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Riparian characteristics of pastoral waterways in the Waikato region, 2002-2012

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Prepared by:
H. Jones[1], M. Kimberley[2], R. Hill[1], D. Borman[1]

[1] Waikato Regional Council, Hamilton
[2] Scion, Rotorua

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

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Peer reviewed by:
Dr. Martin Neale, Golder Associates (NZ) Limited

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Approved for release by:
Dominique Noiton Date July 2016

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Executive summary

The regional riparian characteristics survey monitors the state of riparian fencing, vegetation, and stream-bank erosion (among other characteristics) at waterway sites on pastoral land across the Waikato region. Results of the 2012 survey, undertaken during the summer/autumn of 2012/13, are presented, and changes over the previous 5- and 10-year monitoring periods described. An analysis and review of the survey design was also undertaken. Data collected at 385 waterway sites (comprising 197 in dairy and 188 in drystock) across the region during the 2012 survey were analysed to provide a picture of the state of the riparian characteristics observed.

The proportion of bank length fenced across the Waikato region has steadily increased over the 10-year monitoring period at a rate of about 1.7% of bank length per year (from 34% in 2002 to 51% in 2012). However, approximately half the bank length of the region's waterways in pastoral land was unprotected against stock access at the time of the 2012 survey. This result suggests that further work toward encouraging, supporting, and facilitating the fencing of unprotected stretches of waterways in pastoral land in the region is required. 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 2012 were dominated by non-woody vegetation cover (occupying about 74% of bank length, and dominated by pastoral grasses), as has been the case over the 10-year monitoring period. Woody vegetation, in association with non-woody vegetation, is important because it helps regulate stream water temperature (via stream shading), can contribute to stream-bank stability, and provides additional biodiversity benefits (e.g. bird habitat). This result suggests that there is still much to do in terms of encouraging the restoration of woody riparian vegetation in the region. The majority (about 60%) of riparian margins were relatively narrow in width (i.e. have a buffer width of < 5 m) as at 2012.

The proportion of bank length affected by stream-bank erosion across the Waikato region was relatively small (12%) in 2012 but has significantly increased (from 5% in 2002) over the 10-year monitoring period. However, the magnitude and frequency of storm events is likely to influence the amount of stream-bank erosion observed from year to year. Stream-bank erosion was found to be influenced by several factors including the amount of riparian fencing (i.e. stock access), vegetation structure type, the width and vegetation type of the riparian buffer, stream crossing type, bank slope, and in-stream obstruction type. Riparian soil disturbance is the sum of total stream-bank erosion and pugging disturbance caused by

livestock treading. One quarter of the bank length across the region was characterised as disturbed at the time of the 2012 survey, and of this, 13% was attributed to pugging disturbance. Soil disturbance within riparian margins was strongly influenced by the amount of stock access (and fencing). Regression modelling suggests that the amounts of stream-bank erosion and soil disturbance can be reduced by increasing the proportion of effectively fenced bank length across the region. Increasing the proportion of bank length with woody vegetation (e.g. forest cover), particularly with buffer widths greater than 2 m (if not > 5 m), and reducing the numbers of fords and non-living obstructions (other than dams) per km of stream length in waterways are all changes that are also expected to help reduce the amounts of stream-bank erosion and soil disturbance.

Substantial differences between dairy and drystock land uses in terms of riparian fencing, stock access, buffer width, and soil disturbance were clearly evident in the results presented. In 2012, dairy sites had significantly larger proportions of bank length with effective fencing (70%), no stock access (69%), narrow (< 5 m) buffer widths (71%), and no soil disturbance (84%) than drystock sites (with 29%, 33%, 53%, and 66%, respectively). We conclude that the general level of livestock exclusion from waterways is much greater at dairy sites than at drystock sites in the Waikato region. However, drystock sites had wider riparian buffer margins than dairy sites (i.e. drystock sites had a smaller proportion of bank length with narrow buffer widths). There was no difference detected between dairy and drystock land uses in terms of the proportions of bank length with riparian woody vegetation or with stream-bank erosion. Over the previous 5-year monitoring period, the amount of fencing significantly increased for dairy but not for drystock, with a rate of change of about 3.5% of bank length per year for dairy and about 0.2% 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. The results suggest that there is a need to focus on-going efforts with respect to riparian fencing in the region more toward the drystock land use.

In terms of the state of the riparian characteristics observed, the Lake Taupo and Upper Waikato management zones stood-out as being different to most other zones. In particular, the Lake Taupo zone had the largest (or equal largest) proportion of bank length with effective fencing (67%), woody vegetation (61%), wide (≥ 5 m) buffer widths (69%), and second largest proportion of bank length with no stock access (73%) and no stream-bank erosion (97%). The Lake Taupo zone also had the least number of stream crossings per km of stream length. Considerable emphasis has been placed on promoting the fencing of waterways in both 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 (which requires that stock are excluded from mapped portions of high priority water bodies, including all tributaries flowing into Lake Taupo). Over the 10-year monitoring period, the amount of fencing significantly increased and the amount of stream-bank erosion significantly decreased within the Upper Waikato management zone whereas the amount of woody vegetation in the Lake Taupo zone significantly increased over the same period. Management zones that could benefit the most from future riparian fencing efforts are the Lower Waikato, Coromandel, West Coast, and Waipa zones.

Small to medium-sized waterways (i.e. stream orders 1 to 3) generally had the least effective fencing (39-45% of bank length) and the most stock access (49-61% of bank length) at the time of the 2012 survey. Drains (stream order 0) and small to medium-sized waterways generally had less woody vegetation (9-38% of bank length) and the largest numbers of stream crossings (2-3) per km of stream length. Drains had the smallest proportion of wide buffer widths (about 11% of bank length) and stream orders 1 and 2 had the least stream-bank erosion (approximately 10% of bank length). However, the amount of erosion in stream orders 1 and 2 significantly increased over the past 10 years by about 5-6% of bank length. These findings suggest that small to medium-sized waterways (including drains with respect to the restoration of woody vegetation and the establishment of wider riparian margins) could benefit from future riparian fencing and restoration efforts directed toward them.

It is recommended that some changes be made to the set of sample sites selected in order to improve the efficiency of the survey design and, as a consequence, improve the precision of estimates. Improved precision could allow for the detection of more subtle difference between land uses or management zones (for example) or changes over time. The total number of sample sites should be maintained at approximately 400 but site length could be reduced to 500 m.

1 Introduction

Riparian margins in pastoral land are the strips of land directly adjacent to waterways (e.g. streams or rivers) and water bodies (e.g. lakes) that encompass the interface between pastoral land use systems and freshwater environments (Parkyn & Wilcock, 2004). Therefore, the careful management of these riparian margins is essential in order to maintain or improve freshwater quality and ecosystems (Parkyn & Wilcock, 2004). Well planned and managed riparian margins can also contribute toward more sustainable and productive farming systems (Waikato Regional Council, 2004).

The fencing of riparian margins to prevent stock access to the waterway and stream-bank is an important first step. The use of well-designed and controlled waterway crossing structures (e.g. bridges or culverts) will also contribute to restricting stock access to waterways. Livestock with access to waterways are likely to disturb stream-banks, stream-beds, and riparian vegetation (Quinn et al., 1992), and directly deposit faecal matter into the waterway (Parkyn & Wilcock, 2004; Wilcock, 2006). These actions can result in the direct input of nutrients (e.g. P and N), pathogens (bacteria and viruses) associated with faecal matter, and sediment to the waterway, and in the disturbance of the aquatic ecosystem (Byers, et al., 2005; Sunohara et al., 2012). Effective riparian fencing is also a pre-requisite for the establishment of a dense riparian vegetation cover.

A dense cover of pastoral grass within the riparian margin can act as a filter by encouraging the deposition of sediment, nutrients (particularly P associated with the sediment), and faecal matter contained in surface run-off water before it reaches the waterway (Smith, 1989; Hook, 2003; Schwarte et al., 2011). The planting of woody vegetation (e.g. shrubs and trees) in riparian margins can provide the additional benefits of enhanced biodiversity through the creation of habitat for terrestrial and aquatic life (Parkyn, 2004; Suren et al., 2004), stream shading for regulating water temperature and aquatic plant growth (Quinn et al., 1992; Davies-Colley & Quinn, 1998), and improved stream-bank stability (Miller et al., 2014; Polvi et al., 2014). For best results in terms of enhanced stream-bank stability and run-off filtering capacity, the restoration of riparian vegetation should include the planting of an association of non-woody (e.g. sedges and flaxes) and woody vegetation, particularly indigenous species, and incorporate a grass- or sedge-covered buffer between the planted vegetation and the fence (WRC, 2004). The width of riparian buffers is important and the appropriate width will vary depending on the 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). Benefits to farming systems from well managed riparian margins might include reduced costs (e.g. fewer stock losses through drowning or bogging, less sediment build-up in drains), improved animal welfare and health (e.g. provision of shade, ability to apply animal remedies via a reticulated water supply), and increased amenity values (WRC, 2004).

The Waikato Regional Council has actively promoted the fencing and planting of riparian margins via the Clean Streams project, Project Watershed, and other initiatives (Environment Waikato, 2002). A comprehensive guideline booklet (WRC, 2004) is available to assist landowners manage their riparian margins. DairyNZ has also produced guidelines for riparian planting in the Waikato region (DairyNZ, 2014). The dairy industry (represented by Fonterra Co-operative Group), in partnership with regional councils and central government agencies (Ministry for the Environment and Ministry for Primary Industries), has also promoted the exclusion of dairy cattle from waterways throughout New Zealand via the Dairying and Clean Streams Accord which was initiated in 2003 and ended in 2012 (Fonterra et al., 2003). The Accord set voluntary performance targets in relation to stock exclusion and waterway crossings (among others). The relevant targets included:

- exclusion of dairy cattle from 50% of qualifying waterways and lakes by 2007, and from 90% of qualifying waterways and lakes by 2012, and
- bridges or culverts at 50% of regular waterway crossings by 2007, and at 90% regular waterway crossings by 2012 (Cowie et al., 2006).

Qualifying waterways are permanently flowing streams and drains wider than “a stride” (1 m) and deeper than “ankle depth” (Fonterra et al., 2003; Ministry for Primary Industries, 2013). Annual progress towards the performance targets of the Accord was reported on a regional basis in the annual ‘Dairy and Clean Streams Accord: Snapshot of Progress’ reports produced, initially by the Ministry for the Environment and then, by the Ministry for Primary Industries (MPI). The information on stock exclusion provided by the MPI snapshot reports (e.g. Ministry for Primary Industries, 2013) was based on data collected via Fonterra’s annual On-Farm Environmental and Animal Welfare Assessment (Storey, 2010; Ministry for Primary Industries, 2012). These assessments were described as “non-audited verbal assessments” in the 2013 snapshot report (Ministry for Primary Industries, 2013). A stock exclusion survey was commissioned by the Ministry for Primary Industries (formerly Ministry of Agriculture and Forestry) and undertaken by AsureQuality Ltd in 2011 to independently assess progress in relation to the Clean Streams Accord (Sanson & Baxter, 2011). The stock exclusion survey was based on visual assessments and showed that national levels of full stock exclusion were significantly less than those given by the snapshot reports (Ministry for Primary Industries, 2013).

The Sustainable Dairying: Water Accord (2013) has now taken the place of Dairying and Clean Streams Accord. All dairy companies and DairyNZ are 'accountable partners' under the new Accord. In terms of riparian management, the new Accord requires:

- mandatory exclusion (via permanent fence) of dairy cattle from qualifying waterways, all lakes, and significant wetlands (exclusion from 100% of the length of waterways on dairy farms by 31 May 2017),
- mandatory use of bridges or culverts for regular waterway crossings (100% of crossings to be bridged or culverted by 31 May 2018), and
- all dairy farms to prepare a riparian management plan that identifies where future riparian planting for water quality improvement will occur (100% of dairy farms to have a plan by 31 May 2020 and all planting to be completed by 31 May 2030).

Furthermore, future industry reporting of stock exclusion under the Supply Fonterra initiative will be more robust than it has previously been with results audited as part of the Supply Fonterra: Waterway Management programme (Ministry for Primary Industries, 2013).

To date, Waikato Regional Council has undertaken three region-wide riparian characteristics surveys at approximately 5-yearly intervals (2002, 2007, and 2012) to establish and monitor the state of riparian fencing, vegetation, and stream-bank erosion (among other characteristics) associated with pastoral waterways in the region. The surveys were designed to enable the repeatable, quantitative assessment of key riparian characteristics (Hill & Kelly, 2002). Survey results help to gauge the impact of efforts to promote improved riparian management in the region (e.g. the Clean Streams project and the Dairying and Clean Streams Accord) (Hill & Kelly, 2002) and may be used to help inform policy development and the prioritisation of future efforts. In addition to providing 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, the surveys also enable the examination of differences between land use types, management zones, and stream orders in terms of both state and change over time.

Consistent with the purposes of the riparian characteristics monitoring outlined above, the specific aims of this report are to:

- describe the state of key riparian characteristics of pastoral waterways as observed during the 2012 survey for the Waikato region, 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- and 10-year periods (using the 2007 and 2002 survey data) for the entire Waikato region, by land use type (dairy and drystock), by management zone, and by stream order,
- compare an assessment of stock exclusion based on the 2012 survey results with the estimate for the Waikato region reported in the Dairying and Clean Streams Accord: Snapshot of Progress report for 2011/2012 (Ministry for Primary Industries, 2013),
- examine the riparian characteristics most strongly associated with stream-bank erosion,
- undertake an analysis and review of the survey design based on data from the surveys undertaken to date, and recommend changes for future surveys if required.

2 Methods and materials

The regional riparian characteristics survey involves the observation of the state of riparian fencing, vegetation, and stream-bank erosion (among other characteristics) at sites on pastoral land across the Waikato region. The survey was first undertaken in 2002 and has been repeated twice, at approximately five-yearly intervals, in 2007 and again in 2012. Similar to previous surveys, the 2012 survey was undertaken during the summer/autumn period spanning two calendar years (i.e. 2012/13) but, for convenience, is referred to simply as the "2012 survey". The combined datasets derived from the surveys undertaken to date provide observations of key riparian characteristics at three points in time (2002, 2007, and 2012) spanning a period of 10 years. The following sections describe the original (2002) survey design and its modification over subsequent surveys, sample site selection and sample sizes used, field data collection methodology, and the data analysis undertaken.

2.1 Survey design

The original (2002) survey employed a stratified random sampling design, as described in Hill & Kelly (2002). Stratification of a variable population (e.g. riparian margins) seeks to subdivide the population into meaningful sub-populations (i.e. strata) so as to maximise variation among strata and minimise variation within strata for the purposes of more efficient sampling (Frampton, 2009). In the riparian characteristics survey, the population of riparian margins within the Waikato region was stratified by management zone, land use type, and stream order (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 Waipa (Hill, 2001).

Analysis of a preliminary set of riparian characteristics data (Hill, 2001) indicated that a sample size of approximately 40 sites per management zone was required to provide a dataset with sufficient statistical 'power' to detect a change of 30% or less in the average value of a characteristic over a five-year period (Hill & Kelly, 2002). Therefore, each combination of land use and stream order within a management zone was represented by three randomly-selected replicate sampling sites. Two land use types by seven stream orders by three replicate sites equates to a total of 42 sites per zone. However, not all possible combinations occurred in reality. The numbers of replicate sampling sites representing the most common strata were increased (i.e. weighted on the basis of the number of potential sampling sites) where surplus sample site numbers were available for reallocation due to some possible combinations not existing in reality (Hill & Kelly, 2002). The factors employed to define the strata in the original survey design and the changes in these over successive surveys are discussed in detail below.

2.1.1 Management zones

Management zones are sub-regional areas defined largely on the basis of the physiographic boundaries of major catchments (or part 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 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 2012 survey were the same as those at the time of the 2007 survey. Current management zone boundaries and past changes, together with the 2012 sample site locations, are shown in Figure 1.

The eight management zones subdividing the Waikato region at the time of the 2012 survey were: (1) Central Waikato, (2) Coromandel, (3) Lake Taupo, (4) Lower Waikato, (5) Upper Waikato, (6) Waihou Piako, (7) Waipa, and (8) West Coast. All but two zones (Lake Taupo and West Coast) are described in more detail by the zone management plans (Waikato Regional Council, 2011a; Waikato Regional Council, 2011b; Waikato Regional Council, 2011c; Waikato Regional Council, 2012a; Waikato Regional Council, 2012b; Waikato Regional Council, 2014).

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, West Coast, and Upper Waikato zones have the lowest median pastoral stock density values whereas the Waihou Piako, Waipa, and Central Waikato zones have the highest values (Table A1-2).

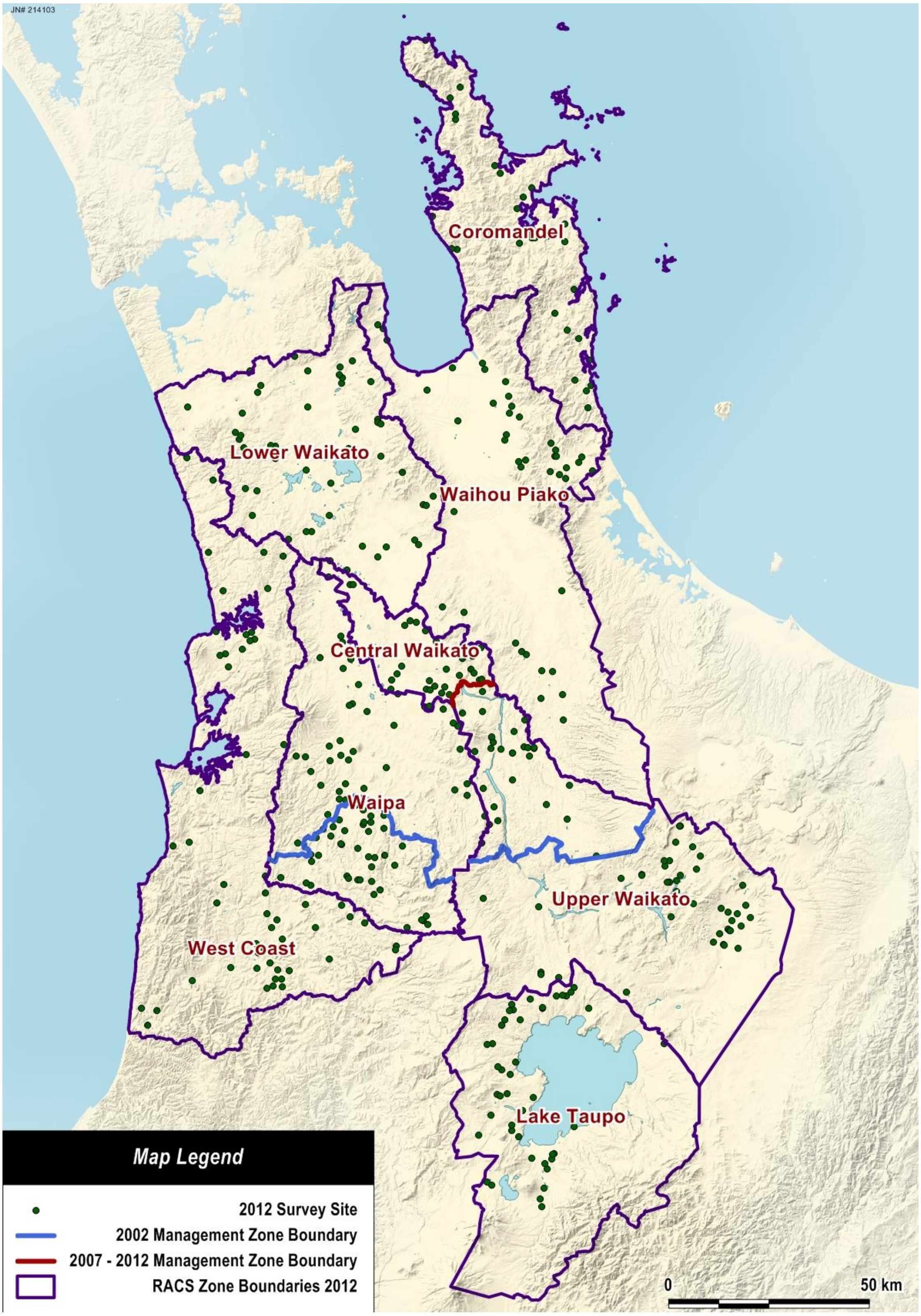

Figure 1: Map showing the sample site locations and management zone boundaries for the 2012 survey (and zone boundary changes since the 2002 survey).

2.1.2 Land use type

The riparian characteristics survey focuses on pastoral land. Two broad pastoral land use types were differentiated for the purposes of the survey; dairy and drystock. It is important to consider the potential effects that different farm management systems – as represented by broad land use type – may have on riparian characteristics. In the 2002 survey, land use type was predicted using Land Use Capability (LUC) (Lynn et al., 2009) class groupings, identifying dairy (LUC 1-4) and drystock (LUC 5-8) land uses, for the purposes of site selection 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 the 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 and 2012 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 a 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 (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). The original survey design recognised seven stream orders (1-6 plus drains). However, one site with a stream order of 7 was sampled in the 2002 survey and was re-sampled in subsequent surveys.

2.2 Sample site selection and sample sizes

Each sampling unit (i.e. a site) consisted of an approximately 1-km long stretch of waterway. Both banks along the 1-km stretch were assessed, meaning a total bank length of approximately 2 km was evaluated at each site (Hill & Kelly, 2002; Storey, 2010). For the 2002 survey, sites representing the various combinations of strata in existence were selected at random from the full set of possible sample sites available. The full set of possible sample sites available was established by intersecting the network of rivers and drains (derived from the NZTOPO 1:50,000 scale river and drain layers) with areas of high and low producing grassland (derived from the Land Cover Database II) and LUC class groupings 1-4 and 5-8 in a Geographic Information System (GIS). The resulting waterway network was partitioned into 1 km-long sections that did not cross tributary junctions.

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). In 2007, some sites were also excluded due to insufficient stream length observed (deemed to be < 400 m). Total sites sampled were 380 in 2002, 310 in 2007, and 400 in 2012. Numbers of pastoral sites sampled in each survey and included in the datasets analysed are given in Table 1. A total of 376 pastoral sites across the Waikato region were sampled during the 2002 survey and of these, 160 were dairy sites (43% of sites sampled) and 216 were drystock sites (57% of sites sampled). Management zone boundary changes and other issues disrupted the fairly even representation of management zones and land use types achieved by the 2002 survey. In 2007, data from 302 pastoral sites were suitable for analysis. The pastoral sites sampled in 2007 included 91 dairy sites (30% of sites sampled) and 211 drystock sites (70% of sites sampled). The 2012 survey yielded a total of 385 pastoral sites suitable for analysis. The pastoral sites sampled in 2012 included 197 dairy sites (51% of sites sampled) and 188 drystock sites (49% of sites sampled).

Table 1: Numbers of sites in pastoral land sampled in the three surveys (2002, 2007 and 2012) and included in the datasets analysed, arranged by management zone and land use type (DY = Dairy, DS = Drystock, TL = Total).

	2002			2007			2012		
Management Zone	**DY**	**DS**	**TL**	**DY**	**DS**	**TL**	**DY**	**DS**	**TL**
Central Waikato (Middle Waikato)†	24	19	43	6	3	9	19	8	27
Coromandel	21	21	42	1	12	13	11	17	28
Lake Taupo	2	38	40	1	40	41	1	40	41
Lower Waikato	15	27	42	7	24	31	28	18	46
Upper Waikato	24	18	42	22	41	63	45	23	68
Waihou Piako (Hauraki)†	34	8	42	28	9	37	29	13	42
Waipa (Middle Waipa)†	19	23	42	25	44	69	49	30	79
Waipa (Upper Waipa)†	20	22	42						
West Coast	1	40	41	1	38	39	15	39	54
Totals	**160**	**216**	**376**	**91**	**211**	**302**	**197**	**188**	**385**

† Management zones names at the time of the 2002 survey are given in parentheses. Changes to the management zone boundaries prior to the 2007 survey included (1) the transfer of the southern part of the Middle Waikato zone into the Upper Waikato zone with the remainder (the northern part) becoming the Central Waikato zone and (2) the merger of the Middle Waipa and Upper Waipa zones (see Figure 1).

The majority (70%) of pastoral sites sampled in the 2002 survey were subsequently re-sampled in both the 2007 and 2012 surveys. All sites sampled in the 2007 survey were selected for re-measurement in the 2012 survey. New sites, and some sites sampled in 2002 but not re-sampled in 2007, were also selected for inclusion in the 2012 survey to better represent previously under-represented strata. More specifically, these additional (to the 2007 survey) sites were selected in order to increase the number of sites representing the dairy land use type and to increase the number of sites representing previously under-represented management zones (e.g. Coromandel and Central Waikato) in accordance with the recommendations of Storey (2010). Where possible, sites meeting these land use and zone requirements were selected from the list of sites sampled in 2002 but not re-sampled in 2007. Whereas new sites that met the requirements were selected randomly from the full set of possible sample sites available. It was necessary to select some replacement sites during the course of the survey to replace sites that were either found to be not suitable (e.g. no permanently flowing water – affecting new sites not previously visited) or for which access was not granted by the landowner. A replacement site was selected by identifying the next site on the list of possible sample sites available that had the same management zone, land use type, and stream order as the site to be replaced.

2.3 Field data collection

2.3.1 Approach and equipment

The overall approach to field data collection employed in the riparian characteristics survey 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 hand-held field data capture devices (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 survey.

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 1 km on average), adjacent to the waterway, observing the riparian characteristics on both banks. 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 2). 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 survey, 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 2 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 were reported as a proportion of stream or bank length.

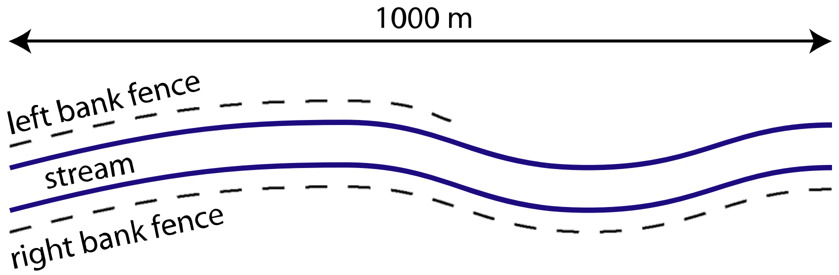

Figure 2: A stylised example of a stream reach that illustrates the concepts of stream length, bank length, and fencing configuration (source: Storey, 2010, p.8).

In the example given in Figure 2, total stream length of the stretch is 1000 m. Total bank length is the sum of total stream length along both banks. In this case, total bank length is 2000 m (1000 m + 1000 m, or 2 x 1000 m). The amount of bank length fenced is 1500 m which equates to 75% of total bank length (1500 m / 2000 m x 100). The fencing in this example is configured as follows: 500 m (50%) of stream length is fenced on both banks; 500 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 2012 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 drip-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. However, the characteristics describing stream-bank erosion were simplified somewhat following the 2002 survey for improved clarity of reporting and efficiency of observation.

The characteristics observed during the 2012 riparian characteristics 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), land use type (e.g. Dairy or Drystock) for the site, specific land use (e.g. beef grazing, maize cropping, planted forest, etc.) directly adjacent to waterway on each bank, and whether or not the waterway qualified as a Clean Streams Accord waterway (i.e. wider than 1 m, more than ankle deep, and permanently flowing).

Continuous characteristics are those characteristics that have the potential to vary spatially along the length of a waterway, on either bank, and can be measured in terms of waterway segment length. Key continuous characteristics observed for both banks along the length of each sample site during the 2012 survey are listed in Table 2. These characteristics describe the nature and status of the riparian fencing, vegetation, and stream-bank erosion present at a site.

Table 2: Key continuous characteristics observed during the 2012 survey.

Characteristic	Category	Description
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 deciduous willow	Predominance of willow (deciduous exotic) species.
	Woody exotic deciduous other	Predominance of deciduous exotic (non-native) tree and shrub species other than willow.
	Woody exotic evergreen	Predominance of evergreen exotic (non-native) tree and shrub species.
	Pastoral grass	Predominance of low (< 1 m) pastoral grass and/or herbaceous weed species.
	Sedges/grasses	Predominance of native or exotic sedge or grass species (excluding pastoral grasses). Rushes and flax species are also included in this category.
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.

Point characteristics are those characteristics that occur, or are best described, at a specific location along the length of a waterway. Two types of point characteristics were observed during the 2012 survey: (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 2012 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 stream 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.

Table 3: Key point characteristics observed at designated locations at each sample site during the 2012 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.

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 stream crossings, obstructions, etc.) were also photographed.

Table 4: Key occurrence-based point characteristics observed during the 2012 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.
	Side entry	Side entries are tributary streams, drains, or pipes that flow into the main stream course.
	Culvert	Pipes channelling the stream water. These will usually be associated with a stream crossing (e.g. road, track, or constructed crossing).
Stream crossing type	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.
	'Bridge' with culvert	Bridge-like structure over culvert.

† 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 during the 2012 survey using the Trimble Juno® devices were regularly down-loaded to the Waikato Regional Council (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 the 2007 and 2012 surveys. Segment lengths for continuous characteristics observed during the 2002 survey were recorded and calculated manually.

2.4 Data analysis

Stratified survey analysis procedures were used in all analyses. Although, the strata as originally defined when the survey was designed would provide the least biased estimates, changes in strata definitions over subsequent surveys meant that it was no longer possible to use the original strata in the analysis. Therefore, the analysis of the 2012 survey data was carried out using updated strata definitions, though broadly based on those used in the original 2002 survey design. Management zones were updated to those used in 2012, and the latest AgriBase™ GIS layer was used to define land use type.

It was also found necessary to aggregate some combinations of management zone by land use type by stream order in order to have adequate numbers of sample sites within each stratum. The aim was to include a minimum of three sample sites per stratum, although several fell below this limit (e.g. there was only one dairy farm site sampled in the Lake Taupo management zone). Samples on watercourses transecting more than one AgriBase™ land use type were assigned to the predominant land use type based on the length of watercourse within each land use type. The strata used in the analysis of the 2012 survey data are summarised in Appendix 2. A somewhat more aggregated set of strata was used in the analysis of changes over time because fewer sites were sampled across all three surveys (2002, 2007, 2012). The strata used for the analysis of change over time are summarised in Appendix 3.

2.4.1 Analysis of state (2012)

The variables of interest from the 2012 survey were all ratios or percentages. Examples of such variables are the proportion of bank length effectively fenced, proportion of bank length with active erosion, and the number of culverts per kilometre of stream length. Efficient estimators of ratio variables for a stratified random survey are given, for example, in Cochran (1977), and were used in the current analysis. Methods for calculating efficient estimators are described below. All analyses were carried out using purpose-written macros coded in SAS Version 9.3.

As an example of the estimation of a simple ratio, the method used to estimate the proportion of bank length effectively fenced, is shown as follows.

The following notation is used:
y_{hi} is the effectively fenced bank length in the i^{th} sample site in the h^{th} stratum
l_{hi} is the total bank length in the i^{th} sample site in the h^{th} stratum
L_h is the total bank length in the h^{th} stratum for the population
n_h is the number of sampled sites in the h^{th} stratum
n_{st} is the number of strata

Firstly, the following quantities are calculated:

$$y_h = \sum_{i=1}^{n_h} y_{hi}$$

$$l_h = \sum_{i=1}^{n_h} l_{hi}$$

$$R_h = y_h / l_h$$

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

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

$$s_{ylh} = \left(\sum y_{hi} l_{hi} - \sum y_{hi} \sum l_{hi} / n_h\right) / (n_h - 1)$$, the covariance between y and l

$$f_h = l_h / L_h$$, the sampling fraction in stratum h:

The estimator R of the proportion of effectively fenced bank is:

(1) $$R = \sum_{h=1}^{n_{st}} L_h R_h \Big/ \sum_{h=1}^{n_{st}} L_h$$

The estimated variance of *R* is:

(2)
$$V(R)=\frac{\sum_h \left(s_{yh}^2-2R_h s_{ylh}+R_h^2 s_{lh}^2\right)L_h\left(1-f_h\right)n_h \big/ l_h^2}{\left(\sum_h L_h\right)^2}$$

A 95% confidence interval for *R* is calculated by multiplying the square root of the variance by a t-value with $\sum_h (n_h-1)$ degrees of freedom.

A more complex procedure was required for the estimation of the ratio of a ratio. As an example, the method used to estimate the proportion of bank length in woody vegetation less than 2 m in width out of the total bank length in woody vegetation is shown as follows.

The following notation is used:

y_{hi} is bank length covered in woody vegetation

x_{hi} is bank length covered in woody vegetation < 2 m wide

l_{hi} is the total bank length

Other notation is similar to the previous example.

Calculate $R_{yh}=y_h/l_h$ and $R_{xh}=x_h/l_h$.

The estimator *R* of the proportion of woody vegetation that is less than 2 m wide out of the total woody vegetation is:

(3)
$$R=\sum_h L_h R_{xh} \Big/ \sum_h L_h R_{yh}$$

The estimated variance of *R* is:

$$V(R)=\frac{\sum_h \begin{pmatrix} s_{xh}^2+Rs_{yh}^2+\left(R_{xh}^2+R^2 s_{yh}^2-2RR_{xh}R_{yh}\right)s_{lh}^2+ \\ 2\left(-R_{xh}+RR_{yh}\right)s_{xlh}+2\left(-R^2R_{yh}+RR_{xh}\right)s_{ylh}-2Rs_{xyh} \end{pmatrix} L_h\left(1-f_h\right)n_h \big/ l_h^2}{\left(\sum_h L_h R_{yh}\right)^2}$$

(4)

A 95% confidence interval for *R* is calculated by multiplying the square root of the variance by a t-value with $\sum_h (n_h-1)$ degrees of freedom.

Estimates for sub-populations within the stratified design (e.g. management zone or land use type as defined by AgriBase™) were calculated using equation (1), but with summations over the sub-population rather than the total population. Tests of significance between sub-populations were performed using least significant difference (LSD) tests, with each pair-wise comparison tested by a t-statistic ($t = (Mean_1 - Mean_2)/\sqrt{(Var_1 + Var_2)}$).

Estimates for stream order were obtained using strata defined by management zone x land use type x stream order, rather than the stream order groupings shown in Appendix 2. Variances for these were based only on strata with 2 or more samples. It can be assumed that these slightly over-estimate the true variance as they are based on fewer samples than used in the estimate which includes strata with single observations.

Land use type identified by AgriBase™ was used in the stratified design. Therefore, estimates using the equation (1) could be obtained directly for each AgriBase™ land use type sub-population. Because the more accurate land use type identification provided by field teams did not always match the AgriBase™ land use type, strata were sometimes split between land use types. However, it was possible to obtain estimates for each land use type using equation (3). For example, to estimate the proportion of bank length effectively fenced for dairy farms, the following variables were created: x_{hi} consisting of effectively fenced bank length for dairy farms but with a value of zero for drystock farms; y_{hi} consisting of total bank length for dairy farms but with a value of zero for drystock farms; l_{hi} consisting of total bank length. Applying equation (3) to these variables provided the required estimate.

2.4.2 Analysis of change over time

Change-over-time analyses of, for example, proportion of bank length fenced based on the three surveys (2002, 2007, and 2012) were performed as follows. Firstly, for each sample site, the difference in fenced bank length between 2007 and 2012 (available for 281 sites), and the difference in fenced bank length between 2002 and 2012 (available for 302 sites), were calculated. Estimates for each of these variables as ratios of total bank length were then obtained using equation (1) and the strata given in Appendix 2. The proportion of bank length fenced in 2012 was used as a base estimate (as the 2012 survey was considered the most comprehensive in terms of sample size and measurement consistency), and estimates for 2007 and 2002 were obtained by subtracting the appropriate difference from the 2012 estimate. This method occasionally produced estimates less than 0% or greater than 100% in which case the values were adjusted to 0% or 100%, respectively. Tests of significance of change over time were obtained using t-statistics ($t = Difference/\sqrt{(Variance\ of\ difference)}$).

2.4.3 Methods for the analysis and review of the survey design

The effect of varying the sample size was investigated using the following approach. A 95% confidence interval for a ratio estimate R given by equation (1) can be calculated using CI = $\pm t \times \surd(\mathrm{V}(R))$, where $\mathrm{V}(R)$ is obtained using equation (2). Predicted confidence intervals for an alternative sample size n' can be obtained using $\mathrm{CI} \times \surd(n/n')$, where n is the sample size of the actual survey (for the 2012 survey, n=385, whereas for 2002-12 change-over-time, n=302). Predicted confidence intervals obtained using this method across a range of n' values for key riparian characteristics can be used to determine the expected confidence intervals (precision) of the average values that would have been obtained for the key characteristics using various sample sizes. The alternative samples sizes can relate to estimates for the entire region or to estimates for a sub-population (e.g. management zone).

The effect of varying the sampling unit length from the 1000 m used in the current design was examined by calculating the average values and associated confidence intervals for key riparian characteristics based on only the first 500 m of stream length at each site (using 2012 data). This procedure was also repeated using the first 250 m at each site.

Estimates of the precision provided by a more efficient survey design were obtained by calculating variances using equation (2), but replacing actual sample sizes n_h in the equation by sample sizes proportional to watercourse length (i.e. $n \times L_h / \sum L_h$). It should be noted that this approach only gives indicative results as it results in many strata with fractional sample sizes. In practice, small strata would have to be aggregated.

3 Results and discussion

The following subsections present and discuss the riparian characteristic survey results in relation to riparian fencing, stock access & exclusion, riparian vegetation, riparian buffer width, stream crossings, and stream-bank erosion. The state (as at the time of the 2012 survey) is described for each of these factors. Change over time (i.e. over the past 5- and 10-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. Average values presented in the graphs are tabulated in Appendix 4.

Additional subsections describing the drivers of stream-bank erosion and the analysis and review of the present survey design (both based on the 2012 survey data) are also included. A summary of key results is provided at the end of each subsection.

3.1 Riparian fencing

3.1.1 State

Approximately half (49%) of the bank length of waterways across the Waikato region in 2012 was found to be effectively fenced (Figure 3). Effective fencing was defined as fencing that is sufficient to prevent stock access to the waterway and adjacent riparian margin. The remainder of the bank length (51%) was either not fenced at all, or was ineffectively fenced.

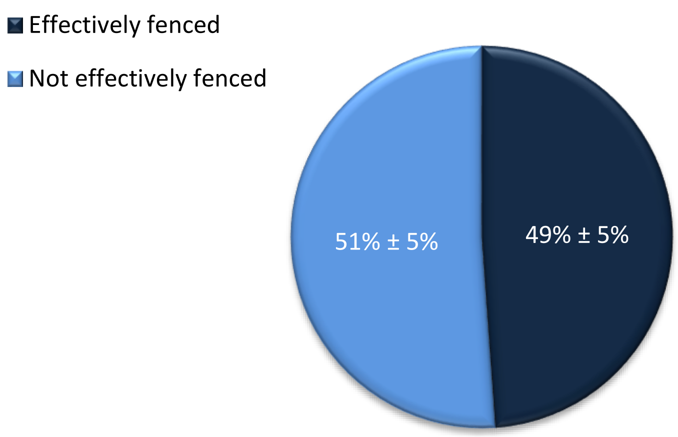

Figure 3: Average proportion of bank length effectively fenced and not effectively fenced across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

Nearly all effective fencing was found to be effective permanent fencing, with effective temporary fencing accounting for only 0.6% of bank length across the region (Table 5).

Temporary fencing was defined as fencing that could be moved or removed with relative ease. The majority of the bank length not effectively fenced was found to be completely unfenced, with ineffective fencing accounting for only 1.3% of bank length across the region. 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 5: Average proportion of bank length occupied by each fence status type across the Waikato region in 2012.

	Fence status type	Proportion of bank length (%)	
		Average	95%CI†
Effectively fenced	Effective permanent	48.3	±4.7
	Effective temporary	0.6	±0.4
Not effectively fenced	Ineffective	1.3	±0.6
	Unfenced	49.8	±4.7

† 95% confidence interval about the average.

The configuration of effective riparian fencing across the region in 2012 was also examined in terms of the average proportions of stream length effectively fenced on either one bank, both banks, or neither bank (Figure 4). About one quarter (26%) of the stream length across the region in 2012 was effectively fenced on one bank only whereas 36% of stream length was effectively fenced on both banks. Effective fencing on both banks is required for complete exclusion of stock from the waterway.

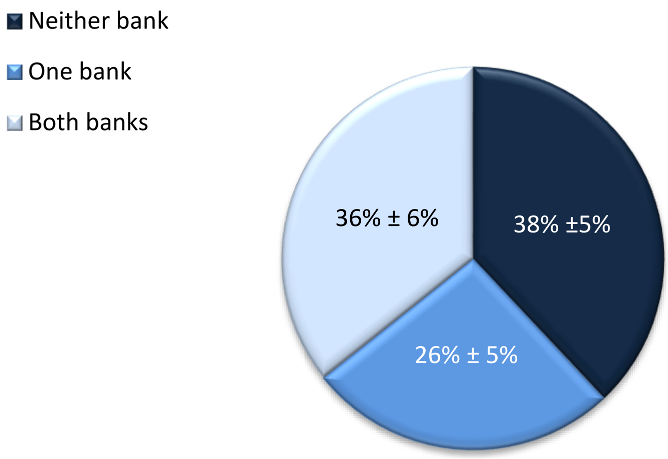

Figure 4: Average proportion of stream length effectively fenced on one bank, both banks, or neither bank across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

There were clear differences in the amount and configuration of effective riparian fencing between dairy and drystock land uses (Figure 5). The average proportion of bank length effectively fenced for dairy land use (70%) was significantly larger than that for drystock (29%).

In terms of the configuration of the effective fencing, the average proportions of stream length effectively fenced on one bank and both banks were significantly larger for dairy than drystock whereas the proportion of stream length with neither bank effectively fenced was significantly larger for drystock than for dairy. These results might reflect both 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 Dairying and Clean Streams Accord which was in place between 2003 and 2012, and the financial strength of the dairy industry over recent years. The Clean Streams Accord has now been superseded by the Sustainable Dairying: Water Accord (2013).

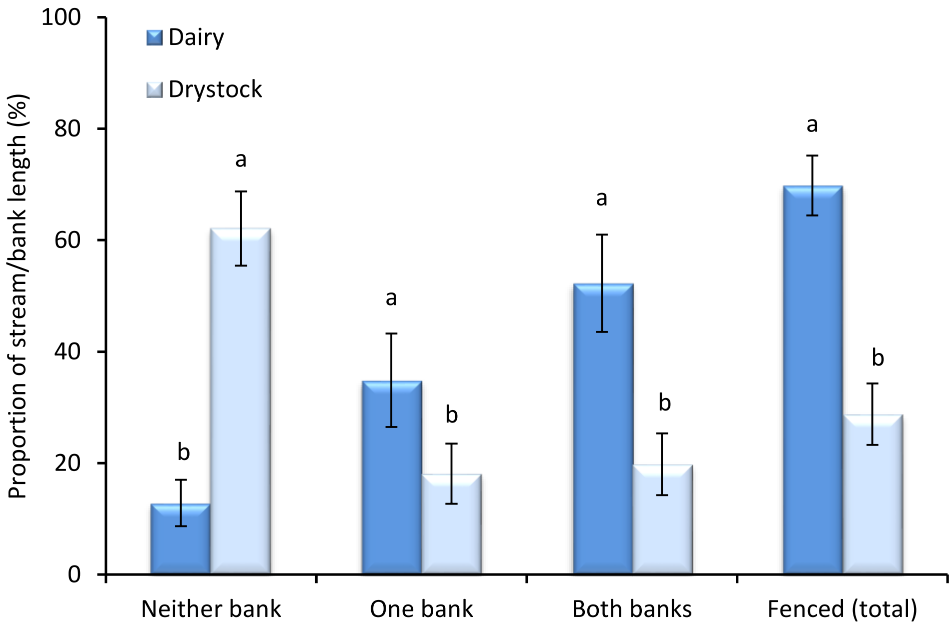

Figure 5: **Average proportion of bank length effectively fenced (total) and average proportion of stream length effectively fenced on one bank, both banks, or neither bank within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly ($P < 0.05$) different.**

The average proportion of bank length effectively fenced for each management zone in 2012 is presented in Figure 6. The Lake Taupo, Upper Waikato, and Waihou Piako management zones had the largest average proportions of bank length effectively fenced (67%, 67%, and 66% respectively) and these were significantly larger than those of the Coromandel, Lower Waikato, and West Coast management zones (43%, 44%, and 19% respectively) which had the smallest proportions of bank length effectively fenced. The hilly and often steep nature of the topography, the occurrence of high intensity rainfall events, and the predominance of drystock farms, is likely to have contributed to the relatively small proportion of bank length effectively fenced in the Coromandel and West Coast management zones. In contrast, considerable emphasis has been placed on promoting the fencing of waterways in the Lake Taupo, Upper Waikato, and Waihou Piako management zones by the Waikato Regional Council through historic soil conservation schemes (see Environment Waikato, 1998; 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 all tributaries flowing into Lake Taupo).

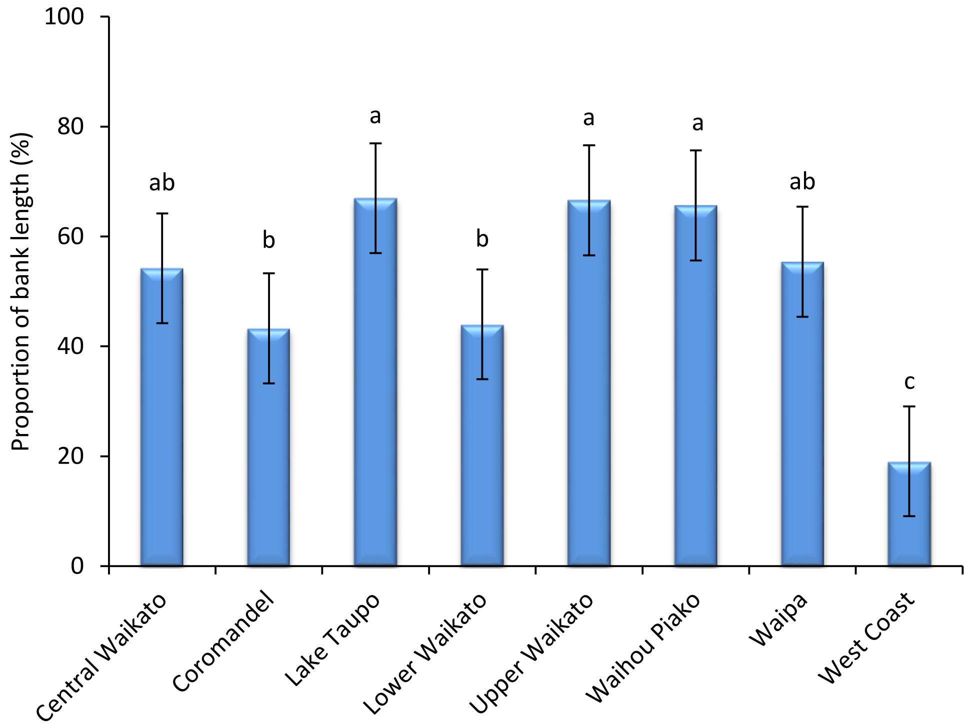

Figure 6: **Average proportion of bank length effectively fenced within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.**

The average proportions of bank length effectively fenced for each stream order in 2012 are presented in Figure 7. Average proportions of bank length effectively fenced were largest for stream orders 0, 5, and 6 (77%, 60%, and 66% respectively), representing drains (stream order 0) and larger waterways (i.e. stream orders 5 and 6). Small to medium-sized waterways (stream orders 1-3) had the smallest proportions of bank length effectively fenced (45%, 42%, and 39% respectively) and these were significantly lower than those for stream orders 0, 5, and 6. These results may be explained as follows. Drains are generally straight, linear features constructed in flat land to drain excess soil water and are, therefore, likely to be fairly straightforward (and potentially less expensive) features to fence-off effectively. Larger waterways (i.e. substantial rivers) present a greater risk of livestock losses and, consequently, are likely to be prioritised for fencing. Small to medium-sized waterways are more likely to be meandering features that occur in steep, hilly terrain which may mean that they are more difficult (and relatively expensive) to fence effectively. Furthermore, the fencing of these smaller waterways may often be a lower priority for landowners who also have larger waterways to fence.

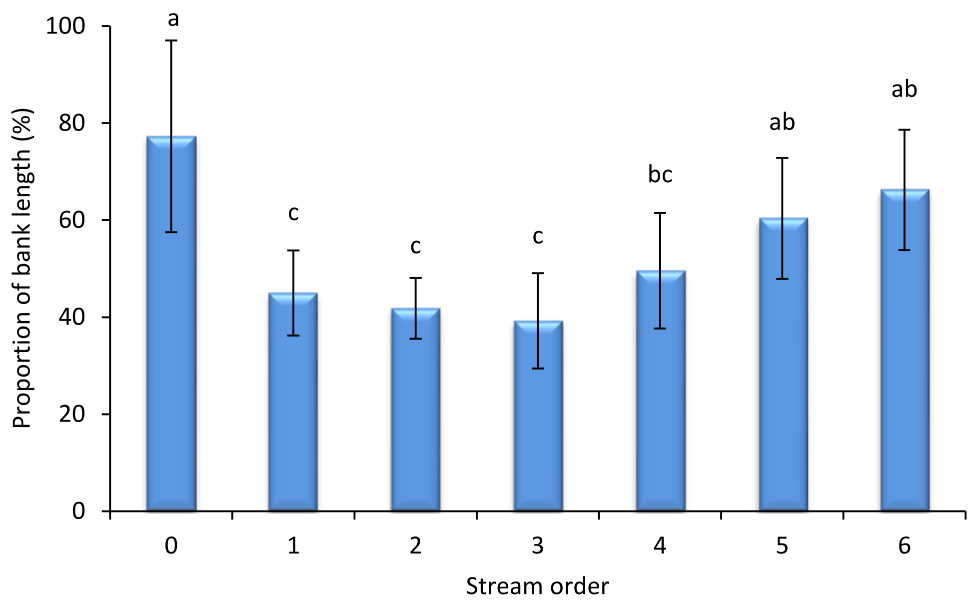

Figure 7: Average proportion of bank length effectively fenced within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.

3.1.2 Change over time

The average proportion of bank length fenced (sum of effectively and ineffectively fenced proportion) across the Waikato region has significantly increased over the past decade from 34% in 2002 to 51% in 2012 (Figure 8, Table 6). The rate of change over this period has been about 1.7% of bank length per year. Based on a total bank length of approximately 48,000 km in pastoral land in the region, of which about 50% (24,000 km) is currently fenced, it is estimated that it will take a further 25 years for the remaining 24,000 km of bank length to be fenced, assuming a constant rate of increase of 2% (rounded) of bank length per year and that all bank length can and will be fenced. The sum of effectively and ineffectively fenced proportions was used for this examination of the change over time because information on the specific status of fenced bank length (i.e. effective or ineffective) was not available for 2002. However, based on the findings of the 2012 and 2007 surveys, ineffective fencing represents a very minor amount of fenced bank length, and fenced bank length proportions are considered to be similar to effectively fenced proportions.

Changes in the configuration of fencing (expressed in terms of proportion of stream length) were also evident (Figure 8, Table 6). The average proportion of stream length fenced on both banks has significantly increased whereas the average proportion of stream length fenced on neither bank has significantly decreased over the past decade. In contrast, the average proportion of stream length fenced on one bank did not change significantly over the same period. The lack of change in the proportion of stream length fenced on one bank over time suggests that where new riparian fencing has been undertaken, both banks were fenced.

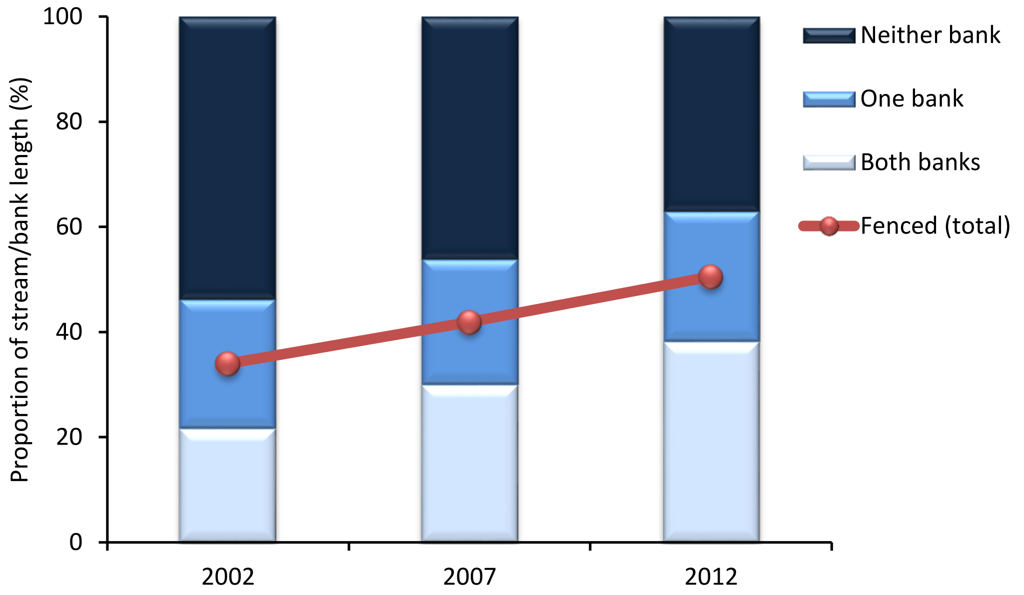

Figure 8: **Average proportion of bank length fenced (total) and average proportion of stream length fenced on one bank, both banks, or neither bank at the three survey periods (2002, 2007, and 2012).**

The magnitude and statistical significance of changes in the proportion of 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 6. Changes in these characteristics over the past 5 years (2007-2012) were approximately half those for the past 10 years which points to a reasonably steady rate of change in fencing over the past decade.

Table 6: **Average change in the proportion of bank length fenced (total) and stream length fenced on one bank, both banks, or neither bank over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.**

	2007-2012 (5-year)		2002-2012 (10-year)	
	Change (pp†)	**95%CI‡**	**Change (pp†)**	**95%CI‡**
Fenced (total)	8.6**	±6.2	16.6**	±5.5
Both banks	8.1 *	±6.9	16.4 **	±5.5
One bank	0.9 NS	±5.0	0.2 NS	±4.6
Neither bank	-9.1 **	±6.4	-16.7 **	±6.4

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Examination of the change in the average proportion of bank length 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 9, Table 7). Over the past decade, the average proportion of bank length fenced significantly increased from 47% in 2002 to 72% in 2012 for dairy and from

23% in 2002 to 30% in 2012 for drystock. Over the past 5 years, the average proportion of bank length fenced has significantly increased for dairy but not for drystock, reflecting a reduction in the rate of change for drystock and an increase in the rate of change for dairy over the past 5 years (2007-2012) relative to the previous 5-year period (2002-2007). The rate of change over the past decade was about 2.5% of bank length per year for dairy and about 0.7% of bank length per year for drystock. Over the past 5 years, the rate of change was about 3.5% of bank length per year for dairy and about 0.2% of bank length per year for drystock. The changes in the average proportion of bank length fenced for dairy likely reflect the emphasis the dairy industry has placed on promoting and encouraging the fencing of waterways via the Dairying and Clean Streams Accord (2003-2012) and the growing financial strength of the industry over this period.

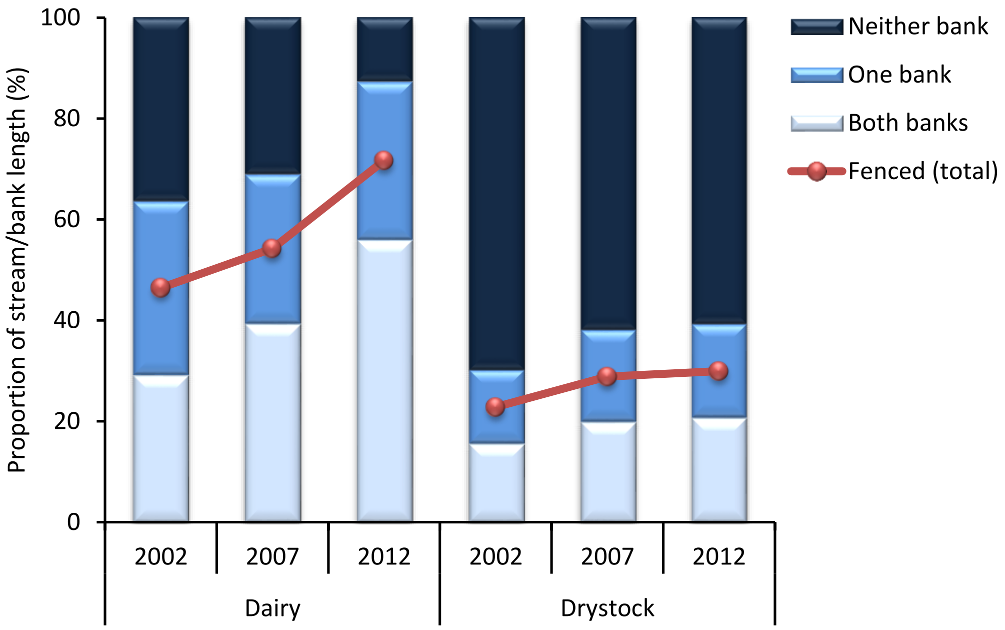

Figure 9: **Average proportion of bank length fenced (total) and average proportion of stream length fenced on one bank, both banks, and neither bank within land use types at the three survey periods (2002, 2007, and 2012).**

Differences in the change in configuration of riparian fencing between dairy and drystock land uses, particularly over the past 5 years, are marked (Figure 9, Table 7). Consistent with the results for the region as a whole, the increase in the average proportion of bank length fenced for dairy over the past 5 years (and to a lesser extent for drystock over the past 10 years) has been associated with a significant increase in the average proportion of stream length fenced on both banks, the commensurate decrease in the average proportion of stream length fenced on neither bank, and no change in the average proportion of stream length fenced on one bank only.

Table 7: Average change in the proportion of bank length fenced (total) and stream length fenced on one bank, both banks, or neither bank within land use types over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.

	Land use type	2007-2012 (5-year)		2002-2012 (10-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Fenced (total)	Dairy	17.4 **	±9.0	25.2 **	±7.8
	Drystock	1.1 NS	±8.6	7.1 **	±4.7
Both banks	Dairy	16.6 **	±11.6	26.8 **	±8.4
	Drystock	0.9 NS	±8.4	5.2 *	±4.2
One bank	Dairy	1.7 NS	±9.2	-3.1 NS	±6.7
	Drystock	0.3 NS	±4.7	3.9 NS	±6.5
Neither bank	Dairy	-18.3 **	±8.4	-23.7 **	±8.6
	Drystock	-1.1 NS	±9.4	-9.1 **	±6.9

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

Change in the average proportion of bank length fenced within management zones over the past decade are presented in Table 8. Significant increases in the average proportion of bank length fenced over the past 10 years were observed within the Upper Waikato, Waihou Piako, and Waipa management zones only. The changes in all other zones over this period were positive but not statistically significant. Variability of estimates within zones was generally large as evidenced by the relatively large 95% confidence intervals, due to smaller sample sizes compared with the region-wide analysis.

Table 8: Average proportion of bank length fenced within management zones at the three survey periods (2002, 2007, and 2012) and average change over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.

	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
Management zone	2002	2007	2012	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Central Waikato	50.0	44.6	61.9	17.2 NS	±33.6	11.9 NS	±14.9
Coromandel	32.4	49.0	43.9	-5.1 NS	±19.0	11.5 NS	±28.8
Lake Taupo	59.4	64.9	67.4	2.5 NS	±10.5	8.0 NS	±13.9
Lower Waikato	36.4	35.6	45.8	10.2 NS	±15.1	9.4 NS	±13.6
Upper Waikato	50.3	58.3	67.2	8.9 NS	±14.3	16.9 **	±10.6
Waihou Piako	52.0	52.1	67.6	15.4 *	±14.8	15.6 **	±8.6
Waipa	26.8	38.2	57.9	19.7 **	±11.5	31.1 **	±9.5
West Coast	6.2	26.5	19.9	-6.6 NS	±17.8	13.7 NS	±19.1

† 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 10 years, the average proportion of bank length fenced has significantly increased in all stream orders except for stream order 6 (Table 9). The stream orders that exhibited the largest magnitude of change over this period were stream orders 1, 4, and 5, with changes of about 22%, 29%, and 32% of bank length respectively.

Table 9: Average proportion of bank length fenced within stream orders at the three survey periods (2002, 2007, and 2012) and average change over the previous 5-year (2007-2012) and 10-year (2002-2012) periods. Stream order 0 represents drains.

Stream order	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
	2002	2007	2012	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	74.2	74.3	78.6	4.3 NS	±14.0	4.3 *	±4.0
1	24.4	34.8	46.5	11.8 NS	±12.8	22.2 **	±12.8
2	29.7	37.2	42.3	5.1 NS	±8.0	12.6 **	±8.3
3	25.2	40.2	41.7	1.5 NS	±6.8	16.5 **	±7.3
4	23.0	37.3	52.4	15.1 **	±10.4	29.4 **	±10.2
5	30.0	45.4	61.5	16.0 NS	±20.8	31.5 **	±15.1
6	44.4	56.7	66.5	9.8 NS	±31.0	22.1 NS	±22.6

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, NS Not significant.

3.1.3 Summary of key riparian fencing results

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

- Approximately half (49%) of the bank length across the Waikato region in 2012 was effectively fenced.
- The average proportion of bank length effectively fenced for dairy (70%) was significantly larger than that for drystock (29%).
- The Lake Taupo, Upper Waikato, and Waihou Piako management zones had the largest average proportions of bank length effectively fenced (67%, 67%, and 66%, respectively).
- Small to medium-sized waterways (stream orders 1-3) had the smallest average proportions of bank length effectively fenced (45%, 42%, and 39%, respectively).
- The average proportion of bank length fenced across the Waikato region has significantly increased over the past decade from 34% in 2002 to 51% in 2012. The rate of change over this period has been about 1.7% of bank length per year.
- The rate of change in the average proportion of bank length fenced over the past decade was about 2.5% of bank length per year for dairy and about 0.7% of bank length per year for drystock. Over the past 5 years, the rate of change was about 3.5% of bank length per year for dairy and about 0.2% of bank length per year for drystock.
- Significant increases in the average proportion of bank length fenced over the past 10 years were observed within the Upper Waikato, Waihou Piako, and Waipa management zones. All other management zones showed increases but these were not statistically significant.
- Over the past 10 years, the average proportion of bank length fenced has significantly increased in all stream orders except for stream order 6.

3.2 Stock access and exclusion

3.2.1 State

On average, 51% of bank length across the Waikato region in 2012 showed no evidence of stock access (Figure 10). The remaining 49% of bank length showed some evidence of either past, recent or current stock access (stock access type are defined in Table 3). Current stock assess, affecting 16% of bank length, refers to stock observed within the waterway or the adjacent riparian margin at the time the survey was undertaken. The amount of stock access (or absence of it) observed (approximately 50% of bank length) across the region corresponds closely to the amount of effective fencing (Figure 3). This association suggests that effective fencing is a useful indicator of stock access.

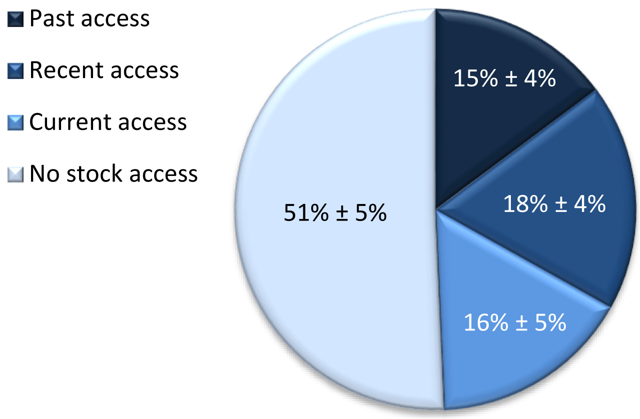

Figure 10: Average proportion of bank length with no stock access and past, recent, or current stock access observed across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

Stock access observed was significantly less for dairy (31% of bank length) than for drystock (67% of bank length) in 2012 (Figure 11). This was also the case for each individual stock access category (i.e. past, recent, and current). However, the difference between dairy and drystock was most marked in relation to current stock access with only 5% of bank length affected for dairy, compared to 27% of bank length for drystock. This result likely reflects the difference in the amount of effective fencing between dairy and drystock land uses (Figure 5).

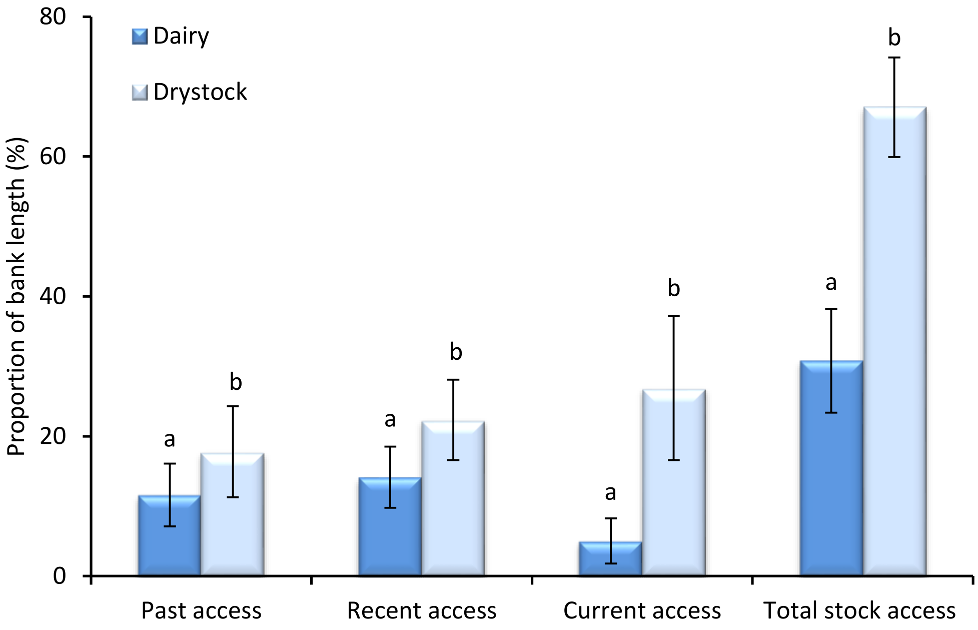

Figure 11: **Average proportion of bank length with total stock access and (constituent) past, recent, or current stock access observed across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly ($P < 0.05$) different.**

Lake Taupo, Upper Waikato, and Waihou Piako management zones had the least stock access in 2012 with average proportions of bank length showing evidence of access (27%, 29%, and 25%, respectively) significantly less than those in the Waipa and West Coast management zones (56% and 84% respectively) which had the most stock assess (Figure 12). The relatively limited 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 the largest amounts of fencing (Figure 6).

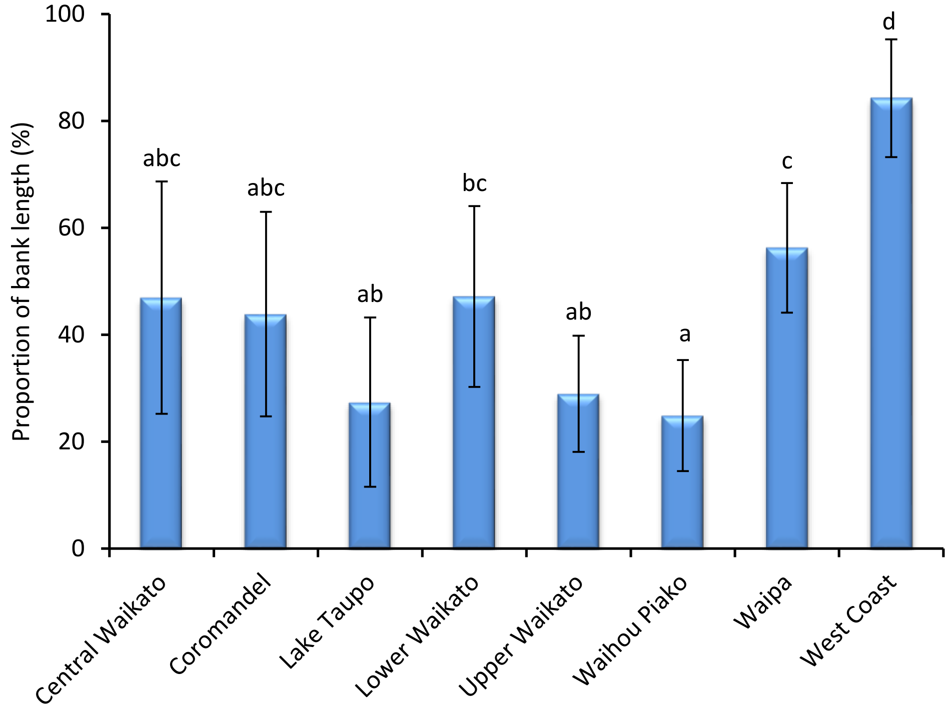

Figure 12: Average proportion of bank length with observed stock access within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.

Observed stock access was least for stream orders 0 (drains) and 6 with approximately 10% of bank length showing evidence of stock access on average (Figure 13). Other stream orders were observed to have between 32% and 61% of bank length showing evidence of stock access. These results generally reflect the amount of effective fencing associated with each stream order (Figure 7).

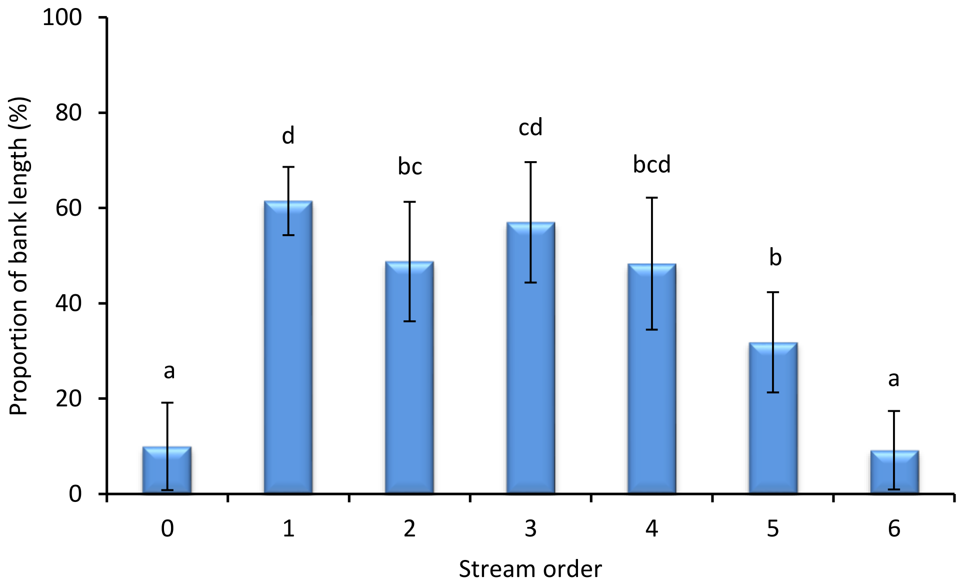

Figure 13: Average proportion of bank length with observed stock access within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.

3.2.2 Analysis of Dairying and Clean Streams Accord qualifying sites

Of the sites sampled in 2012, 142 dairy sites qualified as Dairying and Clean Streams Accord sites. At 72 (51%) of these sites, no evidence of stock access or soil pugging disturbance was observed. The number and proportion of the Dairying and Clean Stream 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 10). Stock exclusion criteria were defined on the basis of the presence of effective fencing, dense (forest/scrub) vegetation cover, and deep channel morphology on both banks. Only 24% 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 to the stock exclusion criteria (recognising the potential for dense vegetation to restrict stock assess) did not increase the proportion of qualifying sites with complete stock exclusion. However, the addition of both dense vegetation and deep channel morphology to the stock exclusion criteria did increase the proportion of sites with complete stock exclusion to 26%. This suggests that effective fencing is the predominant means of stock exclusion in the Waikato region.

The proportions of qualifying sites with complete stock exclusion reported in Table 10 for the various stock exclusion criteria are all substantially less than the proportion of farms with complete stock exclusion (about 47%) reported by Sanson & Baxter (2011). There may be differences in definitions and methodology contributing to the poor correspondence in these estimates (e.g. farms assessed rather than specific sites that may span farm boundaries). Details of the approach used by Sanson & Baxter (2011) in defining and assessing ‘complete stock exclusion’ at the sites they surveyed are not clear. Of the qualifying sites in the present survey, 43% met the broadest stock exclusion criteria (i.e. effective fencing, or dense vegetation, or deep channel morphology) along >75% of stream length (Table 10).

Table 10: Number and proportion of Dairying and Clean Streams Accord qualifying sites (n = 142) 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%	34	24
	>90%	45	32
	>75%	58	41
	>50%	75	53
Effective fencing or forest/scrub on both banks	>99%	34	24
	>90%	45	32
	>75%	58	41
	>50%	80	56
Effective fencing or forest/scrub on both banks or deep channel	>99%	37	26
	>90%	48	34
	>75%	61	43
	>50%	83	58

Estimates of total stock exclusion reported above (26% at best) and by Sanson & Baxter (2011) (about 47% of farms) are both much lower than the estimate reported in the Dairying and Clean Streams Accord: Snapshot of Progress 2011/2012 report (Ministry for Primary Industries, 2013) for the Waikato region (about 86% of farms). The information on stock exclusion provided by the MPI snapshot reports was based on data collected via Fonterra's annual On-Farm Environmental and Animal Welfare Assessment (Storey, 2010; Ministry for Primary Industries, 2012). Despite the differences in approach to the derivation of the different estimates of stock exclusion, the MPI figure appears to be unrealistically high when compared with the more robust estimate provided by Sanson & Baxter (2011). Moreover, the riparian characteristics survey of the Auckland region (Neale et al., 2009) revealed a similar discrepancy between the proportion of Dairying and Clean Streams Accord streams estimated to be effectively fenced on both banks (26%) and the estimate reported by the contemporaneous MPI (formerly Ministry of Agriculture and Forestry) snapshot report (Ministry of Agriculture and Forestry, 2009) which suggested that stock were excluded from 70% of qualifying waterways in the Auckland region. Future industry reporting of stock exclusion under the Supply Fonterra initiative is expected to be more robust as results will be audited as part of the Supply Fonterra: Waterway Management programme (Ministry for Primary Industries, 2013).

On average, 68% of bank length at dairy sites qualifying as Accord sites had effective fencing (Table 11). The addition of dense (forest/scrub) vegetation cover to the stock exclusion criteria increased the proportion of bank length that could be considered to be protected to almost 71%. Adding deep channel morphology to the criteria increased the proportion of bank length protected to about 72%.

Table 11: Average proportion of bank length satisfying various stock exclusion criteria at Dairying and Clean Streams Accord qualifying sites (n = 142).

	Proportion of bank length (%)
Effective fencing	68.3
Effective fencing or forest/scrub vegetation	70.5
Effective fencing or forest/scrub or deep channel	71.7

Analysis of the dairy sites qualifying as Dairying and Clean Streams Accord sites revealed that, on average, 72% of bank length had no observed stock access in 2012 (Figure 14). This value corresponds very closely to the estimate of the proportion of bank length protected (by effective fencing, or dense vegetation cover, or deep channel morphology) at the qualifying sites (Table 11) and is also in keeping with the average proportion of bank length with 'stock exclusion' within the Waikato region (78%) as reported by Sanson & Baxter (2011).

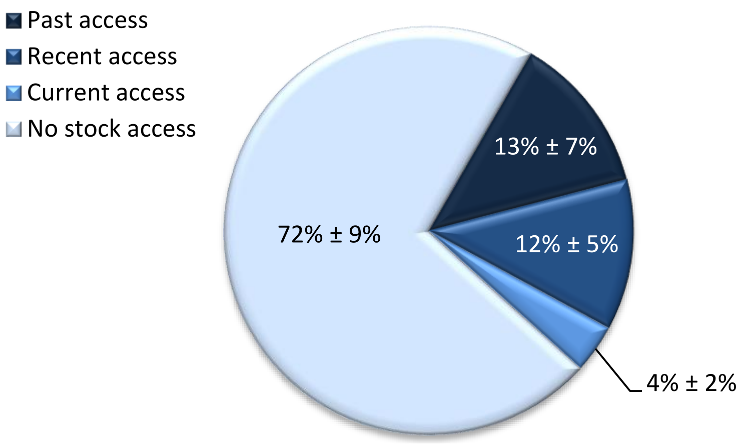

Figure 14: Average proportion of bank length with no stock access and past, recent, or current stock access observed at Dairying and Clean Stream Accord qualifying sites across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

If the performance of the Accord with respect to stock exclusion in the Waikato region was evaluated on the basis of the proportion of bank length with stock exclusion (i.e. no stock access), an increase in the amount of stock exclusion of about 20% of bank length (based on 70% of bank length effectively fenced for dairy) would be required to reach a stock exclusion target of 90% of waterway margins (i.e. bank length).

3.2.3 Summary of key stock access and exclusion results

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

- On average, about half (51%) of the bank length of waterways across the Waikato region in 2012 showed no evidence of stock access (i.e. stock were excluded).

- Stock access observed was significantly less for dairy (31% of bank length, on average) than for drystock (67% of bank length, on average).
- The Lake Taupo, Upper Waikato, and Waihou Piako management zones had the smallest proportions of bank length with stock access (27%, 29%, and 25%, respectively).
- Observed stock access was least for stream orders 0 (drains) and 6 with approximately 10% of bank length showing evidence of stock access.
- The strong correspondence between the fencing and observed stock access confirms that the proportion of bank length effectively fenced is a very good indicator of stock exclusion.
- Only 26% 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). In comparison, the MPI Dairying and Clean Streams Accord snapshot report for 2011/12 reported total stock exclusion at about 86% of farms in the Waikato region.
- On average, 72% of bank length at Dairying and Clean Steams Accord qualifying sites had no observed stock access in 2012. This value corresponds very closely to the estimate of the proportion of bank length protected (by effective fencing, or dense vegetation cover, or deep channel morphology) at the qualifying sites.

3.3 Riparian vegetation

3.3.1 State

Approximately one quarter (26%) of bank length across the Waikato region was occupied by woody riparian vegetation in 2012 with the remaining three quarters (74%) occupied by non-woody vegetation (Figure 15). 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 is also important as it can provide the benefits of stream channel shade (for water temperature regulation), enhanced biodiversity values (e.g. habitat provision), and additional stream-bank stability (e.g. Davies-Colley & Quinn, 1998; Suren et al., 2004; Polvi et al., 2014).

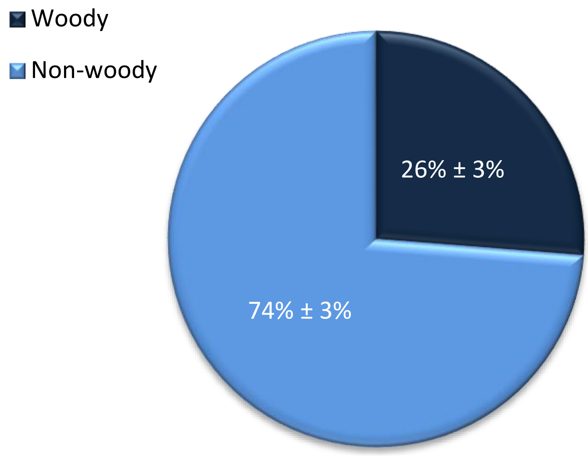

Figure 15: **Average proportion of bank length with woody and non-woody vegetation across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.**

Woody vegetation was further classified into woody willow, woody exotic, and woody native vegetation type categories whereas non-woody vegetation was classified into pastoral grass and sedges/grasses categories. Average proportions of bank length occupied by each vegetation type category across the region in 2012 are presented in Figure 16. Pastoral grass occupied almost half the bank length across the region.

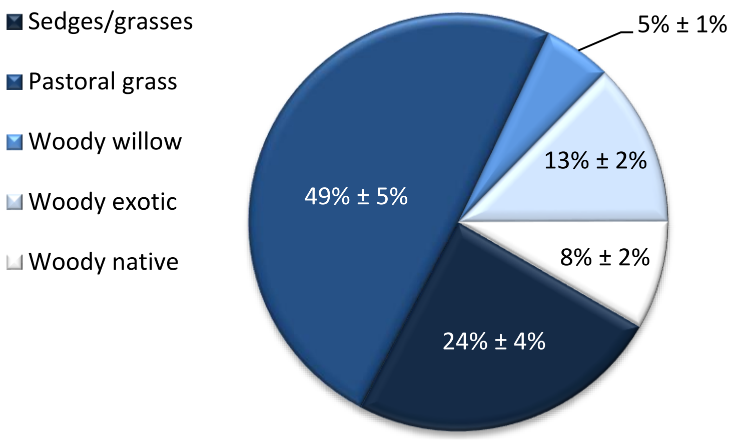

Figure 16: **Average proportion of bank length occupied by individual vegetation types across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.**

No difference in the average proportion of bank length occupied by woody vegetation between dairy and drystock land use was evident (Figure 17). With the exception of woody native vegetation, there were no differences between dairy and drystock in terms of the proportions of bank length occupied by the individual vegetation types. The amount of woody native vegetation for dairy (4% of bank length) was significantly less than that for drystock

(13% of bank length). Drystock farms are more likely to be situated in hill country areas where the occurrence of woody native vegetation is also more likely in general.

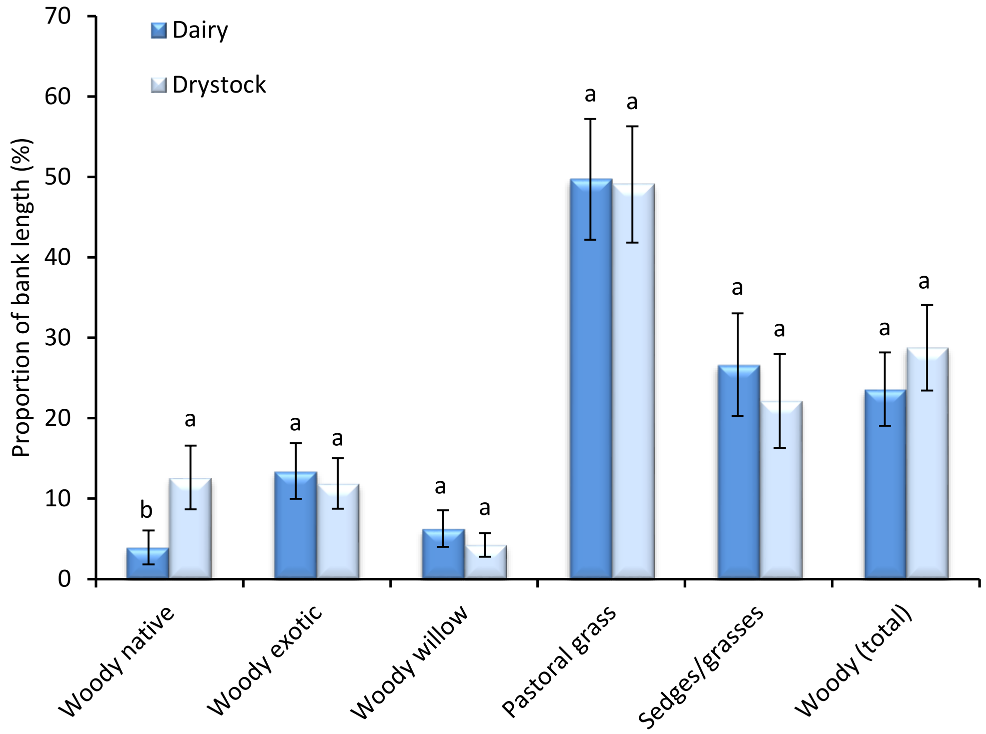

Figure 17: Average proportion of bank length occupied by woody vegetation (total) and individual vegetation types within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.

The proportion of bank length with effectively fenced woody vegetation was significantly larger than the proportion of bank length with woody vegetation not effectively fenced (Figure 18). The main driver for this difference was the proportion of bank length with effectively fenced woody exotic vegetation which was significantly larger than the proportion of bank length with woody exotic vegetation not effectively fenced. In contrast, the proportion of bank length with effectively fenced pastoral grass was significantly smaller than the proportion of bank length with pastoral grass not effectively fenced. In essence, the 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). The reverse is true for non-woody vegetation.

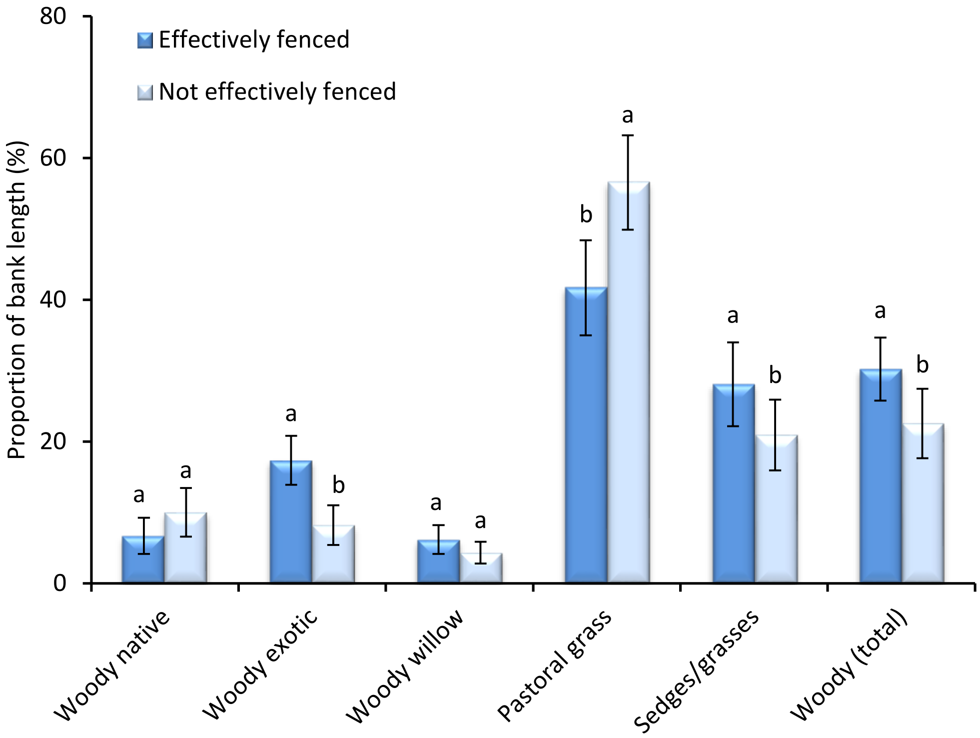

Figure 18: Average proportion of bank length occupied by woody vegetation (total) and individual vegetation types that are effectively fenced or not effectively fenced across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly ($P < 0.05$) different.

In terms of the average proportion of bank length occupied by woody vegetation in 2012, two distinct groups of management zones were evident (Figure 19). The Coromandel, Lake Taupo, and Upper Waikato management zones had the largest proportions of bank length occupied by woody vegetation (56%, 61%, and 45%, respectively) and were significantly different to all other zones which had between 15% and 23% of bank length with woody vegetation. The difference between the two groups of zones appears to be related, at least in part, to either the amount of effective fencing and past soil conservation investment (e.g. Lake Taupo and Upper Waikato; Figure 6) or the general prevalence of woody vegetation and patterns of intensive land use in the landscape (e.g. Coromandel compared to Waihou Piako; Figure 19).

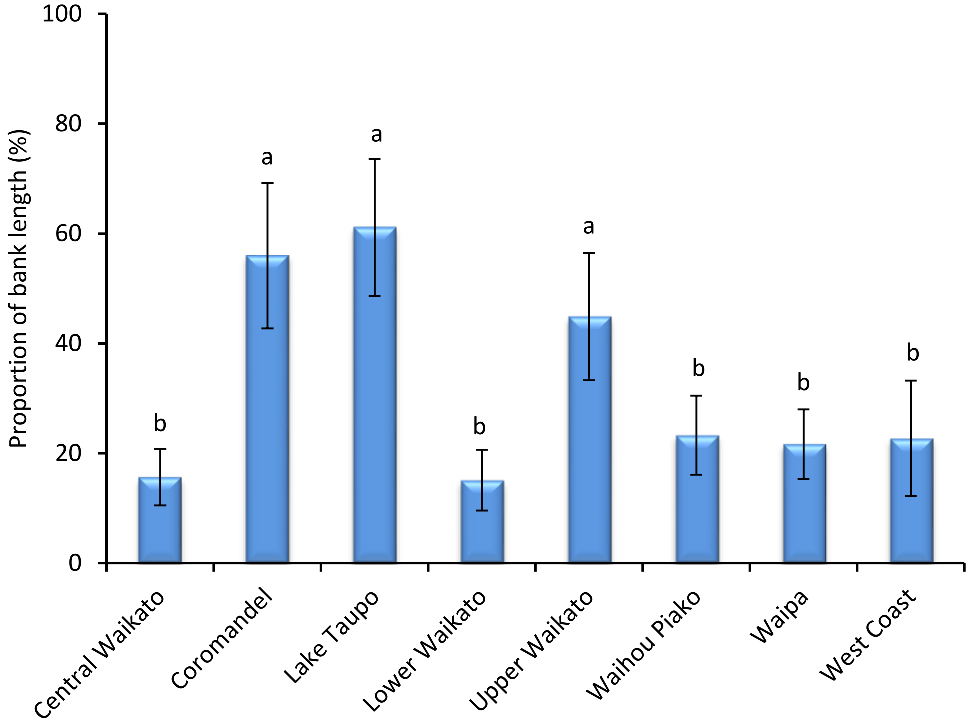

Figure 19: **Average proportion of bank length occupied by woody vegetation within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.**

In broad terms, the average proportion of bank length occupied by woody vegetation in 2012 increased with increasing stream order (Figure 20). Drains had the smallest average proportion of bank length with woody vegetation (9%) 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 (55% and 57%, respectively) and were significantly larger than those of all other stream orders except for stream order 2.

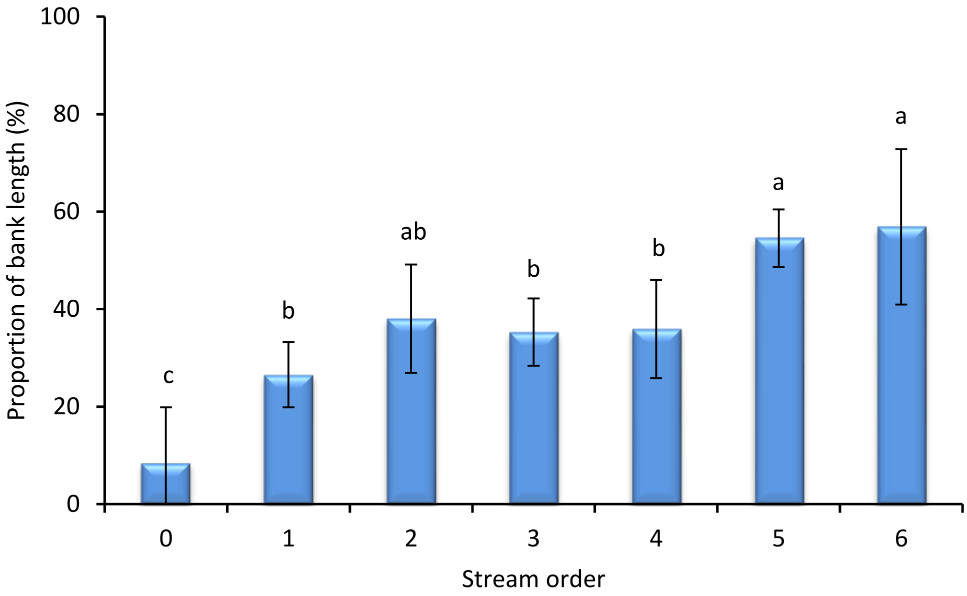

Figure 20: **Average proportion of bank length occupied by woody vegetation within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

3.3.2 Change over time

Over the past decade (2002-2012) there was no significant change in the average proportion of bank length occupied by woody vegetation across the Waikato region (Figure 21, Table 12). However, a small statistically significant decrease over the past 5 years (2007-2012) was detected. This change is due to a significant decrease (6.2% of bank length) in the amount of woody exotic vegetation over that period.

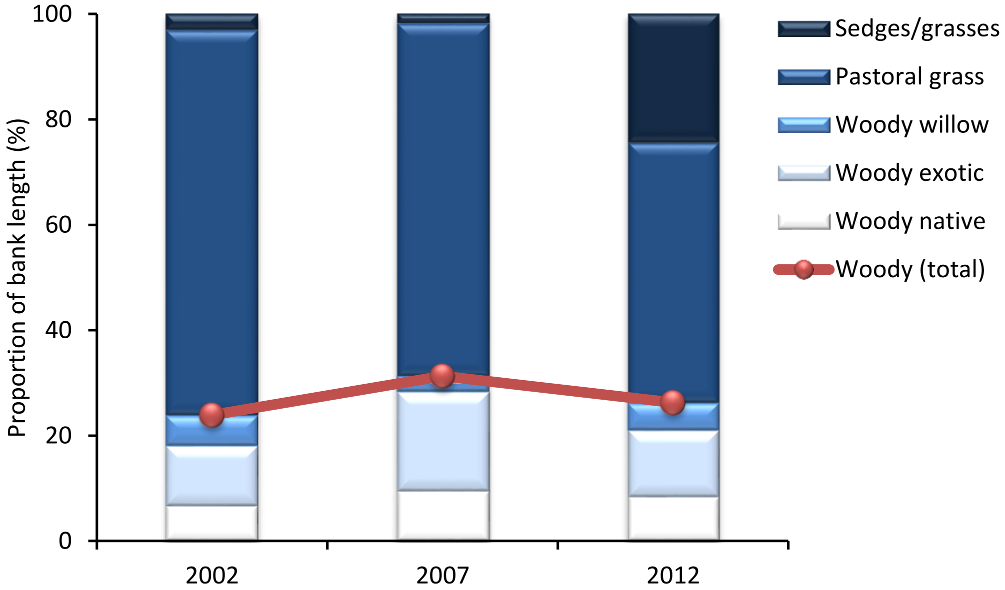

Figure 21: **Average proportion of bank length occupied by woody vegetation and individual vegetation types at the three survey periods (2002, 2007, and 2012).**

The proportion of bank length occupied by the sedges/grasses vegetation type category significantly increased, at the expense of pastoral grass, from around 2-3% in 2002 and 2007 to 24% in 2012 (Figure 21, Table 12). It seems likely that much of this change reflects improved recognition in the field of the occurrence of this vegetation type during the 2012 survey compared with previous surveys rather than reflecting an actual change in vegetation. Although, it is possible that some of the change may also be attributed to an increase in effective fencing (i.e. stock exclusion) over the same period (Figure 8, Table 6).

Table 12: Average change in the proportion of bank length occupied by woody vegetation and individual vegetation types over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.

	2007-2012 (5-year)		2002-2012 (10-year)	
	Change (pp†)	**95%CI‡**	**Change (pp†)**	**95%CI‡**
Woody vegetation	-5.1 *	4.7	2.4 NS	2.6
Woody native	-1.1 NS	2.0	1.7 *	1.4
Woody exotic	-6.2 **	4.5	1.1 NS	2.5
Woody willow	2.2 **	1.0	-0.5 NS	1.3
Pastoral grass	-17.5 **	6.6	-23.7 **	5.4
Sedges/grasses	22.6 **	4.7	21.3 **	4.9

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

The pattern of change in the average proportion of bank length occupied by woody vegetation for both dairy and drystock land uses over the past decade (Figure 22, Table 13) was generally similar to that observed across the region as a whole (Figure 21, Table 12). The main difference was that the decrease in the amount of woody (and woody exotic) vegetation over the past 5 years (2007-2012) was significant for dairy but not for drystock.

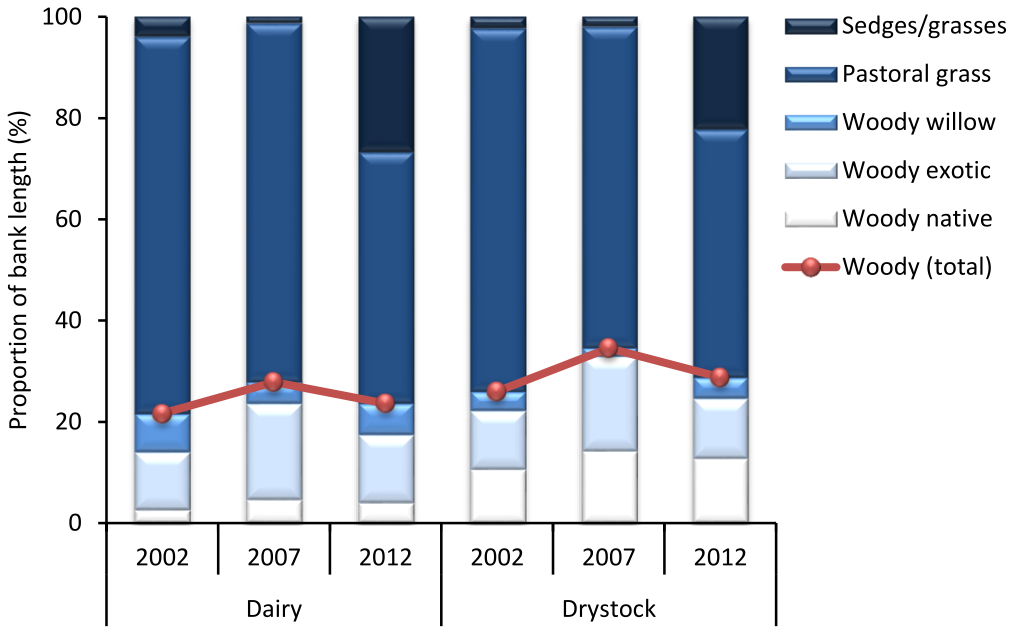

Figure 22: Average proportion of bank length occupied by woody vegetation and individual vegetation types within land use types at the three survey periods (2002, 2007, and 2012).

It is possible that a significant decrease in the proportion of bank length occupied by woody (and woody exotic) vegetation for drystock (Table 13) was not detected due to relatively large variability in the data for the woody and woody exotic vegetation categories for drystock (with approximately twice the variability for dairy for these categories, see 95%CI data in Table 13).

Table 13: 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 (2007-2012) and 10-year (2002-2012) periods.

	Land use type	2007-2012 (5-year)		2002-2012 (10-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Woody vegetation	Dairy	-4.2 *	4.2	2.0 NS	2.6
	Drystock	-5.8 NS	8.0	2.8 NS	4.5
Woody native	Dairy	-0.6 NS	1.9	1.4 *	1.2
	Drystock	-1.5 NS	3.5	2.1 NS	2.4
Woody exotic	Dairy	-5.5 **	4.0	2.0 NS	2.5
	Drystock	-6.8 NS	7.6	0.2 NS	4.5
Woody willow	Dairy	1.9 *	1.6	-1.4 NS	2.0
	Drystock	2.5 **	1.4	0.4 NS	1.4
Pastoral grass	Dairy	-21.1 **	7.2	-24.7 **	6.7
	Drystock	-14.3 **	10.6	-22.6 **	8.1
Sedges/grasses	Dairy	25.4 **	6.8	22.7 **	6.5
	Drystock	20.1 **	6.4	19.8 **	7.1

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

A significant increase in the average proportion of bank length with woody vegetation over the last decade was observed in the Lake Taupo management zone (Table 14). However, no other changes were observed with the exception of a significant decrease in the proportion of bank length with woody vegetation over the past 5 years (2007-2012) in the Waipa zone. The change observed within the Waipa zone was due to significant decreases in amount of woody native and woody exotic vegetation (data not presented) and could potentially be associated with land use intensification. The significant decrease in the proportion of bank length with woody vegetation in the Waipa zone appears to have contributed to the significant region-wide decrease that occurred over the past 5 years (Table 12).

Table 14: Average proportion of bank length occupied by woody vegetation within management zones at the three survey periods (2002, 2007, and 2012) and average change over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.

	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
Management zone	**2002**	**2007**	**2012**	**Change (pp†)**	**95%CI‡**	**Change (pp†)**	**95%CI‡**
Central Waikato	14.5	6.7	15.7	8.9 NS	11.8	1.1 NS	8.5
Coromandel	46.9	52.9	56.0	3.0 NS	11.4	9.1 NS	16.9
Lake Taupo	46.7	59.6	61.1	1.5 NS	5.8	14.5 *	14.3
Lower Waikato	11.2	20.4	15.1	-5.3 NS	10.3	3.9 NS	6.1
Upper Waikato	40.9	48.1	44.9	-3.2 NS	10.0	3.9 NS	4.7
Waihou Piako	22.4	26.4	23.3	-3.1 NS	6.3	0.9 NS	4.1
Waipa	20.7	32.0	21.7	-10.4 **	5.7	0.9 NS	5.9
West Coast	22.2	29.8	22.7	-7.1 NS	17.6	0.5 NS	8.0

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, NS Not significant.

The average proportion of bank length with woody vegetation significantly increased for stream orders 1 and 6 and significantly decreased for drains over the past decade (Table 15). The increase in the amount of woody vegetation associated with stream orders 1 and 6 observed over the 10-year period (2002-2012) were not evident in the past 5-year period (2007-2012), indicating that much of the change occurred between 2002 and 2007.

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

Stream order	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
	2002	2007	2012	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	13.0	15.3	8.5	-6.8 *	6.2	-4.5 *	3.6
1	20.6	31.1	26.6	-4.5 NS	10.3	6.0 *	4.9
2	35.1	36.3	38.0	1.7 NS	10.0	2.9 NS	6.7
3	33.9	38.2	35.3	-2.9 NS	7.1	1.4 NS	5.4
4	35.1	42.9	35.9	-7.0 NS	8.1	0.8 NS	9.5
5	51.7	51.7	54.6	2.8 NS	25.1	2.9 NS	6.9
6	47.1	53.6	56.9	3.3 NS	8.2	9.8 **	4.7

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

3.3.3 Summary of key riparian vegetation results

The key results in relation to riparian vegetation are that:

- Approximately one quarter (26%) of bank length across the Waikato region was occupied by woody riparian vegetation in 2012.
- No difference in the average proportion of bank length occupied by woody vegetation between dairy and drystock was evident.
- The results suggest that there is a positive association between effective fencing and woody vegetation (i.e. bank length with woody vegetation is more likely effectively fenced than not effectively fenced).
- The Coromandel, Lake Taupo, and Upper Waikato management zones had the largest average proportions of bank length occupied by woody vegetation (56%, 61%, and 45%, respectively).
- In broad terms, the proportion of bank length occupied by woody vegetation increased with increasing stream order.
- There has been no significant change in the average proportion of bank length occupied by woody vegetation across the Waikato region over the past decade (although there has been a significant decrease in bank length occupied by woody vegetation over the past 5 years).
- The pattern of change in the average proportion of 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.
- A significant increase in the average proportion of bank length with woody vegetation over the last decade was observed in the Lake Taupo management zone. In contrast, a

significant decrease in the average proportion of bank length with woody vegetation over the past 5 years was observed in the Waipa management zone.

- The average proportion of bank length with woody vegetation significantly increased for stream orders 1 and 6 and significantly decreased for drains over the past decade.

3.4 Riparian buffer width

3.4.1 State

On average, 39% of bank length across the Waikato region had riparian buffer widths of 5 m or more (described here as 'wide') in 2012 (Figure 23). The remaining 61% of bank length had 'narrow' (< 5 m) buffer widths.

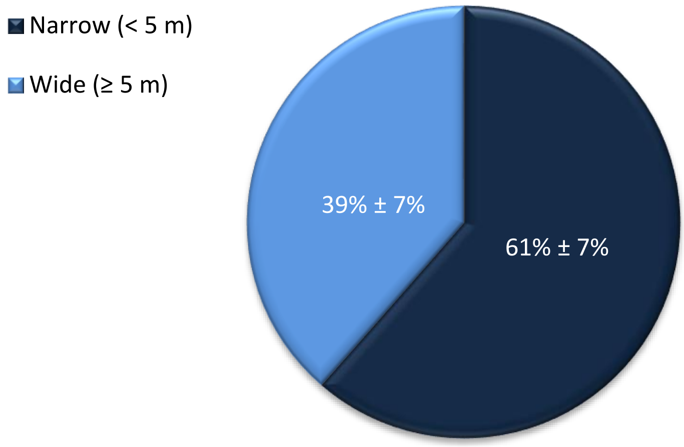

Figure 23: Average proportion of bank length with narrow (< 5 m) and wide (≥ 5 m) buffer widths across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

An examination of individual buffer width categories revealed that a little over one quarter (27%) of the bank length across the region in 2012 had buffer widths less than 2 m and that a further 35% of bank length had a buffer width of 2-5 m, on average (Figure 24). Only 22% 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 steepness and length of surrounding slopes, with steeper and longer slopes requiring wider buffers. On flat land, buffer widths of 1 to 3 m for grassed margins are thought to be acceptable (Waikato Regional Council, 2004).

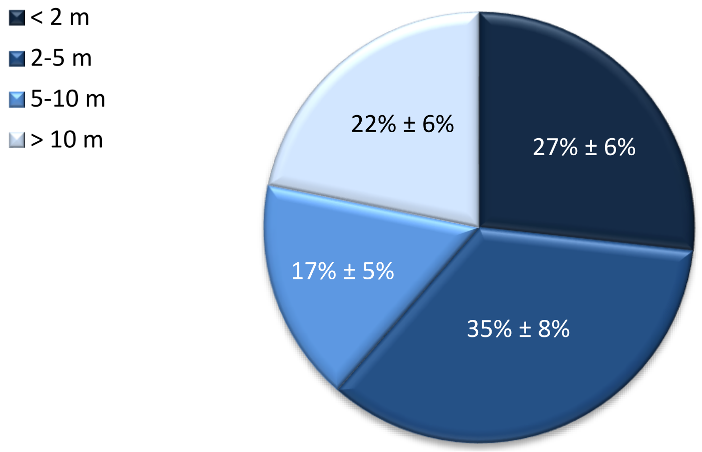

Figure 24: **Average proportion of bank length by individual buffer width category across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.**

Narrow riparian buffer widths (< 5 m) were clearly dominated by non-woody vegetation in terms of the average proportion of bank length occupied, with non-woody vegetation accounting for about 80% of bank length (Figure 25). Wide buffer widths (≥ 5 m) had a somewhat more equal representation of woody and non-woody vegetation, particularly in the 5-10 m category. Although, non-woody vegetation was still dominant, accounting for about 62% of bank length with wide buffer widths.

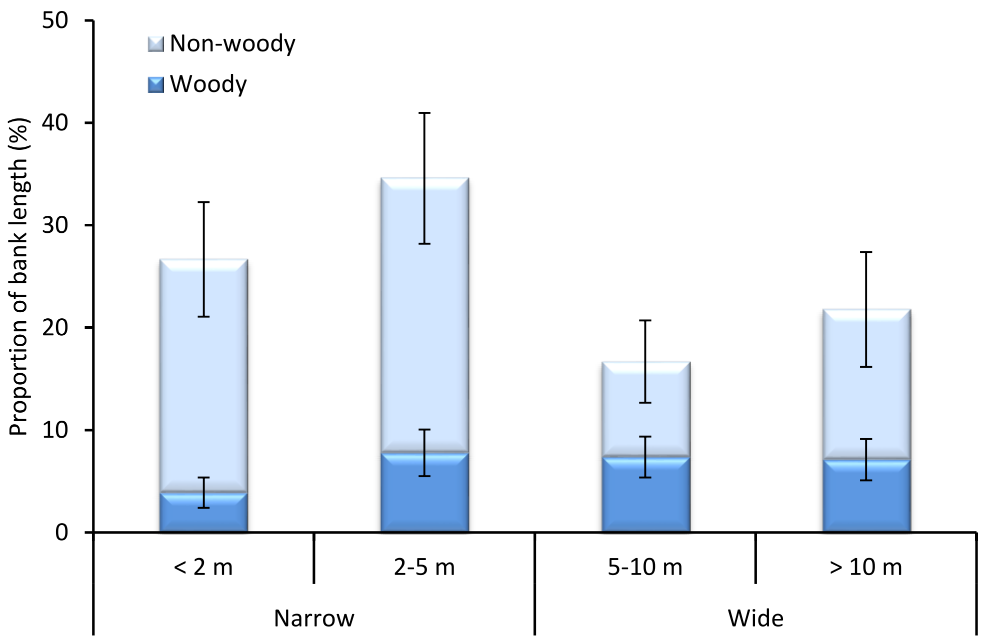

Figure 25: **Average proportion of bank length by individual buffer width categories occupied by woody or non-woody vegetation across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average.**

The drystock land use had a significantly larger proportion of bank length with wide buffer widths (47%) than dairy (29%) (Figure 26). This difference largely relates to the > 10 m buffer width category in which the proportion of bank length for drystock (29%) was significantly larger than that for dairy (15%). The predominance of wide buffer widths 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 89% of the bank length along drains across the region had narrow (< 5 m) buffer width (c.f. Figure 29).

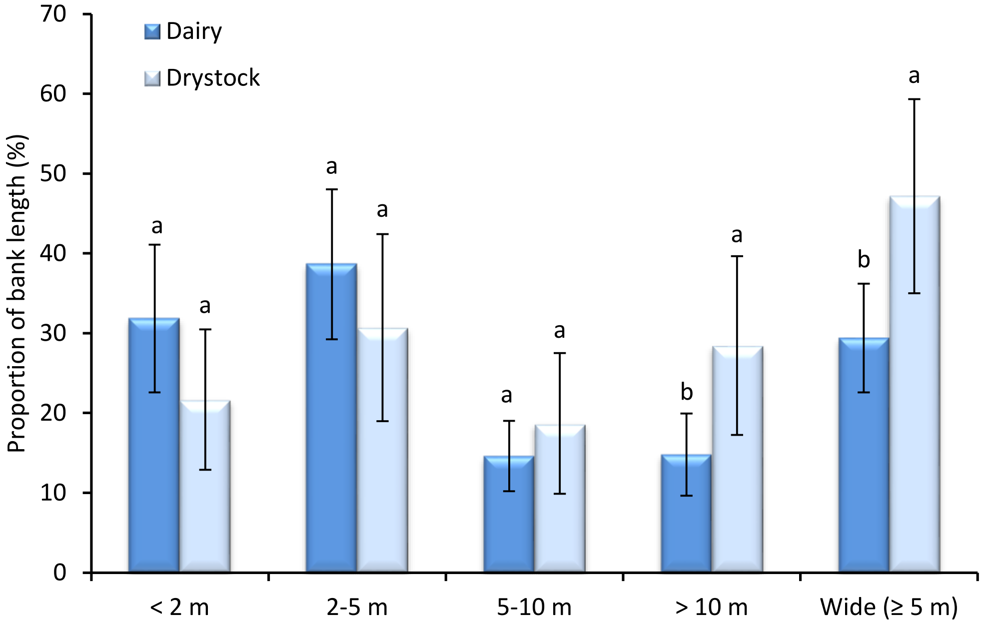

Figure 26: **Average proportion of bank length by wide (≥ 5 m) and individual buffer width categories within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

Further to the results presented in Figure 26, the differences in buffer widths between dairy and drystock land uses are associated with non-woody rather than woody vegetation (Figure 27). No significant differences in the average proportion of bank length occupied by woody vegetation were observed between dairy and drystock for either narrow or wide buffer widths.

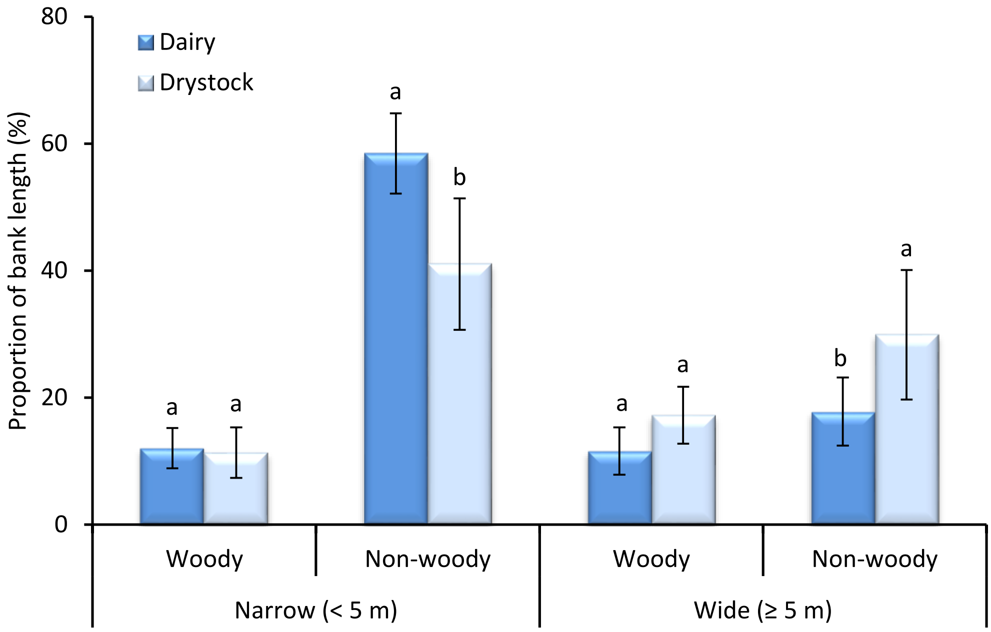

Figure 27: Average proportion of bank length by wide (≥ 5 m) and narrow (< 5 m) buffer width categories with woody or non-woody vegetation within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.

The Lake Taupo and Upper Waikato management zones had the largest proportions of bank length with wide buffer widths (69% and 58%, respectively) (Figure 28). This result could possibly be associated with historic soil conservation schemes in the Lake Taupo and Upper Waikato (see Environment Waikato, 1998; Palmer, 2004). In contrast, the Coromandel, Lower Waikato, and Waihou Piako zones had the smallest average proportions of bank length with wide buffer widths (25%, 11% and 25%, respectively) and these were significantly less than those of the Lake Taupo and Upper Waikato zones.

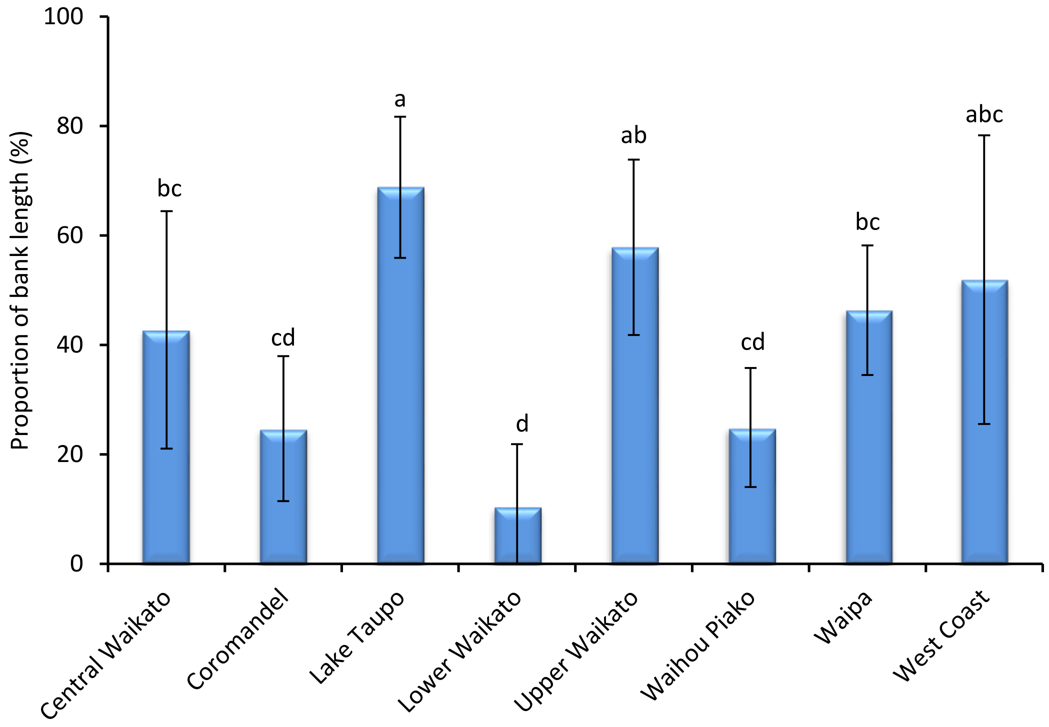

Figure 28: Average proportion of bank length with wide (≥ 5 m) buffer widths within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.

Drains (stream order 0) clearly stand-out as having a significantly smaller proportion of bank length with wide buffer widths (11%) than all other stream orders (Figure 29). 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 buffer widths with increasing stream order from drains through to stream order 3, but not beyond.

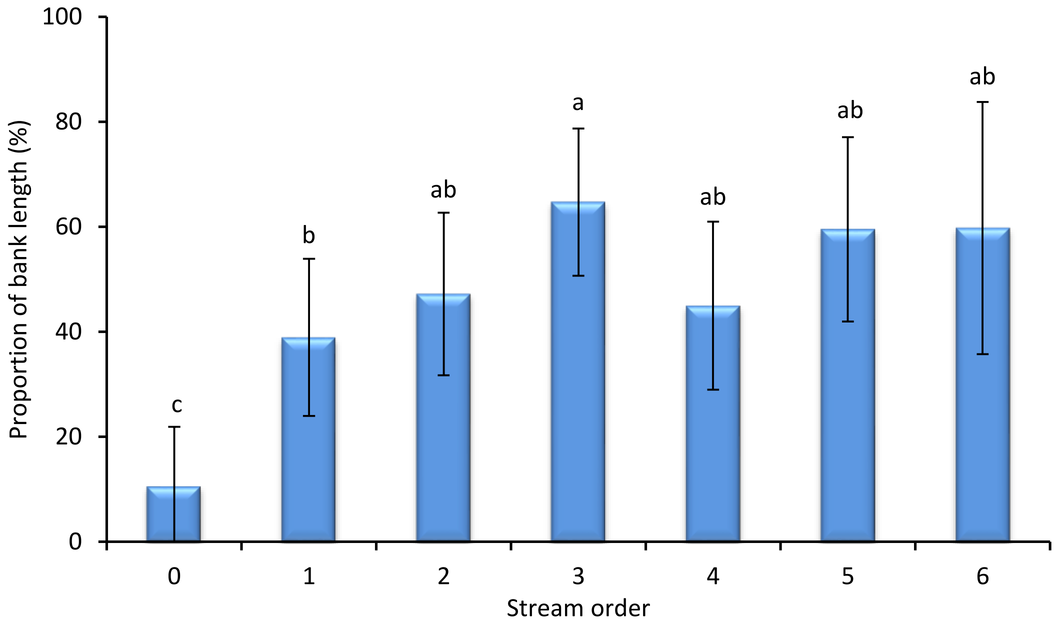

Figure 29: **Average proportion of bank length with wide (≥ 5 m) buffer widths within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.**

3.4.2 Summary of key riparian buffer width results

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

- On average, 39% of bank length across the Waikato region had riparian buffer widths of 5 m or greater (described here as 'wide') whereas 27% of the bank length had buffer widths of less than 2 m.
- Narrow buffer widths (< 5 m) were clearly dominated by non-woody vegetation in terms of the average proportion of bank length occupied, with non-woody vegetation accounting for about 80% of bank length.
- The drystock land use had a significantly larger proportion of bank length with wide buffer widths (47%) than dairy (29%). The difference in buffer width between dairy and drystock is associated with non-woody rather than woody vegetation.
- The Lake Taupo and Upper Waikato management zones had the largest proportions of bank length with wide buffer widths (69% and 58%, respectively).
- Drains (stream order 0) clearly stand-out as having a significantly smaller proportion of bank length with wide buffer widths (11%) than all other stream orders.

3.5 Stream crossings

3.5.1 State

The occurrence and type of stream crossings were observed as part of the riparian characteristics survey. Most of the stream crossings observed across the region in 2012 were categorised as culverts, which accounted for 67% of observed crossings (Figure 30). Approximately 30% of crossings were bridges and only 3% were fords.

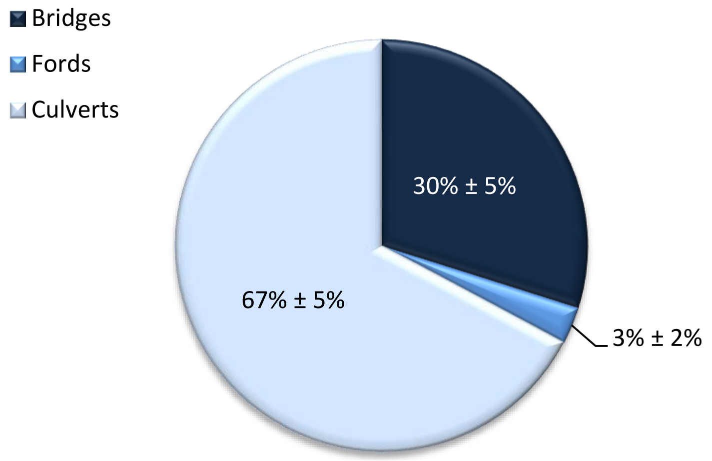

Figure 30: Average proportion of observed crossings that are bridges, fords, or culverts across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

The number of (total) stream crossings per km of stream length, were not significantly different between the land uses (Figure 31). However, the average proportion of stream crossings that were fords was significantly larger for drystock (5%) than for dairy (0.7%). 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 less than 1% of stream 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 exceeded its voluntary performance target of 90% of crossings being either a bridge or a culvert by 2012.

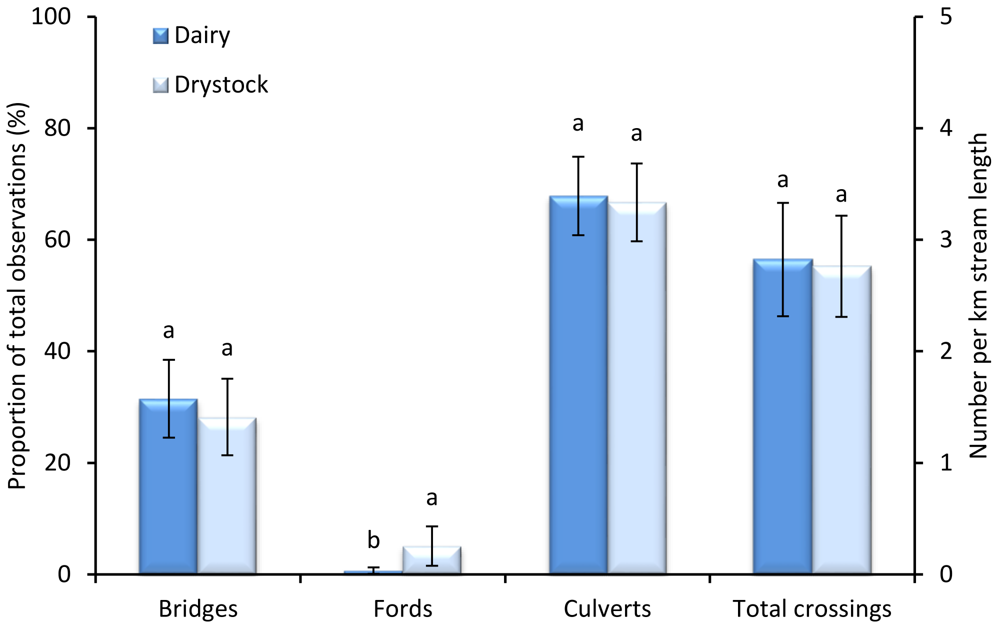

Figure 31: Average proportion of observed crossings that are bridges, fords, or culverts and average number of total crossings observed per km of stream length within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.

On average, the Lake Taupo management zone had the smallest number of crossings per km of stream length (1.2) in 2012 (Figure 32). In contrast, the Central Waikato, Lower Waikato, and Waipa management zones had the largest number of crossings per km of stream length (3.5, 3.6, and 3.1, respectively). The Lake Taupo zone was significantly different to all other zones, except the Waihou Piako zone, in terms of the average number of crossings per km of stream length. The small number of crossings per km of stream length observed in the Lake Taupo zone may be associated with the nature of the topography and the geographic distribution of waterways in the zone.

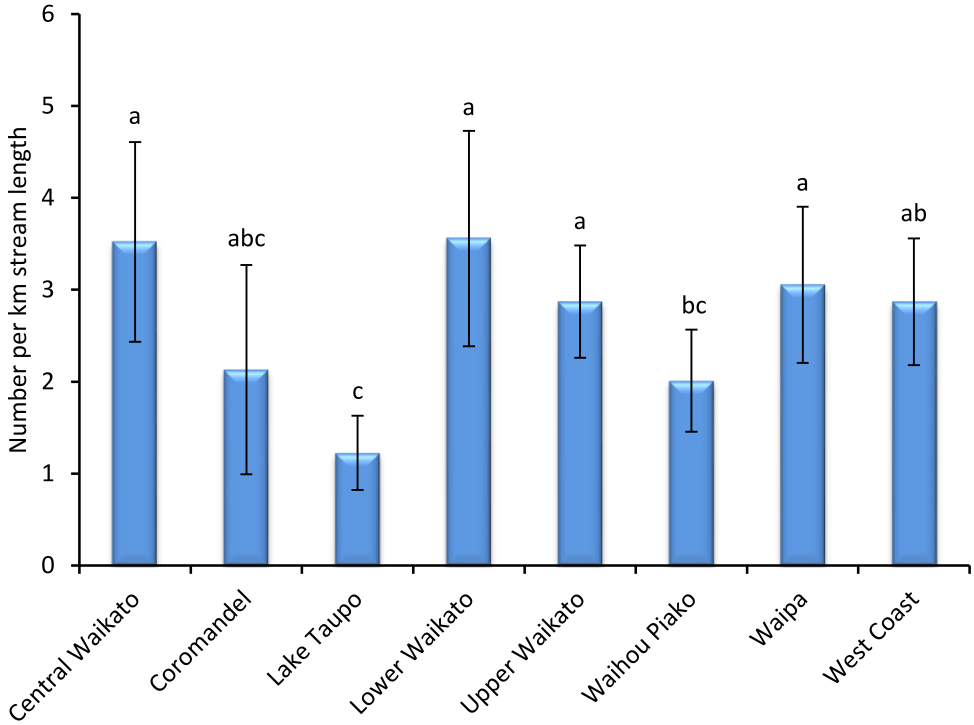

Figure 32: Average number of total crossings observed per km of stream length within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly ($P < 0.05$) different.

A noticeable difference in the number of stream crossings per km of stream length between waterways of stream order 4 or more and waterways of stream order 3 or less was apparent (Figure 33). The smaller waterways (stream order 3 or less) generally had a larger number of crossings per km of stream length on average, with values ranging from 3.4 to 2.0, compared with the larger waterways (stream order 4 or more), with values ranging from 0.6 to 0.2. Cost and other practical or regulatory restrictions are likely responsible for the less common occurrence of crossings over the larger waterways.

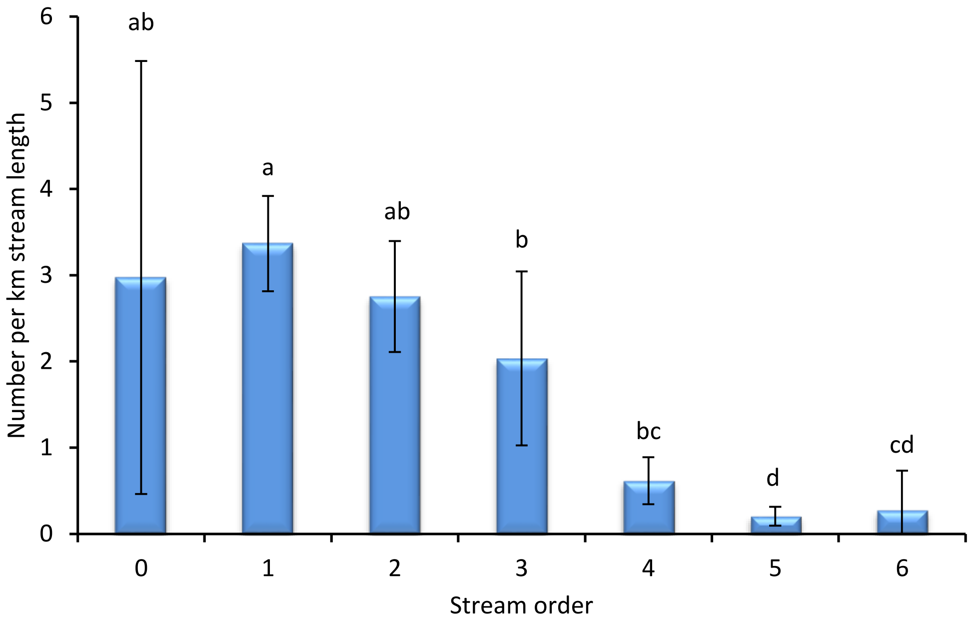

Figure 33: **Average number of total crossings observed per km of stream length within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

3.5.2 Summary of key stream crossing results

The key results in relation to stream crossings are that:

- Most of the stream crossings observed across the region in 2012 were categorised as culverts, which accounted for 67% of observed crossings.
- The number of (total) stream crossings per km of stream length, was not significantly different between the land uses.
- The Lake Taupo management zone had the smallest number of crossings per km of stream length (1.2) in 2012.
- Smaller waterways (stream order 3 or less) generally had a larger number of crossings per km of stream length on average, with values ranging from 3.4 to 2.0, compared with the larger waterways (stream order 4 or more), with values ranging from 0.6 to 0.2.

3.6 Stream-bank erosion

3.6.1 State

The majority (88%) of bank length across the region in 2012 was uneroded (Figure 34). Of the 12% of bank length observed to be eroded, 4% showed signs of active erosion whereas 8% was found to be recent erosion.

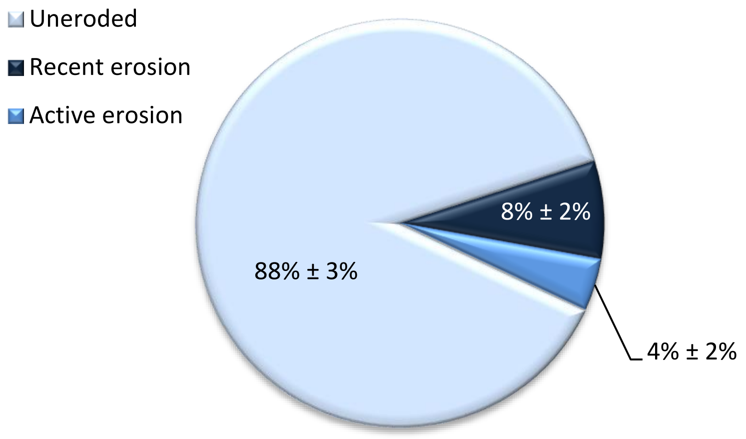

Figure 34: Average proportion of bank length uneroded and with recent or active erosion across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

Soil disturbance is the sum of total stream-bank erosion (active or recent erosion) and pugging disturbance (> 50% pugging disturbance within the riparian margin). One quarter (25%) of the bank length across the region in 2012 was observed to be disturbed and, of this, 13% was attributed to pugging disturbance (Figure 35). The remaining three quarters of bank length was undisturbed.

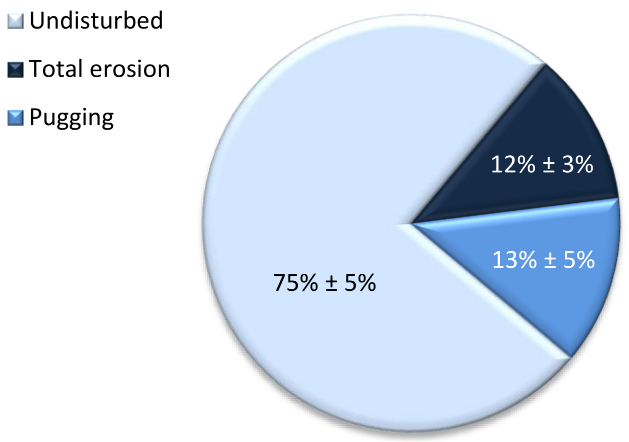

Figure 35: Average proportion of bank length undisturbed and with erosion or pugging disturbance across the Waikato region in 2012. Error term represent the 95% confidence interval about the average.

There was no difference in the average proportion of bank length eroded (either in terms of total erosion or its active or recent components) between dairy and drystock land uses (Figure 36). However, the average proportion of bank length disturbed for dairy (16%) was significantly smaller than that for drystock (34%) due to significantly less pugging for dairy (5% of bank length) compared with drystock (21% of bank length). These results suggest that land use type (and, moreover, the associated level of stock exclusion) has little effect on stream-bank erosion. However, the effect that land use has on soil disturbance reflects the difference in stock exclusion (and effective fencing) between dairy and drystock (Figures 5 & 11) because pugging within the riparian margin is a direct result of stock access to that area.

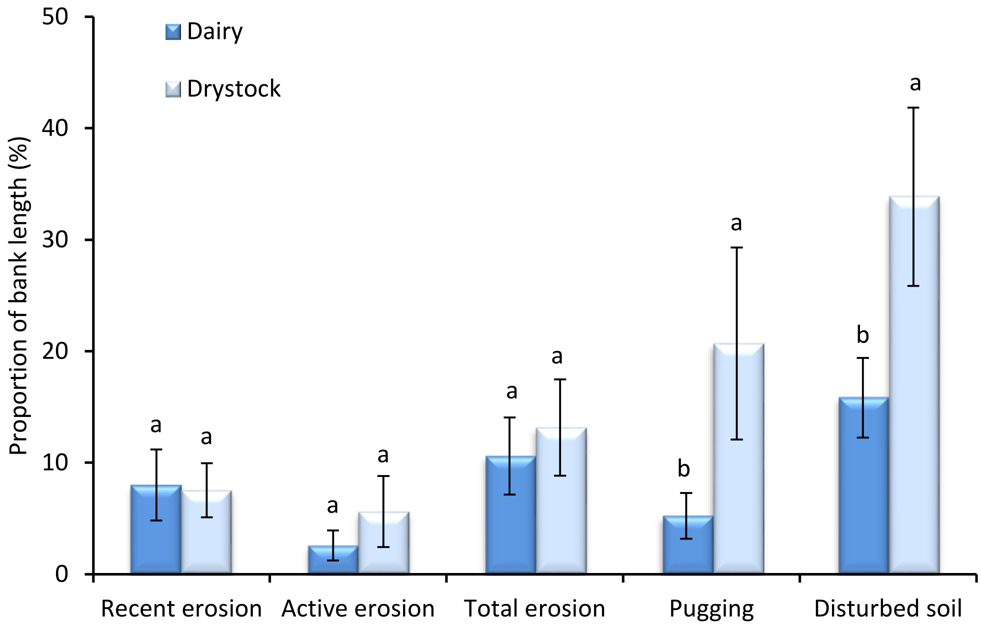

Figure 36: **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) within land use types across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

Figure 37 shows that the proportion of bank length disturbed that was effectively fenced (13%) was significantly smaller than the proportion of disturbed bank length not effectively fenced (35%). In contrast, the presence of effective fencing appears to have had little effect on the proportion of bank length eroded — a result that is consistent with the findings of Williamson et al. (1992) who reported that the undercutting of stream-banks is largely unaffected by the grazing of riparian margins. These results are very similar to those presented in Figure 36 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.

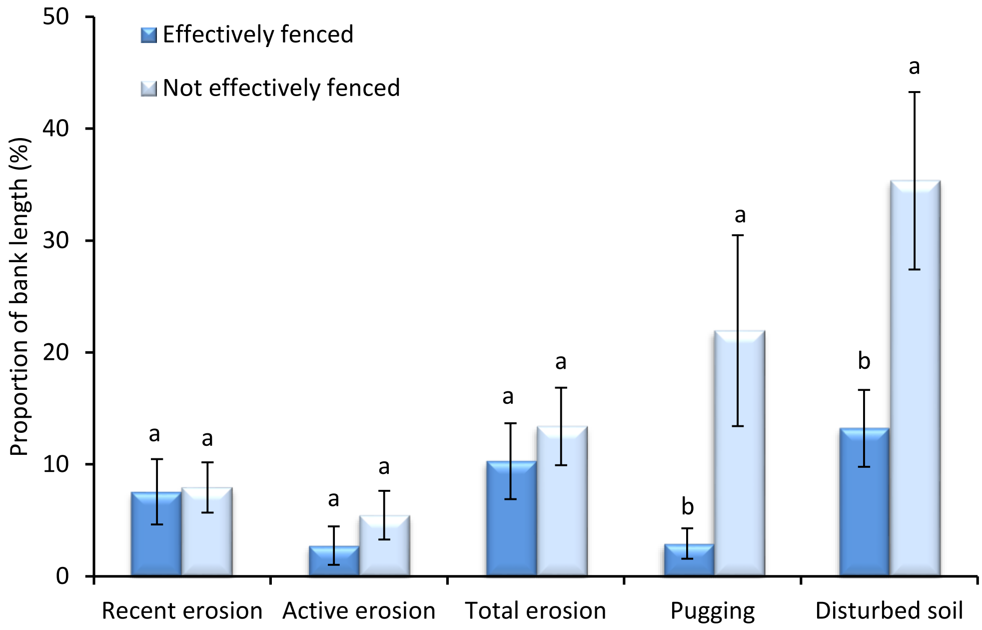

Figure 37: Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) that is effectively fenced or unfenced across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.

The average proportion of disturbed bank length with woody vegetation (17%) was significantly smaller than that with non-woody vegetation (27%) due to significantly less pugging associated with woody vegetation compared with non-woody vegetation (Figure 38). 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 (or by stock access). Although woody vegetation may, in some cases, 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 18). That is, a larger proportion of bank length with woody vegetation occurs in association with effective fencing than without.

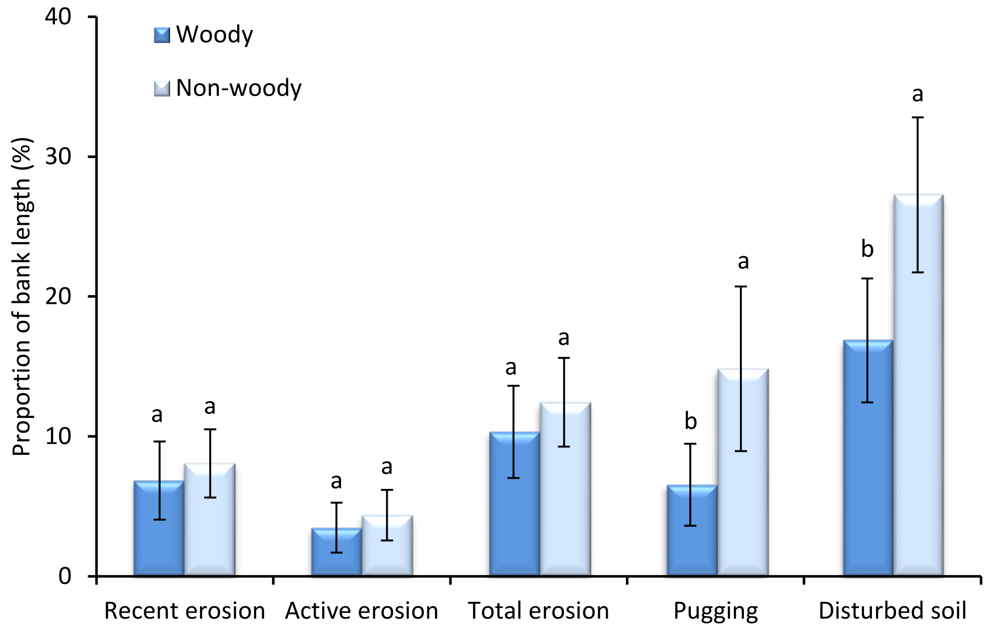

Figure 38: **Average proportion of bank length eroded and bank length disturbed (with active and recent erosion components and pugging disturbance) that is occupied by woody or non-woody vegetation across the Waikato region in 2012. Error bars represent the 95% confidence interval about the average. Within each category, averages carrying the same letter are not significantly (P < 0.05) different.**

The Central Waikato, Lake Taupo, and Upper Waikato management zones had the smallest average proportions of bank length eroded (4%, 3%, and 2%, respectively) and were significantly different to all other zones, for which average proportions of bank length eroded ranged from 11% to 19% (Figure 39). For the Lake Taupo, and Upper Waikato management zones, this result could possibly be, at least in-part, related to historic soil conservation schemes in these zones (see Environment Waikato, 1998; Palmer, 2004). The nature of the topography (predominantly flat land), patterns of land use, and management factors (intensive uses, prevalence of smaller blocks) could possibly explain the result for the Central Waikato zone.

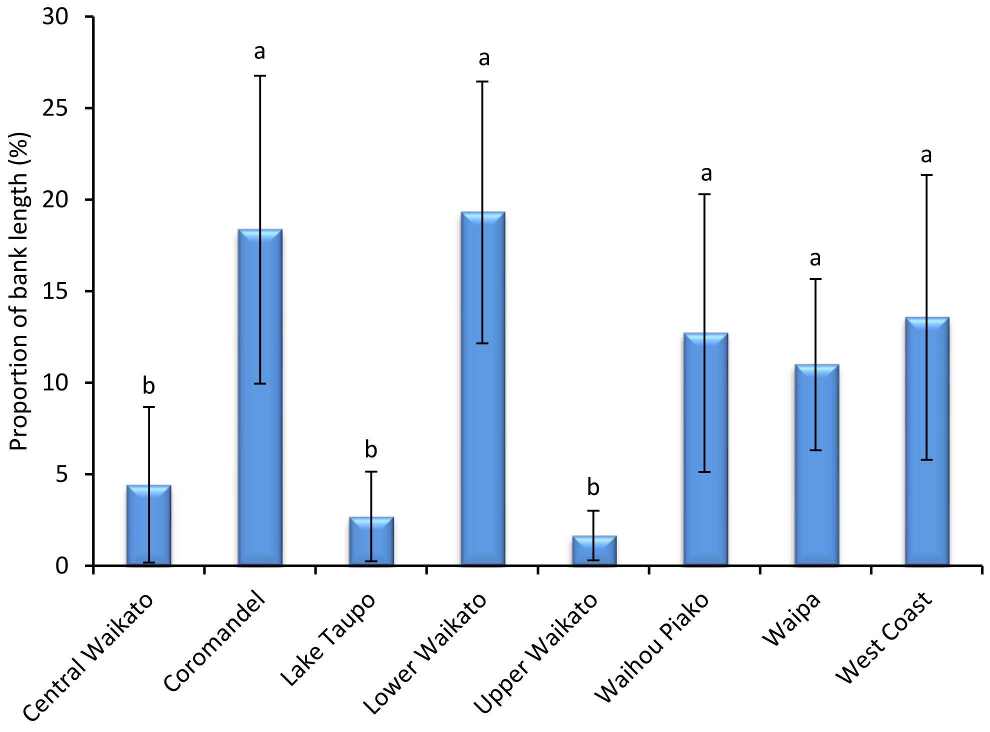

Figure 39: **Average proportion of bank length eroded within each management zone in 2012. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

Figure 40 indicates that stream orders 1 and 2 had the smallest average proportions of bank length eroded (about 10%) and were significantly different to stream orders 4 and 5 which had the largest average proportions of bank length eroded (26% and 20%, respectively).

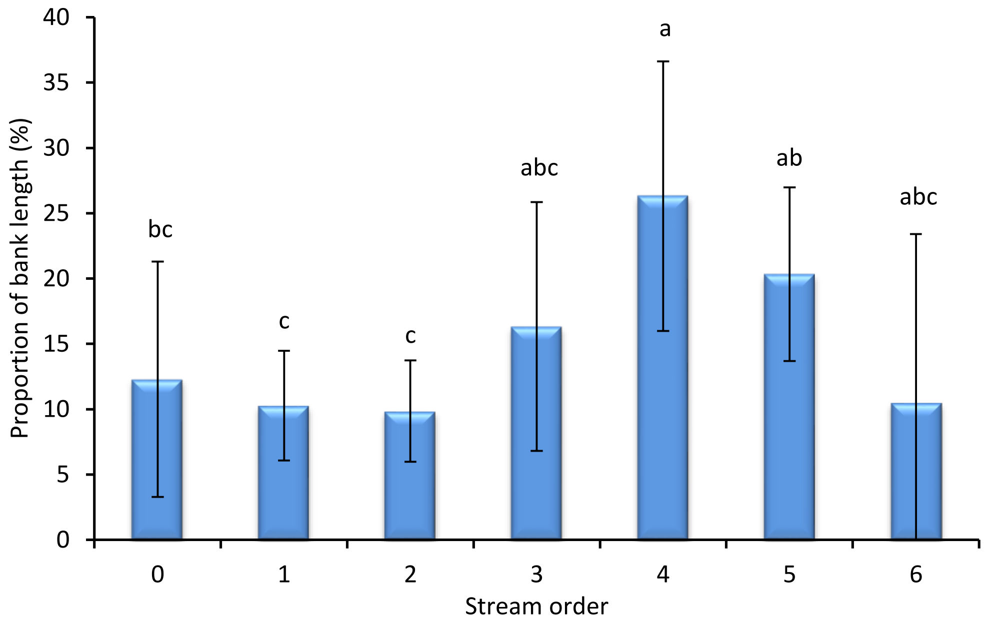

Figure 40: **Average proportion of bank length eroded within each stream order in 2012. Stream order 0 represents drains. Error bars represent the 95% confidence interval about the average. Averages carrying the same letter are not significantly (P < 0.05) different.**

3.6.2 Change over time

A significant increase in the average proportion of bank length eroded (i.e. total erosion) of about 7% of bank length was detected over the past decade (2002-2012) across the Waikato region (Figure 41, Table 16). However, a significant decrease (of about 10% of bank length) in the amount total erosion over the past 5 years (2007-2012) was also detected. Similar changes were found for the recent and active components of total erosion except that active erosion did not change significantly over the past 5 years. 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.

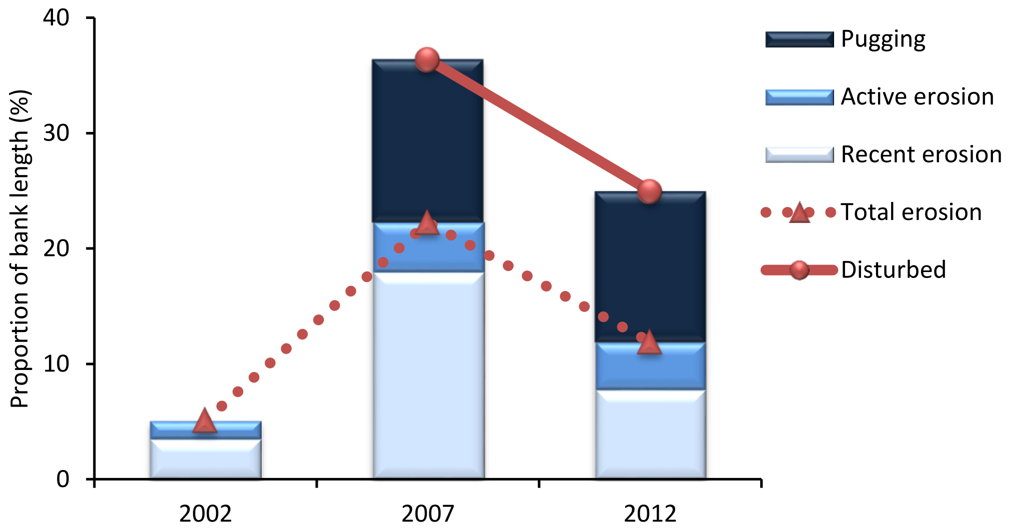

Figure 41: Average proportion of bank length eroded and bank length disturbed (with active and recent components and pugging disturbance) at the three survey periods (2002, 2007, and 2012). Note that pugging disturbance was not assessed in 2002.

The observation of pugging disturbance was first undertaken during the 2007 survey. Therefore, the change in pugging and soil disturbance can only be examined for the 5-year period between 2007 and 2012. Figure 41 and Table 16 show that the average proportion of bank length disturbed significantly decreased by about 11% of bank length over the past 5 years. However, this decrease is primarily due to the decrease in total erosion over the same period because pugging disturbance did not change. It is interesting to note the lack of any significant change in the proportion of bank length with pugging disturbance despite the significant increase in bank length fenced across the region over the same period (Figure 8, Table 6).

Table 16: **Average change in the proportion of bank length eroded or disturbed (including erosion type and pugging components) over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.**

	2007-2012 (5-year)		2002-2012 (10-year)	
	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Active erosion	-0.2 NS	3.4	2.5 **	1.8
Recent erosion	-10.2 **	5.9	4.3 **	2.3
Total erosion	-10.4 **	6.6	6.8 **	3.1
Pugging	-1.0 NS	5.5	-	-
Disturbed	-11.4 *	8.9	-	-

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at α = 0.01, * Significant at α = 0.05, NS Not significant.

An examination of 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 (Figure 42, Table 17). The differences were that the amount of total erosion did not significantly change over the past 5 years for dairy (but did significantly decrease for drystock over the same period) and the amount of active erosion did not significantly change over the past 10 years for drystock (but did significantly increase for dairy over the same period).

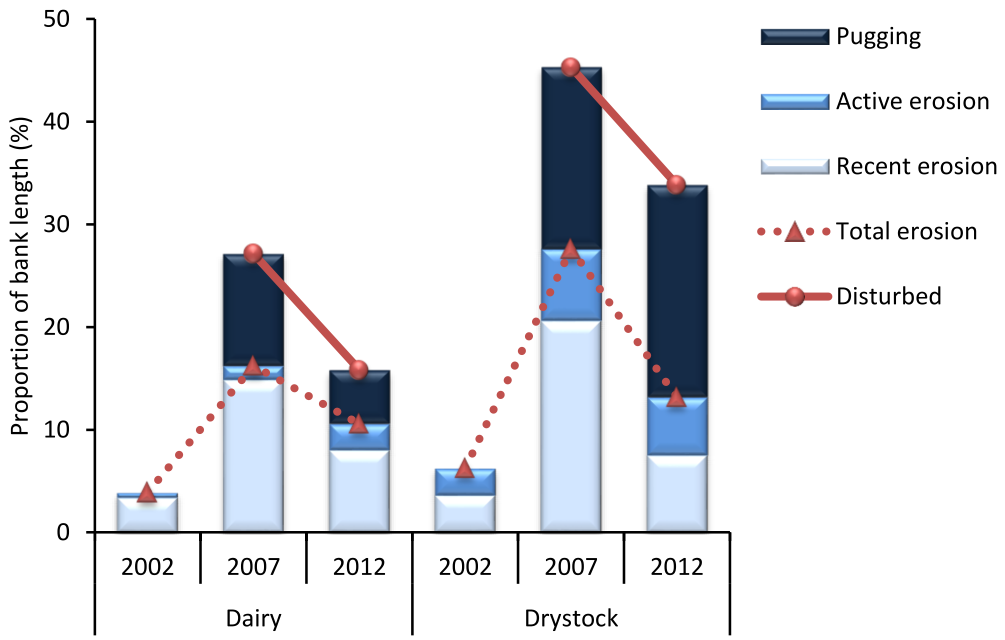

Figure 42: **Average proportion of bank length eroded and bank length disturbed (with active and recent components and pugging disturbance) within land use types at the three survey periods (2002, 2007, and 2012). Note that pugging disturbance was not assessed in 2002.**

Over the past 5 years, the amount of pugging disturbance significantly decreased (by about 6% of bank length) for dairy but did not significantly change for drystock (Figure 42, Table 17). This change is responsible for the significant reduction in the amount of total soil disturbance for dairy over the same period. In contrast, the amount of total soil disturbance for drystock did not significantly change, despite the significant decrease in the amount of total erosion over the same period. The significant decrease in the amount of pugging disturbance for dairy corresponds well with the increase in the amount of fencing for dairy over the same period (Figure 9, Table 7). Furthermore, the lack of any significant change in the amount of pugging disturbance for drystock corresponds well with the absence of any significant change in the amount of fencing for drystock over the same period (Figure 9, Table 7).

Table 17: 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 (2007-2012) and 10-year (2002-2012) periods.

	Land use type	2007-2012 (5-year)		2002-2012 (10-year)	
		Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Recent erosion	Dairy	-6.8 *	6.5	4.6 **	3.4
	Drystock	-13.0 **	9.6	3.9 **	2.7
Active erosion	Dairy	1.2 NS	1.8	2.1 *	1.7
	Drystock	-1.4 NS	6.1	3.0 NS	3.4
Total erosion	Dairy	-5.6 NS	6.7	6.7 **	4.2
	Drystock	-14.4 *	11.2	6.9 **	4.6
Pugging	Dairy	-5.7 *	4.8	-	-
	Drystock	3.0 NS	9.4	-	-
Disturbed	Dairy	-11.3 **	7.4	-	-
	Drystock	-11.5 NS	15.4	-	-

† 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 decade, the average proportion of bank length eroded significantly increased within the Lower Waikato and Waihou Piako management zones by 14% and 9% of bank length, respectively (Table 18). However, much of the change within these zones occurred between 2002 and 2007 because there was no significant change observed over the past 5 years. In contrast, the average proportion of bank length eroded significantly decreased within the Upper Waikato zone by about 3% of bank length over the past 10 years. The Lake Taupo and Waipa zones exhibited significant decreases in the average proportion of bank length eroded over the past 5 years of about 11% and 17% of bank length, respectively.

Table 18: Average proportion of bank length eroded within management zones at the three survey periods (2002, 2007, and 2012) and average change over the previous 5-year (2007-2012) and 10-year (2002-2012) periods.

Management Zone	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
	2002	2007	2012	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
Central Waikato	8.1	4.8	4.4	-0.4 NS	5.0	-3.7 NS	4.1
Coromandel	15.1	58.5	18.4	-40.1 NS	56.2	3.2 NS	24.5
Lake Taupo	1.0	13.4	2.7	-10.7 *	8.4	1.7 NS	4.5
Lower Waikato	5.3	13.7	19.3	5.6 NS	7.6	14.0 **	8.1
Upper Waikato	4.5	22.7	1.7	-21.1 **	11.1	-2.8 **	1.4
Waihou Piako	3.6	14.0	12.7	-1.3 NS	12.4	9.1 *	8.0
Waipa	5.2	27.8	11.0	-16.8 **	6.6	5.8 NS	6.4
West Coast	5.6	31.7	13.6	-18.1 NS	26.0	8.0 NS	8.9

† Percentage point (% of bank length)

‡ 95% Confidence interval about the average.

** Significant at $\alpha = 0.01$, * Significant at $\alpha = 0.05$, NS Not significant.

Stream orders 1, 2 and 5 exhibited significant increases of about 6%, 5%, and 10% of bank length, respectively, in the proportion of bank length eroded over the past decade (Table 19). However, with respect to stream order 2, the average proportion of bank length eroded significantly decreased from about 22% in 2007 to about 10% in 2012. The significant increases in the amount of erosion in order 1 and 2 waterways between 2002 and 2012 may relate to the very small proportions of bank length eroded that were observed in 2002 – meaning even relatively modest increases could be detected as significant. The reason for the significant increase in order 5 waterways is unclear. Stream orders 1 and 2 still had the smallest average proportions of bank length eroded in 2012 (Figure 40).

Table 19: Average proportion of bank length eroded within stream orders at the three survey periods (2002, 2007, and 2012) and average change over the previous 5-year (2007-2012) and 10-year (2002-2012) periods. Stream order 0 represents drains.

Stream order	Average bank length (%)			2007-2012 (5-year)		2002-2012 (10-year)	
	2002	2007	2012	Change (pp†)	95%CI‡	Change (pp†)	95%CI‡
0	7.2	6.8	12.3	5.5 NS	14.6	5.1 NS	8.2
1	3.9	25.1	10.3	-14.8 NS	16.7	6.4 *	5.7
2	4.5	22.4	9.9	-12.5 **	6.3	5.4 **	4.0
3	6.4	26.6	16.3	-10.3 NS	14.1	9.9 NS	11.6
4	16.3	24.8	26.3	1.5 NS	11.2	10.0 NS	10.9
5	10.4	35.5	20.3	-15.1 NS	15.2	9.9 **	5.3
6	5.3	12.4	10.5	-1.9 NS	5.6	5.2 NS	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.

3.6.3 Summary of key stream-bank erosion results

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

- The majority (88%) of bank length across the region in 2012 was uneroded. Of the 12% of bank length observed to be eroded, 4% showed signs of active erosion whereas 8% was found to be recent erosion.
- Soil disturbance is the sum of total stream-bank erosion and pugging disturbance. One quarter (25%) of the bank length across the region in 2012 was observed to be disturbed and, of this, 13% was attributed to pugging disturbance.
- There was no difference in the average proportion of bank length eroded (either in terms of total erosion or its active or recent components) between dairy and drystock land uses whereas the average proportion of bank length disturbed for dairy (16%) was significantly smaller than that for drystock (34%).
- The proportion of bank length disturbed that was effectively fenced (13%) was significantly smaller than the proportion of disturbed bank length not effectively fenced (35%).
- The average proportion of disturbed bank length with woody vegetation (17%) was significantly smaller than that with non-woody vegetation (27%).
- The Central Waikato, Lake Taupo, and Upper Waikato management zones had the smallest average proportions of bank length eroded (4%, 3%, and 2%, respectively).
- Stream orders 1 and 2 had the smallest proportions of bank length eroded (about 10%) and were significantly different to stream orders 4 and 5 which had the largest proportions of bank length eroded (26% and 20%, respectively).
- A significant increase in the proportion of bank length eroded of about 7% of bank length (i.e. from 5% to 12%) was detected over the past decade 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.
- Over the past 5 years, the amount of pugging disturbance significantly decreased (by about 6% of bank length) for dairy but did not significantly change for drystock.
- The average proportion of bank length eroded significantly decreased within the Upper Waikato zone by about 3% of bank length over the past 10 years.
- Stream orders 1, 2 and 5 exhibited significant increases of about 6%, 5%, and 10% of bank length, respectively, in the proportion of bank length eroded over the past decade.

3.7 Drivers of stream-bank erosion

A range of riparian characteristics observed during the 2012 survey that could potentially be associated with stream-bank erosion were investigated using correlation and regression (both simple and multiple) analysis. Three dependent variables were considered: active erosion, total erosion (active or recent erosion), and soil disturbance (active erosion or recent erosion or > 50% pugging disturbance). All three variables were expressed as a proportion of bank length at each sample site. In the sections below, the results of the correlation analysis are presented first, followed by the results of the simple and multiple regression analysis (i.e. a description of the regression models developed).

3.7.1 Correlation analysis

Correlations between the three measures of erosion and the various potential explanatory variables produced by the SAS procedure CORR are presented in Table 20. Of the potential explanatory variables considered in the correlation analysis, the proportion of bank length eroded (total erosion) was significantly negatively correlated with the amount of effective fencing (-0.26), forest vegetation structure (-0.11), woody vegetation with buffer widths greater than 2 m and greater than 5 m (-0.12), total stream crossings per km (-0.12), and culverts per km (-0.14). The negative relationship indicates that an increase in any of these variables may be associated with a decrease in bank length eroded. The effective fencing and stream crossing (total and culverts) variables contribute to bank stability via stock exclusion whereas the forest vegetation and woody vegetation buffer width variable may contribute to bank stability via root networks and perhaps also via stock exclusion (where the woody vegetation is dense). The proportion of bank length eroded was also significantly positively correlated with (total) stock access (0.20), grasses vegetation structure (0.12), bank slope (0.16), fords per km (0.16), and other non-living obstructions (0.15). The positive relationship indicates that an increase in any of these variables may be associated with an increase in bank length eroded. These explanatory variables represent a similar range of factors to those negatively correlated with total erosion (i.e. fencing, stock access, vegetation structure type, the nature of the riparian vegetation buffer, and stream crossing type) but with the addition of bank morphology (bank slope), and the type of in-stream obstruction (other non-living). Although statistically significant, the correlation between all of these variables and total erosion was relatively weak with the largest correlation co-efficient being -0.26 (for effectively fenced bank length). This is probably why the association between total erosion and effective fencing was not apparent when examining average values for the region (Figure 37).

Table 20: Associations between three measures of stream-bank erosion and various explanatory variables (observed during the 2012 survey) expressed using Pearson correlation coefficients.

Group	Variable	Proportion of bank length (%)		
		Active erosion	Total erosion	Soil disturbance
Effective fencing	Both banks (% stream length)	-0.22 **	-0.23 **	-0.40 **
	One bank (% stream length)	-0.17 **	-0.24 **	-0.44 **
	Effectively fenced (% bank length)	-0.22 **	-0.26 **	-0.47 **
Stock access (% bank length)	Current access	0.10 *	0.05 NS	0.30 **
	Current/Recent access	0.22 **	0.18 **	0.49 **
	Current/Recent/Past (total) access	0.21 **	0.20 **	0.52 **
Vegetation type (% bank length)	Woody vegetation	-0.05 NS	-0.09 NS	-0.26 **
	Non-woody vegetation	0.05 NS	0.09 NS	0.26 **
Vegetation structure (% bank length)	Forest	-0.07 NS	-0.11 *	-0.16 **
	Treeland	-0.01 NS	-0.03 NS	-0.19 **
	Scrub	-0.04 NS	-0.09 NS	-0.13 **
	Shrubland	-0.02 NS	0.02 NS	-0.05 NS
	Grasses	0.08 NS	0.12 *	0.26 **
	Wetland	-0.07 NS	-0.07 NS	0.04 NS
Vegetation buffer width (% bank length)	Woody < 2 m	0.14 **	0.08 NS	0.14 **
	Woody > 2 m	-0.09 NS	-0.12 *	-0.30 **
	Woody < 5 m	0.08 NS	0.04 NS	-0.05 NS
	Woody > 5 m	-0.11 *	-0.12 *	-0.24 **
	Non-woody < 2 m	0.02 NS	0.02 NS	0.09 NS
	Non-woody > 2 m	0.03 NS	0.06 NS	0.16 **
	Non-woody < 5 m	-0.01 NS	0.00 NS	0.06 NS
	Non-woody > 5 m	0.07 NS	0.09 NS	0.20 **
Bank characteristics	Bank height (m)	0.00 NS	0.00 NS	-0.15 **
	Bank slope (°)	0.10 NS	0.16 **	0.02 NS
Stream crossings - simplified (no./km)	Total	-0.09 NS	-0.12 *	0.03 NS
	Bridges	-0.06 NS	-0.05 NS	-0.06 NS
	Fords	0.13 *	0.16 **	0.09 NS
	Culverts	-0.09 NS	-0.14 **	0.06 NS
Stream crossings – detailed (no./km)	Constructed fords	0.16 **	0.13 *	0.06 NS
	Streambed fords	0.08 NS	0.13 *	0.07 NS
	Bridges <10 m	-0.04 NS	-0.02 NS	-0.05 NS
	Bridges >10 m	-0.01 NS	-0.01 NS	-0.06 NS
	'Bridge' with culvert	-0.07 NS	-0.09 NS	0.01 NS
	Culverts	-0.09 NS	-0.14 **	0.06 NS
Obstructions (no./km)	Dams	-0.02 NS	0.07 NS	0.02 NS
	Side entries	0.03 NS	0.05 NS	0.14 **
	Willows	0.13 **	0.07 NS	0.03 NS
	Other non-living	0.11 *	0.15 **	0.09 NS
	Other living	0.02 NS	-0.01 NS	0.02 NS

NS Not statistically significant

* Statistically significant ($p<0.05$)

** Statistically significant ($p<0.01$)

The explanatory variables significantly correlated with active erosion were generally similar to those correlated with total erosion (Table 20). One notable difference was that woody vegetation with buffer widths less than 2 m was significantly positively correlated with active erosion.

Soil disturbance was significantly negatively correlated with the amount of effective fencing (-0.47), woody vegetation (-0.26), woody vegetation with buffer widths greater than 2 m and greater than 5 m (-0.30 and -0.24, respectively), and bank height (Table 20). The explanatory variables significantly positively correlated with soil disturbance included (total) stock access (0.52), non-woody vegetation (0.26), woody vegetation with buffer widths less than 2 m (-0.14), non-woody vegetation with buffer width greater than 2 m and greater than 5 m (0.16 and 0.20, respectively), and side entries (0.14). Unlike total erosion, soil disturbance was not significantly correlated with any stream crossing variable. Other points of difference were that: (1) the effective fencing and stock access explanatory variables were more strongly correlated with soil disturbance than total erosion (with correlation coefficients for soil disturbance approximately double those for total erosion), (2) there was an association between non-woody vegetation with wider buffer widths (greater than 2 m and greater than 5 m) and soil disturbance, and (3) there was an association between bank height and soil disturbance. Soil disturbance encompasses total erosion and pugging disturbance. Therefore, the points of difference described above largely result from taking pugging disturbance into account. Pugging disturbance within the riparian margin can only be caused by stock access and so the variables significantly correlated with soil disturbance likely represent factors related to stock access. For example, it is conceivable that high stream banks present a greater physical impediment to stock access than low stream banks. The negative relationship between bank height and soil disturbance supports this.

3.7.2 Simple regression analysis

Simple regression models for predicting active erosion, total erosion, or soil disturbance from the proportion of bank length effectively fenced are presented in Table 21. The R^2 values are low because of considerable variation between sites. This means that these regression models are poor at predicting the amount of erosion or disturbance at a particular sample site. However, the models do provide good estimates of the change in stream-bank erosion or soil disturbance, in response to changes in the proportion of bank length effectively fenced, averaged over a large number of sites.

Table 21: Simple regression models for predicting stream-bank erosion from the proportion of bank length effectively fenced. Shown are regression coefficients with standard errors in parentheses, and the regression R^2.

Coefficient	Active erosion (% bank length)	Total erosion (% bank length)	Soil disturbance (% bank length)
Intercept	7.55 (0.96)	19.48 (1.71)	40.12 (2.18)
Effectively fenced (% bank length)	-0.063 (0.014)	-0.133 (0.025)	-0.338 (0.032)
R^2	0.05	0.07	0.22

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 43). Table 21 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, or soil disturbance of 0.6%, 1.3%, and 3.4% of bank length, respectively. At the extremes, these models predict that the average proportion of bank length with active erosion, total (active or recent) erosion, or soil disturbance with totally unfenced waterways would be 8%, 20% and 40%, respectively. However, with fully fenced waterways, the amount of active erosion, total (active or recent) erosion, or soil disturbance is predicted to be only 1.3%, 6.2% and 6.3%, respectively. In 2012, the average proportions of bank length with active erosion, total (active or recent) erosion, or soil disturbance were observed to be 4%, 12%, and 25%, respectively (Figures 30 & 31).

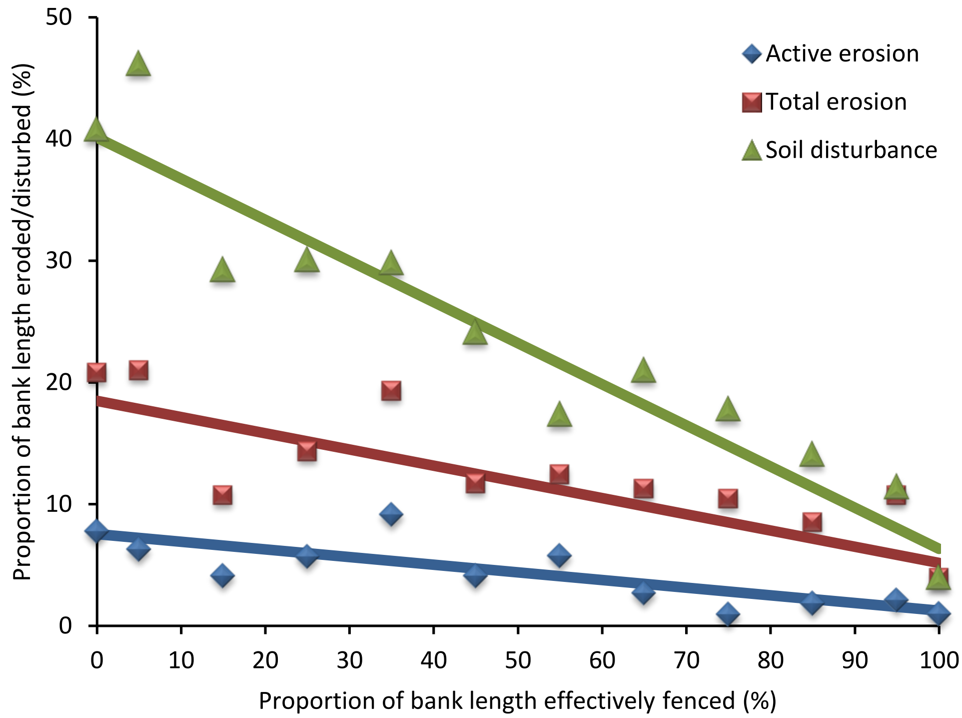

Figure 43: Relationship between three measures of stream-bank erosion (active, total, and soil disturbance) and proportion of bank length effectively fenced. The lines show predicted erosion using the regression equations given in Table 21. The points represent average proportions of bank length eroded or disturbed plotted against proportion of bank length effective fenced in 10% classes.

The proportion of bank length with stock access (current, recent, or past) also provides good predictions of change in the amount of stream-bank erosion or soil disturbance, especially the amount of soil disturbance, averaged across the entire Waikato region (Table 22).

Table 22: Simple regression models for predicting stream-bank erosion from the proportion of bank length with stock access (current, recent, or past). Shown are regression coefficients with standard errors in parentheses, and the regression R^2.

Coefficient	Active erosion (% bank length)	Total erosion (% bank length)	Soil disturbance (% bank length)
Intercept	1.81 (0.72)	8.15 (1.29)	7.82 (1.56)
Stock access (% bank length)	0.056 (0.013)	0.095 (0.023)	0.336 (0.029)
R^2	0.05	0.04	0.27

3.7.3 Multiple regression analysis

Multiple regression models were fitted using the SAS procedure GLMSELECT. A stepwise procedure using the Schwarz Bayesian information criterion (SBC) to select independent variables was used. Models were developed for each of the three dependent variables (i.e. active erosion, total erosion, and soil disturbance). In addition to most of the continuous variables shown in Table 20, the categorical variables stream order and land use type were tested for inclusion, although neither provided significant improvements in prediction. The final multiple regression models are shown in Table 23.

Table 23: Multiple regression models for predicting stream-bank erosion from various explanatory variables. Shown are regression coefficients with standard errors in parentheses, and the regression R^2.

Coefficient	Active erosion (% bank length)	Total erosion (% bank length)	Soil disturbance (% bank length)
Intercept	7.55 (0.96)	11.42 (2.55)	43.64 (2.30)
Effectively fenced (% bank length)	-0.063 (0.014)	-0.123 (0.025)	-0.305 (0.033)
Bank slope (°)	-	0.186 (0.057)	-
Fords (no./km)	-	7.12 (2.56)	-
Other non-living obstructions (no./km)	-	1.39 (0.56)	-
Woody vegetation > 2 m wide (% bank length)	-	-	-0.153 (0.034)
R^2	0.05	0.13	0.26

The regression model for active erosion uses only a single variable, the proportion of bank length effectively fenced. Although a number of other variables were significantly correlated with active erosion (Table 20), none were chosen using the SBC procedure. However, the model for predicting total erosion includes bank slope, and numbers of fords per km and other non-living obstructions per km, in addition to the proportion of bank length effectively fenced. Total erosion is predicted to increase by 7% of bank length for every additional ford per km, and by 1.4% of bank length for every additional non-living obstruction (i.e. other than dams, side entries, and crossings) per km. The soil disturbance model includes the proportion of bank length occupied by woody vegetation with a buffer width > 2 m (in addition to the proportion of bank length effectively fenced). This model predicts that woody vegetation provides about half the reduction in soil disturbance as a similar length of effective fencing.

3.7.4 Summary of key drivers of stream-bank erosion results

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

- Correlation analysis indicated that total erosion is significantly (but relatively weakly) related to fencing, stock access, vegetation structure type (forest and grasses), the nature of the riparian vegetation buffer (woody > 2 m and woody > 5 m), stream crossing type (fords and culverts), bank morphology (slope), and the type of in-stream obstruction (other non-living).
- Soil disturbance was related to a broadly similar set of variables. However, the effective fencing and stock access explanatory variables were more strongly correlated

with soil disturbance than total erosion (with correlation coefficients for soil disturbance approximately double those for total erosion).

- The simple regression models developed can 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. They predict that both stream-bank erosion and soil disturbance could be reduced to about 6% of bank length by fully fencing waterways.
- The multiple regression model developed for total erosion identifies the relative importance of the proportion of bank length effectively fenced, bank slope, numbers of fords per km, and other non-living obstructions per km in predicting the extent of total erosion.

3.8 Analysis and review of survey design

3.8.1 Effect of varying sample size

The effect of varying the sample size used within the current survey design can be examined by predicting 95% confidence intervals (i.e. precision) across a range of sample size values for several key riparian characteristics (Table 24). Predicted 95% confidence intervals that relate to an assessment of the change over the period 2002-2012 in the key characteristics are given in addition to an assessment of the state of those characteristics (i.e. as at 2012).

Table 24 can be used to determine the expected precision of the average values that would have been obtained for the key characteristics by surveys of varying sample sizes. For example, if only 200 sites had been sampled during the 2012 survey (rather than the 385 size that were actually sampled), the overall average proportion of bank length effectively fenced would have had a 95% confidence interval of about ±6.5%. Table 24 can also be used to obtain the expected precision of estimates for sub-populations (e.g. management zone or land use type). For instance, a management zone with 50 samples would have a 95% confidence interval of approximately ±9.6% about the average proportion of bank length with woody vegetation.

Table 24: Predicted 95% confidence intervals across a range of sample sizes for key riparian characteristics based on the 2012 survey (n=385) and the assessment of change over time (2002-2012) (n=302).

	2012 survey					2002-2012 change		
Sample size	Effective fencing	Woody vege.	Total erosion	Stock access	Fords	Fenced	Woody vege.	Total erosion
	(% bank length)				(no./km)	(% bank length)		
25	±18.4	±13.6	±10.6	±19.8	±0.208	±19.5	±9.0	±11.0
50	±13.0	±9.6	±7.5	±14.0	±0.147	±13.8	±6.4	±7.8
100	±9.2	±6.8	±5.3	±9.9	±0.104	±9.8	±4.5	±5.5
200	±6.5	±4.8	±3.8	±7.0	±0.073	±6.9	±3.2	±3.9
300	±5.3	±3.9	±3.1	±5.7	±0.060	±5.6	±2.6	±3.2
400	±4.6	±3.4	±2.7	±5.0	±0.052	±4.9	±2.3	±2.7
500	±4.1	±3.0	±2.4	±4.4	±0.046	±4.4	±2.0	±2.5
600	±3.8	±2.8	±2.2	±4.0	±0.042	±4.0	±1.8	±2.2
Actual average	48.9	26.3	11.9	49.3	0.063	16.6	2.4	6.8
Actual 95%CI	±4.7	±3.5	±2.7	±5.1	±0.053	±5.5	±2.6	±3.1

The 95% confidence intervals for all key characteristics decrease as samples size increases but at a diminishing rate (Table 24). For example, increasing the sample size from 100 to 200 would result in a relatively large improvement in precision (i.e. a reduction in the 95% confidence interval) whereas an increase in sample size from 500 to 600 would yield relatively little improvement in precision. The actual 95% confidence intervals for the 2012 survey, based on *n*=385, are similar to those predicted for a sample size of 400 sites whereas the actual 95% confidence intervals for the assessment of change over time (2002-2012), based on *n*=302, are very similar to those predicted for a sample size of 300 sites. Table 24 suggests that there would be little benefit with respect to precision to be gained in increasing the survey sample size beyond 400 sites for future surveys. The loss in precision that would result from a reduction in sample size below 300 sites would not be desirable because estimates would be less precise and changes more difficult to detect. Therefore, maintaining the survey sample size at around 385 to 400 sites would be appropriate (i.e. at around current levels).

3.8.2 Effect of varying sampling unit length

The effect of varying the sampling unit length from the 1000 m used in the current design was examined (Table 25). The results indicate no loss in precision with shorter sampling units for fencing and stock access, a slight loss in precision for woody vegetation and total erosion, but markedly poorer precision for stream crossing variables (particularly fords). Based on the current survey design, the assessment of the amount of effective fencing would not require any additional sample sites than were used in the 2012 survey (*n*=385) to maintain the precision at a level similar to that obtained in 2012 if the sampling unit length was reduced to 500 m (or 250 m). However, an additional 25, 22, and 3 sites would be required to maintain precision around estimates of the amount of woody vegetation, total erosion, and stock access, respectively.

Optimum sampling unit length will depend on the cost of identifying and accessing a site relative to the time and cost of carrying out the field observations once the site has been accessed. Arranging site access with landowners is a time-consuming component of the survey process. A key benefit of using a shorter sampling unit length (e.g. 500 m) would likely be a reduction in the number of landowners to be contacted (as it is likely that fewer property boundaries would be crossed), leading to time and cost savings. Other benefits to using a shorter sampling unit length are expected to include less time required to observe a site in the field and less variation in land use and management practices across the length of a site. A similar riparian characteristics survey undertaken for the Auckland region (Neale et al., 2009) used a site length of 500 m. The decision of Neale et al (2009) to use a site length of 500 m was determined following the statistical analysis of preliminary field data from a pilot study undertaken in the Waikato region (i.e. Hill, 2001). Their analysis also indicated an increase in the number of sample sites per land use was required to maintain the power of the data to detect change (Neale et al., 2009).

Table 25: Averages and 95% confidence intervals of key variables for a range of sampling unit lengths. Also shown is the predicted increase in sample size required to achieve comparable precision using sampling units of 500 m and 250 m compared with 1000 m.

	Sampling unit length	Effective fencing	Woody vege.	Total erosion	Stock access	Fords	Culverts
		(% bank length)				(no./km)	
Average	1000 m	48.9	26.3	11.9	49.3	0.06	2.12
	500 m	49.6	26.9	10.8	49.2	0.12	2.12
	250 m	49.5	23.8	10.5	48.8	0.14	1.84
95% CI	1000 m	±4.7	±3.5	±2.7	±5.1	±0.05	±0.31
	500 m	±4.5	±4.0	±3.0	±5.1	±0.19	±0.36
	250 m	±4.6	±3.9	±3.5	±5.1	±0.18	±0.51
Increase in sample size required (%)	500 m	-2.2	6.5	5.6	0.8	47.6	7.2
	250 m	-0.9	6.3	12.5	0.7	45.5	22.2

3.8.3 Potential improvements in survey design efficiency

The original (2002) survey design was a stratified random design with strata defined by management zone x land use type x stream order, and with equal numbers of samples per stratum. This design was somewhat unbalanced with large strata under-represented and smaller strata over-represented. Although the original design has been subsequently improved by adding samples to under-represented strata, a significant lack of balance from the original design is still apparent. For example, Appendix 2 indicates that the sampling fraction per stratum ranged from 0.002 (West Coast, drystock, stream order 1, with a total stream length of 3178 km, was represented by 6 sites) to 0.82 (Central Waikato, dairy, stream order 5-7, with a total stream length of 5 km, was represented by 4 sites). In a fully balanced survey design, the sampling fraction should be approximately constant in all strata.

Estimates of the precision (95% confidence intervals) provided for key riparian characteristics by a more efficient survey design were compared with those achieved in the 2012 survey and the assessment of change over the period 2002-2012 (Table 26). The results indicate that major improvements in precision could be achieved with a more efficient allocation of sample units to strata. The results also show that substantial reductions (of 44% to 70%) in sample size, while maintaining the same level of precision achieved by the 2012 survey, are possible with a more efficient design.

Table 26: **The 95% confidence intervals achieved in the 2012 survey are compared with those predicted for a more efficient design of the same sample size for key variables. Reductions in sample size for the more efficient design which achieve the same level of precision are also shown.**

		2012 survey					**2002-2012 change**		
		Effective fencing	Woody vege.	Total erosion	Stock access	Fords	Fence d	Woody vege.	Total erosion
		(bank length %)				(no./km)	(bank length %)		
95%CI	Actual design	±4.71	±3.48	±2.72	±5.08	±0.053	±5.56	±2.57	±3.12
95%CI	Efficient design	±2.83	±2.38	±1.58	±3.41	±0.029	±3.15	±1.70	±1.85
Potential sample size reduction (%)		64	53	66	55	70	68	44	55

Expected levels of precision for a range of sample sizes using the more efficient design are given for key characteristics (Table 27). The 95% confidence intervals presented in Table 27 should be compared with those presented in Table 24. The results demonstrate that an improved survey design could achieve much greater precision for the same cost (Table 27), or similar precision at much less cost (Table 26). For example, a more efficient design could achieve similar or better precision compared with the 2012 survey using only 200 sample sites.

Table 27: **Predicted 95% confidence intervals achieved using a more efficient design across a range of sample sizes for key variables.**

	2012 survey					**2002-2012 change**		
Sample size	Effective fencing	Woody vege.	Total erosion	Stock access	Fords	Fenced	Woody vege.	Total erosion
	(% bank length)				(no./km)	(% bank length)		
25	±11.1	±9.3	±6.2	±13.4	±0.114	±11.1	±6.0	±6.5
50	±7.8	±6.6	±4.4	±9.5	±0.080	±7.8	±4.2	±4.6
100	±5.5	±4.7	±3.1	±6.7	±0.057	±5.5	±3.0	±3.3
200	±3.9	±3.3	±2.2	±4.7	±0.040	±3.9	±2.1	±2.3
300	±3.2	±2.7	±1.8	±3.9	±0.033	±3.2	±1.7	±1.9
400	±2.8	±2.3	±1.5	±3.3	±0.028	±2.8	±1.5	±1.6
500	±2.5	±2.1	±1.4	±3.0	±0.025	±2.5	±1.3	±1.5
600	±2.3	±1.9	±1.3	±2.7	±0.023	±2.3	±1.2	±1.3

A proposed more efficient stratification using 391 sampled sites, with samples approximately proportional to stream length within strata, is presented in Appendix 5. About half of the sample sites for this proposed design could consist of sites re-sampled from the 2012 survey with the remainder being new sites required to boost numbers in under-represented strata. However, this proposed design should only be treated as a guide. The design could also be varied to, for example, ensure adequate precision for sub-populations of interest.

3.8.4 Recommendations for design of future surveys

Based on the analysis and review of the survey design described above, recommendations to be considered with respect to the design of future riparian surveys are a follows.

- Sample sizes should be approximately proportional to watercourse length within each stratum.
- Fewer strata should be used — strata should still be based on management zone x land use type x stream order, but stream order within management zone x land use type combinations should be aggregated where necessary to contain at least 2 sample sites while retaining proportionality to watercourse length.
- Sampling units could be shorter than 1000 m although the optimal length would depend on the relative costs of accessing compared with assessing a site.
- To retain continuity with previous surveys, current sites should be retained in the proposed design where possible (perhaps about half of existing sites).
- As a transitional measure to ensure good change-over-time estimates, some further existing sites could be re-measured in the next survey, and all existing sites in the proposed survey assessed for their full 1000 m length. However, these additional sites and lengths could be eliminated in subsequent surveys.
- The sample size should be maintained at around 385 to 400 sites in order to realise the improvements in precision that could be achieved with a more efficient survey design.

3.8.5 Summary of key analysis and review of survey design results

The key results in relation to the analysis and review of the survey design are that:

- Analysis of the effect of varying sample size suggests maintaining the survey sample size at around 385 to 400 sites would be appropriate (i.e. at around current levels).
- The results indicate no loss in precision with shorter sampling units (e.g. 500 m) for fencing and stock access, a slight loss in precision for woody vegetation and total erosion, but markedly poorer precision for stream crossing variables (particularly fords).
- The original (2002) survey design was somewhat unbalanced with large strata under-represented and smaller strata over-represented. Analysis indicates that major

improvements in precision could be achieved for the same cost (or similar precision for less cost) with a more efficient allocation of sample units to strata.

- A proposed more efficient stratification using 391 sampled sites, with samples approximately proportional to stream length within strata, is presented.

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 past 10 years at a rate of about 1.7% of bank length per year (from 34% in 2002 to 51% in 2012). However, approximately half the bank length of the region's waterways in pastoral land was unprotected against stock access at the time of the 2012 survey. This result suggests that further work toward encouraging, supporting, and facilitating the fencing of unprotected stretches of waterways in pastoral land in the region is required. 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 25 years to complete the fencing of 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 2012 were dominated by non-woody vegetation cover (occupying about 74% of bank length), as has been the case for the past 10 years. Moreover, the non-woody vegetation was dominated by pastoral grasses (occupying about 50% of bank length in 2012). Woody vegetation, in association with non-woody vegetation, is important because it helps regulate stream water temperature (via stream shading), can contribute to stream-bank stability, and provides additional biodiversity benefits (e.g. bird habitat). These results suggest that there is still much to do in terms of encouraging the restoration of woody riparian vegetation in the region. The majority (about 60%) of riparian margins were relatively narrow in width (i.e. have a buffer width of < 5 m) as at 2012. 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 bank length affected by stream-bank erosion across the Waikato region was relatively small (12%) in 2012 but has increased significantly (from 5% in 2002) over the past 10 years. Stream-bank erosion was found to be influenced to some degree by several factors including the amount of riparian fencing (i.e. stock access), vegetation structure type, the width and vegetation type of the riparian buffer, stream crossing type, bank slope, and in-stream obstruction type. However, the magnitude and frequency of storm events is also likely to influence the amount of stream-bank erosion observed from year to year. 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. One quarter of the bank length across the region was characterised as disturbed at the time of the 2012 survey, and of this, 13% was attributed to pugging disturbance. Soil disturbance within riparian margins was strongly influenced by the amount of stock access (and fencing). Regression modelling suggests that the amounts of stream-bank erosion and soil disturbance can be reduced by increasing the proportion of effectively fenced bank length across the region. Increasing the proportion of bank length with woody vegetation (e.g. forest cover), particularly with buffer widths greater than 2 m (if not > 5 m), and reducing the numbers of fords and non-living obstructions (other than dams) per km of stream length in waterways are all changes that would help reduce the amounts of stream-bank erosion and soil disturbance.

4.2 Land use differences

Substantial differences between dairy and drystock land uses in terms of riparian fencing, stock access, buffer width, and soil disturbance were clearly evident in the results presented. In 2012, dairy sites had significantly larger proportions of bank length with effective fencing (70%), no stock access (69%), narrow (< 5 m) buffer widths (71%), and no soil disturbance (84%) than drystock sites (with 29%, 33%, 53%, and 66%, 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 stock exclusion from waterways is much greater at dairy sites than at drystock sites in the Waikato region. However, drystock sites had wider riparian buffer margins than dairy sites (i.e. drystock sites had a smaller proportion of bank length with narrow buffer widths). There was no difference detected between dairy and drystock land uses in terms of the proportions of bank length with riparian woody vegetation or with stream-bank erosion. Over the past 5 years, the amount of fencing significantly increased for dairy but not for drystock, with a rate of change of about 3.5% of bank length per year for dairy and about 0.2% of bank length per year 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. Moreover, the results suggest that there is a need to focus on-going efforts with respect to riparian fencing in the region more toward drystock land use.

4.3 Management zone differences

In terms of the state of the riparian characteristics observed, the Lake Taupo and Upper Waikato management zones stood-out as being different to most other zones. In particular, the Lake Taupo zone had the largest (or equal largest) proportion of bank length with effective fencing (67%), woody vegetation (61%), wide (≥ 5 m) buffer widths (69%), and the second largest proportion of bank length with no stock access (73%) and no stream-bank erosion (97%). The Lake Taupo zone also had the least number of stream crossings per km of stream length. Zones for which the state of particular riparian characteristics were not particularly good in comparison to other zones were the Lower Waikato (effective fencing, woody vegetation, buffer width, and stream-bank erosion), Coromandel (effective fencing and stream-bank erosion), West Coast (effective fencing and stock access), Central Waikato (woody vegetation and buffer width), Waipa (stock access), and Waihou Piako (buffer width) zones. Over the past 10 years, the amount of fencing significantly increased and the amount of stream-bank erosion significantly decreased within the Upper Waikato management zone whereas the amount of woody vegetation in the Lake Taupo zone significantly increased over the same period. These positive results probably reflect the emphasis placed on riparian restoration in the Upper Waikato and Lake Taupo zones through large-scale historic soil conservation schemes (see Environment Waikato, 1998; 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 all tributaries flowing into Lake Taupo). Management zones that could benefit the most from future riparian fencing efforts are the Lower Waikato, Coromandel, West Coast, and Waipa zones.

4.4 Stream order differences

Small to medium-sized waterways (i.e. stream orders 1 to 3) generally had the least effective fencing (39-45% of bank length) and the most stock access (49-61% of bank length) at the time of the 2012 survey. Drains (stream order 0) and small to medium-sized waterways generally had less woody vegetation (9-38% of bank length) and the largest numbers of stream crossings (2-3) per km of stream length. Drains had the smallest proportion of wide buffer widths (about 11% of bank length) and stream orders 1 and 2 had the least stream-bank erosion (approximately 10% of bank length). However, the amount of erosion in stream orders 1 and 2 significantly increased over the past 10 years by about 5-6% of bank length. These findings suggest that the focus for future riparian fencing and restoration efforts would best be directed toward the small to medium-sized waterways (including drains with respect to the restoration of woody vegetation and the establishment of wider riparian margins).

4.5 Survey design review

It is recommended that some changes be made to the set of sample sites selected in order to improve the efficiency of the survey design and, as a consequence, improve the precision of estimates. Improved precision could allow for the detection of more subtle difference between land uses or management zones (for example) or changes over time. The total number of sample sites should be maintained at approximately 400 but site length could be reduced to 500 m.

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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	63,625	Indigenous	4.5
		Pasture	75.2
		Forestry	1.5
		Horticultural & Cropping	2.9
		Other	15.9
Coromandel	195,723	Indigenous	63.0
		Pasture	19.0
		Forestry	15.3
		Horticultural & Cropping	0.2
		Other/No data	2.5
Lake Taupo	349,596	Indigenous	41.5
		Pasture	15.9
		Forestry	20.1
		Horticultural & Cropping	0.1
		Other	22.4
Lower Waikato	291,172	Indigenous	13.4
		Pasture	71.1
		Forestry	7.5
		Horticultural & Cropping	2.7
		Other/No data	5.3
Upper Waikato	432,778	Indigenous	12.6
		Pasture	52.6
		Forestry	32.0
		Horticultural & Cropping	0.6
		Other	2.2

Management Zone	Zone Area (ha)	Land Use Classes†	% Zone Area†
Waihou Piako	394,510	Indigenous	23.5
		Pasture	66.5
		Forestry	7.0
		Horticultural & Cropping	1.0
		Other/No data	2.1
Waipa	306,739	Indigenous	19.3
		Pasture	73.7
		Forestry	4.4
		Horticultural & Cropping	0.6
		Other	2.0
West Coast	424,911	Indigenous	36.0
		Pasture	56.2
		Forestry	5.8
		Horticultural & Cropping	0.1
		Other/No data	2.0

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

Table A1-2: Stock density information for management zones within the Waikato region.

Management Zone	Stock Density Classes (stock units/ha)‡	% Farms‡	Median Pastoral Stock Density (stock units/ha)‡
Central Waikato	Sheep farms (<10.5)	33.4	14.9
	Beef & lower-stocked dairy farms (>=10.5-17.5)	24.1	
	Mid-range of dairy farms (>17.5-24.5)	21.3	
	Higher-stocked dairy farms (>24.5)	21.2	
Coromandel	Sheep farms (<10.5)	37.7	13.4
	Beef & lower-stocked dairy farms (>=10.5-17.5)	26.7	
	Mid-range of dairy farms (>17.5-24.5)	16.8	
	Higher-stocked dairy farms (>24.5)	18.9	
Lake Taupo	Sheep farms (<10.5)	59.4	9.2
	Beef & lower-stocked dairy farms (>=10.5-17.5)	24.2	
	Mid-range of dairy farms (>17.5-24.5)	5.8	
	Higher-stocked dairy farms (>24.5)	10.6	
Lower Waikato	Sheep farms (<10.5)	36.2	13.8
	Beef & lower-stocked dairy farms (>=10.5-17.5)	25.6	
	Mid-range of dairy farms (>17.5-24.5)	18.2	
	Higher-stocked dairy farms (>24.5)	20.0	

Management Zone	Stock Density Classes (stock units/ha)‡	% Farms‡	Median Pastoral Stock Density (stock units/ha)‡
Upper Waikato	Sheep farms (<10.5)	40.5	12.5
	Beef & lower-stocked dairy farms (>=10.5-17.5)	29.6	
	Mid-range of dairy farms (>17.5-24.5)	19.1	
	Higher-stocked dairy farms (>24.5)	10.9	
Waihou Piako	Sheep farms (<10.5)	20.2	20.2
	Beef & lower-stocked dairy farms (>=10.5-17.5)	19.3	
	Mid-range of dairy farms (>17.5-24.5)	27.3	
	Higher-stocked dairy farms (>24.5)	33.2	
Waipa	Sheep farms (<10.5)	30.0	16.1
	Beef & lower-stocked dairy farms (>=10.5-17.5)	24.5	
	Mid-range of dairy farms (>17.5-24.5)	22.4	
	Higher-stocked dairy farms (>24.5)	23.2	
West Coast	Sheep farms (<10.5)	50.0	10.5
	Beef & lower-stocked dairy farms (>=10.5-17.5)	29.8	
	Mid-range of dairy farms (>17.5-24.5)	9.0	
	Higher-stocked dairy farms (>24.5)	11.2	

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

Appendix 2

Table A2-1: Summary of strata used in the analysis of the 2012 survey. The sampling ratio 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	Stream length in population (km)	Number of sites sampled	Sampling ratio
Central Waikato	Dairy	0-2	305	8	0.026
		3-4	22	3	0.137
		5-7	5	4	0.820
	Drystock	0-2	275	5	0.018
		3-7	36	7	0.176
Coromandel	Dairy	0-1	96	4	0.044
		2-3	56	3	0.059
		4-5	28	3	0.114
	Drystock	0-2	402	7	0.017
		3	62	4	0.061
		4-5	32	7	0.202
Lake Taupo	Dairy	0-6	96	1	0.009
	Drystock	0	6	3	0.434
		1	504	11	0.020
		2	111	18	0.152
		3-6	45	8	0.163
Lower Waikato	Dairy	0-1	1,784	8	0.005
		2	142	4	0.021
		3	97	6	0.062
		4	67	6	0.089
		5-7	13	4	0.338
	Drystock	0-2	1,782	8	0.005
		3	169	4	0.015
		4	82	3	0.037
		5-7	32	3	0.096
Upper Waikato	Dairy	0-1	1,238	13	0.010
		2	357	6	0.017
		3	215	8	0.036
		4	84	10	0.106
		5-7	36	11	0.260
	Drystock	0-2	1,093	9	0.007
		3	114	6	0.046
		4-7	34	5	0.140

Management zone	Land use type (AgriBase™)	Stream order	Stream length in population (km)	Number of sites sampled	Sampling ratio
Waihou Piako	Dairy	0	1,661	5	0.003
		1	1186	7	0.006
		2	378	4	0.010
		3	228	3	0.012
		4	97	3	0.034
		5-6	184	6	0.033
	Drystock	0-1	790	7	0.009
		2-6	328	7	0.020
Waipa	Dairy	0	325	3	0.009
		1	968	9	0.008
		2	297	7	0.024
		3	188	7	0.031
		4	121	7	0.055
		5	86	7	0.086
		6	33	5	0.149
	Drystock	0-1	1,417	11	0.007
		2	360	8	0.019
		3	207	5	0.019
		4	112	5	0.043
		5-6	55	5	0.092
West Coast	Dairy	0-1	188	5	0.027
		2	54	4	0.076
		3-4	39	6	0.148
		5-7	17	4	0.224
	Drystock	0	76	4	0.053
		1	3,178	6	0.002
		2	832	3	0.004
		3	466	3	0.006
		4	284	7	0.022
		5	124	7	0.055
		6-7	46	5	0.110
Sum			**23,742**	**385**	

Appendix 3

Table A3-1: Summary of strata used in the analysis of change over time.

Management zone	Land use type (AgriBase™)	Stream order	Stream length in population (km)	Number of sites sampled 2002-2012	Number of sites sampled 2007-2012
Central Waikato	Dairy	0-7	332	5	4
	Drystock	0-7	311	7	4
Coromandel	Dairy	0-7	180	0	0
	Drystock	0-2	402	3	3
		3	62	4	4
		4-5	32	6	5
Lake Taupo	Dairy	0-6	96	1	1
	Drystock	0	6	3	3
		1	504	5	7
		2	111	18	17
		3-6	45	8	8
Lower Waikato	Dairy	0-2	1,926	6	5
		3-7	177	8	6
	Drystock	0-2	1,782	6	8
		3	169	4	3
		4-7	114	6	6
Upper Waikato	Dairy	0-1	1,238	13	13
		2	357	5	6
		3	215	8	7
		4	84	10	7
		5-7	36	9	10
	Drystock	0-2	1,093	7	8
		3	114	6	5
		4-7	34	5	4
Waihou Piako	Dairy	0	1,661	5	4
		1	1,186	6	7
		2	378	4	3
		3-4	325	6	5
		5-6	184	6	5
	Drystock	0-1	790	6	7
		2-6	328	6	4

Management zone	Land use type (AgriBase™)	Stream order	Stream length in population (km)	Number of sites sampled 2002-2012	Number of sites sampled 2007-2012
Waipa	Dairy	0	325	3	2
		1	968	8	9
		2	297	7	6
		3	188	7	6
		4	121	5	5
		5	86	7	5
		6	33	5	4
	Drystock	0-1	1,417	9	7
		2	360	8	7
		3	207	5	5
		4	112	3	3
		5-6	55	5	5
West Coast	Dairy	0-7	298	6	6
	Drystock	0	76	4	4
		1	3,178	5	5
		2	832	3	3
		3	466	3	3
		4	284	6	6
		5	124	6	6
		6-7	46	5	5
Sum			**23,742**	**302**	**281**

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 2012.

		Bank length analysis (% bank length)		Stream length analysis (% stream length) – effectively fenced		
		Effectively fenced (Total)	Not effectively fenced	Both banks fenced	One bank fenced	Neither bank fenced
	Overall	48.9 (4.7)	51.1 (4.7)	35.7 (5.5)	26.3 (5.0)	38.0 (5.1)
Land use type	Dairy	69.8 (5.4)	30.2 (5.4)	52.3 (8.7)	34.9 (8.4)	12.8 (4.2)
	Drystock	28.8 (5.5)	71.2 (5.5)	19.8 (5.5)	18.1 (5.4)	62.1 (6.7)
Management zone	Central Waikato	54.2 (15.9)	45.8 (15.9)	42.4 (19.4)	23.6 (15.4)	34.0 (15.7)
	Coromandel	43.3 (16.4)	56.7 (16.4)	26.4 (15.3)	33.8 (13.8)	39.8 (20.0)
	Lake Taupo	66.9 (15.6)	33.1 (15.6)	60.7 (18.0)	12.5 (11.8)	26.8 (15.2)
	Lower Waikato	44.0 (12.2)	56.0 (12.2)	26.3 (15.7)	35.2 (18.8)	38.5 (15.0)
	Upper Waikato	66.6 (8.7)	33.4 (8.7)	55.4 (9.6)	22.3 (10.0)	22.3 (10.4)
	Waihou Piako	65.6 (9.1)	34.4 (9.1)	47.8 (15.4)	35.7 (14.9)	16.5 (6.4)
	Waipa	55.4 (9.6)	44.6 (9.6)	40.5 (11.2)	29.9 (9.1)	29.6 (10.0)
	West Coast	19.1 (14.4)	80.9 (14.4)	13.2 (13.0)	11.7 (6.0)	75.1 (16.2)
Stream order	0	77.3 (19.8)	22.7 (19.8)	57.2 (39.0)	40.1 (38.7)	2.7 (3.4)
	1	45.0 (8.8)	55.0 (8.8)	29.3 (8.5)	31.4 (9.1)	39.3 (11.1)
	2	41.8 (6.3)	58.2 (6.3)	32.8 (6.7)	18.0 (7.1)	49.2 (7.6)
	3	39.3 (9.8)	60.7 (9.8)	29.8 (10.2)	18.7 (7.7)	51.6 (11.2)
	4	49.6 (11.9)	50.4 (11.9)	37.2 (12.9)	24.7 (9.0)	38.1 (12.5)
	5	60.3 (12.5)	39.7 (12.5)	35.3 (21.4)	49.9 (21.5)	14.8 (9.3)
	6	66.2 (12.4)	33.8 (12.4)	42.9 (22.7)	46.7 (21.9)	10.4 (5.6)

Table A4-2: Average proportion of bank length fenced (total) and average proportion of stream length fenced on one bank, both banks, or neither bank for the region as a whole (overall) and for land use type in 2002, 2007, and 2012.

		Year	Bank length analysis (% bank length)	Stream length analysis (% stream length) – fenced		
			Total fenced	Both banks fenced	One bank fenced	Neither bank fenced
	Overall	**2002**	34.0	21.7	24.6	53.7
		2007	41.9	29.9	24.0	46.1
		2012	50.5	38.1	24.9	37.0
Land use type	**Dairy**	**2002**	46.5	29.2	34.5	36.4
		2007	54.2	39.3	29.7	31.0
		2012	71.7	55.9	31.4	12.7
	Drystock	**2002**	22.8	15.5	14.7	69.8
		2007	28.9	19.8	18.3	61.8
		2012	29.9	20.7	18.6	60.7

Table A4-3: Average proportion of bank length (95% confidence interval in parentheses) of stock assess categories for the region as a whole (overall) and for land use type, management zone, stream order, and Clean Streams Accord categories in 2012.

		Simplified stock access categories (% bank length)		Detailed stock access categories (% bank length)		
		Access (Total)	**No access**	**Past access**	**Recent access**	**Current access**
	Overall	49.3 (5.1)	50.7 (5.1)	14.8 (3.8)	18.3 (3.5)	16.2 (5.3)
Land use type	**Dairy**	30.8 (7.4)	69.2 (7.4)	11.6 (4.5)	14.2 (4.4)	5.0 (3.2)
	Drystock	67.1 (7.1)	32.9 (7.1)	17.8 (6.5)	22.4 (5.7)	26.9 (10.3)
Management zone	**Central Waikato**	46.9 (21.7)	53.1 (21.7)	14.4 (14.8)	16.2 (13.1)	16.4 (13.3)
	Coromandel	43.9 (19.1)	56.1 (19.1)	10.8 (12.5)	24.9 (12.7)	8.2 (8.8)
	Lake Taupo	27.4 (15.8)	72.6 (15.8)	9.6 (6.8)	9.0 (9.1)	7.6 (10.2)
	Lower Waikato	47.2 (16.9)	52.8 (16.9)	8.0 (7.8)	28.8 (9.2)	10.3 (8.9)
	Upper Waikato	29.0 (10.9)	71.0 (10.9)	9.3 (5.4)	11.8 (7.7)	7.9 (5.0)
	Waihou Piako	24.9 (10.4)	75.1 (10.4)	8.0 (7.8)	15.5 (8.4)	1.4 (1.2)
	Waipa	56.3 (12.1)	43.7 (12.1)	16.9 (8.9)	22.8 (6.7)	16.5 (10.1)
	West Coast	84.2 (11.0)	15.8 (11.0)	29.1 (12.4)	13.9 (9.8)	41.3 (21.7)
Stream order	**0**	10.0 (9.2)	90.0 (9.2)	4.7 (5.3)	3.4 (5.0)	1.9 (3.2)
	1	61.4 (7.2)	38.6 (7.2)	19.0 (7.5)	22.3 (6.2)	20.2 (9.8)
	2	48.8 (12.5)	51.2 (12.5)	7.1 (5.9)	19.2 (6.1)	22.2 (16.9)
	3	57.0 (12.6)	43.0 (12.6)	18.7 (5.6)	22.3 (12.7)	16.0 (8.1)
	4	48.3 (13.9)	51.7 (13.9)	8.5 (6.3)	23.1 (10.1)	16.7 (10.6)
	5	31.8 (10.5)	68.2 (10.5)	8.2 (5.6)	8.7 (6.2)	15.0 (9.2)
	6	9.2 (8.2)	90.8 (8.2)	4.9 (7.7)	1.9 (0.0)	2.4 (3.6)
Clean Streams Accord	**Qualifying sites**	28.4 (9.4)	71.6 (9.4)	12.6 (7.0)	12.0 (4.7)	3.8 (2.3)
	All other sites	55.7 (6.6)	44.3 (6.6)	15.4 (4.6)	20.3 (4.5)	20.0 (7.0)

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 2012.

		Simplified vegetation categories (% bank length)		Detailed vegetation categories (% bank length)				
		Woody	Non-woody	Woody native	Woody exotic	Woody willow	Pastoral grass	Sedges/grasses
	Overall	26.3 (3.5)	73.7 (3.5)	8.4 (2.3)	12.7 (2.3)	5.2 (1.3)	49.4 (5.2)	24.4 (4.4)
Land use type	**Dairy**	23.6 (4.6)	76.4 (4.6)	3.9 (2.1)	13.4 (3.5)	6.3 (2.3)	49.7 (7.5)	26.7 (6.4)
	Drystock	28.8 (5.3)	71.2 (5.3)	12.6 (4.0)	11.9 (3.2)	4.3 (1.5)	49.1 (7.2)	22.1 (5.8)
Management zone	**Central Waikato**	15.7 (5.2)	84.3 (5.2)	3.0 (2.6)	9.1 (4.2)	3.5 (2.1)	64.5 (15.4)	19.8 (16.8)
	Coromandel	56.0 (13.3)	44.0 (13.3)	37.6 (18.2)	14.1 (6.6)	4.3 (4.8)	31.5 (14.4)	12.5 (6.2)
	Lake Taupo	61.1 (12.5)	38.9 (12.5)	5.3 (3.2)	50.0 (12.1)	5.8 (3.5)	21.9 (12.1)	17.0 (8.1)
	Lower Waikato	15.1 (5.5)	84.9 (5.5)	5.3 (3.6)	7.9 (4.3)	2.0 (1.3)	63.3 (12.3)	21.6 (12.4)
	Upper Waikato	44.9 (11.6)	55.1 (11.6)	10.2 (7.1)	26.1 (9.6)	8.6 (3.6)	31.0 (11.3)	24.1 (8.0)
	Waihou Piako	23.3 (7.2)	76.7 (7.2)	6.0 (3.3)	11.0 (4.2)	6.2 (4.2)	42.1 (15.0)	34.6 (13.7)
	Waipa	21.7 (6.3)	78.3 (6.3)	6.0 (2.8)	6.9 (3.3)	8.8 (4.1)	57.0 (8.7)	21.3 (7.6)
	West Coast	22.7 (10.5)	77.3 (10.5)	11.0 (7.9)	9.3 (6.3)	2.4 (1.9)	54.5 (14.0)	22.8 (9.7)
Stream order	**0**	8.5 (11.3)	91.5 (11.3)	0.6 (0.3)	7.7 (11.0)	0.3 (0.2)	59.2 (20.9)	32.2 (16.6)
	1	26.6 (6.7)	73.4 (6.7)	6.1 (3.1)	15.6 (4.9)	4.8 (2.4)	52.1 (8.4)	21.4 (5.8)
	2	38.0 (11.1)	62.0 (11.1)	17.2 (9.6)	14.9 (5.5)	5.9 (3.6)	42.0 (12.4)	19.9 (7.7)
	3	35.3 (6.9)	64.7 (6.9)	8.8 (2.9)	15.8 (6.2)	10.7 (5.4)	34.6 (6.4)	30.1 (5.0)
	4	35.9 (10.1)	64.1 (10.1)	5.8 (2.2)	12.3 (4.7)	17.8 (9.8)	44.8 (9.0)	19.3 (7.0)
	5	54.6 (5.9)	45.4 (5.9)	13.6 (10.0)	28.5 (7.5)	12.4 (4.3)	28.5 (7.3)	17.0 (8.6)
	6	56.9 (15.9)	43.1 (15.9)	12.8 (6.0)	12.7 (11.7)	31.4 (10.5)	13.9 (9.0)	29.3 (19.0)
Fencing	**Effectively fenced**	30.2 (4.4)	69.8 (4.4)	6.7 (2.5)	17.3 (3.5)	6.2 (2.0)	41.7 (6.7)	28.1 (5.9)
	Not effectively fenced	22.5 (4.9)	77.5 (4.9)	10.0 (3.4)	8.2 (2.8)	4.3 (1.5)	56.6 (6.7)	20.9 (5.0)

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, and 2012.

		Year	Simplified vegetation categories (% bank length)		Detailed vegetation categories (% bank length)				
			Woody	Non-woody	Woody native	Woody exotic	Woody willow	Pastoral grass	Sedges/ grasses
	Overall	2002	23.9	76.1	6.6	11.5	5.8	73.1	3.0
		2007	31.3	68.7	9.4	18.9	3.0	66.9	1.8
		2012	26.3	73.7	8.4	12.7	5.2	49.4	24.4
Land use type	Dairy	2002	21.6	78.4	2.5	11.5	7.6	74.4	4.0
		2007	27.9	72.1	4.5	19.0	4.4	70.8	1.3
		2012	23.6	76.4	3.9	13.4	6.3	49.7	26.7
	Drystock	2002	26.0	74.0	10.5	11.7	3.8	71.7	2.3
		2007	34.6	65.4	14.1	18.7	1.7	63.4	2.0
		2012	28.8	71.2	12.6	11.9	4.3	49.1	22.1

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 2012.

		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	61.2 (7.1)	38.5 (7.1)	26.7 (6.2)	34.6 (7.5)	16.7 (5.0)	21.8 (6.3)
Land use type	**Dairy**	70.5 (6.8)	29.4 (6.8)	31.8 (9.3)	38.6 (9.4)	14.6 (4.4)	14.8 (5.1)
	Drystock	52.4 (12.2)	47.2 (12.2)	21.7 (8.8)	30.7 (11.7)	18.7 (8.8)	28.5 (11.2)
Management zone	**Central Waikato**	57.3 (21.7)	42.7 (21.7)	19.4 (15.3)	37.9 (24.0)	16.6 (15.1)	26.1 (16.0)
	Coromandel	75.3 (13.2)	24.7 (13.2)	21.1 (20.7)	54.2 (20.7)	11.8 (7.7)	12.9 (8.1)
	Lake Taupo	31.2 (12.9)	68.8 (12.9)	5.4 (6.6)	25.8 (8.3)	31.5 (17.2)	37.3 (16.9)
	Lower Waikato	88.7 (11.4)	10.5 (11.4)	53.0 (21.2)	35.6 (18.3)	2.8 (2.2)	7.7 (11.2)
	Upper Waikato	42.2 (16.0)	57.8 (16.0)	17.1 (13.5)	25.0 (13.4)	34.0 (13.9)	23.8 (10.7)
	Waihou Piako	75.1 (10.9)	24.9 (10.9)	28.3 (16.1)	46.8 (17.3)	9.3 (6.2)	15.6 (9.6)
	Waipa	52.8 (11.7)	46.4 (11.8)	30.9 (12.5)	21.9 (10.0)	16.2 (7.7)	30.1 (9.6)
	West Coast	48.1 (26.4)	51.9 (26.4)	11.4 (12.1)	36.7 (24.0)	22.8 (19.2)	29.1 (24.1)
Stream order	**0**	89.4 (11.3)	10.6 (11.3)	58.3 (17.2)	31.1 (19.6)	1.8 (1.8)	8.8 (10.8)
	1	61.1 (15.0)	38.9 (15.0)	18.4 (7.0)	42.7 (14.5)	18.4 (10.0)	20.5 (13.3)
	2	51.3 (15.4)	47.2 (15.5)	27.2 (18.2)	24.0 (10.7)	17.0 (7.4)	30.2 (15.9)
	3	34.3 (14.0)	64.7 (14.0)	4.9 (4.0)	29.4 (13.6)	25.1 (12.7)	39.6 (17.9)
	4	55.0 (16.0)	45.0 (16.0)	11.7 (7.5)	43.3 (16.1)	16.9 (9.6)	28.1 (12.6)
	5	40.5 (17.6)	59.5 (17.6)	13.5 (11.1)	27.0 (15.7)	28.9 (19.2)	30.6 (10.2)
	6	40.2 (24.0)	59.8 (24.0)	0.8 (1.4)	39.4 (23.9)	37.2 (24.9)	22.5 (11.2)

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 2012.

			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
Vegetation type	Woody	Overall	11.7 (2.6)	14.5 (2.8)	3.9 (1.5)	7.8 (2.3)	7.4 (2.0)	7.1 (2.0)
		Dairy	12.0 (3.2)	11.6 (3.7)	4.2 (2.3)	7.8 (2.5)	7.7 (3.2)	3.9 (1.6)
		Drystock	11.3 (4.0)	17.2 (4.5)	3.6 (1.7)	7.8 (3.9)	7.0 (2.6)	10.2 (3.8)
	Non woody	Overall	49.6 (6.1)	24.0 (6.0)	22.8 (5.6)	26.8 (6.4)	9.3 (4.0)	14.7 (5.6)
		Dairy	58.4 (6.3)	17.8 (5.4)	27.6 (8.8)	30.8 (8.3)	6.9 (2.7)	10.9 (4.6)
		Drystock	41.0 (10.4)	29.9 (10.2)	18.1 (7.7)	22.9 (9.8)	11.7 (7.4)	18.2 (9.9)

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 2012.

		Stream crossing type (% of observed crossings)			Total crossings (number per km stream length)
		Bridges	**Fords**	**Culverts**	**Total**
	Overall	29.9 (4.5)	2.9 (1.8)	67.3 (4.6)	2.8 (0.3)
Land use type	**Dairy**	31.5 (7.0)	0.7 (0.6)	67.8 (7.0)	2.8 (0.5)
	Drystock	28.2 (6.9)	5.1 (3.5)	66.7 (7.0)	2.8 (0.5)
Management zone	**Central Waikato**	27.1 (20.0)	0.9 (0.0)	72.1 (20.0)	3.5 (1.1)
	Coromandel	18.3 (16.5)	18.2 (5.4)	63.5 (16.2)	2.1 (1.1)
	Lake Taupo	35.7 (15.4)	1.2 (1.6)	63.2 (15.4)	1.2 (0.4)
	Lower Waikato	28.4 (11.7)	1.7 (1.6)	69.9 (11.7)	3.6 (1.2)
	Upper Waikato	19.8 (7.5)	1.8 (2.8)	78.4 (7.7)	2.9 (0.6)
	Waihou Piako	42.7 (11.5)	3.0 (2.5)	54.3 (11.8)	2.0 (0.6)
	Waipa	29.9 (7.3)	0.8 (1.2)	69.3 (7.3)	3.1 (0.8)
	West Coast	26.3 (13.4)	4.6 (7.6)	69.1 (13.9)	2.9 (0.7)
Stream order	**0**	35.5 (13.3)	0.0 (0.0)	64.5 (13.3)	3.0 (2.5)
	1	12.1 (6.6)	1.7 (3.5)	86.2 (6.8)	3.4 (0.6)
	2	36.3 (9.7)	3.0 (2.1)	60.7 (10.1)	2.8 (0.6)
	3	61.9 (8.8)	11.1 (4.8)	27.1 (10.1)	2.0 (1.0)
	4	76.1 (18.8)	7.8 (3.6)	16.1 (18.4)	0.6 (0.3)
	5	94.5 (0.0)	0.0 (0.0)	5.5 (0.0)	0.2 (0.1)
	6	64.5 (0.0)	0.0 (0.0)	35.5 (0.0)	0.3 (0.5)

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 2012.

		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	88.1 (2.7)	7.8 (2.0)	4.1 (1.7)	11.9 (2.7)	13.1 (4.8)	25.0 (4.7)	75.0 (4.7)
Land use type	**Dairy**	89.4 (3.5)	8.0 (3.5)	2.6 (1.3)	10.6 (3.5)	5.2 (2.0)	15.8 (3.6)	84.2 (3.6)
	Drystock	86.8 (4.3)	7.5 (2.4)	5.6 (3.2)	13.2 (4.3)	20.7 (8.6)	33.8 (8.0)	66.2 (8.0)
Management zone	**Central Waikato**	95.6 (4.3)	3.2 (2.6)	1.2 (1.8)	4.4 (4.3)	12.6 (16.7)	17.0 (18.0)	83.0 (18.0)
	Coromandel	81.6 (8.4)	14.3 (7.0)	4.1 (3.0)	18.4 (8.4)	12.5 (11.6)	30.8 (14.4)	69.2 (14.4)
	Lake Taupo	97.3 (2.4)	1.8 (1.7)	0.8 (1.5)	2.7 (2.4)	1.1 (1.4)	3.8 (2.7)	96.2 (2.7)
	Lower Waikato	80.7 (7.2)	12.1 (4.7)	7.2 (5.0)	19.3 (7.2)	10.4 (7.9)	29.7 (8.9)	70.3 (8.9)
	Upper Waikato	98.3 (1.4)	1.0 (0.6)	0.7 (0.9)	1.7 (1.4)	8.7 (6.4)	10.3 (7.2)	89.7 (7.2)
	Waihou Piako	87.3 (7.6)	8.6 (6.9)	4.1 (3.2)	12.7 (7.6)	6.0 (4.0)	18.7 (7.5)	81.3 (7.5)
	Waipa	89.0 (4.7)	9.2 (4.6)	1.8 (0.8)	11.0 (4.7)	16.0 (8.9)	27.0 (9.3)	73.0 (9.3)
	West Coast	86.4 (7.8)	7.1 (4.1)	6.5 (6.2)	13.6 (7.8)	23.9 (18.9)	37.5 (16.8)	62.5 (16.8)
Stream order	**0**	87.7 (9.0)	9.7 (10.1)	2.6 (1.8)	12.3 (9.0)	2.2 2.3)	14.4 (8.7)	85.6 (8.7)
	1	89.7 (4.2)	6.4 (2.7)	3.9 (3.1)	10.3 (4.2)	15.6 (9.7)	25.8 (8.8)	74.2 (8.8)
	2	90.1 (3.9)	7.1 (3.0)	2.8 (1.6)	9.9 (3.9)	15.6 (8.4)	25.4 (8.9)	74.6 (8.9)
	3	83.7 (9.5)	10.3 (7.8)	6.0 (2.6)	16.3 (9.5)	8.9 (4.6)	25.2 (10.1)	74.8 (10.1)
	4	73.7 (10.3)	15.0 (7.3)	11.3 (8.7)	26.3 (10.3)	7.5 (8.2)	33.8 (9.7)	66.2 (9.7)
	5	79.7 (6.7)	10.6 (3.7)	9.7 (5.5)	20.3 (6.7)	5.6 (4.9)	26.0 (7.0)	74.0 (7.0)
	6	89.5 (12.9)	8.1 (11.0)	2.4 (2.6)	10.5 (12.9)	3.8 (8.2)	14.4 (12.7)	85.6 (12.7)

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 2012.

		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	89.7 (3.4)	7.5 (2.9)	2.7 (1.7)	10.3 (3.4)	2.9 (1.4)	13.2 (3.4)	86.8 (3.4)
	Not effectively fenced	86.6 (3.5)	7.9 (2.2)	5.5 (2.2)	13.4 (3.5)	22.0 (8.5)	35.3 (7.9)	64.7 (7.9)
Vegetation type	Woody	89.7 (3.3)	6.8 (2.8)	3.5 (1.8)	10.3 (3.3)	6.5 (2.9)	16.9 (4.4)	83.1 (4.4)
	Non woody	87.6 (3.2)	8.1 (2.4)	4.4 (1.8)	12.4 (3.2)	14.8 (5.9)	27.3 (5.5)	72.7 (5.5)

Table A4-11: Average proportion of bank length of stream-bank erosion and soil disturbance categories for the region as a whole (overall) and for land use type in 2002, 2007, and 2012.

		Year	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**	94.9	3.5	1.6	5.1	-	-	-
		2007	77.7	17.9	4.3	22.3	14.1	36.4	63.6
		2012	88.1	7.8	4.1	11.9	13.1	25.0	75.0
Land use type	Dairy	**2002**	96.1	3.4	0.5	3.9	-	-	-
		2007	83.8	14.8	1.4	16.2	10.9	27.1	72.9
		2012	89.4	8.0	2.6	10.6	5.2	15.8	84.2
	Drystock	**2002**	93.8	3.6	2.6	6.2	-	-	-
		2007	72.4	20.6	7.0	27.6	17.7	45.3	54.7
		2012	86.8	7.5	5.6	13.2	20.7	33.8	66.2

Appendix 5

Table A5-1: A proposed more efficient stratification of sample sites.

Management zone	Land use type (AgriBase™)	Stream order	Proposed number of sites	Number of 2012 sites re-sampled	Number of additional sites to be sampled
Central Waikato	Dairy	0-7	5	5	0
	Drystock	0-7	5	5	0
Coromandel	Dairy	0-7	3	3	0
	Drystock	0-1	5	4	1
		2-5	2	2	0
Lake Taupo	Dairy	0-7	1	1	0
	Drystock	0-1	8	8	0
		2-6	3	3	0
Lower Waikato	Dairy	0	22	2	20
		1	8	6	2
		2	2	2	0
		3-7	3	3	0
	Drystock	0	7	1	6
		1	18	1	17
		2	5	5	0
		3-7	4	4	0
Upper Waikato	Dairy	0-1	21	13	8
		2	6	6	0
		3-7	5	5	0
	Drystock	0-1	14	2	12
		2	4	4	0
		3-7	2	2	0
Waihou Piako	Dairy	0	28	5	23
		1	20	7	13
		2	6	4	2
		3	4	3	1
		4	2	2	0
		5-6	3	3	0
	Drystock	0	4	2	2
		1	9	5	4
		2	3	2	1
		3-6	2	2	0

Management zone	Land use type (AgriBase™)	Stream order	Proposed number of sites	Number of 2012 sites re-sampled	Number of additional sites to be sampled
Waipa	Dairy	0	5	3	2
		1	16	9	7
		2	5	5	0
		3	3	3	0
		4	2	2	0
		5-6	2	2	0
	Drystock	0-1	24	11	13
		2	6	6	0
		3	3	3	0
		4-6	3	3	0
West Coast	Dairy	0-7	4	4	0
	Drystock	0-1	55	10	45
		2	14	4	10
		3	8	3	5
		4	5	5	0
		5-7	2	2	0
Sum			**391**	**197**	**194**