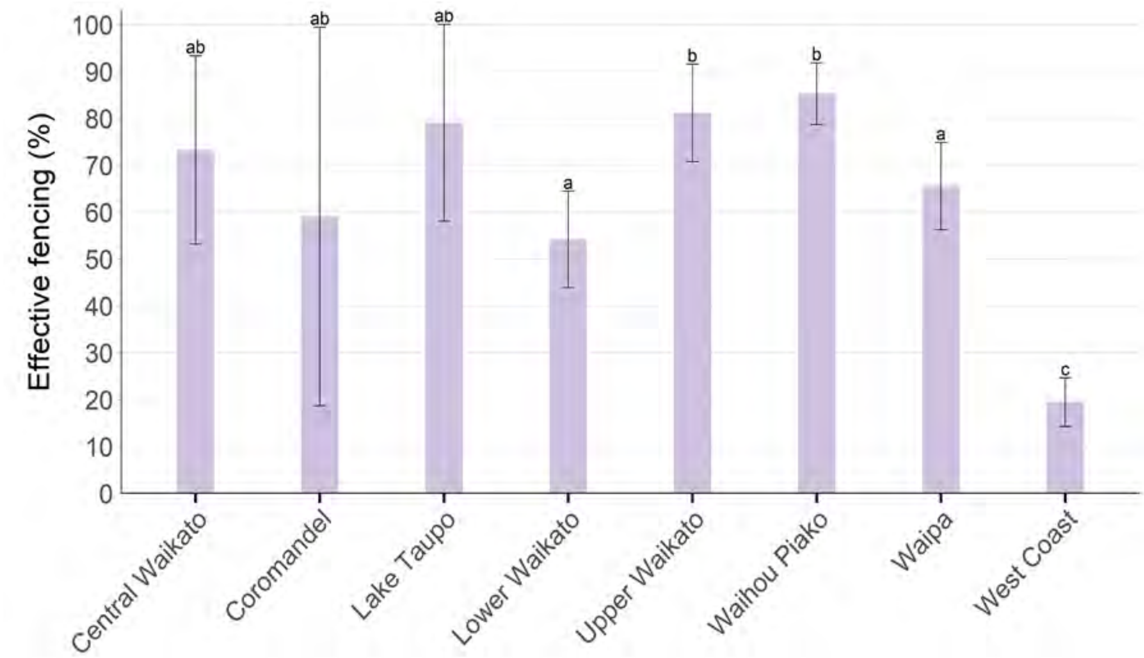


Figure 7. **Average proportion of bank length effectively fenced within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

The average proportions of bank length effectively fenced for each stream order in 2022 are presented in Figure 8. The average proportion of bank length effectively fenced was largest for drains (stream order 0), reflecting the relative ease with which these features can be fenced (often straight, linear features located on flat land) and their location on predominantly dairy enterprises (See Table A1-1). Excluding drains, there was a general increase in the proportion of effectively fenced bank length with increasing stream order. Across larger waterways (stream orders 4 to 6), 72 to 82% of bank length had effective fencing. In contrast, smaller to medium sized waterways (stream orders 1 to 3) had a lower proportion of effective fencing, ranging from 47 to 63%. Larger waterways are often prioritised for fencing as they present a greater risk of livestock losses and are more likely to meet funding criteria for protective measures. Small to medium sized waterways are more likely to occur in steep, hilly terrain, making the establishment of effective fencing challenging and costly. Given that lower order streams often contribute the most to contaminant loads in agricultural catchments (McDowell et al., 2017), it may be necessary to explore alternative strategies for reducing these loads, especially in situations where excluding livestock from waterways is either impractical or not required under regulatory frameworks.

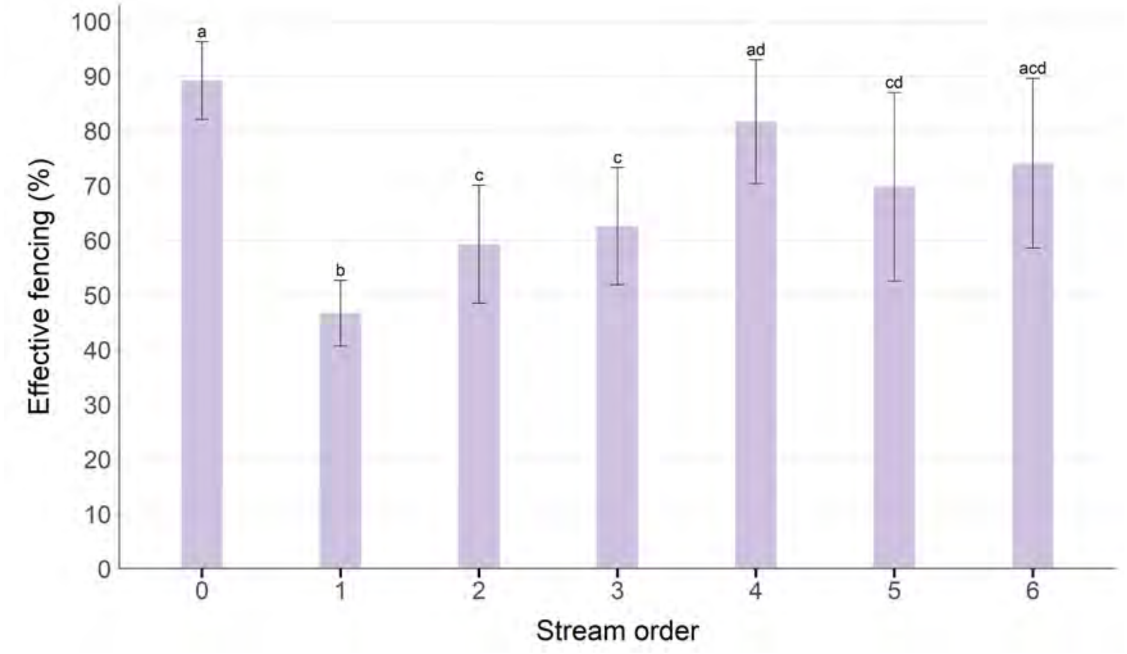


Figure 8. Average proportion of bank length effectively fenced within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.

3.1.2 Change over time

The average proportion of bank length fenced across the Waikato region significantly increased over the past 20 years (t = 11.1, P < 0.0001) from 29% in 2002 to 58% in 2022 (Figure 9, Table 7). This increase occurred at a relatively uniform rate between 2002 and 2017 (about 2.2% bank length per year). Over the past 5 years (2017 to 2022), the proportion of bank length fenced decreased significantly by 3% (t = 2.064, P = 0.04). However, the overall decrease in effective fencing from 2017 to 2022 was only marginally significant and is primarily due to a significant reduction in effective fencing within the West Coast management zone. Once the West Coast sites were removed from the dataset, the proportion of bank length effectively fenced remained unchanged between 2017 and 2022, with a non-significant (P > 0.05) decrease of 1% over the five-year period. Possible reasons for the reduction in the estimates of effective fencing within the West Coast zone are highlighted in the 'management zone' results section (Table 9) below.

At the time of the 2017 survey (Norris et al., 2020) and based on a total bank length of approximately 48,000 km in pastoral land in the region, 61% (28,000 km) was effectively fenced. Based on an annual increase in fencing of 2% of bank length per year, Norris et al. (2020) postulated that it would take a further 20 years to fence the remaining 20,000 km's of bank length, assuming that all bank length can and will be fenced. However, the latest 2022 survey results show that annual increases in the proportion of effectively fenced stream banks have slowed or plateaued in many parts of the region over the past 5 years (Table 7). At the conclusion of the Sustainable Dairying Water Accord in 2017 (DairyNZ, 2018), 87% of riverbanks on dairy farms were effectively fenced (Norris et al., 2020), with a slight increase to 90% in the 2022 survey. Evidently, the region-wide annual increases in effective fencing were primarily driven by increased fencing along waterways on dairy farms due to the impact of the Sustainable Dairying Water Accord. However, unfenced waterways are still prevalent in drystock enterprises and steep hill-country areas where implementing effective fencing remains a difficult and costly task. Hence, significant investment is required to deal with the remaining 42% of unfenced stream banks across the region, most of which of which are located across drystock enterprises.

The magnitude and statistical significance of changes in the proportion of surveyed bank length that is fenced are provided in Table 7. The configuration of that fencing, expressed in terms of stream length fenced over time, is also detailed in Table 7. Over the past twenty years, there has been a significant increase in the average proportion of stream length fenced on both banks ($t = 9.5$, $P < 0.0001$), while the average proportion of stream length fenced on only one bank or neither bank has significantly decreased ($t = 6.97$, $P < 0.0001$). Over the past ten years (2012 - 2022), the proportion of unfenced waterways remained unchanged ($t = 0.96$, $P = 0.34$), while the proportion of stream length fenced on one bank decreased significantly ($t = 3.05$, $P < 0.001$), suggesting that new riparian fencing was targeted towards those streams that were already partially fenced. More recently, from 2017 – 2022, there were no significant changes in the configuration of fencing (expressed in terms of stream length), confirming that overall fencing of waterways has stalled across the region.

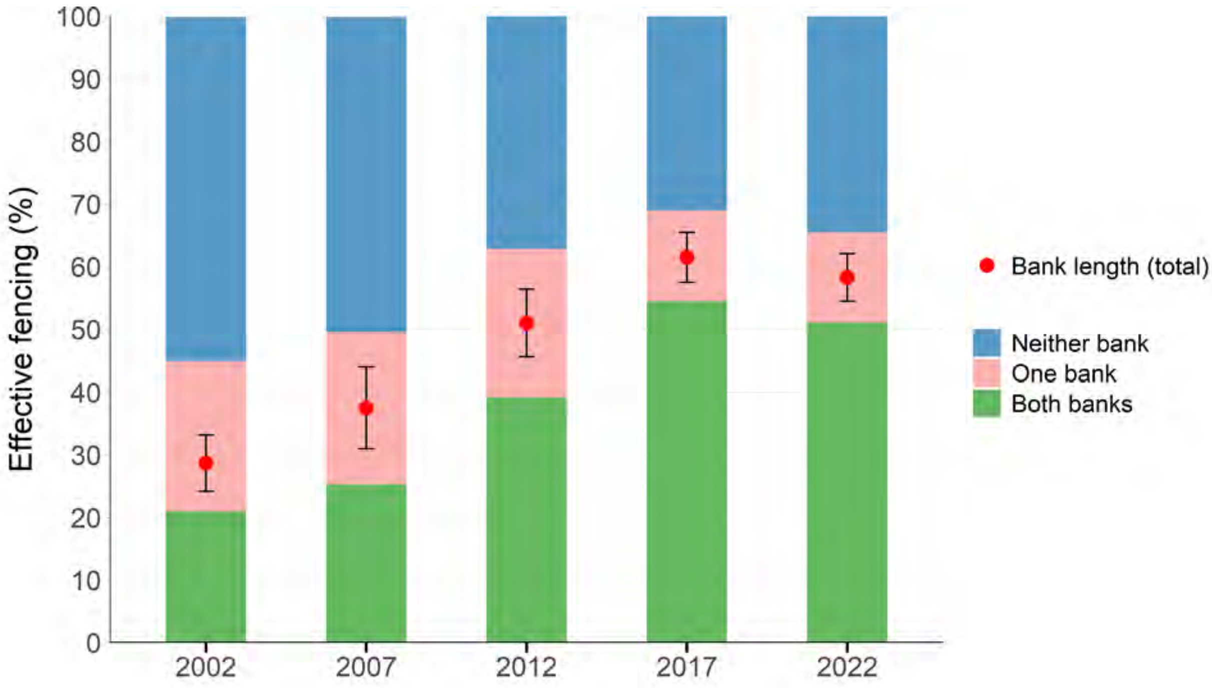


Figure 9. **Average proportion of stream length (one bank, both banks, or neither bank) and average proportion of total bank length (represented by the red symbols) effectively fenced for each the five survey years (2002, 2007, 2012, 2017, and 2022). Error bars represent the 95% confidence interval around the average proportion of effectively fenced bank length.**

Table 7. **Average change in the proportion of effective fencing for total bank length and stream length categories (one bank, both banks or neither bank) over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2022) and 20-year (2002 – 2022) periods.**

Measure	Category	2017 - 2022 (5-year)		2012 – 2022 (10-year)		2007 - 2022 (15-year)		2002 – 2022 (20-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Bank length	Total	-3*	3	7**	5	21**	7	30**	5
Stream length	Both-banks	-3 NS	3	12**	7	26**	8	30**	6
	One-bank	0 NS	4	-9**	6	-10**	7	-10**	6
	Neither-bank	4 NS	4	-3 NS	5	-16**	7	-21**	6

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, NS Not significant.

Despite a small decline in the proportion of stream bank effectively fenced across the region over the past 5 years, the amount of effective permanent fencing increased, although the difference was not statistically significant ($t = 0.5$, $P > 0.05$) (Figure 10). Over the same period, effective temporary fencing decreased significantly ($t = 5.14$, $P < 0.001$). This suggests that some stream banks previously protected by temporary fencing are now permanently fenced. Additionally, it is possible that temporary fencing was removed from surveyed sites in the absence of livestock, resulting in their classification as “unfenced” in 2022, even though they may have been fenced in 2017. Between 2002 and 2022, there was a notable decline in ineffective fencing, with the proportion decreasing from 4.4% to 2.3% ($t = 2.39$, $P < 0.05$) (Figure 10).

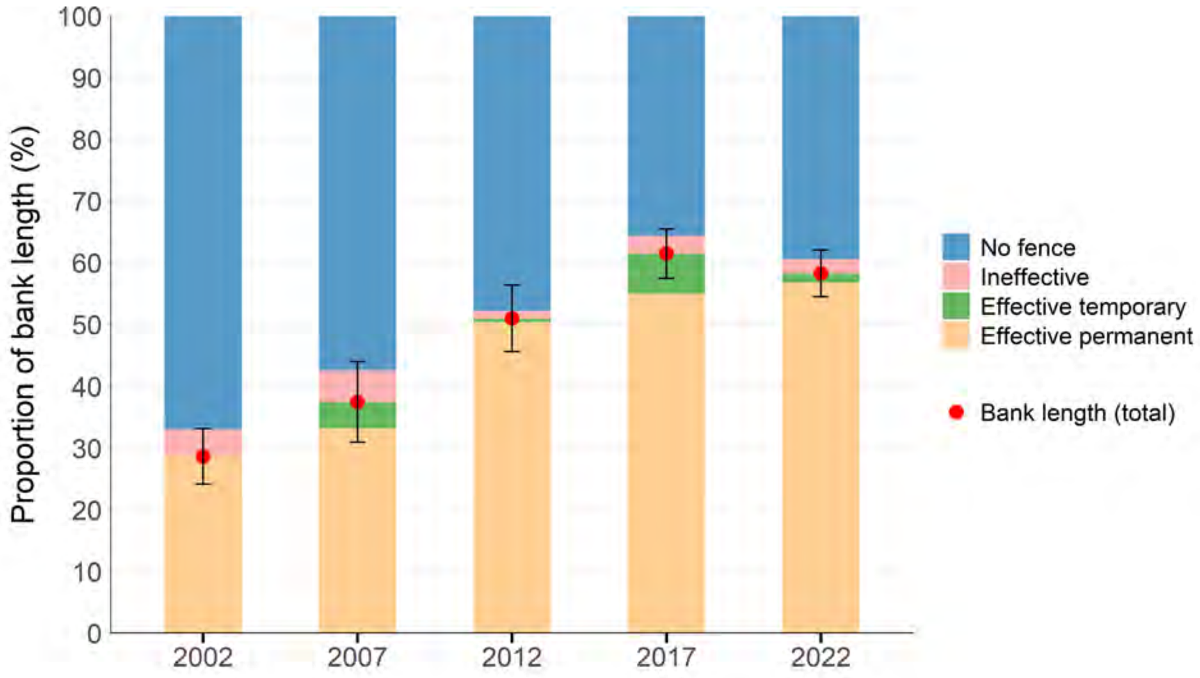


Figure 10. Average proportion of bank length (total – indicated by the red symbols) with no fence or fenced (ineffective, effective temporary or effective permanent) for each of the five survey years (2002, 2007, 2012, 2017, and 2022). Error bars represent the 95% confidence interval around the average proportion of effectively fenced bank length.

Regarding the influence of land use on the temporal variation in the average proportion of effectively fenced bank length, significant differences were observed between dairy and drystock (Figure 11). Over the past twenty years, the average proportion of bank length effectively fenced increased significantly from 44% in 2002 to 88% in 2022 for dairy ($t = 9.82$, $p < 0.0001$) and from 18% in 2002 to 35% in 2022 for drystock ($t = 5.07$, $p < 0.0001$). In the preceding 10-year (2012 – 2022) and 15-year (2007 – 2022) periods, the average proportion of bank length effectively fenced increased significantly for dairy but not for drystock (Table 8). Following the initial 5-year period (2002 – 2007), the rate of change increased for dairy but decreased for drystock. The most significant increase occurred during the 2007 – 2012 period, with an increase of approximately 5% of bank length per year for dairy farms. In contrast, the rate of fencing change for drystock during this period seemed to stall. Over the past 5 years (2017 – 2022), there was a small but non-significant annual increase of 0.2% for both dairy and drystock, suggesting an overall slowdown in the rate of fencing change over recent years. Over the entire monitoring period (2002 – 2022), the rate of change was about 2.2% per year for dairy and 0.9% per year for drystock. The significant increase in the average proportion of bank length fenced for dairy reflects the emphasis the dairy industry and other stakeholders have placed on promoting fencing of waterways through initiatives such as the Sustainable Dairying Water Accord (DairyNZ, 2018).

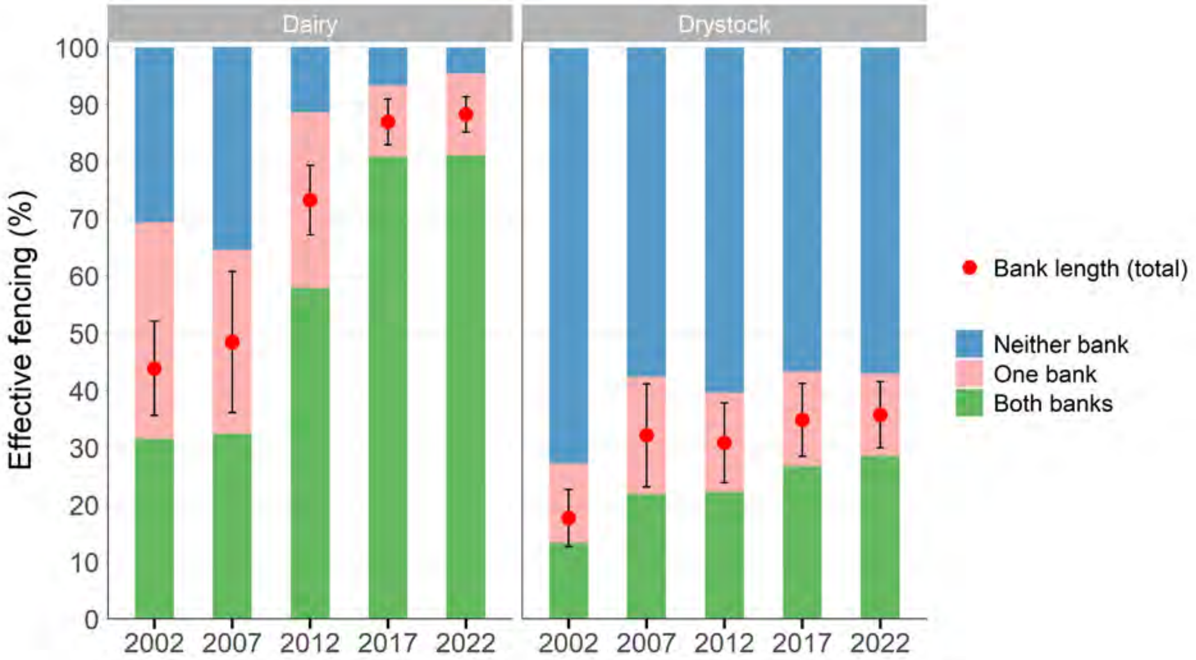


Figure 11. Average proportion of bank length (total) and stream length (one bank, both banks, or neither bank) effectively fenced within land use types at the five survey periods (2002, 2007, 2012, 2017 and 2022). The average proportion of bank length effectively fenced is represented by the red symbols. Error bars represent the 95% confidence interval around the average.

There were clear differences with respect to changes in riparian fencing configuration for dairy and drystock land uses (Figure 11, Table 8). For dairy farms, there were statistically significant increases in the average proportion of stream length effectively fenced on both banks for all time periods except for the 2017 to 2022 period. Correspondingly, there was a decrease in the proportion of bank length fenced on one bank and neither bank for all time periods except from 2017 to 2022. Between 2007 and 2012, efforts primarily focused on fencing previously unfenced waterways, while from 2012 to 2017, there was an increased focus on completing partially fenced stream sections. For drystock, changes in fencing configuration were significant over the entire monitoring period (2002 - 2022), but with no statistically significant changes in measures over the previous 5-year (2017 – 2022), 10-year (2012 – 2022) and 15-year (2007 – 2022) monitoring periods (Figure 11, Table 8).

Table 8. **Average change in the proportion of bank length effectively fenced and stream length fenced on one bank, both banks, or neither bank within land use types over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2022) and 20-year (2002 – 2022) periods.**

		2017–2022 (5-year)		**2012–2022 (10-year)**		**2007–2022 (15-year)**		**2002–2022 (20-year)**	
	Land use type	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Fenced (total)	Dairy	1 NS	4	15**	7	40**	13	44**	9
	Drystock	1 NS	7	5NS	8	4 NS	9	18**	7
Both banks	Dairy	0 NS	6	23**	11	49**	14	49**	12
	Drystock	2 NS	6	6 NS	8	7 NS	10	15**	7
One bank	Dairy	2 NS	5	-16**	10	-18**	12	-23**	12
	Drystock	-2 NS	6	-3 NS	7	-6 NS	7	1 NS	6
Neither bank	Dairy	-2 NS	4	-7**	5	-31**	15	-26**	8
	Drystock	0 NS	8	-3 NS	9	-1 NS	10	-16**	9

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Changes in the average proportion of bank length effectively fenced within management zones over the past twenty years are presented in Table 9. Over the entire monitoring period (2002 - 2022), significant increases were observed in all management zones, except for the Lake Taupō and West Coast zones. In the initial 2002 survey, the Lake Taupō zone had a relatively high proportion of bank length effectively fenced (56%), while for the West Coast zone, a significant decrease in effective fencing over the past 5 years masked any long-term increases. In 2022, there was a high proportion of replacement sites within the West Coast management zone due to land use changes since the previous survey (e.g. pasture to forestry) or because site access was not granted. Replacement sites were only considered if the land use and stream order matched the original site, to satisfy the requirements of random stratified sampling. The high proportion of replacement sites may have contributed to the observed decrease in the proportion of effectively fenced bank length in the West Coast zone since 2017. It is noted that the variance around these estimates were generally high, as indicated by some large 95% confidence intervals values and can be attributed to smaller sample sizes in comparison to the region-wide analysis. Furthermore, due to the high variability of estimates within management zone strata, statistically significant changes could only be detected over extended periods (10 years or more). This underscores the importance of regular, long-term monitoring to observe changes in key riparian attributes at the zone level over time.

Table 9. **Average proportion of bank length effectively fenced within management zones during the five survey periods (2002, 2007, 2012, 2017, and 2022) and average change over the previous 5-year (2017 – 2012), 10-year (2012 – 2022), 15-year (2007 – 2022) and 20-year (2002 – 2022) periods.**

Managemen t zone	Average bank length (%)					2017—2022 (5-year)		2012—2022 (10-year)		2007—2022 (15-year)		2002—2022 (20-year)	
	2002	2007	2012	2017	202 2	Change (pp†)	95 %CI ‡	Change (pp†)	95% CI‡	Chang e (pp†)	95% CI‡	Chang e (pp†)	95% CI‡
Central Waikato	31	51	63	63	73	11 NS	12	11 NS	25	22*	19	42**	26
Coromandel	19	23	42	61	59	-2 NS	12	18 NS	22	36*	32	40*	34
Lake Taupō	56	54	65	73	79	6 NS	11	14 NS	36	25 NS	36	23 NS	34
Lower Waikato	38	42	57	59	54	-5 NS	8	-3 NS	18	12 NS	14	16*	15
Upper Waikato	47	56	77	83	81	-2 NS	6	4 NS	9	25**	18	34**	15
Waihou-Piako	35	42	59	84	85	1 NS	4	27**	11	43**	20	50**	14
Waipā	20	31	53	67	66	-1 NS	8	13 NS	15	35**	13	46**	13
West Coast	7	21	21	28	20	-9*	8	-1 NS	7	-1 NS	15	12NS	7

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Over the past twenty years, the average proportion of surveyed bank length effectively fenced has significantly increased across all stream orders except for 6th order streams (Table 10). Stream orders 4 and 5 demonstrated the most significant changes during this period, with changes of 58% and 47% of bank length, respectively. More recently (2012–2022), statistically significant increases were restricted to stream orders 2, 3, and 4 and over the past 5 years (2017 – 2022), no changes were detected across stream orders. Like the zone-based estimates, the variance around estimates were large for some stream order strata (e.g. orders 5 and 6) due to low replication.

Table 10. **Average proportion of bank length effectively fenced within stream orders during the five survey periods (2002, 2007, 2012, 2017, and 2022) and average change over the previous 5-year (2017 – 2012), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 – 2022) periods.**

Stream order	Average bank length (%)					2017—2022 (5-year)		2012—2022 (10-year)		2007—2022 (15-year)		2002—2022 (20-year)	
	2002	2007	2012	2017	2022	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	61	70	78	90	89	0NS	5	11 NS	17	19 NS	22	28**	19
1	19	29	46	51	47	-4 NS	4	1 NS	7	18**	10	27**	6
2	34	35	44	66	59	-7 NS	7	15**	10	24**	9	25**	12
3	24	33	47	58	63	5 NS	13	16*	15	30**	19	39**	17
4	24	29	48	78	82	4 NS	13	33**	19	52**	20	58**	26
5	23	54	71	81	70	-11 NS	28	-1 NS	41	16 NS	64	47*	41
6	25	51	77	80	74	-6 NS	34	-3 NS	59	23 NS	65	50 NS	57

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

In line with the previous 2017 regional riparian survey, fencing results in 2022 were based on the general land use definition recorded at the start point of each survey segment (Farm type general in Figure 12). To assess the accuracy of this approach, fencing results were also calculated using continuous land use (recorded along the length of the surveyed riparian margin) and Agribase™-defined land use classification (Figure 12). The results derived from continuous land use analysis are the most representative, as they capture more subtle changes in land use and fencing assessments. For example, this method effectively identifies instances where a cropping block occurs within a dairy farm. When comparing the current farm-level approach for estimating land use at the start of each transect to continuous land use estimated along the transect, the proportion of effectively fenced bank length increased from 88% to 92% for dairy farms and from 36% to 37% for drystock farms. Overall, the differences in effective fencing between the three land use classification methods were minimal (Figure 12). This indicates that the current approach of using the general land use definition is an accurate method to report results. Since past surveys measured land use based on the general land use definition, using either Agribase or on-farm assessments, future surveys will likely adopt a similar approach. This will ensure consistency in evaluating land use over time and simplify the definition of land use for each site.

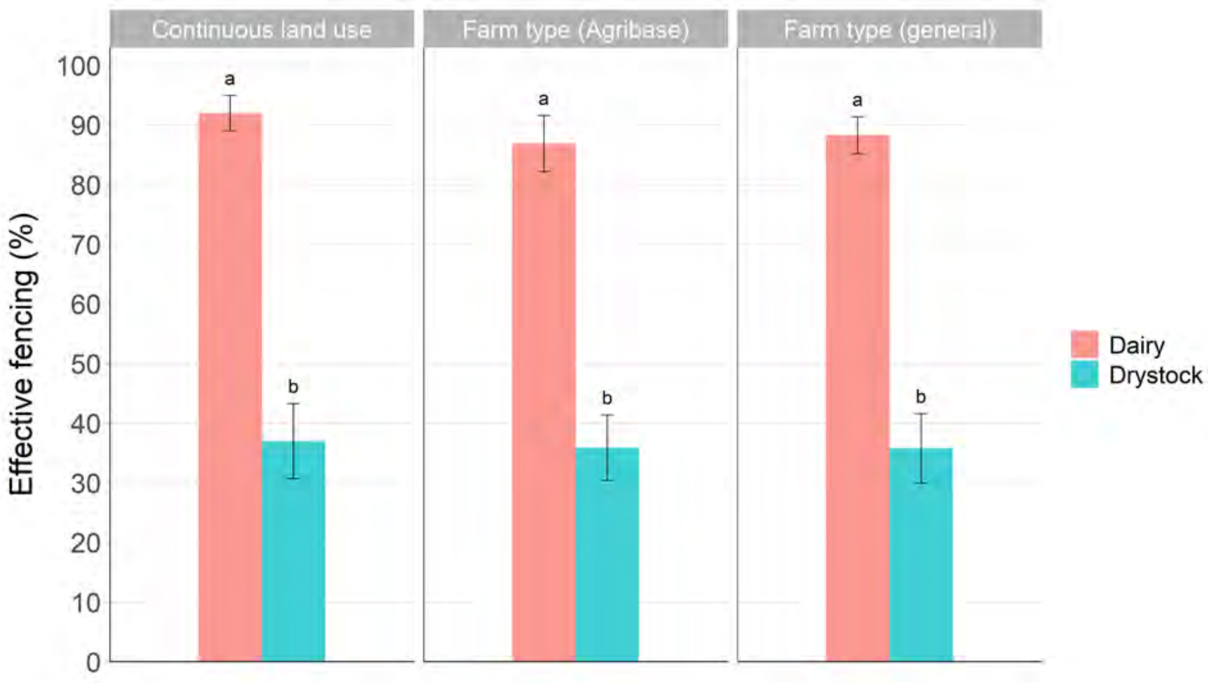


Figure 12. **Average proportion of bank length (total) effectively fenced in 2022 calculated with three land use classification systems including continuous land use (recorded with a handheld Trimble TDC 600), Agribase™-defined land use, and the general land use classification system outlined in Section 2.3.2. Error bars represent the 95% confidence interval about the average. Within each land use category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).**

3.1.3 Summary of key fencing results

The key findings regarding waterway fencing are as follows:

- Across the Waikato region, 58% of surveyed bank length was effectively fenced during the 2022 survey.
- Consistent with the previous survey, the average proportion of surveyed bank length effectively fenced for dairy (88%) was significantly higher than that of drystock (36%).
- The highest proportion of surveyed bank length effectively fenced occurred in the Waihou-Piako zone (85%), with the lowest proportion being in the West Coast management zone (20%).
- The highest average proportion of effective fencing occurred along drains (89%), reflecting the relative ease with which these features can be fenced (often straight, linear features located on flat land). Small to medium sized waterways (stream orders

1–3) had the lowest average proportions of surveyed bank length effectively fenced (47–63%).

- Over the past 20 years (2002 – 2022), the average proportion of surveyed bank length has increased significantly across the region, from 29% in 2002 to 58% in 2022. The rate of change over this period was approximately 1.5% of bank length per year, noting that there was large variance in fencing estimates within respective surveys and within strata.
- There were considerable differences in the rate of change in the average proportion of bank length effectively fenced on dairy farms compared to those on drystock farms. Specifically, dairy farms saw an annual increase in effectively fenced bank length of 2.2% compared to 0.9% for drystock farms. Over the past 5 years (2017 – 2022), the rate of change was 0.2% of bank length per year for both dairy and drystock.
- Significant increases in the average proportion of surveyed bank length fenced over the past twenty years were observed in all except the Lake Taupō and West Coast management zones. Over the past 5 years (2017 – 2022), no changes were observed across management zones, except for the West Coast, which saw a 9% decrease in effectively fenced bank length. It is possible that the large number of replacement sites in the West Coast management zone explains some of the observed decrease in effectively fenced bank length.
- Over the past twenty years, the average proportion of surveyed bank length effectively fenced significantly increased in all stream orders except for stream order 6.
- When a continuous measure was employed to classify land use, only a modest increase in the percentage of effectively fenced bank length was observed, rising from 88% to 92% for dairy farms and from 36% to 37% for drystock farms.

3.2 Stock access and exclusion

3.2.1 State

In 2022, across the Waikato region, 58% of the surveyed bank length showed no evidence of stock access (Figure 13). The remaining 42% of bank length showed evidence of past, recent, or current stock access. Stock access types are defined in Table 3. Current stock access, which refers to stock observed within the waterway or the adjacent riparian margin during the survey, affected approximately 8% of the surveyed bank length. Across the region, the level of stock exclusion from waterways (58% of bank length) was equivalent to the proportion of effectively fenced bank length. This suggests that where effective fencing exists, stock are completely excluded from the waterway. This is a change from the 2017 survey, which found that for about 10% of bank length, stock access occurred in the presence of effective fencing (Norris et al., 2020). This implies that landowners are now less likely to graze effectively fenced riparian margins under recently implemented stock exclusion regulations.

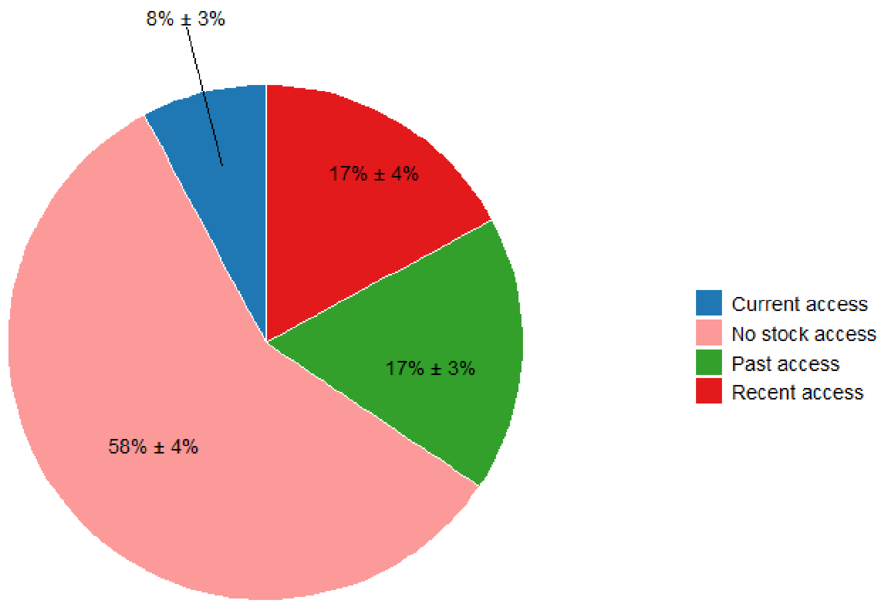


Figure 13. **Average proportion of bank length with no stock access and past, recent, or current stock access observed across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

The proportion of total bank length accessed by stock was significantly less for dairy (12%) compared to drystock (65%) ($t = 14.2$, $P < 0.0001$). The same was true for each individual stock access category (i.e. past, recent, and current). In the current and recent stock access categories, the percentage access values were 13 and 6 times higher for drystock compared to dairy, respectively. These findings are consistent with differences in effective fencing between dairy and drystock land uses (Figure 6).

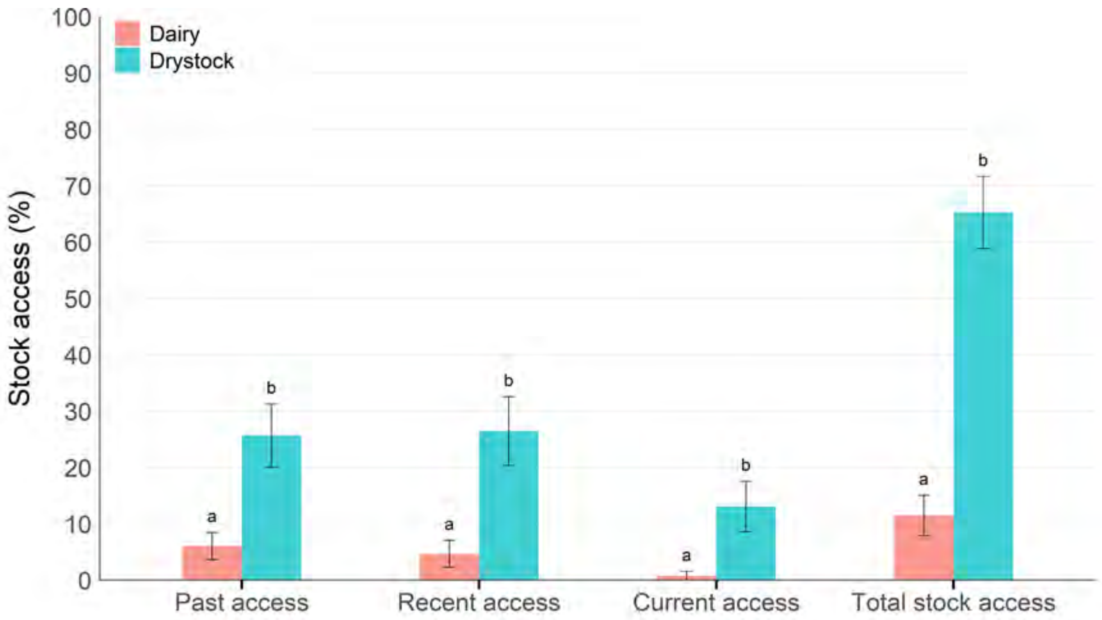


Figure 14. **Average proportion of bank length with total stock access and (constituent) past, recent, or current stock access observed across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

In 2022, the Waihou-Piako and the Upper Waikato management zones had the lowest proportion of sampled bank length with stock access (19% and 16%, respectively). Pairwise comparison revealed that the proportion of bank length with stock access were significantly lower in the Waihou-Piako and the Upper Waikato compared to the Lower Waikato, Waipā, and West Coast management zones, which had proportions of 40%, 38% and 81%, respectively (Figure 15). The lower incidence of stock access in the Waihou-Piako and Upper Waikato zones aligns well with the data on the proportion of effectively fenced bank length. These same zones had the highest proportion of fenced bank length, as seen in Figure 7.

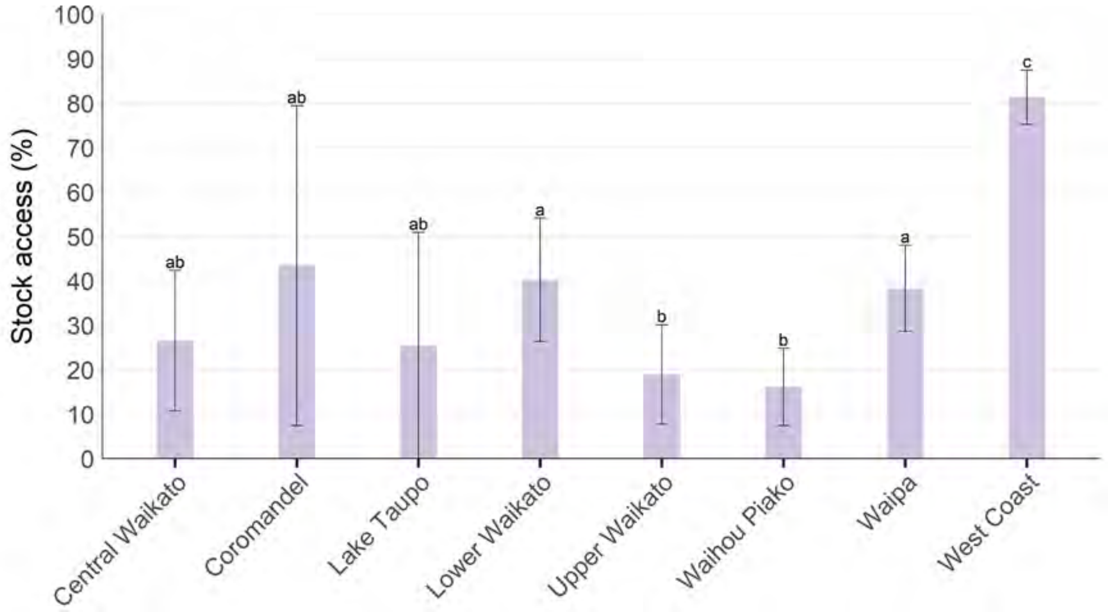


Figure 15. Average proportion of bank length with observed stock access within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.

Figure 16 shows the percentage of surveyed bank length with observed stock access across stream orders. Observed stock access was highest for stream orders 1 – 3, with values of 56%, 39% and 39%, respectively (Figure 16). Drains and 6th order streams had the lowest proportion of bank length with observed stock access (11% and 2%, respectively). Stream orders 4 and 5 had a relatively low occurrence of stock access, with values of 16% and 13%, respectively. The proportion of sampled bank length subject to stock access was significantly lower for drains along with 4th to 6th order streams compared to 1st to 3rd order streams. The extent of stock access along first order streams was significantly greater than for all other stream orders (Figure 16). Overall, smaller streams and rivers (stream orders 1 – 3) had the highest proportion of bank length accessible to stock, which correlates to the low proportion of effective fencing along these waterways (Figure 8). In terms of mitigating the direct input of contaminants into waterways from stock, greater effort is required to protect lower order waterways in the upper reaches of catchments. A recent study by McDowell et al. (2017) examined the impact of stream order and catchment characteristics on contaminant loads across 728 water quality monitoring sites across New Zealand. Contaminant loads from low order streams (< 1 m wide, 30 cm deep) exempt from potential national stock exclusion regulations accounted for an average of 73% for total nitrogen loads and 84% for total phosphorous. Across the Waikato Region, about 53% of sampled bank length along first order streams remained unfenced, with 56% being accessible to stock. Given that lower order streams often contribute the most to contaminant loads in agricultural catchments (McDowell et al., 2017), it may be necessary to explore alternative strategies for reducing these loads. This is especially important in situations where excluding livestock from waterways is either impractical or not required under regulatory frameworks.

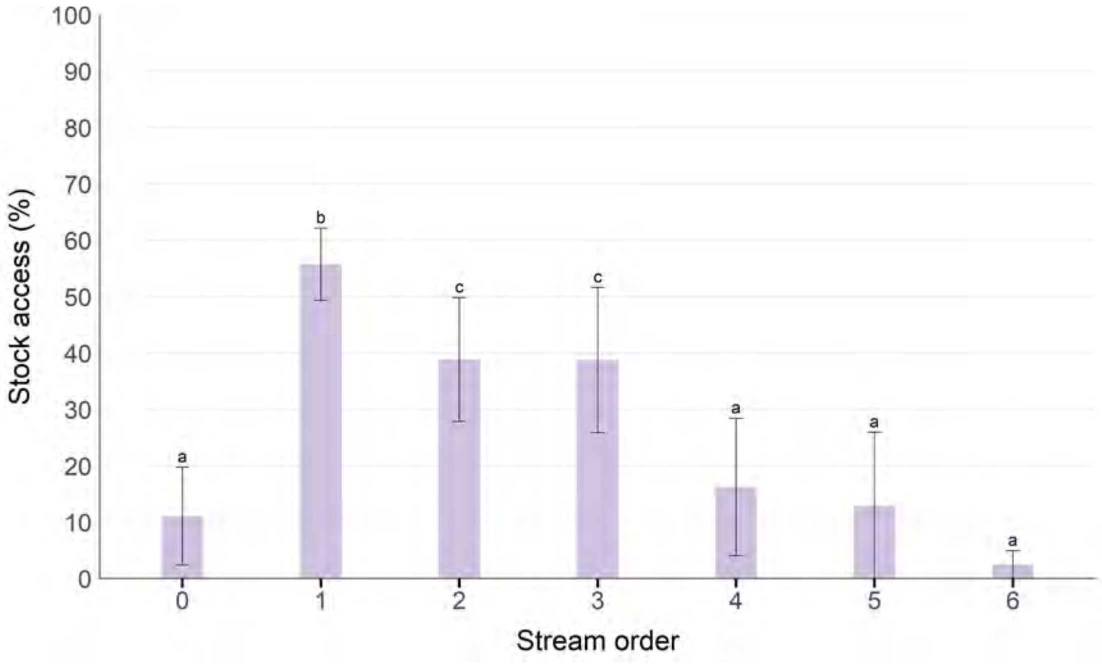


Figure 16. **Average proportion of bank length with observed stock access within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

3.2.2 Change over time

The average proportion of surveyed bank length showing evidence of stock access decreased significantly over the past five years ($t = 4.57$, $P < 0.0001$) from 51% in 2017 to 42% in 2022 (Figure 17, Table 11). This decrease occurred despite a slight overall reduction in the length of bank fenced across the region suggesting an improvement in the efficacy of existing fencing structures. It may also imply that landowners are now less inclined to intentionally graze riparian margins due to implementation of national stock exclusion regulations. The proportion of bank length with evidence of past or recent stock access remained relatively stable ($P > 0.05$ in both cases), while current stock access saw a significant decline of 12% between 2017 and 2022 ($t = 4.77$, $P < 0.0001$).

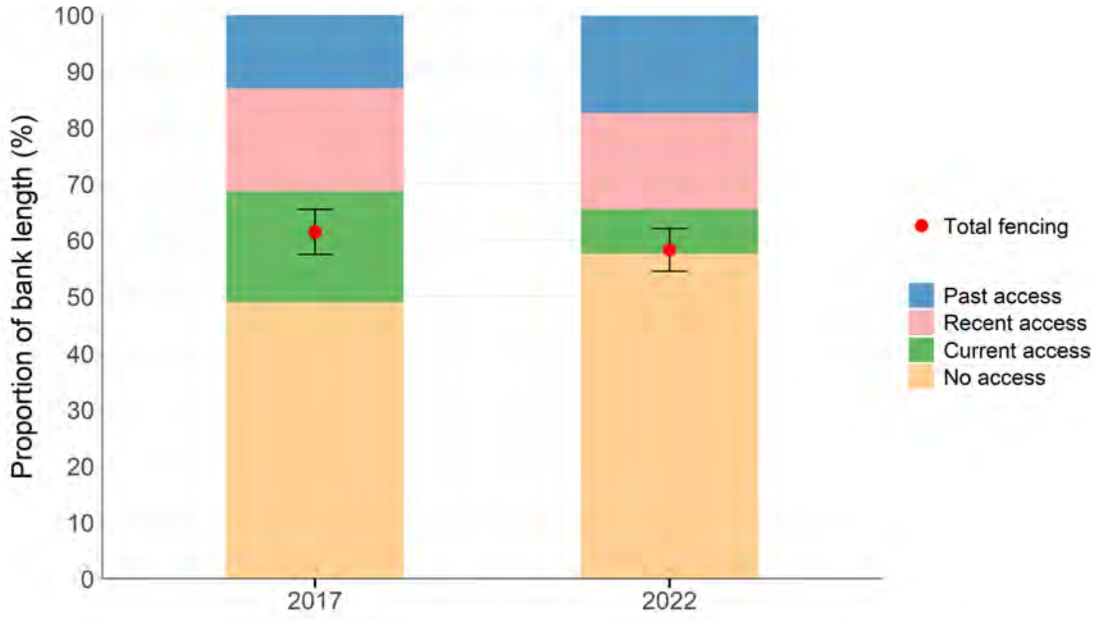


Figure 17. **Average change in the proportion of bank length with no stock access and past, recent, or current stock access observed across the Waikato region for the last two survey years (2017 and 2022). Red dots represent the average proportion of sampled bank length accessible to stock, while error bars show the 95% confidence intervals around the average.**

Table 11. **Average proportion of bank length effectively fenced within management zones during the two most recent survey periods (2017 and 2022) and average change over the previous 5-year (2017 – 2012) period.**

Stock access category	Average bank length (%)		2017 – 2022	
	2017	**2022**	**Change (pp†)**	**95%CI‡**
Past	13	17	4 NS	4
Recent	18	17	-1 NS	4
Current	20	8	-12**	5
Total access	51	42	-9**	4

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Comparable trends in stock access data were identified for both dairy and drystock land uses, consistent with the patterns observed across the region as a whole (Figure 18,

Table 12). Over the past 5 years, the average proportion of bank length with current stock access decreased from 9% in 2017 to 1% in 2022 for dairy ($t = 4.19$, $P < 0.0001$) and from 31% to 13% for drystock ($t = 4.05$, $P < 0.0001$). Notably, within the drystock land use, the proportion of bank length with evidence of past stock access increased significantly from 16% in 2017 to 26% in 2022 ($t = 2.46$, $P < 0.05$), suggesting that although there was evidence of stock presence along riparian margins, there was a decrease in the frequency of grazing. When considering total access, the proportion of bank length subject to stock access (i.e. sum of past, recent, and current access) decreased for both dairy and drystock, by 15% ($t = 4.23$, $P < 0.001$) and 11% ($t = 4.023$, $P < 0.0001$), respectively. This occurred despite the proportion of fencing remaining relatively stable for both dairy and drystock land uses.

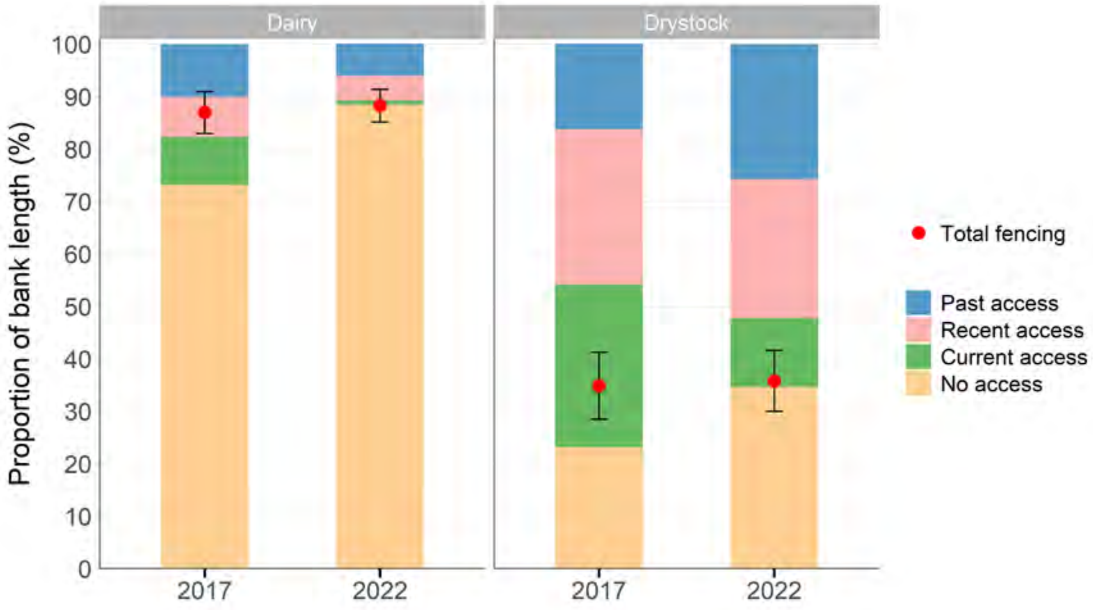


Figure 18. **Average proportion of bank length (total) with no stock access, and past, recent, or current stock access within land use types at the two most recent survey periods (2017 and 2022). Average proportion of bank length effectively fenced (Total fencing) is indicated by the red symbols, with error bars representing the 95% confidence interval about the average.**

Table 12. **Average proportion of bank length with past, recent, or current, as well as total stock access observed across the Waikato region within land use types at each of the two survey periods and average change over the previous 5-year (2017 – 2022) period.**

Stock access category	Land use type	Average bank length (%)		2017 - 2022 (5-year)	
		2017	2022	Change (pp†)	95%CI‡
Past	Dairy	10	6	-4*	4
	Drystock	16	26	10*	8
Recent	Dairy	8	5	-3^{NS}	3
	Drystock	30	27	-3^{NS}	8
Current	Dairy	9	1	-8**	4
	Drystock	31	13	-18**	9
Total access	Dairy	27	12	-15**	5
	Drystock	77	65	-11**	7

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Changes in the average proportion of surveyed bank length subject to stock access within management zones over the past five years (2017 – 2022) are presented in Table 13. Across most management zones, there were decreases in the average proportion of bank length subjected to stock access. Notably, the Lake Taupō zone showed a marginal and non-significant increase of 4%, while statistically significant decreases in stock access occurred in the Coromandel, Lower Waikato, Upper Waikato, Waihou-Piako, and Waipā management zones. Possible factors contributing to reduced stock access include improvements to existing fencing, the use of temporary fencing not captured during the survey, and efforts to minimize grazing by heavier stock units (such as beef cattle) in unfenced paddocks near waterways.

Table 13. Average proportion of bank length subject to stock access (sum of past, recent, and current stock access categories) within management zones at each of the two survey periods and average change over the previous 5-year (2017 – 2022) period.

Management zone	Average bank length (%)		2017 - 2022 (5-year)	
	2017	2022	Change (pp†)	95%CI‡
Central Waikato	38	27	-12[NS]	12
Coromandel	56	44	-13*	10
Lake Taupō	22	26	4[NS]	25
Lower Waikato	56	40	-15**	10
Upper Waikato	29	19	-10*	9
Waihou-Piako	26	16	-9**	7
Waipā	55	38	-17**	11
West Coast	84	81	-3[NS]	7

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Across stream orders, there was a general decrease in the average proportion of surveyed bank length with stock access over the past 5 years (Table 14). For stream orders 0 to 5, the magnitude of change ranged from -4% (5th order streams) to -17% (4th order streams). Note that for 6th order streams, the large magnitude of change should be treated with caution due to the small sample size within this stratum.

Table 14. Average proportion of bank length subject to stock access (sum of past, recent, and current stock access categories) within stream orders at each of the two survey periods and average change over the previous 5-year (2017 – 2022) period.

Stream order	Average bank length (%)		2017 - 2022 (5-year)	
	2017	2022	Change (pp†)	95%CI‡
0	18	11	-7*	7
1	63	56	-8**	5
2	50	39	-11*	10
3	53	39	-14	14
4	33	16	-17*	13
5	17	13	-4	11
6	55	3	-52*	41

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant

3.2.3 Analysis of Dairying and Clean Streams Accord qualifying sites

Of the 223 dairy sites sampled in 2022, 155 qualified as Dairying and Clean Streams Accord sites. The number and proportion of Accord qualifying sites meeting the stock exclusion criteria for specified levels in the proportion of stream length (>50%, >75%, >90%, >99%) were determined (Table 15). The criteria for stock exclusion were determined by the presence of effective fencing, dense (forest/scrub) vegetation cover, and deep channel morphology on both banks. Note that the analysis was limited to sections of waterway where both banks were classified as dairy, with a total of 128 sites satisfying this criterion. This was done to ensure that non-qualifying sections were excluded from the analysis, even if the entire site met the criteria for an Accord site. In terms of total stream length, only 67 (52%) of the Clean Streams sites had effective fencing on both banks along >99% of the waterway (i.e. considered in previous surveys to be equivalent to complete stock exclusion). When including dense vegetation cover and deep channel morphology (which limit stock access), 69 sites (54%) of Accord-qualifying sites had complete stock exclusion and is only marginally higher than the proportion of Accord qualifying sites with effective fencing only. This suggests that effective fencing (rather than dense vegetation and deep channel morphology) is the predominant form of stock exclusion in the Waikato region. In terms of soil disturbance, the proportion of qualifying sites with no evidence of stock access or pugging disturbance was 68%.

Table 15. Number and proportion of Dairying and Clean Streams Accord qualifying sites (n = 128) that satisfy various stock exclusion criteria for specified proportion of stream length levels (>50%, >75%, >90%, >99%)

Stock exclusion criteria	Proportion of stream length levels	Number of sites	Proportion (%)
Effective fencing on both banks	>99%	67	52
	>90%	88	69
	>75%	103	80
	>50%	111	87
Effective fencing or forest/scrub on both banks	>99%	67	52
	>90%	88	69
	>75%	104	81
	>50%	111	87
Effective fencing or forest/scrub on both banks or deep channel	>99%	69	54
	>90%	90	70
	>75%	105	82
	>50%	112	88
No evidence of stock access	100%	87	68

At Accord sites, the surveyed bank length with effective fencing averaged 91% (Table 16). With the addition of dense vegetation (i.e. forest and scrub) and considering deep channel morphology in the stock exclusion criteria, there was only a minimal increase in the proportion of bank length considered protected (93%). With respect to stock access, approximately 88% of the bank length sampled across Accord sites had no observed stock access in 2022 (Figure 19). In 2017, the proportion of bank length across Accord sites without stock access was approximately 10% lower than the length effectively fenced. This implies that in certain instances, stock managed to access the riparian margin by going around fencing and vegetation structures intended to keep them out (Norris et al., 2017). Although the proportion of effective fencing has remained consistent across Accord sites over the past 5 years, the increase in the absence of stock access — from 81% in 2017 to 88% in 2022 — indicates progress in terms of excluding stock from waterways.

Table 16. Average proportion of bank length satisfying various stock exclusion criteria at Dairying and Clean Streams Accord qualifying sites (n = 155).

	Proportion of bank length	
	Average	**95%CI†**
Effective fencing	91	3
Effective fencing or forest/scrub vegetation	92	2
Effective fencing or forest/scrub or deep channel	93	2

† 95% confidence interval about the average

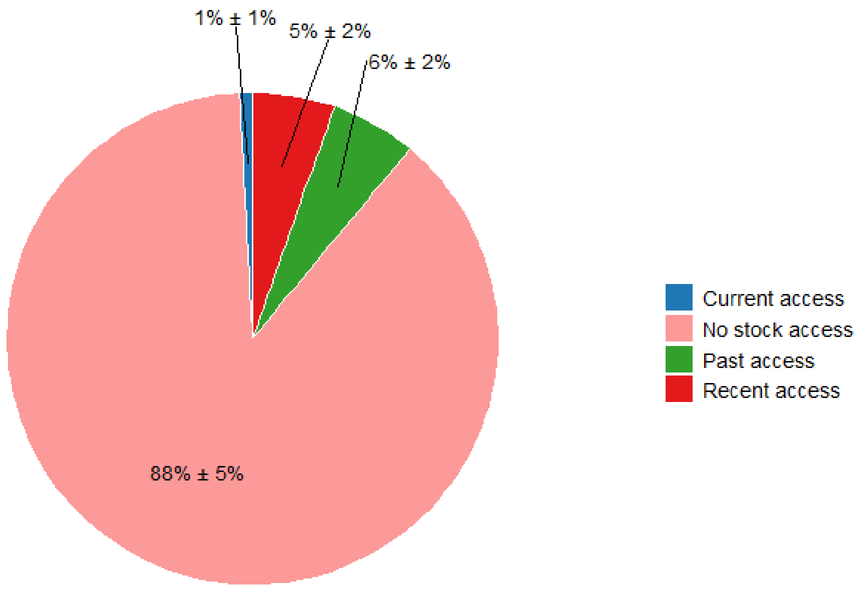


Figure 19. **Average proportion of bank length with no stock access and past, recent, or current stock access observed at Dairying and Clean Stream Accord qualifying sites (n = 160) across the Waikato region in 2022. Error terms represent the 95% confidence interval about the average.**

In line with the 2017 regional riparian findings (Norris et al., 2020), the 2022 estimate of Accord site waterways with complete stock exclusion is lower than the estimate provided in the final Sustainable Dairying Water Accord summary report (DairyNZ, 2018). The 2018 report claimed that stock were excluded from the total length of 98% of all Accord waterways. However, our findings indicate that stock exclusion (i.e., more than 99% of the stream length effectively fenced) is achieved at only 52% of Accord qualifying sites. However, it appears that the 'gap' between Accord results and those reported in earlier regional and national surveys is closing. For example, a 2009 regional riparian survey in the Auckland region (Neale et al. 2009) estimated that only 26% of Dairying and Clean Streams Accord streams were effectively fenced on both banks, compared to 70% stock exclusion reported in the Ministry of Agriculture and Forestry (2009) snapshot report. In 2012, Jones et al. (2016) reported that 26% of the bank length along Accord streams was effectively fenced and protected from stock. Concurrently, the Dairying and Clean Streams Accord: Snapshot of Progress 2011/2012 report (Ministry for Primary Industries, 2013) estimated stock exclusion at 87% nationally and 86% for the Waikato region. By 2017, Norris et al. (2017) estimated that 56% of Accord sites had complete stock exclusion, compared to 98% reported in the Sustainable Dairying Water Accord final summary report (DairyNZ, 2018). Overall, the figures reported in the Dairying and Clean Streams Accord (2003–2012) and Sustainable Dairying Water Accord (2013–2018) summary reports appear to be unrealistically high. This discrepancy is likely due to the use of a verbal assessment process (DairyNZ, 2018) in these reports, compared to the quantitative field observation approaches used in the WRC survey. Nevertheless, as shown in Table 17, over 90% of the bank length along Accord waterways is effectively fenced. This supports earlier findings (section 3.1.2) that industry-led initiatives, such as the Sustainable Dairying Water Accord (DairyNZ, 2018) have significantly improved effective fencing and stock exclusion along waterways on dairy farms across the region.

3.2.4 Analysis of the national stock exclusion regulations

According to national stock exclusion regulations, dairy cattle (including dairy support), beef cattle, deer, and pigs must be excluded from wetlands, lakes, and rivers on low-slope land (defined as having a slope of less than or equal to 5˚) with a 'bank to bank' width of at least 1 metre. For hill-country pasture (areas with a slope greater than 5˚), dairy cattle (including dairy support) and pigs must be excluded from all waterways, regardless of slope. However, for beef cattle and deer, fencing is not required if intensive farming practices (such as fodder cropping, break feeding, and grazing of irrigated pasture) are not undertaken. Additionally, low-intensity beef enterprises on hill-country pastures above 500 metres elevation are exempt from stock exclusion from waterways. In both low-slope and non-low-slope contexts, existing permanent fencing can remain in place regardless of setback distance, but any new fencing must comply with a minimum setback requirement of 3 metres. To evaluate the 2022 data in relation to the national stock exclusion regulations, the proportion of bank length that was effectively fenced was calculated for different vegetation buffer width categories. The assessment was carried out across different slope classes and land use categories for all streams and rivers exceeding 1 metre in width. Slope data was sourced from the New Zealand Land Resource Inventory (NZLRI, version 2.1), and the analysis included three classes: A (0 – 3°), B (4 – 7°), and C (8 – 15°).

3.2.4.1 Low-slope analysis

In 2022, the average proportion of surveyed bank length with effective fencing on pastoral farms was 84, 83, and 83% at sites where the dominant slope of < 3˚, < 7 ˚ and < 15 ˚, respectively (**Error! Reference source not found.** 17). Under the slope threshold of 5 degrees, between 83 and 85% of bank length was effectively fenced on 'low slope' land at the time of the 2022 survey. It is noted that the slope threshold of 5 degrees was amended from 10 degrees following subsequent consultation and review of the 2020 stock exclusion regulations (Ministry for the Environment, 2022). For dairy farms, 93% of bank length was effectively fenced across all slopes classes compared to 65 – 69% for drystock enterprises (Figure 20) and suggests that, for dairy farms, a high proportion of waterways are fenced off, irrespective of slope. Given that the national stock exclusion regulations came into effect in July 2023 for dairy cattle, this analysis demonstrates that a small proportion of bank length across the region (~7%) does not meet current regulations. The 2017 riparian survey (Norris et al., 2020) reported an annual increase in effective fencing along stream banks of 3.1% for dairy. However, over the past 5 years (2017–2022), the annual increase in the proportion of bank length with effective fencing has slowed to about 0.2% per annum. The apparent 'stalling' in the proportion of bank length effectively fenced suggests that further effort is required to achieve complete stock exclusion along the remaining unfenced waterways on dairy farms. For drystock farms, 33–35% of streambanks on low slope land did not meet stock exclusion regulations and suggest that significant work is required across the region to meet the July 2025 deadline.

Under the 'setback' provisions within the Stock Exclusion Regulations 2020, the 3 m buffer is only required for new fencing. Despite 15–20% of fencing on low slope dairy land having a setback of greater than 3 m in 2022 (Figure 20), only 7% of bank length on low slope dairy land requires new fencing with a 3 m setback. Drystock enterprises had a higher proportion (54%) of existing fencing on low slope land with a setback of 3 m or more (Figure 20). This observation is consistent with the location of drystock enterprises in hill country landscapes where vegetation buffer widths are likely to be wider (see section 3.5). However, new fencing is required along 33–35% of streambanks on low slope drystock land and will require set back distances of at least 3 metres.

Table 17. Association between percentage bank length effectively fenced on pastoral enterprises in 2022 and vegetation buffer width categories (< 3 m and ≥ 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (< 3°, < 7°, < 15°). Data is for the assessment of low-slope scenarios under the national stock exclusion regulations (Ministry for the Environment, 2020a).

Land use	Effective fencing x buffer width category	NZLRI class A (< 3°)¥		NZLRI class A+B (< 7°)¥		NZLRI class A+B+C (< 15°)¥	
		No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†
All	Effective fencing total	161	84 ± 5	193	83 ± 5	223	83 ± 4
	Effective fencing < 3 m	161	62 ± 6	193	58 ± 5	223	52 ± 5
	Effective fencing > 3 m	161	22 ± 6	193	25 ± 5	223	31 ± 5
Dairy‡	Effective fencing total	116	93 ± 3	139	93 ± 3	153	93 ± 3
	Effective fencing < 3 m	116	78 ± 7	139	73 ± 6	153	68 ± 7
	Effective fencing > 3 m	116	15 ± 6	139	20 ± 6	153	25 ± 6
Drystock*	Effective fencing total	58	67 ± 13	70	65 ± 12	93	69 ± 10
	Effective fencing < 3 m	58	31 ± 11	70	30 ± 9	93	28 ± 8
	Effective fencing > 3 m	58	36 ± 12	70	35 ± 10	93	41 ± 10

¥ NZLRI slope class
† Mean value and associated 95% confidence interval about the average
‡ Dairy platform (see Table 2)
* Includes dairy support, beef, sheep and beef, deer and pigs (see Table 2)

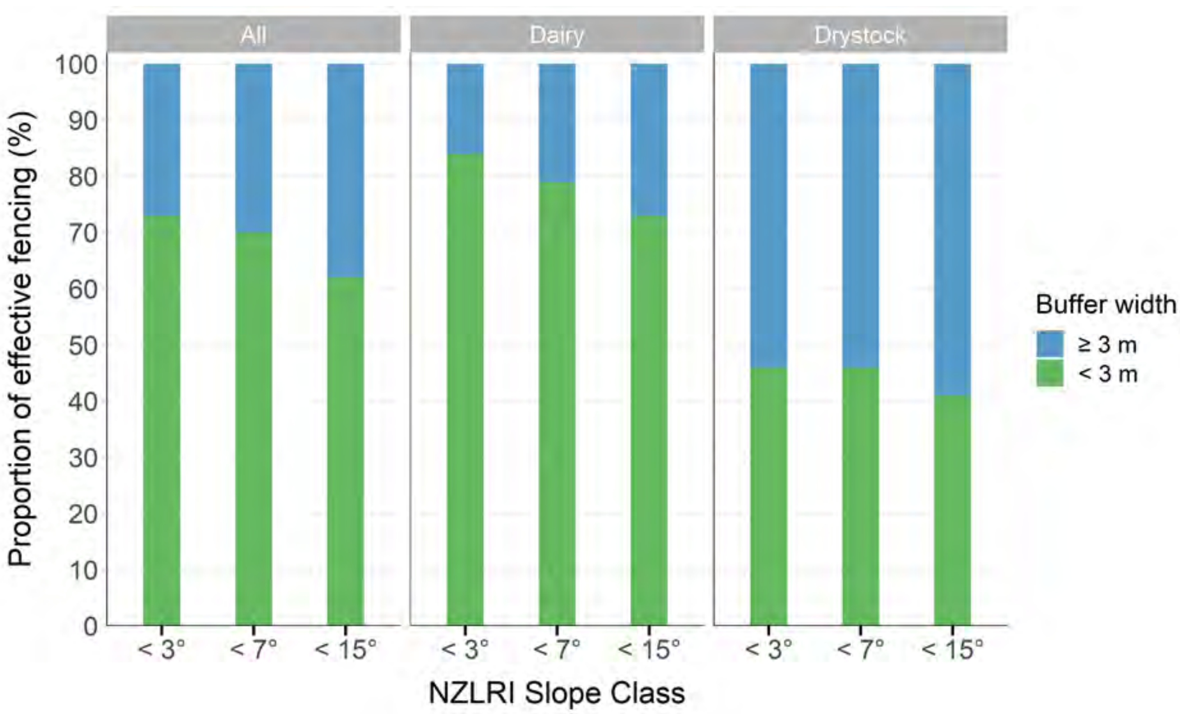


Figure 20. Proportion of effective fencing associated with two vegetation buffer width categories (< 3 m and ≥ 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (< 3°, < 7°, and < 15°) for pastoral land use in 2022. Data is for the assessment of fencing setback requirements (low-slope scenarios) under the national stock exclusion regulations (see Table 13 for land use specifications).

Overall, analysis indicated that under the low slope scenario (< 5°), only a small percentage of bank length under dairy still requires effective fencing (~7%) compared to drystock where about one third of bank length (33–35%) was not fenced at the time of the 2022 survey. Importantly, the increase in fencing appears to have plateaued over the past 5 years (2017 – 2022) for both dairy and drystock and highlights the significant effort required on the part of landowners, co-founders, and regional councils to ensure stock exclusion regulations are met. It is important to note that the stock exclusion regulations come into effect in July 2025 for drystock (beef cattle and deer) and hence the full impact of impending regulations may not have been captured during the 2022 survey. Additionally, freshwater farm regulations, effective from 2023 to 2025 (WRC, 2024), are expected to motivate landowners to complete fencing along waterways that currently do not meet stock exclusion requirements. Therefore, the 2027 riparian survey will be critical in evaluating whether these regulations are improving compliance for those waterways that are currently unfenced.

3.2.4.2 Non-low slope analysis

Under the updated stock exclusion regulations (Ministry for the Environment, 2022), fencing requirements under land classed as 'non-low slope' (i.e. > 5˚) would apply to all dairy cattle, pigs, and dairy support. For drystock enterprises, including beef cattle and deer, fencing on non-low slope land is required only where intensive farming practices are undertaken including fodder-cropping, break-feeding, or grazing on irrigated pasture. Results from the non-low slope analysis are presented in Table 18, with land use divided into dairy and intensive drystock, defined as having a whole farm stocking rate of greater than 12 SU/ha and/or the presence of break feeding or irrigated pasture along any stretch of a survey transect. Whole farm stocking rate was calculated using the most up to date version of the Agribase™ database.

On non-low slope land, the average proportion of bank length with effective fencing was 90% for dairy across all slope class categories (≥ 3°, ≥ 7°, ≥ 15°) and ranged from 53–60% for intensively managed drystock systems (Table 18). Assuming a slope threshold of 5° (Ministry for the Environment, 2022), the percentage of bank length effectively fenced on non-low slope land in 2022 was 90% for dairy and 60% for high intensity drystock. In terms of buffer width, a much higher percentage (67–69%; Figure 21) of effective fencing on non-low slope dairy land was associated with wide buffer widths (> 3 m) compared to that of low-slope land (15–20%). For drystock, 68–76% of effective fencing was associated with wide buffer widths (Figure 21), compared to 54% on low slope land. In terms of exclusion of dairy cattle from streams on non-low slope land, about 10% of bank length still requires fencing (Table 18); while for high intensity drystock enterprises, approximately 55–59% of stream banks on non-low slope land requires fencing by July 2025. Over the past twenty years, the proportion of bank length fenced across sites surveyed in the region has increased at about 2.2% and 0.9% of bank length per year for dairy and drystock land uses respectively.

Table 18. Association between percentage bank length effectively fenced on pastoral enterprises in 2022 and vegetation buffer width categories (< 3 m and ≥ 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (≥ 3°, ≥ 7°, ≥ 15°). Data is for the assessment of non-low slope scenarios under the national stock exclusion regulations (Ministry for the Environment, 2020a).

Land use	Effective fencing x buffer width category	NZLRI class A (≥ 3°)[¥]		NZLRI class A+B (≥ 7°)[¥]		NZLRI class A+B+C (≥ 15°)[¥]	
		No. sites	Percentage bank length (%)[†]	No. sites	Percentage bank length (%)[†]	No. sites	Percentage bank length (%)[†]
Dairy‡	Effective fencing total	80	90 ± 5	57	90 ± 6	44	90 ± 8
	Effective fencing < 3 m	80	36 ± 9	57	33 ± 11	44	35 ± 12
	Effective fencing > 3 m	80	54 ± 10	57	56 ± 12	44	54 ± 15
Drystock (high intensity)*	Effective fencing total	28	60 ± 22	25	60 ± 26	16	53 ± 147
	Effective fencing < 3 m	28	19 ± 15	25	16 ± 15	16	11 ± 52
	Effective fencing > 3 m	28	41 ± 21	25	45 ± 22	16	41 ± 126

[¥] NZLRI slope class
† Mean value and associated 95% confidence interval about the average
‡ Dairy platform (see Table 2)
* Includes dairy support, beef, sheep and beef, deer, and pigs land use (see Table 2) with a whole farm stocking rate of > 14 SU/ha or evidence of break feeding at the time of the survey.

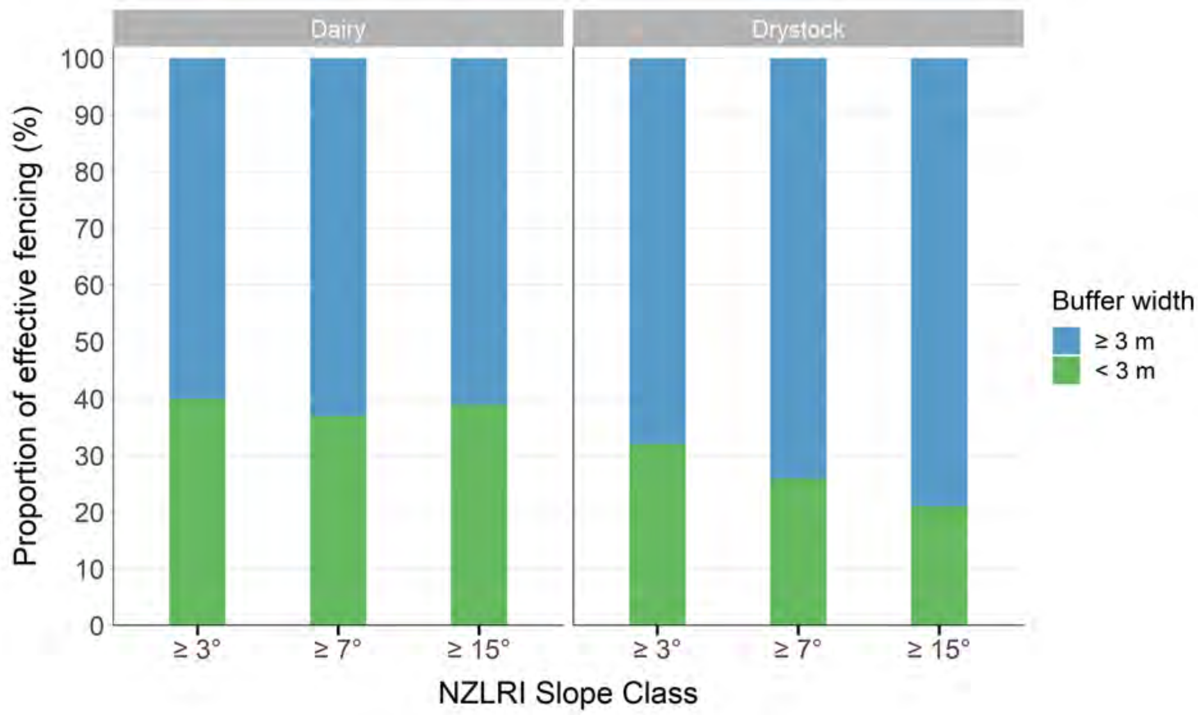


Figure 21. Proportion of effective fencing associated with two vegetation buffer width categories (< 3 m and > 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (> 3°, > 7° and > 15°) for dairy and drystock land uses in 2022. Data is for the assessment of fencing setback requirements (non-low slope scenarios) under the draft national stock exclusion regulations (see Table 13 for land use specifications).

3.2.5 Analysis of stock exclusion requirements under Plan Change 1

Stock exclusion requirements under Proposed Plan Change 1 (PC1) applies to the Upper Waikato, Central Waikato, and Waipā management zones. The regulations differ from the national stock exclusion regulations in that a stocking rate of 18 units per hectare is used to assess whether fencing is required in a paddock where the average slope is greater than 15 degrees. Like the national regulations, all cattle, horses, deer, and pigs must be excluded from water bodies on 'low slope' land (< 15 degrees). In terms of setback distances, new fencing must be located at a distance of at least 3 m from the edge of any wetland listed in Table 3.7.7 of the Waikato Regional Plan; at least 3 m from the outer edge of the bed for all other bodies; and 1 m from the edge of a drain, except for cases where the bank-to-bank width is less than 2 m, in which case no setback is required.

Analysis was undertaken to evaluate the 2022 stock exclusion survey results against the Proposed PC1 requirements as outlined in Schedule C of the 2020 decisions version document (Waikato Regional Council, 2020). This analysis involved calculating the proportion of bank length effectively fenced under a range of vegetation buffer width categories. Additionally, analysis was undertaken for 'low slope' (< 15˚) and 'non-low slope' (> 15˚) land including all drains (stream order 0) as well as permanent and ephemeral streams and rivers (stream order 1 – 6) with a bank-to-bank width of least 1 m (Table 19, Table A4-13). As for the national stock exclusion analysis, the NZLRI slope classes were used to define 'low slope' (slope classes = A, B, C) and 'non-low slope' land (slope class ≠ A, B, C). Effective fencing was determined based on the continuous land use measurements described in Section 2.3.2. This calculation included forest/scrub areas or deep channel morphology as indicators of natural or constructed barriers created by topography or vegetation. To evaluate the 2022 stock exclusion results for drains, these were separated into those wider than 2 m, for which a setback distance of at least 1 m is required, and those less than 2 m wide, for which no setback is required. For low-slope analysis, sites were considered only if the whole-farm stocking rate was greater than 18 SU/ha and/or if there was evidence of break feeding of stock adjacent to the surveyed waterway. Whole-farm stocking rates were estimated using the latest version of the Agribase™ database.

Effective fencing results for the low slope (< 15˚) and non-low slope (> 15˚), high intensity scenarios are shown in Table 19. For low-slope land, the proportion effectively fenced banks for narrow (< 2 m) and wide (> 2 m) drains was 91% and 70%, respectively. Overall, there were only 8 wide drains sampled across PC1 catchments, with all sites located in the Lower Waikato management zone. When considering streams and rivers (Stream orders 1 – 6; n = 98), the proportion of bank length effectively fenced ranged from 59% (Central Waikato) to 92% (Upper Waikato) with an overall average of 80% across PC1 catchments. This value is only marginally higher to that calculated in 2017 (79%), and demonstrates that in PC1 catchments, the rate of fencing increase has stalled over the past 5 years. In terms of non-low slope land, the low number of drains (n = 0 – 1) is not surprising given that drains are usually located on flat land where water tables are typically elevated. There were relatively few streams and rivers situated on non-low slope, high stock intensity land uses (n = 15) in PC1 catchments. However, those that were identified had a high percentage of bank length effectively fenced, with the range across PC1 zones being 82 to 97%.

It is important to note that our survey design did not consider 'high intensity pastoral activities' in the survey design and hence strata may have under-represented the occurrence of these farm systems. Furthermore, high intensity land uses were approximated using whole-farm estimates of stock density using the Agribase™ database. Overall, the analyses demonstrates that a far higher proportion of sites on low slope land are affected by PC1 rules compared to those on non-low slope land. This can be attributed to the generally more intensive land uses (e.g. diary platform) associated with low slope land and the presence of structures such as wide drains. Results demonstrate that a high proportion of drains are effectively fenced, with approximately 10 – 20% bank length remaining unfenced or ineffectively fenced. For streams and rivers, approximately 20% of bank length remains unfenced, with the Central Waikato (41%) and Lower Waikato (30%) having the highest proportion of ineffective fencing along qualifying waterways.

Table 19. Percentage bank length with complete stock exclusion (effective fencing or forest/scrub or deep channel morphology) in Plan Change 1 zones for drains (Strahler order 0; channel width < 2 m and channel width ≥ 2 m) and streams and rivers (Strahler orders 1 – 6) in 2017. Data is for the assessment of low-slope (< 15°) and non-low slope (≥ 15°) stock exclusion scenarios as outlined in Schedule C of Plan Change 1 (Ministry for the Environment, 2020a).

Slope class¥	Zone	Narrow drains (channel width < 2 m)		Wide drains (channel width ≥ 2 m)		Streams and rivers (Strahler order 1 – 6)	
		No. sites	Percentage bank length (%)‡	No. sites	Percentage bank length (%)‡	No. sites	Percentage bank length (%)‡
Low-slope (< 15°)	All Plan Change 1 Zones	30	91 ± 6	8	70 ± 44	98	80 ± 7
	Central Waikato	2	92	0	0	5	59 ± 252
	Lower Waikato	20	91 ± 9	8	70 ± 44	19	70 ± 17
	Upper Waikato	1	100	0	0	35	92 ± 7
	Waipā	7	91 ± 15	0	0	39	79 ± 13
Non-low slope (≥15°), high intensity*	All Plan Change 1 Zones	0	-	0	-	15	88 ± 13
	Central Waikato	0	-	0	-	0	0
	Lower Waikato	0	-	0	-	0	0
	Upper Waikato	0	-	0	-	5	97 ± 25
	Waipā	0	-	0	-	10	82 ± 20

¥ NZLRI slope class

‡ Mean value and associated 95% confidence interval about the average. In some cases, there was insufficient data to calculate a confidence interval.

* Whole farm stocking rate of > 18 SU/ha or evidence of break feeding at the time of the survey.

As with the national stock exclusion regulations (section 3.2.4), PC1 setback requirements only apply to new fencing along streams and rivers (stream orders 1-6) and drains with a channel width (bank-to-bank) of at least 2 m. In 2022, 80% of the bank length for streams and rivers on low slope land was effectively fenced (Table 20). Therefore, the 3 m setback requirement applies only to the remaining 20% of unfenced or ineffectively fenced bank length. For narrow drains less than 2 m in width, no setback is required. However, approximately 10% of these drains still require stock exclusion. For wider drains (> 2 m), a minimum 1 m setback is required, and this applies to about 30% of bank length along wide drains on low-slope land within PC1 catchments.

For existing fencing along streams and rivers on low slope land, approximately 50% had a setback distance of at least 3 m (Figure 22). For narrow drains (less than 2 m wide) on low slope land, 65% of existing fencing had a setback distance of at least 1-m. In contrast, for wide drains (greater than 2 m wide), 88% of fencing was associated with a buffer width of at least 3 m. Although PC1 setback requirements only relate to wide drains, the 2022 survey results demonstrate that a high proportion of existing fencing along drains currently complies with the regulations. For non-low slope land, the 2022 dataset did not include any drains which resulted in data gaps for the 2022 setback width analysis (Table 20, Figure 22). For streams and rivers on high intensity non-low slope land, approximately 63% of existing fencing was associated with a setback distance of at least 3 m.

Table 20. **Association between the percentage of bank length with complete stock exclusion and three vegetation buffer width categories (< 1 m, < 3 m, and ≥ 3 m) for drains (Strahler order 0; channel width < 2 m and channel width ≥ 2 m) and streams and rivers (Strahler orders 1–6) for pastoral enterprises across Plan Change 1 Zones, 2022. Data is for the assessment of fencing setback requirements under low-slope (< 15°) and non-low slope (≥ 15°) scenarios as outlined in Schedule C of Plan Change 1 (Waikato Regional Council, 2020).**

Slope class[¥]	Stock exclusion† x buffer width category	Narrow drains (channel width < 2 m)		Wide drains (channel width ≥ 2 m)		Streams and rivers (Strahler order 1 – 6)	
		No. sites	Percentage bank length (%)‡	No. sites	Percentage bank length (%)‡	No. sites	Percentage bank length (%)‡
Low-slope (< 15°)	Stock exclusion total	30	91 ± 6	8	70 ± 44	98	80 ± 7
	Stock exclusion < 1 m	30	35 ± 9	8	12 ± 14	98	17 ± 7
	Stock exclusion < 3 m	30	86 ± 8	8	63 ± 52	98	40 ± 9
	Stock exclusion > 3 m	30	5 ± 4	8	7 ± 9	98	40 ± 9
Non-low slope (≥15°), high intensity*	Stock exclusion total	0	-	0	-	15	88 ± 13
	Stock exclusion < 1 m	0	-	0	-	15	18 ± 19
	Stock exclusion < 3 m	0	-	0	-	15	51 ± 29
	Stock exclusion > 3 m	0	-	0	-	15	37 ± 30

[¥] NZLRI slope class
† Proportion of bank with effective fencing or forest/scrub or deep channel morphology
‡ Mean value and associated 95% confidence interval about the average. In some cases, there was insufficient data to calculate a confidence interval.
* Whole farm stocking rate of > 18 U/ha or evidence of break feeding at the time of the survey.

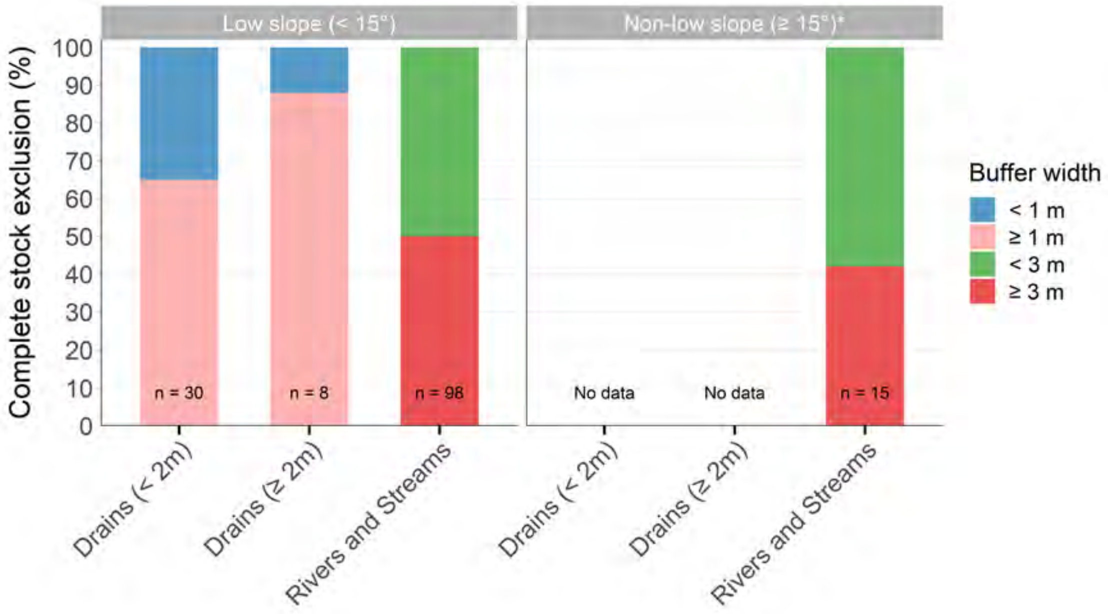


Figure 22. **Proportion of complete stock exclusion (effective fencing or forest/scrub or deep channel morphology) associated with varying vegetation buffer width categories for drains (Strahler order 0; channel width < 2 m and channel width > 2 m) and rivers and streams (Strahler orders 1–6) for low-slope (< 15°) and non-low slope (> 15°), high stock intensity (*) scenarios. Data is for the assessment of fencing setback requirements (low-slope and non-low slope) as outlined in Schedule C of Plan Change 1 (WRC, 2020).**

3.2.6 Summary of key stock exclusion results

The key results in relation to stock exclusion results are that:

- On average, across the Waikato region, approximately 58% of sampled bank length was completely excluded from stock in 2022.
- The proportion of total bank length accessed by stock was significantly less for dairy (12%) compared to drystock (65%).
- The Waihou-Piako and the Upper Waikato management zones had the lowest proportion of sampled bank length with stock access (19% and 16%, respectively).
- Observed stock access was lowest for stream orders 0 (drains) and 6, with the proportion of bank length showing evidence of stock access being 11% and 2%, respectively.
- About 52% of the Dairying and Clean Streams Accord qualifying sites had effective fencing on both banks along >99% of the waterway (i.e. considered in previous surveys to be equivalent to complete stock exclusion). At Accord sites, the surveyed bank length with effective fencing averaged 91%, lower than the 98% reported in the Sustainable Dairying Water Accord final summary report for 2018 (DairyNZ, 2018).
- Although the proportion of effective fencing has remained consistent across Accord sites over the past 5 years (2017 – 2022), the increase in the absence of stock access — from 81% in 2017 to 88% in 2022 — indicates progress in terms of excluding stock from waterways.
- Under the national stock exclusion regulations (Ministry for the Environment, 2020) and based on a revised slope threshold of <5˚, only a small percentage of surveyed bank length under dairy required fencing (7%) in 2022, compared to 33 – 35% for drystock enterprises. Although there are no setback requirements for existing fencing, only 15–20% of exiting fencing on low slope dairy land had a setback of 3 m or greater. Drystock enterprises had a higher proportion (54%) of existing fencing on low slope land with a setback of 3 m or more. In 2022, a greater proportion of bank length on non-low slope land (> 5˚) required fencing, with 10% for dairy and 40% for high intensity drystock. However, the proportion of existing fencing with setback widths of 3 m or more was higher on non-low slope land compared to low slope land for both dairy (67 – 69%) and drystock (68 – 76%). The deadline for exclusion of dairy and pigs from all waterways was July 2023, with the 2022 results suggesting that 7 – 10% of surveyed bank length did not comply with stock exclusion regulations. For intensive drystock, the percentage of bank length requiring fencing to meet the 2025 deadline on low slope and non-low slope land is 33 – 35% and 40%, respectively.
- Under the Proposed PC1 stock exclusion regulations (Waikato Regional Council, 2020), 80% of the bank length along rivers and streams on low slope land (< 15˚) was effectively fenced. For narrow drains (< 2 m), 90% of the bank length was effectively fenced, whereas for wide drains (>2 m), only 70% was fenced. It is important to note that only new fences along wide drains require a minimum setback of 1 m. On non-low slope land, there were only small number of river and streams on intensively managed land (n=15), with 88% of the surveyed bank length being effectively fenced. For existing fencing along streams and rivers on low slope land, approximately 50% had a setback distance of at least 3 m. For narrow drains (less than 2 m wide) on low slope land, 65% of existing fencing had a setback distance of at least 1 m; while for wide drains (greater than 2 m wide), 88% of fencing was associated with a buffer width of at least 3 m. For streams and rivers on high intensity non-low slope land, approximately 63% of existing fencing was associated with a setback distance of at least 3 m.

3.3 Riparian vegetation

3.3.1 State

In 2022, approximately one quarter (27%) of surveyed bank length across the Waikato region was covered by woody riparian vegetation with the remaining three quarters (73%) occupied by non-woody vegetation (Figure 23). While non-woody vegetation effectively filters sediment, nutrients, and pathogens from surface runoff from surrounding paddocks (Schwarte et al., 2011), woody riparian vegetation offers additional benefits. These benefits include shading effects for water temperature regulation, enhanced biodiversity values such as habitat provision and organic matter inputs for aquatic food webs, improved stability of stream banks, and attenuation of dissolved nutrients from shallow ground water (McKergow et al., 2016; Mckergow et al., 2020; Mckergow et al., 2022). The survey design for the regional riparian survey focuses on assessing the proportion of bank length covered by major vegetation types. As such, the methodology does not provide information on the effectiveness of the riparian margins in achieving functional objectives such as stream temperature regulation through shading or contaminant and sediment filtering. To fully capture these benefits, several other metrics not measured under the current survey approach would need to be considered. Examples include canopy height, shading effect and location of vegetation relative to the waterway (Rutherford et al., 2023; Rutherford, 2023). While these metrics would be valuable, they fall outside the scope of the regional survey design. Additionally, the extra effort required to measure them would reduce the number of sites surveyed, thereby decreasing the statistical power to assess other important metrics, such as the proportion of bank length that is fenced.

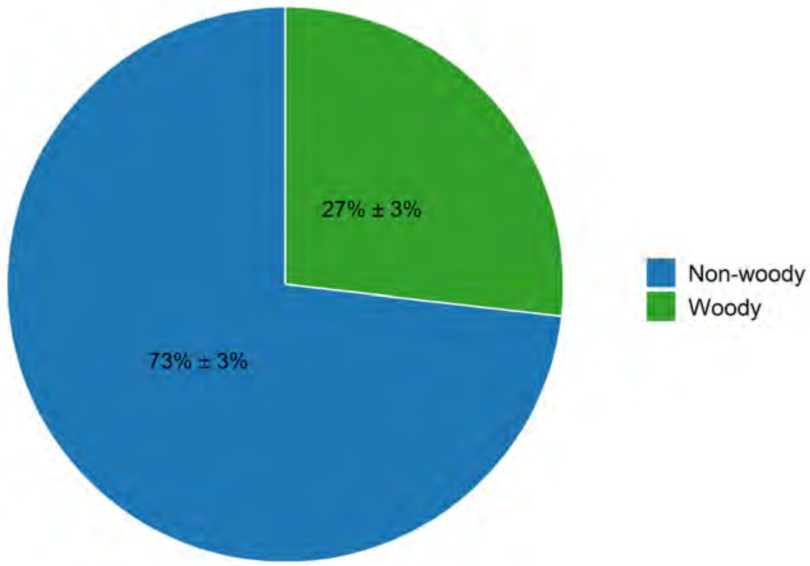


Figure 23. Average proportion of bank length with woody and non-woody vegetation across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.

Woody vegetation was further classified into exotic (willow, evergreen, and other deciduous) and native vegetation, while non-woody vegetation was categorised as either 'grass and weeds' or 'flax/sedge/rush'. The average proportions of surveyed bank length occupied by each vegetation type are shown in Figure 24. Grass and weeds covered 64% of the bank length across the region, while flax, sedge and rush species – typically found in wet or damp areas – occupied 9% of the bank length. Regarding woody vegetation, 11% of bank length was occupied by native species and 15% by exotic species (i.e. 6% willow, 5% evergreen, and 4% deciduous).

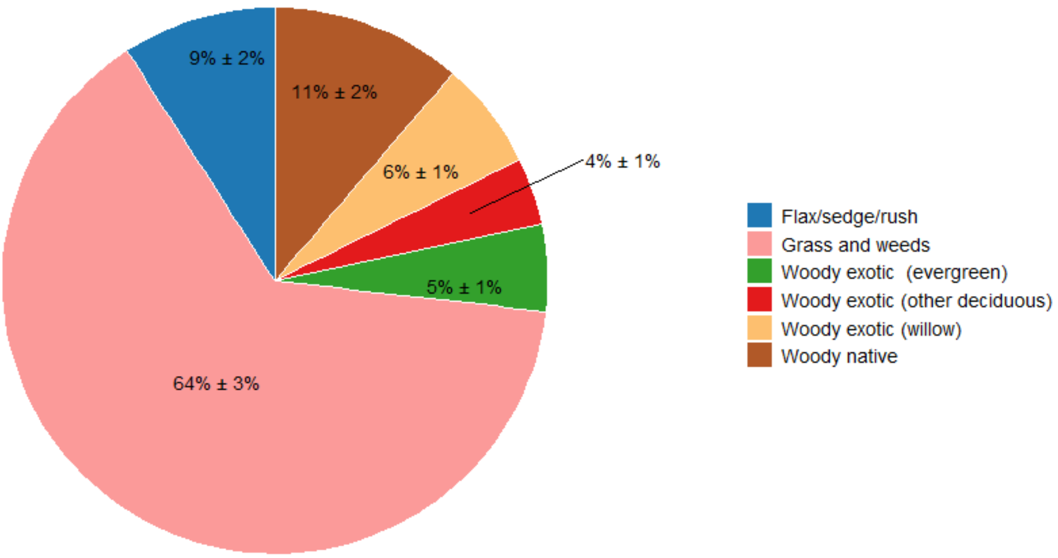


Figure 24. **Average proportion of bank length occupied by individual vegetation types across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

Consistent with previous surveys, grass and weeds provided the greatest coverage of bank length across both dairy and drystock land uses. However, there was significantly more coverage for dairy (72%) compared to drystock (59%) ($t = 4.16$, $P < 0.0001$) (Figure 25). The proportion of surveyed bank length occupied by woody vegetation was similar between dairy and drystock land uses ($t = 1.24$, $P = 0.21$). However, woody native vegetation occupied significantly less bank length along dairy streams (7%) compared to those in drystock (14%) ($t = 2.58$, $P < 0.05$). Furthermore, the coverage of flax, sedge and rush was significantly lower in dairy (4% of bank length) than in drystock (13% of bank length) ($t = 5.29$, $P < 0.0001$). These findings are consistent with the prevalence of drystock farms in hill country areas, where remnant native or restored riparian vegetation tends to cover larger areas.

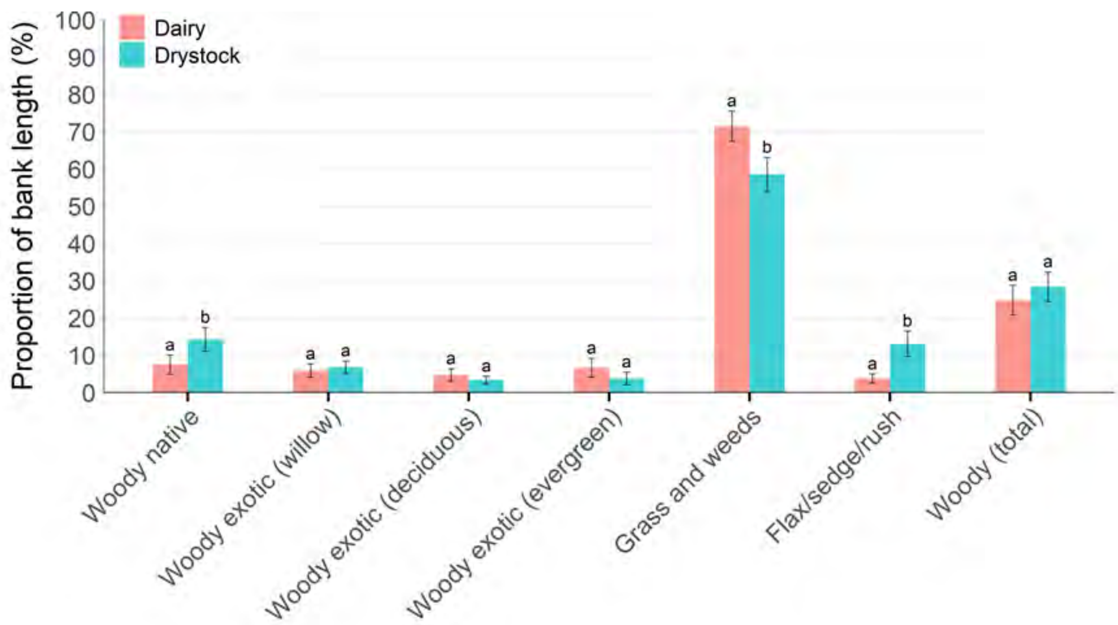


Figure 25. **Average proportion of bank length occupied by individual vegetation types across the Waikato region in 2022. Error terms represent the 95% confidence interval about the average.**

The proportion of surveyed bank length with effectively fenced woody vegetation was significantly larger than the proportion of bank length with woody vegetation not effectively fenced ($t = 2.53$, $P < 0.05$) (Figure 26). The primary driver of this difference was the higher proportion of woody exotic species in areas with effective fencing compared to those with ineffective fencing. Both deciduous and woody evergreen species covered a significantly higher proportion ($P < 0.05$) of effectively fenced bank length compared to unfenced bank length (Figure 26). Woody exotic (willow) vegetation was also more prevalent along effectively fenced bank length compared to unfenced, although the difference was not statistically significant ($t = 1.43$; $P > 0.05$). The proportion of bank length with effectively fenced flax/sedge/rush was significantly lower than that of bank length with flax/sedge/rush not effectively fenced. This indicates that most occurrences of flax/sedge/rush are not linked to restoration efforts but are instead due to the persistence of native wetland vegetation types. For riparian margins vegetated with grass and weeds, there was no difference between effectively fenced and not effectively fenced bank length. Overall, results suggest that fenced riparian margins are far more likely to contain woody species compared to unfenced margins.

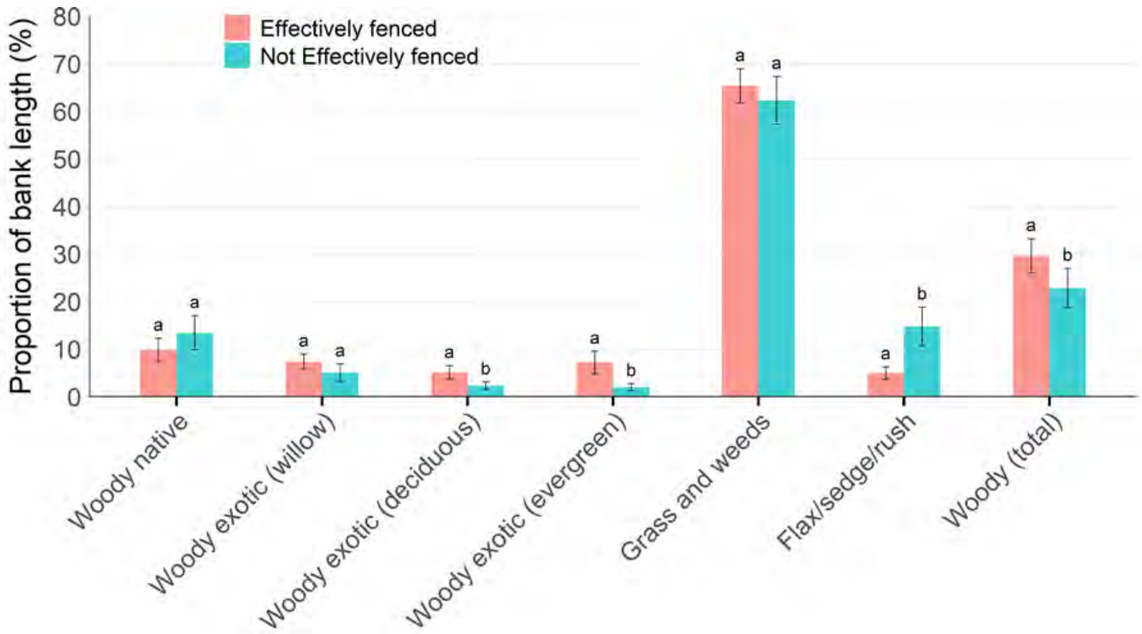


Figure 26. **Average proportion of bank length occupied by woody vegetation (total) and individual vegetation types that are effectively fenced or not effectively fenced across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly ($P < 0.05$) different.**

Figure 27 shows the average proportion of bank length occupied by woody vegetation across management zones in 2022. Streams in the Coromandel, Lake Taupō, and Upper Waikato management zones had the highest proportions of bank length covered by woody vegetation, at 59%, 48%, and 44%, respectively, with proportions being significantly greater than for other management zones. The prevalence of woody species along these stream banks is linked to riparian restoration and planting efforts associated with WRC soil conservation schemes and industry initiatives such as the Dairying and Clean Stream Accord. In the Coromandel, the high proportion of woody vegetation is also attributed to the abundance of native forest in the zone and the remnants of forest along riparian margins. The Central Waikato, Waihou-Piako, Waipā, and West Coast zones had a similar proportion of bank length occupied by woody vegetation, with values ranging from 20 – 24%. The Lower Waikato had the lowest proportion of bank length covered by woody vegetation (24%), due, in part, to the high proportion of drains on predominantly flat land in the zone (See Table A2-1), which are typically dominated by grass and weed species.

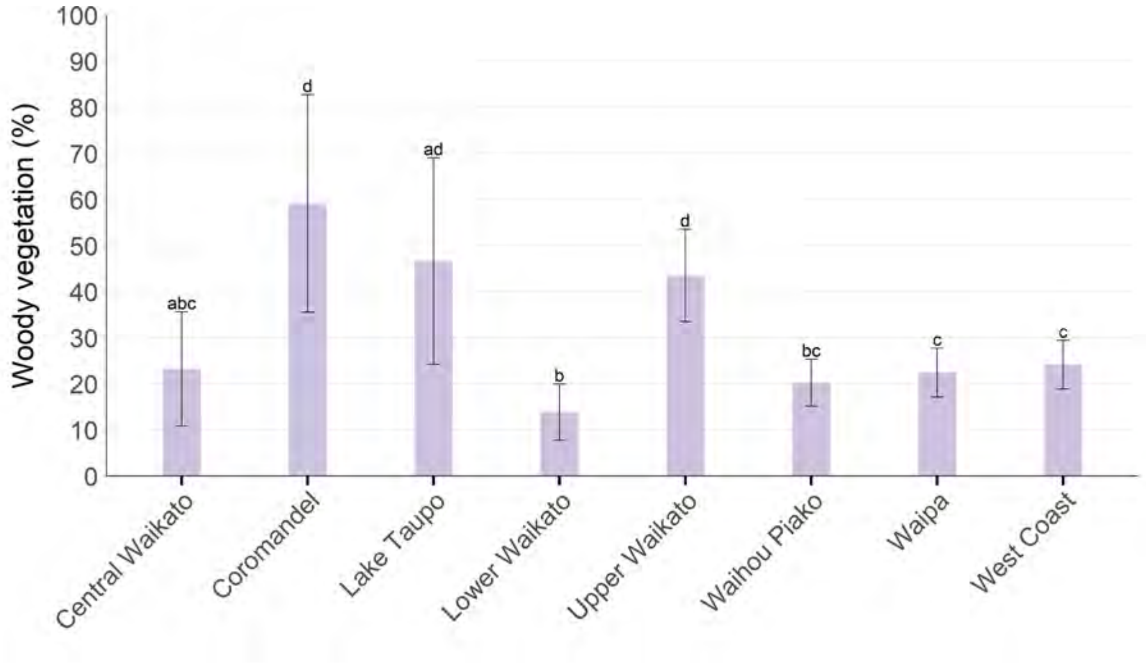


Figure 27. Average proportion of bank length occupied by woody vegetation within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.

There was a direct relationship between stream order and the proportion of bank length occupied by woody vegetation (Figure 28). In general, the proportion of bank length occupied by woody vegetation increased with increasing stream order. Drains had the lowest proportion of bank length with woody vegetation (8%), with the proportion being significantly lower than for all other stream orders. Drains are most prevalent within dairy systems on flat land and typically occupy narrow segments of land dominated by pasture and weed species. Although larger streams (i.e. stream orders 5 and 6) were associated with a higher proportion of woody vegetation (Figure 28), the variability of estimates were high indicating that some larger order streams were dominated by non-woody species. Nevertheless, results suggest that riparian retirement and restoration efforts are typically focussed on larger stream orders in the lower reaches of catchments. To improve downstream water quality, habitat, and ecological health, it is essential to increase efforts to re-establish a combination of woody and non-woody vegetation types alongside drains and smaller stream orders. While establishment of woody riparian vegetation is important for optimising riparian margin functionality, it is only one aspect and should be implemented alongside other riparian management practices, such as fencing, maintaining adequate buffer width and ensuring diverse vegetation composition. These factors should be evaluated at the individual site level to account for site-specific conditions when designing effective riparian margins.

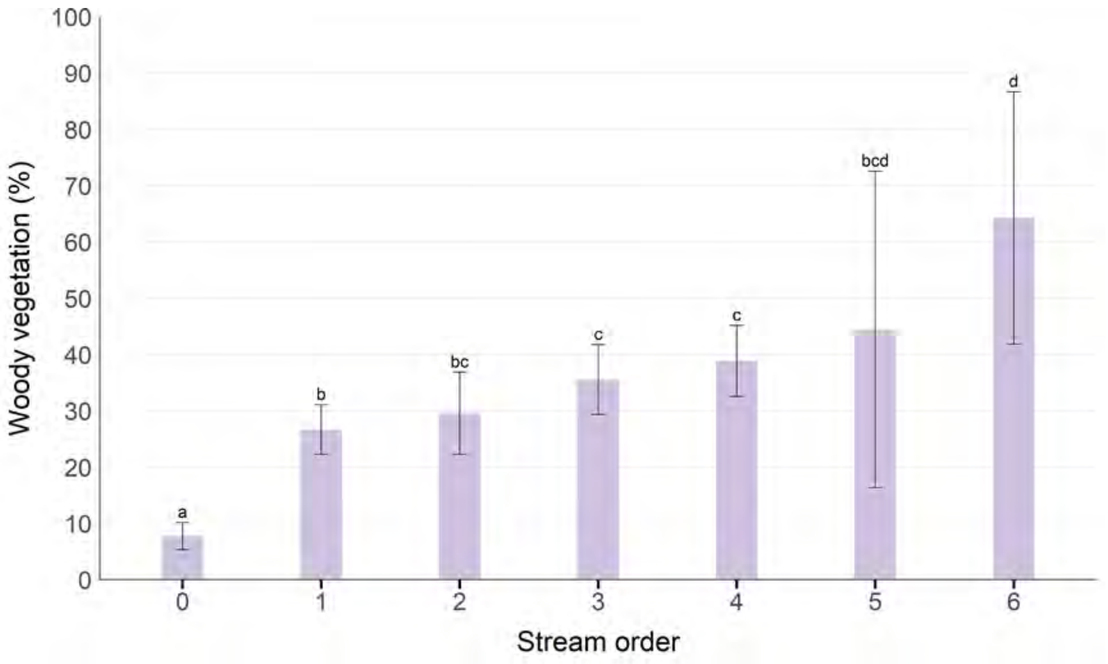


Figure 28. Average proportion of bank length occupied by woody vegetation within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.

3.3.2 Change over time

Across the Waikato region, there was no statistically significant change in the average proportion of surveyed bank length occupied by woody vegetation across the Waikato region ($t = 0.63$, $P = 0.5$) (Figure 29, Table 21). However, over the past 5-year period (2017 – 2022), there was a significant increase in the proportion of bank length with woody vegetation ($t = 2.9$, $P = 0.004$) driven by statistically significant increases in both native and willow species. The long-term trend from 2002 to 2022 shows a general decrease in grass and weed species ($t = 2.02$, $P = 0.04$), as well as woody exotic vegetation ($t = 3.2$, $P < 0.01$). In contrast, there was an increase in the coverage of woody native species ($t = 4.8$, $P < 0.0001$) and flax/sedge rush ($t = 2.49$, $P < 0.05$), reflecting the impact of riparian restoration efforts. It should be noted that the category 'woody exotic other' includes both deciduous and evergreen woody vegetation, and these categories were not distinguished during the 2002 and 2007 surveys.

Over time, the proportion of bank length occupied by flax/sedge/rush varied, with a particularly large increase from 3% in 2007 to 24% in 2012. As noted in the previous regional riparian characteristics report (Norris et al., 2020), it is likely that the flax/sedge/rush category was overestimated during the 2012 survey (Figure 30) and represents an anomaly in the long-term dataset. Over the full monitoring period, the proportion of bank length occupied by flax/sedge/rush increased significantly from 6% in 2002 to 9% in 2022. This change is likely due to the recovery of previously grazed wetlands following stock exclusion.

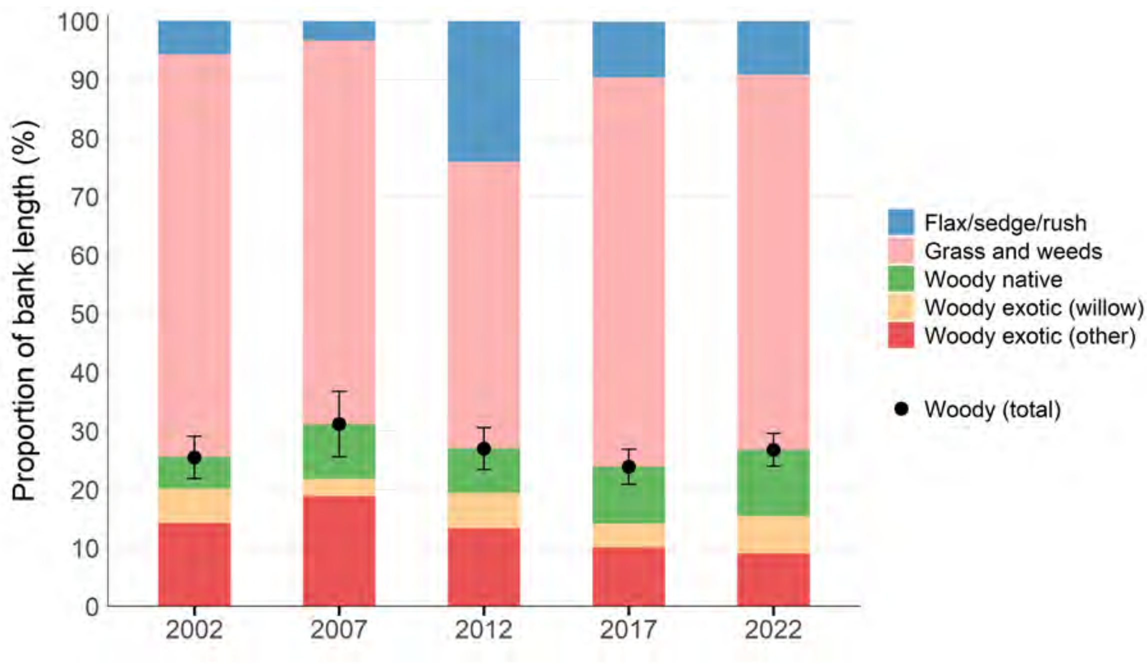


Figure 29. **Average proportion of bank length occupied by woody vegetation and individual vegetation types at the four survey periods (2002, 2007, 2012, 2017 and 2022). Total proportion of woody vegetation coverage is indicated by the black symbols, with error bars representing the 95% confidence intervals.**

Table 21. **Average change in the proportion of bank length occupied by woody vegetation and individual vegetation types over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 – 2022) periods.**

	2017 - 2022 (5-year)		2012 - 2022 (10-year)		2007 - 2022 (15-year)		2002 - 2022 (20-year)	
Vegetation type	**Change (pp†)**	**95%CI‡**	**Change (pp†)**	**95%CI‡**	**Change (pp†)**	**95%CI‡**	**Change (pp†)**	**95%CI‡**
Woody (total)	3**	2	-0 NS	4	-4 NS	5	1NS	4
Woody native	2*	2	4**	2	2 NS	3	6**	2
Woody exotic (willow)	2**	1	1 NS	2	4**	2	1 NS	2
Woody exotic (other)	-1NS	1	-4 **	3	-10**	5	-5**	3
Grass and weeds	-2 NS	3	15**	5	-1 NS	6	-5*	5
Flax/sedge/rush	-1 NS	2	-15**	5	6**	3	3*	3

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

In terms of the effect of land use on vegetation coverage across riparian margins, the pattern of change over time was similar to that observed across the region as a whole (Figure 30, Table 22). Over the past twenty years, woody native vegetation increased significantly for both dairy (5%) and drystock (6%). However, the coverage of 'woody exotic other' (comprising woody evergreen and woody deciduous species) decreased significantly for drystock over past 5, 10, 15, and 20 years, whereas no such trend was observed for dairy. Furthermore, from 2002 to 2022, the proportion of bank length occupied by flax, sedge, and rush species increased for drystock, but remained unchanged for dairy.

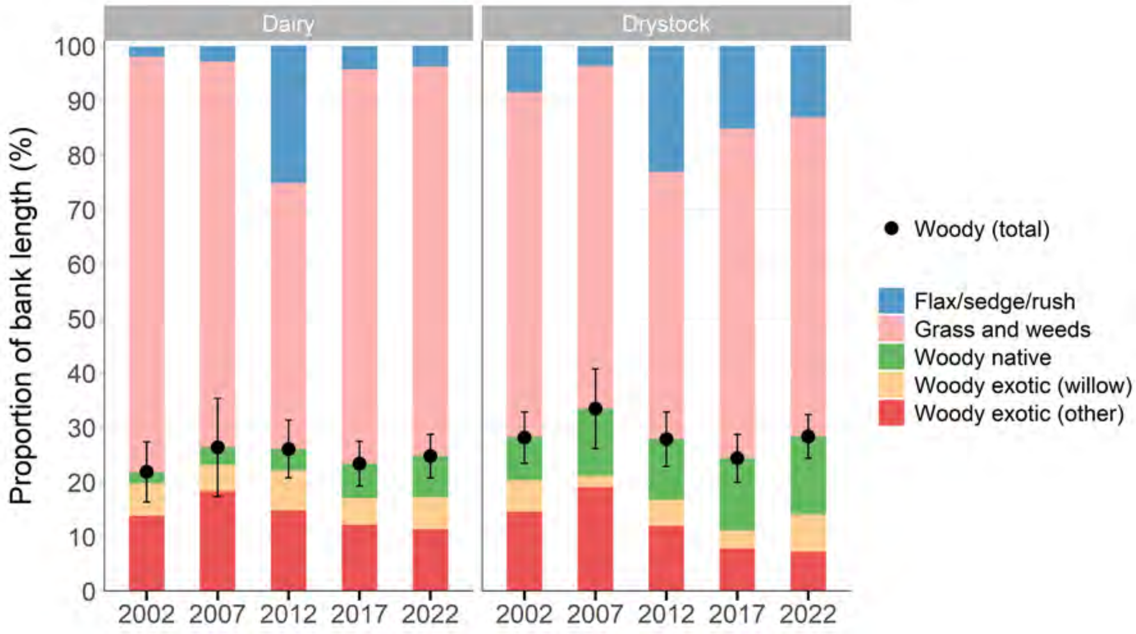


Figure 30. **Average proportion of bank length occupied by woody vegetation and individual vegetation types within land use types at the four survey periods (2002, 2007, 2012, 2017, and 2022). Total proportion of woody vegetation coverage is indicated by the black symbols, with error bars representing the 95% confidence intervals.**

Table 22. **Average change in the proportion of bank length occupied by woody vegetation and individual vegetation types within land use types over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 – 2022) periods.**

		2017 - 2022 (5-year)		2012 - 2022 (10-year)		2007 - 2022 (15-year)		2002 - 2022 (20-year)	
Vegetation type	Land use type	Change (pp†)	95%CI ‡	Change (pp†)	95%CI‡	Chang e (pp†)	95%CI‡	Chang e (pp†)	95%CI ‡
Woody (total)	Dairy	1.3 NS	4	-1.3 NS	6	-2	9	3 NS	6
	Drystock	4*	4	0.5 NS	6	-5	7	0 NS	6
Woody native	Dairy	1.1 NS	3	4*	3	4**	3	5**	3
	Drystock	1.1 NS	3	3.1 NS	4	2	5	6**	4
Woody exotic (willow)	Dairy	1 NS	1	-1 NS	3	1	4	0 NS	3
	Drystock	4**	2	2 NS	2	5**	2	1 NS	3
Woody exotic (other)	Dairy	-0.8 NS	2	-4 NS	5	-7	8	-2 NS	5
	Drystock	-0.7 NS	2	-5**	4	-12**	6	-7**	5
Grass and weeds	Dairy	-0.9 NS	4	23**	7	1	9	-5 NS	6
	Drystock	-1.9 NS	5	10*	8	-5	8	-5 NS	7
Flax/sedge/ rush	Dairy	-0.4 NS	2	-21**	6	1	3	2 NS	2
	Drystock	-2.1 NS	4	-10**	7	10**	4	5*	4

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Over the previous 20-year (2002 – 2022) monitoring period, a significant increase ($P < 0.05$) in woody vegetation was observed for the Coromandel; while for other zones, no significant changes ($P > 0.05$) were observed (Table 24). More recently, from 2017 –2022, there were significant increases ($P < 0.05$) in the proportion of bank length occupied by woody vegetation in the Central Waikato (5%), Waihou-Piako (3%) and West Coast (6%) management zones (Table 23). Changes in woody vegetation in these zones are associated primarily with increases in the amount of native and woody willow vegetation (data not presented). The increase in these vegetation types is likely connected to riparian restoration initiatives, including the planting and regeneration of native species. For the Waihou-Piako, woody vegetation decreased by 5% over the previous 10-year period (2012 – 2022) and may reflect initial land use intensification, followed by establishment of woody species in the proceeding years (i.e. an increase of 3% from 2017 to 2022).

Table 23. Average proportion of bank length occupied by woody vegetation within management zones at each of the five survey periods (2002, 2007, 2012, 2017, and 2022) and average change over the previous 5-year (2017 – 2012), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 –2022) periods.

Management zone	Average bank length (%)					2017 – 2022 (5-year)		2012 – 2022 (10-year)		2007 - 2022 (15-year)		2002 - 2022 (20-year)	
	2002	2007	2012	2017	2022	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
Central Waikato	24	26	21	18	23	**5***	4	3 NS	21	-3 NS	14	0 NS	14
Coromandel	29	37	51	48	59	11 NS	12	8 NS	18	22 NS	25	**30***	26
Lake Taupō	55	62	57	53	47	-7 NS	13	-10 NS	27	-15 NS	31	-8 NS	29
Lower Waikato	16	20	14	14	14	0 NS	4	0 NS	7	-6 NS	9	-2 NS	9
Upper Waikato	36	45	46	44	44	0 NS	5	-3 NS	14	-1 NS	17	7 NS	13
Waihou-Piako	26	29	26	18	20	**3***	3	**-5***	5	-9 NS	9	-6 NS	7
Waipā	23	31	23	19	23	4 NS	4	0 NS	8	-9 NS	9	-1 NS	9
West Coast	21	27	21	19	24	**6***	5	3 NS	9	-2 NS	15	4 NS	8

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Considering stream orders, there were varying degrees of change over the 20-year (2002 – 2022) monitoring period, with none of the changes being significant (Table 24). Over the past 10-year (2012 – 2022) and 5-year (2017 – 2022) monitoring periods, there was a general increase in the proportion of bank length with woody vegetation across most stream orders, reflecting the outcomes of riparian restoration initiatives. However, the increase in woody vegetation was significant only for drains (2012 – 2022) and first order streams (2017 – 2022) and failure to detect significant changes across other stream orders is related to the large variance in measurements across sites.

Table 24. Average proportion of bank length occupied by woody vegetation within stream orders at each of the four survey periods (2002, 2007, 2012, 2017, and 2022) and average change over the previous 5-year (2017 – 2012), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 – 2022) periods.

Stream order	Average bank length (%)					2017 - 2022 (5-year)		2012 - 2022 (10-year)		2007 - 2022 (15-year)		2002 – 2022 (20-year)	
	2002	2007	2012	2017	2022	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
0	10	12	4	7	8	1 NS	2	**4***	3	-5 NS	11	-2 NS	6
1	24	32	28	24	27	**3***	3	-1 NS	6	-5 NS	9	3 NS	6
2	32	34	32	30	30	0 NS	6	-2 NS	9	-4 NS	9	-2 NS	11
3	31	33	36	32	36	4 NS	7	0 NS	12	3 NS	13	5 NS	14
4	44	53	35	33	39	6 NS	7	4 NS	18	-14 NS	15	-6 NS	20
5	42	43	41	37	45	7 NS	10	4 NS	36	1 NS	47	3 NS	32
6	56	56	58	51	64	14 NS	33	6 NS	51	8 NS	55	8 NS	68

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

3.3.3 Summary of key riparian vegetation results

For riparian vegetation, the key results are as follows:

- About one quarter (27%) of surveyed bank length across the Waikato region was covered by woody vegetation in 2022.
- The average proportion of bank length occupied by woody vegetation was similar between dairy and drystock land uses.
- A greater proportion of woody vegetation was observed in areas with effective fencing compared to unfenced riparian margins).
- The Coromandel, Lake Taupō, and Upper Waikato management zones had the highest proportion of bank length occupied by woody vegetation with values of 59%, 48%, and 44%, respectively.
- Overall, the proportion of bank length occupied by woody vegetation increased with increasing stream order.
- Across the region, there was no change in the proportion of surveyed bank length with woody vegetation over the past 20 years (2002 – 2022); however, there was an increase in woody vegetation over the past 5 years (2017 – 2022).
- Coverage of woody native vegetation and flax/sedge/rushes have increased over the past twenty years, while coverage of grass and weed species and 'woody exotic other' (woody evergreen and woody deciduous) have decreased over the same period.
- The trend in the average proportion of surveyed bank length occupied by woody vegetation for both dairy and drystock land uses over the past twenty years closely resembled the overall pattern observed across the entire region.
- The Coromandel management zone saw a significant increase in woody vegetation over the past twenty years (2002 – 2022), whereas no significant changes were observed in other zones during the same period. However, significant increases in woody vegetation were observed across the Central Waikato, Waihou-Piako, and West Coast management zones over the previous 5-year (2017 – 2022) monitoring period.
- A general increase in woody vegetation coverage was observed across stream orders over the past decade; however, only drains and first order streams registered significant increases over either of the previous 5- or 10-year monitoring periods.

3.4 Riparian buffer width

3.4.1 State

In 2022, 62% of surveyed bank length across the Waikato region had riparian buffer widths of 5 m or less (described here as 'narrow') (Figure 31). The remaining 38% of surveyed bank length had 'wide' buffer widths of more than 5 m.

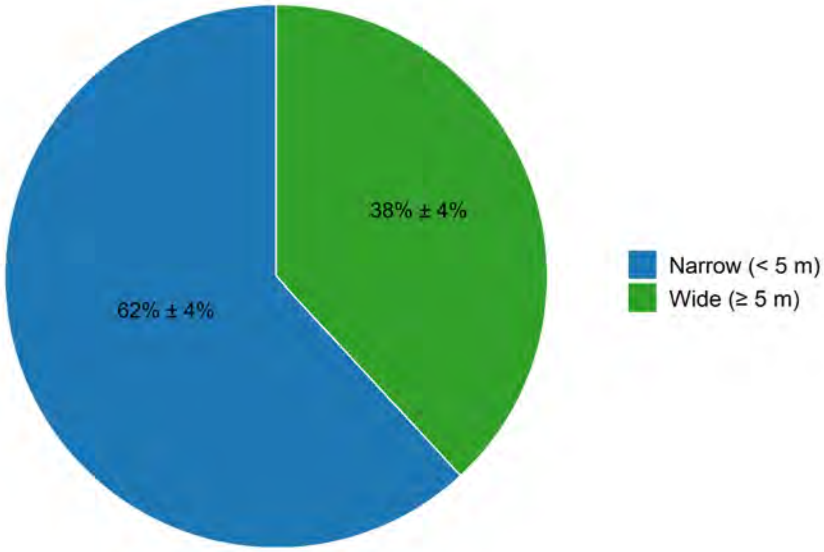


Figure 31. Average proportion of bank length with narrow (< 5 m) and wide (≥ 5 m) buffer widths across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.

Overall, 37% of surveyed bank length across the region had a buffer width of less than 2 m and a further 25% of bank length had a buffer width of 2 – 5 m (Figure 32). About 23% of bank length had a buffer width of greater than 10 m. The establishment of riparian margins for restoration planting necessitates careful consideration of buffer widths. According to the Waikato Regional Council Clean Stream management guide (2004), a minimum buffer width of 5 m is recommended for riparian margins where restoration planting is planned. However, if the objective is to achieve self-sustaining, low maintenance indigenous vegetation cover, a buffer width exceeding 10 m is advised (Parklyn et al., 2000). The determination of an appropriate buffer width depends on site specific characteristics such as aquatic features, slope, and lithology (Collier et al., 1995; McKergow et al., 2016). Notably, on flat terrain, buffer widths of 1 – 3 m for grassed margins are deemed acceptable for improving water quality outcomes (e.g., reducing suspended sediment) (Waikato Regional Council, 2004). A recent review by Fenemor and Samarasinghe (2020) focussed on a range of New Zealand studies to assess riparian margins, and the setback width required to achieve a range of ecosystem responses. These ecosystem responses included, amongst other factors, reduction in nutrient via overland flow, improved channel and bank stability, attenuation of flood flows and increased freshwater ecosystem health. The study concluded that although setback width is an important factor, it represents only one of multiple factors to be considered when designing interventions aimed at achieving the specified functional objectives within a given catchment.

It is important to note that the current survey design lacks an assessment of buffer width efficacy in mitigating or attenuating contaminant transfer because information relating to landscape characteristics (e.g. slope and lithology) and more detailed vegetation characteristics (e.g. vegetation height and density) are not captured at the survey transect scale. It is recommended that future surveys include more detailed site assessment variables and make use of remote data capture techniques (e.g. drones) to improve the assessment of buffer width efficacy.

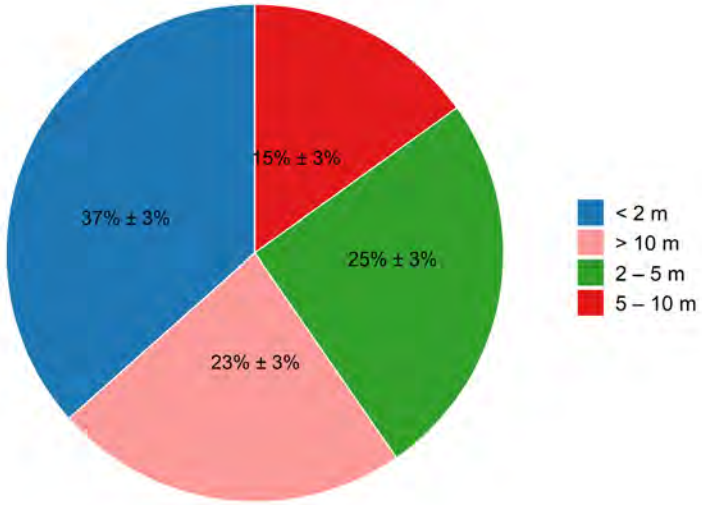


Figure 32. **Average proportion of bank length by individual buffer width category across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

There was a clear correlation between vegetation type and generalised buffer width categories (Figure 33). Around 70% of non-woody vegetation occurred within buffer widths less than 5 m, while approximately 60% of woody vegetation was found in buffer widths of 5 m or more. The proportion of woody vegetation associated with a buffer width of less than 2 m was relatively low at approximately 13%.

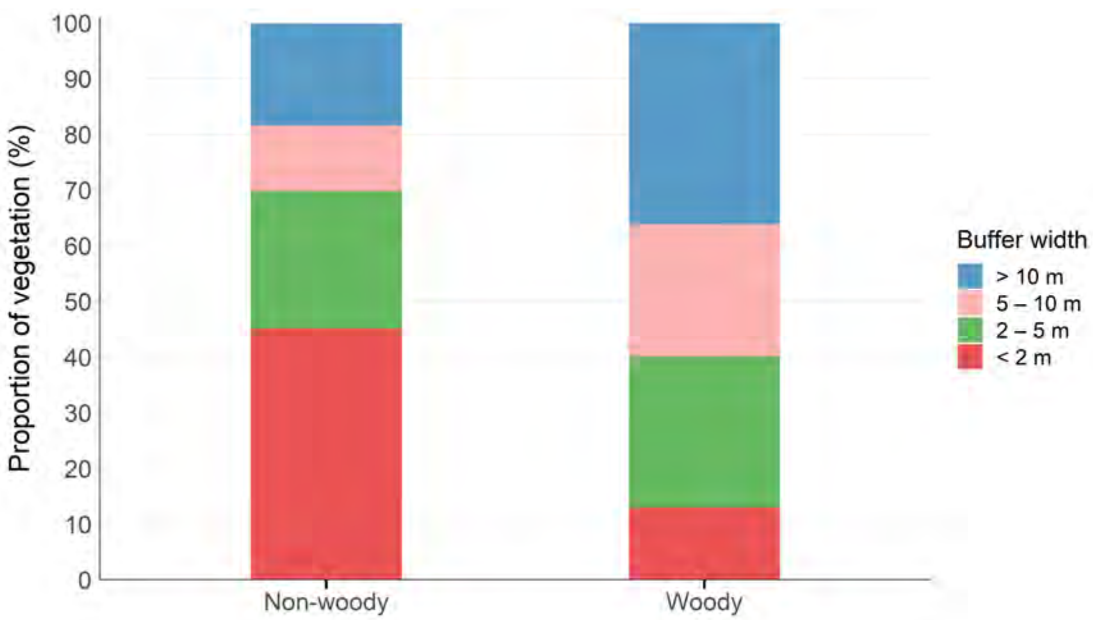


Figure 33. **Average proportion of non-woody and woody vegetation located within individual buffer width categories across the Waikato region in 2022.**

The differences in vegetation buffer widths between dairy and drystock were significant for all buffer width categories (Figure 34). Overall, drystock enterprises had a significantly higher proportion of bank length with 'wide buffers' (47%) compared to dairy (26%) (t = 5.7, P < 0.0001). Conversely, dairy farms had a significantly higher proportion of bank length with 'narrow' buffers (74%) compared to drystock (53%) (t = 5.7, P < 0.0001). Dairy was characterised by predominantly very narrow buffers (< 2 m, 63%), while drystock was characterised by wide (5 – 10 m, 19%) and very wide (> 10 m, 28%) buffers. Consistent with the findings from previous surveys, the prevalence of wider buffers under drystock relative to dairy may be attributed to the generally more extensive nature of drystock farming and the high proportion of narrow drains (stream order 0) on dairy farms.

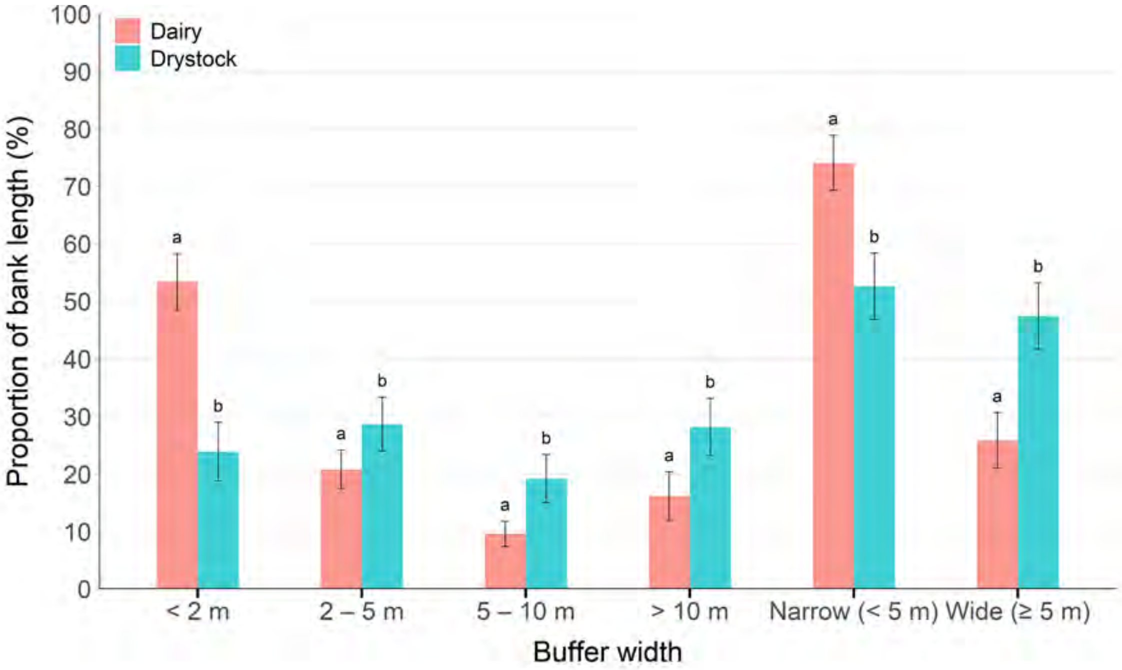


Figure 34. Average proportion of bank length by narrow (< 5 m), wide (≥ 5 m) and individual buffer width categories within land use types across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.

Further to the findings shown in Figure 34, differences in vegetation type between land use within narrow and wide buffer categories were associated with non-woody rather than woody vegetation (Figure 35). That is, regardless of buffer width, there were significant differences in the proportion of bank length with non-woody vegetation between dairy and drystock farms. For narrow buffers, a significantly greater proportion of vegetation was non-woody for dairy (85%) compared to drystock (58%) (t = 7.1, P < 0.0001). The opposite was true for wide buffers, where a significantly greater proportion of vegetation was non-woody for drystock (42%) compared to dairy (15%) (t = 7.1, P < 0.0001).

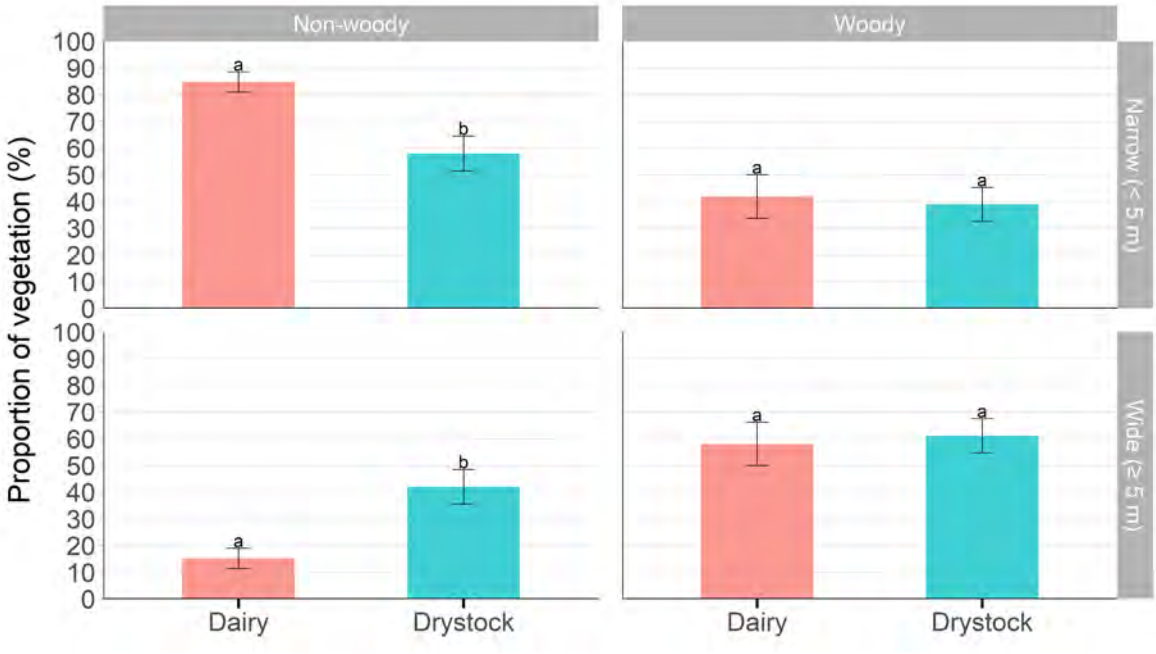


Figure 35. **Average proportion of non-woody and woody vegetation within narrow (< 5 m) and wide (≥ 5 m) buffer width categories for dairy and drystock land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each vegetation x buffer width category, averages carrying the same letter are not significantly ($P < 0.05$) different.**

The greatest proportion of surveyed bank length with wide buffers was observed in Taupō management zone (70%), significantly higher than all except the Lower Waikato and West Coast management zones (Figure 36). This result can be attributed to the extensive soil conservation schemes implemented within the Taupō management zone over time (Waikato Regional Council, 1998; Palmer, 2004). Additionally, the prevalence of wide gully systems, influenced by the dominant pumice geology (Smith and Vale, 2024), leads to the retirement of large areas adjacent to these gully systems. In contrast, the Lower Waikato and Waihou-Pikao management zones had the lowest average proportion of bank length with wide buffers (23% and 20%, respectively), significantly lower than all except the Central Waikato management zone. As demonstrated in Table A2-1, the largest network of drains (with narrow set back margins) is found in the Lower Waikato, Waihou-Piako, and Central Waikato.

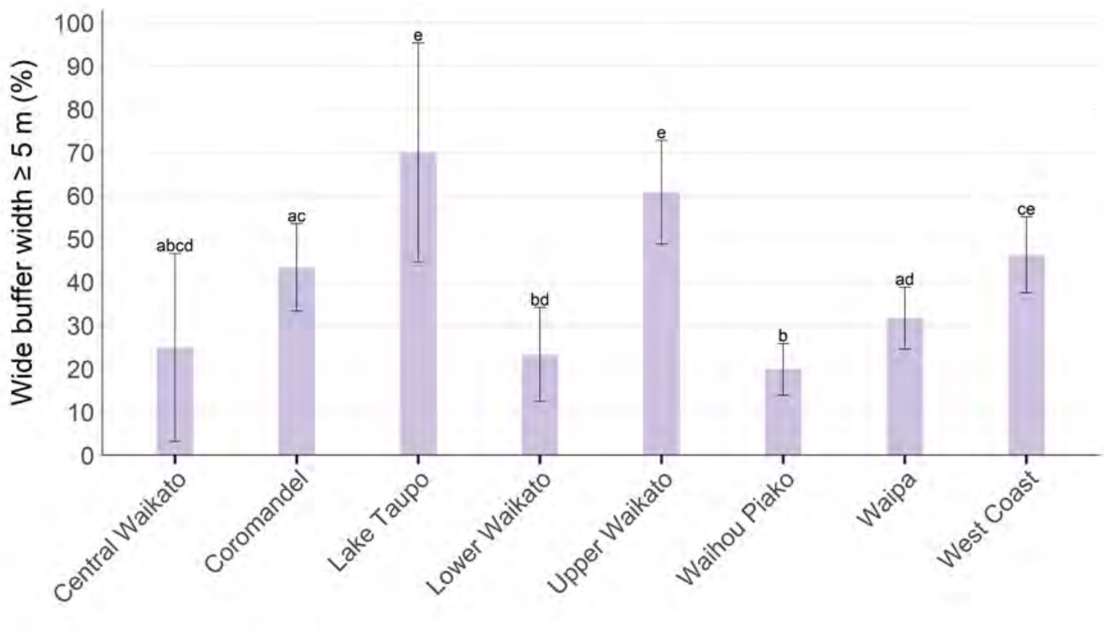


Figure 36. **Average proportion of bank length with wide (≥ 5 m) buffer widths within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.**

As shown in Figure 37, drains (stream order 0) stand out as having a lower proportion of bank length with a wide buffer width (5%) compared to all other stream orders. Drains typically occur in high intensity agricultural systems (e.g. dairying on flat land) and tend to be fenced relatively close to the channel (i.e. with a narrow buffer width) to minimise loss of productive agricultural land. In terms of other stream orders, there was a general trend of an increasing proportion of wide buffers with increasing stream size. It is recognised that there is high variability in the estimates for 5th and 6th order streams due to low sample numbers for these strata.

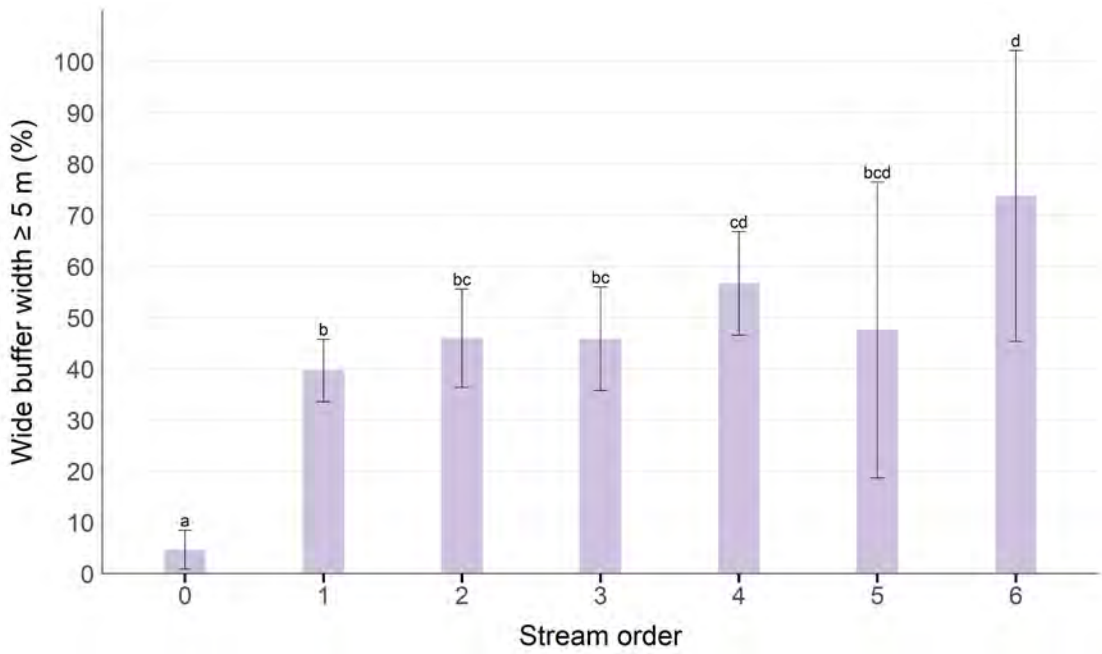


Figure 37. **Average proportion of bank length with wide (≥ 5 m) buffer widths within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.**

3.4.2 Summary of key riparian buffer width results

- On average, 38% of surveyed bank length across the Waikato region had wide buffer widths of 5 m or more, while the remaining 62% of surveyed bank length had narrow buffer widths of less than 5 m.
- There was a clear association between vegetation type and buffer width, with 70% of non woody vegetation occurring within narrow buffers and 60% of woody vegetation occurring within wide buffers.
- Streams on dairy farms had a significantly larger proportion of bank length with buffer widths of less than 2 m (63%) compared to drystock (53%). Drystock had a significantly higher proportion of bank length under all other buffer categories compared to dairy. Differences in vegetation type between land use within narrow and wide buffer categories were associated with non-woody rather than woody vegetation.
- The greatest proportion of surveyed bank length with wide buffers was observed in Taupō management zone (70%), with the lowest proportion observed in the Lower Waikato and Waihou-Pikao management zones (23% and 20%, respectively).
- Drains (stream order 0) stand out as having a lower proportion of bank length with a wide buffer width (5%) compared to all other stream orders.

3.5 Waterway crossings

3.5.1 State

As with previous riparian characteristic surveys, waterway crossings were observed as part of the survey in 2022. Most waterway crossings across the region were classified as culverts (83%) (Figure 38). The remaining waterway crossings were categorised as either bridges (12%) or fords (5%).

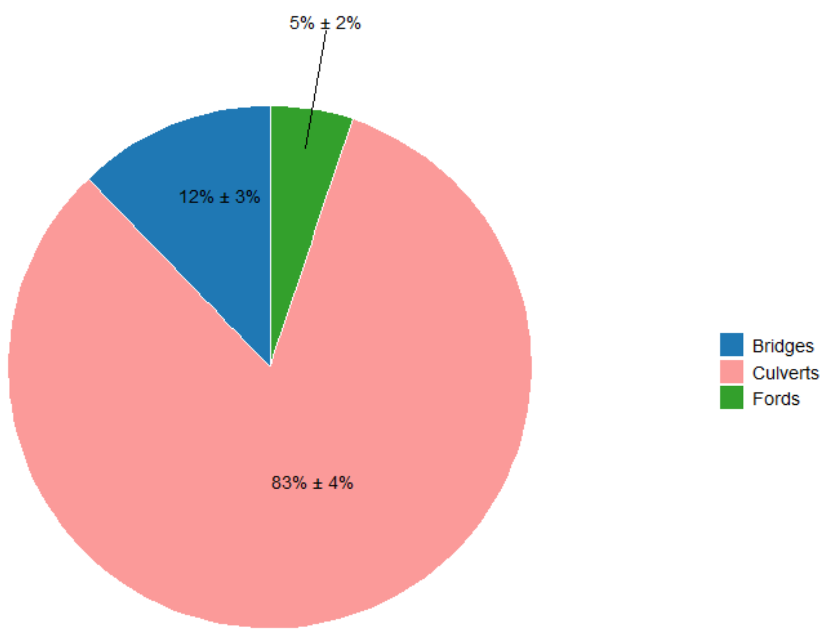


Figure 38. Average proportion of observed crossings that are bridges, culverts or fords across the Waikato region in 2022 (n = 285). Error terms represent the 95% confidence interval about the average.

In terms of the total number of crossings per km of stream length, there were no differences between dairy and drystock land uses (Figure 39). However, when examining individual crossing types as a proportion of total observations, the proportion of fords was significantly greater for drystock (9%) compared to dairy (1%) ($t = 3.4$, $P < 0.001$). Drystock farms more often occur in remote hill-country areas, where fords are more likely to be used to cross waterways in difficult to access areas. Furthermore, the dairy industry actively encourages the use of bridges and culverts through initiatives such as the Dairying and Clean streams Accord. With less than 1% of crossings on dairy farms being classified as something other than a culvert or bridge, the 2022 results demonstrate that the Accord has successfully achieved its voluntary performance target of having 100% of crossings as either bridges or culverts by 2018.

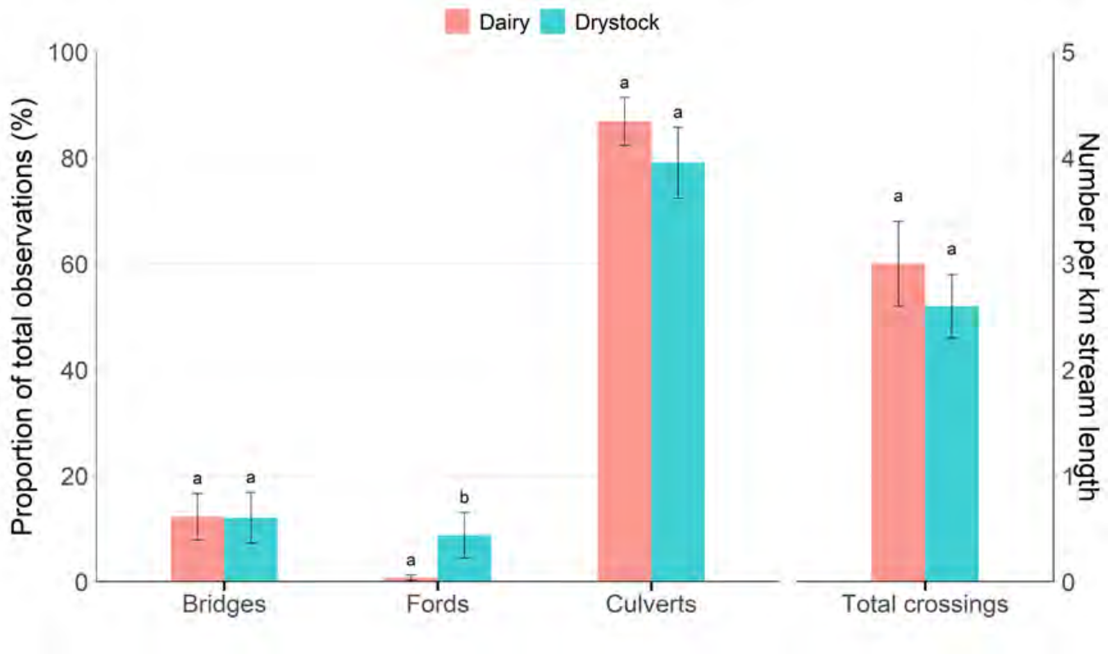


Figure 39. **Average proportion of observed crossings that are bridges, fords or culverts within land use types across the Waikato region in 2022. Error bars represent the 95% confidence around the average proportions. The secondary axis indicates the average number of obstructions observed along each 1 km segment of waterway.**

On average, the Lake Taupō management zone had the lowest number of crossings per km of stream length (1.6) in 2022, while the highest number of crossings were observed in the Central Waikato (5.1) (Figure 40). The relatively low number of waterway crossings within the Taupō management zone can be attributed to the prevalence of extensive gully systems, which pose challenges for constructing crossings. For the remaining management zones, differences in the number of crossings are broadly related to land use, with fewer crossings occurring in areas dominated by low intensity land uses (e.g. sheep). These land uses typically occur in hill-country landscapes characterised by steep topography, which may restrict road access and negate the need for stream crossing structures. Furthermore, lower stream orders (i.e. stream order 1 and 2) are most prevalent in hill country catchments and require fewer stream crossings due to narrow channels and generally lower flows.

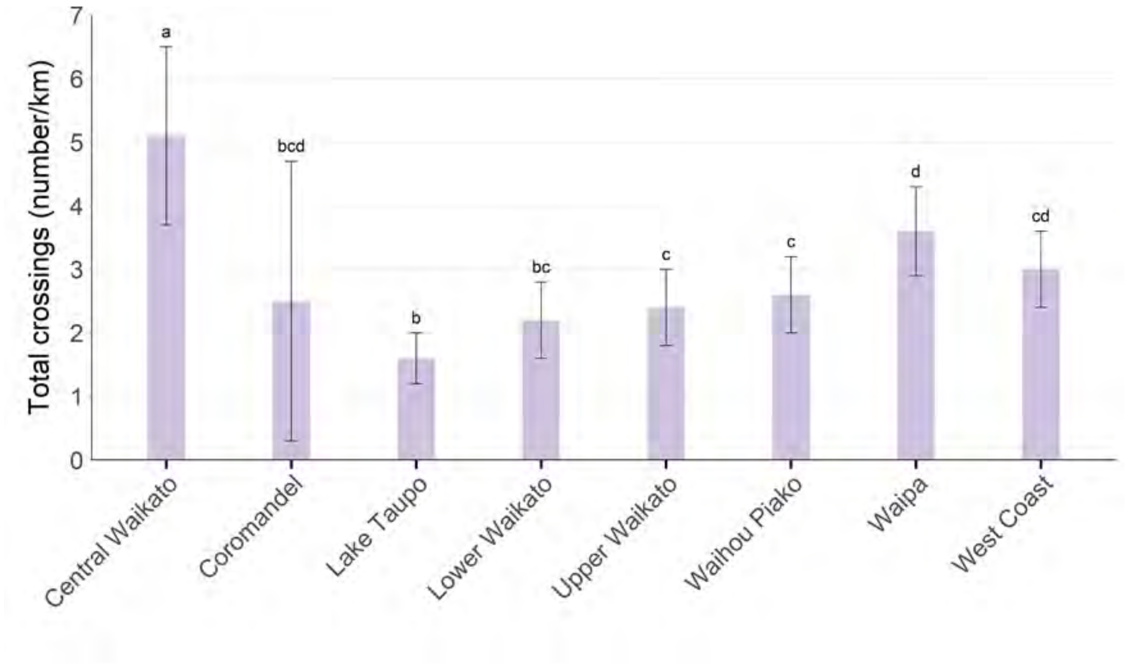


Figure 40. **Average number of total crossings observed per km of stream length within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

There was a general decrease in the occurrence of water crossings with increasing stream order, with orders 4 or more having significantly less crossings than all other streams (Figure 41). In general, smaller streams (stream order 3 or less) had a higher occurrence of crossings per km of stream length, ranging from 1.9 to 3.2. In contrast, larger streams (stream order 4 or more) have fewer crossings, with values ranging from 0 to 0.7 crossings per km of stream length. Practical and regulatory constraints, including cost considerations, likely contributed to the less frequent occurrence of crossings over larger streams and rivers.

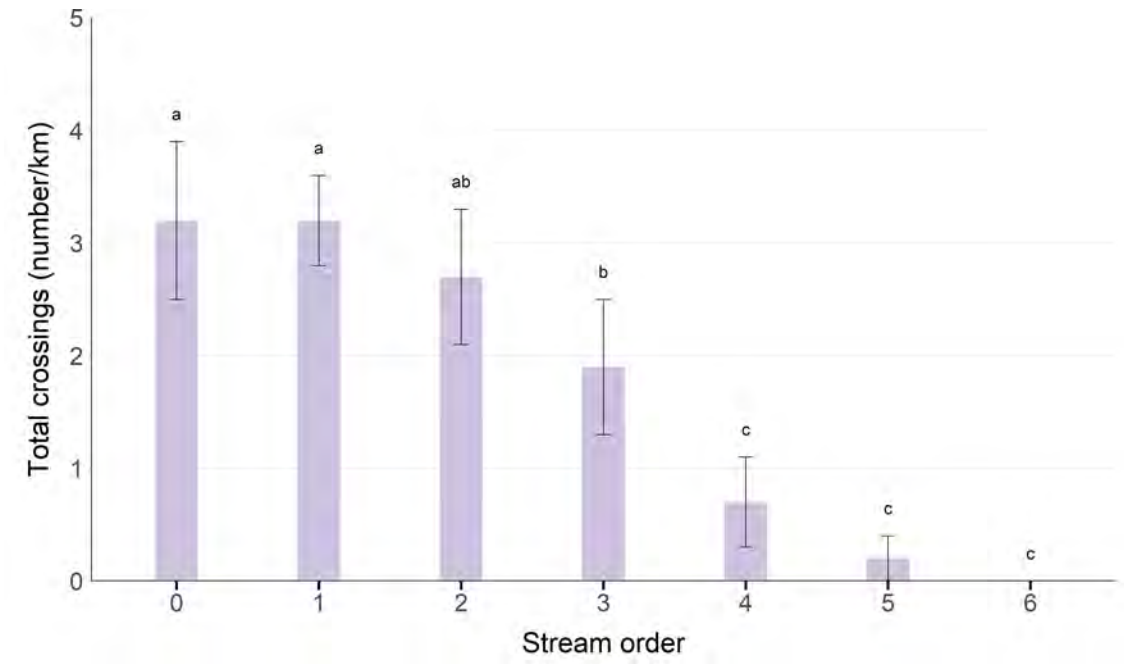


Figure 41. **Average number of total crossings observed per km of stream length within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95%**

3.5.2 Summary of key stream crossings results

- Most waterway crossings across the Waikato region were categorised as culverts (83%) in 2022, with the remaining waterway crossings being categorised as either bridges (14%) or fords (3%).
- There were no differences in the total number of crossings per km of stream length between dairy and drystock. However, there were significantly more fords observed across drystock farms (9%) compared to dairy (< 1%).
- The Lake Taupō management zone had the lowest number of crossings per km of stream length (1.6) while the highest number of crossings were observed in the Central Waikato (5.1)
- Smaller streams (stream order 3 or less) had a higher occurrence of crossings per km of stream length, ranging from 1.9 to 3.2. In contrast, larger streams (stream order 4 or more) have fewer crossings, with values ranging from 0 to 0.7.

3.6 Stream-bank erosion

3.6.1 State

The majority (91%) of surveyed bank length across the region in 2022 was uneroded (Figure 42). Of the 9% of bank length observed to be eroded, 4% showed signs of active erosion while 5% had recent erosion.

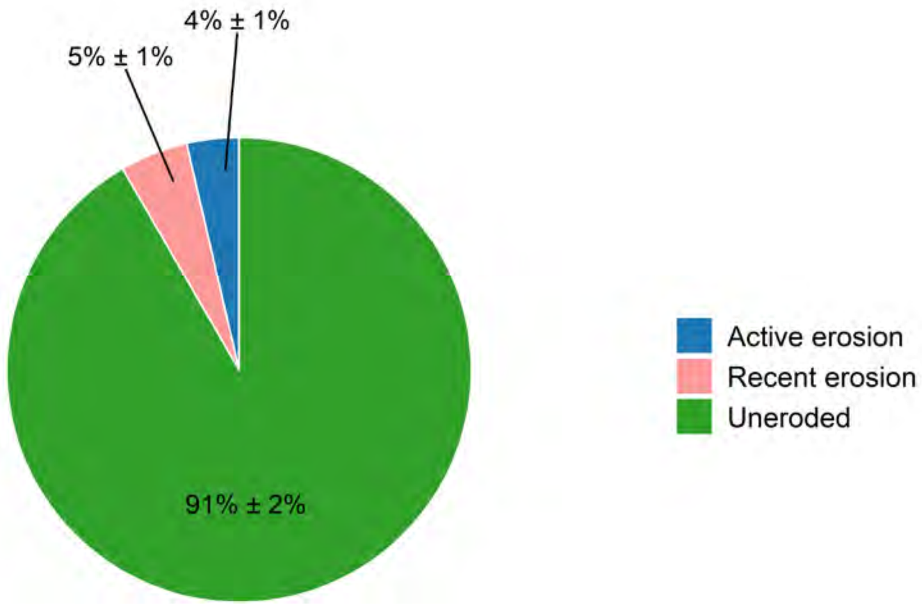


Figure 42 **Average proportion of bank length uneroded and with active or recent erosion across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.**

Soil disturbance is the sum of total stream-bank erosion (active or recent erosion) and pugging disturbance (where more than 50% of the riparian margin is affected). In 2022, approximately 10% of the surveyed bank length in the region showed evidence of disturbance, and of this, 1% of bank length showed evidence of pugging disturbance (Figure 43). The remaining 90% remained undisturbed.

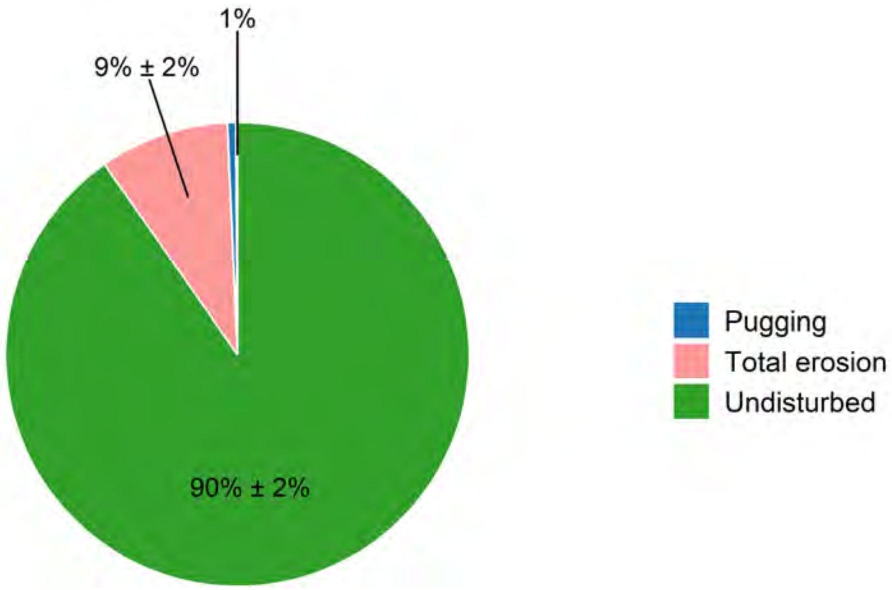


Figure 43. Average proportion of bank length undisturbed and with erosion or pugging disturbance across the Waikato region in 2022 (n = 430). Error terms represent the 95% confidence interval about the average.

Streams on drystock farms had a significantly higher proportion of bank length with active erosion compared to those on dairy farms ($t = 2.7$, $P < 0.01$), while the proportion of bank length with recent erosion was similar between land uses ($t = 0.18$, $P > 0.5$) (Figure 44). When considering total erosion (sum of recent and active erosion), there was no significant difference in the proportion of eroded bank length between land uses ($t = 1.89$, $P = 0.06$). However, the proportion of bank length that was disturbed (sum of total erosion and pugging > 50%) was significantly higher for drystock compared to dairy ($t = 2.37$, $P < 0.05$). These findings align with variations in stock exclusion (and effective fencing) between dairy and drystock systems (Figures 6 and 11). In drystock systems, where stock exclusion levels were generally lower, soil disturbance levels were higher. Additionally, drystock farms are primarily located in hill country regions, which feature a higher proportion of high-energy streams and steep topography, which increases the likelihood of streambank erosion during storm events.

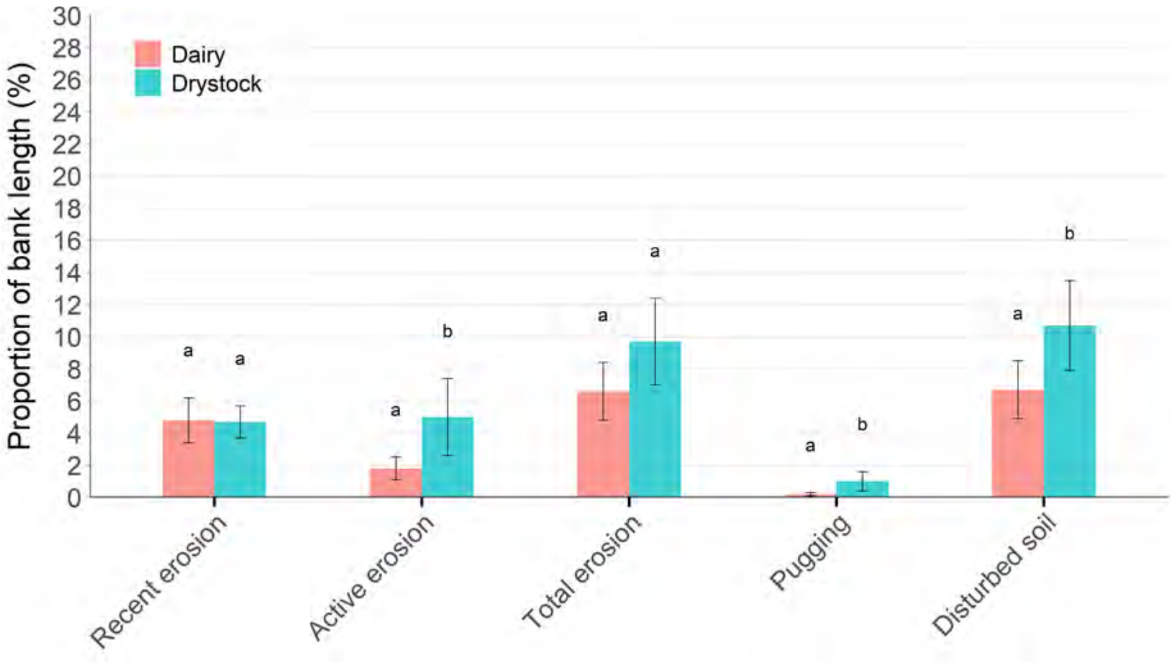


Figure 44. **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) within land use types across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

Figure 45 shows that the average proportion of bank length effectively fenced and undisturbed (91%) was significantly higher than the proportion of bank length unfenced and undisturbed (82%) (t = 3.99, P < 0.0001). Undisturbed soil includes areas with no evidence of pugging or bank erosion. The difference in the proportion of undisturbed bank length is primarily due to the higher total pugging in unfenced bank length compared to fenced bank length, underscoring the importance of effective fencing in excluding livestock from riparian margins. In contrast, effective fencing seems to have had minimal impact on stream bank erosion, as both active and recent erosion components show non-significant differences between fenced and unfenced bank length. This finding is consistent with the 2012 riparian survey results and seems to suggest that undercutting of stream banks is largely unaffected by the grazing of riparian margins (Jones et al, 2016; Williamson et al., 1992). Despite the overall low proportion of bank length affected by pugging (~1%), pugging (> 50%) was significantly more prevalent in unfenced riparian margins (1% of bank length) compared to fenced riparian margins (0%). Disturbed soil (sum of total erosion and pugging > 50%) was similar between fenced and unfenced areas, with no statistically significant difference (t = 0.62, P = 0.5).

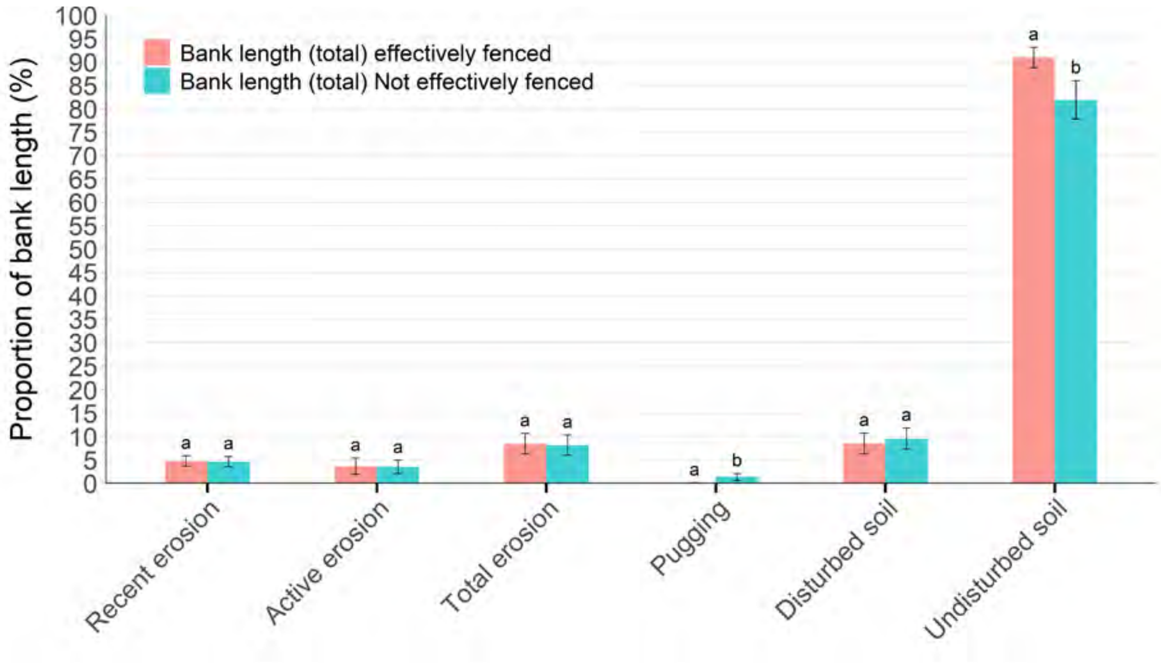


Figure 45. **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) that is effectively fenced or unfenced across the Waikato region in 2022. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

The proportion of eroded bank length ranged from 1 to 20% across the eight management zones (Figure 46). Due to the large variance in erosion measurements between sites, there were large 95% confidence intervals for most management zones. The Central Waikato, Coromandel, and Lower Waikato had the highest proportion of eroded stream bank with values of 20%, 17%, and 13%, respectively. It is unclear as to why the Central Waikato had elevated streambank erosion relative to other zones, especially when considering previous surveys (Norris et al, 2020 and Jones et al., 2016) demonstrated a low incidence of stream bank erosion across the zone. For the Coromandel and parts of the Lower Waikato (e.g. Matahuru Catchment), high levels of stream bank erosion may reflect the nature of the topography, patterns of land use, and management factors (predominantly hill country, sheep and beef; Table A1-2). The low proportion of stream bank erosion in the Lake Taupō and Upper Waikato management zones may, at least in-part, be related to historic soil conservation schemes in these zones (see Environment Waikato, 1998; Palmer, 2004).

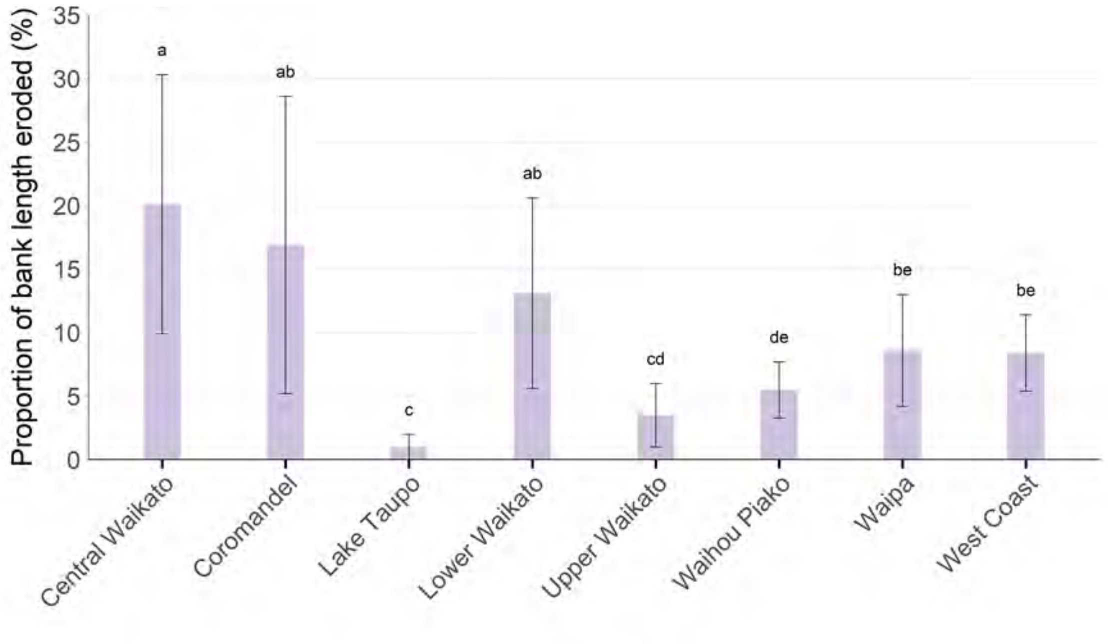


Figure 46. **Average proportion of bank length eroded within each management zone in 2022. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

First order streams exhibited the lowest mean percentage of bank length eroded (4%), significantly lower than that observed in second to fifth order streams (P < 0.05; Figure 47). This is likely attributable to the narrower channel width of headwater streams, resulting in a reduced riverbank area susceptible to erosion. Fourth order streams had the highest proportion of eroded bank length (31%), and was significantly (P < 0.05) higher than first, second and third order streams. Despite fifth and sixth-order streams showing relatively high proportions of bank length with erosion (22 – 24%), the high variance in measurements across sites resulted in mean values not being significantly different from those observed in second to fifth order streams.

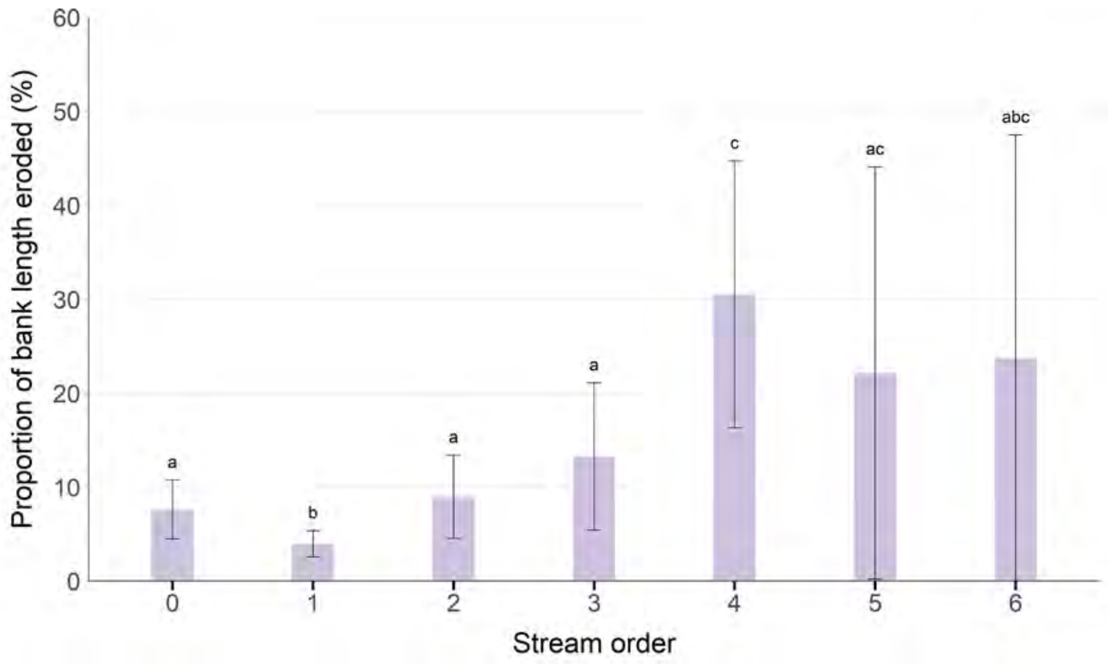


Figure 47. **Average proportion of bank length eroded within each stream order in 2022. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

3.6.2 Change over time

A significant increase in the average proportion of surveyed bank length eroded (i.e. sum of active and recent erosion) of about 3% occurred over the past twenty years (2002 – 2022) across the region ($t = 2.5$, $P = 0.01$) (Figure 48, Table 25). There has been a statistically significant decrease over the past 5 years (9%) ($t = 4$, $P < 0.0001$) and no change over the proceeding 10-year period (2012 – 2022) ($t = 1.46$, $P = 0.15$). The highest proportion of eroded bank length was observed in 2007 (21%), significantly greater than that observed in 2022 (8%) ($t = 4.6$, $P < 0.0001$). The occurrence of active erosion changed over time, with similar proportions observed in 2007, 2012, and 2017. A significant decrease in the proportion of surveyed bank length with active erosion of 3% occurred over the past 5 years (2017 – 2022) ($t = 2.7$, $P < 0.001$). Recent erosion also varied over monitoring periods, peaking at 17% in 2007 and 10% in 2017, both significantly ($P < 0.05$) higher than the levels recorded in 2022.

It is likely that the amount of total stream bank erosion observed in a particular survey year will be, to some extent, influenced by the number, magnitude, and frequency of storm events that lead to high flows in the year or years prior to the survey being undertaken (e.g. Henshaw et al., 2012; Palmer et al., 2014). The first half of 2023 experienced significantly higher precipitation, with average rainfall in January, February, and May exceeding the 1991 – 2020 mean monthly rainfall by 1.5 to 4 times (NIWA, 2023). Elevated river flows can obscure stream bank erosion, and given that the bank erosion metric is observational, it is plausible that erosion not observed in 2022 was recorded in previous years when river levels were lower. Additionally, the 2022 survey introduced the Trimble TDC600 device. Although its GPS accuracy is comparable to the Juno device used in 2012 and 2017, the improved user interface and data collection efficiency resulted in a higher number of erosion data points being collected in 2022 compared to previous survey years. For example, approximately 3,600 erosion points were recorded in 2022, compared to 1,900 in 2017. The enhancement in data collection precision may explain the lower observed erosion in 2022 due to less generalisation of the attribute along the length of the survey transect. Furthermore, the subjective nature of stream-bank erosion assessment implies that temporal comparisons of erosion are less reliable than those of more objective metrics, such as changes in fencing or livestock access.

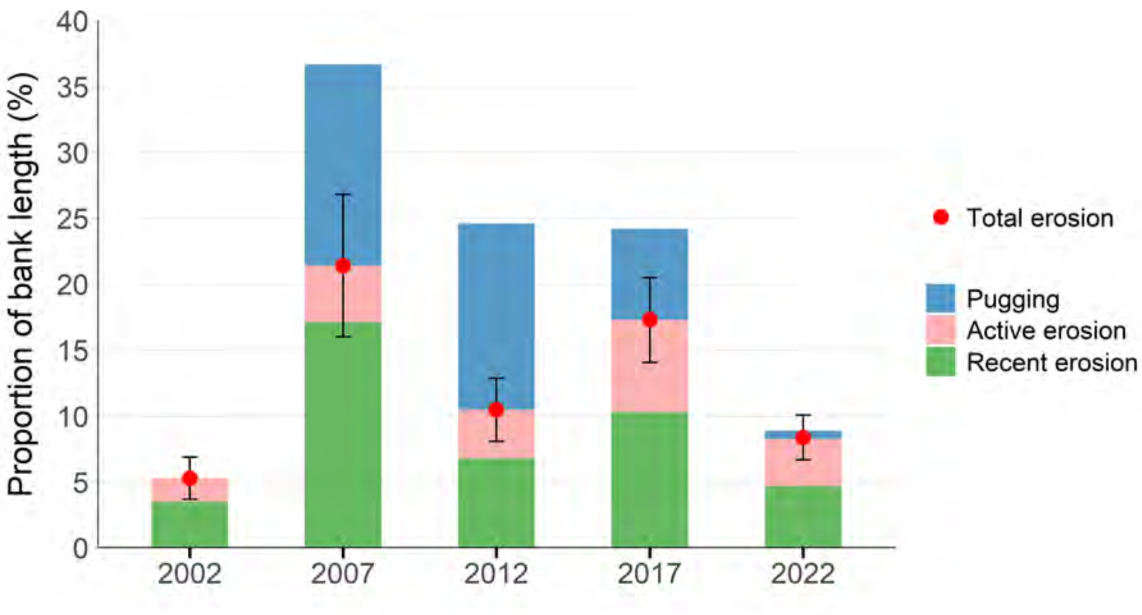


Figure 48. Average proportion of bank length eroded and bank length disturbed (with active and recent components and pugging disturbance) at the four survey periods (2002, 2007, 2012, 2017, and 2022). Note that pugging disturbance was not assessed in 2002. Red symbols represent the average proportion of bank length eroded (sum of active and recent) for each for each of the five survey years. Error bars represent the 95% confidence intervals about the average.

The observation of pugging disturbance was first undertaken during the 2007 survey. Therefore, the change in pugging and soil disturbance could not be examined for the previous 20-year period between 2002 and 2022. Figure 48 and Table 25 show that the average proportion of surveyed bank length disturbed (i.e. sum of active and recent erosion, and pugging) decreased significantly over the past 15-year monitoring period from 37% in 2007 to 9% in 2022 ($t = 9.9$, $P < 0.0001$). Most notable is the steady decrease in pugging since 2012, with an 8% reduction in observed bank length with pugging between 2012 and 2017 and a further 7% decrease between 2017 and 2022. As demonstrated in section 3.2.1, only 8% of sites across the region showed evidence of stock grazing the riparian margin during the survey, significantly less than the 20% measured in 2017. In this report, pugging disturbance is defined as 'more than 50% of the riparian margin disturbed by pugging'. Like erosion, the pugging attribute is somewhat subjective, and some areas recorded as having less than 50% pugging may in fact have had more than 50%. Nevertheless, the past two surveys have shown significant reductions in pugging, suggesting that fencing efforts are effectively keeping livestock away from waterways.

Table 25. Average change in the proportion of bank length eroded or disturbed (including erosion type and pugging components) over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2017), and 20-year (2002 – 2022) periods.

	2017–2022 (5-year)		2012–2022 (10-year)		2007–2022 (15-year)		2002–2022 (20-year)	
	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
Active erosion	-3**	2.	0 NS	2	-1 NS	2	2*	2
Recent erosion	-6**	2.	-2 NS	2	-12**	5	1 NS	1
Total erosion	-9**	3.	-2NS	3	-13**	6	3*	2
Pugging	-6**	2.	-14**	4	-15**	3	-	-
Disturbed	-15**	4	-16**	5	-28**	6	-	-

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, NS Not significant.

The changes in stream-bank erosion over time for dairy and drystock land uses followed similar patterns to those observed across the region as a whole (Figure 49, Table 26). Over the past 20 years (2002 – 2022), there was no change in total erosion (and associated active and recent components) for dairy ($t = 1.29$, $P = 0.2$). However, for drystock, total erosion increased significantly over the past 20 years ($t = 2.17$, $P = 0.03$), nearly double the rate observed for dairy. The proportion of surveyed bank length with erosion varied over time for both dairy and drystock, influenced by specific conditions at the time of the survey (e.g. river levels) severity of storm events prior to the survey and sensitivity of the GPS device used at the time of the survey. Consistent with overall results, both dairy and drystock saw significant increases in total erosion between 2012 and 2017 ($P < 0.01$), followed by significant decreases from 2017 – 2022 ($P < 0.01$). For both land uses, the proportion of eroded stream bank in 2022 was similar to that measured in 2012, with no statistically significant changes over the preceding 10-year period.

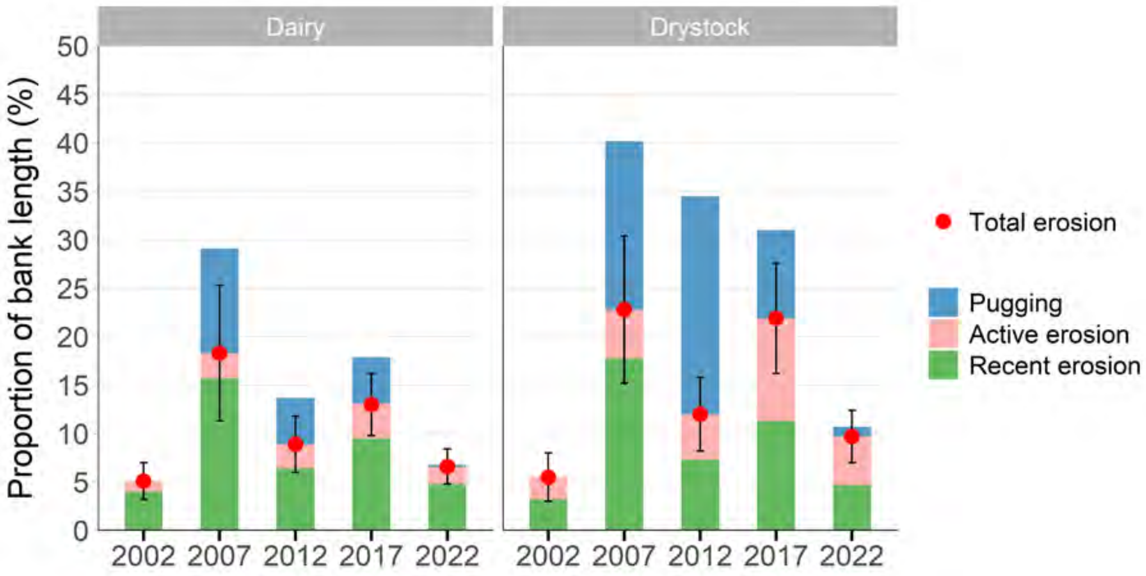


Figure 49. Average proportion of bank length eroded and bank length disturbed (with active and recent components and pugging disturbance) within land use types at the four survey periods (2002, 2007, 2012, 2017, and 2022). Note that pugging disturbance was not assessed in 2002. Red dots represent the average proportion of bank length eroded (sum of active and recent) for each of the five survey years. Error bars represent the 95% confidence intervals about the average.

Over the past 15 years (2007–2022), total disturbance decreased significantly for both dairy (22% of bank length, $t = 4.6$, $P < 0.0001$) and drystock (30% of bank length, $t = 7.2$, $P < 0.0001$) land uses, reflecting reductions in both recent erosion and pugging components (Figure 49, Table 26). In 2022, pugging was observed along 0.2% of surveyed bank length in dairy and about 1% in drystock, significantly lower than for all other survey years. It is unclear as to why pugging rates were so low across 2022 in both dairy and drystock. For dairy, this reduction may be attributed to the high coverage of effective fencing (88%) and the associated low rates of stock access to riparian margins (<1% current access). However, for drystock, pugging disturbance was about 1% in 2022, despite effective fencing covering only 36% of surveyed bank length and current stock access being observed at 13% of sites. We hypothesize that although stock access to riparian margins was significantly reduced in 2022 compared to previous survey years (see section 3.2.2), the lower rates of pugging may be related to differences in the data collection approach across survey years. In 2022, the introduction of Trimble TDC 600 devices, which provided an enhanced user interface and improved data collection efficiency, resulted in a significantly greater number of points being collected compared to previous surveys. Consequently, pugging was more likely to be observed over shorter distances rather than generalising the attribute over large reaches of the riparian margin. Nonetheless, the lower rates of pugging in 2022 appear to correlate with the generally reduced rates of stock access to waterways compared to earlier survey years.

Table 26. Average change in the proportion of bank length eroded and disturbed (including erosion type and pugging components) within land use types over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2 022), and 20-year (2002 – 2022) periods.

	Land use type	2017 - 2022 (5-year)		2012 – 2022 (10-year)		2007 – 2022 (15-year)		2002 – 2022 (20-year)	
		Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
Active erosion	Dairy	-2*	1	1^{NS}	1	-1^{NS}	2	1^{NS}	1
	Drystock	-6*	5	0^{NS}	3	0^{NS}	4	3^{NS}	3
Recent erosion	Dairy	-5**	3	-2^{NS}	3	-11**	7	1^{NS}	2
	Drystock	-7**	4	-3^{NS}	3	-13**	7	1^{NS}	2
Total erosion	Dairy	-7**	3	-2^{NS}	3	-12**	7	2^{NS}	2
	Drystock	-12**	6	-2^{NS}	5	-13**	8	4*	4
Pugging	Dairy	-5**	3	-5**	2	-11**	7	-	-
	Drystock	-8**		-22**	8	-17**	5	-	-
Disturbed	Dairy	-11**	4	-7**	4	-22**	10	-	-
	Drystock	-20**	7	-24**	8	-30**	8	-	-

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Over the past twenty years, the average proportion of surveyed bank length eroded remained largely unchanged across management zones, except for the Waihou-Piako zone, which saw a significant increase (3 to 6% of bank length, Table 27). For the Upper Waikato, Waihou-Piako, Waipā, and West Coast zones, there was a significant decrease in bank erosion (8–14%) over the last 5 years (2017 – 2022). No significant change in bank erosion was observed in the Central Waikato, Coromandel, Lake Taupō, and Lower Waikato zones over the 2017 to 2022 period.

Table 27. Average proportion of bank length eroded within management zones at the four survey periods (2002, 2007, 2012, 2017, and 2022) and average change over the previous 5-year (2017 – 2022), 10-year (2012 – 2022), 15-year (2007 – 2022), and 20-year (2002 – 2022) periods.

Management zone	Average bank length (%)					2017 - 2022 (5-year)		2012 – 2022 (10-year)		2007 – 2022 (15-year)		2002 - 2022 (20-year)	
	2002	2007	2012	2017	2022	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
Central Waikato	9	14	5	17	20	4^{NS}	7	16*	12	6^{NS}	11	11^{NS}	12
Coromandel	7	23	20	28	17	-11^{NS}	29	-3^{NS}	15	-6^{NS}	12	10^{NS}	12
Lake Taupō	4	9	3	14	1	-13^{NS}	22	-2^{NS}	11	-8^{NS}	17	-3^{NS}	11.
Lower Waikato	7	15	17	19	13	-6^{NS}	12	-3^{NS}	9	-2^{NS}	9	6^{NS}	8
Upper Waikato	4	18	1	12	4	-8*	7	3^{NS}	3	-14*	12	0^{NS}	3
Waihou-Piako	3	18	11	13	6	-8**	5	-6^{NS}	7	-12**	8	3*	2
Taupō	5	28	12	15	9	-7*	6	-3^{NS}	7	-20**	12	4^{NS}	5
West Coast	7	29	10	23	8	-14**	7	-2^{NS}	7	-20*	19	1^{NS}	7

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Over the past 20 years (2002 – 2022), the average proportion of surveyed bank length with erosion increased for 4th to 6th order streams (22% – 29%). However, the change was not statistically significant due to the large variance around estimates (Table 28). All other stream orders saw small but non statistically significant changes over the same 20-year period. From 2017 to 2022, stream orders 1 and 2 exhibited significant decreases of 11.5% and 11.3%, respectively. The reason for the significant decrease in 1st and 2nd order streams is unclear. Drains (stream order 0) saw small fluctuations in total erosion over time, although no significant changes were recorded. Overall, drains and stream orders 1 and 2 had the smallest average proportions of bank length eroded in 2022.

Table 28. Average proportion of bank length occupied by woody vegetation within stream orders at each of the four survey periods (2002, 2007, 2012, and 2017) and average change over the previous 5-year (2012 – 2017), 10-year (2007 – 2017), and 15-year (2002 – 2017) periods. Stream order 0 represents drains.

Stream order	Average bank length (%)					2017 – 2022 (5-year)		2012 - 2022 (10-year)		2007 – 2022 (15-year)		2002 - 2022 (20-year)	
	2002	2007	2012	2017	2022	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡	Change (pp†)	95% CI‡
0	6.9	8.0	11.0	13.1	7.6	-5.5 NS	6.0	-3.3 NS	8.1	-0.3 NS	8.7	0.7 NS	3.5
1	4.0	22.6	7.6	15.5	4.0	-11.5**	5.1	-3.7*	3.6*	-18.6**	10.3	0 NS	2.9
2	5.1	23.4	10.4	20.3	9.0	-11.3**	7.8	-1.4 NS	4.1	-14.4**	7.1	3.9 NS	5.5
3	7.0	23.3	14.4	21.9	13.3	-8.7 NS	9.7	-1.2 NS	10.5	-10 NS	13.2	6.3 NS	9.0
4	14.8	24.9	24.4	30.4	30.5	0.1 NS	19.0	6.1 NS	21.8	5.6 NS	24.3	15.7 NS	23.0
5	7.9	31.4	19.7	32.2	22.2	-10.0 NS	26.4	2.4 NS	40.7	-9.3 NS	49.9	14.3 NS	28.6
6	5.6	16.4	10.4	37.9	23.7	-14.1 NS	195	13.3 NS	206	7.3 NS	360	18.1 NS	220

† Percentage point (% of bank length)
‡ 95% Confidence interval about the average.
** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

3.6.3 Summary of key stream-bank erosion results

- Most (91%) of the surveyed bank length across the region in 2022 was uneroded. Of the 9% of bank length observed to be eroded, 4% showed evidence of active erosion while 5% had recent erosion.
- Soil disturbance is the sum of total stream bank erosion (i.e. recent and active) and pugging. Approximately 10% of the surveyed bank length across the region in 2022 was observed as disturbed, with only 1% of this being attributed to pugging.
- There was no significant difference in the proportion of eroded bank length between land uses. However, there was significantly more bank length with active erosion for drystock (5%) compared to dairy (2%).
- There was a significantly higher proportion of undisturbed bank length associated with effective fencing (91%) compared to ineffective fencing (82%).
- The central Waikato, Coromandel, and Lower Waikato zones had the highest proportion of eroded stream bank with values of 20%, 17%, and 13%, respectively. The lowest proportion of stream bank eroded was in the Lake Taupō and Upper Waikato management zones, with values of 3.5% and 1%, respectively.
- First order streams had the smallest average proportion of bank length eroded (4%), significantly lower than for all other stream orders, except for 6th order streams. Fourth order streams had the largest average proportion of stream bank eroded (31%), significantly higher than for stream orders 0–3.
- The proportion of bank length eroded fluctuated over the monitoring period averaging 5%, 21%, 11%, 17%, and 9% in 2002, 2007, 2012, 2017, and 2022, respectively. When

considering the full 20-year monitoring period (2002 – 2022), the proportion of bank eroded across the Waikato region increased significantly from 5.3% to 9%.

- The temporal changes in stream-bank erosion for dairy and drystock land uses exhibited patterns similar to those observed for the region as a whole.
- Over the past twenty years (2002 – 2022), there was no change in total erosion (and associated active and recent components) for dairy. However, for drystock, total erosion increased significantly, at nearly double the rate observed for dairy. Consistent with overall results, both dairy and drystock saw significant increases in total erosion between 2012 and 2017 ($P < 0.01$), followed by significant decreases from 2017 to 2022 ($P < 0.01$). For both land uses, the proportion of eroded stream bank in 2022 was similar to that measured in 2012.
- Over the past twenty years, the average proportion of surveyed bank length eroded remained largely unchanged across management zones, except for the Waihou-Piako zone, which saw a significant increase (3 to 6% of bank length).
- Over the past twenty years, the average proportion of bank length eroded did not change across all stream orders. However, from 2017 to 2022, stream orders 1 and 2 exhibited significant decreases of 11.5% and 11.3%, respectively.

3.7 Factors associated with stream-bank erosion

This section explores some general linkages between stream bank erosion and fencing using the analysis procedures outlined in Section 2.4.4. Simple linear regression models between four measures of erosion as dependent variables and the percentage bank length effectively fenced were applied to the 2007, 2012, 2017 and 2022 data. Linear regressions and associated 95% confidence intervals are shown in Figure 50, with '*' symbols indicating those models where the slope and intercept coefficients were significantly different to zero.

In 2022, only one variable, 'some erosion,' showed a negative association with fencing, as indicated by a statistically significant slope coefficient of -0.072 ($P < 0.01$). This means that an increase in the proportion of bank length effectively fenced is linked to a general decrease in the proportion of bank length showing 'some erosion,' which includes active or recent bank erosion or any disturbance in the riparian margin. This contrasts with the 2007, 2012, and 2017 survey findings. The three previous surveys indicated that an increase in effective fencing was associated with decreases in active erosion, total erosion (eroded), total disturbance and 'some erosion' (defined as any evidence of erosion) (Figure 50).

Table 29 displays the slope and intercept coefficients, and R^2 from the regression models based solely on the 2022 data. During the 2022 survey, three out of the four erosion metrics showed no significant association with effective fencing, as indicated by non-significant slope coefficients. However, the intercept was significantly different from zero in all three models, suggesting that the predicted erosion value is statistically different from zero when fencing is absent. Despite this, the low R^2 values and non-significant slope coefficients provide sufficient evidence to conclude that there is no meaningful association between the average proportion of bank length fenced and the extent of active erosion, total erosion, or total disturbance. While simple linear regression models provide a general indication of associations between variables, more comprehensive analyses (e.g., multiple regression analysis or principal component analysis) would be needed to better account for confounding variables not considered in the current approach.

Possible reasons for the lack of association between fencing and erosion is two-fold. Firstly, as discussed in section 3.6.2, the levels of erosion were notably low in 2022, owing to the unusually high river flows associated with unseasonally high rainfall, which likely obscured evidence of stream bank erosion at many sites. Secondly, the Trimble TDC 600 device provided an improved user interface, which increased the number of points collected along any given transect and improved the level of precision. The enhancement in data collection precision may explain the lower observed erosion in 2022 due to less generalisation of the attribute along the length of the survey transect.

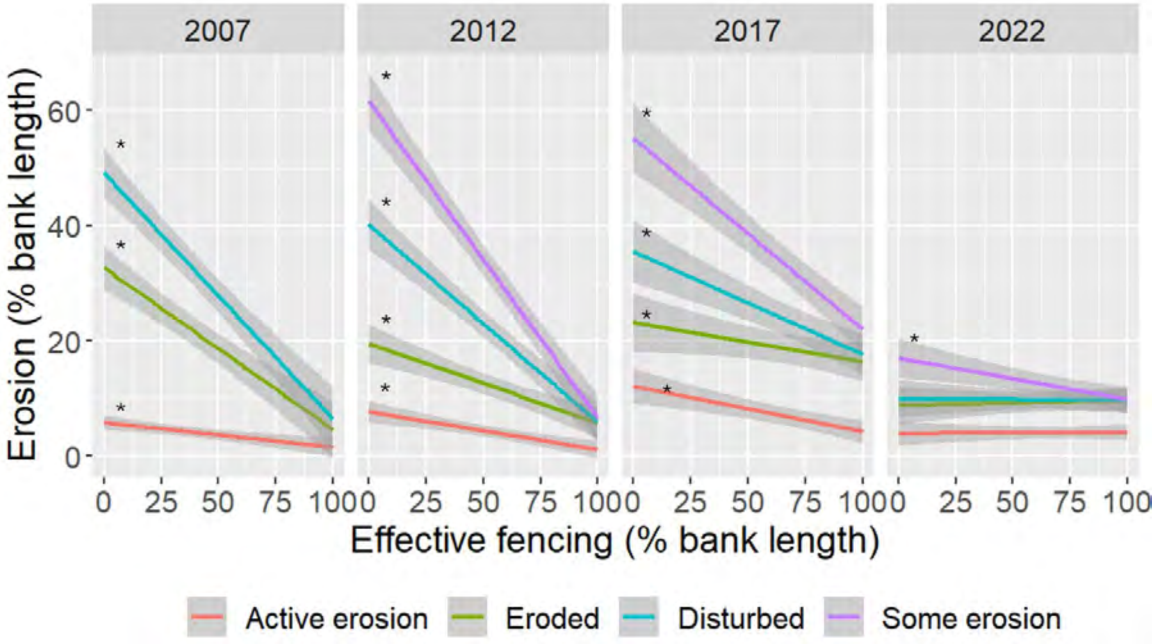


Figure 50. **Relationship between four measures of stream bank erosion (y axis) and % bank length effectively fenced (x axis) for the 2007, 2012, 2017, and 2022 surveys. The lines show predicted erosion using the linear regression equations and shaded areas show 95% confidence intervals of the predictions.**

Table 29. **Regression models for predicting stream bank erosion from % bank length effectively fenced based on the 2022 survey data The table shows regression coefficients (intercept and slope) with standard errors, and the regression R^2.**

Coefficient	Active erosion		Total erosion[1]		Soil disturbance[2]		Any evidence of erosion or pugging ('some erosion')[3]	
	% bank length	SE†	% bank length	SE†	% bank length	SE†	% bank length	SE†
Intercept	3.9 **	1.1	8.8 **	1.7	9.9 **	1.7	17.0 **	1.8
Effectively fenced (% bank length)	0.002 NS	0.014	0.008 NS	0.020	-0.003 NS	0.021	-0.072 **	0.023
R^2	0.00		0.00		0.00		0.02	

† Standard error
** Significant at α = 0.01, NS Not significant.
[1] Active or recent erosion. [2] Total stream-bank erosion or > 50% pugging disturbance. [3] Total stream-bank erosion or any level of pugging disturbance.

3.8 Recommendations for design of future surveys

The regional riparian survey was established for the purpose of quantifying the state and trend of key riparian characteristics along rivers, streams and drains through pastoral land in the Waikato region. Characteristics include fencing, vegetation (type and extent), buffer width, stream crossings, and stream bank erosion. Prior to the development of the regional riparian survey in 2002, there was a lack of detailed riparian data necessary for evaluating the long-term impacts of enhanced riparian management. Consequently, the survey was designed to quantitatively assess riparian characteristics and monitor changes over time. In addition to analysing region-wide state and trends, the survey also aimed to quantify differences in riparian characteristics (state and trend) across various land use types (e.g., dairy and drystock), management zones, and stream orders.

Based on our evaluation of the current survey design, we conclude that it yields robust estimates of riparian characteristics across the region on a 5-year cycle. Key variables, such as the percentage of effectively fenced bank length and the percentage of stream bank erosion, are reported from subsamples surveyed throughout the entire region and for specific domains of interest, including land use types, management zones, and stream orders. We recommend maintaining the current design with minimal changes in future survey cycles. Although redistributing sample numbers among strata based on the most efficient design could yield slightly more precise estimates for individual samples, it would reduce the precision of estimates necessary to determine changes across survey years. However, minor adjustments in the number of sample units assessed per stratum could be adopted to reduce the sampling effort in over-represented strata and increase sample numbers in under-represented strata, without compromising the precision of state and trend estimates. Table 30 lists the 10 strata with a deficit of 5 or more samples, and the 7 strata with an excess of 5 or more samples when compared with the most efficient design. A small change to the number of samples per cycle could gradually improve the efficiency of sampling effort whilst not greatly compromising estimates of change over time. Furthermore, when sample sites cannot be sampled for some reason, they should be replaced with samples sites selected from under-represented samples.

Any change in samples should be carried out with care. If samples are to be reduced in a stratum, this should be accomplished by selecting samples to be removed at random. New samples could be selected in a stratum using GIS routines to generate points randomly along all watercourses in the stratum spaced a minimum distance of 500 m and discarding points that fall within existing sampling units. Selected points would be used as centre locations of new units, but these could then be adjusted up to a few hundred metres if necessary to satisfy practical requirements (e.g. to maintain a unit within a single stream order or to fit a unit within one farm property).

Table 30. Strata (identified by Management Zone/Land use/Strahler) with the greatest deficit and greatest excess of samples compared with the most efficient design.

	Stratum	Number of 2022 samples	Stream length (km)	Efficient sample number	Deficit or excess
Under-sampled strata	**West Coast/Drystock/1**	**44**	**4377**	**65**	**-21**
	Lower Waikato/Drystock/1-2	**9**	**1806**	**27**	**-18**
	Upper Waikato/Dairy/1	**14**	**1668**	**25**	**-11**
	Upper Waikato/Drystock/1	**7**	**959**	**14**	**-7**
	Lake Taupo/Drystock/1	**4**	**756**	**11**	**-7**
	Coromandel/Drystock/1	**4**	**693**	**10**	**-6**
	Waihou-Piako/Drystock/1	**6**	**804**	**12**	**-6**
	West Coast/Drystock/2	**12**	**1146**	**17**	**-5**
	Waipā/Drystock/1	**20**	**1665**	**25**	**-5**
	Lower Waikato/Drystock/0,5-6	**3**	**505**	**8**	**-5**
Over-sampled strata	**West Coast/Drystock/5**	**6**	**64**	**1**	**5**
	Lake Taupo/Drystock/3	**7**	**122**	**2**	**5**
	Upper Waikato/Dairy/4	**7**	**117**	**2**	**5**
	West Coast/Drystock/6-7	**6**	**10**	**0**	**6**
	Lower Waikato/Dairy/0	**27**	**1398**	**21**	**6**
	Lake Taupo/Drystock/2	**10**	**221**	**3**	**7**

The regional riparian survey utilises a statistical design known as designed-based inference whereby random sampling from a finite population provides estimates of population parameters. The advantage of designed-based inference is that it does not require assumptions on the distribution of potential outcomes and is therefore relatively easy to implement. Given that the current survey approach yields accurate estimates of various riparian characteristics (e.g., fencing and vegetation) at the regional scale, it is recommended to continue this approach for future iterations of the survey. A limitation of designed-based inference is that it only provides estimates of population parameters, and as such, it is not possible to produce spatial maps showing the current state of riparian margins across the region. One approach could be to implement a statistical framework using model-based inference to model the distribution of riparian characteristics spatially across the region. Such an approach could provide opportunity to identify areas within the region with particular local characteristics. For example, model outputs could produce maps of the region showing areas with particular vegetation characteristics and how these metrics differ from the regional average.

To improve data quality control, it is recommended that future surveys include additional field validation and inter-calibration of data collection among survey teams. This could involve both teams conducting surveys across a representative subset of sites. Such an approach would enable a quantitative statistical assessment of differences in the way that data is collected, especially for more subjective attributes (e.g., erosion type and extent). While the current survey utilised a 'quick guide' reference document to aid field staff in interpreting key attributes, it would be beneficial for future survey cycles if WRC developed a comprehensive field guide. This guide would build on previous documents (Hill, 2001) and incorporate updates to the survey methodology since the original survey in 2002. With the advent of high accuracy aerial imagery, there are opportunities to enhance estimates of certain riparian metrics using remote sensing and machine learning technologies. For example, numerous studies have utilised satellite or multi spectral drone imagery to assess composition of riparian vegetation (Rusnák et al, 2022) and quantify buffer width (Goetz, 2006). Furthermore, light detection and ranging (LiDAR) data and development of other laser technologies have provided opportunities to quantify streambank erosion at the site level (Rusnák et al, 2022). However, remote sensing technologies still require a considerable field effort to ensure adequate calibration of data. There are also questions as to how useful these techniques would be assessing 'fine scale', subjective characteristics such as fencing type and effectiveness. A study by WRC (Booth, 2018) explored a remote sensing approach using aerial imagery to assess riparian characteristics at 16 of the regional survey sites in the Central Waikato. While the approach provided accurate measurements of vegetation and waterway crossings, it was generally unsuitable for determining fine-scale measurements of fencing type, stock access, and streambank erosion. Although WRC will continue to explore emerging technologies for assessing riparian characteristics, it is anticipated that the current survey approach will remain in operation for the foreseeable future as this is deemed to provide the most accurate assessment of the full range of riparian characteristics required by the survey.

4 Summary, conclusions, and recommendations

4.1 Region-wide state and trend

The proportion of bank length effectively fenced across the surveyed sites in the Waikato region increased significantly over the past 20 years from 29% in 2002 to 58% in 2022. Although fencing increased at a relatively uniform rate between 2012 and 2017 – 3.8% of bank length per year for dairy and 1.2% of bank length for drystock – the rate of fencing appears to have stalled over the past 5 years (2017–2022) to about 0.2% per annum. As of 2022, about 42% of surveyed bank length across the region was unfenced and was therefore unprotected from stock access. The increase in fencing measured in prior survey years was largely a result of significant increases in fencing across dairy farms brought about by industry led initiatives such as the Sustainable Dairying Water Accord. Given that much of the remaining 42% of unfenced waterway is across low-intensity hill-country pasture, a concerted effort is required on the part of industry, farmers, and regional council to ensure high risk waterways are excluded from livestock. In the 2022 survey, there was a strong relationship between stock access and proportion of bank length effectively fenced, suggesting that the amount of fencing is an accurate indicator of stock exclusion. Overall, total stock access to riparian margins decreased over the past 5 years (2017–2022), despite minimal change to overall fencing across the region. This may suggest an improvement in the efficacy of existing fencing structures or that landowners are now less inclined to intentionally graze riparian margins due to implementation of national stock exclusion regulations.

In line with previous surveys, riparian margins across the Waikato Region were dominated by non-woody vegetation (occupying about 73% of surveyed bank length), with grass and weeds occupying 64% of surveyed bank length across the region. Woody vegetation occupied 27% of surveyed bank length, with woody native species covering 11% of the surveyed river margins. Woody vegetation provides several important ecosystem functions, including regulation of water temperature through shading, stabilisation of riverbanks, enhanced removal of dissolved nutrients near the plant root zone, and provides additional biodiversity benefits (e.g. bird habitat). While the total coverage of woody species across riparian margins is relatively low, the coverage of woody native species across riparian margins increased by about 6% over the past 20 years. Noting that establishment of woody species is not always possible (e.g. narrow buffer zones adjacent to drains), In such situations, plantings of native sedges, rushes, and flax should be considered to improve nutrient attenuation across riparian margins. In terms of buffer width, about 60% of the riparian margins across the region were considered narrow (< 5 m) as of 2022. In general, wider buffer zones are associated with greater benefits for stream health, providing more habitat for indigenous vegetation establishment and providing greater filtering of contaminants from runoff, increasing soil infiltration of soluble pollutants, sediment trapping, stream bank stabilisation and flood attenuation.

The proportion of bank length affected by stream bank erosion across the region in 2022 was approximately 9%, significantly lower than the 17% measured in 2017 and similar to that measured in 2012. Overall, the total erosion measured in 2022 was low compared to the previous survey. This reduction could be attributed to unusually high river flows during the 2022/23 field season, which may have masked bank erosion. Large differences in erosion measures between surveys have occurred previously (e.g. 2002–2007 and 2012–2017) and it is noted that the assessment of stream-bank erosion is somewhat subjective, making comparisons over time less reliable than, for example, changes in fencing or stock access. Furthermore, the magnitude and frequency of storm events prior to the survey along with flow levels at the time of the survey is likely to influence the amount of stream bank erosion observed from year to year (the percent bank length eroded fluctuated over the monitoring period ranging from 5% in 2002 to 22% in 2007). Riparian disturbance is the sum of total stream-bank erosion and pugging disturbance caused by livestock treading. About 10% of the surveyed bank length in 2022 was disturbed, with 1% (> 50% of the riparian margin) of this being due to pugging disturbance caused by livestock treading. The decrease in the incidence of significant pugging over the past 10 years indicates that riparian fencing efforts are resulting in measurable reductions in soil disturbance. Regression models predicting erosion using effectively fenced bank length as the independent variable shows that there is great variation between individual samples and that there was no overall effect of fencing on total disturbance. Additionally, the overall measures of erosion recorded in the 2022 survey were lower than reported in previous surveys. This was likely due to the presence of elevated stream water levels during the 2022 survey that masked erosion. Similarly, erosion metrics (Active erosion and total erosion) did not exhibit significant correlations with effective fencing. Compared to previous survey years, there appears to be lower overall levels of erosion and disturbance.

4.2 Land-use differences

In 2022, there were considerable differences between dairy and drystock land uses with respect to riparian fencing, stock access, buffer width, and soil disturbance. Dairy sites had significantly more bank length with effective fencing (88%), no stock access (89%), narrow (< 5 m) buffer widths (74%) and no soil disturbance (93%), compared to drystock sites (with 36%, 35%, 53%, and 89%, respectively). Effective fencing and stock access are good indicators of stock exclusion from waterways and overall, stock exclusion from waterways in the Waikato region remains significantly higher for dairy compared to drystock. In terms of riparian buffer width, drystock enterprises had a significantly higher proportion of bank length with 'wide buffers' (47%) compared to dairy (26%) due to the generally more extensive nature of drystock farming and the high proportion of narrow drains (stream order 0) on dairy farms. While there were no significant differences between land uses with respect to woody vegetation, native species were more prevalent along streambanks on drystock farms (14.3%) compared to dairy (7.5%). However, there was significantly more bank length eroded for drystock (10%) compared to dairy (6%).

Over the past two decades (2002 to 2022), the mean proportion of bank length effectively fenced has increased significantly, rising by 49% for dairy and 17% for drystock systems. From 2002 to 2022, dairy farms saw an annual increase in effectively fenced bank length of 2.2% compared to 0.9% for drystock Over the past 5 years (2017–2022), the rate of change slowed considerably with a 0.2% increase in bank length effectively fenced per year for both dairy and drystock. The emphasis placed on improving stock exclusion on dairy farms by the Dairying and Clean Streams Accord appears to have had a positive impact on the amount of riparian fencing observed at dairy sites in the Waikato region, particularly between 2012 and 2017. However, the 2022 estimate of Accord site waterways with complete stock exclusion is significantly lower (52%) compared to the 98% reported in the final Sustainable Dairying Water Accord summary (DairyNZ, 2018). This discrepancy highlights the need for continued efforts in the dairy sector to achieve full stock exclusion from waterways. Additionally, the results indicate an ongoing need to direct riparian fencing efforts towards drystock land uses.

4.3 Management zone differences

Of the eight management zones in the Waikato region, the Upper Waikato and Waihou-Piako management zones had the highest proportion of bank length effectively fenced (81% and 85%, respectively) and had significantly higher proportions than those of the Lower Waikato, Waipā, and West Coast management zones (54%, 66%, and 20%, respectively). These zones also had the lowest amount of total stock access (19% and 15% respectively) and apart from the Lake Taupō zone, had the lowest amount of streambank erosion (4% and 6% respectively). The Lake Taupō zone stood out as having the highest proportion of 'wide' (> 5 m) riparian buffers and lowest incidence of stream bank erosion (1% of surveyed bank length). Significant efforts have been made by WRC and its predecessors to encourage fencing of waterways in the Waihou-Piako, Upper Waikato, and Lake Taupō management zones through historic soil conservation initiatives (Waikato Regional Council, 1998b; Palmer, 2004) and adherence to Method 4.3.5.3 of the Waikato Regional Plan, which mandates the exclusion of livestock from mapped portions of high-priority water bodies, including specific sections of the Waihou River and all tributaries flowing into Lake Taupō. The high proportion of bank length effectively fenced in the Waihou-Piako zone in 2022 (85%) is consistent with efforts undertaken through the Dairying and Clean Streams Accord process in this predominantly dairy catchment. Consistent with previous surveys, the West Coast management zone exhibited the lowest proportion of bank length with effective fencing (20%) and no stock access (19%) and clearly stands out as one that could benefit most from future riparian fencing efforts.

4.4 Stream order differences

The average proportion of bank length effectively fenced was largest for drains (89%), reflecting the relative ease with which these features can be fenced (often straight, linear features located on flat land) and their location on predominantly dairy enterprises. Lower order streams (stream orders 1–3) had the lowest proportion of bank length effectively fenced, ranging from 47–63%, while across larger waterways (stream orders 4 – 6), 72–82% of bank length had effective fencing. Larger waterways are often prioritised for fencing as they present a greater risk of livestock losses and are more likely to meet funding criteria for protective measures. Small to medium sized waterways are more likely to occur in steep, hilly terrain, making the establishment of effective fencing more challenging and costly.

In terms of stream bank erosion, eroded bank length was lowest for small to medium streams and rivers despite high levels of stock access. This finding is consistent with the 2012 riparian survey results and seems to suggest that undercutting of stream banks is largely unaffected by the grazing of riparian margins. For riparian vegetation, drains stood out as having the lowest coverage of woody vegetation (8% of surveyed bank length) and proportion of wide buffer widths (5%). Consistent with previous surveys, findings from the 2022 survey suggest that future riparian restoration efforts should be targeted towards small and medium sized waterways where stock access remains high, and coverage of woody vegetation is generally low. To improve water quality at the catchment scale, the best management practice is to start with protecting and enhancing riparian margins along headwater streams. This involves the conservation and restoration of riparian remnants, while achieving source control, and subsequently extending these efforts downstream. It is important that riparian restoration efforts are carefully planned to ensure that site specific factors (e.g. slope, geology and land use) along with functional objectives (e.g. filtering of contaminants) are taken into account. For example, a larger buffer width will be required for steeper land for effective filtering of contaminants.

4.5 Policy analysis

The 2022 riparian survey results were assessed against the regulations outlined in the Action for Healthy Waterways package (Ministry for the Environment, 2020a). Some amendments were made to the definition of low slope land (now defined as land under 5 degrees) since the previous analysis in 2017. Across dairy farms, 93% of bank lengths on low slope land (< 5˚) were effectively fenced, whereas drystock enterprises had only 65% to 67% of bank length effectively fenced. On non-low slope land (> 5˚), about 90% of waterways on dairy farms were effectively fenced, compared to 60% for high intensity drystock systems. Given that the national stock exclusion regulations came into effect in July 2023 for dairy cattle, the analysis demonstrates that a small proportion of bank length across the region (7% on low slope and 10% on non-low slope land) does not meet current regulations.

The 2017 riparian survey (Norris et al., 2020) reported an annual increase in effective fencing along stream banks of 3.1% for dairy. However, over the past 5 years (2017–2022), the annual increase in the proportion of bank length with effective fencing has slowed to about 0.2% per annum. The apparent 'stalling' in the proportion of bank length effectively fenced suggests that further effort is required to achieve complete stock exclusion along the remaining unfenced waterways on dairy farms. For intensive drystock operations, 33–35% of streambanks on 'low slope' and 40% on non-low slope land did not comply with stock exclusion regulations, highlighting the need for substantial work across the region to meet the July 2025 deadline. According to the 'setback' provisions within the Stock Exclusion Regulations 2020, a 3-m buffer is mandated only for new fencing. Although 15–20% of fencing on low slope dairy land had a setback greater than 3 m in 2022, this is largely irrelevant since only new fencing must adhere to the 3-m setback requirement. Drystock enterprises saw a significantly higher proportion (54%) of existing fencing on low slope land with a setback of 3 m or more. However, new fencing with a 3 m setback is required along 33–35% of streambanks on low slope drystock land.

Analysis was also undertaken to evaluate the 2022 stock exclusion survey results against the Proposed PC1 requirements as outlined in Schedule C of the 2020 decisions version document (Waikato Regional Council, 2020). Overall, 80% of the bank length along rivers and streams on low slope land (< 15˚) was effectively fenced across qualifying management zones (Upper Waikato, Central Waikato, Lower Waikato, and Waipā). For narrow drains (< 2 m), 90% of the bank length was effectively fenced compared to 70% for wide drains (> 2 m). On non-low slope land, there were only a small number of rivers and streams on intensively managed land (n=15), with 88% of the surveyed bank length being effectively fenced. Of the streams and rivers on low slope land with existing fencing, approximately 50% had a setback distance of at least 3 m. For narrow drains (< 2 m wide) on low slope land, 65% of existing fencing had a setback distance of at least 1 m; while for wide drains (> 2 m wide), 88% of fencing was associated with a buffer width of at least 3 m. Streams and rivers on high-intensity, non-low slope land had 63% of existing fencing with a setback distance of at least 3 m. Overall, the results indicate that fencing of narrow drains (< 2 m) in PC1 zones is largely complete, with approximately 9% of bank length remaining unfenced or ineffectively fenced. A greater percentage of bank length remains unfenced across qualifying streams and rivers (20%) in the Central Waikato (41%) and Lower Waikato (30%) management zones.

4.6 Survey design review

The WRC regional riparian survey provides robust estimates of riparian characteristics across the region on a 5-year cycle. Estimates of key variables (e.g. percentage of effectively fenced bank length and the percentage of vegetation types) are provided with good precision and are reported from subsamples surveyed throughout the entire region as well as for specific domains of interest, including land use types, management zones, and stream orders. We recommend maintaining the current design with minimal changes in future survey cycles to ensure consistency in the survey approach. Minor adjustments in the number of sample units assessed per stratum could be adopted to reduce the sampling effort in over-represented strata and increase sample numbers in under-represented strata, without compromising the precision of state and trend estimates. While resource intensive, the current field-based approach remains the best approach for quantifying riparian characteristics across the region and it is envisaged the current methodology will remain in place for the foreseeable future. Undertaking a review of statistical methods is recommended to assess if the current approaches are fit for purpose or could be improved upon for future cycles of the survey. A limitation of the current designed-based inference is that it only considers estimates of population parameters, and as such, it is not possible to produce spatial maps showing the current state of riparian margins across the region. One approach could be to implement a statistical framework using model-based inference to model the distribution of riparian characteristics spatially across the region. Such an approach could provide opportunity to identify areas within the region with particular local characteristics. In terms of collection of riparian information, additional survey methods such as remote sensing, machine learning technologies, and drone footage are being considered as potential options to support the current field-based approach.

5 References

Assure Quality. 2024. Agribase. https://www.asurequality.com/services/agribase/ [accessed 26 July 2024].

Booth R. 2018. A comparison of riparian monitoring methods in the Central Waikato zone. Unpublished presentation. Hamilton, Waikato Regional Council. Doc. No. 13778934

Burrell TK, O'Brien JM, Graham SE, Simon KS, Harding JS and McIntosh AR. 2014. Riparian shading mitigates stream eutrophication in agricultural catchments. Freshwater Science 33 (1): 73-84.

Cochran WG. 1977. Sampling techniques. 3rd ed. New York, John Wiley & Sons.

Collins AL, Hughes CO, Zhang Y. 2009. Mitigating diffuse water pollution from agriculture: Riparian buffer strip performance with width. CABI Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 4(39): 1-15.

Cowie B, van Voorthuysen R, Ridley G. 2006. A monitoring and reporting strategy for the Dairying and Clean Streams Accord: measuring the environmental outcomes of implementing the accord. Wellington, Ministry for the Environment.

Dairy Tomorrow. 2022. Dairy tomorrow: the future of New Zealand dairying. Protecting Our Environment. https://www.dairynz.co.nz/media/jp1dzgml/sustainable-dairying-annual-report-protecting-our-environment-2022-v141.pdf [accessed 26 July 2024].

DairyNZ. 2014. Getting riparian planting right in the Waikato. DairyNZ publication 40-062. Hamilton, DairyNZ Limited. https://www.dairynz.co.nz/media/leojopce/waikato_riparian_management.pdf [accessed 26 July 2024]

DairyNZ. 2015. Sustainable Dairying Water Accord: three years on…progress report for the 2015/16 season. DairyNZ publication 40-003. Hamilton, DairyNZ Limited. https://www.dairynz.co.nz/media/iermcnuy/water_accord_report_3_years_on_web.pdf [accessed 26 July 2024].

DairyNZ. 2018. Sustainable Dairying Water Accord: five years on…progress report for the 2017/18 season. Hamilton, DairyNZ Limited. https://www.dairynz.co.nz/media/bfaee1uj/water-accord-progress-report-5-years-on.pdf [accessed 26 July 2024].

Davies-Colley RJ, Meleason MA, Hall RMJ, Rutherford JC. 2009. Modelling the time course of shade, temperature, and wood recovery in streams with riparian forest restoration. New Zealand Journal of Marine and Freshwater Research 43(3): 673-688.

Davies-Colley RJ and Payne GW. 2023. Cooling streams with riparian trees: thermal regime depends on total solar radiation penetrating the canopy. Austral Ecology 48(6): 1064-1073.

Death, RG. 2018. Buffer management: benefits and risks. Innovative River Solutions report prepared for Greater Wellington Regional Council, Wellington.

Federal Interagency Stream Restoration Working Group. 2001. Stream corridor restoration: principles, processes, and practices. Springfield, VA, National Technical Information Service (NTIS). https://www3.uwsp.edu/cnrap/UWEXLakes/PublishingImages/resources/restoration project/StreamRestorationHandbook.pdf [accessed 21 August 2024].

Fenemor A and Samarasinghe O. 2020. Riparian setback distances from water bodies for high-risk land uses and activities. Manaaki Whenua Landcare Research contract report LC3832 prepared for Tasman District Council, Richmond.

Fonterra Co-operative Group, Local Government New Zealand, Ministry for the Environment, Ministry of Agriculture and Forestry. 2003. Dairying and Clean Streams Accord between Fonterra Co-operative Group, Regional Councils, Ministry for the Environment, and Ministry of Agriculture and Forestry, May 2003.

Frampton C. 2009. Design of sampling programmes. In: Land and Soil Monitoring: A guide for SoE and Regional Council Reporting. Hamilton, Land Monitoring Forum. 7-86.

Goetz, SJ. 2006. Remote sensing of riparian buffers: past progress and future prospects. JAWRA Journal of the American Water Resources Association 42(1): 133-143.

Gregory SV, Swanson FJ, McKee, WA, Cummins KW. 1991. An ecosystem perspective of riparian zones. BioScience 41(8): 540-551.

Henshaw AJ, Thorne CR, Clifford NJ. 2012. Identifying causes and controls over river bank erosion in a British upland catchment. Catena 100: 107-119.

Hill RB. 2001 in press. A strategy for assessing the character of riparian margins in the Waikato Region. Environment Waikato Internal Report 2001/07. Hamilton, Waikato Regional Council (Environment Waikato).

Hill RB, Kelly J. 2002. Regional riparian characteristics: 2002 survey manual. Environment Waikato Technical Report 2002/07. Hamilton, Waikato Regional Council (Environment Waikato).

Horizons Regional Council. 2018. Overview of the One Billion Trees Criteria against SLUI Grants. Horizons Regional Council, Palmerston North. https://www.horizons.govt.nz/HRC/media/Media/Land/Overview-of-the-One-Billion-Trees-Criteria-against-SLUI-Grants-web1.pdf?ext=.pdf [accessed 16 January 2025].

Hughes AO, Quinn JM, McKergow LA. 2012. Land use influences on suspended sediment yields and event sediment dynamics within two headwater catchments, Waikato, New Zealand. New Zeal J Mar Freshw Res. 46(3): 315–333.

Jones H, Kimberley M, Hill R, Borman D. 2016. Riparian characteristics of pastoral waterways in the Waikato region, 2002–2012. Waikato Regional Council Technical Report 2015/49. Hamilton, Waikato Regional Council.

Langer ER, Steward GA, Kimberley MO. 2008, Vegetation structure, composition and effect of pine plantation harvesting on riparian buffers in New Zealand. Forest Ecology and Management 256(5): 949-957.

LAWA Land Air Water Aotearoa. 2024. Stream order. https://www.lawa.org.nz/learn/glossary/s/stream-order [accessed 26 July 2024].

LAWA Land Air Water Aotearoa. 2025. Actions for healthy waterways. https://www.lawa.org.nz/explore-data/actions [accessed 16 January 2025].

Lind L, Hasselquist EM, Laudon H. 2019. Towards ecologically functional riparian zones: a meta analysis to develop guidelines for protecting ecosystem functions and biodiversity in agricultural landscapes. Journal of Environmental Management 249: 109391.

McDowell R, Cox N, Snelder TH. 2017. Assessing the yield and load of contaminants with stream order: would policy requiring livestock to be fenced out of high-order streams decrease catchment contaminant loads? Journal of Environment Quality 46(5): 1038-1047.

McDowell RW, Monaghan RM, Smith C, Manderson A, Basher L, Burger DF, Laurenson S, Pletnyakov P, Spiekermann R, Depree C. 2020. Quantifying contaminant losses to water from pastoral land uses in New Zealand III. What could be achieved by 2035? New Zealand Journal of Agricultural Research 64(3): 390-410.

McKergow L, Matheson FE, Quinn J. 2016. Riparian management: A restoration tool for New Zealand streams. Ecological Management & Restoration 17(3): 218-227.

McKergow L, Goeller B, Woodward B, Matheson F and Tanner C. 2020. Attenuation of diffuse-source agricultural sediment and nutrients by riparian buffer zones: A review to support guideline development. NIWA Client Report 2020037H prepared for DairyNZ, Hamilton.

McKergow L, Matheson F, Goeller B and Woodward B. 2022. Riparian buffer design guide: design to meet water quality objectives. NIWA Information Series 103. Auckland, NIWA National Institute of Water & Atmospheric Research.

Ministry for the Environment. 2020a. Action for healthy waterways: decisions on the national direction for freshwater - an at-a-glance summary. Wellington, Ministry for the Environment. https://environment.govt.nz/assets/publications/Files/action-for-healthy-waterways.pdf [accessed 26 July 2024].

Ministry for the Environment. 2022. Stock exclusion factsheet. Wellington, Ministry for the Environment. https://environment.govt.nz/assets/publications/Essential-Freshwater-Stock-exclusion-factsheet.pdf [accessed 24 July 2024].

Monaghan R, Manderson A, Basher L, Spiekermann R, Dymond J, Smith C, Muirhead R, Burger D, McDowell, R. 2021. Quantifying contaminant losses to water from pastoral landuses in New Zealand II. The effects of some farm mitigation actions over the past two decades. New Zealand Journal of Agricultural Research 64(3): 365-389.

Neale MW, Barnes GE, McArdle B. 2009. A survey of the riparian characteristics of the Auckland region. Auckland Regional Council Technical Report 2009/002. Auckland, Auckland Regional Council.

Norris M, Jones H, Kimberley M, Borman D. 2020. Riparian characteristics of pastoral waterways in the Waikato region, 2002-2017. Waikato Regional Council Technical Report 2020/12. Hamilton, Waikato Regional Council.

Norris T, Morgan E, Pigott E. 2023. Riparian characteristics survey of the Moakurarua Catchment (2022-2023). Waikato Regional Council Internal Series Report 2023/07. Hamilton, Waikato Regional Council.

Palmer J. 2004. Upper Waikato Zone: River and Catchment Asset Management Plan. Environment Waikato Technical Report 2004/24. Hamilton, Waikato Regional Council (Environment Waikato).

Parkyn SM, Davies-Colley RJ, Cooper AB, Stroud MJ. 2005. Predictions of stream nutrient and sediment yield changes following restoration of forested riparian buffers. Ecological Engineering 24(5): 551-558.

Parkyn SM, Shaw W, Eades P. 2000. Review of information on riparian buffer width necessary to support sustainable vegetation and meet aquatic functions. NIWA Client Report ARC00262 prepared for Auckland Regional Council, Auckland.

Parkyn SM, Davies-Colley RJ, Halliday NJ, Costley KJ, Croker GF. 2003. Planted riparian buffer zones in New Zealand: do they live up to expectations? Restoration Ecology 11 (4): 436-447.

Pursey BJ, Arthington AH. 2003. Importance of riparian zone to the conservation and management of freshwater fish: a review. Marine and Freshwater Research 54(1): 1-16.

Quinn J. 2016. Benefits of riparian management. NIWA Client Report HAM2016-035 prepared for Environment Southland, Invercargill.

R Core Team. 2024. R: a language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing.

Renouf K, Harding JS. 2015. Characterising riparian buffer zones of an agriculturally modified landscape. New Zealand Journal of Marine and Freshwater Research 49(3): 323-332.

Resource Management Act 1991. (No 69) (as at 05 June 2024). https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html [accessed 26 July 2024].

Rusnák, M, Goga, T, Michaleje, L, Šulc Michalková, M, Máčka, Z., Bertalan, L, Kidová, A. 2022. Remote sensing of riparian ecosystems. Remote Sensing 14(11): 2645.

Särndal C, Swensson B, Wretman, J. 1993. Model assisted survey sampling. New York, Springer Verlag.

Schwarte KA, Russell JR, Morrical DG. 2011. Effects of pasture management and off-stream water on temporal/ spatial distribution of cattle and stream bank characteristics in cool-season grass pastures. American Society of Animal Science (89): 3236-3247.

Storey R 2010. Riparian characteristics of pastoral streams in the Waikato Region, 2002 and 2007. Environment Waikato Technical Report 2010/07. Hamilton, Waikato Regional Council (Environment Waikato).

Te Uru Rākau – New Zealand Forest Service. 2024. One Billion Trees fund annual monitoring and evaluation report 2023-24. Wellington, Ministry for Primary Industries. https://www.mpi.govt.nz/dmsdocument/66483-One-Billion-Trees-Fund-annual-monitoring-and-evaluation-report-2023-2024 [accessed 16 January 2025].

Waikato Regional Council. 1998a. Waikato State of the Environment Report 1998. Hamilton, Waikato Regional Council (Environment Waikato).

Waikato Regional Council. 1998b. Asset Management Plan: Lake Taupō Catchment Control Scheme. Environment Waikato Policy Series 1997/09. Hamilton, Waikato Regional Council (Environment Waikato).

Waikato Regional Council. 2004. Clean streams: a guide to managing waterways on Waikato farms. 2nd ed. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2017. Waikato Freshwater Strategy. Hamilton, Waikato Regional Council. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/Fresh-water-strategy-2017-COMBINED-web.pdf [accessed 26 July 2024].

Waikato Regional Council. 2020. Proposed Waikato Regional Plan Change 1: Waikato and Waipā river catchments. Decisions version (volume 2 of 2). Waikato Regional Council Policy Series 2020/02. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2024. Proposed Waikato Regional Plan Change 1. https://www.waikatoregion.govt.nz/council/policy-and-plans/healthy-rivers-plan-for-change/ [accessed 26 July 2024].

Waikato Regional Council. 2024. Shovel Ready programme closedown report. Integrated Catchment Management Committee Meeting Report 7 November 2024. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2025. Shovel ready projects. https://www.waikatoregion.govt.nz/council/about-us/shovel-ready-projects/ [accessed 14 January 2025].

Waikato Regional Council 2025. Zone Management Plans. https://www.waikatoregion.govt.nz/council/policy-and-plans/hazard-and-catchment-management/zone-management-plans/ [accessed 17 January 2025].

Wilcock RJ, Monoghan RM, Quinn JM, Srinivasan MS, Houlbrooke DJ, Duncan MJ, Wright-Stow AE, Scarsbrook MR. 2013. Trends in water quality of five dairy farming streams in response to adoption of best practice and benefits of long-term monitoring at the catchment scale. Marine and Freshwater Research 64(5): 401-412.

6 Appendices

Appendix 1: Land use information for management zones

Table A1-1. Land use information for management zones within the Waikato region

Management Zone	Zone Area (ha)	Land use Classes†	% Zone Area
Central Waikato	63,625	Forestry	1.1
		Horticultural & Cropping	2.7
		Indigenous	4.4
		Other/No Data	17.4
		Pasture	74.4
Coromandel	195,723	Forestry	15.2
		Horticultural & Cropping	0.2
		Indigenous	63.1
		Other/No Data	2.5
		Pasture	18.9
Lake Taupō	349,596	Forestry	21.3
		Horticultural & Cropping	0.1
		Indigenous	41.4
		Other/No Data	22.7
		Pasture	14.5
Lower Waikato	291,172	Forestry	4.8
		Horticultural & Cropping	2.7
		Indigenous	13.3
		Other/No Data	8.1
		Pasture	71.1
Upper Waikato	432,778	Forestry	29.3
		Horticultural & Cropping	0.6
		Indigenous	12.7
		Other/No Data	2.8
		Pasture	54.7
Waihou-Piako	394,510	Forestry	6.3
		Horticultural & Cropping	1
		Indigenous	23.5
		Other/No Data	2.7
		Pasture	66.5
Waipā	306,739	Forestry	3.9
		Horticultural & Cropping	0.6
		Indigenous	19.3
		Other/No Data	2.3
		Pasture	73.9
West Coast	424,911	Forestry	5.6
		Horticultural & Cropping	0.1
		Indigenous	36
		Other/No Data	2.1
		Pasture	56.3

† Based on LCDB 5.0

Table A1-2. Stock density information for management zones within the Waikato region. Livestock classes are defined as sheep (< 10.5 SU/ha), Beef & lower-stocked dairy farms (≥ 10.5 – 17.5 SU/ha), Mid-range of dairy farms (≥ 17.5 – 24.5 SU/ha), or Higher stocked dairy farms (> 24.5 SU/ha).

Management Zone	Stock Density Classes (stock units/ha) ‡	% Farms ‡	Median Pastoral Stock Density (stock units/ha)‡
Central Waikato	Sheep farms	37.1	13.2
	Beef farms and lower stocked dairy farms	26.7	
	Mid-range of dairy farms	17	
	Higher stocked dairy farm	19.3	
Coromandel	Sheep farms	50.5	10.5
	Beef farms and lower stocked dairy farms	25.7	
	Mid-range of dairy farms	9.8	
	Higher stocked dairy farm	13.9	
Lake Taupō	Sheep farms	64.9	8.3
	Beef farms and lower stocked dairy farms	19.2	
	Mid-range of dairy farms	6.2	
	Higher stocked dairy farm	9.7	
Lower Waikato	Sheep farms	42.3	12.3
	Beef farms and lower stocked dairy farms	26	
	Mid-range of dairy farms	17.4	
	Higher stocked dairy farm	14.3	
Upper Waikato	Sheep farms	36.3	13.7
	Beef farms and lower stocked dairy farms	29.6	
	Mid-range of dairy farms	22.4	
	Higher stocked dairy farm	11.7	
Waihou-Piako	Sheep farms	27	17.4
	Beef farms and lower stocked dairy farms	23.6	
	Mid-range of dairy farms	27.9	
	Higher stocked dairy farm	21.6	
Waipā	Sheep farms	35.2	14.8
	Beef farms and lower stocked dairy farms	25.1	
	Mid-range of dairy farms	22.8	
	Higher stocked dairy farm	17	
West Coast	Sheep farms	55.3	9.8
	Beef farms and lower stocked dairy farms	27.1	
	Mid-range of dairy farms	8	
	Higher stocked dairy farm	9.5	

‡ Waikato Regional Council stock density indicator data based on the AsureQuality AgriBase database and LCDB 5.0.

Appendix 2: Population stream length and sample size

Table A2-1. Stream length and number of samples selected by management zone, farm type and stream order in each survey year.

Management Zone	Land use type (AgriBase™)	Stream Order	Stream length in population (km)‡				Number sample units‡				
			2007	2012	2017	2022	2002	2007	2012	2017	2022
Central Waikato	Dairy	0	187	191	203	199	1	1	1	1	1
		1	79	75	98	99	1	1	3	1	1
		2	22	21	23	24	1	1	5	1	1
		3	17	17	17	17	2	1	3	2	3
		4	3	1	1	2	1	1	1	1	1
		5	2	2	2	2	2	2	7	2	2
	Drystock	0	73	73	56	58	1	1	1	1	1
		1	216	221	202	208	2	0	2	2	2
		2	54	57	54	55	0	0	2	1	1
		3	30	30	30	29	1	0	3	3	2
		4	7	7	5	4	1	1	0	0	0
		5	7	7	8	8	0	0	0	0	0
Coromandel	Dairy	0	10	11	16	16	0	0	0	0	0
		1	102	103	116	122	0	0	4	0	0
		2	38	38	42	40	0	0	1	0	0
		3	22	21	23	29	0	0	1	0	0
		4	12	12	12	8	0	0	3	1	1
		5	2	2	1	1	2	0	0	0	0
	Drystock	0	12	11	5	6	0	0	0	0	0
		1	708	699	687	693	1	1	4	4	4
		2	178	173	172	175	2	2	4	2	2
		3	94	94	89	85	6	5	4	4	4
		4	17	19	17	21	4	3	5	3	3
		5	6	6	5	5	4	2	2	2	2
Lake Taupō	Dairy	1	19	18	35	14	1	0	1	0	0
		2	3	3	4	2	1	1	1	1	2
		3	0	0	0	3	0	0	0	0	0
		0	13	13	10	10	2	2	2	1	0
	Drystock	1	863	832	800	756	8	10	11	4	4
		2	265	242	237	221	19	18	17	10	10
		3	139	132	126	122	8	8	8	7	7
		4	44	31	30	29	1	1	1	1	1
		5	5	7	7	7	0	0	0	0	0
		6	10	10	7	7	0	0	0	0	0
Lower Waikato	Dairy	0	1279	1265	1394	1398	2	2	2	26	27
		1	503	452	520	523	2	2	5	7	7
		2	150	138	154	155	3	3	5	4	4
		3	93	82	90	88	1	1	5	1	1
		4	65	62	65	71	4	2	5	2	2
		5	8	7	8	10	2	1	3	1	1
		6	6	6	6	6	1	0	0	0	0
	Drystock	0	474	536	491	478	2	0	0	2	1
		1	1361	1440	1412	1430	5	0	2	5	5
		2	355	375	373	376	5	5	5	4	4
		3	194	207	206	214	7	5	5	2	2
		4	97	102	105	100	4	4	4	2	2
		5	24	26	25	23	1	1	1	1	1
		6	4	4	4	4	2	3	2	1	1

†Based on a Land Information NZ (LINZ) 1:50000 hydrology layer.
‡ Number of transects sampled (500 m) within each stream length population.

Table A2-2 (continued)

Management Zone	Land use type (AgriBase™)	Stream Order	Stream length in population (km)‡				Number sample units‡				
			2007	2012	2017	2022	2002	2007	2012	2017	2022
Upper Waikato	Dairy	0	57	52	57	57	1	1	1	1	1
		1	1137	1588	1622	1668	8	8	8	14	14
		2	349	514	551	557	5	6	6	7	7
		3	226	337	341	335	7	7	6	6	6
		4	70	103	118	117	10	7	10	7	7
		5	21	23	22	20	5	6	7	4	4
		6	2	1	1	1	3	3	3	3	3
		7	2	0	1	1	0	0	0	0	0
	Drystock	0	12	14	12	12	0	0	0	0	0
		1	1168	1192	981	959	6	6	6	7	7
		2	344	353	277	270	8	7	7	5	5
		3	172	176	127	137	9	7	8	5	5
		4	59	54	42	43	5	3	4	3	3
		5	4	5	5	7	2	2	2	2	2
		7	2	1	0	0	0	0	0	0	0
Waihou-Piako	Dairy	0	1596	1603	1665	1624	9	5	6	33	32
		1	1221	1197	1210	1180	11	9	9	15	15
		2	379	386	390	378	8	5	6	8	8
		3	206	213	216	214	4	1	3	3	3
		4	80	84	75	72	7	3	2	2	2
		5	95	94	91	93	7	3	3	3	3
		6	11	10	11	11	7	3	5	3	3
	Drystock	0	279	263	235	266	0	0	0	0	0
		1	821	834	782	804	2	3	3	7	6
		2	242	244	223	231	4	1	1	2	2
		3	118	119	107	106	2	1	1	1	1
		4	41	41	39	40	3	2	2	1	1
		5	24	26	24	22	0	0	0	0	0
		6	2	1	2	2	0	0	0	0	0
Waipā	Dairy	0	306	303	318	327	3	1	2	5	5
		1	949	951	1134	1125	9	9	10	16	15
		2	283	287	330	321	4	3	4	3	3
		3	180	181	219	211	7	6	7	6	6
		4	96	99	112	108	5	5	8	5	5
		5	58	56	59	56	7	5	7	5	5
		6	13	13	15	14	5	4	5	4	4
	Drystock	0	84	87	80	75	3	3	3	3	2
		1	1832	1806	1663	1665	9	6	7	17	19
		2	514	506	474	478	12	11	11	10	10
		3	291	290	260	266	7	5	5	5	5
		4	138	132	107	107	9	6	5	4	4
		5	50	52	48	45	4	3	3	3	3
		6	6	6	4	4	2	2	2	2	2

Table A2-3 (continued)

		Stream Order	Stream length in population (km)‡				Number sample units‡				
			2007	2012	2017	2022	2002	2007	2012	2017	2022
West Coast	Dairy	0	13	11	14	16	0	0	0	0	0
		1	187	192	237	222	0	0	3	3	3
		2	45	52	62	58	1	1	3	1	1
		3	29	25	34	33	0	0	3	0	0
		4	16	14	18	18	0	0	1	0	0
		5	5	5	14	14	0	0	1	0	0
		6	0	0	2	2	0	0	0	0	0
	Drystock	0	75	78	72	72	3	3	2	2	2
		1	4419	4418	4350	4377	7	7	8	44	44
		2	1150	1141	1141	1146	5	4	4	12	12
		3	623	627	617	616	7	5	5	9	9
		4	294	300	299	299	6	6	8	6	6
		5	70	72	64	64	6	6	9	6	6
		6	10	10	6	6	6	6	6	6	6
		7	5	5	4	4	0	0	0	0	0

Appendix 3: Strata and predicted number of sampling units

Table A3-1. Aggregated groupings of management zone, farm type and stream order used to define strata. The sampling fraction is the ratio of the total stream length in the sampled sites to the stream length in the population for the stratum.

Management Zone	Land use type (AgriBase™)	Stream Order	Number of sample units in stratum by year					Year used for determining stream length	Stream length (km)	Sampling fraction (2022 samples per km)†	Predicted sample size*
			2002	2007	2012	2017	2022				
Central Waikato	Dairy	0	1	1	1	1	1	2007	187	0.0053	2.8
		1	1	1	3	1	1	2007	79	0.0127	1.2
		2	1	1	5	1	1	2012	21	0.0476	0.3
		3	2	1	3	2	3	2007	17	0.1176	0.3
		4	1	1	1	1	1	2007	3	0.3333	0.0
		5	2	2	7	2	2	2007	2	1	0.0
	Drystock	0 – 5	5	2	8	7	6	2007	387	0.0181	5.9
Coromandel	Dairy	0 – 5	2	0	9	1	1	2012	187	0.0053	2.8
	Drystock	0, 5	4	2	2	2	2	2007	18	0.1111	0.3
		1	1	1	4	4	4	2012	699	0.0057	10.6
		2	2	2	4	2	2	2007	178	0.0112	2.7
		3	6	5	4	4	4	2007	94	0.0426	1.4
		4	4	3	5	3	3	2007	17	0.1765	0.3
Lake Taupo	Dairy	1 – 2	2	1	2	1	2	2007	22	0.0455	0.3
	Drystock	0	2	2	2	1	0	2007	13	0.0769	0.2
		1	8	10	11	4	4	2007	863	0.0046	13.1
		2	19	18	17	10	10	2007	265	0.0377	4.0
		3	8	8	8	7	7	2007	139	0.0504	2.1
		4 – 6	1	1	1	1	1	2007	59	0.0169	0.9
Lower Waikato	Dairy	0	2	2	2	26	27	2017	1394	0.0187	21.1
		1	2	2	5	7	7	2012	452	0.0155	6.8
		2	3	3	5	4	4	2007	150	0.0267	2.3
		3	1	1	5	1	1	2012	82	0.0122	1.2
		4	4	2	5	2	2	2007	65	0.0308	1.0
		5 – 6	3	1	3	1	1	2007	14	0.0714	0.2
	Drystock	0, 5 – 6	5	4	3	4	3	2007	502	0.008	7.6
		1 – 2	10	5	7	9	9	2007	1716	0.0052	26.0
		3	7	5	5	2	2	2007	194	0.0103	2.9
		4	4	4	4	2	2	2007	97	0.0206	1.5

† Number of sampling units divided by population stream length
* Predicted sample sizes are based on a population stream length of 28,382 km's and a sample size of 430 sites

Table A3-2 (continued)

Management Zone	Land use type (AgriBase™)	Stream Order	Number of sample units in stratum by year					Year used for determining stream length	Stream length (km)	Sampling fraction (2022 samples per km)†	Predicted sample size*
			2002	2007	2012	2017	2022				
Upper Waikato	Dairy	0	1	1	1	1	1	2007	57	0.0175	0.9
		1	8	8	8	13	14	2007	1137	0.0114	17.2
		2	5	6	6	7	7	2007	349	0.0201	5.3
		3	7	7	6	6	6	2007	226	0.0265	3.4
		4	10	7	10	7	7	2007	70	0.1	1.1
		5	5	6	7	4	4	2007	21	0.1905	0.3
		6 – 7	3	3	3	3	3	2007	4	0.75	0.1
	Drystock	0, 5 –	2	2	2	2	2	2007	18	0.1111	0.3
		1	6	6	6	8	7	2007	1168	0.0068	17.7
		2	8	7	7	5	5	2007	344	0.0145	5.2
		3	9	7	8	5	5	2007	172	0.0291	2.6
		4	5	3	4	3	3	2007	59	0.0508	0.9
Waihou-Piako	Dairy	0	9	5	6	33	32	2012	1603	0.0206	24.3
		1	11	9	9	15	15	2007	1221	0.0123	18.5
		2	8	5	6	8	8	2007	379	0.0211	5.7
		3	4	1	3	3	3	2007	206	0.0146	3.1
		4	7	3	2	2	2	2007	80	0.025	1.2
		5	7	3	3	3	3	2007	95	0.0316	1.4
		6	7	3	5	3	3	2007	11	0.2727	0.2
	Drystock	0, 4 –	3	2	2	1	1	2007	346	0.0029	5.2
		1	2	3	3	7	6	2012	834	0.0084	12.6
		2	4	1	1	2	2	2007	242	0.0083	3.7
		3	2	1	1	1	1	2007	118	0.0085	1.8
Waipā	Dairy	0	3	1	2	5	5	2012	303	0.0165	4.6
		1	9	9	10	16	15	2007	949	0.0169	14.4
		2	4	3	4	3	3	2007	283	0.0106	4.3
		3	7	6	7	6	6	2007	180	0.0333	2.7
		4	5	5	8	5	5	2007	96	0.0521	1.5
		5	7	5	7	5	5	2007	58	0.0862	0.9
		6	5	4	5	4	4	2007	13	0.3077	0.2
	Drystock	0	3	3	3	3	2	2007	84	0.0357	1.3
		1	9	6	7	18	19	2012	1806	0.01	27.4
		2	12	11	11	10	10	2007	514	0.0195	7.8
		3	7	5	5	5	5	2007	291	0.0172	4.4
		4	9	6	5	4	4	2007	138	0.029	2.1
		5	4	3	3	3	3	2007	50	0.06	0.8
		6	2	2	2	2	2	2007	6	0.3333	0.1
West Coast	Dairy	0 – 6	1	1	11	4	4	2012	299	0.0134	4.5
	Drystock	0	3	3	2	2	2	2007	75	0.0267	1.1
		1	7	7	8	43	44	2012	4418	0.0097	66.9
		2	5	4	4	12	12	2012	1141	0.0105	17.3
		3	7	5	5	9	9	2007	623	0.0144	9.4
		4	6	6	8	6	6	2007	294	0.0204	4.5
		5	6	6	9	6	6	2007	70	0.0857	1.1
		6 – 7	6	6	6	6	6	2007	15	0.4	0.2

† Number of sampling units divided by population stream length
* Predicted sample sizes are based on a population stream length of 28,382 km's and a sample size of 430 sites

Appendix 4: Raw data

Table A4-1. Average proportion of bank length (95% confidence interval in parentheses) effectively or not effectively fenced and average proportion of stream length effectively fenced on both banks, one bank or neither bank for the region as a whole (overall) and for land use type, management zone and stream order categories in 2022. The number of samples (n) analysed within each population has been included for reference.

			Bank length analysis (% bank length)		---------------Stream length analysis---------------		
		n	Effectively fenced (total)	Not effectively fenced	Both banks fenced	one bank fenced	Neither bank fenced
	Overall	430	58.3 (3.8)	41.7 (3.9)	51.1 (3.9)	14.4 (2.9)	34.5 (4.1)
Land use type	Dairy	223	88.3 (3.1)	11.7 (3.2)	81.1 (4.7)	14.4 (4.1)	4.5 (2.4)
	Drystock	207	35.8 (5.8)	64.2 (6.1)	28.6 (5.6)	14.4 (4)	57 (6.6)
Management zone	Central Waikato	15	73.3 (20.1)	26.7 (20.6)	64.9 (19.9)	16.8 (3.7)	18.3 (20.4)
	Coromandel	16	59.1 (40.4)	40.9 (40.4)	55.2 (40.5)	7.8 (4.6)	37 (40.4)
	Lake Taupō	24	79.1 (30.2)	20.9 (30.1)	73.9 (30.7)	10.4 (16.6)	15.7 (31.8)
	Lower Waikato	58	54.2 (10.3)	45.8 (11.8)	41.5 (10.6)	25.4 (10.6)	33.1 (12.4)
	Upper Waikato	64	81.2 (10.4)	18.8 (10.5)	77.3 (11.1)	7.8 (6.7)	14.9 (10.8)
	Waihou-Piako	76	85.3 (6.6)	14.7 (6.7)	78.5 (8.2)	13.5 (6.6)	8 (6.4)
	Taupō	88	65.6 (9.3)	34.4 (9.6)	58.3 (10.1)	14.7 (5.6)	27 (9.3)
	West Coast	89	19.5 (5.2)	80.5 (5.6)	13 (4.4)	13.1 (5.4)	73.9 (6.9)
Stream order	0	72	89.2 (7.1)	10.8 (7.2)	83.2 (9.1)	11.9 (5.3)	4.9 (5.6)
	1	146	46.7 (6)	53.3 (6)	40.3 (6.1)	12.8 (4.4)	46.9 (6.5)
	2	72	59.3 (10.8)	40.7 (11.3)	53.2 (11)	12 (5.1)	34.7 (11.2)
	3	54	62.6 (10.7)	37.4 (10.9)	50.8 (11.4)	23.7 (10.5)	25.6 (12.3)
	4	38	81.7 (11.3)	18.3 (10.7)	75.5 (12.5)	12.4 (7.2)	12.1 (11.2)
	5	29	69.8 (17.2)	30.2 (26.2)	45.2 (33.6)	49.3 (37.3)	5.5 (12.6)
	6	19	74.1 (15.5)	25.9 (20.6)	50.2 (23)	47.9 (30.5)	1.9 (20.4)

Table A4-2. Average proportion of bank length effectively fenced (total) and average proportion of stream length effectively fenced on one bank, both banks, or neither bank for the region as a whole (overall) and for land use type in 2002, 2007, 2012, 2017 and 2022. The number of samples (n) analysed within each population are included for reference.

		Year	n	Bank length analysis (% bank length)	-------------Stream length analysis------------- (% stream length)		
				Total fenced	**Both banks fenced**	**one bank fenced**	**Neither bank fenced**
	Overall	**2002**	374	28.7 (4.5)	21 (5.7)	23.9 (5.5)	55 (5.0)
		2007	298	37.5 (6.5)	25.3 (7.3)	24.3 (6.4)	50.3 (7.2)
		2012	382	51 (5.4)	39.2 (6.8)	23.7 (5.7)	37.1 (5.4)
		2017	432	61.5 (4)	54.5 (4.3)	14.5 (3.3)	31 (4.5)
		2022	430	58.3 (3.8)	51.1 (3.9)	14.4 (2.9)	34.5 (4.1)
Land use type	Dairy	**2002**	160	43.9 (8.2)	31.6 (11.5)	37.8 (11.6)	30.6 (7.2)
		2007	91	48.5 (12.3)	32.5 (12.7)	32.1 (12)	35.5 (14.7)
		2012	196	73.3 (6.1)	57.9 (10.6)	30.8 (10.3)	11.4 (3.7)
		2017	244	87 (4.0)	80.9 (4.9)	12.5 (3.4)	6.6 (3.7)
		2022	223	88.3 (3.1)	81.1 (4.7)	14.4 (4.1)	4.5 (2.4)
	Drystock	**2002**	214	17.7 (5.0)	13.4 (5.0)	13.9 (4.7)	72.6 (6.8)
		2007	207	32.2 (9.0)	21.9 (9.2)	20.6 (6.2)	57.5 (9.9)
		2012	186	30.9 (7)	22.3 (7.1)	17.4 (5.8)	60.3 (8)
		2017	188	34.9 (6.4)	26.8 (6.3)	16.6 (5.8)	56.6 (7.7)
		2022	207	35.8 (5.8)	28.6 (5.6)	14.4 (4.0)	57 (6.6)

Table A4-3. Average proportion of bank length (95% confidence interval in parentheses) of stock access categories for the region as a whole (overall) and for land use type, management zone, stream order and Clean Streams Accord categories in 2022. The number of samples (n) analysed within each population are included for reference.

		n	Simplified stock access categories (%bank length)		Detailed stock access categories (% bank length)		
			Access (Total)	No access	Past access	Recent access	Current access
	Overall	430	42.3 (4.3)	57.7 (4.3)	17.3 (3.4)	17.1 (3.7)	7.8 (2.6)
Land use type	**Dairy**	223	11.5 (3.6)	88.5 (3.6)	6.1 (2.4)	4.7 (2.4)	0.8 (0.8)
	Drystock	207	65.3 (6.4)	34.7 (6.4)	25.7 (5.6)	26.5 (6.1)	13.1 (4.5)
Management zone	**Central Waikato**	15	26.6 (15.8)	73.4 (15.8)	15.7 (10.9)	8.2 (13.8)	2.8 (6.8)
	Coromandel	16	43.5 (36)	56.5 (36)	5.7 (11.2)	33.7 (38.2)	4.1 (6.4)
	Lake Taupō	24	25.5 (31.2)	74.5 (31.2)	13.8 (22.1)	11.7 (12.8)	0 (0)
	Lower Waikato	58	40.3 (13.9)	59.7 (13.9)	14.5 (11.3)	20 (13.2)	5.8 (7.3)
	Upper Waikato	64	19 (11.2)	81 (11.2)	6.6 (4.6)	8.7 (8.3)	3.7 (6.4)
	Waihou-Piako	76	16.2 (8.7)	83.8 (8.7)	10.2 (6)	5.1 (3.6)	1 (1.9)
	Taupō	88	38.4 (9.7)	61.6 (9.7)	18.6 (7.8)	15.2 (7.9)	4.6 (4.3)
	West Coast	89	81.4 (6.1)	18.6 (6.1)	32.1 (8)	28.6 (7.8)	20.7 (8)
Stream order	**0**	72	11.1 (8.7)	88.9 (8.7)	2.3 (2.3)	8.4 (8.3)	0.4 (1)
	1	146	55.8 (6.4)	44.2 (6.4)	22.4 (5.3)	23.2 (6.1)	10.3 (4.2)
	2	72	38.9 (11)	61.1 (11)	17.4 (9.4)	14.3 (6.5)	7.2 (6.4)
	3	54	38.8 (12.9)	61.2 (12.9)	18.6 (8.9)	13.1 (8)	7.1 (7.6)
	4	38	16.3 (12.2)	83.7 (12.2)	7.1 (8.8)	2.7 (4.3)	6.4 (8.2)
	5	29	13 (18.1)	87 (18.1)	6.1 (13)	1.4 (7)	5.5 (13.3)
	6	19	2.5 (27.8)	97.5 (27.8)	1.5 (23.6)	0.4 (10.4)	0.7 (19.8)
Clean streams Accord	**Qualifying sites**	160	11.9 (3.8)	88.1 (5.0)	5.6 (2.4)	5.4 (2.3)	0.8 (0.8)
	All other sites	270	46.0 (5.8)	54.0 (6.0)	19.9 (3.7)	46.4 (3.5)	9.7 (3.0)

Table A4-4. Average proportion of bank length with stock access for the region as a whole (overall) and for land use type in 2017 and 2022. The number of samples (n) analysed within each population are included for reference.

		Year	n	Simplified stock access categories (%bank length)		Detailed stock access categories (% bank length)		
				Access (Total	No access	Past access	Recent access	Current access
	Overall	**2017**	418	51 (4.3)	49 (4.3)	13 (2.7)	18.3 (3.3)	19.7 (4)
		2022	430	42.3 (4.3)	57.7 (4.3)	17.3 (3.4)	17.1 (3.7)	7.8 (2.6)
Land use type	Dairy	**2017**	238	26.8 (5.7)	73.2 (5.7)	10 (3.1)	7.7 (3.1)	9.1 (4)
		2022	223	11.5 (3.6)	88.5 (3.6)	6.1 (2.4)	4.7 (2.4)	0.8 (0.8)
	Drystock	**2017**	180	76.8 (5.8)	23.2 (5.8)	16.3 (4.4)	29.6 (6.1)	31 (7.2)
		2022	207	65.3 (6.4)	34.7 (6.4)	25.7 (5.6)	26.5 (6.1)	13.1 (4.5)

Table A4-5. Average proportion of bank length of vegetation categories for the region as a whole (overall) and for land use type in 2002, 2007, 2012, 2017 and 2022. The number of samples (n) analysed within each population are included for reference.

	Year	n	Simplified vegetation categories (% bank length)		-----------------------Detailed vegetation categories-------------------- (% bank length)				
			Woody	Non-woody	Woody native	Woody exotic (willow)	Woody exotic (other)	Grass and weeds	Flax/sedge/rush
Overall	2002	374	25.5 (3.6)	74.5 (3.6)	5.4 (2.0)	5.9 (1.9)	14.3 (3.0)	68.8 (3.9)	5.7 (1.8)
	2007	298	31.2 (5.6)	68.8 (5.6)	9.3 (3.1)	3 (1.5)	18.9 (4.5)	65.5 (5.8)	3.3 (1.6)
	2012	383	27 (3.6)	73 (3.6)	7.7 (2.2)	6 (1.6)	13.4 (2.6)	48.9 (5.1)	24 (4.3)
	2017	432	23.9 (3.0)	76.1 (3.0)	9.7 (2.3)	4.1 (1.2)	10.1 (2)	66.5 (3.7)	9.5 (2.4)
	2022	430	26.8 (2.8)	73.2 (2.8)	11.3 (2.1)	6.4 (1.2)	9.1 (1.7)	64.1 (3.1)	9.1 (2)
Dairy	2002	160	21.9 (5.5)	78.1 (5.5)	2 (1.5)	6 (2.9)	13.8 (4.5)	76.3 (5.8)	1.8 (1.5)
	2007	91	26.4 (9.0)	73.6 (9.0)	3.2 (2.3)	4.8 (4.1)	18.4 (7.1)	70.8 (8.9)	2.8 (2.6)
	2012	197	26.1 (5.3)	73.9 (5.3)	3.9 (1.9)	7.3 (2.6)	14.9 (4.5)	48.8 (7.2)	25.2 (6.4)
	2017	244	23.4 (4.1)	76.6 (4.1)	6.3 (2.9)	4.9 (1.8)	12.2 (3.0)	72.4 (4.4)	4.2 (1.7)
	2022	223	24.8 (4.0)	75.2 (4.0)	7.5 (2.6)	5.9 (1.8)	11.4 (3.0)	71.5 (4.1)	3.8 (1.2)
Drystock	2002	214	28.2 (4.7)	71.8 (4.7)	7.9 (3.2)	5.8 (2.6)	14.6 (4.1)	63.3 (5.3)	8.5 (2.9)
	2007	207	33.5 (7.3)	66.5 (7.3)	12.3 (4.4)	2.1 (1.2)	19.1 (5.9)	62.9 (7.5)	3.6 (1.9)
	2012	186	27.9 (5.0)	72.1 (5.0)	11.1 (3.9)	4.8 (2.0)	12 (3.0)	49.1 (7.2)	23 (5.9)
	2017	188	24.4 (4.4)	75.6 (4.4)	13.2 (3.6)	3.3 (1.5)	7.9 (2.5)	60.5 (5.7)	15.1 (4.6)
	2022	207	28.4 (4.0)	71.6 (4.0)	14.3 (3.2)	6.8 (1.7)	7.3 (1.9)	58.6 (4.5)	13.1 (3.4)

Table A4-6. Average proportion of bank length (95% confidence interval in parentheses) of buffer width categories for the region as a whole (overall) and for land use type, management zone, and stream order categories in 2022. The number of samples (n) analysed within each population are included for reference.

		Year	n	Simplified buffer width categories (% bank length)		---------------Detailed buffer width categories-------------- (% bank length)			
				Narrow (< 5 m)	Wide (> 5 m)	< 2 m	2 - 5 m	5 - 10 m	> 10 m
	Overall	2022	430	61.9 (3.8)	38.1 (3.8)	36.6 (3.4)	25.3 (3.1)	15.1 (2.5)	23.1 (3.3)
Land use type	**Dairy**	2022	223	74.1 (4.8)	25.9 (4.8)	53.4 (4.9)	20.8 (3.4)	9.6 (2.2)	16.2 (4.2)
	Drystock	2022	207	52.6 (5.8)	47.4 (5.8)	23.9 (5.1)	28.7 (4.7)	19.2 (4.2)	28.2 (5)
Management zone	**Central Waikato**	2022	15	75.1 (21.7)	24.9 (21.7)	53 (20.9)	22.1 (11.8)	18 (18.8)	6.9 (12.5)
	Coromandel	2022	16	56.6 (10.1)	43.4 (10.1)	14 (8.4)	42.6 (10)	23.5 (9.4)	19.9 (14.6)
	Lake Taupō	2022	24	30 (25.4)	70 (25.4)	21.1 (25.6)	8.9 (6.5)	21.9 (18.4)	48.1 (16.3)
	Lower Waikato	2022	58	76.7 (10.8)	23.3 (10.8)	44.2 (9)	32.5 (11.4)	16.3 (8.7)	7 (4.4)
	Upper Waikato	2022	64	39.2 (12)	60.8 (12)	16.1 (8)	23.1 (6.9)	22.8 (7.5)	38 (12.1)
	Waihou-Piako	2022	76	80.1 (6)	19.9 (6)	58.5 (8.3)	21.6 (4.6)	9.1 (2.9)	10.8 (4.9)
	Taupō	2022	88	68.3 (7.1)	31.7 (7.1)	46 (7.8)	22.3 (5.9)	10.1 (3.6)	21.6 (7.1)
	West Coast	2022	89	53.7 (8.8)	46.3 (8.8)	27.3 (7.4)	26.4 (7.3)	14 (5.6)	32.2 (8.9)
Stream order	**0**	2022	72	95.3 (3.8)	4.7 (3.8)	84.6 (6)	10.8 (4.2)	1.7 (1.6)	2.9 (2.7)
	1	2022	146	60.3 (6.1)	39.7 (6.1)	33 (5.3)	27.3 (4.7)	14.2 (3.7)	25.5 (5.5)
	2	2022	72	54 (9.6)	46 (9.6)	28.4 (9)	25.7 (8.6)	21.2 (8.6)	24.8 (8.1)
	3	2022	54	54.1 (10.1)	45.9 (10.1)	27 (9.2)	27.2 (6)	16.7 (6.4)	29.1 (9.2)
	4	2022	38	43.3 (10.1)	56.7 (10.1)	13.9 (7.8)	29.4 (7.6)	28 (7.1)	28.7 (9.6)
	5	2022	29	52.4 (28.9)	47.6 (28.9)	4.7 (7.2)	47.8 (31.1)	19.5 (10.1)	28 (26.8)
	6	2022	19	26.2 (28.4)	73.8 (28.4)	2.8 (12.3)	23.3 (24.8)	38.8 (21.7)	35.1 (33.1)

Table A4-7. Average proportion of bank length (95% confidence interval in parentheses) of buffer width categories by vegetation type for the region as a whole (overall) and for land use type categories in 2022. The number of samples (n) analysed within each population are included for reference.

		n	Simplified buffer width categories (% bank length)		------------Detailed buffer width categories---------- (% bank length)			
			Narrow (< 5 m)	**Wide (> 5 m)**	**< 2 m**	**2 - 5 m**	**5 - 10 m**	**> 10 m**
Woody	Overall	395	40.1 (4.9)	59.9 (4.9)	13 (2.6)	27.1 (4.1)	23.8 (3.6)	36.1 (5.5)
	Dairy	199	41.9 (8.1)	58.1 (8.1)	19 (4.9)	22.8 (5.3)	20.5 (5)	37.6 (9.3)
	Drystock	196	38.9 (6.4)	61.1 (6.4)	9.1 (3.2)	29.9 (5.8)	26 (4.9)	35.1 (6.7)
Non woody	Overall	425	69.8 (4)	30.2 (4)	45.2 (4)	24.6 (3.5)	11.8 (2.7)	18.3 (3.3)
	Dairy	219	84.8 (3.8)	15.2 (3.8)	64.7 (5)	20.1 (3.7)	6 (1.7)	9.2 (3.1)
	Drystock	206	58 (6.5)	42 (6.5)	29.8 (6.2)	28.2 (5.5)	16.4 (4.6)	25.5 (5.5)

Table A4-8. Average proportion of observed crossings by stream crossing type and number of total crossings (95% confidence interval in parentheses) for the region as a whole (overall) and for land use type, management zone, and stream order categories in 2022. The number of samples (n) analysed within each population are included for reference.

				Stream crossing type (% of observed crossings)			Total crossings (number per km stream length)
		Year	n	Bridges	Fords	Culverts	Total
	Overall	2022	285	12.2 (3.2)	5.1 (2.4)	82.7 (3.9)	2.8 (0.3)
Land use type	**Dairy**	2022	147	12.3 (4.4)	0.8 (1.3)	86.9 (4.5)	3 (0.4)
	Drystock	2022	138	12.1 (4.8)	8.8 (4.3)	79.1 (6.7)	2.6 (0.3)
Management zone	**Central Waikato**	2022	9	12.3 (26)	0 (0)	87.7 (26)	5.1 (1.4)
	Coromandel	2022	10	1.9 (5)	15.8 (16.4)	82.3 (17.8)	2.5 (2.2)
	Lake Taupō	2022	15	42.4 (46.9)	9.1 (8.8)	48.4 (46.8)	1.6 (0.4)
	Lower Waikato	2022	37	7.9 (8.4)	0.7 (1.6)	91.5 (8.6)	2.2 (0.6)
	Upper Waikato	2022	41	13.4 (9.4)	2.7 (4.7)	83.9 (10.1)	2.4 (0.6)
	Waihou-Piako	2022	53	14.3 (6.8)	6.5 (10.2)	79.2 (11.1)	2.6 (0.6)
	Taupō	2022	59	10.4 (6)	6.5 (5.3)	83.1 (8.1)	3.6 (0.7)
	West Coast	2022	61	12.5 (6.9)	5.5 (4.9)	82 (8.4)	3 (0.6)
Stream order	**0**	2022	51	3.8 (3.5)	0 (0)	96.2 (3.5)	3.2 (0.7)
	1	2022	123	7.5 (3.9)	3.6 (2.6)	88.9 (4.5)	3.2 (0.4)
	2	2022	59	21.9 (10.2)	8.4 (9.9)	69.8 (13.4)	2.7 (0.6)
	3	2022	33	46.8 (17)	14.4 (10.9)	38.8 (18.8)	1.9 (0.6)
	4	2022	11	33.9 (54.9)	46.7 (55.4)	19.3 (48.4)	0.7 (0.4)
	5	2022	6	76.3 (201.7)	0	23.7 (201.7)	0.2 (0.4)
	6	2022	2	28.6 (0)	0	71.4 (0)	0 (0.6)

Table A4-9. Average proportion of bank length (95% confidence interval in parentheses) of stream-bank erosion and soil disturbance categories for the region as a whole (overall) and for land use type, management zone, and stream order categories in 2022. The number of samples (n) analysed within each population are included for reference.

		n	Stream-bank erosion categories (% bank length)				Soil disturbance categories (% bank length)			
			Uneroded	Recent Erosion	Active Erosion	Total Erosion	< 50% Pugging	> 50% Pugging	Disturbed	Un-disturbed
	Overall	430	91.6 (1.7)	4.7 (0.8)	3.6 (1.4)	8.4 (1.7)	3.8 (1.4)	0.6 (0.3)	9 (1.8)	91 (1.8)
Land use type	Dairy	223	93.4 (1.8)	4.8 (1.4)	1.8 (0.7)	6.6 (1.8)	1.8 (1.1)	0.2 (0.1)	6.7 (1.8)	93.3 (1.8)
	Drystock	207	90.3 (2.7)	4.7 (1)	5 (2.4)	9.7 (2.7)	5.3 (2.4)	1 (0.6)	10.7 (2.8)	89.3 (2.8)
Management zone	Central Waikato	15	79.9 (10.2)	13.5 (5)	6.6 (6)	20.1 (10.2)	2.6 (3.4)	0.5 (1.2)	20.7 (9.7)	79.3 (9.7)
	Coromandel	16	83.1 (11.7)	8.7 (4.4)	8.3 (8.7)	16.9 (11.7)	12.7 (23.3)	1.8 (3)	18.7 (10.7)	81.3 (10.7)
	Lake Taupō	24	99 (1.2)	0.9 (1.2)	0.1 (0.2)	1 (1.2)	1.2 (2.4)	1.2 (2.5)	2.2 (2.7)	97.8 (2.7)
	Lower Waikato	58	86.9 (7.5)	6.3 (2.5)	6.9 (7)	13.1 (7.5)	6.4 (5.4)	1.2 (1.6)	14.3 (7.6)	85.7 (7.6)
	Upper Waikato	64	96.5 (2.5)	2.6 (1.9)	0.9 (0.8)	3.5 (2.5)	3.8 (4.1)	0.3 (0.3)	3.8 (2.6)	96.2 (2.6)
	Waihou-Piako	76	94.5 (2.2)	4.2 (1.9)	1.2 (1)	5.5 (2.2)	2.1 (1.3)	0.4 (0.4)	5.9 (2.2)	94.1 (2.2)
	Taupō	88	91.4 (4.4)	5.1 (3)	3.6 (2.7)	8.6 (4.4)	1.9 (1.2)	0.4 (0.3)	9 (4.4)	91 (4.4)
	West Coast	89	91.6 (3)	4.2 (1.4)	4.2 (2.1)	8.4 (3)	3.5 (1.3)	0.5 (0.3)	8.9 (3.1)	91.1 (3.1)
Stream order	0	72	92.4 (3.1)	6.2 (2.7)	1.4 (0.8)	7.6 (3.1)	0.1 (0.1)	3 (1)	7.7 (3.2)	92.3 (3.2)
	1	146	96 (1.4)	2.6 (0.9)	1.4 (0.8)	4 (1.4)	1.1 (0.7)	5.7 (2.8)	5.1 (1.6)	94.9 (1.6)
	2	72	91 (4.4)	5.4 (2.8)	3.6 (2.4)	9 (4.4)	0.1 (0.1)	1.9 (1.9)	9.1 (4.4)	90.9 (4.4)
	3	54	86.7 (7.8)	6.5 (3.3)	6.7 (5.9)	13.3 (7.8)	0.3 (0.4)	2 (1.8)	13.6 (7.9)	86.4 (7.9)
	4	38	69.5 (14.2)	13.7 (5.5)	16.8 (11.5)	30.5 (14.2)	0 (0.1)	0.2 (0.4)	30.6 (14.2)	69.4 (14.2)
	5	29	77.8 (21.9)	13 (13.1)	9.1 (11.6)	22.2 (21.9)	0.3 (1)	0.9 (3.3)	22.4 (21.7)	77.6 (21.7)
	6	19	76.3 (131.1)	7.6 (83.5)	16.2 (60.4)	23.7 (131.1)	0 (0)	0.1 (11.5)	23.7 (131.1)	76.3 (131.1)

Table A4-10. Average proportion of bank length (95% confidence interval in parentheses) of stream-bank erosion and soil disturbance categories for fencing and vegetation categories in 2022. The number of samples (n) analysed within each population are included for reference

		n	Stream-bank erosion categories (% bank length)				Soil disturbance categories (% bank length)		
			Un-eroded	Recent Erosion	Active erosion	Total Erosion	> 50% Pugging	Disturbed	Un-disturbed
Fencing	Effectively fenced	367	91 (2.2)	4.8 (1.1)	3.7 (1.7)	8.5 (2.2)	0.1 (0.1)	8.6 (2.2)	91.4 (2.2)
	Not effectively fenced	295	81.9 (4.1)	4.6 (1.1)	3.5 (1.4)	8.2 (2.2)	1.4 (0.7)	9.6 (2.3)	90.4 (2.3)
Vegetation	Woody	395	88 (3.5)	4.7 (1.2)	5.1 (3.1)	9.8 (3.4)	0.4 (0.2)	10.2 (3.4)	89.8 (3.4)
	Non woody	425	86.9 (2.5)	4.7 (0.9)	3.1 (0.9)	7.8 (1.5)	0.7 (0.4)	8.5 (1.5)	91.5 (1.5)

Table A4-11. Average proportion of bank length of stream-bank erosion and soil disturbance categories for the region as a whole (overall) and for land use type in 2002, 2007, 2012, 2017 and 2022. The number of samples (n) analysed within each population are included for reference.

		Year	n	Stream-bank erosion categories (% bank length)				Soil disturbance categories (% bank length)			
				Uneroded	Recent Erosion	Active Erosion	Total Erosion	> 50% Pugging	< 50% Pugging	Disturbed	Un-disturbed
	Overall	**2002**	374	94.7 (1.6)	3.5 (1)	1.8 (0.8)	5.3 (1.6)	-	-	-	-
	Overall	**2007**	298	78.6 (5.4)	17.1 (5.3)	4.3 (2)	21.4 (5.4)	15.3 (3.2)	0 (0)	36.6 (5.3)	63.4 (5.3)
	Overall	**2012**	380	89.5 (2.4)	6.8 (1.8)	3.7 (1.4)	10.5 (2.4)	14.1 (4.5)	15 (4.4)	24.6 (4.5)	75.4 (4.5)
	Overall	**2017**	418	82.7 (3.2)	10.3 (2.3)	7 (2.1)	17.3 (3.2)	6.9 (2.1)	12.9 (2.8)	24.2 (3.7)	75.8 (3.7)
	Overall	**2022**	430	91.6 (1.7)	4.7 (0.8)	3.6 (1.4)	8.4 (1.7)	0.6 (0.3)	3.8 (1.4)	9 (1.8)	91 (1.8)
Land use type	Dairy	**2002**	160	94.9 (1.9)	4 (1.6)	1.1 (0.5)	5.1 (1.9)	-	-	-	-
Land use type	Dairy	**2007**	91	81.7 (7)	15.7 (6.5)	2.6 (1.6)	18.3 (7)	10.8 (6.8)	0 (0)	29.1 (9.3)	70.9 (9.3)
Land use type	Dairy	**2012**	196	91.1 (2.9)	6.4 (2.6)	2.5 (1)	8.9 (2.9)	4.8 (1.8)	9 (4)	13.7 (3.4)	86.3 (3.4)
Land use type	Dairy	**2017**	238	87 (3.2)	9.5 (2.7)	3.6 (1.3)	13 (3.2)	4.8 (2.9)	8.2 (3.6)	17.8 (4)	82.2 (4)
Land use type	Dairy	**2022**	223	93.4 (1.8)	4.8 (1.4)	1.8 (0.7)	6.6 (1.8)	0.2 (0.1)	1.8 (1.1)	6.7 (1.8)	93.3 (1.8)
Land use type	Drystock	**2002**	214	94.5 (2.5)	3.2 (1.2)	2.3 (1.4)	5.5 (2.5)	-	-	-	-
Land use type	Drystock	**2007**	207	77.2 (7.6)	17.7 (7.4)	5.1 (2.9)	22.8 (7.6)	17.4 (4.3)	0 (0)	40.3 (7.7)	59.7 (7.7)
Land use type	Drystock	**2012**	184	88 (3.8)	7.3 (2.5)	4.7 (2.5)	12 (3.8)	22.5 (8.1)	20.4 (7.3)	34.6 (7.6)	65.4 (7.6)
Land use type	Drystock	**2017**	180	78.1 (5.7)	11.3 (3.7)	10.6 (4.1)	21.9 (5.7)	9.1 (3.2)	17.9 (4.5)	31.1 (6.4)	68.9 (6.4)
Land use type	Drystock	**2022**	207	90.3 (2.7)	4.7 (1)	5 (2.4)	9.7 (2.7)	1 (0.6)	5.3 (2.4)	10.7 (2.8)	89.3 (2.8)

Table A4-12. Association between percentage bank length effectively fenced on pastoral enterprises in 2022 and detailed vegetation buffer width categories across three New Zealand Land Resource Inventory (NZLRI) slope classes (< 3°, < 7°, < 15°). Data is for the assessment of low-slope scenarios under the proposed national stock exclusion regulations1.

Land use	Effective fencing x buffer width category	NZLRI class A (< 3°)¥		NZLRI class A+B (< 7°)¥		NZLRI class A+B+C (< 15°)¥	
		No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†
All	Effective fencing total	161	84.2 (5.1)	193	83.2 (4.7)	223	83 (4.5)
	Effective fencing < 1 m	161	23 (4.9)	193	21.4 (4.4)	223	19.2 (3.9)
	Effective fencing 1 - 2 m	161	28.3 (4.4)	193	25.6 (4)	223	22.1 (3.5)
	Effective fencing 2 - 3 m	161	10.5 (2.5)	193	10.8 (2.4)	223	10.4 (2.2)
	Effective fencing 3 - 5 m	161	8.8 (2.5)	193	9.1 (2.3)	223	9.5 (2.1)
	Effective fencing 5 - 10 m	161	7.4 (2.7)	193	7.8 (2.5)	223	10.6 (2.8)
	Effective fencing > 10 m	161	6.1 (3.1)	193	8.4 (3)	223	11.1 (3.2)
Dairy‡	Effective fencing total	116	93.2 (3)	139	92.9 (3)	152	92.5 (3.1)
	Effective fencing < 1 m	116	31.6 (6.9)	139	29.2 (6)	152	26.7 (5.7)
	Effective fencing 1 - 2 m	116	35.4 (6)	139	32.7 (5.4)	152	29.5 (5.2)
	Effective fencing 2 - 3 m	116	11.1 (3.5)	139	11.3 (3.1)	152	11.5 (3)
	Effective fencing 3 - 5 m	116	4.9 (2)	139	6.5 (2.1)	152	7.9 (2.3)
	Effective fencing 5 - 10 m	116	4.6 (2.5)	139	5.9 (2.5)	152	8.1 (2.8)
	Effective fencing > 10 m	116	5.5 (3.9)	139	7.4 (3.4)	152	8.8 (3.8)
Drystock*	Effective fencing total	58	67.1 (13.4)	70	65.3 (11.6)	93	68.9 (9.6)
	Effective fencing < 1 m	58	6.7 (5.1)	70	7.2 (5)	93	8.2 (4.8)
	Effective fencing 1 - 2 m	58	14.8 (6.5)	70	12.7 (5.6)	93	11.2 (4.3)
	Effective fencing 2 - 3 m	58	9.3 (3.3)	70	9.9 (4.4)	93	8.8 (3.3)
	Effective fencing 3 - 5 m	58	16.4 (6.6)	70	14 (5.7)	93	11.8 (4.2)
	Effective fencing 5 - 10 m	58	12.8 (6.2)	70	11.2 (5.3)	93	14.2 (5.5)
	Effective fencing > 10 m	58	7.1 (4.2)	70	10.3 (5.4)	93	14.6 (5.4)

¥ NZLRI slope class
† Mean value and associated 95% confidence interval about the average
‡ Dairy platform (see Table 2)
* Includes dairy support, beef, sheep and beef, deer and pigs (see Table 2)
1 Ministry for the Environment 2020a. Action for healthy waterways – Decisions on the national direction for freshwater: An at-a-glance summary. Wellington: Ministry for the Environment.

Table A4-13. Association between percentage bank length effectively fenced on pastoral enterprises in 2022 and detailed vegetation buffer width categories across three New Zealand Land Resource Inventory (NZLRI) slope classes (> 3°, > 7°, > 15°). Data is for the assessment of non-low slope scenarios under the proposed national stock exclusion regulations1.

Land use	Effective fencing x buffer width category	NZLRI class A (> 3°)¥		NZLRI class A+B (> 7°)¥		NZLRI class A+B+C (> 15°)¥	
		No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†	No. sites	Percentage bank length (%)†
Dairy‡	Effective fencing total	80	89.9 (5.3)	57	89.6 (6.3)	44	89.5 (7.6)
	Effective fencing < 1 m	80	9.5 (4.7)	57	8.1 (5.1)	44	8 (4.3)
	Effective fencing 1 - 2 m	80	13.2 (4.7)	57	12.3 (4.9)	44	14.3 (6.3)
	Effective fencing 2 - 3 m	80	12.8 (4.5)	57	13 (5.6)	44	13 (6.3)
	Effective fencing 3 - 5 m	80	15.4 (3.8)	57	15.3 (4.3)	44	14.1 (5.1)
	Effective fencing 5 - 10 m	80	15.2 (4.4)	57	15.5 (4.9)	44	12.6 (5.3)
	Effective fencing > 10 m	80	23.8 (8.8)	57	25.3 (10.8)	44	27.4 (13.4)
Drystock (high intensity)*	Effective fencing total	28	59.6 (21.9)	25	60.2 (25.8)	16	52.6 (146.8)
	Effective fencing < 1 m	28	4.3 (8.7)	25	4.6 (10.1)	16	0.9 (4.8)
	Effective fencing 1 - 2 m	28	5.3 (4.8)	25	5.3 (5.6)	16	5.3 (35)
	Effective fencing 2 - 3 m	28	9.2 (9.6)	25	5.6 (3.8)	16	5 (17.9)
	Effective fencing 3 - 5 m	28	8.1 (4.7)	25	8.8 (5.5)	16	8.3 (31.4)
	Effective fencing 5 - 10 m	28	14.3 (8.8)	25	16.8 (9.4)	16	14.9 (48.4)
	Effective fencing > 10 m	28	18.5 (11.5)	25	19.1 (11.6)	16	18.1 (64.2)

¥ NZLRI slope class
† Mean value and associated 95% confidence interval about the average
‡ Dairy platform (see Table 2)
* Includes dairy support, beef, sheep and beef, deer and pigs land use (see Table 2) with a whole farm stocking rate of > 14 SU/ha or evidence of break feeding at the time of the survey.
[1] Ministry for the Environment 2020a. Action for healthy waterways – Decisions on the national direction for freshwater: An at-a-glance summary. Wellington: Ministry for the Environment.

Table A4-14. Association between the percentage of bank length with complete stock exclusion and three vegetation buffer width categories (< 1 m, < 3 m and > 3 m) for drains (Strahler order 0; channel width < 2 m and channel width > 2 m) and streams and rivers (Strahler orders 1-6) in Plan Change 1 zones, 2017. Data is for the assessment of fencing setback requirements under low-slope (< 15°) and non-low slope (> 15°) scenarios under Schedule C of Plan Change 1[2].

	Slope class¥	Stock exclusion† x buffer width category	Drains (channel width < 2 m)		Drains (channel width > 2 m)		Streams and rivers (Strahler orders 1 - 6)	
			No. sites	Proportion of bank length (%)‡	No. sites	Proportion of bank length (%)‡	No. sites	Proportion of bank length (%)‡
Central Waikato	Low-slope (< 15°)	Effective fencing total	2	92	0	-	5	59 (252)
		Effective fencing < 1 m	2	30	0	-	5	14 (46)
		Effective fencing < 3 m	2	85	0	-	5	47 (254)
		Effective fencing > 3 m	2	6	0	-	5	12.6 (48)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	0	-
		Effective fencing < 1 m	0	-	0	-	0	-
		Effective fencing < 3 m	0	-	0	-	0	-
		Effective fencing > 3 m	0	-	0	-	0	-
Lower Waikato	Low-slope (< 15°)	Effective fencing total	20	91 (9)	8	70 (44)	19	70 (17)
		Effective fencing < 1 m	20	33 (15)	8	12 (14)	19	19 (18)
		Effective fencing < 3 m	20	87 (12)	8	63 (52)	19	44 (22)
		Effective fencing > 3 m	20	4 (5)	8	7 (9)	19	26 (14)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	0	-
		Effective fencing < 1 m	0	-	0	-	0	-
		Effective fencing < 3 m	0	-	0	-	0	-
		Effective fencing > 3 m	0	-	0	-	0	-
Upper Waikato	Low-slope (< 15°)	Effective fencing total	1	100	0	-	35	92 (7)
		Effective fencing < 1 m	1	44	0	-	35	3 (4)
		Effective fencing < 3 m	1	100	0	-	35	19 (15)
		Effective fencing > 3 m	1	0	0	-	35	74 (16)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	5	97 (25)
		Effective fencing < 1 m	0	-	0	-	5	6 (44)
		Effective fencing < 3 m	0	-	0	-	5	39 (275)
		Effective fencing > 3 m	0	-	0	-	5	58 (270)
Waipā	Low-slope (< 15°)	Effective fencing total	7	91 (15)	0	-	39	79 (13)
		Effective fencing < 1 m	7	44 (20)	0	-	39	32 (16)
		Effective fencing < 3 m	7	83 (20)	0	-	39	60 (13)
		Effective fencing > 3 m	7	8 (13)	0	-	39	19 (10)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	10	82 (20)
		Effective fencing < 1 m	0	-	0	-	10	27 (31)
		Effective fencing < 3 m	0	-	0	-	10	59 (31)
		Effective fencing > 3 m	0	-	0	-	10	23 (29)

¥ NZLRI slope class
† Proportion of bank with effective fencing or forest/scrub or deep channel morphology
‡ Mean value and associated 95% confidence interval about the average
* Whole farm stocking rate of > 18 SU/ha or evidence of break feeding at the time of the survey.
[2] WRC 2020. Proposed Waikato Regional Plan Change 1: Waikato and Waipā River Catchments. Decisions version (volume 2 of 2). Waikato Regional Council Policy Series 2020/02. Hamilton, Waikato Regional Council (WRC).

Appendix 5: Survey123 forms

Regional Riparian Survey

Riparian Charateristics Survey

What is being captured?

General Site Details

Position*

Lat: -37.818313 Lon: 175.563704

General Site Details

Site ID

Site Status

-Please select-

Sampling Date

17/01/2025

Field Observer

-Please select-

Farm Type

-Please select-

Land Use

-Please select-

Break Feeding

-Please select-

Accord Stream

-Please select-

Permanent

-Please select-

COMMENTS

Submit

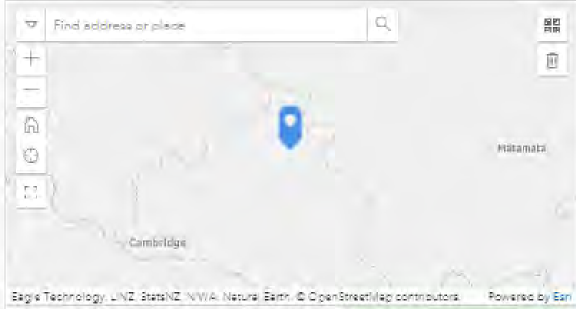
Regional Riparian Survey

Riparian Charateristics Survey

What is being captured?

True Left Details

Position*



Lat: -37.818313 Lon: 175.563704

True Left Details

Land Use

-Please select-

Fence Type

-Please select-

Fencing Status

-Please select-

Vegetation Type

-Please select-

Vegetation Structure

-Please select-

Vegetation Management

-Please select-

Vegetation Width

-Please select-

Erosion Type

-Please select-

Obstruction Type

-Please select-

Obstruction Length

SIDE

COMMENTS

Submit

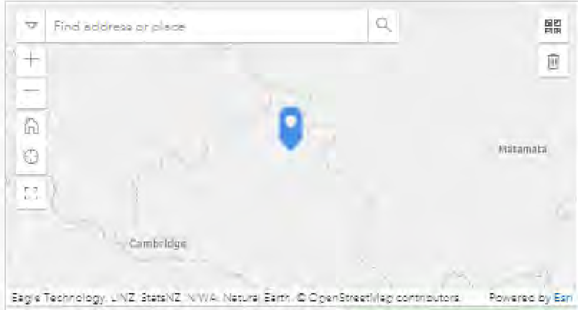
Regional Riparian Survey

Riparian Charateristics Survey

What is being captured?

True Left Details

Position*



Lat: -37.818313 Lon: 175.563704

True Right Details

Land Use

-Please select-

Fence Type

-Please select-

Fencing Status

-Please select-

Vegetation Type

-Please select-

Vegetation Structure

-Please select-

Vegetation Management

-Please select-

Vegetation Width

-Please select-

Erosion Type

-Please select-

Obstruction Type

-Please select-

Obstruction Length

SIDE

COMMENTS

Submit

Bank Height

-Please select-

Channel Type

-Please select-

Channel Shape

-Please select-

Channel Width

-Please select-

Stream Bed

-Please select-

Stock Access

-Please select-

COMMENTS

Submit