Waikato Regional Council Technical Report 2020/12

Riparian characteristics of pastoral waterways in the Waikato region, 2002-2017

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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November 2020

Document #: 17195058

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Acknowledgement

We wish to acknowledge the outstanding contribution of the wider project team to the 2017 riparian characteristics survey. Many thanks to: Claire Kotze for helping set-up the survey and for co-ordinating and assisting to direct the field teams; all those involved in the field data collection (Karne Robertson, Paula Stevenson, Rebecca Booth and Cullum Parker); Richard Glass for setting up the data capture forms, guidance in the use of the field devices and for the spatial correction of the data collected; and Mark Hamer for support and assistance in relation to field team training. Thanks also to Helen Andersen for assisting with the preparation of letters to landowners. We would also very much like to thank all the landowners who granted us permission to access the sites on or via their property. The survey could not have been successfully completed without the assistance and co-operation of all those involved.

Table of Contents

Figures

Tables

Executive summary

The Waikato Regional Council (WRC) has conducted four region wide surveys (2002, 2007, 2012 and 2017) to establish, and track changes in the state of fencing, vegetation, buffer width, waterway crossings and stream-bank erosion at sites on pastoral land across the Waikato region. This report presents findings from the most recent survey (conducted during the summer/autumn period of 2017/2018 and referred to henceforth as the '2017 survey') in conjunction with changes in measured attributes over the previous 5, 10, and 15-year monitoring periods. Data from the 2017 survey were collected from 432 waterway sites comprising 244 in dairy and 188 in drystock. Results from the 2017 survey were also assessed in relation to proposed stock exclusion regulations as outlined in the Action for Healthy Waterways package (2020 'Decisions on the national direction for freshwater' document[1]) and Waikato Regional Council's Plan Change 1 decisions version document (Schedule C)[2]. Finally, a review of the survey design based on historical survey data was conducted and recommendations made for future iterations of the survey.

The proportion of surveyed bank length fenced across the Waikato region has steadily increased over the 15-year monitoring period at a rate of about 2.2% of bank length per year (from 28% in 2002 to 61% in 2017). Approximately 40% of surveyed bank length in pastoral land remained unprotected against stock access at the time of the 2017 survey suggesting that further work is required to encourage, support and facilitate riparian fencing efforts in the region. The strong correspondence 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 (effective fencing was defined as that which is sufficient to prevent stock access to the waterway and is adjacent to riparian margins).

Riparian margins in pastoral land across the Waikato region in 2017 were dominated by non-woody vegetation cover (occupying about 76% of bank length and dominated by pastoral grasses), as has been the case over the entire 15-year monitoring period. Woody vegetation, in association with non-woody vegetation, is important because it provides a range of additional benefits including shading effects (for water temperature regulation), enhanced biodiversity values (e.g. habitat provision and inputs of organic matter for aquatic food webs) and stream-bank stability. Results indicate that continued efforts are required to encourage the restoration of woody riparian vegetation in the region. About half (54%) of riparian margins were classed as narrow (i.e. < 5 m).

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[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.

The proportion of bank length affected by stream-bank erosion across the region was approximately 17% in 2017 and has significantly increased from 5% in 2002. The magnitude and frequency of storm events 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 soil disturbance is the sum of total stream-bank erosion and pugging disturbance caused by livestock treading. About one quarter (24%) of the surveyed bank length across the region was characterised as disturbed at the time of the 2017 survey, and of this, 7% was attributed to pugging disturbance. Importantly, there was a significant reduction in pugging (8% of bank length) for the five-year period between 2012 and 2017 which 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 show that, although there is great variation between individual samples, the effect of effective fencing on stream-bank erosion and soil disturbance, when averaged over a large number of sites, is considerable. It is estimated that for every 10 percentage point increase in effectively fenced bank length across the region, there would be a reduction in the average proportions of bank length with total erosion (active or recent) and soil disturbance (total erosion or pugging disturbance > 50%) of 0.7% and 1.8% respectively.

There were substantial differences between dairy and drystock land uses with respect to riparian fencing, stock access, buffer width and soil disturbance. In 2017, dairy sites had significantly more bank length with effective fencing (87%), no stock access (74%), narrow (< 5 m) buffer widths (68%) and no soil disturbance (82%) compared to drystock sites (with 36%, 25%, 40% and 69%, respectively). Overall, the level of livestock exclusion from waterways remains considerably greater at dairy compared to drystock sites, although drystock sites did have wider riparian buffer margins (i.e. drystock sites had a smaller proportion of bank length with narrow buffer widths). While there was no significant difference in the proportion of bank length with riparian woody vegetation between dairy and drystock land uses, there was significantly more bank length eroded for drystock (22%) compared to dairy (13%). Over the 2012 – 2017 period, the proportion of bank length effectively fenced significantly increased for dairy but not for drystock, with a rate of change of about 3.8% of bank length per year for dairy and about 1.2% for drystock. The emphasis placed on improving stock exclusion on dairy farms by the Dairying and Clean Streams Accord (and subsequent Sustainable Dairying: Water Accord) appears to have had a positive impact on the amount of riparian fencing observed at dairy sites in the Waikato region. Results suggest that there is a continued need to focus riparian fencing efforts toward drystock land use.

Of the eight management zones in the Waikato Region, the Lake Taupo, Upper Waikato and Waihou-Piako management zones had the largest proportion of surveyed bank length with effective fencing (75%, 80% and 84% respectively) and no stock access (84%, 69% and 74% respectively), and the lowest amount of stream bank erosion (14%, 12% and 13% respectively). The Lake Taupo and Upper Waikato zones also stood out as having an elevated proportion of bank length with woody vegetation (52% and 44% respectively) and wide (≥ 5 m) buffers (96% and 57% respectively). Considerable emphasis has been placed on promoting the fencing of waterways in the Lake Taupo and Upper Waikato management zones by the Waikato Regional Council through historic soil conservation schemes and Method 4.3.5.3 of the Waikato Regional Plan. These regulations require that stock are excluded from mapped portions of high priority water bodies, including all tributaries flowing into Lake Taupo. In the Waihou-Piako zone, the proportion of bank length effectively fenced increased significantly (26%) over the 2012 – 2017 period, consistent with efforts undertaken through successive dairy industry accords in this predominantly dairy catchment. The West Coast zone clearly stands out as the zone that could benefit the most from future riparian fencing and restoration efforts as it had the lowest proportion of surveyed bank length with effective fencing (28%), the highest proportion of surveyed bank length with evidence of stock access (84%) and the second highest incidence of stream bank erosion (23%) in the region.

At the time of the 2017 survey, small to medium-sized streams (i.e. Strahler orders 1 – 3) generally had the least proportion of bank length with effective fencing (50 – 57%) and the most stock access (49 – 64%). Drains (stream order 0) and small to medium-sized streams generally had less woody vegetation (7 – 32% of bank length) and the largest numbers of waterway crossings (2 – 3) per km of stream length. Drains had the smallest proportion of wide buffer widths (≥ 5 m; about 8% of bank length) and stream orders 1 and 2 had the least stream-bank erosion (approximately 15 – 20% of bank length). However, the amount of erosion in stream orders 1 and 2 did increase significantly over the past 5 years by about 7 – 8% of bank length. Overall, findings suggest that riparian fencing and restoration efforts are be best directed towards small and medium-sized waterways where levels of stock exclusion are elevated, and the prevalence of woody vegetation remains comparably low. While drains could benefit from increased buffer widths, there are practical limitations to establishing woody vegetation around these structures (e.g. drain maintenance).

An analysis of the 2017 riparian survey data set against the proposed national stock exclusion regulations found that only a small percentage of surveyed bank length under low-slope (< 10°) dairy land use required effective fencing (6 – 7%) in 2017[3]. For low-slope drystock, approximately

[3] Data analysis was conducted between March and June 2020.

one third of surveyed bank length (28 – 37%) in 2017 was not effectively fenced. Only about one third (33 – 39%) of the existing effective fencing on low-slope, dairy land use was associated with a setback distance of greater than 3 m (minimum setback requirement for all new fencing). For drystock, a greater proportion of existing fencing (50 – 61%) met or exceeded this threshold. For non-low slope land (> 10°), a greater percentage of bank length required effective fencing for both dairy (13 – 16%) and high intensity drystock (56 – 57%) land uses. However, more of the existing effective fencing met or exceeded setback requirement thresholds (≥ 3 m) with approximately two thirds of effective fencing on dairy (65 – 69%) and three quarters of effective fencing on drystock (74 – 76%) associated with a setback of more than 3 m. Assuming a deadline of July 2023 for exclusion of dairy cattle and pigs and a deadline of July 2025 for exclusion of dairy support cattle, beef cattle, and deer, the rate of fencing required on low-slope land (% bank length per year) to exclude stock from remaining unfenced sections is approximately 2.2% for dairy and 6.2% for drystock. On non-low slope land (July 2023 deadline), the rate is approximately 4.8% for dairy and 6.2% for high intensity drystock. Over the entire fifteen-year monitoring period and across all slope classes, the rate of change in bank length effectively fenced was about 3.1% of bank length per year for dairy and about 1.3% of bank length per year for drystock.

Under the proposed Plan Change 1 (PC1) regulations (outlined in Schedule C of the 2020 decisions version document) and for low-slope land use (< 15°), the percentage surveyed bank length effectively fenced in 2017 for narrow (< 2 m; bank to bank) and wide drains (≥ 2 m; bank to bank) was 90% and 79% respectively across qualifying management zones (Upper Waikato, Central Waikato, Lower Waikato and Waipā)[4]. For streams and rivers (Strahler orders 1 – 6), approximately 79% of bank length was effectively fenced. There were very few drain transects sampled on non-low slope (> 15°), high stock intensity land (n < 2) and comparably few streams and rivers (n = 16). The latter had a high percentage of bank length effectively fenced (96%). Approximately 55% of the existing effective fencing on low-slope streams and rivers was associated with a setback distance of greater than 3 m, the minimum setback requirement for all new fencing on these waterways. For drains, 74% and 64% of effectively fenced bank length was associated with a setback distance of greater than 1 m for narrow and wide drains respectively, noting that the minimum setback distance of 1 m applies only to drains with a bank-to-bank width of greater or equal to 2 m. Overall, results indicate that fencing of narrow drains (< 2 m) in PC1 zones is largely complete with approximately 10% bank length remaining unfenced or ineffectively fenced. A greater percentage of bank length remains unfenced across qualifying streams and rivers (21%), particularly in the Central Waikato (47%) and Lower Waikato (35%) management zones.

[4] Data analysis was conducted between March and June 2020.

Assessment of the current survey design suggests that measured variables (e.g. the percentage of effectively fenced bank length) are provided with good precision, both for the region as a whole and for domains of interest such as land use, management zones and Strahler order. Consequently, it is recommended that the current survey design and statistical analysis framework (i.e. design-based inference) be maintained without much change in future cycles of the survey except for minor adjustments to the number of sample units assessed per stratum to reduce the sampling effort in over-represented strata and to increase sample numbers in under-represented strata. In terms of data capture, it is envisioned that the current field survey methodology, while time consuming and resource intensive, 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. Nevertheless, alternative survey techniques such as remote sending, aerial photography and drone footage are being considered as viable options to supplement field scale survey data.

1 Introduction

1.1 Riparian margins: a general introduction

Riparian margins are the strips of land directly adjacent to waterways (e.g. streams or rivers) and water bodies (e.g. lakes) which represent the interface between the aquatic and terrestrial environments (Lind et al., 2019). These zones provide important ecosystem services for the preservation of surface water quality including sediment trapping, nutrient and toxin sequestration, stream bank stabilisation, flood attenuation and the maintenance of in-stream biodiversity (Collier et al., 1995; Vigiak et al., 2016; Daigneault et al., 2017). The functionality of these zones for supporting water quality may, however, be compromised through land clearance for pastoral agriculture and the subsequent ingress of livestock into riparian areas and streams. Resulting effects include the direct disturbance of streambanks, streambeds and riparian vegetation (Quinn et al., 1992; McKergow at al., 2016), and the deposition of faecal matter directly into the waterway (Parkyn & Wilcock, 2004; Wilcock, 2006). These actions result in nutrient (e.g. nitrogen and phosphorus) and pathogen (bacteria and viruses) inputs, increased sediment transfer into the waterway and general disturbance of the aquatic ecosystem (Byers et al., 2005; Sunohara et al., 2012; Davies-Colley, 2013). Careful management of riparian zones is, therefore, crucial to maintain or improve condition and functionality, particularly where degradation has occurred.

An important first step in the restoration and protection of riparian margins is fencing to prevent stock access and the use of well-designed and controlled waterway crossing structures such as bridges and culverts (Ministry for the Environment, 2001). Indeed much of the science used to inform policy for the improvement of water quality has highlighted fencing-off streams from livestock as a highly effective and quick strategy to mitigate contaminant inputs to waterways (McKergow et al., 2007; McDowell et al., 2017; Ministry for the Environment, 2019). Effective riparian fencing is also a pre-requisite for the establishment of riparian vegetation cover, without which the functionality of these zones for supporting surface water quality is greatly reduced (Franklin et al., 2019; Auckland Council, 2020). In New Zealand, recommendations for the restoration of riparian vegetation include planting an association of non-woody (e.g. sedges and flaxes) and woody vegetation, particularly indigenous species (e.g. manuka and lemonwood) and the inclusion of a grass or sedge-covered buffer between the planted vegetation and the fence (Waikato Regional Council, 2004; DairyNZ, 2014). Buffer width requirements will vary depending on the aquatic characteristic(s) to be managed (Collier et al. 1995), however, in general it is considered that the greater the buffer width, the more obvious benefits to stream health. For example, Parkyn et al. (2000) considered 10 m to be the threshold for indigenous vegetation succession with lesser widths offering fewer long-term benefits to aquatic and terrestrial biota and also requiring ongoing weed maintenance. Additional considerations include site characteristics (e.g. slope steepness and length of slope) and the intended purpose of the margin (e.g. restoration of woody vegetation or stock exclusion only) (Waikato Regional Council, 2004).

1.2 Riparian restoration and protection: regional and national initiatives

With an increased emphasis on surface water quality in recent years, the restoration and preservation of riparian margins is a major focus of regional authorities who are tasked with the integrated management of New Zealand's natural and physical resources under the Resource Management Act (Resource Management Act, 1991; Ministry for Primary Industries, 2016). The Waikato Regional Council (WRC), for example, has actively promoted the fencing and planting of riparian margins via the Clean Streams project, Project Watershed and other initiatives (Campbell, 2002), and a comprehensive set of guidelines has been published to assist landowners to manage their riparian margins (Waikato Regional Council, 2004). There have also been several industry-lead initiatives to promote stock exclusion from waterways and riparian restoration, most notably the Dairying and Clean Streams Accord (2002 – 2012) (Fonterra et al., 2003) which transitioned into the Sustainable Dairying Water Accord (2013 – 2018) (DairyNZ, 2015). This pan-sector initiative set out to deliver sustainable improvements in New Zealand's water quality outcomes by enhancing dairy farm performance through the promotion of good management practices. Key objectives in relation to riparian buffer and waterway management included:

- 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 bridged 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).

At the conclusion of the programme (2017/18 reporting period), these objectives were purported to have been largely met for the 11,079 dairy farms covered by the accord process with stock permanently excluded from 98% of accord waterways, 100% of stock crossing points bridged or culverted and riparian management plans developed for 52% of dairy farms with waterways (DairyNZ, 2018). The Sustainable Dairying Water Accord is currently transitioning to the 'Dairy Tomorrow Strategy' which contains several environmental commitments including leading efforts to further improve water quality and enhance biodiversity (Dairy Tomorrow, 2017).

1.3 Riparian restoration and protection: policy frameworks

Riparian restoration is likely to be further enhanced with the upcoming implementation of mandatory stock exclusion rules as outlined in national policy documents and council plans. In the Waikato region, stock exclusion rules are proposed under Plan Change 1 which covers all land in the Waikato River and Waipā River catchments (Addenbrooke et. al, 2016). Requirements outlined in Schedule C of the 2020 decisions version document (Waikato Regional Council, 2020) include mandatory exclusion of stock (cattle, horses, deer and pigs) from all waterbodies on land with a slope of up to 15 degrees, or where the slope is greater than 15 degrees and farming on the adjoining land exceeds 18 stock units/ha. Set back distances, which only apply to new fencing (i.e. existing permanent fences can remain in place) must be at least 3 m from the outer edge of waterbodies or at least 1 m from the outer edge of wide drains (≥ 2 m). For narrow drains (< 2 m), no setback is required. Waterbodies are defined as wetlands (≥ 50 m^2), lakes and any river or drain that that is permanently or intermittently flowing and is more than a metre wide (bank-to-bank). Rules also exist with regards to stock crossing structures which must be in place to prevent direct stock access to waterbodies. It is noted that data analysis for this report (March – June 2020) was conducted occurred during the final appeals process relating to the decision version document.

A similar suite of regulations is proposed under the Action for Healthy Waterways package where stock exclusion from wetlands, lakes and rivers more than one metre wide (bank to bank) will be mandatory with smaller water bodies (i.e. those less than 1 m) to be managed through farm specific freshwater farm plans (FW-FPs). Specific requirements as outlined in the 'Decisions on the national direction for freshwater document' (Ministry for the Environment, 2020a) include the fencing of all qualifying waterbodies on low-slope areas (less than 10 degrees) used for dairy and beef cattle, deer and pigs. Hill country stock exclusion (i.e. on a slope greater or equal to 10 degrees) applies for 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. Implementation requirements are immediate for new systems, by 1 July 2023 for dairy cattle and pigs (all land) and by 1 July 2025 for dairy support cattle, beef cattle and deer (all low-slope land). Implementation is by 1 July 2023 for dairy support cattle, beef cattle and deer on non-low slope land with intensive land use practices (Ministry for the Environment 2020b).

1.4 Regional riparian characteristics survey: overview and rational

The Waikato region includes more than 20 rivers and 1420 streams 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 (Waikato Regional Council, 1998a). With the demands on the region's rivers and streams continuing to increase, the long-term management of these resources is now more important than ever to ensure that fresh water quality and aquatic biodiversity within the Waikato region are preserved for future generations. Riparian management is an important tool to help achieve these outcomes and, as previously outlined, there have been numerous regional and national initiatives (including policy instruments) focussed on the preservation and restoration of riparian margins. In an attempt to assess these impacts, WRC established a riparian characteristics monitoring programme in 2002 to provide quantitative estimates of the amount of fencing, vegetation and erosion along rivers, streams and drains through pastoral land (Hill & Kelly, 2002; Jones et al., 2016). Prior to the first survey in 2002, an absence of detailed riparian information made it difficult to benchmark the effects of improved riparian management over the long-term. Thus, the survey was designed to enable the repeatable, quantitative assessment of key riparian characteristics and to provide a region-wide picture of the state of riparian characteristics and the changes in some of these (i.e. fencing, vegetation and stream-bank erosion) over time. Differences in riparian characteristics between land use types, management zones and stream orders (state and change over time) are also examined. While time consuming and resource intensive, field observation was selected as the most appropriate means of collecting the data required for a robust 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 2017/2018 (referred to henceforth as the '2017 survey'). Previous surveys have been conducted in 2002, 2007 and 2012. Specifically, 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 2017 survey for the Waikato region. Fencing, vegetation and stream-bank bank erosion are described by land use type (dairy and drystock), by management, zone and by stream order;
- describe the changes in riparian fencing, vegetation and stream-bank erosion over the previous 5, 10 and 15 year periods (using the 2002, 2007, 2012 and 2017 survey data) for the entire Waikato region, by land use type (dairy and drystock), by management zone and by stream order;

- compare stock exclusion results from the 2017 survey with those reported in the Sustainable Dairying Water Accord final summary report (DairyNZ, 2018);
- evaluate the 2017 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 some general factors associated with 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 characteristics (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 now been repeated three times, at approximately five-yearly intervals, in 2007, 2012 and most recently in 2017. As with previous surveys, the 2017 survey was undertaken during the summer/autumn period spanning two calendar years (i.e. 2017/18) and is henceforth referred to as the “2017 survey”. The combined datasets derived from the surveys undertaken to date provide observations of key riparian characteristics at four points in time (2002, 2007, 2012 and 2017) spanning a period of 15 years. The following sections describe the methodology used for the 2017 survey including sample site selection, field data collection and the data analysis undertaken. A brief overview of the original (2002) survey design is provided for context with relevant details on design modifications to subsequent surveys provided in each subsection.

2.1 Survey design

The original (2002) regional riparian characteristics survey employed a stratified random sampling design, as described in Hill & Kelly (2002). The rationale for this stratification is given in Hill & Kelly (2002) and stemmed from preliminary methodology development work undertaken in the Upper Waipā (Hill, 2001). In brief, stratification of a variable population (e.g. riparian margins) seeks to subdivide the population into meaningful sub-populations (i.e. strata) to maximise variation among strata and minimise variation within strata for the purposes of more efficient sampling (Frampton, 2009). In the 2002 survey design, the population of riparian margins within the Waikato region was stratified by management zone, land use type and stream order with approximately equal numbers of samples per stratum. In subsequent surveys, sample allocation occurred on a proportional basis to improve representation across previously under or overrepresented strata. Specific changes to the 2017 survey design and the factors employed to define the strata 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) within the region with some adaptations to align with political and management-related boundaries. Management zones provide a convenient basis for the subdivision of the Waikato region into areas of generally 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 & 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 2017 survey were the same as those at the time of the 2007 survey. Current management zone boundaries and past changes, together with the 2017 sample site locations, are shown in Figure 1.

The eight management zones subdividing the Waikato region at the time of the 2017 survey were: (1) Coromandel, (2) Waipā, (3) West Coast, (4) Central Waikato, (5) Waihou Piako, (6) Lake Taupo, (7) Lower Waikato and (8) Upper Waikato. Zones are described in more detail by the respective zone management plans (Addenbrooke et. al., 2016; Archer et. al., 2017; Archer et. al, 2019; Botting & McKenzie, 2017; Leland et. al., 2019; Waikato Regional Council, 2011; Waikato Regional Council, 2012; Waikato Regional Council, 2017).

Land use and stock density information for each management zone is provided in Appendix 1 (Table A1-1 and A1-2) to aid in the characterisation of the zones. Pastoral land uses are predominant in all management zones except Coromandel and Lake Taupo where indigenous cover is predominant. On a proportional basis, substantial areas of forestry also occur in the Upper Waikato and Lake Taupo zones (Table A1-1). The Lake Taupo and West Coast zones have the lowest median pastoral stock density values whereas the Waihou Piako and Waipā zones have the highest values (Table A1-2).

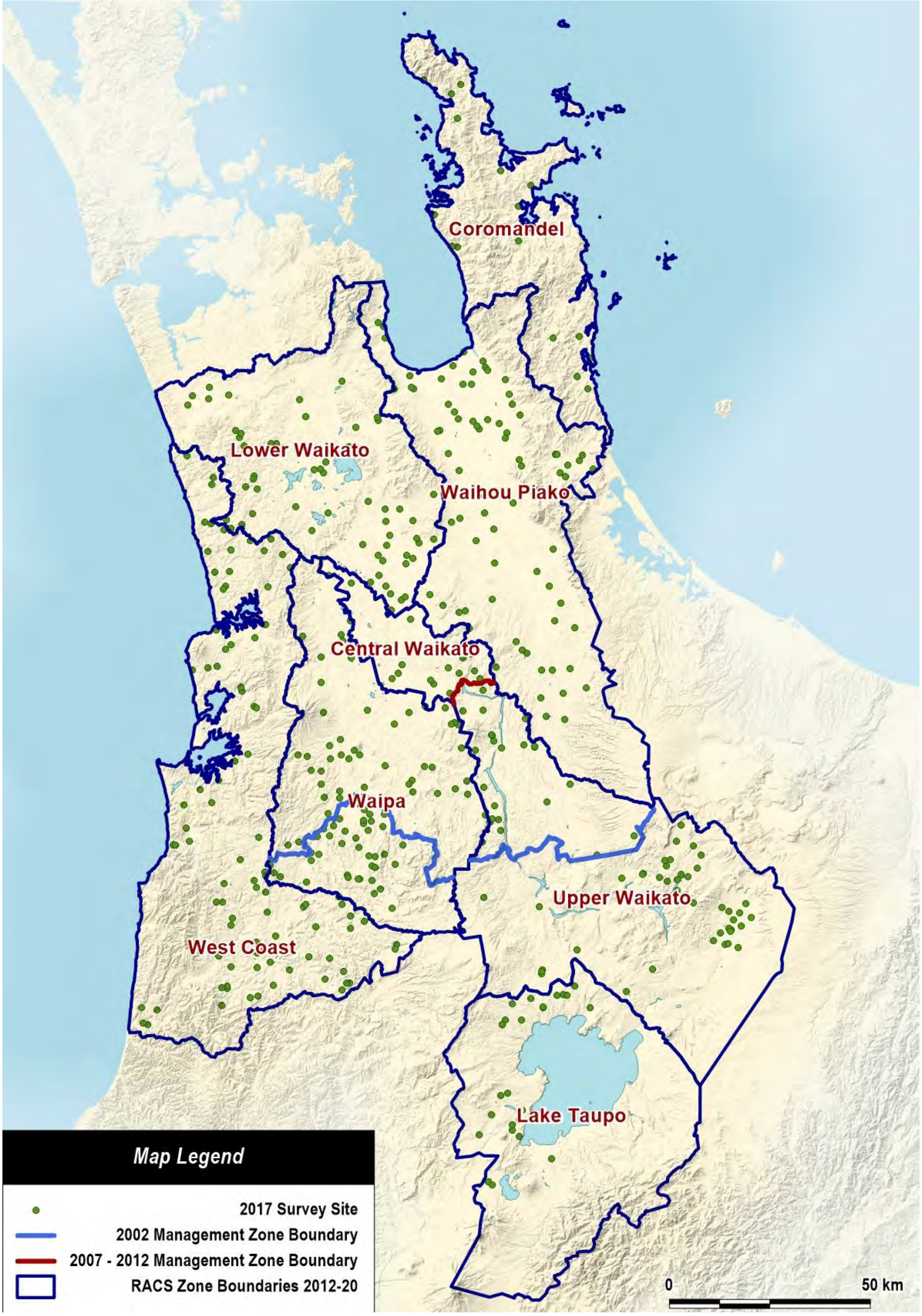

Figure 1. **Map showing sample site locations and River and Catchment Management Services (RACS) zone boundaries for the 2017 survey (and zone boundary changes since the 2002 survey).**

2.1.2 Land use type

The riparian characteristics survey focuses on pastoral land use differentiated by two broad land use types namely dairy and drystock. In the 2002 survey, Land Use Capability (LUC) class groupings (Lynn et al., 2009) were used to predict dairy (LUC 1 – 4) and drystock (LUC 5 – 8) land uses for the purposes of site selection. This was because no other spatial land use information was available at the time. The use of LUC class groupings as a proxy for land use type was based on the assumption that dairy farming tends to occur on flat to rolling land whereas drystock farming predominantly occurs on rolling to steep land (Hill & Kelly, 2002). The original survey design aimed to achieve a similar number of sites representing dairy farms and drystock farms. However, the actual land use type at a site may have differed from the land use type predicted by the LUC. In the 2007, 2012 and 2017 surveys, the AgriBase™ database was used to predict land use type at previously unvisited (e.g. replacement) sites. AgriBase™ is a database provided by AsureQuality that holds information on the land use activities undertaken on individual properties that has been voluntarily supplied by the landowners. Sites previously sampled were assumed to have the same land use type as previously assessed until confirmed at the time of re-sampling. A change in land use at a site from either dairy or drystock to some other land use type (e.g. from drystock to forestry) would result in that site being excluded from the analysis of the survey data.

2.1.3 Stream order

Stream order, as a representation of stream size, was described using the Strahler system of ranking stream channels. The Strahler system ranks streams on a scale from 1 to 7 based on the number and size of tributaries contributing flow to a given stretch of waterway. The larger the stream order (Strahler) number, the larger the stream or river (Figure 2; Selby, 1985). Drains were differentiated from other waterways for the purposes of the survey by using a stream order designation of zero (Hill & Kelly, 2002). For analysis of stock exclusion results with respect to Plan Change 1 regulations (Waikato Regional Council, 2020), drains were further separated into narrow (< 2 m) and wide (≥ 2 m) drain classes

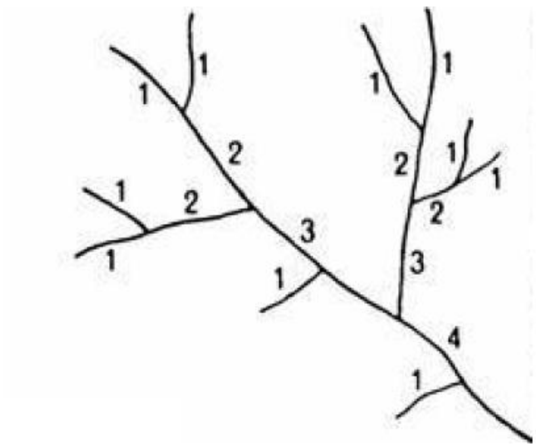

Figure 2. Strahler order (Selby, 1985).

2.2 Sample site selection and sample sizes

For the 2017 survey, each sampling unit (i.e. a site) consisted of an approximately 500 m long stretch of waterway. Both banks along the 500 m stretch were assessed, meaning a total bank length of approximately 1 km was evaluated at each site. The use of a 500 m survey length (as opposed to the 1 km length used in previous surveys) was based on analysis of the 2012 survey data which demonstrated only a minimal loss in precision for key variables under a 500 m sampling regime (Jones et al., 2016). With a modest increase in the number of sites (~ 30), the power of the data to detect change was maintained except for fords (a stream crossing variable) where reducing the sample length resulted in less precision and a large increase in the required sample size (~ 180) to mitigate this. Nevertheless, the practical benefits of reducing the sample length were considered greater than the reduction in precision for this one variable, and consequently this change was implemented. Benefits included significant time and cost savings associated with a 50% reduction in survey length and the requirement for fewer landowner contacts (i.e. fewer property boundaries crossed by shorter sample lengths).

The number of sampling sites analysed from each survey and the year when they were first selected is summarised in Table 1. The original 2002 survey consisted of data from 373 sampling units. In the 2007 survey, some sites were excluded due to insufficient stream length and only 284 of the original sites were reassessed along with 13 new sites added from under-represented strata. In the 2012 survey, 312 sites from previous surveys were reassessed and 70 new sites added. Finally, the 2017 survey used 279 sampling units from earlier surveys and added 153 new units from under-represented strata. A core set of approximately 263 to 299 of the original 2002 sites were included in each subsequent survey for trend analysis. New sites were randomly selected from a Geographic Information System (GIS)-derived data base which used LCDB4.1, NZLRI/FSL (New Zealand Land Resource Inventory/Fundamental Soils Layer), AgriBase™ and zone datasets to derive site data. In all surveys, a small proportion (< 4%) of the total number of sites sampled was excluded from subsequent data analyses because the land use type was found to be something other than dairy or drystock (i.e. non-pastoral).

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

Survey year	Number of units used in survey				
	Units selected in 2002	Units selected in 2007	Units selected in 2012	Units selected in 2017	All units
2002	373				373
2007	284	13			297
2012	299	13	70		382
2017	263	4	12	153	432

The number of sites used within each combination of management zone, farm type and stream order are shown for each survey year in Appendix 2 (Table A2-1). Management zone boundaries were revised after the 2002 survey and the number of management zones reduced from nine to eight (see Figure1). Table A2-1 is based on current management zone boundaries but uses farm type defined using the year each survey was undertaken.

According to the 2002 design specification, three sampling units were to be selected randomly per stratum (defined by combinations of management zone, farm type and stream order) although sample sizes were to be increased in the most common strata to compensate for strata combinations that did not exist in reality (Hill & Kelly, 2002). Table A2-1 indicates that the actual number of samples per stratum varied considerably. Management zone boundaries for the Lake Taupo, Lower Waikato and West Coast zones have not changed, and the number of samples per stratum in these management zones varied between 0 and 19 (2002 – 2012).

Under stratified random sampling, it is assumed that samples are randomly selected from within their respective strata. Generally, more samples are selected from larger strata, but to satisfy the requirements of probability sampling, it is necessary that no strata have zero samples. Strictly speaking, strata with no observations should be excluded from all analyses. As evidenced in Table A2-1, many smaller strata have zero samples. The work-around adopted in the current analysis was to redefine strata by aggregating some stream orders within each management zone x farm type so that all strata had at least one sample. These redefined strata are shown in Appendix 3 (Table A3-1).

It is acknowledged that in two aspects, the strata used in the analysis differ from the strata used originally when samples were selected. Firstly, current management zone boundaries were used to define strata, when in reality, sites selected in 2002 were sampled using 2002 management zones. An assumption in stratified random sampling is that all units selected from the same stratum have the same inclusion probability and this would not generally be true for units from different 2002 management zones within the same 2017 strata. The effect would be minor so long as the inclusion probabilities did not differ greatly. Secondly, stream orders were combined to avoid strata with zero observations. This should have only a minor effect as these aggregated strata were mostly small.

When determining which stratum a sampling unit belonged to, the farm type at the time the sample was selected was used. This ensured that the inclusion probability of the unit at the time it was selected was correctly calculated. This created difficulties in determining population stream length in a stratum when samples were chosen in different years as streams lengths within each land use class changed slightly over time. The work-around adopted in the analysis was to average the selection year of samples within the stratum and use the closest available stream length year to determine the stream length of the stratum (Table A3- 1).

2.3 Field data collection

2.3.1 Approach and equipment

The overall approach to field data collection has remained constant since the inaugural survey in 2002. However, the specific equipment and procedures used have been improved and refined with successive surveys as field-based data capture technology has advanced and as our experience with the approach has grown. The main change in this regard occurred between the 2002 and 2007 surveys. During the 2002 survey, field observations were recorded manually on pre-printed field sheets and the spatial location of changes in characteristics along the length of the sample site were determined using a GPS device (Hill & Kelly, 2002). In subsequent surveys, field observations were recorded digitally using computers with in-build 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.

After locating the pre-determined start point at a sample site using a GPS enabled device, the necessary initial observations at the start point were made. Survey staff then proceeded to walk the length of the sample site (approximately 500 m on average), adjacent to the waterway, observing the riparian characteristics on both banks. Due to fencing and/or stream crossing restrictions (e.g. deep channels), most assessments were conducted from one bank only. Changes in characteristics from those observed at the start point were recorded together with the spatial location of the 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 and 2017 surveys, observations similar to those 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, in particular, are central to the presentation of the survey results as most characteristics are reported as a proportion of stream or bank length.

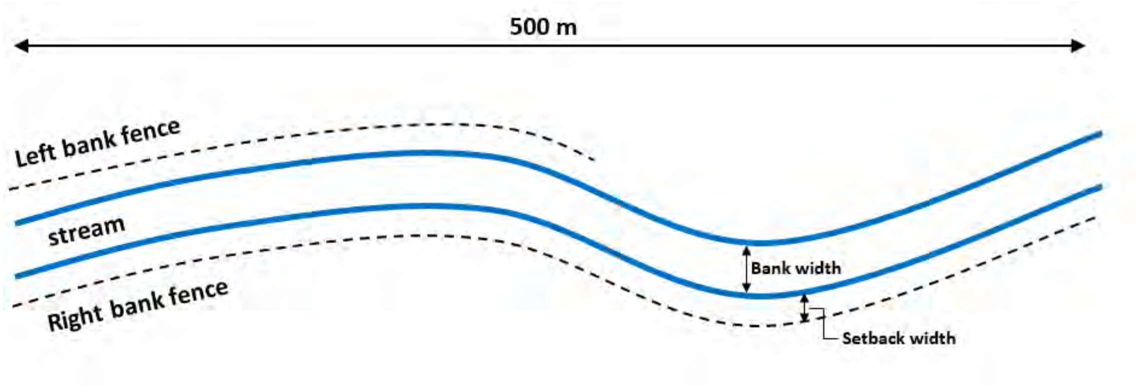

Figure 3. **A stylised example of a stream reach that illustrates the concepts of stream length, bank length and fencing configuration (based on Storey, 2010, p.8). Bank width and setback width concepts are also included for reference.**

In the example given in Figure 3, total stream length of the stretch is 500 m. Total bank length is the sum of 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 length fenced is 750 m which equates to 75% of total bank length (750 m / 1000 m x 100). The fencing in this example is configured as follows: 250 m (50%) of stream length is fenced on both banks; 250 m (50%) is fenced on one bank only; and 0 m (0%) of stream length is fenced on neither bank (Storey, 2010).

The Trimble Juno® devices used in the 2017 survey ran the mobile GIS software ArcPad Version 10 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 inception of the survey except for some minor clarification of naming terms to improve clarity of reporting and efficiency of observation. For example in the 2017 survey, 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 stream crossing type was included under 'culvert' (Table 4).

As in previous surveys, the characteristics observed during the 2017 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 as a whole. These included site metadata (site identification number, date observed and observer), site status (e.g. new or re-sampled), general land use (e.g. dairy or drystock), specific land use directly adjacent to waterway on each bank (e.g. beef grazing, maize cropping, planted forest, 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 that have the potential to vary spatially along the length of a waterway and can be measured in terms of waterway segment length. Key continuous characteristics observed for both banks along the length of each sample site are listed in Table 2 and include the nature and status of the riparian fencing, vegetation and stream-bank erosion present at a site. In a change from previous surveys, 2017 land use was also recorded as a continuous characteristic. This allowed more subtle changes in land use not captured under the general land use assessment to be captured, for example, where a block of forestry was present along a surveyed stretch within a drystock enterprise.

Point characteristics are those characteristics that occur, or are best described, at a specific location along the length of a waterway. Consistent with the 2012 survey, two types of point characteristics were observed: (1) those observed at three designated locations (i.e. the start, middle and end points) at each sample site 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 2017 survey are listed in Table 3 (designated locations) and Table 4 (occurrence-based). Bank height, bank slope and stock access were observed at the start, middle and end points at each site whereas obstructions and waterway crossings were observed where they were found to occur (i.e. occurrence-based). Characteristics describing stream channel type, channel width and aquatic vegetation were also observed at the start, middle and end points.

Photographs featuring the waterway and the adjacent riparian margin were taken at the start, middle and end point at each site. Any significant or unusual features observed (e.g. significant waterway crossings, obstructions, etc.) were also photographed.

Table 2. Key continuous characteristics observed during the 2017 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. The fence is robust and will stop stock movement.
	Ineffective, permanent	The fence is permanently in place, with large concrete or wooden posts. The fence is not robust and stock will move through/across it.
	Effective, temporary	The fence is easily removed; posts may be waratahs, standards, or wooden stakes. The fence is robust and will stop stock movement.
	Ineffective, temporary	The fence is easily removed; posts may be waratahs, standards, or wooden stakes. The fence is not robust and stock will move through/across it.
Vegetation type	Woody native	Predominance of native trees/shrubs.
	Woody exotic willow	Predominance of willow (deciduous exotic) species.
	Woody exotic other (deciduous)	Predominance of deciduous exotic (non-native) tree and shrub species other than willow.
	Woody exotic other (evergreen)	Predominance of evergreen exotic (non-native) tree and shrub species.
	Grass and weeds	Predominance of low (< 1 m) pastoral grass and/or herbaceous weed species.
	Flax/sedge/rush	Predominance of (mainly indigenous) flax, sedge and rush species. Species often occur in wet or damp areas.
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.
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 2017 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 2017 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 Post data collection: routine spatial correction and automated data extraction

Field data collected using Trimble Juno® devices was regularly downloaded to the WRC computer system as the survey progressed. The raw spatial location data associated with the observations of riparian characteristics was corrected to improve the accuracy of the location information. The routine correction of raw spatial location data is undertaken because GPS location in the field is calculated based on information from satellites visible to the device at the time of recording. The correction process adds known ground survey locations (from the Land Information New Zealand network of base-stations) to the calculation method which improves accuracy to (usually) between 2 – 5 metres. Waikato Regional Council uses Pathfinder Office software to undertake the correction process.

The field data (with corrected spatial location 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 computer scripts) which calculated the segment lengths of each observation and ‘chainage’ (cumulative lengths) at each site sampled. Statistical analyses could then be performed on the extracted data (described in the section below). The automated data extraction process was used for all except the 2002 survey where segment lengths for continuous characteristics were recorded and calculated manually.

2.4 Data analysis

2.4.1 Methods of estimating population parameters

The parameters estimated from the riparian survey are mostly ratios or percentages. In this sense, the survey is somewhat unusual as most surveys are concerned with estimating population totals or averages. It would certainly be possible to estimate population totals from the riparian survey, but the interest was predominately 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 which is a ratio rather than a total. Examples of typical ratios estimated from the survey are given in Table 5. The first step in estimating a ratio is to calculate its numerator and denominator for each sampling site. This is achieved by summing bank lengths of each characteristic within the sampling unit and was carried out using purpose-built procedures written in R (R Core Team, 2018). Note that for many sampling units, denominator and/or numerator variables were zero. For example, when estimating the proportion of bank length effectively fenced in streams of order 0 (drains), the denominator was zero for any sampling unit other than those sampling drains. Similarly, when estimating the ratio for a management zone, denominator numerator variables were both zero for all sampling units outside the management zone.

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 2017 survey, estimates for previous measurement years were also obtained. These estimates differ somewhat from previously reported values because the analysis methods used in the current study varied slightly from those used in earlier analyses. For example, in the analysis of the 2012 data (Jones et al. 2016), strata were defined using the 2012 land use classes. However, in the current analysis, sampling units were assigned to strata using land use at the time the sampling unit was selected. This ensured inclusion probabilities were more accurately determined. Therefore, values in the current report can be regarded as the best estimates for each measurement year currently available.

Methods for estimating ratios in stratified random surveys are described in standard texts such as Cochran (1977) and Särndal et al. (1993). However, these texts do not describe methods for estimating the change in a ratio over time although Särndal et al. (1993) describes a general approach for estimating functions of survey variables in stratified random sampling which can be applied to changes in ratios. This approach was used to derive equations for estimating differences in ratios over time along with their 95% confidence intervals as described below.

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 N_h. Therefore, when the denominator is bank length, N_h 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) $$R = \sum_{h=1}^{H} (N_h y_h/n_h) \Big/ \sum_{h=1}^{H} (N_h x_h/n_h)$$

The estimated variance of *R* is:

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

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.

2.4.3 Estimation of change in ratio over time

In this section we describe how the change in a ratio over time is estimated (e.g. the change in proportion of bank length effectively fenced between 2012 and 2017). Firstly, the ratios are calculated for times 1 and 2 using Equation (1). We refer to these as R_1 and R_2 respectively. The difference between the ratios is the required estimator, i.e.,

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

As R_{diff} is a function of population totals, its variance can be estimated using the Taylor linearization technique as described by Särndal et al. (1993). Applying this method is somewhat complex because of the fact that sampling units can vary between times 1 and 2. Some units were measured at both times but others were measured only at time 1 or at time 2. In previous analyses of the survey, estimates of change over time were based only on units measured in both measurement years. However, to maximise the available information from the survey, it was desirable that all measurements be used in the calculation of R_{diff}, and this approach was adopted in the current analysis.

In the formula for the variance of R_{diff} which is given below, the numerator and denominator at time 1 are denoted by *y*1 and *x*1 respectively. At time 2 they are denoted by *y*2 and *x*2. 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\left(R_{diff}\right) = {} & \frac{\sum\left(N^2 n_{11} s^2 y1_{11}/n_1^2\right)}{\left(\sum N\overline{x1}_1\right)^2} + \frac{\left(\sum N\overline{y1}_1\right)^2 \sum\left(N^2 n_{11} s^2 x1_{11}/n_1^2\right)}{\left(\sum N\overline{x1}_1\right)^4} - 2\frac{\left(\sum N\overline{y1}_1\right)\sum\left(N^2 n_{11} sy1x1_{11}/n_1^2\right)}{\left(\sum N\overline{x1}_1\right)^3} \\
& + \frac{\sum\left(N^2 n_{22} s^2 y2_{22}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^2} + \frac{\left(\sum N\overline{y2}_2\right)^2 \sum\left(N^2 n_{22} s^2 x2_{22}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^4} - 2\frac{\left(\sum N\overline{y2}_2\right)\sum\left(N^2 n_{22} sy2x2_{22}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^3} + \\
& + \frac{\sum\left(N^2 n_{12} s^2 y1_{12}/n_1^2\right)}{\left(\sum N\overline{x1}_1\right)^2} + \frac{\left(\sum N\overline{y1}_1\right)^2 \sum\left(N^2 n_{12} s^2 x1_{12}/n_1^2\right)}{\left(\sum N\overline{x1}_1\right)^4} - 2\frac{\left(\sum N\overline{y1}_1\right)\sum\left(N^2 n_{12} sy1x1_{12}/n_2^2\right)}{\left(\sum N\overline{x1}_1\right)^3} + \\
& + \frac{\sum\left(N^2 n_{12} s^2 y2_{12}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^2} + \frac{\left(\sum N\overline{y2}_2\right)^2 \sum\left(N^2 n_{12} s^2 x2_{12}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^4} - 2\frac{\left(\sum N\overline{y2}_2\right)\sum\left(N^2 n_{12} sy2x2_{12}/n_2^2\right)}{\left(\sum N\overline{x2}_2\right)^3} + \\
& + 2\frac{\left(\sum N\overline{y1}_1\right)\sum\left(N^2 n_{12} sy2x1_{12}/(n_1 n_2)\right)}{\left(\sum N\overline{x1}_1\right)^2\left(\sum N\overline{x2}_2\right)} + 2\frac{\left(\sum N\overline{y2}_2\right)\sum\left(N^2 n_{12} sy1x2_{12}/(n_1 n_2)\right)}{\left(\sum N\overline{x1}_1\right)\left(\sum N\overline{x2}_2\right)^2} - \\
& - 2\frac{\sum\left(N^2 n_{12} sy1y2_{12}/(n_1 n_2)\right)}{\left(\sum N\overline{x1}_1\right)\left(\sum N\overline{x2}_2\right)} - 2\frac{\left(\sum N\overline{y1}_1\right)\left(\sum N\overline{y2}_2\right)\sum\left(N^2 n_{12} sx1x2_{12}/(n_1 n_2)\right)}{\left(\sum N\overline{x1}_1\right)^2\left(\sum N\overline{x2}_2\right)^2}
\end{aligned}
$$

2.4.4 Factors associated with stream-bank erosion

Factors associated with stream bank erosion were investigated by linear regression analysis (using the R lm() function) for the 2017 data. As this analysis was concerned with identifying drivers of stream bank erosion rather than obtaining unbiased estimates of riparian characteristics across the region, the stratified nature of the survey was ignored in this analysis. The following four dependent variables were considered in this analysis: active erosion, active or recent erosion, disturbed soil (active or recent erosion or >50% pugging) and any evidence of erosion or disturbance (active or recent erosion or any level of pugging). All variables were expressed as percentages of bank length for each sample site. Independent variables used in these regressions were percentage effectively fenced bank length and percentage bank length with woody vegetation.

3 Results and discussion

The following subsections present and discuss the riparian characteristic survey results in relation to riparian fencing, stock access and exclusion, riparian vegetation, riparian buffer width, waterway crossings and stream-bank erosion. The state (as at the time of the 2017 survey) is described for each of these factors. Change over time (i.e. over the past 5, 10 and 15-year periods) is examined for riparian fencing, riparian vegetation and stream-bank erosion. Information presented in these subsections follows 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 2017 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 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

Approximately two thirds (61%) of the surveyed bank length of sampled waterways across the Waikato region in 2017 was found to be 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 (39%) was either not fenced at all or ineffectively fenced.

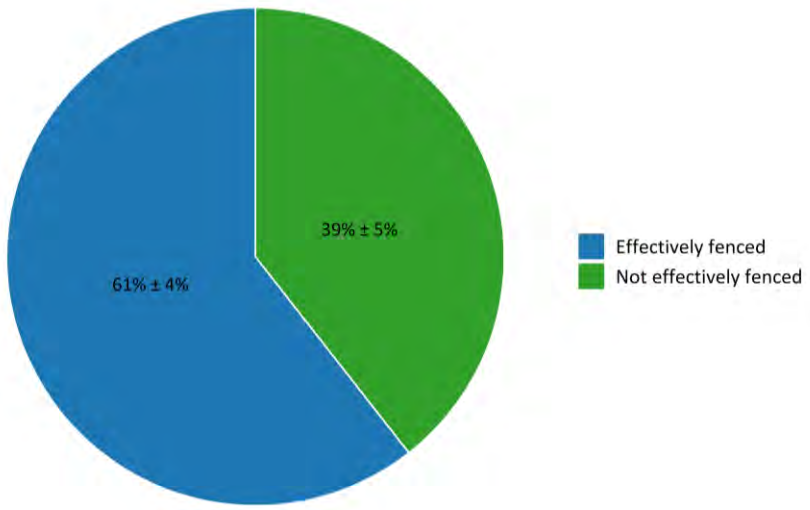

Figure 4. Average proportion of bank length effectively fenced and not effectively fenced across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.

Most fencing was found to be effective permanent fencing (54%) with effective temporary fencing accounting for only 6% of 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 not effectively fenced was found to be completely unfenced, with ineffective fencing accounting for only 3% of bank length. These results suggest that where fencing has been erected, it is predominantly both 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 2017.

	Fence status type	Proportion of bank length (%)	
		Average	95%CI†
Effectively fenced	Effective permanent	54	±4
	Effective temporary	6	±2
Not effectively fenced	Ineffective	3	±1
	Unfenced	37	±4

† 95% confidence interval about the average.

The configuration of effective riparian fencing across the region in 2017 was also examined with regards to the proportion of stream length effectively fenced on either one bank, both banks or neither bank (Figure 5). Approximately half (54%) of the surveyed stream length in 2017 was effectively fenced on both banks with a relatively small proportion of stream length (15%) fenced on only one bank. About one third (32%) of surveyed stream length was lacking effective fencing on both banks. Effective fencing on both banks is required for complete exclusion of stock from the waterway.

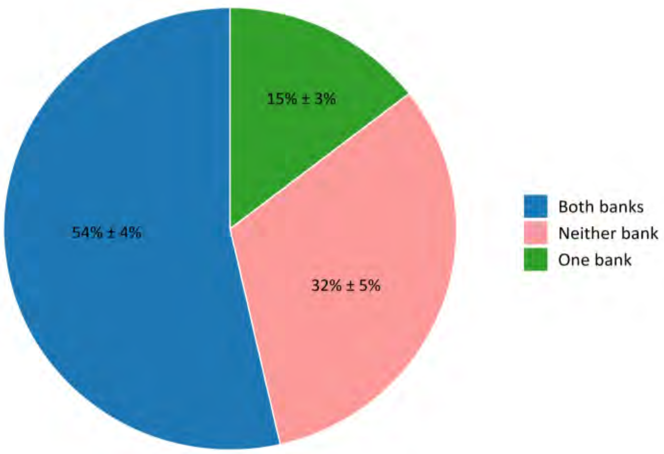

Figure 5. Average proportion of stream length effectively fenced on one bank, both banks or neither bank across the Waikato region in 2017 (n = 429). Error terms represent the 95% confidence interval about the average.

Consistent with previous surveys, there were clear differences in the amount and configuration of effective riparian fencing between dairy and drystock land uses (Figure 6). The average proportion of total bank length effectively fenced was significantly greater for dairy (87%)

compared to drystock (36%) ($t = 13.2$, $p < 0.0001$). Similarly, the proportion of stream length effectively fenced on both banks was significantly greater for dairy compared to drystock ($t = 13.8$, $p < 0.0001$), while a significantly greater proportion of stream length remained unfenced on both banks for drystock compared to dairy ($t = 11.4$, $p < 0.0001$). The proportion of stream length effectively fenced on only one bank was comparable between land uses ($t = 0.99$, $p = 0.32$). Survey results are consistent with the generally flatter terrain in which dairy farms tend to be situated (making fencing relatively easier and less expensive), the emphasis the dairy industry has placed on promoting and encouraging the fencing of waterways via the Sustainable Dairying Water Accord (DairyNZ, 2015), and the financial strength of the dairy industry over the last decade or more.

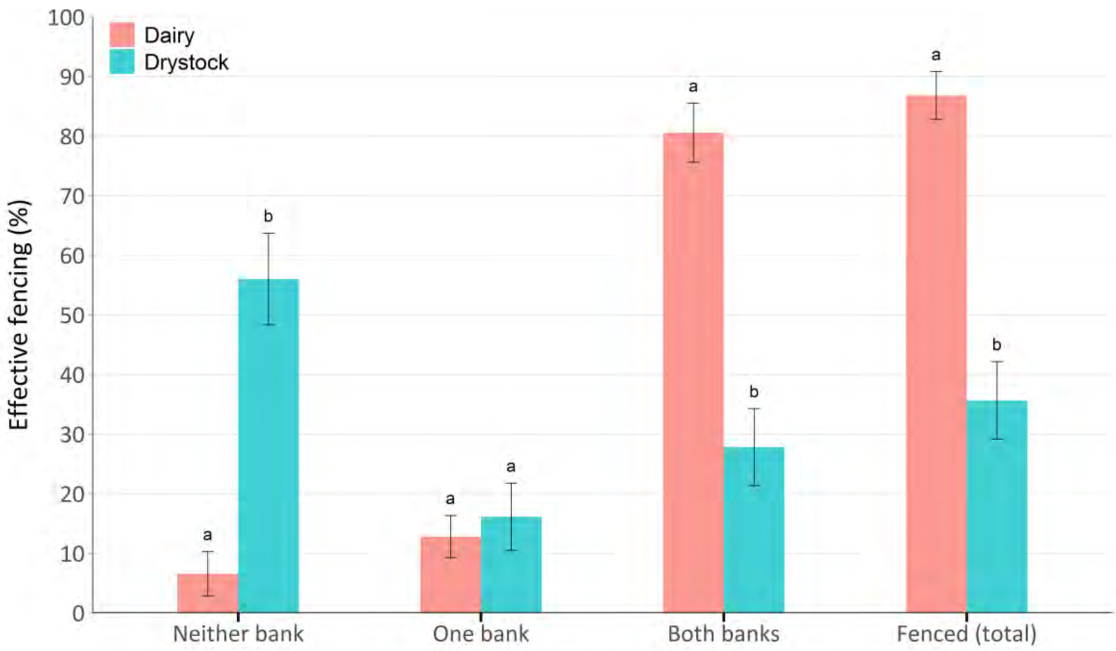

Figure 6. **Average proportion of bank length effectively fenced (total) and average proportion of stream length effectively fenced on one bank, both banks, or neither bank within land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different (α = 0.05).**

The average proportion of surveyed bank length effectively fenced for each management zone in 2017 is presented in Figure 7 with data also tabulated in Appendix A4-1. The proportion of bank length effectively fenced at surveyed sites was comparable between the Central Waikato, Coromandel, Lake Taupo, Lower Waikato and Waipā zones ranging from 60 – 75%. The Waihou Piako zone had the highest average proportion of bank length effectively fenced (84%) with the lowest proportion present in the West Coast management zone (28%). The hilly and often steep nature of the topography and the predominance of drystock farms is likely to have contributed to the relatively small proportion of bank length effectively fenced in the West Coast management zone. In contrast, considerable emphasis has been placed on promoting the fencing of waterways in the Waihou Piako, Upper Waikato and Lake Taupo management zones by the WRC through historic soil conservation schemes (see Waikato Regional Council, 1998b;

Palmer, 2004) and Method 4.3.5.3 of the Waikato Regional Plan (which requires that stock are excluded from mapped portions of high priority water bodies, including selected portions of the Waihou River and all tributaries flowing into Lake Taupo).

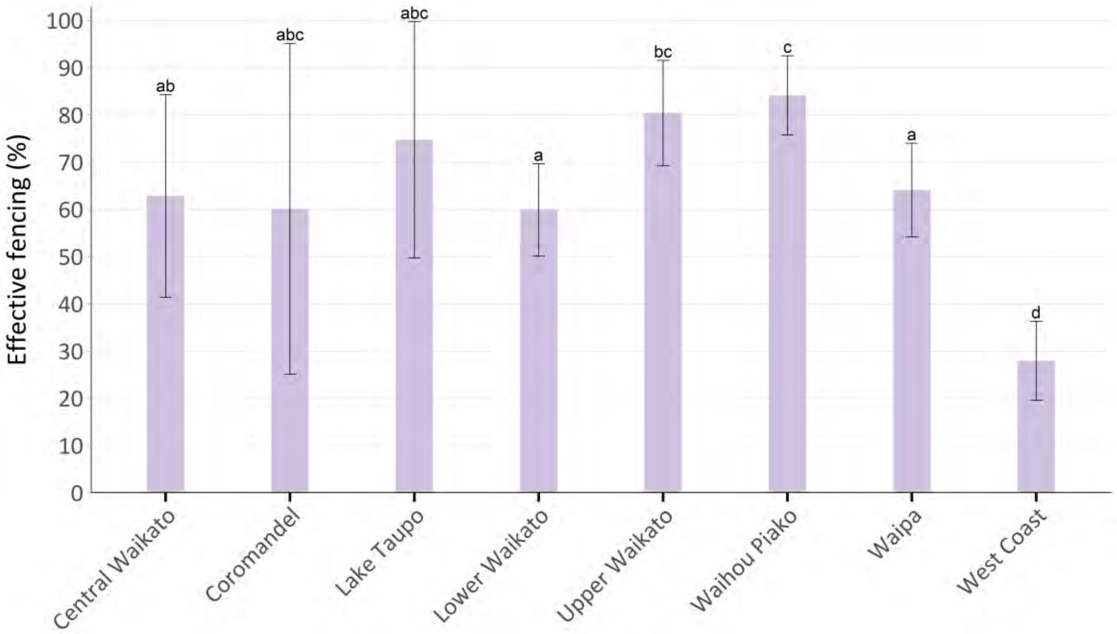

Figure 7. Average proportion of bank length effectively fenced within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).

The average proportions of surveyed bank length effectively fenced for each stream order in 2017 are presented in Figure 8. Excluding drains (0 order), there was a general increase in effective fencing with increasing stream order. Similar proportions of effective fencing were present across larger waterways (stream orders 4 – 6), ranging from 78 – 80%. In contrast, the proportion of effective fencing across small to medium-sized waterways (stream orders 1 – 3) ranged from 50 – 65%. About 90% of drain bank length was effectively fenced, significantly higher than effective fencing proportions on stream orders 1 – 3.

Overall, the high proportion of effective fencing for drains (stream order 0) reflects the relative ease with which these features can be fenced (often straight, linear features located on flat land) and their location predominantly on dairy enterprises (see Appendix A2-1). For larger waterways (stream orders 4 – 6), elevated effective fencing proportions reflect calculated measures to prevent livestock losses and the associated prioritisation of effective fencing. In contrast, small to medium-sized waterways (stream orders 1 – 3) are likely to occur in steep, hilly terrain and are consequently more difficult (and relatively expensive) to fence effectively. Additionally, the fencing of small streams may be a lower priority for landowners who must prioritise the fencing of larger waterways. Evidently, it is these lower order streams which typically dominate contaminant load contributions in agricultural catchments (McDowell et al. 2017) and alternative strategies to mitigate contaminant inputs are required where stock exclusion is neither a viable option nor required under regulatory frameworks (see Sections 3.2.3 and 3.2.4).

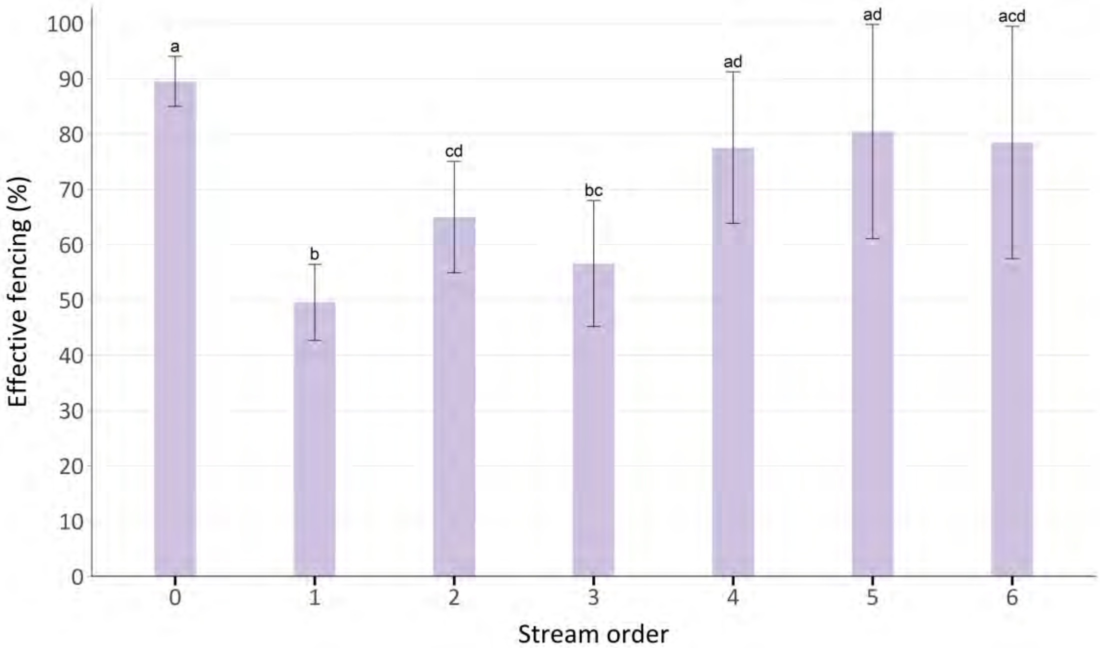

Figure 8. Average proportion of bank length effectively fenced within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).

3.1.2 Change over time

The average proportion of surveyed bank length effectively fenced across the Waikato region has significantly increased over the past fifteen years ($t = 11.4$, $p < 0.0001$) from 28% in 2002 to 61% in 2017 (Figure 9, Table 7). This increase has occurred at a relatively uniform rate (about 2.2% of bank length per year) which points to a reasonably steady rate of change in fencing over the past fifteen years. Based on a total bank length of approximately 48,000 km in pastoral land in the region, of which about 61% (28,000 km) is currently fenced, it is estimated that it will take a further 20 years for the remaining 20,000 km of bank length to be effectively fenced (i.e. complete stock exclusion), assuming a constant rate of increase of 2% (rounded) of bank length per year and that all bank length can and will be fenced. It should be noted that these estimates do not include ineffective fencing which was considered in the same category as unfenced. Only a small proportion of bank length across survey years was ineffectively fenced (< 5%) which suggests that new fencing is predominantly effective

The magnitude and statistical significance of changes in the proportion of surveyed bank length fenced and the configuration of that fencing (expressed in terms of stream length fenced) over time, as described above, are given in Table 7. In terms of fencing configuration, the average proportion of stream length fenced on both banks has significantly increased ($t = 9.69$, $p < 0.0001$) whereas the average proportion of stream length fenced on one bank or neither bank has significantly decreased ($t = 7.71$, $p < 0.0001$) over the past fifteen years. In general, the increase in the proportion of stream length fenced on both banks approximated the decrease in fencing on neither bank suggesting that where new riparian fencing was undertaken, both banks were fenced. However, more recently (2012 – 2017 period), changes in stream length fenced on one bank or neither bank have been comparable, possibly reflecting the completion of partial fencing jobs (note the proportion of fencing on one bank only, remained relatively consistent between 2002 and 2012; Figure 9).

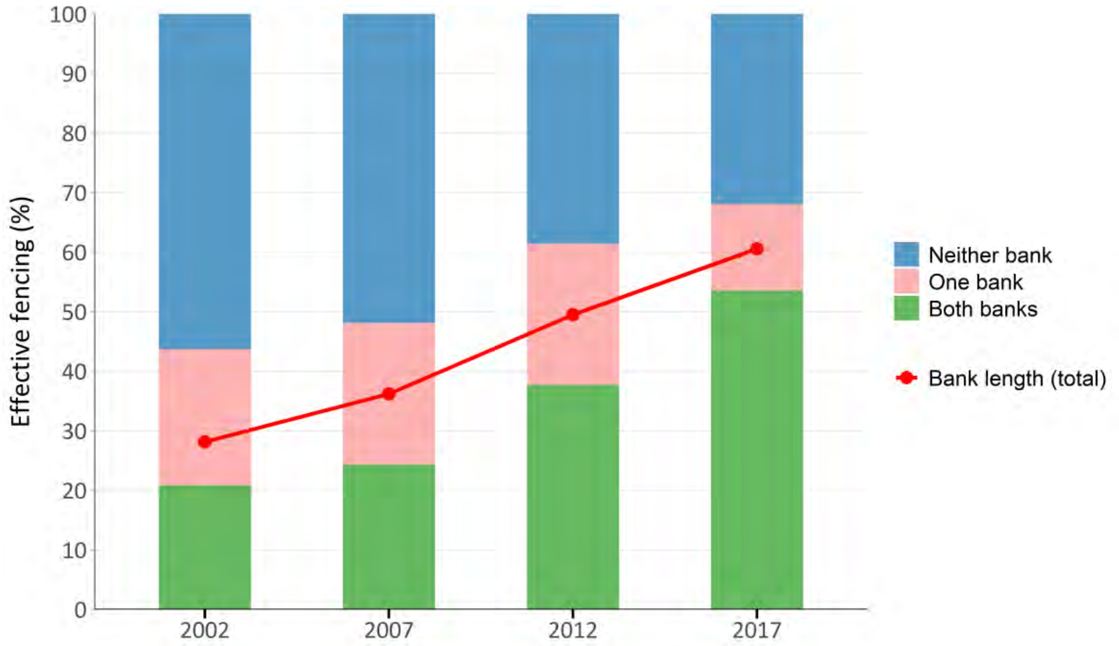

Figure 9. Average proportion of bank length (total) and stream length (one bank, both banks, or neither bank) effectively fenced for each the four survey years (2002, 2007, 2012 and 2017).

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 (2012 – 2017), 10-year (2007 – 2017) and 15-year (2002 – 2017) periods.

Measure	Category	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Bank length	Total	11 **	6	24 **	7	32 **	6
	Both banks	16 **	7	29 **	8	33 **	7
Stream length	One bank	-9 **	6	-9 *	7	-8 **	6
	Neither bank	-7 *	6	-20 **	8	-24 **	6

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

Examination of the change in the average proportion of surveyed bank length effectively fenced over time for dairy and drystock land use has revealed clear differences between the land uses in terms of the trajectories of the change (Figure 10, Table 8). Over the past fifteen years, the average proportion of bank length effectively fenced has significantly increased from 44% in 2002 to 87% in 2017 for dairy ($t = 8.66$, $p < 0.0001$) and from 19% in 2002 to 36% in 2017 for drystock ($t = 4.26$, $p < 0.0001$). With regards to the preceding 5-year (2012 – 2017) and 10-year

(2007 – 2017) periods, the average proportion of bank length effectively fenced has significantly increased for dairy but not for drystock (Table 8). This indicates an increase in the rate of change relative to the initial 5-year period (2002 – 2007) for dairy but a decrease in the rate of change for drystock. The most rapid increase in the rate of fencing for dairy occurred during the 2007 – 2012 period where the rate of change was about 5% of bank length per year. In contrast, the rate of fencing change for drystock during this period appeared to stall. In the 5-year period since the last survey, the rate of change was about 3.8% of bank length per year for dairy and about 1.2% of bank length per year for drystock. The rate of change over the entire fifteen-year monitoring period was about 3.1% of bank length per year for dairy and about 1.3% of bank length per year for drystock. The notable increase in the average proportion of bank length effectively fenced for dairy reflects the emphasis the dairy industry and others have placed on promoting fencing of waterways (e.g. Sustainable Dairying Water Accord; DairyNZ 2015).

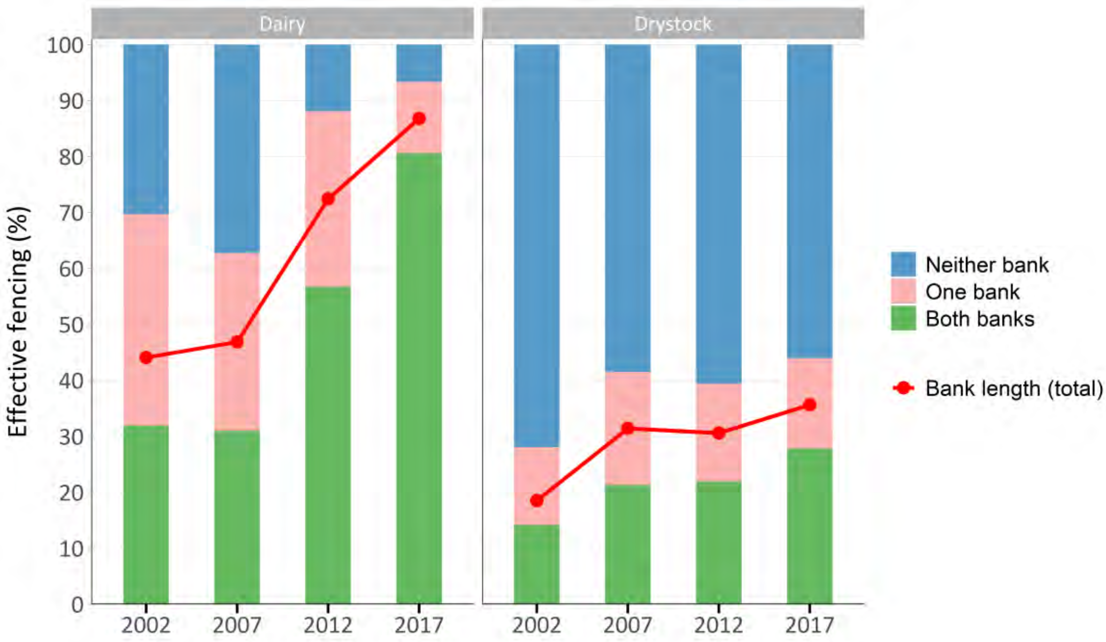

Figure 10. **Average proportion of bank length (total) and stream length (one bank, both banks or neither bank) effectively fenced within land use types at the four survey periods (2002, 2007, 2012 and 2017).**

Changes in riparian fencing configuration were noticeably different for dairy and drystock land uses (Figure 10, Table 8). For dairy, changes in the average proportion of stream length effectively fenced on both banks, one bank and neither bank were significant for all periods except for 2012 – 2017 where the change in fencing on neither bank was minimal. The placement of new fencing appears to have been initially targeted largely at unfenced areas (2007 – 2012) with a more recent focus on completing partially fenced stream sections (2012 – 2017). For drystock, changes in stream length measures were significant only over the entire monitoring timeframe (2002 – 2017) with minimal change observed in these measures over the last 10 years.

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 (2012 – 2017), 10-year (2007 – 2017) and 15-year (2002 – 2017) periods.**

	Land use type	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Fenced (total)	Dairy	14 **	7	40 **	12	43 **	10
	Drystock	5 NS	9	4 NS	11	17 **	8
Both banks	Dairy	24 **	12	50 **	13	49 **	13
	Drystock	6 NS	9	6 NS	11	14 **	8
One bank	Dairy	-19 **	11	-19 **	12	-25 **	13
	Drystock	-1 NS	8	-4 NS	8	2 NS	7
Neither bank	Dairy	-5 NS	5	-31 **	14	-24 **	9
	Drystock	-5 NS	11	-2 NS	12	-16 **	10

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

Changes in the average proportion of surveyed bank length effectively fenced within management zones over the past fifteen years are presented in Table 9. Considering the entire monitoring period, significant increases were observed in all except the Lake Taupo management zone, where the proportion of bank length effectively fenced in 2002 was relatively high (59%). Over the last five years, significant increases were restricted to the Coromandel and Waihou Piako zones. Changes in the average proportion of bank length effectively fenced in all other zones over this period were positive but not statistically significant. Variability of estimates within zones was generally high as evidenced by some large 95% confidence interval values (due to smaller sample sizes compared with the region-wide analysis).

Table 9. **Average proportion of bank length effectively fenced within management zones at 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.**

Management zone	Average bank length (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Central Waikato	30	50	61	63	2 NS	15	13 NS	20	33 **	23
Coromandel	20	23	41	60	19 *	15	37 *	32	40 *	33
Lake Taupo	59	52	64	75	11 NS	34	23 NS	31	16 NS	32
Lower Waikato	38	43	58	60	2 NS	19	17 NS	17	22 *	16
Upper Waikato	46	52	73	80	7 NS	12	29 **	20	34 **	17
Waihou Piako	35	42	58	84	26 **	11	42 **	19	49 **	14
Waipā	19	30	52	64	12 NS	14	34 **	14	45 **	12
West Coast	7	21	20	28	8 NS	9	7 NS	18	21 **	9

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

Over the past fifteen years, the average proportion of surveyed bank length effectively fenced has significantly increased in all stream orders except for stream order 6 (Table 10). The stream orders that exhibited the largest magnitude of change over this period were stream orders 4 and 5, with changes of about 53% and 58% of bank length respectively. More recently (2012 – 2017), significant increases in the proportion of bank length effectively fenced have been restricted to stream orders 2 and 4. Variability of estimates within stream orders was generally large, particularly for higher order streams (e.g. orders 5 and 6) where there was less replication within strata.

Table 10. Average proportion of bank length effectively fenced within stream orders at the three 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 (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	61	70	78	90	12 ^{NS}	17	20 ^{NS}	22	28 **	18
1	19	27	43	50	6 ^{NS}	8	22 **	11	31 **	8
2	33	34	42	65	23 **	11	31 **	11	32 **	12
3	24	32	45	57	11 ^{NS}	14	24 *	20	33 **	15
4	24	29	48	78	30 **	17	49 **	19	53 **	26
5	22	53	70	80	10 ^{NS}	33	27 ^{NS}	55	58 *	47
6	24	51	76	79	2 ^{NS}	64	27 ^{NS}	77	54 ^{NS}	67

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

For the 2017 survey, fencing results were calculated using continuous land use and assessed against those generated using the general land use definition (Section 2.3.2) and the AgriBase™ defined land use classification. Results reported using continuous land use are the most representative because more subtle changes in land use fencing assignments were captured, for example where a forestry block was established on a dairy enterprise. Overall, differences in effective fencing between the three land use classifications were small (Figure 11) indicating that the current general land use definition is an appropriate way to report results. Using continuous land use, the percentage of bank length effectively fenced increased marginally from 87% to 91% for dairy and from 36% to 39% for drystock.

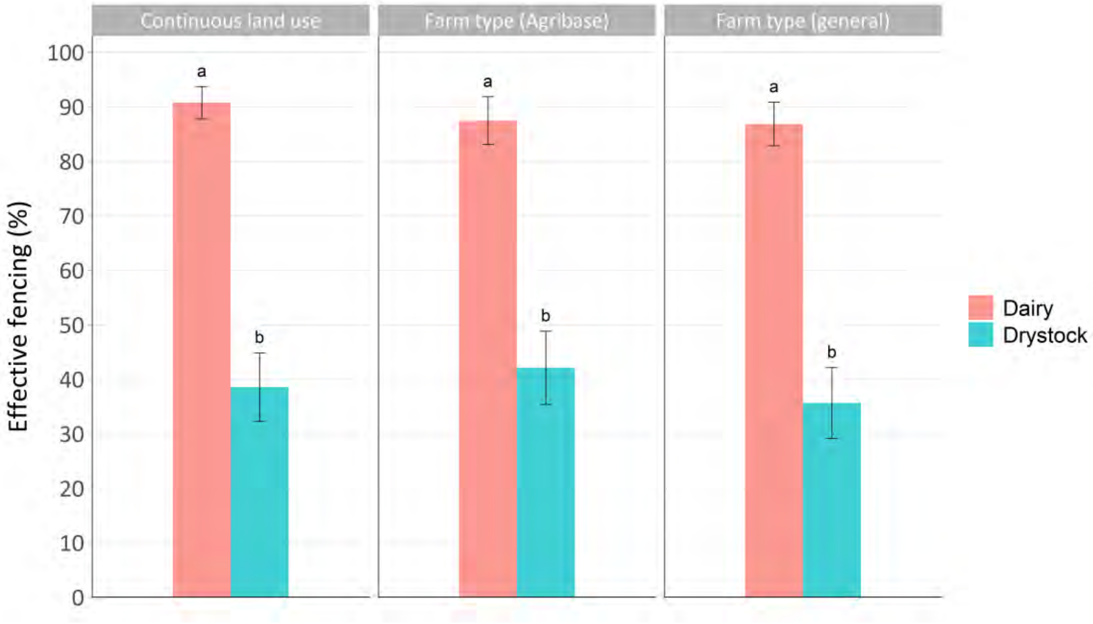

Figure 11. **Average proportion of bank length (total) effectively fenced in 2017 calculated with three land use classification systems including continuous land use (recorded with a handheld GPS), Agribase™ defined land use, and the general land use classification system outlined in Section 2.3.2. Error 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 riparian fencing results

The key results in relation to the fencing of waterways are that:

- Approximately two thirds (61%) of the surveyed bank length across the Waikato region in 2017 was effectively fenced.
- The average proportion of surveyed bank length effectively fenced for dairy (87%) was significantly higher than that for drystock (36%).
- The Waihou Piako zone had the largest average proportion of surveyed bank length effectively fenced (84%) with the lowest proportion being in the West Coast management zone (28%).
- Small to medium-sized waterways (stream orders 1 – 3) had the lowest average proportions of surveyed bank length effectively fenced (50 – 65%).
- The average proportion of surveyed bank length fenced across the Waikato region has significantly increased over the past fifteen years from 28% in 2002 to 61% in 2017. The rate of change over this period has been about 2.2% of bank length per year.
- The rate of change in the average proportion of surveyed bank length fenced over the past fifteen years was about 3.1% of bank length per year for dairy and about 1.3% of bank length per year for drystock. Over the past 5 years, the rate of change was about 3.8% of bank length per year for dairy and about 1.2% of bank length per year for drystock.

- Significant increases in the average proportion of surveyed bank length fenced over the past fifteen years were observed in all except the Lake Taupo management zone. Over the last five years, significant increases were restricted to the Coromandel and Waihou Piako zones.
- Over the past fifteen years, the average proportion of surveyed bank length fenced has significantly increased in all stream orders except for stream order 6.
- Only a small increase in the percentage of surveyed bank length effectively fenced was observed when a continuous measure was used to classify land use (87% to 91% for dairy and 36% to 39% for drystock).

3.2 Stock access and exclusion

3.2.1 State

On average, 49% of surveyed bank length across the Waikato region in 2017 showed no evidence of stock access (Figure 12). The remaining 51% of bank length showed some evidence of either past, recent or current stock access (stock access types are defined in Table 3). Current stock access, affecting 22% of bank length, refers to stock observed within the waterway or the adjacent riparian margin at the time the survey was undertaken. Across the region, there was a difference of about 10% between the amount of stock access observed (approximately 50% of bank length) and the amount of effective fencing (approximately 60% of bank length). This implies for about 10% of bank length, stock access to the riparian margin occurred in the presence of effective fencing. While this may have occurred in some instances (e.g. stock bypassing fencing structures through gates), it may also reflect the presence of new fencing. Indeed, the amount of effective fencing (61%) corresponded well to the percentage of bank with no stock access (49%) when percent past access (12%) was included.

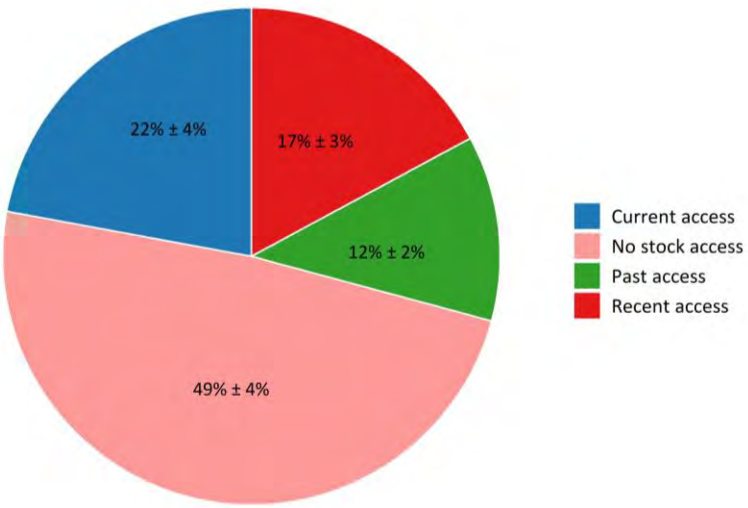

Figure 12. Average proportion of bank length with no stock access and past, recent, or current stock access observed across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.

In 2017, the amount of total stock access observed was significantly less for dairy (26% of bank length) than for drystock (75% of bank length) (Figure 13; $t = 12.0$, $p < 0.0001$). This was also the case for each individual stock access category (i.e. past, recent, and current). For recent and current stock access categories, percentage access values were about three times greater for drystock compared to dairy. This result is consistent with differences in the amount of effective fencing between dairy and drystock land uses (Figure 6).

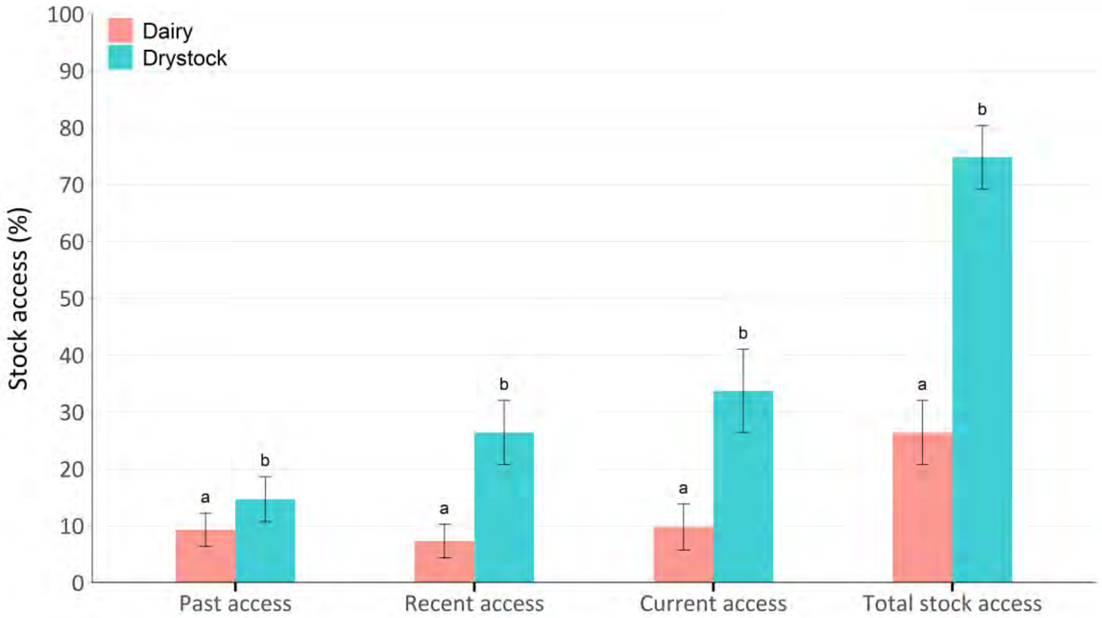

Figure 13. Average proportion of bank length with total stock access and (constituent) past, recent or current stock access observed across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).

The Lake Taupo, Upper Waikato and Waihou Piako management zones had the least stock access in 2017 with average proportions of surveyed bank length showing evidence of access (16%, 31%, and 26%, respectively) significantly less than those in the Lower Waikato, Waipā and West Coast management zones (56%, 54% and 84% respectively) (Figure 14). Lower incidence of stock access within the Lake Taupo, Upper Waikato, and Waihou Piako zones corresponds well with data on the proportion of bank length effectively fenced (these same zones had highest proportion of fenced bank length; Figure 7).

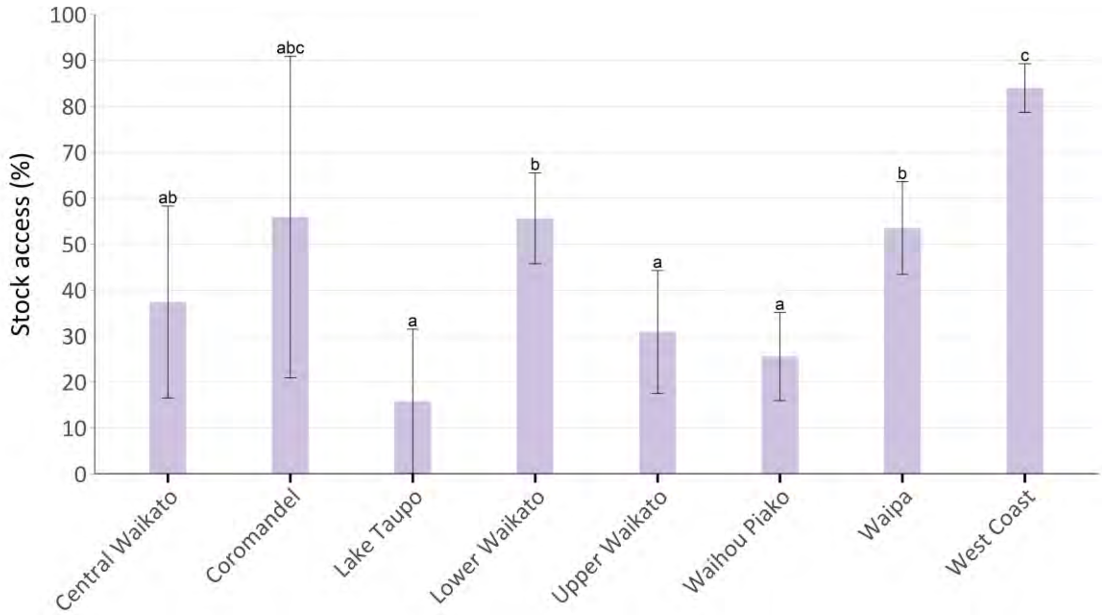

Figure 14. **Average proportion of bank length with observed stock access within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

The percentage of surveyed bank length with observed stock access was highest for first order streams (64%) and equal lowest for drains and fifth order streams (18%) (Figure 15). Results were, on the whole, consistent with the amount of effective fencing associated with each stream order (see Figure 8). The one exception was for stream order 6 where observed access was relatively high at 54%, noting that the variance around the mean for this estimate was considerable due to a limited sample size (see Table A4-3). Observed stock access was least for stream orders 0 (drains) and 5 with approximately 18% of bank length showing evidence of stock access on average. Other stream orders were observed to have between 34% and 64% of bank length showing evidence of stock access.

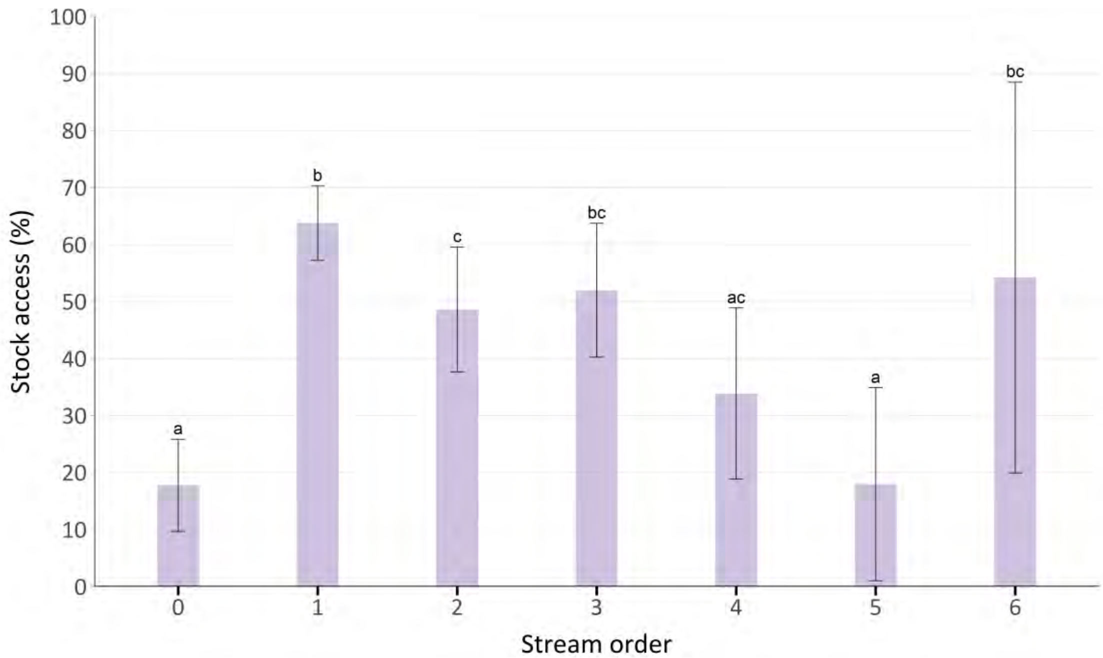

Figure 15. **Average proportion of bank length with observed stock access within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

3.2.2 Analysis of Dairying and Clean Streams Accord qualifying sites

Of the dairy sites sampled in 2017, 146 qualified as Dairying and Clean Streams Accord sites. The number and proportion of Accord qualifying sites meeting stock exclusion criteria for specified levels in the proportion of stream length they occupy (>50%, >75%, >90%, >99% of stream length) were determined (Table 11). Stock exclusion criteria were based on the presence of effective fencing, dense (forest/scrub) vegetation cover and deep channel morphology on both banks. Only 53% of qualifying sites had effective fencing on both banks along >99% of stream length (i.e. considered here to be equivalent to complete stock exclusion). The addition of dense vegetation cover and deep channel morphology to the stock exclusion criteria (recognising these as having the potential to restrict stock assess) resulted in only a minimal increase in the proportion of qualifying sites with complete stock exclusion (56% including dense vegetation cover and deep channel morphology). This suggests that effective fencing is the predominant means of stock exclusion in the Waikato region. The proportion of qualifying sites with no evidence of stock access or soil pugging disturbance was 62%, comparable to the complete stock exclusion estimate of 56% (Table 11).

Table 11. Number and proportion of Dairying and Clean Streams Accord qualifying sites (n = 146) 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%	77	53
	>90%	97	66
	>75%	110	75
	>50%	127	87
Effective fencing or forest/scrub on both banks	>99%	79	54
	>90%	97	66
	>75%	110	75
	>50%	127	87
Effective fencing or forest/scrub on both banks or deep channel	>99%	82	56
	>90%	100	68
	>75%	111	76
	>50%	128	88
No evidence of stock access	100%	90	62

The proportion of surveyed bank length with effective fencing at Accord sites, averaged 90% (Table 12). The addition of dense vegetation cover (i.e. forest/scrub) and deep channel morphology to the stock exclusion criteria resulted in only a minimal increase in the respective proportions of bank length considered to be protected. In terms of stock access, 81% of bank length across the sampled Accord sites had no observed stock access in 2017 (Figure 16). This value is about 10% less than the effective fencing estimate (Table 12) suggesting that in some cases stock were able to access the riparian zone through or around fencing and vegetation structures deemed to exclude stock.

Table 12. **Average proportion of bank length satisfying various stock exclusion criteria at Dairying and Clean Streams Accord qualifying sites (n = 146).**

	Proportion of bank length (%)
Effective fencing	90
Effective fencing or forest/scrub vegetation	90
Effective fencing or forest/scrub or deep channel	91

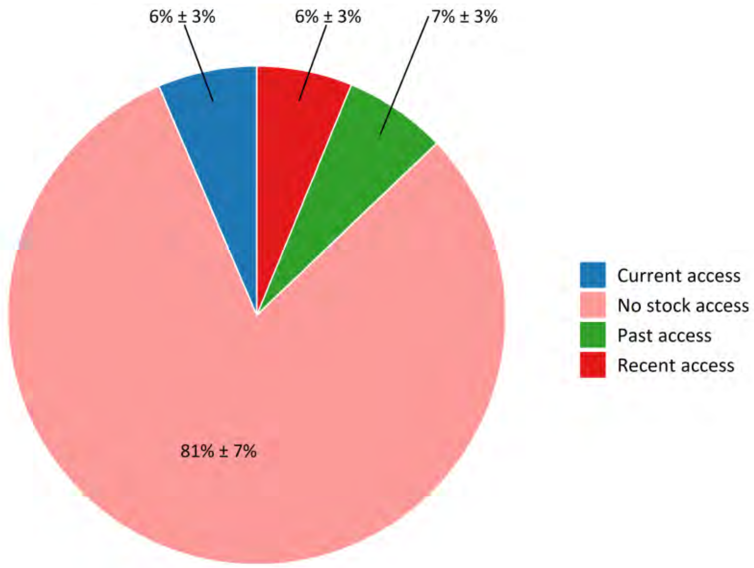

Figure 16. **Average proportion of bank length with no stock access and past, recent, or current stock access observed at Dairying and Clean Stream Accord qualifying sites (n = 146) across the Waikato region in 2017. Error terms represent the 95% confidence interval about the average.**

Overall, our estimate of the number of Accord site waterways with complete stock exclusion (56%) appears to be lower than estimates provided in the Sustainable Dairying Water Accord final summary report (DairyNZ, 2018) where stock was purported to be excluded from 98% of the length of all accord waterways. Notably, however, the 'gap' between Accord results and those reported in earlier regional and national surveys appears to be closing. For example, in 2009 and 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 Sanson & Baxter's 2011 national survey, estimates of total stock exclusion were reported at 47%, while in the previous iteration to this survey, Jones et al. (2016) estimated that stock was permanently excluded from 26% of stream bank length. In contrast, concurrent stock exclusion estimates in Dairying and Clean Streams Accord: Snapshot of Progress 2011/2012 report (Ministry for Primary Industries, 2013) were 87% nationally and 86% for the Waikato region. In general, 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 and most likely reflect the use of a verbal assessment process (DairyNZ, 2018) compared to the quantitative field observation approaches used in the aforementioned surveys. Nevertheless, considerable progress has been made at excluding stock from these waterways as evidenced in the high proportion of total bank length with effective fencing (90%).

3.2.3 Analysis of the proposed national stock exclusion regulations

Under the proposed national stock exclusion regulations, stock (dairy and beef cattle, deer and pigs) must be excluded from wetlands, lakes and rivers/streams in all low-slope areas (< 10°) where the 'bank-to-bank' width of the water body is more than a metre wide (Ministry for the Environment, 2020a; Ministry for the Environment 2020b). Hill country stock exclusion (≥ 10° slope) applies for all dairy cattle and pigs, but for deer and beef cattle only when intensive farming practices are undertaken including fodder-cropping, break-feeding or grazing on irrigated pasture. For both low-slope and non-low slope scenarios, existing permanent fences can remain in place, but a minimum setback distance of 3 m is required for all new fencing. In an effort to evaluate the 2017 survey data against these requirements, the proportion of bank length effectively fenced for varying vegetation buffer width categories was calculated across slope class and land use categories for all streams and rivers more than 1 m wide (Table 13, Table 14, Table A4-12 and Table A4-13). Three slope classes were evaluated including classes A (0 – 3°), B (4 – 7°) and C (8 – 15°) obtained from the New Zealand Land Resource Inventory (NZLRI, version 2.1) at 1:250,000 scale. To capture land use change at a 'sub farm' scale, effective fencing was calculated using the continuous land use measurements outlined in Section 2.3.2.

3.2.3.1 Low-slope analysis

In 2017, the average percentage of surveyed bank length with effective fencing on pastoral enterprises was 87, 85 and 81% at sites where the predominant slope was < 3°, < 7° and < 15° respectively (Table 13). This indicates that under the proposed slope threshold of 10°, between 81 and 85% of bank length was effectively fenced on 'low-slope' land at the time of the 2017 survey. In terms of land use and across all slope classes, the percentage of bank length with effective fencing was clearly elevated for dairy (93 – 94% effectively fenced) compared to drystock (63 – 72% effectively fenced) (Table 13) and suggests that for dairy, targeted efforts to fence off waterways have occurred across a range of landscapes (Fonterra et al. 2003; DairyNZ 2015). Data was comparable across slope classes (and within a land use) which may also reflect the coarse scale at which the slope data was derived (1:250,000), that is, dairy pastures will likely be on flat land (< 3°) even when the predominant NZLRI slope class for a land parcel is of a higher degree. Assuming a deadline of July 2023 for exclusion of dairy and pigs and a deadline of July 2025 for exclusion of dairy support cattle, beef cattle and deer (Ministry for the Environment 2020b), the annual rate of fencing required on low-slope land (% bank length per year) to exclude stock from remaining unfenced sections is approximately 2.2% for dairy and 6.2% for drystock. Over the past fifteen years, the proportion of bank length fenced across the region has increased at about 3.1% and 1.3% of bank length per year for dairy and drystock land use respectively.

Under the revised regulations, the required 3 m setback distance only applies to new fencing which, in 2017 and under low-slope scenarios, would equate to approximately 6 – 7% of bank length for dairy and 28 – 37% of bank length for drystock (Table 13). For dairy, only about one third (33 – 39%) of the existing effective fencing was associated with a setback distance of greater or equal to 3 m while for drystock, a greater proportion of effective fencing (50 – 61%) met or exceeded this threshold (Figure 17). This observation is consistent with the location of drystock enterprises in hill country landscapes where vegetation buffer widths are likely to be wider. There was also a greater proportion of effective fencing associated with very narrow buffer widths (< 1 m) for dairy (13 – 16%) compared to drystock (2 – 4%) (Appendix A4-12), noting that no setback would be required for new fencing on these waterways

Table 13. Association between percentage bank length effectively fenced on pastoral enterprises in 2017 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 proposed 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	87 ± 5	193	85 ± 4	224	81 ± 5
	Effective fencing < 3 m	161	58 ± 7	193	53 ± 7	224	44 ± 6
	Effective fencing ≥ 3 m	161	29 ± 7	193	32 ± 6	224	37 ± 6
Dairy‡	Effective fencing total	117	94 ± 2	137	93 ± 2	150	93 ± 2
	Effective fencing < 3 m	117	66 ± 7	137	63 ± 7	150	57 ± 7
	Effective fencing ≥ 3 m	117	28 ± 7	137	31 ± 7	150	36 ± 7
Drystock*	Effective fencing total	54	72 ± 15	72	68 ± 11	91	63 ± 12
	Effective fencing < 3 m	54	40 ± 16	72	34 ± 13	91	25 ± 10
	Effective fencing ≥ 3 m	54	32 ± 15	72	34 ± 13	91	38 ± 12

¥ 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)

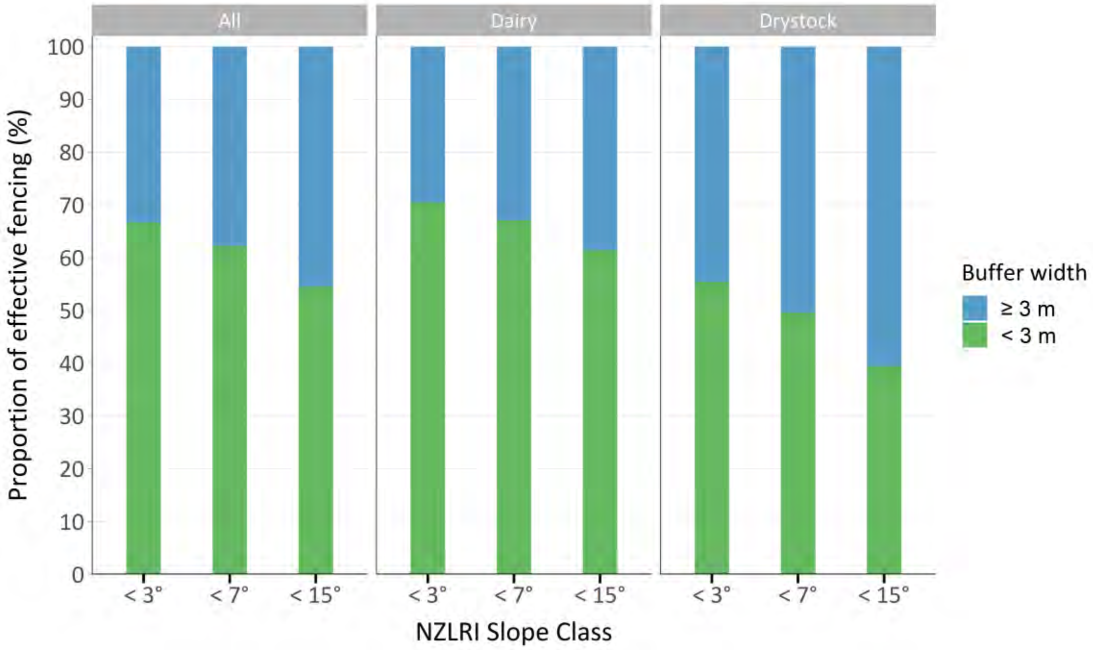

Figure 17. Proportion of effective fencing associated with two vegetation buffer width categories (< 3 m and ≥ 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (< 3°, < 7° and < 15°) for pastoral land use in 2017. Data is for the assessment of fencing setback requirements (low-slope scenarios) under the proposed national stock exclusion regulations (see Table 13 for land use specifications).

Overall, results indicate that under 'low-slope' scenarios (< 10°), only a small percentage of bank length under dairy still requires effective fencing (6 – 7%) compared to drystock where approximately one third of bank length (28 – 37%) was not effectively fenced at the time of the 2017 survey. Thus, for dairy, the setback requirement threshold (≥ 3 m) is largely irrelevant on low-slope land unless replacement of exiting fencing is considered, for example due to aging or damage (e.g. storm events). For drystock systems, there appears to be greater potential for a general increase in riparian buffer widths as the proposed setback requirements are implemented across a greater length of unfenced waterway. Importantly, only about one third (33 – 39%) of the existing effective fencing on dairy land use was associated with a setback distance of greater or equal to 3 m while for drystock, a larger proportion of effective fencing (50 – 61%) met or exceeded this threshold.

3.2.3.2 Non-low slope analysis

Under the proposed national stock exclusion regulations, fencing requirements under land classed as 'non-low slope' would apply to all dairy cattle (excluding dairy support) and pigs (unless housed). For dry stock enterprises including beef cattle, dairy support and deer, fencing is required only where intensive farming practices are undertaken including fodder-cropping, break-feeding or grazing on irrigated pasture. Data for the non-low slope analysis is presented in Table 14 and is divided into two stock categories namely dairy cattle (there were no pig enterprises in the 2017 survey) and high intensity drystock defined as having a whole farm stocking rate of greater than 14 SU/ha and/or the presence of break feeding or irrigated pasture along a given survey transect. Whole farm stocking rate was estimated using the AgriBase™ database (Section 2.1.2).

For respective dairy and high intensity drystock systems on non-low slope land, the average percentage of bank length with effective fencing ranged from 84 – 87% and 43 – 48% across the three non-low slope class categories (≥ 3°, ≥ 7° and ≥ 15°) (Table 14). Thus, under the proposed slope threshold of 10°, the percentage of bank length effectively fenced on non-low slope land in 2017 ranged from 84 – 87% for dairy and from 43 – 44% for high intensity drystock. In contrast to the low-slope scenario (Section 3.2.3.1), approximately two thirds (65 – 69%) of effective fencing on non-low slope dairy enterprises was associated with a setback of at least 3 m (Figure 18), an indication of wider buffer margins in hill country contexts. For drystock, approximately three quarters (74 – 76%) of the effective fencing on non-low slope land in 2017 was associated with a buffer width of at least 3 m. It should be noted that there were comparably few sites (15 – 30) where stock intensity, land use criteria (e.g. break feeding) and associated slope thresholds met the definition of 'high intensity' drystock (Table 14). Assuming a deadline of July 2023 for exclusion of dairy, pigs and high intensity drystock land use (Ministry for the Environment 2020b), the rate of fencing required on non-low slope land (% bank length per year) to exclude stock from remaining unfenced sections is approximately 4.8% for dairy and 15.5% for high intensity drystock. Over the past fifteen years, the annual increase in bank length fenced across the region was 2.2%. Over the past fifteen years, the proportion of bank length fenced across the region has increased at about 3.1% and 1.3% of bank length per year for dairy and drystock land use respectively.

Table 14. Association between percentage bank length effectively fenced on pastoral enterprises in 2017 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 proposed 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	87	87 ± 6	67	87 ± 7	54	84 ± 9
	Effective fencing < 3 m	87	29 ± 8	67	27 ± 8	54	29 ± 9
	Effective fencing ≥ 3 m	87	59 ± 10	67	59 ± 11	54	55 ± 12
Drystock (high intensity)*	Effective fencing total	30	48 ± 21	21	43 ± 25	15	44 ± 141
	Effective fencing < 3 m	30	15 ± 14	21	10 ± 12	15	11 ± 75
	Effective fencing ≥ 3 m	30	32 ± 16	21	33 ± 20	15	33 ± 104

[¥] 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.

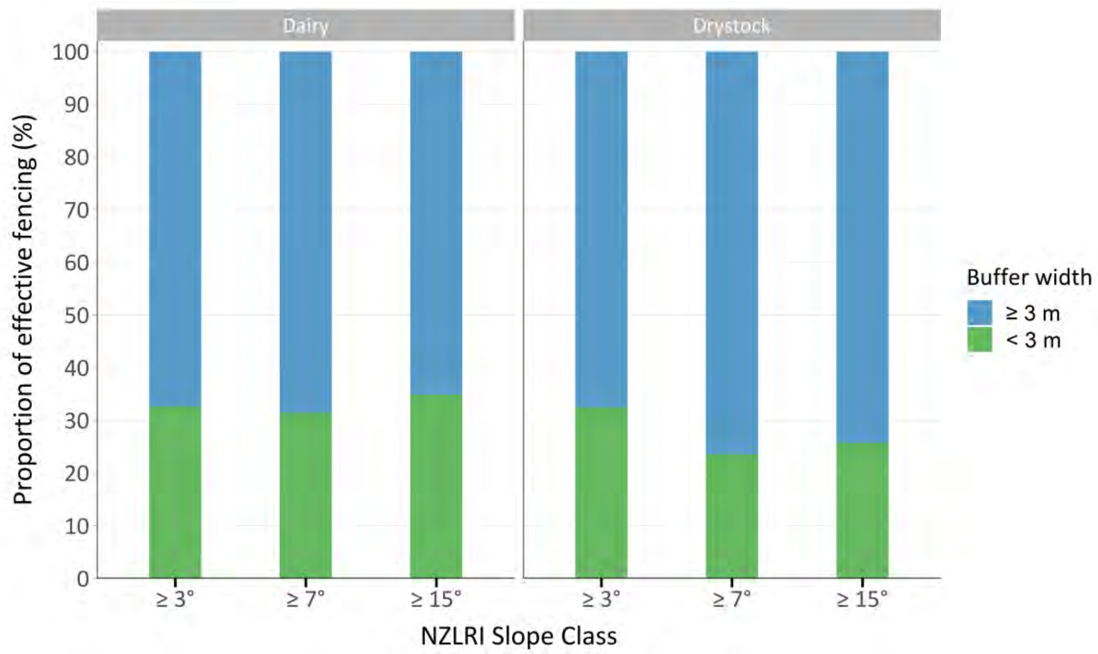

Figure 18. **Proportion of effective fencing associated with two vegetation buffer width categories (< 3 m and ≥ 3 m) across three New Zealand Land Resource Inventory (NZLRI) slope classes (≥ 3°, ≥ 7° and ≥ 15°) for dairy and drystock land uses in 2017. Data is for the assessment of fencing setback requirements (non-low slope scenarios) under the proposed national stock exclusion regulations (see Table 14 for land use specifications).**

Compared with low-slope land use contexts, results indicate that in 2017 and under 'non-low slope' scenarios (≥ 10°), a greater percentage of bank length under dairy (13 – 16%) and drystock (56 – 57%) still required effective fencing. However, more of this fencing was compliant with setback requirement thresholds (≥ 3 m), noting that these would only apply to new fencing. Approximately two thirds (65 – 69%) of effectively fenced dairy bank length and three quarters (74 – 76%) of effectively fenced drystock bank length was associated with a setback of more than 3 m.

3.2.4 Analysis of stock exclusion requirements under Plan Change 1

Under Plan Change 1 (PC1) which applies to the Upper Waikato, Central Waikato, Lower Waikato and Waipā management zones, stock must be excluded from all waterways in land with a slope of up to 15 degrees, or with a slope over 15 degrees where the stocking rate in any paddock adjoining a water body exceeds 18 stock units (Waikato Regional Council, 2020). Set back distances, which only apply to new fencing (i.e. existing permanent fences can remain in place), must be at least 3 m from the outer edge of waterbodies or at least 1 m from the outer edge of wide drains (≥ 2 m; bank to bank). For narrow drains (< 2 m; bank to bank), no setback is required.

In this analysis we evaluate the 2017 stock exclusion survey results against PC1 requirements as outlined in Schedule C of the 2020 decisions version document (Waikato Regional Council, 2020). To evaluate the 2017 survey data against these requirements, the proportion of bank length effectively fenced for varying vegetation buffer width categories was calculated. These calculations were made across two slope class categories (< 15° termed 'low-slope' and ≥ 15° termed 'non-low slope') for all permanently or intermittently flowing streams and rivers (Strahler order 1 – 6) and drains (Strahler order 0) with a minimum channel width of 1 m (Table 15, Table 16 and Table A4-14). As in Section 3.2.3, NZLRI slope class (1:250,000 scale) was used as a proxy to differentiate low-slope (class = A, B, C) from non-low slope (class ≠ A, B, C) land. Effective fencing was calculated using the continuous land use measurements outlined in Section 2.3.2 and included forest/scrub or deep channel morphology as a proxy for a natural or constructed barrier formed by topography or vegetation. Drains were separated into those wider than 2 m, for which a fencing setback distance of at least 1 m is required, and those less than 2 m in width for which no setback requirements apply. Sites on non-low slope land were only analysed where the whole farm stocking rate was greater than 18 SU/ha (estimated using the AgriBase™ database; Section 2.1.2) and/or there was evidence of break feeding of stock along the sampled transect.

Table 15 summarises the proportion of bank length effectively fenced for PC1 zones (combined and individual) across low-slope (< 15°) and non-low slope (≥ 15°), high stock intensity scenarios in 2017. For low-slope land uses, the percentage of bank length effectively fenced for narrow (< 2 m) and wide drains (≥ 2 m) was 90% and 79% respectively. There were only a few sites sampled with wide drains (n = 6) with most of the narrow drains located in the lower Waikato zone (n = 23). For streams and rivers (Strahler orders 1 – 6; n = 101), approximately 79% of bank length was effectively fenced (range across PC1 zones was 53 – 90%). Not surprisingly, there were very few drain transects sampled on non-low slope land (n = 0 – 1) (drains tend to be located on lowland terrain where water tables are typically elevated). There were also comparably few streams and rivers located on non-low slope, high stock intensity land uses (n = 16) in these zones, however, those that were identified had a high percentage of bank length effectively fenced (range across PC1 zones was 92 – 98%).

It should be noted that our survey design did not account for 'high intensity pastoral activities' as part of the overall design stratification so this land use may be underrepresented in these results. Nevertheless, results do suggest that low-slope land will be considerably more affected by PC1 stock exclusion rules due to the general presence of more intensive land use practices and also specific structures such as wide drains (≥ 2m). Results indicate that fencing of drains is largely complete with approximately 10% bank length remaining unfenced or ineffectively fenced. A greater percentage of bank length remains unfenced across qualifying streams and rivers (21%), particularity in the Central Waikato (47%) and Lower Waikato (35%) management zones.

Table 15. 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	32	90 ± 6	6	79 ± 45	101	79 ± 6
	Central Waikato	2	93	0	-	5	53 ± 82
	Lower Waikato	23	89 ± 8	5	77 ± 48	20	65 ± 15
	Upper Waikato	1	99	0	-	36	90 ± 9
	Waipā	6	87 ± 26	1	100	40	87 ± 9
Non-low slope (≥15°), high intensity*	All Plan Change 1 Zones	1	79	0	-	16	96 ± 23
	Central Waikato	0	-	0	-	2	92
	Lower Waikato	0	-	0	-	0	-
	Upper Waikato	0	-	0	-	7	98
	Waipā	1	79	0	-	7	94 ± 10

¥ 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.

In terms of fencing setback requirements, these would apply only to the installation of new fencing adjacent to streams and rivers (3 m setback) and also to drains with a bank-to-bank width of greater or equal to 2 m (1 m setback). Thus, for rivers and streams (Strahler orders 1 – 6) on low-slope land, the 3 m setback requirement would apply to approximately 21% of bank length which remained unfenced or ineffectively fenced at the time of the 2017 survey (Table 15). No setback requirements would apply for the approximately 10% of bank length under narrow drains (< 2 m) which still require stock exclusion. For wide drains (≥ 2 m), the 1 m setback requirements would apply to approximately 21% of unfenced bank length, noting that there were only few transects sampled for this category (n = 6).

Approximately 55% of the existing effective fencing on low-slope streams and rivers was associated with a setback distance of greater or equal to 3 m (Figure 19). For drains, 74% and 64% of effective fencing was associated with a setback distance of at least 1 m for narrow and wide drains respectively. While setback requirements would only apply to wide drains, results indicate that overall, much of the existing fencing around drains would be compliant under this regulatory framework. As noted previously, there were far fewer drain and stream and river transects sampled on non-low slope, high stock intensity land resulting in data gaps for the setback width analysis (Table 16; Figure 19). For streams and rivers, about 44% of existing fencing on non-low slope, high stock intensity land was compliant with setback requirements in 2017.

Table 16. 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, 2017. 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	32	90 ± 6	6	79 ± 45	101	79 ± 6
	Stock exclusion < 1 m	32	23 ± 10	6	29 ± 63	101	3 ± 2
	Stock exclusion < 3 m	32	79 ± 8	6	56 ± 70	101	36 ± 10
	Stock exclusion ≥ 3 m	32	10 ± 7	6	23 ± 31	101	43 ± 9
Non-low slope (≥ 15°), high intensity*	Stock exclusion total	1	79	0	-	16	96 ± 23
	Stock exclusion < 1 m	1	11	0	-	16	7 ± 24
	Stock exclusion < 3 m	1	56	0	-	16	54 ± 49
	Stock exclusion ≥ 3 m	1	23	0	-	16	42 ± 50

¥ 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 SU/ha or evidence of break feeding at the time of the survey.

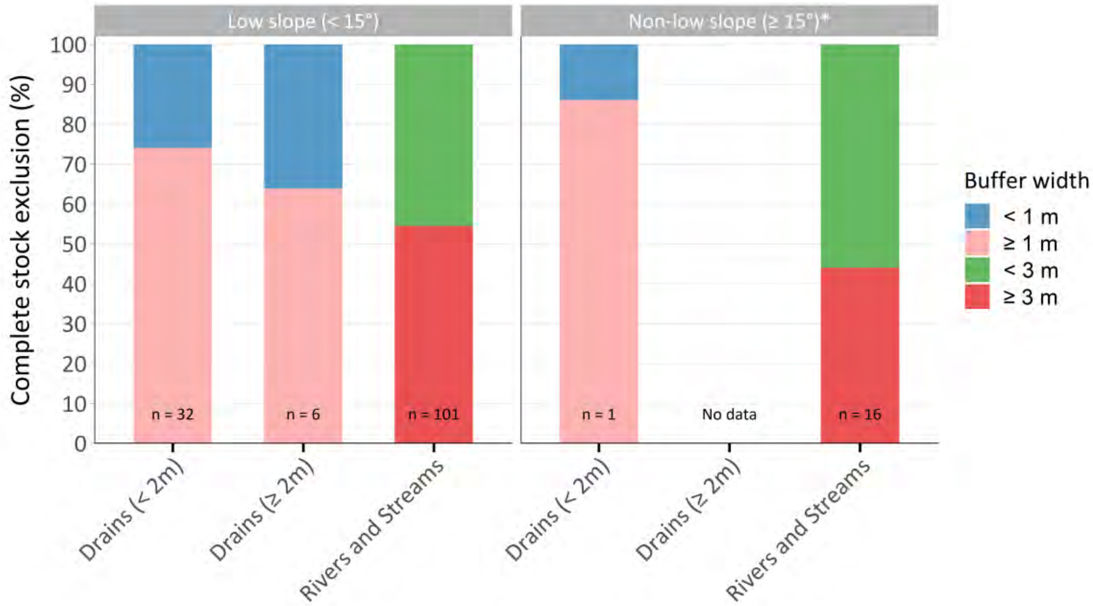

Figure 19. Proportion of complete stock exclusion (effective fencing or forest/scrub or deep channel morphology) associated with varying vegetation buffer width categories for drains (Strahler order 0; channel width < 2 m and channel width ≥ 2 m) and rivers and streams (Strahler orders 1 – 6) for low-slope (< 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 (Waikato Regional Council, 2020). The number of survey samples (n) within each slope and watercourse category is provided for reference.

3.2.5 Summary of key stock exclusion results

The key results in relation to stock access to, and exclusion from, waterways are that:

- On average, about half (49%) of the surveyed bank length of waterways across the Waikato region in 2017 showed no evidence of stock access.
- Stock access observed was significantly less for dairy (26% of bank length, on average) than for drystock (75% of bank length, on average).
- The Lake Taupo, Upper Waikato and Waihou Piako management zones had the smallest proportions of surveyed bank length with stock access (16%, 31%, and 26%, respectively).
- Observed stock access was least for stream orders 0 (drains) and 5 with approximately 18% of surveyed bank length showing evidence of stock access.
- About 56% of Dairying and Clean Streams Accord qualifying sites had effective fencing, or dense (forest/scrub) vegetation, or deep channel morphology on both banks along > 99% of stream length (i.e. considered here to be equivalent to complete stock exclusion). The average proportion of surveyed bank length with complete stock exclusion was 91%. In comparison, the Sustainable Dairying Water Accord final summary report for 2018 (DairyNZ, 2018) reported total stock exclusion along 98% of the length of accord waterways.
- On average, 81% of surveyed bank length at Dairying and Clean Steams Accord qualifying sites had no observed stock access in 2017. This value is about 10% less than the effective fencing estimate (91%) suggesting that, in some cases, stock were able to access the riparian zone through or around fencing and vegetation structures deemed to exclude stock.
- Under the proposed national stock exclusion regulations (Ministry for the Environment 2020a) and based on a low-slope threshold of < 10°, only a small percentage of surveyed bank length under dairy required effective fencing (6 – 7%), compared to drystock where approximately one third of bank length (28 – 37%) was not effectively fenced in 2017. About one third (33 – 39%) of the existing effective fencing on dairy land use was associated with a setback distance of greater or equal to 3 m (minimum setback requirement for all new fencing) while for drystock, a greater proportion of effective fencing (50 – 61%) met or exceeded this threshold. For non-low slope land (≥ 10°), a greater percentage of bank length required effective fencing in 2017 for both dairy (13 – 16%) and high intensity drystock (56 – 57%) land uses. However, more of the existing effective fencing was compliant with setback requirement thresholds (≥3 m). Approximately two thirds (65 – 69%) of dairy bank length and three quarters (74 – 76%) of drystock bank length was associated with a setback of at least 3 m. Assuming a deadline of July 2023 for exclusion of dairy and pigs, and a deadline of July 2025 for

exclusion of dairy support cattle, beef cattle, and deer, the rate of fencing required on low-slope land (% bank length per year) to exclude stock from remaining unfenced sections is approximately 2.2% for dairy and 6.2% for drystock. On non-low slope (July 2023 deadline), the rate is approximately 4.8% for dairy and 15.5% for high intensity drystock. Over the past fifteen years, the proportion of bank length fenced across the region has increased at about 3.1% and 1.3% of bank length per year for dairy and drystock land use respectively.

- Under Plan Change 1 (PC1) regulations (Waikato Regional Council, 2020) and for low-slope land use (< 15°), the percentage surveyed bank length effectively fenced in 2017 for narrow (< 2 m) and wide drains (≥ 2 m) was 90% and 79% respectively across qualifying management zones (Upper Waikato, Central Waikato, Lower Waikato and Waipā). For streams and rivers (Strahler orders 1 – 6), approximately 79% of bank length was effectively fenced. There were few drain transects sampled on non-low slope (< 15°), high stock intensity land (n = 0 – 1) and comparably few streams and rivers (n = 16). The latter had a high percentage of bank length effectively fenced (96%). Approximately 55% of the existing effective fencing on low-slope streams and rivers was associated with a setback distance of greater or equal to 3 m, the minimum setback requirement for all new fencing on these waterways. For drains, 74% and 64% of effectively fencing was associated with a setback distance greater or equal to 1 m for narrow and wide drains respectively, noting that the minimum setback distance of 1 m applies only to new fencing and for drains with a bank-to-bank width of at least 2 m.

3.3 Riparian vegetation

3.3.1 State

Approximately one quarter (24%) of surveyed bank length across the Waikato region was occupied by woody riparian vegetation in 2017 with the remaining three quarters (76%) occupied by non-woody vegetation (Figure 20). Although non-woody vegetation is effective for filtering sediment, nutrients, and pathogens from surface run-off from surrounding paddocks (e.g. Schwarte et al., 2011), woody riparian vegetation provides a range of additional benefits including shading effects (for water temperature regulation), enhanced biodiversity values (e.g. habitat provision and inputs of organic matter for aquatic food webs) and stream-bank stability (e.g. Davies-Colley & Quinn, 1998; Polvi et al., 2014).

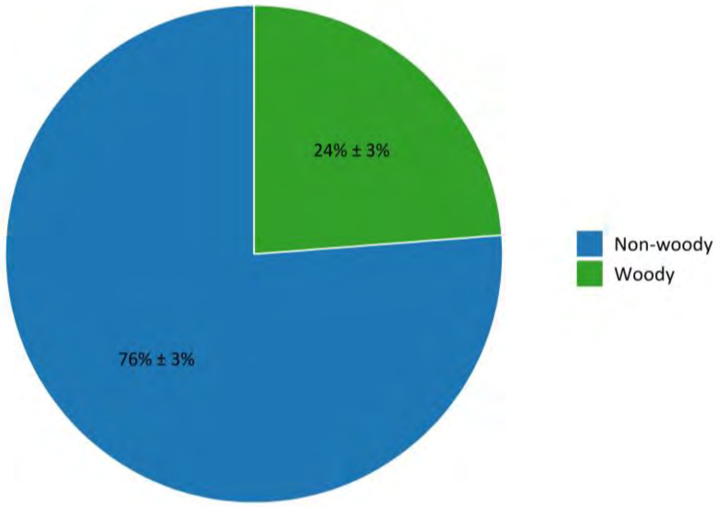

Figure 20. Average proportion of bank length with woody and non-woody vegetation across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.

Woody vegetation was further classified into exotic (willow, evergreen and other deciduous) and native vegetation, whereas non-woody vegetation was classified into 'grass and weeds' and 'flax/sedge/rush'. Average proportions of surveyed bank length occupied by each vegetation type category across the region in 2017 are presented in Figure 21. Grass and weeds occupied two thirds of the bank length across the region (66%) while 10% of bank length was occupied by flax, sedge and rush species which typically occur in wet or damp areas. In terms of woody vegetation, about 10% bank length was occupied by native species and 14% by exotic species.

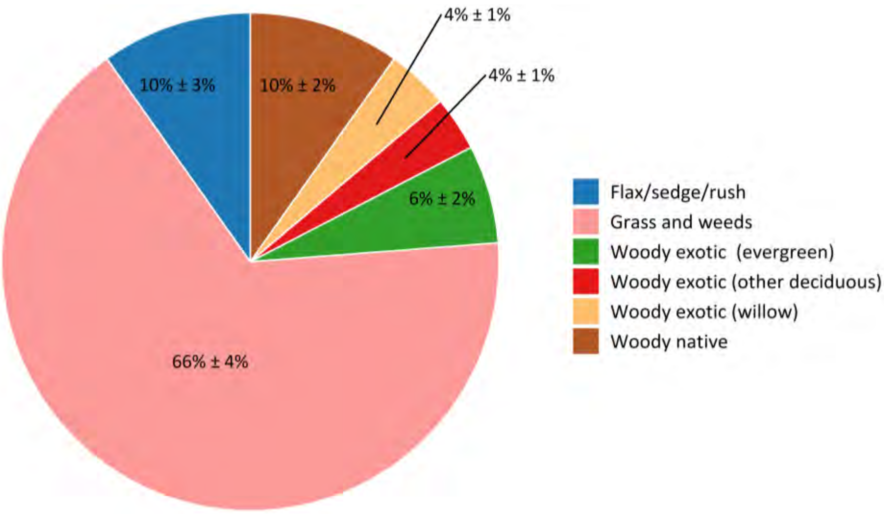

Figure 21. Average proportion of bank length occupied by individual vegetation types across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.

Grass and weeds was the predominant vegetation type across both land uses although there was significantly more coverage for dairy (73% of bank length) than for drystock (60% of bank length) ($t = 3.49$, $p = 0.0005$) (Figure 22). The proportion of surveyed bank length occupied by total woody vegetation was comparable between dairy and drystock land use ($t = 0.63$, $p = 0.53$). However, there was significantly less woody native vegetation for dairy (6% of bank length) than for drystock (13% of bank length) ($t = 3.05$, $p = 0.0024$). There was also significantly less flax, sedge and rush coverage for dairy (4% of bank length) than for drystock (15% of bank length) ($t = 4.30$, $p < 0.0001$). Overall, these results are consistent with the location of drystock farms in predominantly hill country areas where areas under native or restored riparian vegetation are generally larger (see Section 3.4).

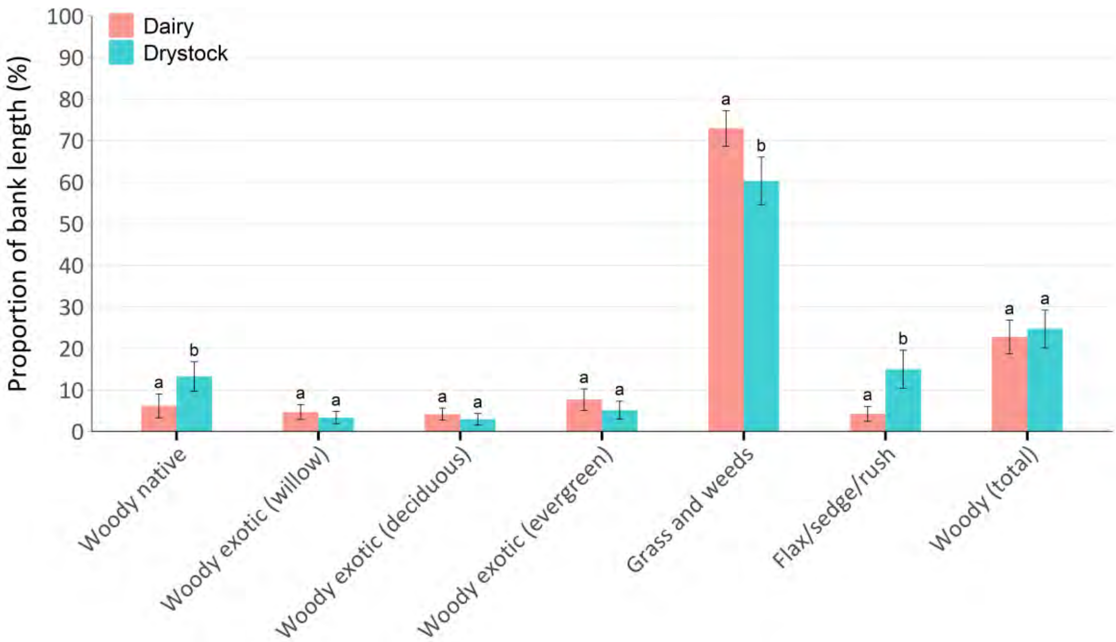

Figure 22. Average proportion of bank length occupied by individual vegetation types across the Waikato region in 2017. Error terms represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).

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 ($t = 5.42$, $p < 0.001$) (Figure 23). The main driver for this difference was attributed to the woody exotic (evergreen) component which was significantly higher in the presence of effective compared to ineffective fencing. In contrast, the proportion of bank length with effectively fenced flax/sedge/rush was significantly smaller than the proportion of bank length with flax/sedge/rush not effectively fenced. This suggests that most instances where this vegetation type occurs are not associated with restoration efforts but rather the persistence of native wetland vegetation types. There was no difference in the proportion of effective or ineffective fencing associated with grass and weeds. Overall, results suggest that there is a positive association between effective fencing and woody vegetation (i.e. a larger proportion of bank length is occupied by woody vegetation where effective fencing is in place compared to where there is no effective fencing).

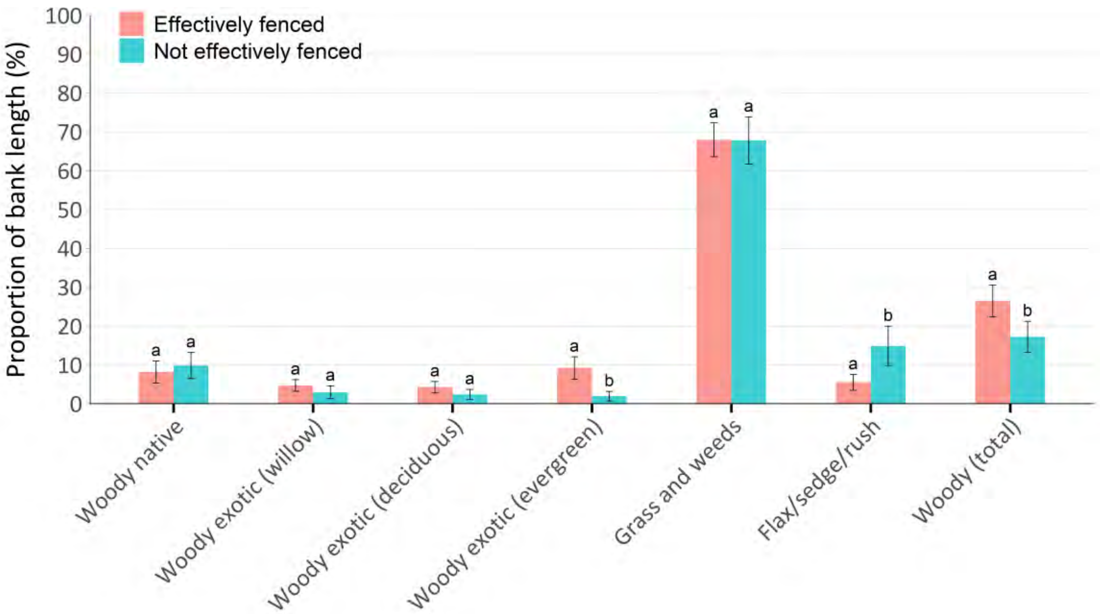

Figure 23. **Average proportion of effectively fenced or not effectively fenced bank length occupied by woody vegetation (total) and individual vegetation types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).**

In terms of the average proportion of bank length occupied by woody vegetation in 2017, two distinct groups of management zones were evident (Figure 24). The Coromandel, Lake Taupo and Upper Waikato management zones had the largest proportions of bank length occupied by woody vegetation (48%, 52%, and 44%, respectively) and were significantly different to all other zones which had between 13% and 19% of bank length with woody vegetation. The difference between the two groups of zones could be attributed to either the amount of effective fencing and past soil conservation investment (e.g. Lake Taupo and Upper Waikato; Figure 7), or the general prevalence of woody vegetation and patterns of intensive land use in the landscape (e.g. Coromandel compared to Waihou Piako; Figure 24).

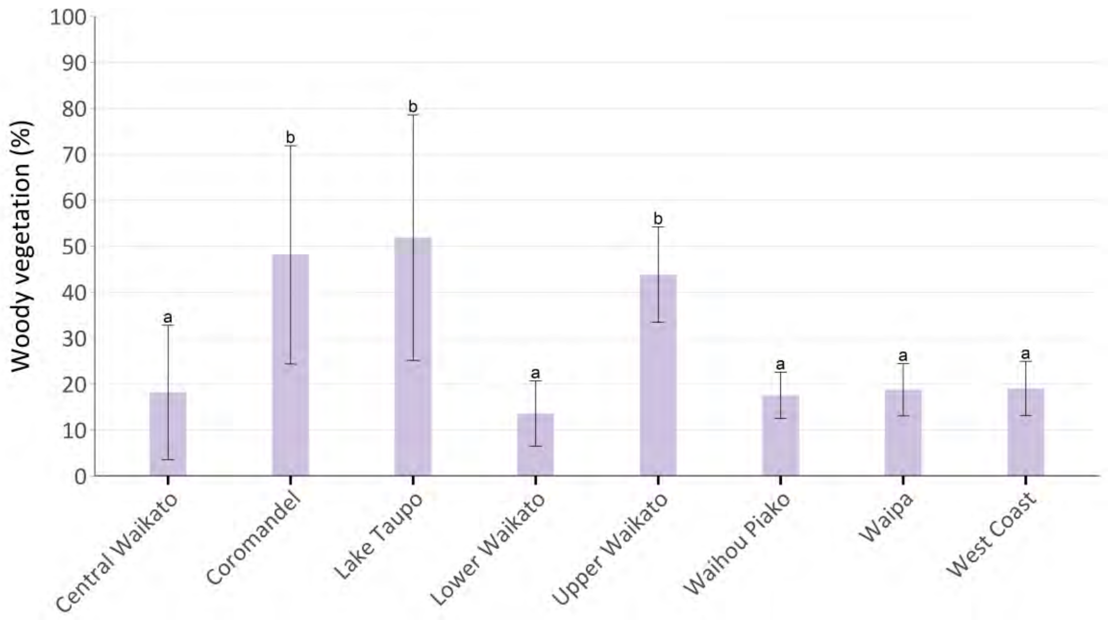

Figure 24. **Average proportion of bank length occupied by woody vegetation within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

In broad terms, the average proportion of surveyed bank length occupied by woody vegetation in 2017 increased with increasing stream order (Figure 25). Drains had the smallest average proportion of bank length with woody vegetation (7%) which was significantly lower than all other stream orders. Stream orders 5 and 6 had the largest average proportions of bank length with woody vegetation (38% and 57%, respectively), although the variability of estimates for these orders was large.

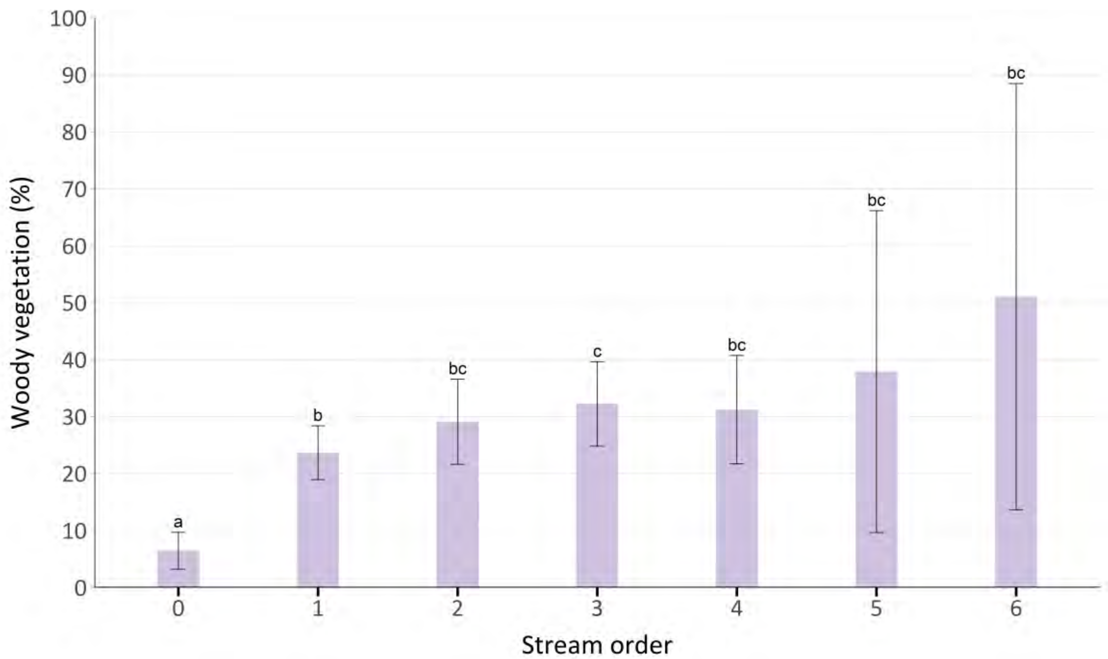

Figure 25. **Average proportion of bank length occupied by woody vegetation within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

3.3.2 Change over time

Over the past fifteen years (2002 – 2017) there was no significant change in the average proportion of surveyed bank length occupied by woody vegetation across the Waikato region ($t = 0.96$, $p = 0.34$) (Figure 26, Table 17). However, a statistically significant decrease over the past 10 years (2007 – 2017) was detected ($t = 5.70$, $p < 0.0001$) reflecting primarily a decrease (9% of bank length) in the amount of other woody exotic vegetation over that period. It should be noted that the 'woody exotic (other)' category reported here reflects the sum of the 'woody exotic (deciduous)' and 'woody exotic (evergreen)' categories (differentiation of these vegetation types was not made in the 2002 and 2007 surveys). The decrease in woody exotic vegetation over the past 10 years may reflect the replacement of exotic species with native woody and non woody species through targeted riparian restoration efforts.

The proportion of surveyed bank length occupied by the grass and weeds category has remained relatively unchanged over the past fifteen years averaging 68% in 2002 and 66% in 2017. However, a significant increase in grass and weeds coverage (17%) ($t = 6.38$, $p < 0.0001$), was observed over the past 5 years (2012 – 2017) primarily at the expense of flax/sedge/rush for which a significant decrease was observed (-14%) ($t = 5.62$, $p < 0.0001$). It is likely that much of this change reflects an overestimation of flax/sedge/rush during the 2012 survey (Figure 9, Table 7) due to due to misclassification of category descriptors (this was limited to the flax/sedge/rush and grass and weeds categories).

Figure 26. Average proportion of bank length (total) occupied by woody vegetation and individual vegetation types at the four survey periods (2002, 2007, 2012 and 2017).

Table 17. Average change in the proportion of bank length occupied by woody vegetation and individual vegetation types over the previous 5-year (2012 – 2017), 10-year (2007 – 2017) and 15-year (2002 – 2017) periods.

	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	Change (ppt†)	95%CI‡	Change (ppt†)	95%CI‡	Change (ppt†)	95%CI‡
Woody (total)	-3 NS	4	-8 **	5	-2 NS	4
Woody native	2 NS	3	0 NS	3	4 **	3
Woody exotic (willow)	-2 *	2	1 NS	2	-2 NS	2
Woody exotic (other)	-3 *	3	-9 **	3	-4 *	3
Grass and weeds	17 **	5	1 NS	6	-2 NS	5
Flax/sedge/rush	-14 **	5	6 **	3	4 *	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.

The pattern of change in the average proportion of surveyed bank length occupied by woody vegetation for both dairy and drystock land uses over the past decade (Figure 27, Table 18) was generally similar to that observed across the region as a whole (Figure 26, Table 17). The main difference was that the decrease in the amount of woody exotic vegetation over the 5, 10 and 15-year monitoring periods was significant for drystock but not for dairy. Both dairy and drystock exhibited small but significant increases in the average proportion of bank length occupied by woody native vegetation (4 – 5%) and flax/sedge/rush (2 – 6%).

Figure 27. Average proportion of bank length (total) occupied by woody vegetation and individual vegetation types within land use types at the four survey periods (2002, 2007, 2012 and 2017).

Table 18. 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 (2012 – 2017), 10-year (2007 – 2017) and 15-year (2002 – 2017) periods.

	Land use type	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Woody (total)	Dairy	-3 NS	5	-3 NS	8	2 NS	6
	Drystock	-4 NS	6	-9 *	8	-4 NS	6
Woody native	Dairy	2 NS	3	3 NS	4	4 *	3
	Drystock	2 NS	5	0 NS	5	5 *	4
Woody exotic (willow)	Dairy	-3 NS	3	0 NS	3	-1 NS	3
	Drystock	-1 NS	2	1 NS	2	-3 NS	3
Woody exotic (other)	Dairy	-2 NS	4	-6 NS	4	-1 NS	5
	Drystock	-4 *	4	-11 **	5	-7 **	5
Grass and weeds	Dairy	24 **	7	1 NS	8	-4 NS	7
	Drystock	11 **	8	-2 NS	8	-2 NS	8
Flax/sedge/rush	Dairy	-21 **	6	1 NS	3	2 *	2
	Drystock	-7 *	7	11 **	5	6 *	5

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

Over the previous 5 year (2012 – 2017), 10 year (2007 – 2007) and 15 year (2002 – 2017) monitoring periods, significant changes in the average proportion of surveyed bank length with woody vegetation were restricted to the Waihou-Piako and Waipā management zones (Table 19). In both zones, a reduction in woody vegetation was observed, particularly in the Waihou-Piako zone where the magnitude of change was significant for each of the monitoring periods (-8 to –12%). Changes in woody vegetation in these zones were associated primarily with a decrease in the amount of woody exotic vegetation (data not presented) which may reflect a combination of initial land use intensification and then later the replacement of exotic species with native ones.

Table 19. Average proportion of bank length occupied by woody vegetation within management zones at the 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.

Management zone	Average bank length (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Central	24	27	21	18	-2 NS	21	-9 NS	14	-6 NS	16
Coromandel	33	37	52	48	-4 NS	20	11 NS	25	16 NS	26
Lake Taupo	56	61	57	52	-5 NS	28	-9 NS	25	-4 NS	32
Lower Waikato	16	20	14	14	0 NS	8	-6 NS	10	-3 NS	10
Upper Waikato	38	46	47	44	-3 NS	13	-2 NS	16	6 NS	13
Waihou Piako	26	29	26	18	-8 **	6	-12 *	9	-8 *	8
Waipā	24	32	23	19	-4 NS	8	-13 *	11	-5 NS	10
West Coast	20	26	21	19	-2 NS	9	-7 NS	16	-1 NS	9

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

Across stream orders, there was a general decrease in the average proportion of surveyed bank length with woody vegetation over each of the monitoring periods (Table 20). However, the magnitude of change was significant only for fourth order streams between 2007 and 2017 where woody vegetation decreased from 54% to 31%. The decrease in woody vegetation between 2002 and 2017 was greatest in higher order streams (Strahler order 3 – 6), possibly reflecting the location of these streams on more intensive land use types and associated intensification over the past fifteen years.

Table 20. 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 (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	10	12	4	6	2 NS	3	-6 NS	11	-3 NS	7
1	24	32	28	24	-4 NS	6	-8 NS	9	0 NS	6
2	32	34	32	29	-3 NS	9	-5 NS	8	-3 NS	10
3	31	34	36	32	-4 NS	10	-1 NS	12	1 NS	14
4	45	54	35	31	-3 NS	17	-23 **	16	-14 NS	20
5	42	44	42	38	-4 NS	35	-6 NS	43	-5 NS	31
6	57	56	58	51	-7 NS	62	-5 NS	60	-6 NS	77

† 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

The key results in relation to riparian vegetation are that:

- Approximately one quarter (24%) of surveyed bank length across the Waikato region was occupied by woody riparian vegetation in 2017.
- There was no difference in the average proportion of surveyed bank length occupied by woody vegetation between dairy and drystock land use.
- The results suggest that there is a positive association between effective fencing and woody vegetation (i.e. effectively fenced bank length has a higher proportion of woody vegetation than bank length that is not effectively fenced).
- The Coromandel, Lake Taupo and Upper Waikato management zones had the largest proportions of surveyed bank length occupied by woody vegetation (48%, 52%, and 44%, respectively)
- In broad terms, the proportion of surveyed bank length occupied by woody vegetation increased with increasing stream order.
- There has been no significant change in the average proportion of surveyed bank length occupied by woody vegetation across the Waikato region over the past fifteen years

(although there has been a significant decrease in bank length occupied by woody vegetation over the past 10 years).

- The pattern of change in the average proportion of surveyed bank length occupied by woody vegetation for both dairy and drystock land uses over the past decade was generally similar to that observed across the region as a whole.
- Significant changes in the average proportion of surveyed bank length with woody vegetation were restricted to the Waihou-Piako and Waipā management zones, where net decreases were observed over the previous 5, 10, and 15-year monitoring periods.
- The average proportion of surveyed bank length with woody vegetation significantly increased for stream orders 1 and 6 and significantly decreased for drains over the past decade.
- Over the past decade, the average proportion of surveyed bank length with woody vegetation significantly decreased for fourth order streams.

3.4 Riparian buffer width

3.4.1 State

On average, 46% of surveyed bank length across the Waikato region had riparian buffer widths of 5 m or more (described here as 'wide') in 2017 (Figure 28). The remaining 54% of bank length had 'narrow' (< 5 m) buffer widths.

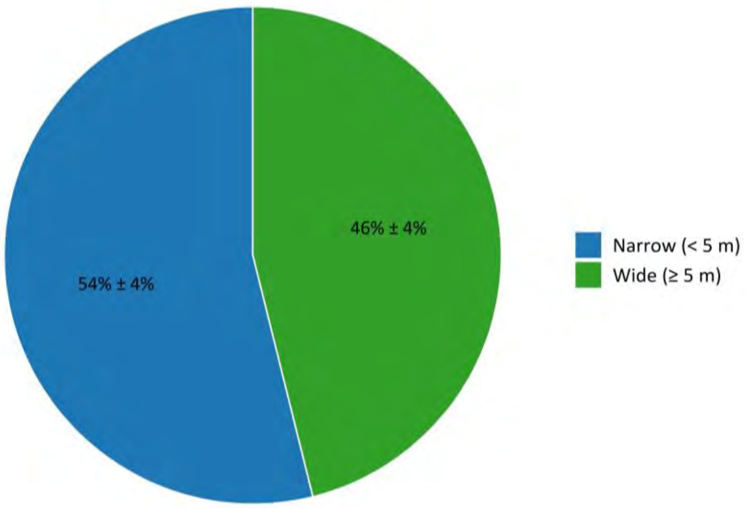

Figure 28. Average proportion of bank length with narrow (< 5 m) and wide (≥ 5 m) buffer widths across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.

An examination of individual buffer width categories revealed that approximately one quarter (23%) of the surveyed bank length across the region in 2017 had buffer widths of less than 2 m and that, on average, a further 31% of bank length had a buffer width of 2 – 5 m (Figure 29). About 29% of bank length had a buffer width of greater than 10 m. A buffer width of at least 5 m is recommended for riparian margins where restoration planting is planned (Waikato Regional Council, 2004) and a width of greater than 10 m is recommended if self-sustaining, low-maintenance indigenous vegetation cover is desired (Parkyn et al., 2000). An appropriate buffer width will depend on the aquatic characteristics to be managed in conjunction with specific site characteristics such as slope and lithology (Collier et al. 1995). On flat land and for improved water quality outcomes (e.g. a reduction in suspended sediment), buffer widths of 1 to 3 m for grassed margins are thought to be acceptable (Waikato Regional Council, 2004). It is noted that the current survey design does not allow for an assessment of buffer width efficacy (i.e. for mitigating or attenuating contaminant transfer) because related landscape characteristics (e.g. slope, lithology) are not being captured at a survey transect scale. To this end, inclusion of more detailed site assessment variables will be considered in future surveys in conjunction with the use of remote data capture techniques (e.g. drone image capture) to facilitate this.

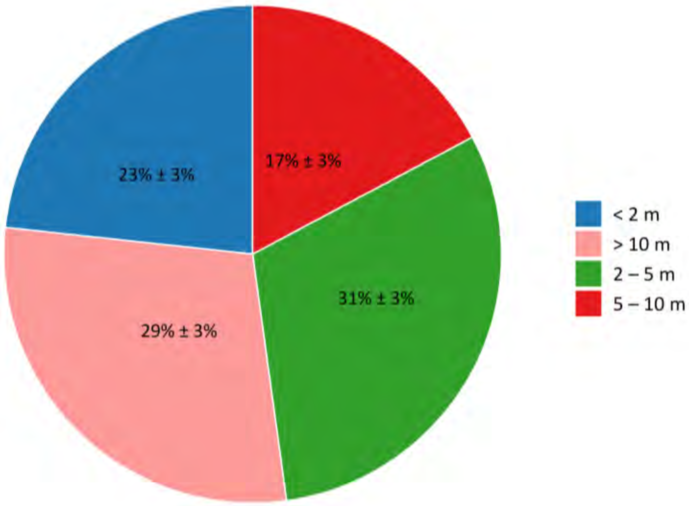

Figure 29. **Average proportion of bank length by individual buffer width category across the Waikato region in 2017 (n = 432). Error terms represent the 95% confidence interval about the average.**

Non-woody vegetation was clearly associated with narrow vegetation buffers with approximately 60% of non-woody vegetation located in buffer width zones of less than 5 m (Figure 30). In contrast wide vegetation buffers contained more woody vegetation with approximately 65% of woody vegetation associated with a vegetation buffer width of greater than 5 m. The proportion of woody vegetation associated with buffer width of less than 2 m was notably low at approximately 6%.

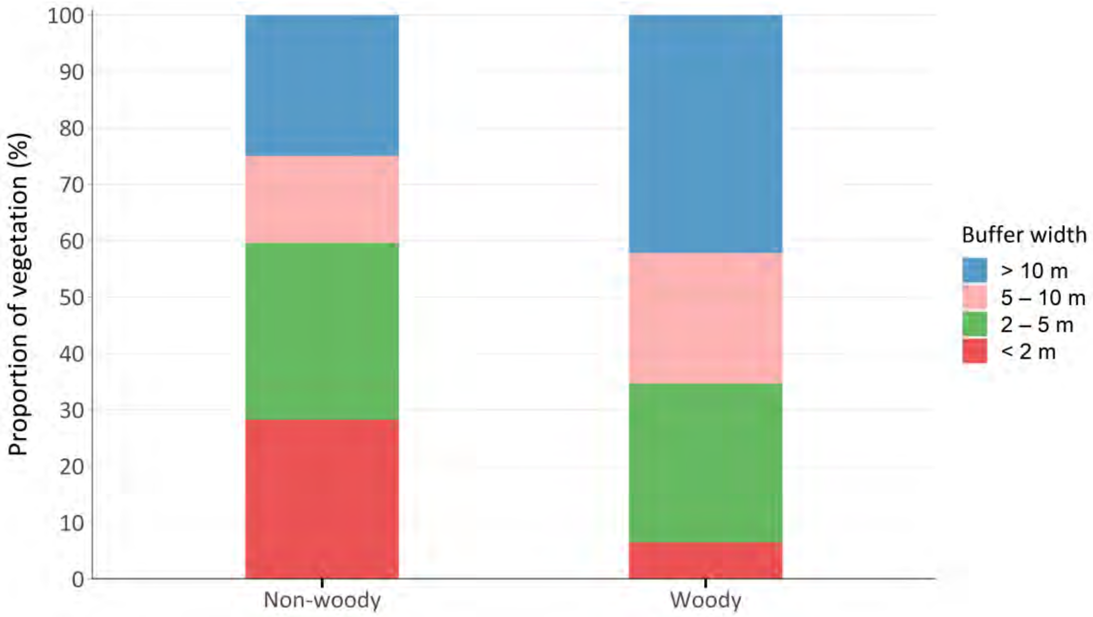

Figure 30. Average proportion of non-woody and woody vegetation located within individual buffer width categories across the Waikato region in 2017.

Differences in vegetation buffer widths between dairy and drystock land use were significant for all buffer widths except the 2 – 5 m category (Figure 31). A significantly larger proportion of surveyed bank length had wide buffers under drystock (60%) compared to dairy (32%) ($t = 7.65$, $p < 0.0001$). Conversely, the proportion of bank length with narrow buffers was significantly lower for drystock (40%) compared to dairy (68%) ($t = 7.65$, $p < 0.0001$). These differences were related largely to the < 2 m and > 10 m individual buffer width categories, that is, dairy was characterised by predominantly very narrow buffers (< 2 m, 37%) while drystock was characterised by predominantly very wide buffers (> 10 m, 40%). The predominance of wide buffers under drystock relative to dairy may relate to the generally more extensive nature of the drystock land use and to the prevalence of drains (stream order 0) on dairy farms. Approximately 92% of the bank length along drains across the region had narrow (< 5 m) buffers (c.f. Figure 34).

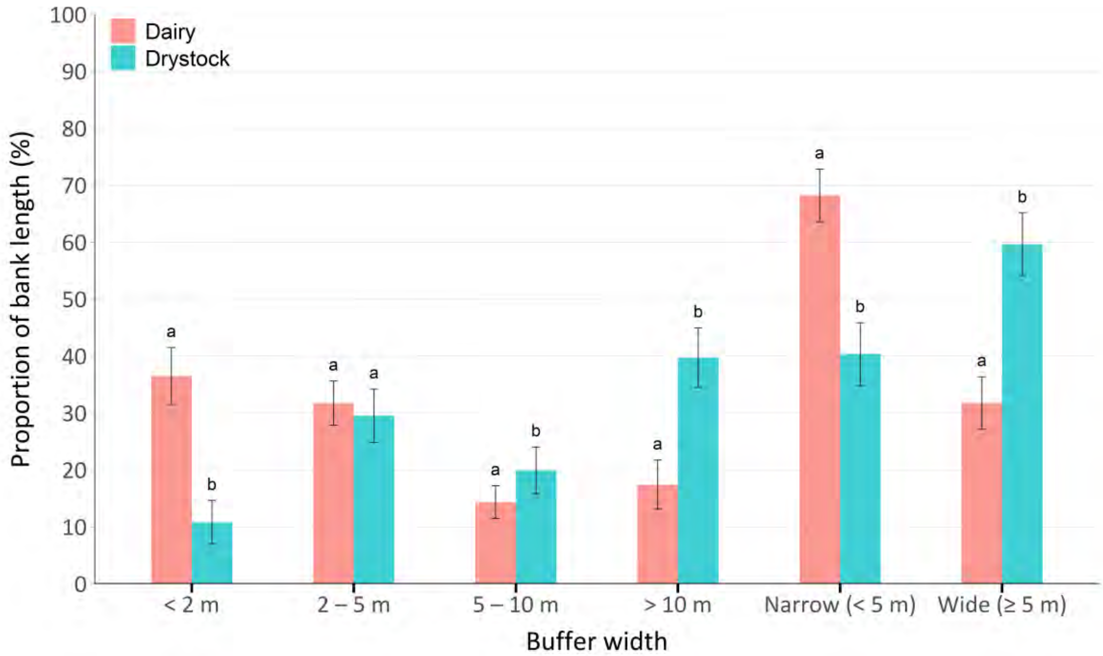

Figure 31. Average proportion of bank length by narrow (< 5 m), wide (≥ 5 m) and individual buffer width categories within land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).

Further to the results presented in Figure 31, differences in vegetation type between land use within narrow and wide buffers categories were associated with non-woody rather than woody vegetation (Figure 32). For narrow buffers, a significantly greater proportion of vegetation was non-woody for dairy (76%) compared to drystock (44%) ($t = 8.13$, $p < 0.0001$). This trend was reversed for wide buffers where a significantly greater proportion of vegetation was non-woody for drystock (56%) compared to dairy (24%) ($t = 8.13$, $p < 0.0001$).

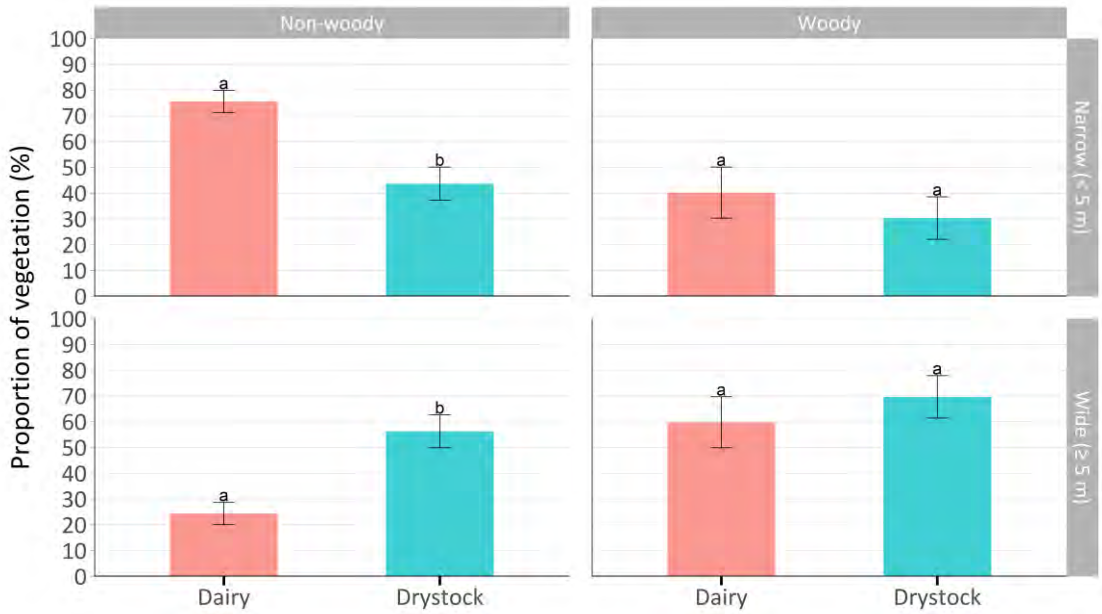

Figure 32. Average proportion of non-woody and woody vegetation within narrow (< 5 m) and wide (≥ 5 m) buffer width categories for dairy and drystock land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each vegetation x buffer width category, averages carrying the same letter are not significantly different ($\alpha = 0.05$).

The Lake Taupo management zones had the largest proportion of surveyed bank length with wide buffers (96%), significantly more than all other zones (Figure 33). This result could possibly be associated with historic soil conservation schemes in this zone (see Waikato Regional Council, 1998b; Palmer, 2004). In contrast, the Lower Waikato and Waihou Piako zones had the lowest average proportions of bank length with wide buffers (29% and 31% respectively), significantly less than all other zones. These zones are characterised by extensive drain networks (see Table A2-1) which tend to be associated with narrow set back margins (Figure 34).

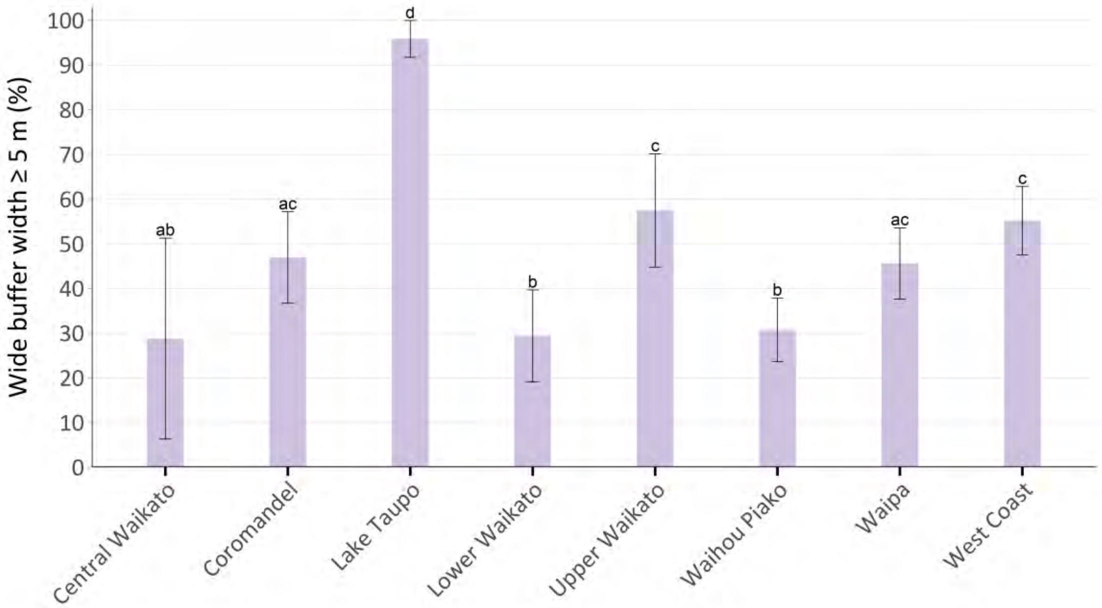

Figure 33. Average proportion of bank length with wide (≥ 5 m) buffer widths within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).

Drains (stream order 0) clearly stand-out as having a significantly lower proportion of surveyed bank length with wide buffers (8%) than all other stream orders (Figure 34). Drains are usually linear features more prevalent in areas of intensive agricultural production (e.g. dairying in generally flat land) that tend to be fenced-off relatively close to the drain channel (i.e. with a predominantly narrow buffer width). There appears to be a general trend of an increasing proportion of wide buffers with increasing stream order from drains through to stream order 4, but not beyond (due to high variability and small sample sizes for order 5 and order 6 streams).

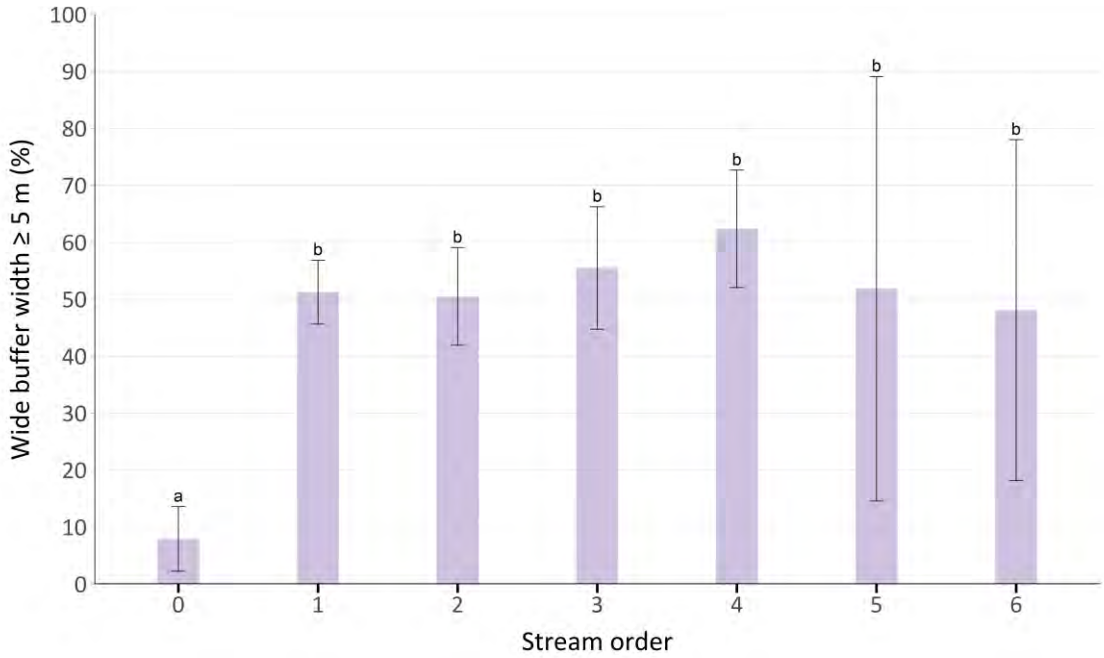

Figure 34. Average proportion of bank length with wide (≥ 5 m) buffer widths within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).

3.4.2 Summary of key riparian buffer width results

The key results in relation to riparian buffer widths are that:

- On average, 46% of surveyed bank length across the Waikato region had riparian buffer widths of 5 m or greater (described here as 'wide') whereas 23% of the bank length had buffer widths of less than 2 m.
- Non-woody vegetation was clearly associated with narrow vegetation buffers with approximately 60% of non-woody vegetation located in buffer widths of less than 5 m
- Drystock land use had a significantly larger proportion of surveyed bank length with wide buffers (60%) compared to dairy (32%). Differences in vegetation type between land use within narrow and wide buffer categories were associated with non-woody rather than woody vegetation.
- The Lake Taupo management zones had the largest proportion of surveyed bank length with wide buffers (96%) with lowest proportion present in the Lower Waikato and Waihou Piako zones (29% and 31% respectively)
- Drains (stream order 0) clearly stand-out as having a significantly smaller proportion of surveyed bank length with wide buffers (8%) than all other stream orders.

3.5 Waterway crossings

3.5.1 State

The occurrence and type of waterway crossings were observed as part of the riparian characteristics survey. Most of the waterway crossings observed across the region in 2017 were categorised as culverts, which accounted for 83% of observed crossings (Figure 35). Approximately 14% of crossings were bridges and only 3% were fords.

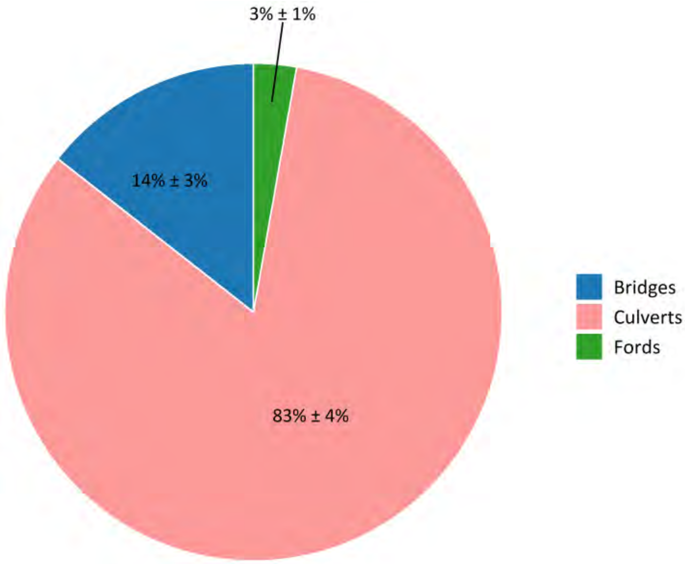

Figure 35. Average proportion of observed waterway crossings that are bridges, culverts or fords across the Waikato region in 2017 (n = 272). Error terms represent the 95% confidence interval about the average.

The number of (total) waterway crossings per km of stream length, were not significantly different between the land uses (Figure 36). However, the average proportion of waterway crossings that were fords was significantly larger for drystock (4%) than for dairy (1%) ($t = 2.37$, $p = 0.019$). The difference in the proportion of fords between the land uses may be due to the expected predominance of drystock farms in more remote, hill country areas where fords are more likely to be used as a means of stream crossing. Also, the use of bridges or culverts at regular waterway crossings on dairy farms was promoted by the Dairying and Clean Streams Accord. With only 1% of waterway crossings on dairy farms observed to be something other than a culvert or bridge (i.e. a ford) in the Waikato region, the survey indicates that the Accord has effectively met its voluntary performance target of 100% of crossings being either a bridge or a culvert by 2018.

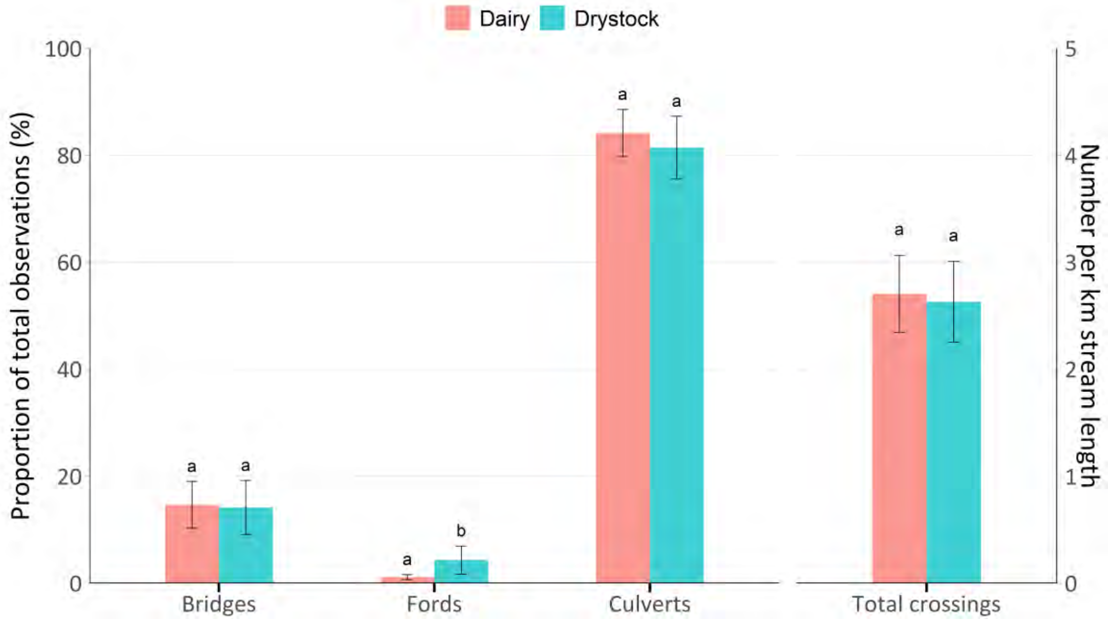

Figure 36. **Average proportion of observed waterway crossings that are bridges, fords or culverts (left-hand axis) and total number of crossings per km (right-hand axis) within land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different (α = 0.05).**

On average, the Lake Taupo management zone had the smallest number of crossings per km of stream length (1.9) in 2017 while the highest number of crossings were found in the Central Waikato zone (4.8) (Figure 37). Differences relate broadly to land use across zones, with a tendency for fewer crossings in regions dominated by sheep and low intensity drystock enterprises (Appendix A2-1). These land uses are often located in hill country contexts where steep topography may restrict road access and by extension stream crossing structures. Lower order streams (predominant in hill country catchments) will also require fewer crossing structures due to narrower channel widths and lesser flows.

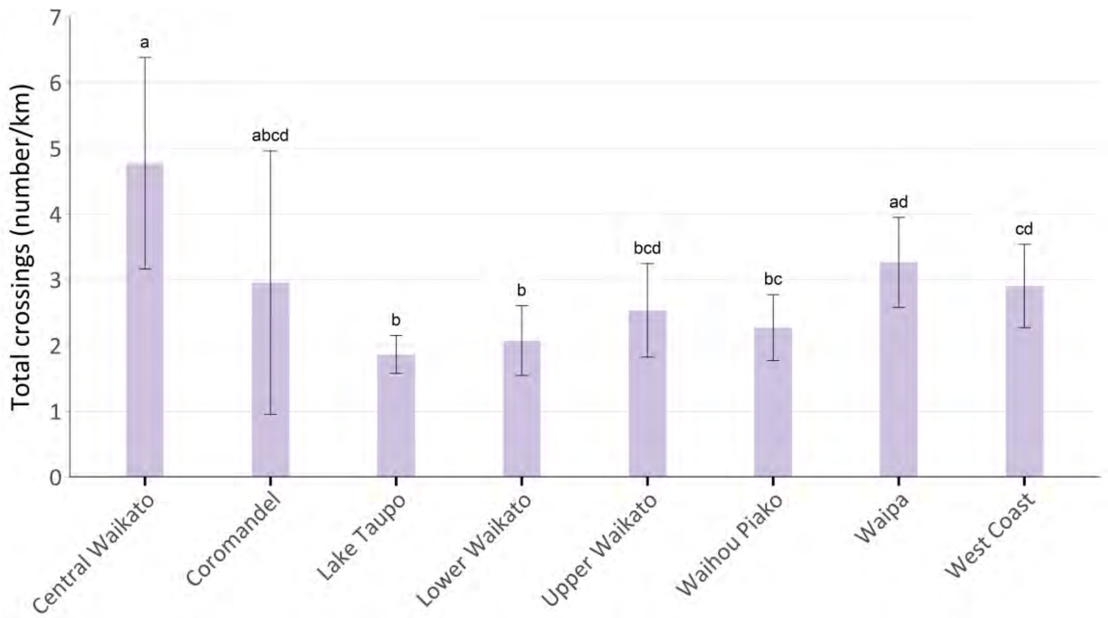

Figure 37. **Average number of total waterway crossings observed per km of stream length within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

A noticeable difference in the number of waterway crossings per km of stream length between streams of order 4 or more and streams of order 3 or less was apparent (Figure 38). The smaller streams (stream order 3 or less) generally had a larger number of crossings per km of stream length on average, with values ranging from 1.9 to 3.2, compared with the larger streams (stream order 4 or more), with values ranging from 0.02 to 0.6. Cost and other practical or regulatory restrictions are likely responsible for the less common occurrence of crossings over the larger streams and rivers.

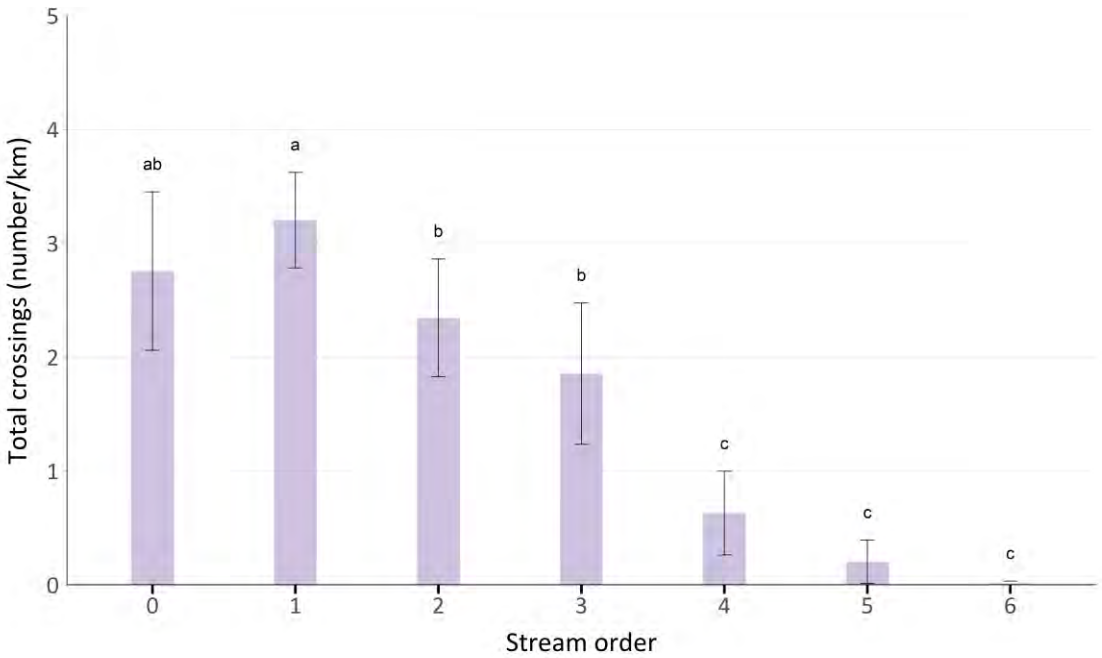

Figure 38. Average number of total waterway crossings observed per km of stream length within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).

3.5.2 Summary of key stream crossing results

The key results in relation to waterway crossings are that:

- Most of the waterway crossings observed across the region in 2017 were categorised as culverts, which accounted for 83% of observed crossings.
- The number of (total) waterway crossings per km of surveyed stream length, was not significantly different between the land uses.
- The Lake Taupo management zone had the smallest number of crossings per km of surveyed stream length (1.9) in 2017.
- Smaller waterways (stream order 3 or less) had a larger number of crossings per km of surveyed stream length on average, with values ranging from 1.9 to 3.2, compared with the larger waterways (stream order 4 or more), with values ranging from 0.02 to 0.6.

3.6 Stream-bank erosion

3.6.1 State

The majority (83%) of surveyed bank length across the region in 2017 was uneroded (Figure 39). Of the 17% of bank length observed to be eroded, 7% showed signs of active erosion while 10% had recent erosion.

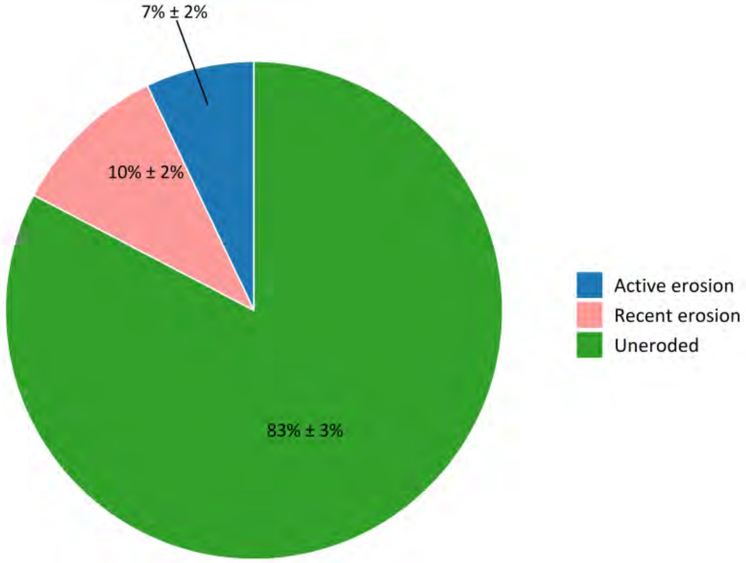

Figure 39. Average proportion of bank length uneroded and with active or recent erosion across the Waikato region in 2017 (n = 418). Error terms represent the 95% confidence interval about the average.

Soil disturbance is the sum of total stream-bank erosion (active or recent erosion) and pugging disturbance (> 50% pugging disturbance within the riparian margin). About one quarter (24%) of the surveyed bank length across the region in 2017 was observed to be disturbed and, of this, 7% of bank length showed evidence of pugging disturbance (Figure 40). The remaining three quarters (76%) of bank length was undisturbed.

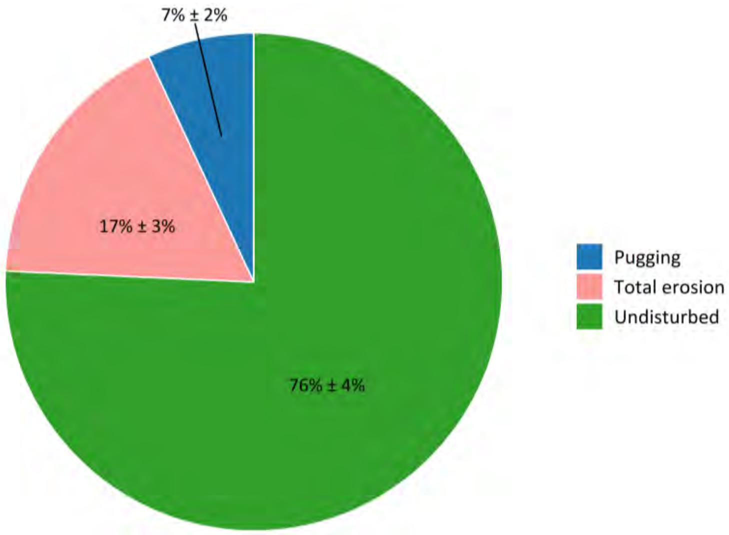

Figure 40. Average proportion of bank length undisturbed and with erosion or pugging disturbance across the Waikato region in 2017 (n = 418). Error terms represent the 95% confidence interval about the average.

Significantly more bank length was eroded (i.e. total erosion) for drystock (22%) compared to dairy (13%) (t = 2.81, p = 0.0052), driven largely by a greater active erosion component for drystock (Figure 41). Similarly, there was significantly more disturbed soil for drystock (31%) compared to dairy (18%) (t = 3.48, p = 0.0005), although differences in the amount pugging were marginally non-significant (t = 1.95, p = 0.052). Results are consistent with differences in stock exclusion (and effective fencing) between dairy and drystock (Figures 5 & 11), that is, in drystock systems where levels of stock exclusion were lower on average, levels of soil disturbance were elevated. Drystock systems are also located in predominantly in hill country settings with more high energy streams resulting in a greater likelihood of streambank erosion during storm events.

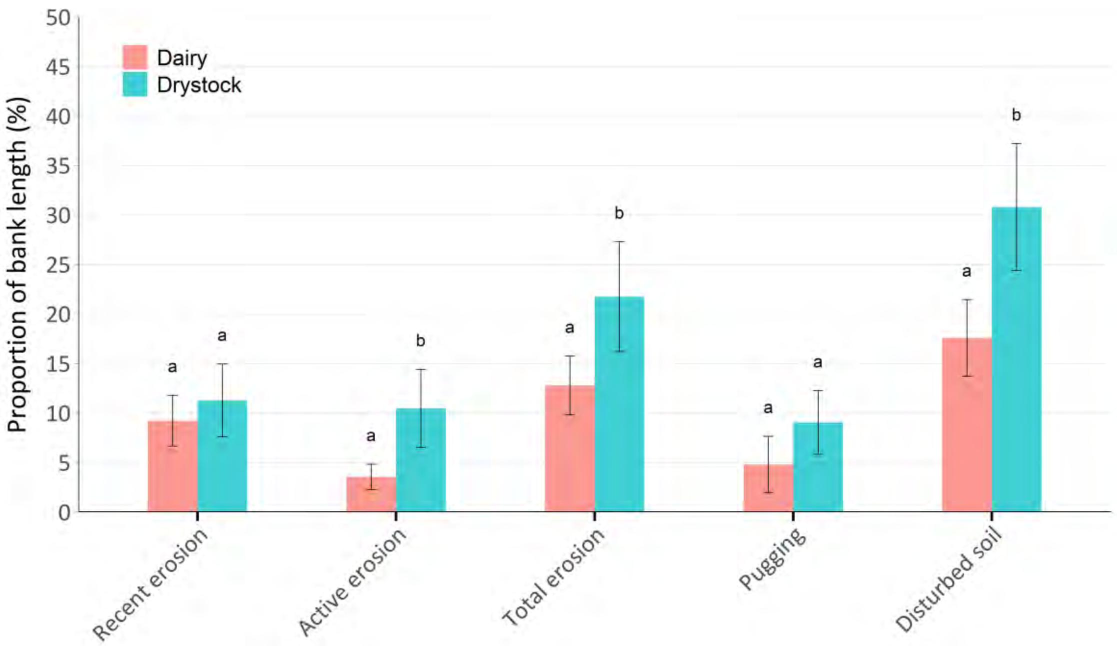

Figure 41. Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) within land use types across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different (α = 0.05).

Figure 42 shows that there was significantly less pugging disturbance (t = 4.45, p < 0.0001) and total erosion (t = 2.46, p = 0.014) in the presence of effective compared to ineffective fencing. Differences were particularly marked for pugging disturbance (3% of bank length with effective fencing compared to 13% with ineffective fencing), highlighting the importance of effective fencing for excluding stock from riparian margins. Overall, there was a significantly lower proportion of disturbed bank length associated with effective fencing (17%) compared to ineffective fencing (36%) (t = 4.88, p < 0.0001). Differences in total erosion appear to be driven by the active erosion component which was significantly lower in the presence of effective compared to ineffective fencing (t = 2.98, p = 0.0030). Results are very similar to those presented in Figure 41 in relation to the differences in stream-bank erosion and disturbance associated with land use type. As previously noted, the land use-related differences observed with respect to soil disturbance reflect differences in the amount of effective fencing.

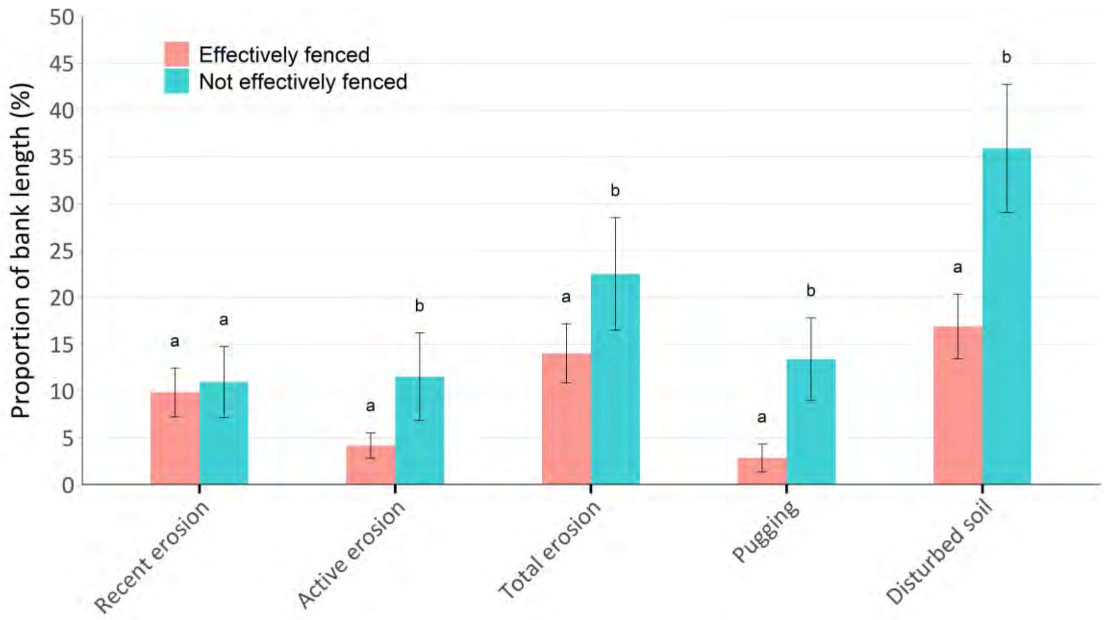

Figure 42. **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) that is effectively fenced or unfenced across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different (α = 0.05).**

The average proportion of surveyed bank length with soil disturbance and woody vegetation (18%) was significantly smaller than that with non-woody vegetation (26%) ($t = 2.84$, $p = 0.0046$). This was associated primarily with significantly less pugging under woody vegetation compared with non-woody vegetation ($t = 3.34$, $p < 0.0001$) (Figure 43). However, the presence of woody vegetation had little effect on the average proportion of bank length eroded (either in terms of total erosion or its active or recent components). This result suggests that stream-bank erosion may be affected more by factors such as bank morphology and the magnitude and frequency of storm (high flow) events that scour and undercut stream banks than by the presence of a woody vegetation cover. Although woody vegetation may sometimes provide a barrier to stock access, the observed association between woody vegetation and the proportion of bank length disturbed (pugged) most likely reflects the association between effective fencing and woody vegetation (Figure 23). That is, a larger proportion of bank length with woody vegetation occurs in association with effective fencing than without.

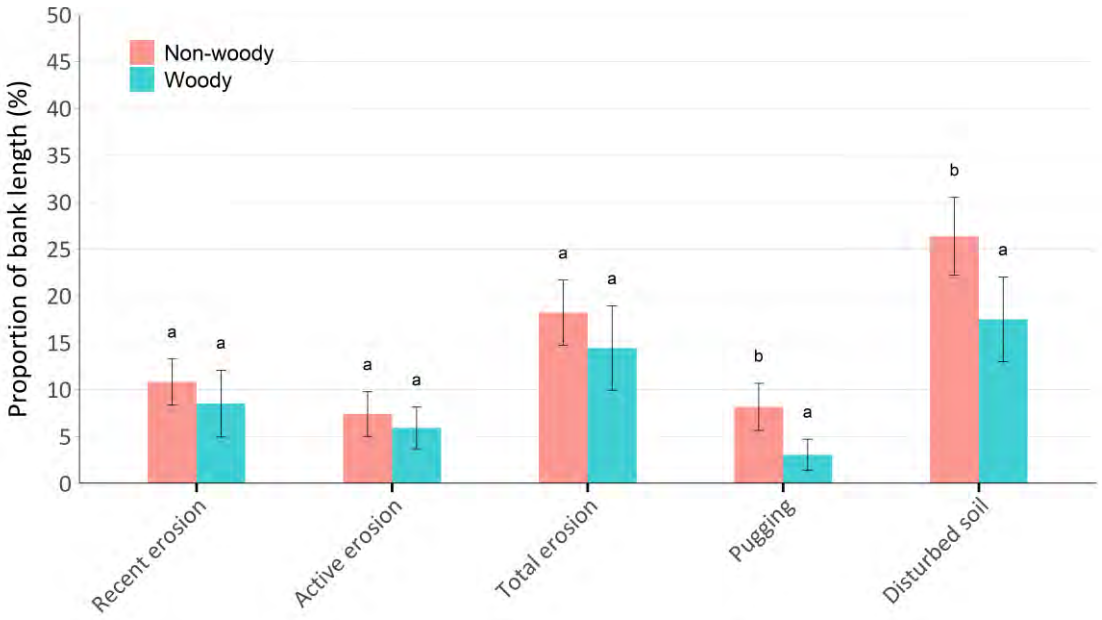

Figure 43. **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) that is occupied by woody or non-woody vegetation across the Waikato region in 2017. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly different (α = 0.05).**

The proportion of bank length eroded ranged from 12 to 29% across management zones (Figure 44). Due to large variances around individual means, differences were not significant between management zones, except between the West Coast zone (23%) and the Upper Waikato and Waihou Piako zones (12 to 13%). Notably, stream bank erosion was elevated in the Coromandel and West Coast zones (29 and 23% of bank length respectively), possibly reflecting the nature of the topography, patterns of land use and management factors (predominantly hill country, sheep and beef; Table A1-2). The lowest levels of stream bank erosion were observed in the Upper Waikato and Waihou Piako zones (12 and 13% respectively).

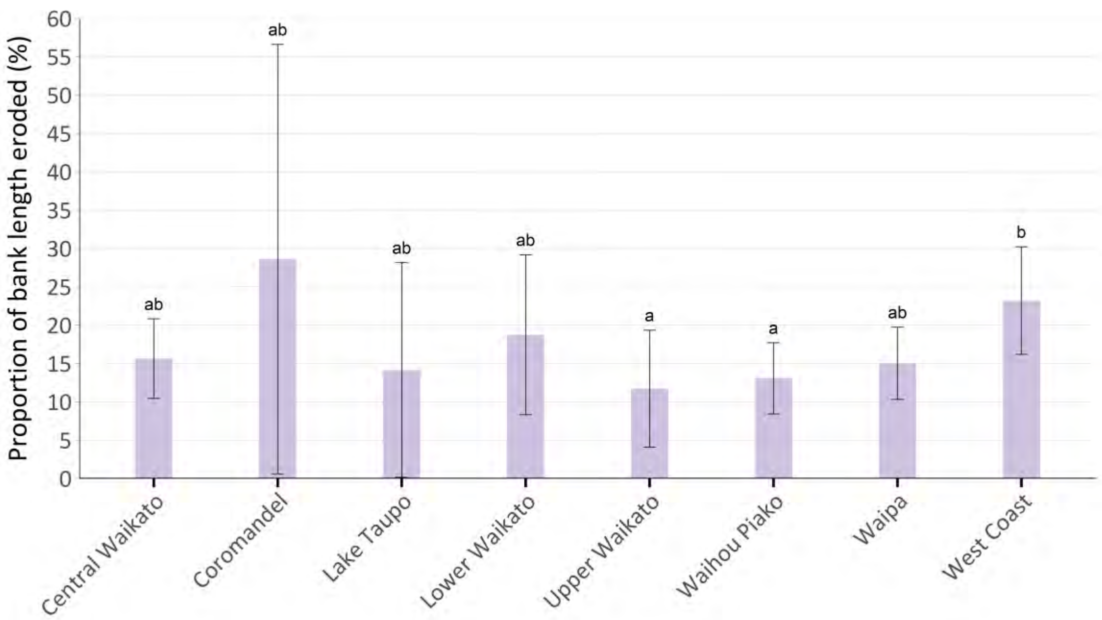

Figure 44. **Average proportion of bank length eroded within each management zone in 2017. Average proportion of bank length eroded within each management zone in 2017. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different (α = 0.05).**

Figure 45 indicates that stream orders 1 and 2 had the smallest average proportions of bank length eroded (about 15%) and were significantly different to stream order 5 which had the largest average proportions of bank length eroded (49%).

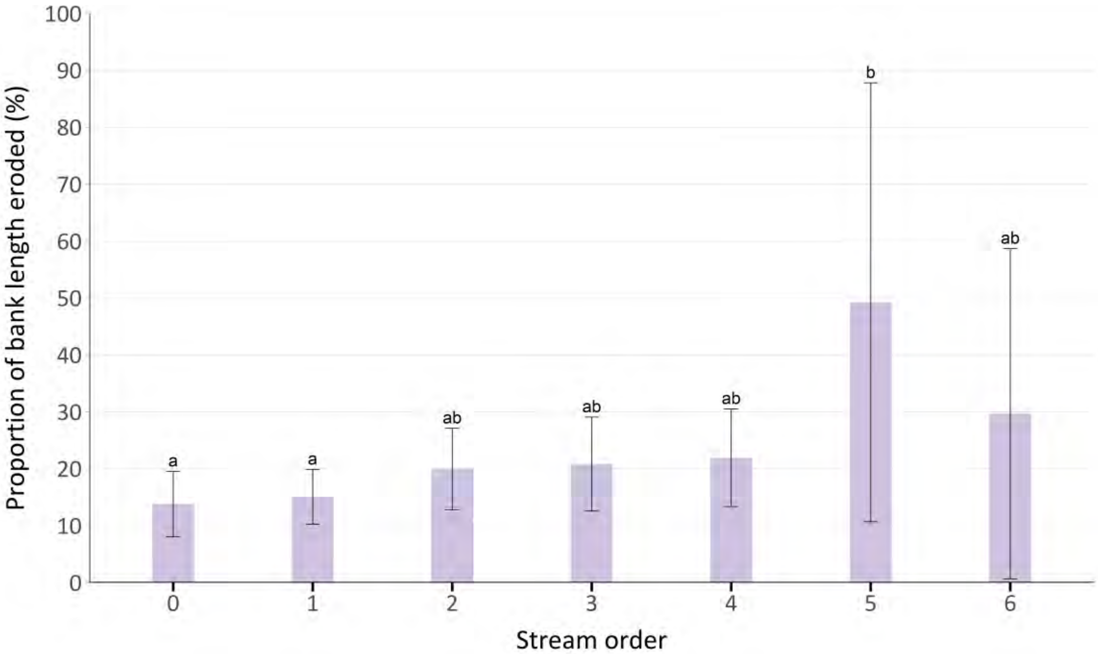

Figure 45. Average proportion of bank length eroded within each stream order in 2017. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly different ($\alpha = 0.05$).

3.6.2 Change over time

A significant increase in the average proportion of surveyed bank length eroded (i.e. total erosion) of about 12% of bank length was detected over the past fifteen years (2002 – 2017) across the Waikato region ($t = 6.77$, $p < 0.0001$) (Figure 46, Table 21). There has been a significant increase in total erosion over the past 5 years (7% of bank length) ($t = 3.57$, $p = 0.0004$) following an observed decrease between 2007 and 2012. Similar changes were found for the recent and active components of total erosion except that the reduction in recent erosion over the last 10 years was significant ($t = 2.35$, $p = 0.019$). 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). Also, because the assessment of stream-bank erosion is somewhat subjective, comparisons of erosion over time are likely to be less reliable compared with, for example, changes in the amount of fencing or stock access.

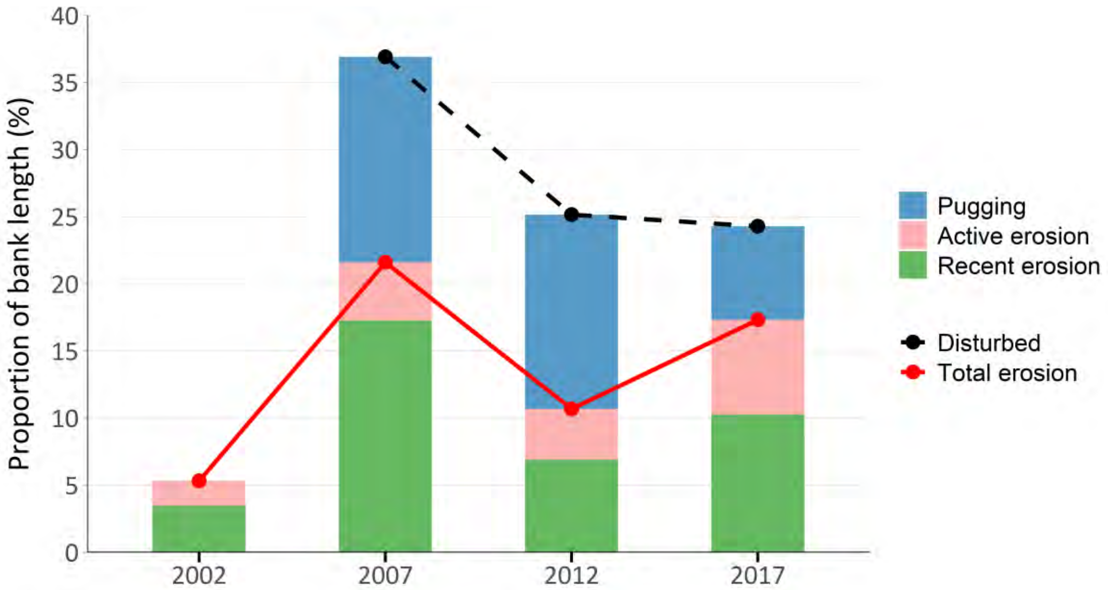

Figure 46. **Average proportion of bank length eroded (total) and bank length disturbed (with active and recent components and pugging disturbance) at the four survey periods (2002, 2007, 2012 and 2017). Note that pugging disturbance was not assessed in 2002.**

The observation of pugging disturbance was first undertaken during the 2007 survey, hence, changes in pugging and soil disturbance could not be examined for the fifteen-year period between 2002 and 2017. Figure 46 and Table 21 show that the average proportion of surveyed bank length disturbed significantly decreased by about 13% of bank length over the past 10 years ($t = 4.03$, $p < 0.0001$). This decrease was related to significant reductions in recent erosion (7% of bank length; $t = 2.35$, $p = 0.019$) and pugging (8% of bank length, $t = 4.56$, $p < 0.0001$) over this period. There was also a significant reduction in pugging (8% of bank length) for the five-year period between 2012 and 2017 ($t = 3.15$, $p = 0.0017$), although any reductions in overall soil disturbance were offset by significant increases in active ($t = 2.61$, $p = 0094$) and recent erosion ($t = 2.45$, $p = 0.015$). The overall reduction in pugging over the past decade is encouraging and indicates that riparian fencing efforts (see Figure 9) are resulting in measurable reductions in soil disturbance.

Table 21. **Average change in the proportion of bank length eroded or disturbed (including erosion type and pugging components) over the previous 5-year (2012 – 2017), 10-year (2007 – 2017) and 15-year (2007 – 2017) periods.**

	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Active erosion	3 **	2	3 ^{NS}	3	5 **	2
Recent erosion	3 *	3	-7 *	6	7 **	2
Total erosion	7 **	4	-4 ^{NS}	6	12 **	3
Pugging	-8 **	5	-8 **	4	-	-
Disturbed	-1 ^{NS}	5	-13 **	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.

An examination of the change in the amount of stream-bank erosion over time for dairy and drystock land uses (Figure 47, Table 22) revealed similar patterns to that found for the region as a whole (Figure 46, Table 21). There was a significant increase in total erosion (and associated active and recent components) over the past 15 years for dairy (t = 3.26, p = 0.0012) and drystock (t = 3.83, p = 0.0002), more so for drystock where the increase was about double that observed for dairy. Changes in the amount of stream bank erosion were not significant for dairy over the past 5 or 10 years. For drystock, there was a significant increase in active erosion over the 2007 – 2017 period (t = 2.19, p = 0.030) and a significant increase in total erosion over the 2012 – 2017 period (t = 3.03, p = 0.0027).

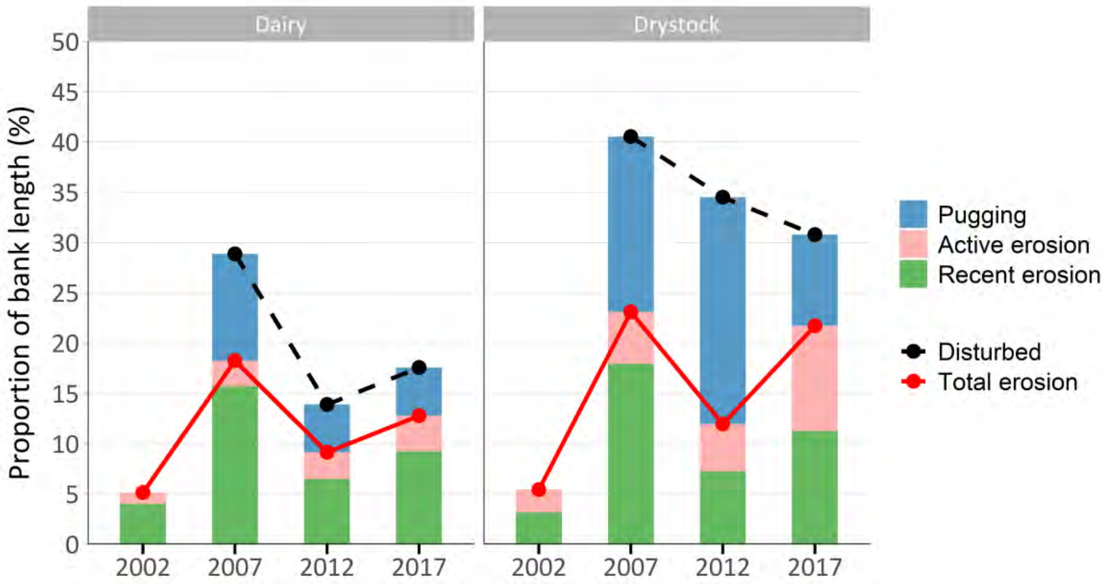

Figure 47. Average proportion of bank length eroded and bank length disturbed (with active and recent components and pugging disturbance) within land use types at the four survey periods (2002, 2007, 2012 and 2017). Note that pugging disturbance was not assessed in 2002.

Over the past 10 years, total soil disturbance significantly decreased for both dairy (11% of bank length, t = 2.19, p = 0.030) and drystock (10% of bank length, t = 2.02, p = 0.044) land use, reflecting reductions in both recent erosion and pugging components (Figure 47, Table 22). For drystock, the reduction in pugging disturbance over this period (8% of bank length) was significant (t = 3.15, p = 0.0018). In contrast, changes in overall soil disturbance over the last 5 years were not significant for either land use, this despite a large and significant reduction in pugging disturbance for drystock (13% of bank length, t = 3.09, p = 0.0022). Trends in soil disturbance for dairy and drystock land use categories are broadly in line with changes in the proportion of bank length effectively fenced (Figure 10, Table 8). Over the past 10 years (2007 – 2017) and for dairy, the observed 11% decline in soil disturbance corresponded with a 40% increase in effective fencing. For drystock, the link between soil disturbance and effective fencing was less clear, particularly for the pugging component which was observed to decrease significantly despite only a minimal increase in the overall amount effective fencing. This may reflect the effects of more fencing along certain stream orders. For example, over the past 5 years (2012 – 2017), a significant decrease in pugging disturbance (11% of bank length) was associated with a significant increase in the proportion of bank length effectively fenced (39%) for fourth order streams (data not presented).

Table 22. 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 (2012 – 2017), 10-year (2007 – 2017) and 15-year (2007 – 2017) periods.

	Land use type	2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Active erosion	Dairy	1 NS	2	1 NS	2	2 **	1
	Drystock	6 *	5	5 *	5	8 **	4
Recent erosion	Dairy	3 NS	4	-6 NS	7	5 **	3
	Drystock	4 NS	4	-7 NS	8	8 **	4
Total erosion	Dairy	4 NS	4	-5 NS	8	8 **	3
	Drystock	10 **	6	-1 NS	9	16 **	6
Pugging	Dairy	0 NS	4	-6 NS	7	-	-
	Drystock	-13 **	9	-8 **	5	-	-
Disturbed	Dairy	4 NS	5	-11 *	10	-	-
	Drystock	-4 NS	9	-10 *	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.

Over the past fifteen years, the average proportion of surveyed bank length eroded significantly increased (6 to 16% of bank length) in all except the Coromandel and Lake Taupo management zones (Table 23). For the Central Waikato, Upper Waikato and West Coast zones, there was a significant increase in bank erosion (11 – 13%) over the last 5 years (2012 – 2017). An overall decrease in bank erosion was observed in Upper Waikato, Waihou Piako, Waipā and West Coast zones over the 2007 – 2017 year period (i.e. less observed bank erosion in the 2012 survey), although this decrease was only significant (α = 0.05) for the Waihou Piako zone.

Table 23. Average proportion of bank length eroded within management zones at 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 (2007 – 2017) periods.

Management zone	Average bank length (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Central Waikato	9	15	5	16	11 **	7	1 NS	5	6 *	5
Coromandel	7	23	20	29	9 NS	18	5 NS	29	22 NS	28
Lake Taupo	4	9	3	14	11 NS	19	5 NS	15	10 NS	23
Lower Waikato	7	15	17	19	2 NS	11	3 NS	11	12 *	10
Upper Waikato	3	20	1	12	11 **	7	-8 NS	16	8 *	8
Waihou Piako	3	18	11	13	2 NS	7	-5 NS	9	11 **	5
Waipā	5	28	12	15	3 NS	8	-13 *	12	10 **	6
West Coast	7	29	10	23	13 **	9	-5 NS	21	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.

Over the past fifteen years, the average proportion of surveyed bank length eroded significantly increased (7 – 42% of bank length) for all except order 4 and 5 streams (Table 24). The reason for the large increase in order 5 waterways (42%) over this period is unclear, although it should be noted that confidence intervals around the mean estimate did increase with increasing stream order due to fewer samples. Except for order 5 streams, much of the increase in bank erosion occurred between 2002 and 2007 with a general decrease observed between 2007 and 2012. In terms of the last 5 years, significant increases in bank erosion have been limited to order 1 and 2 streams (7 and 8% respectively). Drains and order 1 streams had the smallest average proportions of bank length eroded in 2017 (14 and 15% respectively; Figure 45).

Table 24. Average proportion of bank length eroded within stream orders at 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 (2007 – 2017) periods. Stream order 0 represents drains.

Stream order	Average bank length (%)				2012 – 2017 (5-year)		2007 – 2017 (10-year)		2002 – 2017 (15-year)	
	2002	2007	2012	2017	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	6	8	11	14	3 NS	9	6 NS	10	7 *	7
1	4	23	8	15	7 *	6	-8 NS	12	11 **	5
2	5	25	12	20	8 **	6	-5 NS	7	15 **	7
3	7	23	14	21	7 NS	10	-2 NS	14	14 **	8
4	11	28	21	22	1 NS	14	-6 NS	15	11 NS	11
5	8	31	19	49	30 NS	46	19 NS	55	42 *	39
6	10	35	16	30	14 NS	66	-5 NS	73	20 NS	60

† 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

The key results in relation to stream-bank erosion are that:

- The majority (83%) of surveyed bank length across the region in 2017 was uneroded. Of the 17% of bank length observed to be eroded, 7% showed signs of active erosion while 10% had recent erosion.
- Soil disturbance is the sum of total stream-bank erosion and pugging disturbance. Approximately one quarter (24%) of the surveyed bank length across the region in 2017 was observed to be disturbed and, of this, 7% was attributed to pugging disturbance.
- There was significantly more bank length eroded for drystock (22%) compared to dairy (13%) land use and also significantly more disturbed soil in drystock (31%) compared to dairy (18%).
- There was a significantly lower proportion of disturbed bank length associated with effective fencing (17%) compared to ineffective fencing (36%).

- The average proportion of disturbed bank length in woody vegetation (18%) was significantly lower than in non-woody vegetation (26%).
- In 2017, the lowest proportion of stream bank eroded was in the Upper Waikato and Waihou Piako zones (12 and 13% respectively) and the highest proportion in the Coromandel and West coast zones (29 and 23% of bank length respectively).
- Stream orders 1 and 2 had the smallest proportions of bank length eroded (about 15%) and differed significantly from stream order 5 which had the largest proportion of bank length eroded (49%).
- The percent bank length eroded has fluctuated over the monitoring period averaging 5%, 22%, 11% and 17% in 2002, 2007, 2012 and 2017 respectively. When considering the full 15-year time frame (2002 – 2017), a significant increase in the proportion of bank length eroded of about 12% (i.e. from 5% to 17%) was detected across the Waikato region.
- The change in the amount of stream-bank erosion over time for dairy and drystock land uses revealed similar patterns to that found for the region as a whole.
- There was a significant increase in total erosion over the past 15 years for dairy and drystock, more so for drystock (16% of bank length) where the increase was double that observed for dairy (8% of bank length).
- Over the past 10 years, total soil disturbance significantly decreased for both dairy (11% of bank length) and drystock (10% of bank length) land use, reflecting reductions in both recent erosion and pugging components.
- Over the past fifteen years, the average proportion of bank length eroded increased significantly (6 to 16% of bank length) in all except the Coromandel and Lake Taupo management zones.
- Over the past fifteen years, the average proportion of bank length eroded increased significantly (7 – 42%) for all except order 4 and 5 streams.

3.7 Factors associated with stream-bank erosion

This section explores some general linkages between stream bank erosion and effective fencing using the analysis procedures outlined in Section 2.4.4. Linear regression models between four dependent variables (i.e. measures of erosion) and percentage bank length effectively fenced are summarised in Table 25 and their predictions are displayed in Figure 48. The low R^2 values (due to considerable variation between sites) mean that these regression models are poor at predicting the amount of erosion or disturbance at a particular sample site. Nevertheless, the models do provide useful estimates of the change in stream-bank erosion or soil disturbance, in response to changes in the proportion of bank length effectively fenced, when averaged over a large number of sites.

The models demonstrate that the effect of effective fencing on stream-bank erosion or soil disturbance, when averaged over a large number of sites, is very considerable. For example, the simple regression models provide good estimates of the reduction in stream-bank erosion or soil disturbance averaged across the entire Waikato region that could be expected for any increase in the proportion of effectively fenced bank length (Figure 48). Table 25 indicates that for every 10 percentage point increase in effectively fenced bank length, there would be a reduction in the average proportions of bank length with active erosion, total (active or recent) erosion, soil disturbance (total erosion or pugging disturbance > 50%) or any evidence of erosion or pugging (total erosion or pugging disturbance) of 0.8%, 0.7%, and 1.8% and 3.4% of bank length, respectively. At the extremes, these models predict that the average proportion of bank length with active erosion, total erosion, soil disturbance or any evidence of erosion or pugging with totally unfenced waterways would be 12%, 23%, 36% and 56% respectively. However, with fully fenced waterways, the amount of active erosion, total (active or recent) erosion, soil disturbance or any evidence of erosion or pugging is predicted to be 4%, 16%, 18% and 22% respectively. In 2017, the average proportions of bank length with active erosion, total (active or recent) erosion or soil disturbance were observed to be 7%, 17%, 24% respectively (see Figures 39 and 40).

Table 25. Regression models for predicting stream bank erosion from % bank length effectively fenced. 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[3]	
	% bank length	SE†	% bank length	SE†	% bank length	SE†	% bank length	SE†
Intercept	12.2 **	1.6	23.3 **	2.6	36.0 **	2.8	55.8 **	3.1
Effectively fenced (% bank length)	-0.080 **	0.020	-0.069 *	0.033	-0.183 **	0.036	-0.338 **	0.039
R^2	0.04		0.01		0.06		0.16	

† Standard error, ** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, [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.

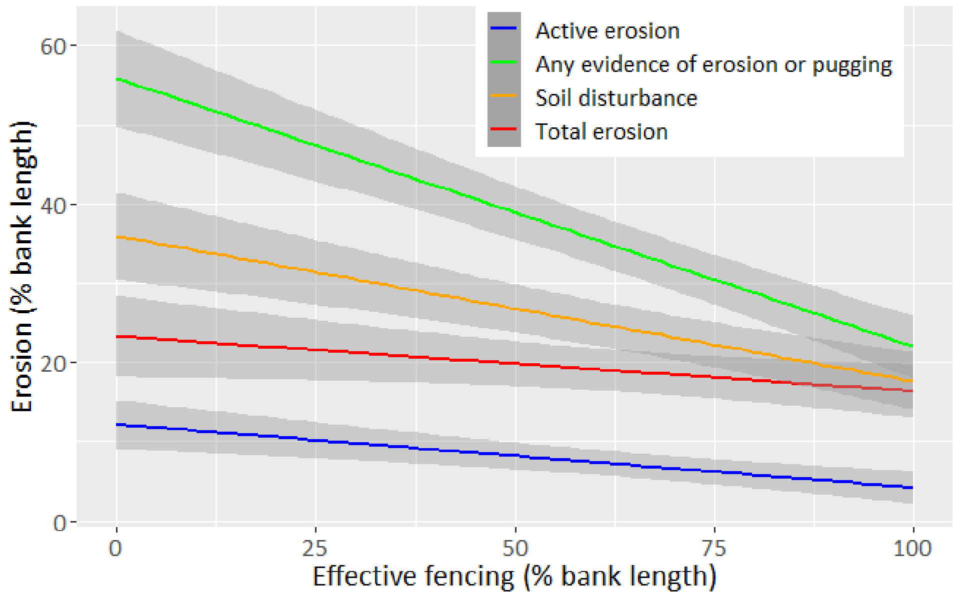

Figure 48. **Relationship between four measures of stream bank erosion (y axis) and % bank length effectively fenced (x axis). The lines show predicted erosion using the regression equations given in Table 25 and shaded areas show 95% confidence intervals of the predictions.**

More complex multiple regression models between the four dependent variables and percentage bank length fenced and with woody vegetation are shown in Table 26. These regressions were carried out to test whether woody vegetation could result in reduced erosion after accounting for fencing. These regressions indicate that the percentage effectively fenced bank length with woody vegetation had a significant effect only on the total erosion and soil disturbance category (i.e. 'any evidence of erosion or pugging'). No significant effects were observed for the active erosion, total erosion or soil disturbance categories (total stream-bank erosion or > 50% pugging disturbance) suggesting that stream bank erosion and soil disturbance weren't significantly reduced in surveyed streams with more woody vegetation. On the whole, results are consistent those presented in Sections 3.3 and 3.6 , that is, 1) a larger proportion of bank length with woody vegetation occurred in association with effective fencing than without (Figure 23) and by extension less pugging disturbance where woody vegetation predominates and 2) the presence of woody vegetation had little effect on the average proportion of bank length eroded (either in terms of total erosion or its active or recent components) (Figure 43). Significant associations between stream bank erosion and woody vegetation measures may eventuate in forthcoming survey analyses as riparian restoration efforts are advanced, particularly in relation to the establishment of woody vegetation. Associations may well be positive as new forest-shaded morphologies establish resulting in natural channel widening processes (Hughes 2012 et al., Parkyn et al. 2005).

Table 26. Regression models for predicting stream bank erosion from % bank length effectively fenced and % bank length with woody vegetation. 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[3]	
	% bank length	SE†	% bank length	SE†	% bank length	SE†	% bank length	SE†
Intercept	12.3 **	1.7	24.0 **	2.8	37.7 **	3.0	60.0 **	3.2
Effectively fenced (% bank length)	-0.079 **	0.020	-0.067 *	0.034	-0.178 **	0.036	-0.324 **	0.039
Woody vegetation (% bank length)	-0.005	0.026	-0.031	0.044	-0.076	0.047	-0.189 **	0.051
R^2	0.04		0.01		0.07		0.18	

† Standard error, ** Significant at α = 0.01, * Significant at α = 0.05, [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 purpose of this riparian characteristics survey is to assess the state and trend of key riparian characteristics along rivers, streams and drains through pastoral land in the Waikato region. Characteristics include fencing, vegetation, buffer width, crossings and stream bank erosion. Prior to the first survey in 2002, an absence of detailed riparian information made it difficult to benchmark the effects of improved riparian management over the long-term. Thus, the survey was designed to enable the repeatable, quantitative assessment of riparian characteristics and to provide a region-wide picture of the state of riparian characteristics and the changes in some of these (i.e. fencing, vegetation and stream-bank erosion) over time. Differences in riparian characteristics between land use types, management zones and stream orders (state and change over time) are also examined.

From our assessment of the current survey design, we conclude that measured variables (e.g. the percentage of effectively fenced bank length) are provided with an acceptable level of precision, both for the region as a whole and for domains of interest such as land use, management zones and Strahler order. Consequently, it is recommended that the current design be maintained with minimal change in future cycles of the survey except for some minor adjustments to the number of sample units assessed per stratum in future measurement cycles. This is necessary to reduce the sampling effort in over-represented strata and to increase sample numbers in under-represented strata. Table 27 lists the strata with the greatest excess of samples and those with the greatest deficit when compared with an efficient design. A change to 10% of samples per cycle would gradually improve the efficiency of sampling effort whilst not greatly compromising estimates of change over time.

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, 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 27. 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 2017 samples	Stream length (km)	Efficient sample number	Deficit or excess
West Coast/Drystock/1	43	4350	69	-26
Lower Waikato/Drystock/1-2	7	1412	22	-15
Waipā/Drystock/1	13	1663	26	-13
Upper Waikato/Drystock/1	3	981	15	-12
Coromandel/Drystock/1	2	687	11	-9
Lake Taupo/Drystock/1	4	800	13	-9
Upper Waikato/Dairy/1	18	1622	26	-8
Waihou Piako/Drystock/1	5	782	12	-7
West Coast/Drystock/2	11	1141	18	-7
Lower Waikato/Drystock/0,5-6	3	491	8	-5
Coromandel/Dairy/0-5	5	16	0	5
Central Waikato/Drystock/0-5	6	56	1	5
Upper Waikato/Dairy/4	7	118	2	5
Waipā/Dairy/4	7	112	2	5
Upper Waikato/Dairy/5	6	22	0	6
Waihou Piako/Dairy/0	32	1665	26	6

The statistical analysis methods used in the survey and described in this report are based on a framework known as design-based inference. This approach is the traditional method of analysing surveys of finite populations and has the advantage of requiring few assumptions other than those associated with the randomised nature of the survey design. It is recommended that this approach continue to be used as the main method of analysing data from future cycles of the survey. However, it is also worth considering whether other analysis approaches might be useful. An alternative framework often used in survey analysis is called model-based inference. If applied to the riparian survey, this approach could involve modelling the distribution of riparian characteristics spatially across the region. This approach might extract additional useful information from survey data such as identifying areas within the region with particular local characteristics. For example, the analysis could produce maps of the region showing areas with higher or lower than average levels for variables of interest such as riparian fencing or vegetation.

In terms of data capture, alternative survey techniques will be considered when there is opportunity to increase the efficiency and accuracy of measures. In this regard, remote data capture techniques including the use of satellite derived information (including remote sensing), aerial photography and drone footage have the potential to increase the scope and scale of the survey (e.g. Dufour et al. 2013; Klemas 2014). Remote assessment techniques would, nevertheless, still require the use of the field-scale survey data to ground truth results and there are also questions as to how useful these techniques would be for assessing 'fine scale', subjective characteristics such as fencing type and effectiveness. In 2018, WRC undertook a preliminary assessment of an aerial photography approach for assessing riparian characteristics at 16 of the regional survey sites located in the Central Waikato Zone (Booth, 2018). This assessment concluded that aerial imagery was generally not suitable for determining fencing, stock access and erosion characteristics but was potentially useful for evaluating riparian vegetation and waterway crossings. Consequently, it is envisioned that the current field survey methodology, while time consuming and resource intensive, 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 fenced across the Waikato region has steadily increased over the 15-year monitoring period at a rate of about 2.2% of bank length per year (from 28% in 2002 to 61% in 2017). Approximately 40% of surveyed bank length of the region's waterways in pastoral land were unprotected against stock access at the time of the 2017 survey suggesting that further work is required to encourage, support and facilitate riparian fencing efforts in the region. Assuming a constant rate of increase in riparian fencing of 2% of bank length per year, and that all waterways can and will eventually be fenced, it would take a further 20 years to complete the fencing of all pastoral waterways in the region. The strong correspondence 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.

Riparian margins in pastoral land across the Waikato region in 2017 were dominated by non-woody vegetation cover (occupying about 76% of bank length), as has been the case for the past 15 years. Moreover, the non-woody vegetation was dominated by pastoral grasses and weeds (occupying about 66% of bank length in 2017). Woody vegetation, in association with non-woody vegetation, is important because it helps to regulate stream water temperature (via stream shading), can contribute to stream-bank stability and provides additional biodiversity benefits (e.g. bird habitat). Results indicate that continued efforts are required to encourage the restoration of woody riparian vegetation in the region. Where this is not possible, (e.g. narrow buffer widths adjacent to drains), plantings of native sedges, rushes and flax should be considered, noting that the retention of a grass filter strip is still recommended for trapping sediment from runoff. About half (54%) of riparian margins were classed as narrow (i.e. have a buffer width of < 5 m) as at 2017. Wider buffer widths could be promoted in relation to new riparian fencing, particularly in areas of steep terrain (i.e. in hill country).

The proportion of surveyed bank length affected by stream-bank erosion across the region was approximately 17% in 2017 and has significantly increased from 5% in 2002. The magnitude and frequency of storm events 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). Also, because the assessment of stream-bank erosion is somewhat subjective, comparisons of erosion over time are likely to be less reliable compared with, for example, changes in the amount of fencing or stock access. Riparian soil disturbance is the sum of total stream-bank erosion and pugging disturbance caused by livestock treading. About one quarter (24%) of the bank length across the region was characterised as disturbed at the time of the 2017 survey, and of this, 7% was attributed to pugging disturbance. Importantly, there was a significant reduction in pugging (8% of bank length) since the last survey in 2012 which 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 show that, although there is great variation between individual samples, the effect of effective fencing on stream-bank erosion and soil disturbance, when averaged over a large number of sites, is considerable. It is estimated that for every 10 percentage point increase in effectively fenced bank length across the region, there would be a reduction in the average proportions of bank length with total erosion (active or recent) and soil disturbance (total erosion or pugging disturbance > 50%) of 0.7% and 1.8% respectively. In additional regression analyses, the presence of woody vegetation with effective fencing had no significant effect on active erosion, total erosion or soil disturbance (total-stream bank erosion or > 50% pugging disturbance) across surveyed streams.

4.2 Land use differences

There were substantial differences between dairy and drystock land uses with respect to riparian fencing, stock access, buffer width and soil disturbance. In 2017, dairy sites had significantly more bank length with effective fencing (87%), no stock access (74%), narrow (< 5 m) buffer widths (68%) and no soil disturbance (82%), compared to drystock sites (with 36%, 25%, 40% and 69% respectively). Effective fencing, stock access and soil disturbance all relate in some way to stock exclusion from waterways. Therefore, we conclude that the general level of livestock exclusion from waterways in the Waikato region remains considerably greater at dairy compared to drystock sites. However, drystock sites did have wider riparian buffer margins (i.e. smaller proportion of bank length with narrow buffer widths). While there was no difference in the proportion of bank length with riparian woody vegetation between dairy and drystock, there was significantly more bank length eroded for drystock (22%) compared to dairy (13%). Over the 2012 – 2017 period, the proportion of bank length effectively fenced significantly increased for dairy but not for drystock, with a rate of change of about 3.8% of bank length per year for dairy and about 1.2% for 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. Results suggest that there is a continued need to focus riparian fencing efforts toward drystock land use.

4.3 Management zone differences

Of the eight management zones in the Waikato Region, the Lake Taupo, Upper Waikato and Waihou-Piako zones had the largest proportion of surveyed bank length with effective fencing (75%, 80% and 84% respectively) in 2017. These zones also had the largest proportion of surveyed bank length with no stock access (84%, 69% and 74% respectively) and the lowest amount of stream bank erosion (14%, 12% and 13% respectively). Compared to the other management zones, the Lake Taupo and Upper Waikato zones also stood out as having an elevated proportion of bank length with woody vegetation (52% and 44% respectively) and wide (≥ 5 m) buffer widths (96% and 57% respectively). Considerable emphasis has been placed on promoting the fencing of waterways in the Lake Taupo and Upper Waikato management zones by the Waikato Regional Council through historic soil conservation schemes such as Method 4.3.5.3 of the Waikato Regional Plan (which requires that stock are excluded from mapped portions of high priority water bodies, including all tributaries flowing into Lake Taupo). The high proportion of bank length effectively fenced in the Waihou-Piako zone (a significant increase of 26% was observed over the 2012 – 2017 period) was consistent with efforts undertaken through the Dairying and Clean Streams Accord process in this predominantly dairy catchment. The West Coast zone had the lowest proportion of bank length with effective fencing (28%) and no stock access (16%) and the second highest incidence of stream bank erosion (23%) and clearly stands out as the zone that could benefit the most from future riparian fencing efforts.

4.4 Stream order differences

Small to medium-sized waterways (i.e. stream orders 1 – 3) generally had the least effective fencing (50 – 57% of bank length) and the most stock access (49 – 64% of bank length) at the time of the 2017 survey. Drains (stream order 0) and small to medium-sized waterways generally had less woody vegetation (7 – 32% of bank length) and the largest numbers of waterway crossings (2 – 3) per km of stream length. Drains had the lowest proportion of wide buffer widths (about 8% of bank length) and stream orders 1 and 2 had the least stream-bank erosion (approximately 15 – 20% of bank length). However, the amount of erosion in stream orders 1 and 2 did increase significantly over the past 5 years by about 7 – 8% of bank length. Overall, findings suggest that riparian fencing and restoration efforts are be best directed towards small and medium-sized waterways where levels of stock exclusion are elevated and the prevalence of woody vegetation remains comparably low. While drains could benefit from increased buffer widths, there are practical limitations to establishing woody vegetation around these structures (e.g. drain maintenance).

4.5 Policy analysis

An analysis of the 2017 riparian survey data set against the regulations proposed in the Action for Healthy Waterways package (Ministry for the Environment, 2020a) found that only a small percentage of surveyed bank length under low-slope (< 10°) dairy land use required effective fencing (6 – 7%). For low-slope drystock, approximately one third of surveyed bank length (28 – 37%) in 2017 was not effectively fenced. Only one third (33 – 39%) of the existing effective fencing on low-slope dairy land use was associated with a setback distance of greater or equal to 3 m (minimum setback requirement for all new fencing) while for drystock, a greater proportion of effective fencing (50 – 61%) met or exceeded this threshold. For non-low slope land (≥ 10°), a greater percentage of bank length required effective fencing in 2017 for both dairy (13 – 16%) and high intensity drystock (56 – 57%) land uses. However, more of the existing effective fencing met or exceeded setback requirement thresholds (≥ 3 m) with approximately two thirds (65 – 69%) of dairy bank length and three quarters (74 – 76%) of drystock bank length associated with a setback of less than 3 m. Assuming a deadline of July 2023 for exclusion of dairy cattle and pigs and a deadline of July 2025 for exclusion of dairy support cattle, beef cattle and deer, the rate of increase in fencing required on low-slope land (% bank length per year) to exclude stock from remaining unfenced sections is approximately 2.2% for dairy and 6.2% for drystock. On non-low slope land (July 2023 deadline), the rate is approximately 4.8% for dairy and 6.2% for high intensity drystock. Over the past fifteen years, the proportion of bank length fenced across the region has increased at about 3.1% and 1.3% of bank length per year for dairy and drystock land use respectively.

Under Plan Change 1 (PC1) regulations (outlined in Schedule C of the 2020 decisions version document; (Waikato Regional Council, 2020) and for low-slope land use (< 15°), the percentage surveyed bank length effectively fenced in 2017 for narrow (< 2 m) and wide drains (≥ 2 m) was 90% and 79% respectively across qualifying management zones (Upper Waikato, Central Waikato, Lower Waikato and Waipā). For streams and rivers (Strahler orders 1 – 6), approximately 79% of surveyed bank length was effectively fenced. There were very few drain transects sampled on non-low slope (< 15°), high stock intensity land (< 2) and comparably few streams and rivers (n = 16). The latter had a high percentage of bank length effectively fenced (96%). Approximately 55% of the existing effective fencing on low-slope streams and rivers was associated with a setback distance of greater or equal to 3 m, the minimum setback requirement for all new fencing on these waterways. For drains, 74% and 64% of effectively fenced bank length was associated with a setback distance of greater than 1 m for narrow and wide drains respectively, noting that the minimum setback distance of 1 m applies only to drains with a bank-to-bank width of greater or equal to 2 m. Overall, results indicate that fencing of narrow drains (< 2 m) in PC1 zones is largely complete with approximately 10% bank length remaining unfenced or ineffectively fenced. A greater percentage of bank length remains unfenced across qualifying streams and rivers (21%), particularity in the Central Waikato (47%) and Lower Waikato (35%) management zones.

4.6 Survey design review

The regional riparian characteristics survey provides robust estimates on the state and trend of key riparian characteristics in the region on a five-yearly cycle. Measured variables (e.g. the percentage of effectively fenced bank length) are provided with good precision, both for the region as a whole and for domains of interest such as land use and management zones. It is recommended that the current design and statistical analysis framework (i.e. design-based inference) be maintained without much change in future cycles of the survey except for some minor adjustments to the number of sample units assessed per stratum to reduce the sampling effort in over-represented strata and to increase sample numbers in under-represented strata. In terms of data capture, it is envisioned that the current field survey methodology, while time consuming and resource intensive, 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. Nevertheless, alternative survey techniques such as remote sending, aerial photography and drone footage are being considered as viable options to supplement field scale survey data.

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6 Appendices

Appendix 1

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	63625	Forestry	1.1
		Horticultural & Cropping	2.7
		Indigenous	4.4
		Other/No Data	17.4
		Pasture	74.4
Coromandel	195722	Forestry	15.2
		Horticultural & Cropping	0.2
		Indigenous	63.1
		Other/No Data	2.5
		Pasture	18.9
Lake Taupo	349595	Forestry	21.3
		Horticultural & Cropping	0.1
		Indigenous	41.7
		Other/No Data	22.7
		Pasture	14.2
Lower Waikato	291172	Forestry	4.8
		Horticultural & Cropping	2.7
		Indigenous	13.3
		Other/No Data	8.1
		Pasture	71.1
Upper Waikato	432778	Forestry	29.3
		Horticultural & Cropping	0.6
		Indigenous	12.7
		Other/No Data	2.8
		Pasture	54.7
Waihou Piako	394509	Forestry	6.3
		Horticultural & Cropping	1.0
		Indigenous	23.5
		Other/No Data	2.7
		Pasture	66.5
Waipā	306739	Forestry	3.9
		Horticultural & Cropping	0.6
		Indigenous	19.3
		Other/No Data	2.3
		Pasture	73.9
West Coast	424911	Forestry	5.6
		Horticultural & Cropping	0.1
		Indigenous	36.0
		Other/No Data	2.1
		Pasture	56.3

† Based on LCDB4.1

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), 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	36.2	13.4
	Beef & lower-stocked dairy farms	25.9	
	Mid-range of dairy farms	15.9	
	Higher-stocked dairy farms	22.0	
Coromandel	Sheep farms	47.0	11.1
	Beef & lower-stocked dairy farms	27.3	
	Mid-range of dairy farms	10.3	
	Higher-stocked dairy farms	15.5	
Lake Taupo	Sheep farms	62.2	8.7
	Beef & lower-stocked dairy farms	20.2	
	Mid-range of dairy farms	6.3	
	Higher-stocked dairy farms	11.1	
Lower Waikato	Sheep farms	40.7	12.8
	Beef & lower-stocked dairy farms	23.8	
	Mid-range of dairy farms	16.6	
	Higher-stocked dairy farms	18.9	
Upper Waikato	Sheep farms	37.3	13.8
	Beef & lower-stocked dairy farms	27.2	
	Mid-range of dairy farms	22.6	
	Higher-stocked dairy farms	12.8	
Waihou Piako	Sheep farms	24.9	18.5
	Beef & lower-stocked dairy farms	21.2	
	Mid-range of dairy farms	26.1	
	Higher-stocked dairy farms	27.7	
Waipā	Sheep farms	33.8	15.4
	Beef & lower-stocked dairy farms	23.0	
	Mid-range of dairy farms	21.5	
	Higher-stocked dairy farms	21.6	
West Coast	Sheep farms	54.1	9.9
	Beef & lower-stocked dairy farms	27.0	
	Mid-range of dairy farms	8.8	
	Higher-stocked dairy farms	10.2	

‡ Waikato Regional Council stock density indicator data based on the AsureQuality AgriBase database and LCDB4.1

Appendix 2

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	2002	2007	2012	2017
Central Waikato	Dairy	0	187	191	203	1	1	1	1
		1	79	75	98	1	1	3	1
		2	22	21	23	1	1	5	1
		3	17	17	17	2	1	3	2
		4	3	1	1	1	1	1	1
		5	2	2	2	2	2	7	2
	Drystock	0	73	73	56	1	1	1	1
		1	216	221	202	2	0	2	2
		2	54	57	54	0	0	2	1
		3	30	30	30	1	0	3	3
		4	7	7	5	1	1	0	0
		5	7	7	8	0	0	0	0
Coromandel	Dairy	0	10	11	16	0	0	0	0
		1	102	103	116	0	0	4	0
		2	38	38	42	0	0	1	0
		3	22	21	23	0	0	1	0
		4	12	12	12	0	0	3	1
		5	2	2	1	2	0	0	0
	Drystock	0	12	11	5	0	0	0	0
		1	708	699	687	1	1	4	4
		2	178	173	172	2	2	4	2
		3	94	94	89	6	5	4	4
		4	17	19	17	4	3	5	3
		5	6	6	5	4	2	2	2
Lake Taupo	Dairy	1	19	18	35	1	0	1	0
		2	3	3	4	1	1	1	1
	Drystock	0	13	13	10	2	2	2	1
		1	863	832	800	8	10	11	4
		2	265	242	237	19	18	17	10
		3	139	132	126	8	8	8	7
		4	44	31	30	1	1	1	1
		5	5	7	7	0	0	0	0
		6	10	10	7	0	0	0	0
Lower Waikato	Dairy	0	1279	1265	1394	2	2	2	26
		1	503	452	520	2	2	5	7
		2	150	138	154	3	3	5	4
		3	93	82	90	1	1	5	1
		4	65	62	65	4	2	5	2
		5	8	7	8	2	1	3	1
		6	6	6	6	1	0	0	0
	Drystock	0	474	536	491	2	0	0	2
		1	1361	1440	1412	5	0	2	5
		2	355	375	373	5	5	5	4
		3	194	207	206	7	5	5	2

		4	97	102	105	4	4	4	2
		5	24	26	25	1	1	1	1
		6	4	4	4	2	3	2	1
Upper Waikato	Dairy	0	57	52	57	1	1	1	1
		1	1137	1588	1622	8	8	8	13
		2	349	514	551	5	6	6	7
		3	226	337	341	7	7	6	6
		4	70	103	118	10	7	10	7
		5	21	23	22	5	6	7	4
		6	2	1	1	3	3	3	3
		7	2	0	1	0	0	0	0
	Drystock	0	12	14	12	0	0	0	0
		1	1168	1192	981	6	6	6	8
		2	344	353	277	8	7	7	5
		3	172	176	127	9	7	8	5
		4	59	54	42	5	3	4	3
		5	4	5	5	2	2	2	2
		7	2	1	0	0	0	0	0
Waihou Piako	Dairy	0	1596	1603	1665	9	5	6	33
		1	1221	1197	1210	11	9	9	15
		2	379	386	390	8	5	6	8
		3	206	213	216	4	1	3	3
		4	80	84	75	7	3	2	2
		5	95	94	91	7	3	3	3
		6	11	10	11	7	3	5	3
	Drystock	0	279	263	235	0	0	0	0
		1	821	834	782	2	3	3	7
		2	242	244	223	4	1	1	2
		3	118	119	107	2	1	1	1
		4	41	41	39	3	2	2	1
		5	24	26	24	0	0	0	0
		6	2	1	2	0	0	0	0
Waipā	Dairy	0	306	303	318	3	1	2	5
		1	949	951	1134	9	9	10	16
		2	283	287	330	4	3	4	3
		3	180	181	219	7	6	7	6
		4	96	99	112	5	5	8	5
		5	58	56	59	7	5	7	5
		6	13	13	15	5	4	5	4
	Drystock	0	84	87	80	3	3	3	3
		1	1832	1806	1663	9	6	7	18
		2	514	506	474	12	11	11	10
		3	291	290	260	7	5	5	5
		4	138	132	107	9	6	5	4
		5	50	52	48	4	3	3	3
		6	6	6	4	2	2	2	2
West Coast	Dairy	0	13	11	14	0	0	0	0
		1	187	192	237	0	0	3	3
		2	45	52	62	1	1	3	1
		3	29	25	34	0	0	3	0
		4	16	14	18	0	0	1	0
		5	5	5	14	0	0	1	0
		6	0	0	2	0	0	0	0

Drystock	0	75	78	72	3	3	2	2
	1	4419	4418	4350	7	7	8	43
	2	1150	1141	1141	5	4	4	12
	3	623	627	617	7	5	5	9
	4	294	300	299	6	6	8	6
	5	70	72	64	6	6	9	6
	6	10	10	6	6	6	6	6
	7	5	5	4	0	0	0	0

† Based on a Land Information NZ (LINZ) 1:50000 hydrology layer.

‡ Number of transects sampled (500 m) within each stream length population.

Appendix 3

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 (2017 samples per km)
			2002	2007	2012	2017			
Central Waikato	Dairy	0	1	1	1	1	2007	187	0.0053
		1	1	1	3	1	2007	79	0.0127
		2	1	1	5	1	2012	21	0.0476
		3	2	1	3	2	2007	17	0.1176
		4	1	1	1	1	2007	3	0.3333
		5	2	2	7	2	2007	2	1.0000
	Drystock	0 – 5	5	2	8	7	2007	387	0.0181
Coromandel	Dairy	0 – 5	2	0	9	1	2012	187	0.0053
	Drystock	0, 5	4	2	2	2	2007	18	0.1111
		1	1	1	4	4	2012	699	0.0057
		2	2	2	4	2	2007	178	0.0112
		3	6	5	4	4	2007	94	0.0426
		4	4	3	5	3	2007	17	0.1765
Lake Taupo	Dairy	1 – 2	2	1	2	1	2007	22	0.0455
	Drystock	0	2	2	2	1	2007	13	0.0769
		1	8	10	11	4	2007	863	0.0046
		2	19	18	17	10	2007	265	0.0377
		3	8	8	8	7	2007	139	0.0504
		4 – 6	1	1	1	1	2007	59	0.0169
Lower Waikato	Dairy	0	2	2	2	26	2017	1394	0.0187
		1	2	2	5	7	2012	452	0.0155
		2	3	3	5	4	2007	150	0.0267
		3	1	1	5	1	2012	82	0.0122
		4	4	2	5	2	2007	65	0.0308
		5 – 6	3	1	3	1	2007	14	0.0714
	Drystock	0, 5 – 6	5	4	3	4	2007	502	0.0080
		1 – 2	10	5	7	9	2007	1716	0.0052
		3	7	5	5	2	2007	194	0.0103
		4	4	4	4	2	2007	97	0.0206
Upper Waikato	Dairy	0	1	1	1	1	2007	57	0.0175
		1	8	8	8	13	2007	1137	0.0114
		2	5	6	6	7	2007	349	0.0201
		3	7	7	6	6	2007	226	0.0265
		4	10	7	10	7	2007	70	0.1000
		5	5	6	7	4	2007	21	0.1905
		6 – 7	3	3	3	3	2007	4	0.7500
	Drystock	0, 5 – 7	2	2	2	2	2007	18	0.1111
		1	6	6	6	8	2007	1168	0.0068
		2	8	7	7	5	2007	344	0.0145

		3	9	7	8	5	2007	172	0.0291
		4	5	3	4	3	2007	59	0.0508
Waihou Piako	Dairy	0	9	5	6	33	2012	1603	0.0206
		1	11	9	9	15	2007	1221	0.0123
		2	8	5	6	8	2007	379	0.0211
		3	4	1	3	3	2007	206	0.0146
		4	7	3	2	2	2007	80	0.0250
		5	7	3	3	3	2007	95	0.0316
		6	7	3	5	3	2007	11	0.2727
	Drystock	0, 4 – 6	3	2	2	1	2007	346	0.0029
		1	2	3	3	7	2012	834	0.0084
		2	4	1	1	2	2007	242	0.0083
		3	2	1	1	1	2007	118	0.0085
Waipā	Dairy	0	3	1	2	5	2012	303	0.0165
		1	9	9	10	16	2007	949	0.0169
		2	4	3	4	3	2007	283	0.0106
		3	7	6	7	6	2007	180	0.0333
		4	5	5	8	5	2007	96	0.0521
		5	7	5	7	5	2007	58	0.0862
		6	5	4	5	4	2007	13	0.3077
	Drystock	0	3	3	3	3	2007	84	0.0357
		1	9	6	7	18	2012	1806	0.0100
		2	12	11	11	10	2007	514	0.0195
		3	7	5	5	5	2007	291	0.0172
		4	9	6	5	4	2007	138	0.0290
		5	4	3	3	3	2007	50	0.0600
		6	2	2	2	2	2007	6	0.3333
West Coast	Dairy	0 – 6	1	1	11	4	2012	299	0.0134
	Drystock	0	3	3	2	2	2007	75	0.0267
		1	7	7	8	43	2012	4418	0.0097
		2	5	4	4	12	2012	1141	0.0105
		3	7	5	5	9	2007	623	0.0144
		4	6	6	8	6	2007	294	0.0204
		5	6	6	9	6	2007	70	0.0857
		6 – 7	6	6	6	6	2007	15	0.4000

Appendix 4

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 2017. The number of samples (n) analysed within each population has been included for reference.

		n	Bank length analysis (% bank length)		---------- Stream length analysis ---------- (% stream length)		
			Effectively fenced (total)	Not effectively fenced	Both banks fenced	One bank fenced	Neither bank fenced
	Overall	432	60.6 (4.2)	39.4 (0.9)	53.6 (4.4)	14.5 (3.4)	31.9 (4.7)
Land use type	Dairy	244	86.8 (4.0)	13.2 (1.2)	80.6 (5.0)	12.8 (3.6)	6.6 (3.7)
	Drystock	188	35.7 (6.5)	64.3 (1.4)	27.8 (6.5)	16.2 (5.6)	56.0 (7.7)
Management zone	Central Waikato	15	62.9 (21.5)	37.1 (15.5)	55.5 (21.9)	14.7 (6.4)	29.9 (21.6)
	Coromandel	16	60.2 (35.0)	39.8 (2.6)	51.9 (35.5)	16.4 (19.9)	31.6 (37.3)
	Lake Taupo	24	74.7 (30.9)	25.3 (0.5)	68.6 (32.5)	12.3 (21.5)	19.0 (32.9)
	Lower Waikato	58	59.9 (9.8)	40.1 (2.1)	48.8 (11.7)	25.6 (13.2)	25.6 (12.6)
	Upper Waikato	64	80.4 (11.1)	19.6 (3.1)	75.5 (11.9)	10.0 (6.2)	14.5 (11.3)
	Waihou Piako	78	84.2 (8.4)	15.8 (1.0)	79.5 (9.6)	9.2 (6.3)	11.3 (8.3)
	Waipā	89	64.1 (9.9)	35.9 (2.6)	56.0 (10.6)	16.4 (7.1)	27.6 (10.5)
	West Coast	88	28.0 (8.4)	72.0 (2.1)	21.8 (7.9)	12.4 (6.5)	65.8 (10.0)
Stream order	0	73	89.5 (4.5)	10.5 (2.6)	82.6 (7.8)	15.0 (7.1)	2.4 (1.7)
	1	145	49.6 (6.9)	50.4 (1.4)	43.7 (6.9)	12.4 (4.8)	43.9 (7.7)
	2	71	65.0 (10.1)	35.0 (0.9)	56.1 (12.4)	17.9 (10.9)	26.0 (10.5)
	3	54	56.6 (11.4)	43.4 (2.7)	46.3 (12.3)	20.5 (10.0)	33.2 (12.6)
	4	38	77.6 (13.7)	22.4 (4.4)	72.6 (15.4)	9.9 (10.5)	17.5 (13.8)
	5	29	80.5 (19.3)	19.5 (12.3)	68.7 (29.0)	23.5 (28.0)	7.8 (17.2)
	6	19	78.5 (30.2)	21.5 (9.2)	67.2 (33.1)	22.4 (32.0)	10.4 (35.9)

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 and 2017. 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	28.1 (4.5)	20.9 (5.7)	22.9 (5.4)	56.2 (4.9)
		2007	298	36.2 (6.5)	24.3 (7.2)	23.8 (6.4)	51.9 (7.3)
		2012	382	49.5 (5.6)	37.7 (6.9)	23.7 (5.8)	38.5 (5.6)
		2017	432	60.6 (4.2)	53.6 (4.4)	14.5 (3.4)	31.9 (4.7)
Land use type	Dairy	2002	160	44.1 (8.6)	31.9 (12.6)	37.8 (12.5)	30.3 (7.2)
		2007	91	46.9 (12.7)	31.0 (12.6)	31.8 (12.2)	37.2 (15.4)
		2012	196	72.4 (6.5)	56.8 (11.3)	31.4 (10.9)	11.9 (4.0)
		2017	244	86.8 (4.0)	80.6 (5.0)	12.8 (3.6)	6.6 (3.7)
	Drystock	2002	214	18.5 (5.0)	14.2 (5.0)	13.9 (4.5)	71.9 (6.6)
		2007	207	31.4 (9.0)	21.3 (9.2)	20.2 (6.2)	58.5 (9.8)
		2012	186	30.6 (6.8)	22.0 (7.0)	17.4 (5.7)	60.6 (7.8)
		2017	188	35.7 (6.5)	27.8 (6.5)	16.2 (5.6)	56.0 (7.7)

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 2017. 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	432	51.3 (4.1)	48.7 (48.7)	12.1 (2.5)	17.1 (3.2)	22.1 (4.2)
Land use type	**Dairy**	244	26.4 (5.6)	73.6 (73.6)	9.3 (2.9)	7.3 (2.9)	9.8 (4.0)
	Drystock	188	74.8 (5.6)	25.2 (25.2)	14.7 (4.0)	26.4 (5.6)	33.7 (7.3)
Management zone	**Central Waikato**	15	37.4 (20.9)	62.6 (62.6)	8.8 (18.7)	12.9 (15.7)	15.8 (9.1)
	Coromandel	16	55.9 (35.0)	44.1 (44.1)	15.0 (17.3)	6.3 (12.2)	34.6 (31.6)
	Lake Taupo	24	15.8 (32.3)	84.2 (84.2)	0.0 (0.0)	0.0 (0.0)	15.8 (32.3)
	Lower Waikato	58	55.6 (9.9)	44.4 (44.4)	12.5 (5.7)	31.9 (11.5)	11.3 (10.5)
	Upper Waikato	64	30.9 (13.4)	69.1 (69.1)	7.1 (4.2)	2.8 (3.3)	21.0 (12.8)
	Waihou Piako	78	25.6 (9.6)	74.4 (74.4)	12.9 (7.2)	8.5 (5.8)	4.2 (4.8)
	Waipā	89	53.5 (10.1)	46.5 (46.5)	11.2 (5.5)	21.8 (8.9)	20.5 (9.1)
	West Coast	88	84.0 (5.3)	16.0 (16.0)	16.5 (5.9)	23.5 (7.2)	44.0 (10.1)
Stream order	**0**	75	17.8 (8.1)	82.2 (82.2)	7.9 (5.2)	6.2 (5.0)	3.7 (3.6)
	1	146	63.8 (6.5)	36.2 (36.2)	10.8 (3.4)	21.0 (5.5)	32.0 (7.3)
	2	71	48.6 (11.0)	51.4 (51.4)	13.1 (7.3)	15.6 (7.3)	19.8 (8.8)
	3	54	52.0 (11.7)	48.0 (48.0)	23.0 (9.1)	19.5 (8.7)	9.5 (8.9)
	4	38	33.9 (15.0)	66.1 (66.1)	14.5 (9.4)	10.6 (10.1)	8.7 (10.2)
	5	29	18.0 (16.9)	82.0 (82.0)	4.2 (9.2)	7.4 (13.5)	6.4 (16.9)
	6	19	54.2 (34.3)	45.8 (45.8)	26.6 (27.7)	25.2 (23.5)	2.4 (30.9)
Clean Streams Accord	**Qualifying sites**	146	19.3 (6.7)	80.7 (6.7)	6.7 (2.9)	6.2 (2.9)	6.4 (3.4)
	All other sites	286	53.8 (5.6)	46.2 (5.6)	14.2 (2.9)	17.4 (3.5)	22.3 (4.5)

Table A4-4: Average proportion of bank length (95% confidence interval in parentheses) of vegetation categories for the region as a whole (overall) and for land use type, management zone, stream order, and fencing categories in 2017. The number of samples (n) analysed within each population are included for reference.

		n	Simplified vegetation categories (% bank length)		Detailed vegetation categories (% bank length)					
			Woody	Non-woody	Woody native	Woody exotic (willow)	Woody exotic (deciduous)	Woody exotic (evergreen)	Grass and weeds	Flax/sedge/rush
	Overall	432	23.8 (3.0)	76.2 (3.0)	9.8 (2.3)	4.0 (1.1)	3.6 (1.0)	6.4 (1.7)	66.4 (3.7)	9.8 (2.5)
Land use type	Dairy	244	22.8 (4.0)	77.2 (4.0)	6.2 (2.9)	4.7 (1.8)	4.2 (1.5)	7.7 (2.6)	72.9 (4.3)	4.3 (1.8)
Land use type	Drystock	188	24.7 (4.5)	75.3 (4.5)	13.2 (3.6)	3.4 (1.5)	3.0 (1.4)	5.2 (2.2)	60.3 (5.8)	15.0 (4.6)
Management zone	Central Waikato	15	18.2 (14.6)	81.8 (14.6)	2.1 (0.7)	6.5 (14.9)	8.5 (5.8)	1.2 (3.4)	80.5 (14.7)	1.3 (0.3)
Management zone	Coromandel	16	48.1 (23.7)	51.9 (23.7)	26.4 (25.7)	5.9 (3.4)	5.5 (6.3)	10.2 (7.8)	50.7 (23.6)	1.2 (1.6)
Management zone	Lake Taupo	24	51.9 (26.7)	48.1 (26.7)	11.7 (7.2)	3.1 (2.6)	4.0 (3.9)	33.1 (22.6)	33.0 (30.3)	15.1 (24.9)
Management zone	Lower Waikato	58	13.6 (7.1)	86.4 (7.1)	7.5 (6.3)	1.5 (2.0)	3.9 (3.3)	0.8 (1.1)	75.8 (10.5)	10.6 (6.9)
Management zone	Upper Waikato	64	43.8 (10.4)	56.2 (10.4)	13.0 (7.2)	8.6 (4.2)	5.9 (4.2)	16.3 (8.1)	50.0 (11.3)	6.2 (5.8)
Management zone	Waihou Piako	78	17.6 (5.1)	82.4 (5.1)	6.0 (3.7)	4.0 (3.0)	2.4 (1.4)	5.1 (2.7)	78.0 (5.9)	4.4 (3.9)
Management zone	Waipā	89	18.8 (5.7)	81.2 (5.7)	8.8 (4.4)	3.5 (3.2)	2.9 (1.6)	3.5 (2.6)	73.9 (6.1)	7.3 (3.0)
Management zone	West Coast	88	19.1 (5.9)	80.9 (5.9)	10.7 (5.0)	3.3 (2.0)	2.4 (2.0)	2.6 (1.9)	62.8 (7.9)	18.1 (6.8)
Stream order	0	75	6.5 (3.2)	93.5 (3.2)	1.2 (1.0)	0.5 (1.0)	2.8 (2.1)	2.1 (1.8)	91.1 (3.8)	2.4 (2.0)
Stream order	1	146	23.7 (4.7)	76.3 (4.7)	10.6 (3.8)	2.8 (1.3)	3.6 (1.6)	6.6 (2.7)	62.2 (5.9)	14.1 (4.4)
Stream order	2	71	29.1 (7.5)	70.9 (7.5)	14.7 (5.9)	3.2 (3.3)	2.9 (2.1)	8.3 (4.3)	63.1 (7.8)	7.8 (4.8)
Stream order	3	54	32.3 (7.4)	67.7 (7.4)	10.2 (4.6)	11.2 (6.5)	4.8 (3.6)	6.0 (4.3)	62.1 (7.9)	5.7 (6.0)
Stream order	4	38	31.2 (9.5)	68.8 (9.5)	4.1 (2.6)	13.4 (8.0)	4.5 (2.3)	9.3 (5.4)	66.5 (9.2)	2.3 (1.6)
Stream order	5	29	37.9 (28.3)	62.1 (28.3)	16.1 (18.9)	7.4 (8.9)	4.3 (4.7)	10.1 (13.0)	59.3 (29.3)	2.8 (6.7)
Stream order	6	19	51.1 (37.4)	48.9 (37.4)	29.1 (28.7)	14.7 (37.2)	6.2 (11.9)	1.1 (11.6)	43.9 (40.1)	5.0 (35.8)
Fencing	Effectively fenced	328	26.5 (4.1)	73.5 (4.1)	8.2 (2.8)	4.8 (1.5)	4.3 (1.5)	9.2 (2.9)	68.0 (4.4)	5.5 (2.0)
Fencing	Not effectively fenced	260	17.2 (4.0)	82.8 (4.0)	9.9 (3.4)	3.0 (1.6)	2.4 (1.3)	2.0 (1.2)	67.8 (6.1)	14.9 (5.1)

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 and 2017. 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	25.9 (3.5)	74.1 (3.5)	5.8 (2.1)	6.0 (2.0)	14.1 (2.9)	68.0 (3.9)	6.1 (1.9)
		2007	298	31.3 (5.5)	68.7 (5.5)	9.8 (3.2)	2.9 (1.4)	18.7 (4.5)	65.3 (5.7)	3.3 (1.6)
		2012	383	27.1 (3.5)	72.9 (3.5)	8.0 (2.2)	5.9 (1.6)	13.1 (2.3)	49.1 (5.1)	23.9 (4.3)
		2017	432	23.8 (3.0)	76.2 (3.0)	9.8 (2.3)	4.0 (1.1)	9.9 (2.0)	66.4 (3.7)	9.8 (2.5)
Land use type	Dairy	2002	160	20.8 (5.4)	79.2 (5.4)	2.1 (1.6)	6.0 (3.1)	12.8 (4.1)	77.4 (5.7)	1.8 (1.5)
		2007	91	25.4 (8.5)	74.6 (8.5)	3.1 (2.4)	4.6 (3.9)	17.7 (6.6)	71.7 (8.4)	3.0 (2.8)
		2012	197	25.3 (5.1)	74.7 (5.1)	4.0 (2.0)	7.2 (2.7)	14.1 (4.1)	49.1 (7.2)	25.5 (6.6)
		2017	244	22.8 (4.0)	77.2 (4.0)	6.2 (2.9)	4.7 (1.8)	11.9 (2.8)	72.9 (4.3)	4.3 (1.8)
	Drystock	2002	214	28.9 (4.6)	71.1 (4.6)	8.0 (3.2)	6.0 (2.6)	14.9 (4.0)	62.4 (5.3)	8.7 (2.9)
		2007	207	34.0 (7.2)	66.0 (7.2)	12.8 (4.5)	2.2 (1.2)	19.1 (5.8)	62.4 (7.4)	3.5 (1.9)
		2012	186	28.5 (5.0)	71.5 (5.0)	11.3 (3.9)	4.8 (2.0)	12.3 (2.9)	49.0 (7.2)	22.5 (5.8)
		2017	188	24.7 (4.5)	75.3 (4.5)	13.2 (3.6)	3.4 (1.5)	8.1 (2.8)	60.3 (5.8)	15.0 (4.6)

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 2017. 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
	Overall	432	53.9 (3.5)	46.1 (3.5)	23.3 (3.1)	30.6 (3.1)	17.2 (2.5)	28.9 (3.3)
Land use type	**Dairy**	244	68.2 (4.6)	31.8 (4.6)	36.5 (5.0)	31.7 (3.9)	14.4 (2.9)	17.4 (4.3)
	Drystock	188	40.4 (5.5)	59.6 (5.5)	10.8 (3.8)	29.5 (4.7)	19.9 (4.1)	39.7 (5.2)
Management zone	**Central Waikato**	15	71.2 (22.5)	28.8 (22.5)	38.4 (18.4)	32.8 (13.5)	1.7 (0.8)	27.1 (22.6)
	Coromandel	16	53.1 (10.2)	46.9 (10.2)	12.4 (16.1)	40.7 (10.4)	32.0 (14.5)	15.0 (15.2)
	Lake Taupo	24	4.1 (5.5)	95.9 (5.5)	0.1 (0.3)	4.0 (5.5)	9.8 (8.0)	86.1 (9.4)
	Lower Waikato	58	70.6 (10.3)	29.4 (10.3)	40.5 (11.0)	30.2 (9.5)	17.2 (7.6)	12.2 (6.6)
	Upper Waikato	64	42.5 (12.7)	57.5 (12.7)	16.3 (9.6)	26.2 (8.1)	20.7 (8.1)	36.7 (13.4)
	Waihou Piako	78	69.3 (7.1)	30.7 (7.1)	38.1 (7.5)	31.2 (6.4)	12.7 (4.3)	18.0 (6.1)
	Waipā	89	54.4 (8.0)	45.6 (8.0)	20.6 (7.1)	33.8 (7.7)	16.9 (5.3)	28.7 (8.3)
	West Coast	88	44.8 (7.7)	55.2 (7.7)	11.1 (4.4)	33.7 (6.9)	19.4 (6.0)	35.7 (7.4)
Stream order	**0**	75	92.1 (5.7)	7.9 (5.7)	71.1 (8.9)	21.0 (6.2)	3.2 (2.3)	4.7 (5.0)
	1	146	48.8 (5.6)	51.2 (5.6)	17.3 (4.3)	31.5 (4.4)	16.5 (3.8)	34.8 (5.4)
	2	71	49.5 (8.6)	50.5 (8.6)	19.6 (8.7)	29.9 (7.5)	26.0 (7.8)	24.5 (6.5)
	3	54	44.5 (10.7)	55.5 (10.7)	9.3 (5.0)	35.2 (9.1)	19.5 (7.3)	36.0 (11.5)
	4	38	37.6 (10.3)	62.4 (10.3)	3.1 (3.3)	34.5 (9.4)	26.8 (8.3)	35.6 (9.5)
	5	29	48.1 (37.3)	51.9 (37.3)	2.5 (3.5)	45.7 (35.8)	18.2 (19.3)	33.6 (32.2)
	6	19	51.9 (29.9)	48.1 (29.9)	0.0 (0.9)	51.9 (29.9)	35.7 (29.5)	12.4 (43.5)

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 2017. 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**
Management zone	**Woody**	**Overall**	263	34.7 (6.3)	65.3 (6.3)	6.5 (2.3)	28.2 (5.6)	23.1 (4.7)	42.2 (7.2)
		Dairy	131	40.2 (9.9)	59.8 (9.9)	10.3 (4.8)	29.9 (8.0)	24.1 (7.1)	35.7 (11.3)
		Drystock	132	30.4 (8.2)	69.6 (8.2)	3.6 (1.7)	26.8 (7.8)	22.4 (6.3)	47.3 (9.1)
	Non woody	**Overall**	411	59.6 (3.9)	40.4 (3.9)	28.2 (3.7)	31.4 (3.5)	15.4 (2.9)	24.9 (3.7)
		Dairy	233	75.6 (4.3)	24.4 (4.3)	43.3 (5.5)	32.3 (4.4)	11.8 (2.8)	12.6 (3.6)
		Drystock	178	43.7 (6.4)	56.3 (6.4)	13.3 (4.8)	30.4 (5.4)	19.1 (5.0)	37.2 (6.4)

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 2017. The number of samples (n) analysed within each population are included for reference.

		n	Stream crossing type (% of observed crossings)			Total crossings (number per km stream length)
			Bridges	**Fords**	**Culverts**	**Total**
	Overall	272	14.4 (3.3)	2.8 (1.4)	82.8 (3.6)	2.7 (0.3)
Land use type	**Dairy**	154	14.7 (4.4)	1.2 (0.5)	84.2 (4.4)	2.7 (0.4)
	Drystock	118	14.2 (5.0)	4.4 (2.6)	81.5 (5.8)	2.6 (0.4)
Management zone	**Central Waikato**	9	12.6 (24.9)	3.1 (8.3)	84.3 (22.4)	4.8 (1.6)
	Coromandel	7	0.5 (3.4)	14.9 (18.8)	84.7 (19.3)	3.0 (2.0)
	Lake Taupo	19	43.5 (43.1)	7.6 (6.4)	48.9 (43.4)	1.9 (0.3)
	Lower Waikato	39	14.6 (10.4)	0.7 (1.7)	84.7 (10.5)	2.1 (0.5)
	Upper Waikato	37	14.3 (8.2)	0.0 (0.0)	85.7 (8.2)	2.5 (0.7)
	Waihou Piako	51	17.8 (8.1)	4.2 (5.2)	78.0 (10.3)	2.3 (0.5)
	Waipā	56	12.5 (6.9)	2.5 (3.5)	85.0 (7.0)	3.3 (0.7)
	West Coast	54	13.1 (5.9)	1.7 (2.4)	85.3 (6.6)	2.9 (0.6)
Stream order	**0**	50	4.3 (4.3)	0.0 (0.0)	95.7 (4.3)	2.8 (0.7)
	1	118	9.0 (3.8)	1.8 (1.6)	89.2 (4.0)	3.2 (0.4)
	2	57	25.4 (10.1)	5.1 (5.5)	69.5 (11.8)	2.3 (0.5)
	3	32	61.8 (17.6)	4.4 (6.3)	33.8 (17.6)	1.9 (0.6)
	4	9	27.2 (51.0)	48.9 (61.0)	23.9 (53.2)	0.63 (0.37)
	5	5	100 (0)	0	0	0.20 (0.50)
	6	1	100 (0)	0	0	0.02 (0.52)

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 2017. 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**
	Overall	418	82.7 (3.2)	10.3 (2.2)	7.1 (2.1)	17.3 (3.2)	7.0 (2.1)	24.3 (3.7)	75.7 (3.7)
Land use type	**Dairy**	238	87.2 (0.0)	9.2 (2.6)	3.6 (1.3)	12.8 (3.0)	4.8 (2.9)	17.6 (3.9)	82.4 (3.9)
	Drystock	180	78.3 (0.0)	11.3 (3.7)	10.5 (3.9)	21.7 (5.5)	9.1 (3.2)	30.8 (6.4)	69.2 (6.4)
Management zone	**Central Waikato**	15	84.4 (5.2)	13.9 (5.2)	1.7 (2.5)	15.6 (5.2)	0.6 (2.7)	16.3 (5.9)	83.7 (5.9)
	Coromandel	16	71.4 (29.8)	20.7 (22.6)	7.9 (7.8)	28.6 (29.8)	9.9 (22.9)	38.5 (29.9)	61.5 (29.9)
	Lake Taupo	18	85.8 (21.4)	4.5 (5.3)	9.6 (18.9)	14.2 (21.4)	11.2 (23.3)	25.4 (44.4)	74.6 (44.4)
	Lower Waikato	58	81.3 (10.4)	8.9 (5.8)	9.8 (8.0)	18.7 (10.4)	8.8 (5.0)	27.5 (10.9)	72.5 (10.9)
	Upper Waikato	63	88.3 (7.6)	9.0 (7.1)	2.7 (2.1)	11.7 (7.6)	2.8 (5.0)	14.5 (8.9)	85.5 (8.9)
	Waihou Piako	77	86.9 (4.7)	8.8 (4.1)	4.2 (2.7)	13.1 (4.7)	1.8 (1.3)	14.9 (4.7)	85.1 (4.7)
	Waipā	85	85.0 (4.7)	10.2 (3.0)	4.8 (3.4)	15.0 (4.7)	10.1 (6.2)	25.1 (7.1)	74.9 (7.1)
	West Coast	86	76.8 (7.0)	11.8 (5.3)	11.4 (5.1)	23.2 (7.0)	9.7 (4.3)	32.9 (7.7)	67.1 (7.7)
Stream order	**0**	74	86.2 (5.7)	9.9 (4.6)	3.9 (2.8)	13.8 (5.7)	1.9 (2.3)	15.7 (6.1)	84.3 (6.1)
	1	140	84.9 (4.8)	8.1 (3.1)	7.0 (3.6)	15.1 (4.8)	9.8 (3.7)	24.9 (5.8)	75.1 (5.8)
	2	66	80.1 (7.2)	11.8 (5.8)	8.1 (4.8)	19.9 (7.2)	7.0 (4.8)	26.9 (9.0)	73.1 (9.0)
	3	53	79.2 (8.3)	14.8 (7.7)	6.0 (3.7)	20.8 (8.3)	4.2 (5.3)	25.0 (9.0)	75.0 (9.0)
	4	37	78.1 (8.6)	9.8 (3.5)	12.1 (8.7)	21.9 (8.6)	2.0 (2.3)	23.9 (8.4)	76.1 (8.4)
	5	29	50.8 (38.5)	35.2 (30.4)	14.1 (11.8)	49.2 (38.5)	0.1 (3.7)	49.3 (38.5)	50.7 (38.5)
	6	19	70.3 (45.1)	19.2 (44.4)	10.4 (6.8)	29.7 (45.1)	0.0 (0.0)	29.7 (45.1)	70.3 (45.1)

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 2017. 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	328	75.5 (4.3)	9.9 (2.6)	4.2 (1.4)	14.0 (3.2)	2.9 (1.5)	16.9 (3.5)	83.1 (3.5)
Fencing	Not effectively fenced	260	42.2 (6.7)	11.0 (3.8)	11.5 (4.7)	22.5 (6.0)	13.4 (4.4)	35.9 (6.8)	64.1 (6.8)
Vegetation type	Woody	291	75.7 (5.6)	8.5 (3.6)	5.9 (2.2)	14.4 (4.5)	3.1 (1.6)	17.5 (4.5)	82.5 (4.5)
Vegetation type	Non woody	407	58.6 (4.4)	10.8 (2.4)	7.4 (2.4)	18.2 (3.5)	8.2 (2.5)	26.4 (4.1)	73.6 (4.1)

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 and 2017. 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
Overall		2002	374	94.7 (1.7)	3.5 (0.9)	1.8 (0.8)	5.3 (1.7)	-	-	-
		2007	298	78.4 (5.6)	17.3 (5.4)	4.3 (2.1)	21.6 (5.6)	15.3 (3.2)	36.9 (5.4)	63.1 (5.4)
		2012	380	89.3 (2.4)	6.9 (1.8)	3.8 (1.4)	10.7 (2.4)	14.5 (4.7)	25.2 (4.6)	74.8 (4.6)
		2017	418	82.7 (3.2)	10.3 (2.2)	7.1 (2.1)	17.3 (3.2)	7.0 (2.1)	24.3 (3.7)	75.7 (3.7)
Land use type	Dairy	2002	160	94.8 (2.0)	4.0 (1.7)	1.1 (0.5)	5.2 (2.0)	-	-	-
		2007	91	81.7 (7.3)	15.7 (6.7)	2.5 (1.6)	18.3 (7.3)	10.6 (7.0)	28.9 (9.7)	71.1 (9.7)
		2012	196	90.8 (3.0)	6.5 (2.7)	2.7 (1.1)	9.2 (3.0)	4.8 (1.8)	13.9 (3.5)	86.1 (3.5)
		2017	238	87.2 (3.0)	9.2 (2.6)	3.6 (1.3)	12.8 (3.0)	4.8 (2.9)	17.6 (3.9)	82.4 (3.9)
	Drystock	2002	214	94.6 (2.4)	3.2 (1.2)	2.3 (1.3)	5.4 (2.4)	-	-	-
		2007	207	76.9 (7.7)	18.0 (7.5)	5.2 (2.9)	23.1 (7.7)	17.4 (4.4)	40.5 (7.8)	59.5 (7.8)
		2012	184	88.0 (3.8)	7.3 (2.5)	4.7 (2.4)	12.0 (3.8)	22.6 (8.1)	34.5 (7.6)	65.5 (7.6)
		2017	180	78.3 (5.5)	11.3 (3.7)	10.5 (3.9)	21.7 (5.5)	9.1 (3.2)	30.8 (6.4)	69.2 (6.4)

Table A4-12: Association between percentage bank length effectively fenced on pastoral enterprises in 2017 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 regulations[1].

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	87.1 (4.8)	193	84.5 (4.1)	224	80.9 (5.1)
	Effective fencing < 1 m	161	12.1 (4.0)	193	10.6 (3.4)	224	8.7 (2.8)
	Effective fencing 1 - 2 m	161	29.2 (6.6)	193	25.7 (6.0)	224	25.7 (6.0)
	Effective fencing 2 - 3 m	161	16.7 (4.3)	193	16.3 (4.1)	224	16.3 (4.1)
	Effective fencing 3 - 5 m	161	13.7 (3.6)	193	13.0 (3.3)	224	13.0 (3.3)
	Effective fencing 5 - 10 m	161	10.4 (3.8)	193	10.4 (3.3)	224	11.9 (3.2)
	Effective fencing > 10 m	161	5.0 (2.5)	193	8.6 (4.3)	224	5.0 (4.3)
Dairy‡	Effective fencing total	117	93.7 (2.5)	137	93.4 (2.4)	150	93.4 (2.2)
	Effective fencing < 1 m	117	15.8 (5.6)	137	14.6 (5.0)	150	13.2 (4.4)
	Effective fencing 1 - 2 m	117	32.2 (8.0)	137	30.3 (7.3)	150	27.4 (6.7)
	Effective fencing 2 - 3 m	117	18.0 (4.8)	137	17.8 (4.7)	150	16.8 (4.3)
	Effective fencing 3 - 5 m	117	12.6 (3.8)	137	13.0 (3.7)	150	14.8 (3.7)
	Effective fencing 5 - 10 m	117	10.5 (3.7)	137	10.9 (3.4)	150	13.8 (3.7)
	Effective fencing > 10 m	117	4.6 (3.3)	137	6.8 (4.2)	150	7.5 (3.8)
Drystock*	Effective fencing total	54	72.5 (14.8)	72	68.0 (10.6)	91	62.6 (11.6)
	Effective fencing < 1 m	54	3.8 (4.1)	72	3.1 (3.1)	91	2.1 (2.1)
	Effective fencing 1 - 2 m	54	22.4 (12.6)	72	17.2 (9.9)	91	12.6 (7.0)
	Effective fencing 2 - 3 m	54	13.9 (9.6)	72	13.5 (8.4)	91	10.0 (5.9)
	Effective fencing 3 - 5 m	54	16.0 (8.0)	72	12.9 (6.5)	91	11.7 (5.0)
	Effective fencing 5 - 10 m	54	10.4 (9.2)	72	9.5 (7.0)	91	9.2 (5.3)
	Effective fencing > 10 m	54	5.8 (4.0)	72	11.9 (9.8)	91	17.0 (8.9)

¥ 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 2017 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 regulations[1].

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	87	87.3 (6.1)	67	86.6 (7.0)	54	84.4 (9.2)
	Effective fencing < 1 m	87	4.4 (3.4)	67	4.3 (3.7)	54	4.7 (4.6)
	Effective fencing 1 – 2 m	87	11.4 (4.9)	67	10.7 (5.4)	54	11.8 (6.7)
	Effective fencing 2 – 3 m	87	12.8 (4.7)	67	12.2 (4.2)	54	13.0 (4.7)
	Effective fencing 3 – 5 m	87	17.1 (5.6)	67	17.3 (6.2)	54	14.1 (6.6)
	Effective fencing 5 – 10 m	87	18.2 (5.7)	67	18.9 (6.4)	54	14.0 (6.8)
	Effective fencing > 10 m	87	23.5 (7.6)	67	23.2 (8.1)	54	26.9 (10.2)
Drystock (high intensity)*	Effective fencing total	30	47.6 (21.2)	21	43.4 (24.8)	15	44.1 (141.0)
	Effective fencing < 1 m	30	1.3 (2.0)	21	0.9 (1.9)	15	1.2 (12.2)
	Effective fencing 1 – 2 m	30	2.1 (2.6)	21	1.5 (2.4)	15	0.9 (8.6)
	Effective fencing 2 – 3 m	30	12.1 (13.2)	21	7.8 (11.3)	15	9.3 (70.0)
	Effective fencing 3 – 5 m	30	7.3 (4.1)	21	8.5 (5.2)	15	8.2 (27.1)
	Effective fencing 5 – 10 m	30	8.0 (5.7)	21	7.5 (6.8)	15	7.0 (33.1)
	Effective fencing > 10 m	30	16.8 (10.7)	21	17.2 (12.2)	15	17.5 (59.7)

¥ 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	93	0	-	5	53 (82)
		Effective fencing < 1 m	2	4	0	-	5	10 (43)
		Effective fencing < 3 m	2	91	0	-	5	42 (77)
		Effective fencing > 3 m	2	2	0	-	5	11 (20)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	2	92
		Effective fencing < 1 m	0	-	0	-	2	11
		Effective fencing < 3 m	0	-	0	-	2	34
		Effective fencing > 3 m	0	-	0	-	2	58
Lower Waikato	Low-slope (< 15°)	Effective fencing total	23	89 (8)	5	77 (48)	20	65 (15)
		Effective fencing < 1 m	23	30 (15)	5	31 (68)	20	2 (2)
		Effective fencing < 3 m	23	83 (10)	5	58 (76)	20	45 (19)
		Effective fencing > 3 m	23	6 (6)	5	20 (31)	20	20 (12)
	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	99	0	-	36	90 (9)
		Effective fencing < 1 m	1	2	0	-	36	1 (1)
		Effective fencing < 3 m	1	47	0	-	36	20 (15)
		Effective fencing > 3 m	1	52	0	-	36	70 (16)
	Non-low slope (> 15°), high intensity*	Effective fencing total	0	-	0	-	7	98
		Effective fencing < 1 m	0	-	0	-	7	2
		Effective fencing < 3 m	0	-	0	-	7	63
		Effective fencing > 3 m	0	-	0	-	7	35
Waipā	Low-slope (< 15°)	Effective fencing total	6	87 (26)	1	100	40	87 (9)
		Effective fencing < 1 m	6	14 (26)	1	0	40	4 (5)
		Effective fencing < 3 m	6	60 (34)	1	29	40	43 (18)
		Effective fencing > 3 m	6	28 (39)	1	71	40	43 (17)
	Non-low slope (> 15°), high intensity*	Effective fencing total	1	79	0	-	7	94 (10)
		Effective fencing < 1 m	1	11	0	-	7	12 (52)
		Effective fencing < 3 m	1	56	0	-	7	43 (46)
		Effective fencing > 3 m	1	23	0	-	7	51 (48)

¥ 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).