2003-04/01

Manaaki Whenua
Landcare Research

Motueka Riparian Typology Assessment

Prepared for

Stakeholders of the
Motueka Integrated Catchment Management Programme

Manaaki Whenua
Landcare Research

Tasman District Council

CAWTHRON

June 2004

Motueka Riparian Typology Assessment

Motueka Integrated Catchment Management (Motueka ICM) Programme Report Series

by

Chris Phillips and Michael Marden

Landcare Research
PO Box 69
Lincoln
NEW ZEALAND
Phone: +64 3 325 6700
Fax: +64 3 325 2418
Email: PhillipsC@LandcareResearch.co.nz

Cover Photo: Motueka River

PREFACE

An ongoing report series, covering components of the Motueka Integrated Catchment Management (ICM) Programme, has been initiated in order to present preliminary research findings directly to key stakeholders. The intention is that the data, with brief interpretation, can be used by managers, environmental groups and users of resources to address specific questions that may require urgent attentin or may fall outside the scope of ICM research objectives.

We anticipate that providing access to environmental data will foster a collaborative problem-solving approach through the sharing of both ICM and privately collected information. Where appropriate, the information will also be presented to stakeholders through follow-up meetings designed to encourage feedback, discussion and coordination of research objectives.

1. Introduction

Riparian zones are the three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems (Gregory et al. 1991). In terms of managing catchments to meet a wide range of environmental needs, the riparian zone is probably the most important place in the catchment. It is here, where the land meets the water, that management can have a profound effect on enhancing stream habitat and water quality. In short, biophysical functions such as stream bank stability, filtering of overland flow, shading for temperature and nuisance aquatic plant control, woody debris inputs, cover and spawning habitats for fish species, and denitrification and nutrient uptake from shallow groundwater) can all be managed to protect streams from changes that land development activities might have on stream health (Collier et al. 1995. Due to their location and the functions they provide, riparian zones can, and often do, have a disproportionately large role in controlling the effects of broader catchment activities on streams and downstream aquatic ecosystems (MFE 2000).

Riparian management is recognised as an important aspect of land and water management in all regions of New Zealand. Plans produced by regional councils include a range of methods for promoting riparian management (Boothroyd and Langer 1999). . As the biophysical roles and human uses of streams and riparian zones vary from headwaters to lowland reaches of rivers, it seems reasonable that a management framework or classification system is required that accounts for these variations in order that management actions at a site are matched with riparian functions. Why do we need such a framework or classification? It is important that the various functions of riparian zones outlined above can be recognised by a range of non-experts who may be involved in a variety of activities that impinge upon these zones. Further, a framework can provide a way to link a common set of approaches and methods for managing these functions across a wide set of local and regional conditions.

One such framework or classification for management was developed by Quinn (1999; 2001a) for the Piako and Waihou River catchments in the Waikato region. This was further developed for the Canterbury region (Quinn et al. 2001b) by investigating the use of GIS-based land and river databases to predict riparian classes. In this latter study, sites were classified into 4 classes according to their current and potential riparian functions and then discriminant function models were developed to classify new sites based on on-site and GIS database information. Models that incorporated on-site and other GIS information gave the best predictions for site affinity (77% correct for current functions and 84% for potential functions compared to 25% expected by chance), but those based on GIS data alone were also useful and sufficiently accurate in their predictions of potential functions (59% correct) to be useful for preliminary mapping.

In this report, we apply the methods developed by Quinn et al. (2001a,b) to the Motueka and Riwaka River catchments with two aims. Firstly, to classify current and potential functions at river reaches to assist in prioritising where riparian management interventions might have the most beneficial effects, and secondly to group a wide range of attributes to produce a series of stream-riparian types. We draw heavily on the Quinn et al. (2001b) report and our results are presented following the style and layout of that report to enable comparisons to be made.

2. Methods

2.1 Study area

The Motueka and Riwaka River catchments (hereafter referred to as the Motueka catchment) are about 2,200 km^2 and are located in the north west of the South Island of New Zealand (Fig. 1). The Motueka River rises in elevation from sea level to 1600 m in alpine headwaters and delivers 95% of the fresh water to Tasman Bay, a productive and shallow coastal body of high cultural, economic, and ecological significance (Basher et al. in press).

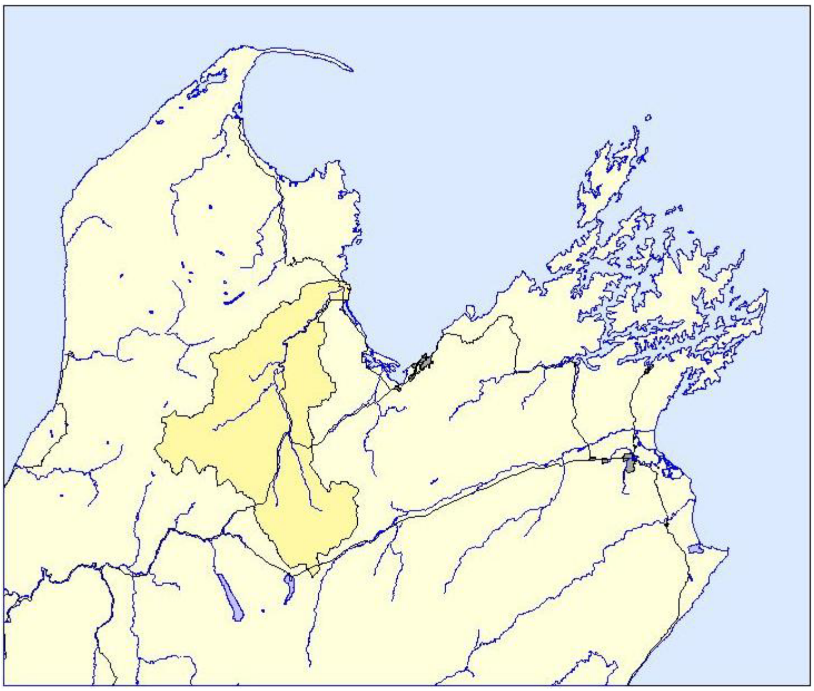

Figure 1 Location map of the Motueka River catchment

Average annual precipitation is about 1300-1550 mm, the annual discharge of the Motueka River is 844 mm, and mean annual flow is 58.1 m3 s-1. The climate is cool and humid with distinct wet and dry (austral summer) seasons.

The geology is mixed with clearly defined terranes that include erodible granites (mid-basin), clay-bound gravels (mid-basin), ultra-mafic mineral formation (eastern headwaters), sandstone-siltstone (eastern headwaters), and complex limestone, marble, and calcareous mudstone (western headwaters).

The alluvial plains in different parts of the catchment support a wide range of horticulture on young relatively fertile soils, much of which is irrigated from groundwater aquifers. Rolling and steep hill country in the lower basin contain low-fertility soils and are grazed or in plantation forest, while the rugged mountainous terrain in the headwaters with a mixture of thin-infertile to thick fertile soils are mostly in native "bush" conservation estate.

The Motueka River supports a nationally significant brown trout fishery and annual surveys over the last 6 years have consistently shown that the observed number of adult trout were about one third of the numbers seen in 1985.

In a broad sense, there are 4 sub-regions which tend to show similar characteristics of landform, geology, climate and river form. These are the western ranges, southeastern ranges, central lower relief Moutere gravels, and the alluvial plains.

Western ranges – are steep indigenous forest-, tussock-, scrub-clad rivers and streams such as the headwaters of the Wangapeka, Baton, and Pearse Rivers. This sub-region has a wide range of lithologies but is generally on the older harder rocks. The area is mostly in Kahurangi National Park with minor areas of exotic forestry and pastoral agriculture. Most of these rivers are “natural” and range in size from small headwater streams to wide, higher order rivers with well developed terraces.

Southeastern ranges – are steep indigenous forest-, tussock-, scrub-clad rivers and streams such as the headwaters of the Motueka River. The sub-region includes the Red Hills, an area of ultra-mafic rocks and coincides with Richmond Forest Park but also includes areas of exotic forestry. Most of the rivers are “natural” and include a wide range in size.

Central lower relief Moutere gravels – a much lower relief zone with many ephemeral streams of low order. Land uses are varied and include indigenous forest remnants, reverting scrub, pastoral farming and widespread exotic forestry. Riparian areas are typically modified, particularly in areas of pastoral farming, with little or no vegetated buffer strips. In exotic forests, buffers vary both in type and extent.

Alluvial plains – these areas occupy the valley floors of reaches of the Motueka, Motupiko, Sherry, Tadmor Rivers. They have well developed terrace sequences and cover a wide range of land uses but are predominantly in pastoral farming and horticulture.

2.2 Survey methods

One hundred and fifty six sites that cover the range of riparian conditions present within the Motueka and Riwaka River catchments were surveyed to provide information for developing a riparian management classification (RMC, see Appendix 1 for site location details, Fig. 2). Spatial coverage of sites was not uniform and was predicated on accessibility, with many smaller headwater streams, particularly in the steep western and southeastern ranges not being sampled. Trade-offs between resources, physical access or access via permit limited the coverage of the western and southeastern ranges.

Site characteristics that affect key riparian functions and human uses were assessed at each site using the methodology of Quinn et al (2001a,b), photographs taken and representative cross-sections were sketched. Data were also collected on the stream/riparian physical attributes at three different spatial scales: catchment scale, valley scale, and reach scale (Table 1). Some of this information was assessed in the field and other data were obained from the River Environment Classification (REC) database (Snelder et al. 1999) or the Land Environments of New Zealand database (LENZ) (Leathwick et al. 2003).

On-site assessments were made of the activity of riparian functions at each site. Functions such as those played by riparian vegetation in terms of streambank stability, denitrification of groundwater inflows, shading of the channels for temperature and instream plant control, wood debris and leaf litter input, enhancement of fish spawning and general fish habitat, downstream flood control, recreational use and aesthetics. The potential role of these functions if best practice riparian management was applied was also assessed. These current and potential riparian functions and human uses were ranked as: 0 (absent), 1 (low activity), 2 low-moderate activity), 3 (moderate activity), 4 (high activity), or 5 (very high activity).

Table 1. Details of physical attributes that describe the stream at the catchment scale, valley segment scale, and stream reach scale (after Quinn et al. 2001b; Snelder et al. 1999).

Spatial scale	Physical attribute	Explanatory notes
Catchment	Dominant catchment baserock index	Soft sedimentary = 1; Loess = 2; Alluvium & sand = 3; Mixed igneous = 4; Hard sedimentary = 5
Valley segment	Riparian land use	Cattle, conservation, crop, dairy, forestry, horticulture, sheep, urban
	Channel shape category	1 = channelised; 2 = straight; 3 = meandering; 4 = sinuous
	Valley bottom width category	1 = <50 m; 2 = 50–200 m; 3 = 200–400 m; 4 = 400–1500 m; 5 = >1500 m
	REC reach morphology index#	1 = CG; 2 = SG; 3 = EP; 4 = NP; 5 = ER; 6 = NR; 7 = BR; 8 = EP; 9 = FM; 10 = TR
	Land drainage class	1 = very poor; 2 = poor; 3 = impeded; 4 = moderate; 5 = good
	Landslope	degrees
Reach	Water width	Estimate of the average wetted stream width
	Non-vegetated width	Estimate of channel width lacking terrestrial vegetation
	Bankfull width	Total width at bankfull discharge
	Channel slope index	1 = <0.2º; 2 = 0.2º–0.5º; 3 = 0.5º–1.0º; 4 = 1.0º–2.0º; 5 = >2.0º
	Land-slope index	1 = <2º; 2 = 2.0º–5.0º; 3 = 5.0º–15.0º; 4 = 15.0º–25.0º 5 = >25º
	Substrate composition	Bedrock, boulder, cobble, gravel, sand, silt, clay
	Shade ratio	Bank + vegetation height/channel width
	Bank height	Estimate of average bank height
	Periphyton categories:	0 = none; 1 = slippery; 2 = obvious; 3 = abundant; 4 = excessive (>80% FGA)
	Macrophyte species and % cover	Species present, % total bed covers. Bryophyte cover noted separately
	Woody debris index	0 = absent; 1 = sparse; 2 = common; 3 = abundant;
	Stock bank damage index	0 = none; 1 = minor; 2 = moderate; 3 = extensive
	Streambank stability	Assessment of the % of banks stable undercut or slumped
	Riparian veg. & bank cover	List of dominant riparian vegetation
	Riparian wetland index	1 = present; 2 = absent
	Stock access to stream	No / Yes (0 / 1)
	Stock damage classes	0 = none; 1 = minor; 2 = moderate; 3 = extensive
	Riparian fencing	% of each bank fenced and bank to fence distance
	Fencing type	0 = none; 1 = electric 1 or 2 wire; 2 = post & batten

2.3 Riparian function assessment protocols

This section summarises the rationale for assessing each riparian function and is largely reproduced from the report of Quinn et al. (2001b). Our assessments did not include the riparian zone functions of enhancing terrestrial biodiversity, providing wildlife corridors, and habitat and landscape connectivity, though some acknowledgement of these aspects may have "coloured" assessments of potential functions in relation to aesthetics, in particular.

2.3.1 Bank stabilisation

The role of riparian vegetation in stabilising banks depends on the ability of vegetation to: (1) reinforce bank strength through root network strengthening (Rutherfurd et al. 1999; Lyons et al. 2000; Simon & Collison in press), (2) provide a well-developed upper soil layer or a dense root system that protects against surface soil erosion (Dunaway et al. 1994), (3) pump out water from the soil, and provide macropores for drainage, lowering erosion potential owing to bank sloughing and slumping (Thorne 1990), and/or (4) buttress the toe of the streambank protecting it from shear failure (Thorne 1990). Key factors influencing these stabilizing functions are: the height of the streambanks relative to the depth of root penetration, bank angles, the erosive power of the stream under high flows (including local effects such as whether the reach is straight or meandering with many erosion-prone bends), and whether the banks are protected by other features (e.g., boulders, bedrock, or large woody debris).

Grasses, herbs, and forbs are expected to provide good bank stabilization of small banks (<0.5 m) and those with low angles (<45º), whereas shrubs and trees give better protection for higher and steeper banks (Burckhardt & Todd 1998; Abernethy & Rutherfurd 1999). The following notes provide guidance for assessing the height of streambank that can be effectively strengthened by vegetation roots (Abernathy & Rutherford 1999). Groundcover (typically up to 1 m high including prostrate shrubs, grasses, sedges and forbs) provide reinforcement of banks to a depth <0.3 m. Understorey trees (typically 1–5 m high) have roots down to about 1 m and extend laterally to about the dripline. Overstorey species have a central rootball or rootplate of dense roots that can usually be considered as half a sphere that has a diameter five times the diameter of the trunk. Root density declines rapidly beyond the root ball and for reinforcement purposes there are usually few roots beyond the canopy dripline or below about 2 m under bank surface. Watson et al. (1999) report maximum root depths of 1.8–3.1 m for 8 to 25-year-old *Pinus radiata* and 1.3–1.6 m for 6 to 32-

year-old kanuka. Root depths for the common cabbage tree (*Cordyline australis)* may reach depths of up to 2 m in fine alluvial soils but are typically 0.6-1.0m for trees around 7 or 8 years old (Czernin 2002). The root stabilization function will be greatest where the bank height is less than the depth of root penetration. A plant trial of 12 common native riparian colonisers found that the differences in below ground performance for the first few years were not significant but once plants reached around 3-4 years inter-species differences in both abov- and below-ground performance became apparent (Marden & Phillips 2002; Phillips 2001; Phillips et al. 2001).

2.3.2 Filtering contaminants from overland flow

Filtering of contaminants from overland flow can be an important function of the riparian zone. To be effective, the zone needs to: (1) slow the flow of surface runoff, enhancing settling of particulates;and/or (2) increase infiltration into the soil, enhancing filtration of particulates (Smith 1989; Cooper et al. 1995; Williamson et al. 1996; McKergow et al. 2003). These filtering and settling functions are enhanced by the zone having flat topography, dense ground cover of grassy vegetation or litter under riparian forest that increase surface roughness, and soil characteristics that increase hydraulic conductivity (low compaction, high sand content, abundant macropores). Obviously, the zone must receive surface runoff from the adjacent landscape for this filtering role to operate. The function will be compromised if the surface runoff is channelised, so that runoff passes rapidly through the riparian area with little time for settling of particulates or infiltration into riparian soils. The likelihood of surface runoff occurring increases with rainfall intensity, slope length, slope angle and convergence of flows, and decreases with infiltration rate. Animal trampling typically reduces infiltration rate (Nguyen et al. 1998) and excluding stock from the riparian reverses this effect (Cooper et al. 1995). The quantity of sediment carried in surface runoff increases with the clay content of the soil. Guidelines are available to predict the optimal width of grass strip (% hillslope length) to filter suspended sediment from surface runoff in relation to slope length, slope angle, drainage and clay content (Collier et al. 1995).

2.3.3 Nutrient uptake by riparian plants

Nutrient uptake by riparian plants is an important function where infiltration surface runoff or shallow groundwater passes through the root zone before entering the stream (Fig. 3). In contrast, the function is unimportant where groundwater bypasses the root zone of riparian plants. This may occur in deeply incised streams, where tile drains deliver most of the shallow groundwater directly to the stream, or where deep groundwater emerges in the streambed as springs (Prosser et al. 1999).

Riparian vegetation type influences this function via vegetation rooting depth in relation to bank height and groundwater flows—larger trees and shrubs have deeper roots that can intercept deeper groundwater. Large plants also have a greater biomass and hence generally store more nutrient in plant tissue than small plants. Harvesting of these plants (e.g., by timber harvest or controlled animal grazing and subsequent removal of the animals) contributes to long-term removal of these stored nutrients from the riparian area. Plants nearest the stream are most likely to interact with groundwater, but nutrient uptake is expected to increase with the width of the zone of deep-rooting riparian plants.

The transpiration of riparian vegetation can also pump water from the riparian soils, leading to hydraulic gradients that draw river water into the riparian area where it is exposed to nutrient uptake and removal processes.

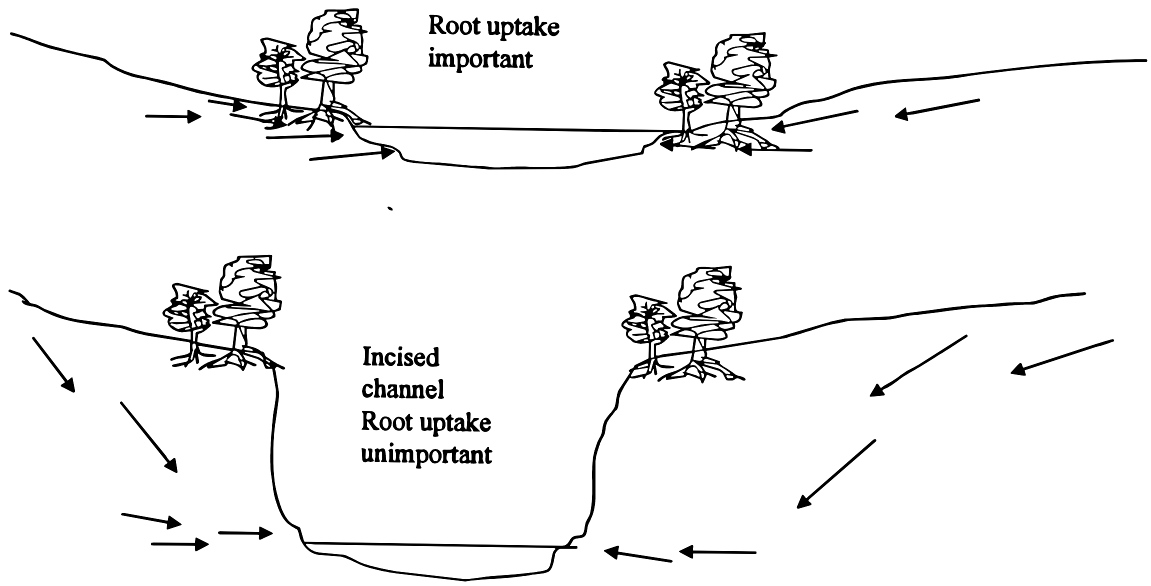

Figure 3 Schematic showing the influence on channel shape on interaction between shallow groundwater and the root zone of riparian vegetation (after Quinn et al. 2001b).

2.3.4 Denitrification

Denitrification is a process by which bacteria reduce nitrate to nitrous oxide and N_2 gases that are lost to the atmosphere, providing permanent N removal from the water (Willems et al. 1997). The process requires nitrate N, low oxygen conditions provided by waterlogged soils, and an available carbon source to drive the process (Knowles 1982). It is most important in riparian areas where shallow groundwater passes through wetlands before emerging in the stream (Prosser et al. 1999). Riparian plants can enhance the process by their roots increasing the supply of carbon at depth within the streamside soils.

2.3.5 Shading for instream temperature control

Cool groundwater entering shallow streams heats quickly under direct solar radiation in unshaded conditions (Rutherford et al. 1997, 1999). The rate of heating decreases with stream depth, as the mass of water absorbing the incident radiation increases, and with shading vegetation, that absorbs and reflects much of the incident radiation. The ability of riparian vegetation to shade the channel decreases with stream width and the height of the vegetation (Davies-Colley & Quinn 1998). Mature trees produce a closed canopy over channels narrower than about 6 m but the shade gap between the trees on either banks increases above this width (Davies-Colley & Quin 1998). Tussock grasses, sedges and flaxes only provide effective shade in very narrow channels (i.e., <c. 2 m). Streams with poorly conductive beds (e.g., clay or bedrock) are expected to heat more rapidly than equivalently shaded streams with conductive beds (e.g., gravels), due to less conductive loss to the ground and less exchange with groundwater. Streambanks and hills can also provide topographic shade, independent of riparian vegetation, and are particularly important in incised streams (Rutherford et al. 1999).

2.3.6 Shading for instream plant control

Riparian shade can control stream lighting and thus control instream plant growth below nuisance levels, whilst maintaining the biodiversity benefits and desirable functions that plants provide (Biggs 2000). Shading of 60–80% is expected to prevent proliferation of filamentous green algae (Quinn et al. 1997b; Davies-Colley & Quinn 1998), but 90% shading is needed to prevent growth of some emergent macrophytes in low gradient streams (Wilcock et al. 1998).

Shade control of instream primary production also reduces the instream processing of nutrients (uptake of dissolved nutrients into plant biomass) (Quinn et al. 1997b), so that increased shade can result in increased export of dissolved nutrients and higher concentrations downstream (Howard-Williams & Pickmere 1999). Decomposition of leaf litter from riparian trees also results in uptake of dissolved nutrients from the stream water, but this is not expected to compensate for the reduction in uptake by plants under highly shaded conditions (Quinn et al. 2000a). The overall effect of riparian plantings that shade the stream on downstream nutrient concentrations depends on the balance of the increased riparian uptake versus decreased instream uptake. If downstream nutrient concentrations are more important than control of nuisance plants (and temperature) at the reach (e.g., if the stream drains to a nutrient-sensitive lake or river reach of high recreational value), then riparian plantings need to be planned and managed to maintain open lighting conditions (>c. 50%) whilst retaining the nutrient removal within the riparian zone (e.g., by managing for low-growing, or spaced deciduous, riparian vegetation). Because of this site-specific, trade-off nature of the decisions on shade control to enhance instream uptake of dissolved nutrients, this issue was not included in our riparian function assessments during this study. Modelling studies (Parkyn et al. 2001) indicate that, provided that the groundwater interacts with the riparian area, riparian protection/planting that starts in the headwaters will result in lower instream dissolved nutrient concentrations, despite the effect of channel shading on instream uptake, because riparian uptake processes will dominate.

2.3.7 Input of large woody debris and leaf litter

Large woody debris (LWD) and leaf litter can play important roles in streams as food resources and habitat (Collier & Halliday 2000; Quinn et al. 2000b). The role of leaf litter and LWD depends on the retentiveness of the stream, which decreases with stream size (Webster et al. 1994; Webster et al. 1999) and flooding frequency. LWD input is most stable in smaller streams, especially where the channel width is less than the typical wood piece length, and in low gradient streams that lack the power during floods to transport wood downstream. LWD can be a key habitat forming feature, increasing habitat diversity and cover for invertebrates and fish, and often forms the deepest pools (Quinn et al. 1997a). LWD is particularly important as invertebrate habitat in sandy and silty bedded streams (Collier & Halliday 2000). Natural restoration of LWD to streams is a much longer term process (several decades to centuries) than restoration of shade (several years to decades, depending on stream size). However, it is possible to reintroduce LWD to riverbeds artificially to speed up this process.

2.3.8 Enhancing instream fish habitat and fish spawning areas

Riparian vegetation enhances fish habitat by providing cover and also encourages the input of terrestrial insect food items from overhanging vegetation (Main & Lyon 1988; Jowett et al. 1996). Cover can take the form of overhanging plants, tree roots, LWD and leaf packs. Higher over-storey vegetation is less effective fish cover than low-growing grasses and shrubs that grow just above stream level or hang into the stream.

Riparian zones also provide spawning areas for some galaxiid fish species, such as banded kokopu (Mitchell & Penlington 1982), and short-jawed kokopu that spawn in leaf litter/woody debris during high flows and inanga that spawn in riparian grasses in tidal lowland reaches (near the salt wedge) (Mitchell & Eldon 1991). Removal of riparian vegetation in upland areas is expected to reduce the suitability for banded kokopu spawning by eliminating the moist microclimate and leaf litter found under forest, but details of spawning requirements are sketchy. Intensive stock grazing is also expected to reduce the spawning success for inanga by removing the dense grassy vegetation and by stock trampling eggs and exposing them to desiccation due to sunlight and wind during their month-long incubation period.

2.3.9 Controlling downstream flooding

Riparian forest and wetlands are expected to attenuate the peak flow of runoff into the stream channel in small rainfall events (Smith 1992). Furthermore, well-developed riparian vegetation has greater hydraulic roughness than short grass and hence retards the progress of flood flows as they spill out into the riparian area (Coon 1998). This may cause increased local flooding of the riparian area and adjacent land, but is expected to reduce the peak flow in downstream reaches. Factors expected to influence these effects are the likelihood of overbank flows (less in deeply incised channels), the size of the riparian area and floodplain, the extent of wetlands, and the roughness (size/density) in relation to the flow depth) of the riparian vegetation.

2.3.10 Recreation

Riparian management can influence human recreation of the riparian area and the stream by changing stream aesthetics, naturalness, access, and the fishability of the stream (Mosley 1989). These effects are generally more important long medium-sized streams, with access to safe swimming and fishing spots, and in areas of high human access, such as urban streams and reserves.

Riparian management also influences boating/canoeing. Overhanging willows and LWD can be hazardous for boating, whereas native planting plays a particularly important role in enhancing recreational use. Walkways, picnicking facilities (tables and seating), weed control (especially blackberry and other invasives) and vehicle-parking areas are all important for enhancing recreational use. Angling use requires particular attention to riparian planting design to provide both overhanging cover and low vegetation to allow fly-casting.

2.3.11 Landscape and stream aesthetics

Riparian areas can enhance landscape aesthetics substantially by providing vegetation diversity with ribbons of green within developed pastoral and urban landscapes (Mosley 1989). We have assumed that shrubs and trees have greater aesthetic appeal than grasses, and that native vegetation has more appeal than exotic vegetation.

3. Results

3.1 General characteristics of the Motueka study sites

The 156 sites included in the survey covered a wide range of conditions from small, first-stream order, headwater streams to large high-order rivers (Table 2). The typical surveyed stream reach had none or little riparian fencing, 80% of the stream banks were stable, and stock damage to the banks was judged to be minor, though in half the sites stock had access to the stream banks. Woody debris was typically sparse and, despite low levels of stream shade, periphyton was only “slippery” and macrophytes were typically absent. Both banks were about 20% fenced at most of the sites. Riparian wetlands were observed at only a few sites, probably reflecting the low rainfall, permeable soils, and general landscape geomorphology in the study area.

Grass was the most common dominant riparian vegetation type, followed by willows, native trees and shrubs. There was also a high proportion of other exotic weedy vegetation and shrubs such as broom and gorse.

Table 2. Summary of stream and riparian characteristics (*see Table 1 for index definitions). Checked and correct at 16 sept 2002

Characteristic	N	mean	median	SD	Min	Max
Catchment area (km2)	156	211	183	498	0.3	2060
REC stream order	156	3.51	3.5	1.32	1	6
Rec flow size class	156	3.85	4	0.98	2	6
Water width (m)	156	11.3	4	18.9	0.3	100
Non-vegetated width (m)	156	18.3	6	28.2	0.3	150
Bankfull width (m)	156	23.1	8.25	34.7	0	200

Valley width index	156	2.7	3	1.2	1	5
Shade ratio*	156	1.6	1.1	2.3	0.05	15
LENZ Landslope index*	147	2.9	2	3.2	0	19.3
REC Channel slope index*	156	0.02	0.013	0.03	0	0.3
% stable bank	156	78	80	22	10	100
Streambank height R (m)	156	2.7	2	2.8	0	15
Streambank height L (m)	156	2.9	2	2.9	0	15
% macrophyte cover	156	4.3	0	13.5	0	100
Periphyton abundance scale	156	1.4	1	0.85	1	4
Wood input index*	155	0.8	1	0.7	0	3
Bank stock damage index	156	0.6	0	0.9	0	3
Riparian wetlands index*	156	0.15	0	0.36	0	1
Riparian fence type index*	156	0.6	0	0.87	0	2
% left bank fenced	156	18.7	0	35.6	0	100
% right bank fenced	156	19.8	0	36.6	0	100

3.2 Assessment of current riparian functions

The field assessment of riparian functions is summarized in Table 3. The various functions differed in their average assessed current and potential activity and also varied widely in activity between the sites. Denitrification, nutrient uptake and downstream flooding contribution were assessed to be the least active current functions at the sites, whereas shade for and temperature and fish habitat were judged the most active. Applying best practicable riparian management at the sites was judged to be capable of improving most riparian functions substantially (Table 3). Best practicable riparian management was assumed to involve fencing out stock from the stream/riparian area and managing the area for the development of long grasses, shrubs and trees within this protected area. The average improvement expected was greatest for functions that related to vegetation improvements such as bank stability, shading, aesthetics and litter input and least for downstream flooding mitigation and fish habitat.

Table 3. Summary of the assessed current (_C) and potential (_P) riparian functions at sites in Motueka River Catchment. Functions scored from 0 (not active) to 5 (very highly active). Checked and correct at 16 sept 2002

Riparian functions	Mean	Median	StdDev	Min	Max
Bank stability_C	2.5	2.5	1.2	0	5
Bank stability_P	4.0	4	1.0	1	5
Overland flow filtering_C	2.5	2.5	1.2	0	5

Overland flow filtering_P	3.9	4	1.2	0	5
Nutrient uptake_C	1.7	2	1.0	0	5
Nutrient uptake_P	3.1	3	1.1	0	5
Denitrification_C	2.4	2	1.0	0	5
Denitrification_P	3.7	4	0.9	0	5
Shade for temp_C	2.8	3	1.5	0	5
Shade for temp_P	3.2	4	1.6	0	5
Shade for plant control_C	1.7	2	0.6	0	5
Shade for plant control_P	2.1	2	0.7	0	5
Wood input_C	2.3	2	1.3	0	5
Wood input_P	2.8	3	1.4	0	5
Litter input_C	2.3	2	1.2	0	5
Litter input_P	3.8	4	1.0	0	5
Fish habitat_C	2.8	3	1.5	0	5
Fish habitat_P	3.2	4	1.6	0	5
Downstream flooding_C	1.8	2	0.6	0	5
Downstream flooding_P	2.1	2	0.7	0	5
Recreation_C	2.3	2	1.3	0	5
Recreation_P	2.8	3	1.4	0	5
Aesthetics_C	2.3	2	1.2	0	5
Aesthetics_P	3.8	4	1.0	0	5

3.3 Predicting riparian function activity

3.3.1 Predicting current riparian functions (RMC-C)

The factors influencing the activity of riparian functions were evaluated using the same methodology as Quinn et al (2001). Multivariate statisitics (MOPED programme developed by Ian Jowett of NIWA) were used to analyse both current and potential functions. First the sites were clustered based on their current riparian functions in a 4 x 4 Self Organising Map (SOM) using k-medoids (Kauffman and Rousseeuw 1990). The Silhoutte index indicated the optimal number of clusters (maximising between cluster differences and minimising within cluster differences) was four, with each of the current riparian function ratings differing between these 4 clusters (ANOVA, $P < 0.05$, Fig. 4) (see Appendix 7.1 for site classification details).

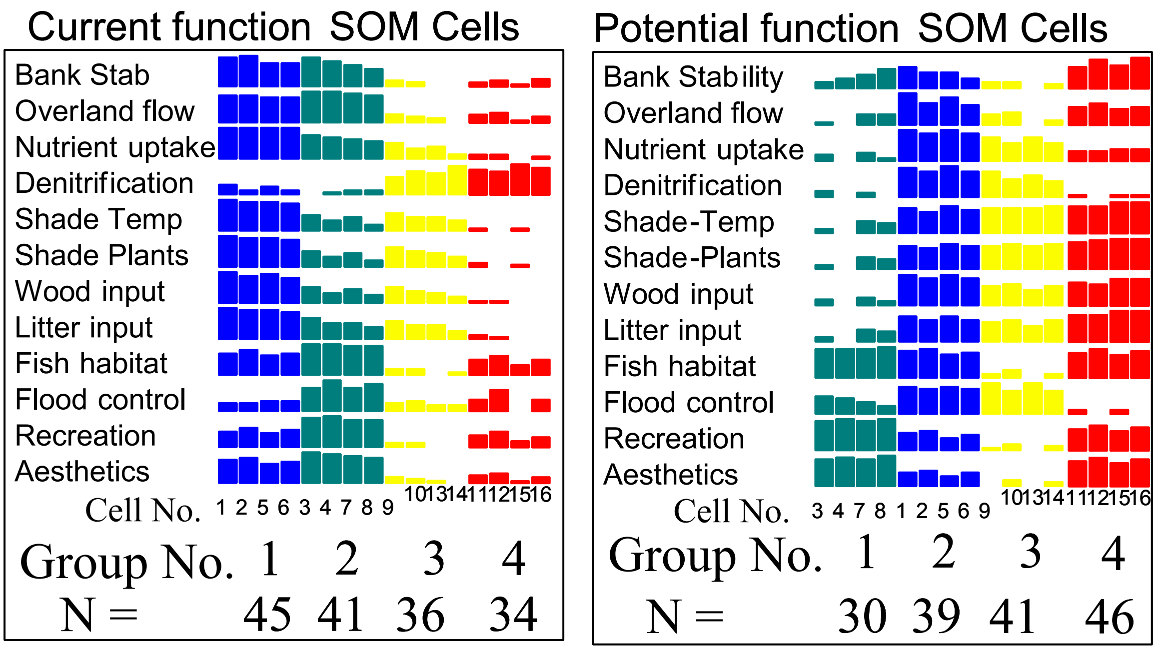

Figure 4 Comparison of mean function ratings amongst the individual Self Organising Map (SOM) cells and the four RMC classes based on current and potential riparian function ratings at Nelson stream sites. The relative height of the bars indicates the activity of the functions (0 to 5 scale).

The differences in environmental variables between these clusters were tested by one-way ANOVA. A number of variables assessed on-site and from the GIS databases differed most strongly between the clusters (Table 4). These variables related largely to the widths of streams and valleys, source of flow, size of catchment as well as to stream shading.

Class 1 sites (n = 45) were typically in small to moderate size catchments and generally had high activity ratings for vegetation-related functions such as shade, litter input, and bank stability and moderate rankings for the other functions (Figure 5) (see Appendix 7.2 for examples). Class 2 sites (n = 41) had high ratings for aesthetics, recreation and fish habitat and moderate rankings for other functions. These sites were typically larger order streams with lower stream gradients. Class 3 sites (n = 36) generally had low ratings for all functions except for denitrification and moderate rankings for functions related to vegetation. Class 4 sites (n = 34) had low rankings for most functions. These sites tended to be in no special grouping and occurred both at the large and small scale. In several instance, sites had some degree of channel modification.

Table 4 Results of one-way ANOVA of environmental variables amongst 4 clusters of sites based on current riparian functions. * variables were log transformed with averages reported as geometric means, other variables are arithmetic means.

Variable/cluster	**F**	**P**	**1**	**2**	**3**	**4**
Water width (m) *	36.9	0.000	0.6	1.3	0.2	0.5
Non-vegetated width (m) *	33.1	0.000	0.7	1.5	0.5	0.8
Flow size class	31.1	0.000	3.5	4.9	3.3	3.8
Bankfull width (m) *	30.5	0.000	0.8	1.6	0,6	0.9
Catchment area *(km2)	28.0	0.000	3.1	4.3	2.9	3.4
SOF index	27.9	0.000	1.8	2.0	1.2	1.7
REC stream order	21.1	0.000	3.1	4.8	2.9	3.3
Shade ratio	17.3	0.000	2.8	0.4	2.5	0.5
Stock damage to banks index	9.4	0.000	0.4	0.3	1.2	0.6
Bank stability (%)	7.0	0.000	88	81	68	72
Stock access to stream index	6.2	0.001	0.3	0.3	0.7	0.7
Riparian wetlands present index	6.1	0.001	0.0	0.1	0.2	0.3
REC slope (m/m)	5.7	0.001	0.027	0.010	0.015	0.021
Average bank height (m)	5.7	0.001	3.7	3.2	2.0	1.8
Wet/dry index	5.2	0.002	0.93	1.00	0.77	0.97
Valley bottom width category	4.0	0.009	2.2	3.2	2.7	2.8
Channel shape index	3.8	0.013	2.5	2.3	2.7	2.6
Channel slope index	3.5	0.017	4.6	4.5	4.1	4.2
Landslope index	3.0	0.034	3.0	2.5	2.4	2.3
Woody debris index	2.3	0.078	0.95	0.68	0.86	0.56
Domain landslope (degrees)	2.2	0.090	3.8	3.2	2.2	2.2
Riparian fencing type index	2.2	0.091	0.4	0.5	0.9	0.5

The variables in Table 4 were used to develop a discriminant model to predict cluster affinity. This model assigned 74% of the sites to the correct cluster (c.f. 25% expected by chance), with the most correct hits for Class 2 (78%), Class 3 (77%), Class 1 (74%) and least for Class 4 (66%). Function 1 of the discriminant model (that accounted for 59% of the overall variance explained) was most strongly correlated with variables relating to how wide the streams were, the source of flow and similar catchment variables. These findings suggest that the width of the stream, its source of flow and catchment size, as well as the amount of shade and cover are important in determining riparian functions in the Motueka River catchment. The 74% correct prediction rate for site classification implies that this discriminant model could be used as a way for non-experts to assess likely riparian functions at a site, based on the mix of site and map information in Table 4. The model would predict the class affinity and attributes of the site deduced from the typical riparian function ratings for that class (e.g., Fig 4a).

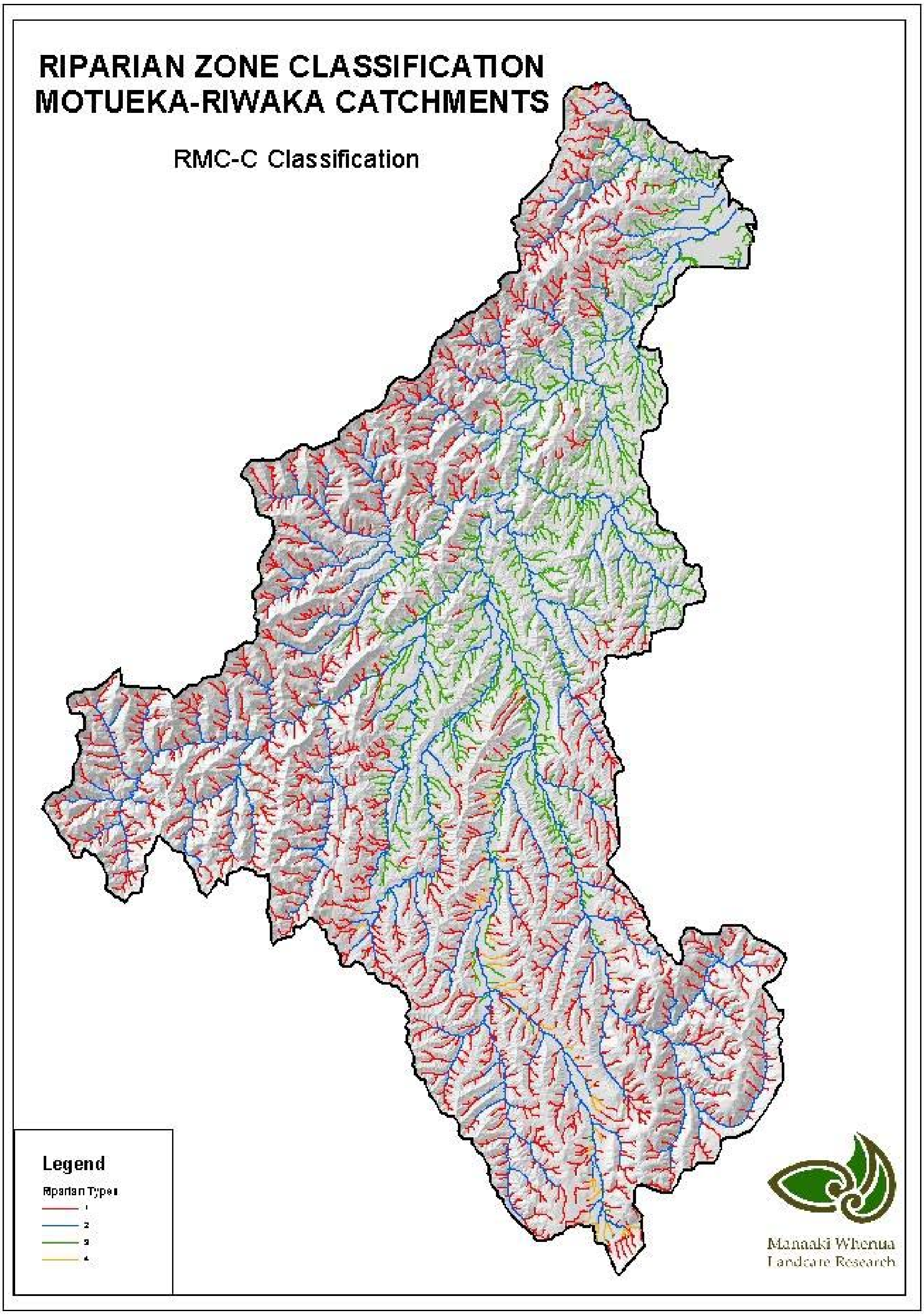

Figure 5 Map of RMC-C types for the Motueka-Riwaka catchments.

A second discriminant function model was developed, using only the information obtainable from GIS databases. This model assigned 62% of the sites to the correct cluster. Function 1 of the discriminant model (that accounted for 83% of the overall variance explained) was also most strongly correlated with catchment variables such as source of flow index (r = 0.85) and catchment area (r = 0.78). Function 2 (15% of the variance explained) was most strongly correlated with catchment area (r = -0.57).

3.3.2 Predicting potential riparian functions (RMC-P)

The same clustering and modelling procedures were also carried out using the potential riparian function activity ratings. This also resulted in 4 main clusters, and each of the riparian functions differed in potential activity ratings between these clusters (ANOVA, $P < 0.05$). The differences in environmental variables between these clusters were tested by one-way ANOVA. Variables that related to the size of the stream, its geomorphic setting and size of contributing catchment differed most strongly between clusters. A number of other variables also showed statistically significant differences between clusters based on potential riparian funcitons.

Class 1 sites (N = 30) had high ratings for potential activity for fish habitat and recreation and aesthetics functions (Figure 6). These were typically small-sized stream in the western and southeastern ranges. Most of these areas are in conservation-managed lands and are already providing a range of functions. Class 2 sites (N = 39) were typically rivers in valley floors and had high potential ratings for virtually all functions. Class 3 (N = 41) were similar to Class 2 but had lower potential ratings for functions such as bank stability, recreation and aesthetics, and wood and litter input. Class 4 (N = 46) again had high potential ratings for most riparian functions but had low ratings for flood control and denitrification.

The discriminant model that included all the variables in Table 5 allocated 82% of sites to the correct cluster (c.f. expected by chance). Function 1 of the discriminant model (that accounted for 78% of the overall variance explained) was most strongly correlated with water width (r = 0.95), non-vegetaetd width (r = 0.87), and bankfull width (r = 0.85), whereas function 2 (13% of the variance explained) was most strongly correlated with the riparian wetland index (r = 0.64), and function 3 (8% of the variance explained) was most strongly correlated with land slope index. A second discriminant model was developed using only information available from the GIS databases. This model assigned 65% of the sites to the correct cluster. Function 1 of the discriminant model (that accounted for 84% of the overall variance explained) was most strongly correlated with catchment area (r = 0.82), flow size class (r = 0.79), source of flow index (r = 0.77) and stream order (r = 0.76). Function 2 (11% of the variance explained) was most strongly correlated with REC sloper (r = -0.69).

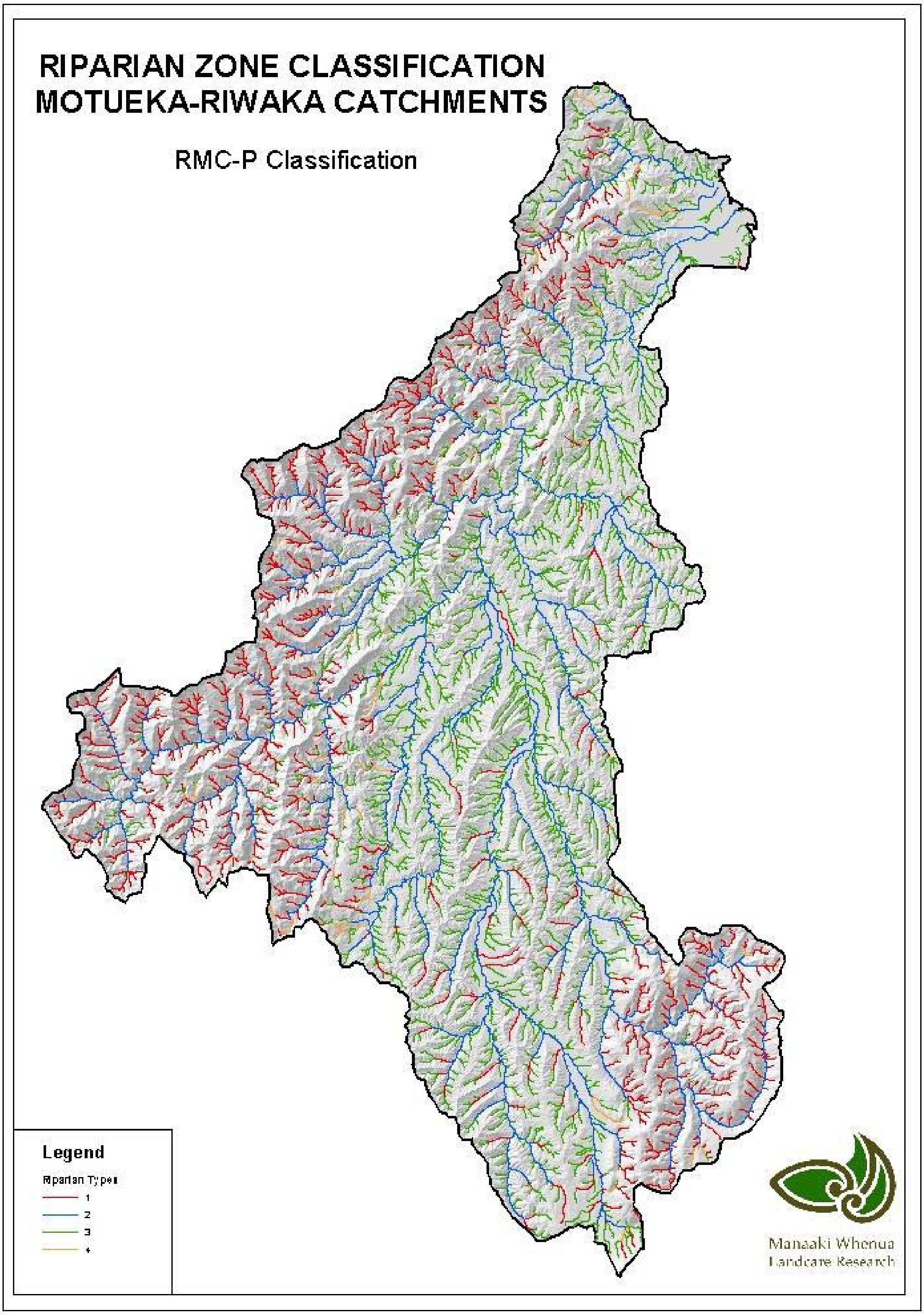

Figure 6 Map of RMC-P types for the Motueka-Riwaka catchments.

The discriminant models provide a means for non-experts to assess the likely actual and potential riparian functions at a site by inputting key information on the site characteristics and examining the characteristics of the cluster to which the site is allocated. The models can also be used to map the distribution of classes developed from potential riparian functions using Land Environment NZ (LENZ) (previously known as Environmental Domains) and the River Environment Classification (REC) databases.

Table 5 Results of one-way ANOVA of environmental variables amongst 4 clusters of sites based -on predicted riparian functions. * variables were log transformed with averages reported as geometric means, other variables are arithmetic means.

Variable/cluster	**F**	**P**	**1**	**2**	**3**	**4**
Water width (m) *	79.2	0.000	0.4	1.3	0.1	0.7
Non-vegetated width (m) *	55.5	0.000	0.6	1.5	0.4	0.8
Bankfull width (m) *	49.9	0.000	0.8	1.6	0.5	0.9
Catchment area (km2)*	32.6	0.000	3.2	4.3	2.8	3.2
Flow size class	28.7	0.000	3.6	4.8	3.2	3.7
SOF index	28.2	0.000	1.9	2.0	1.2	1.8
REC stream order	26.0	0.000	3.1	4.7	2.7	2.6
Riparian wetlands present index	11.4	0.000	0.4	0.0	0.3	0.0
Stock damage to banks index	9.5	0.000	0.8	0.3	1.2	0.3
Shade ratio	8.2	0.000	1.4	0.4	2.7	1.9
Average bank height (m)	7.9	0.000	1.7	3.5	1.8	3.7
Wet/dry index	7.1	0.000	0.9	1.0	0.8	1.0
Land slope index	5.1	0.003	2.3	2.5	2.4	3.1
REC slope (m/m)	4.7	0.004	0.0	0.0	0.0	0.0
Stock access to stream index	4.4	0.006	0.7	0.4	0.6	0.3
Valley bottom width category	3.8	0.012	2.5	3.1	2.8	2.2
Riparian fencing type index	3.7	0.014	0.4	0.5	0.9	0.4
Bank stability %	3.5	0.017	75.7	75.8	71.4	86.7
Domain soil particle size	3.4	0.019	2.3	2.4	2.3	2.9
Channel shape index	3.0	0.032	2.5	2.4	2.8	2.5
Domain landslope (degrees)	2.2	0.095	2.6	2.9	2.3	4.0
Domain land drainage class	1.5	0.237	4.4	4.7	4.8	4.7
Baserock index	0.8	0.502	2.0	1.8	1.7	2.2
REC Elevation class	0.5	0.673	2.8	2.7	2.7	2.6
REC sinuosity	0.3	0.786	1.2	1.1	1.2	1.2
REC morphology class	0.1	0.963	5.2	5.1	5.3	5.1

3.3.3 Knowledge-based approach to riparian management classfication (RMC-K)

The results of the assessments of current and potential riparian functions amongst the streams examined in the Motueka River catchment highlight some key morphological factors that need to be considered in management decisions. These were channel width, source and permanence of flow, and the slope of the adjacent land. Using parameters such as these derived from the various spatial databases it is possible to combine this with expert knowledge and produce a “knowledge-based classification” – RMC-K. This relies on a more intimate knowledge of the river environments and landscapes of the catchment but provides a way to extend detailed local knowledge across terrain that has not been visited or studied in any detail.

Key parameters deemed to be statistically important for determining the current and potential riparian functions in the Motueka catchment factors generally related to the size and width of the stream and its valley, the slope of the channel, and the source of flow. In general terms, the influence of the riparian zone on instream habitat decreases when the channel becomes wide enough to limit the shading effect that trees and tall vegetation have, and the delivery and retention of wood and leaf litter. This suggests that streams can be separated into those with narrow channels and those with wider channels. Our assessments of potential shading function for control of stream temperature and in-stream vegetation growth in relation to channel width indicate that the shading function decreases from “high activity” (rating 4 or 5) to “low-moderate activity” (rating 2) at a non-vegetated channel width of approximately 20m (Fig. 7). This is consistent with findings from Quinn et al (2000) who found around 10m for Canterbury streams. These figures are also consistent with changes in stream lighting measured with canopy analysers in relation to stream width and riparian vegetation (Davies-Colley & Quinn 1998). These results indicate that a non-vegetated channel width of between 10 and 20m is an appropriate cut-off for distinguishing sites above which the riparian shading functions are likely to be ineffective.

Local landform is another key morphological influence on riparian functions and riparian management because of its influence on the need for the riparian area to act as a filter for contaminants in surface runoff. The combination of the slope of adjacent land to the stream as well as the width of the valley bottom will influence the efficiency of any riparian buffer to remove contaminants from any overland flow that is generated. The greater the slope the greater will be the width of buffer required to provide contaminant removal. In a similar manner, wide flat valley bottoms will not require wide riparian buffers as it is unlikely that riparian zones in flat land will receive much surface runoff, making the filtering function less active.

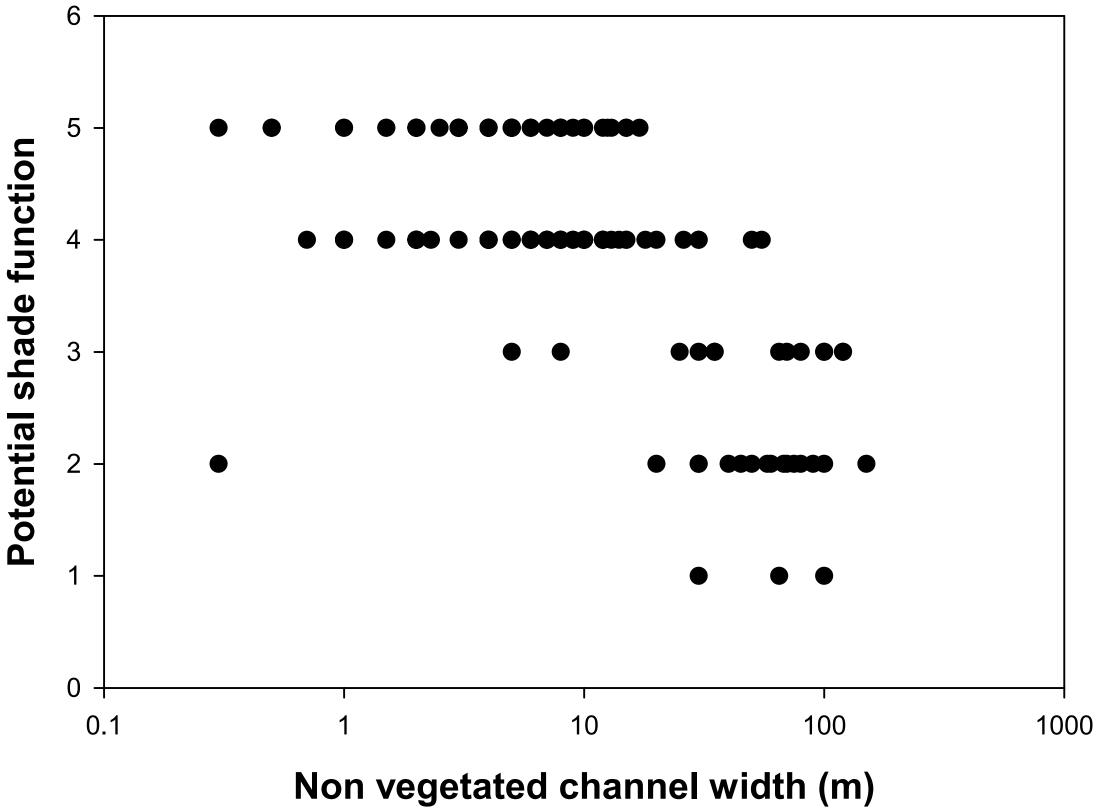

Figure 7 Effect of channel width on assessed potential riparian shading function for temperature control at sites in Motueka catchment. Function ratings from 0 (no activity) to 5 (very high activity).

3.3.4 Mapping the RMC-K reaches

Mapping the locations of these RMC-K classes or types is useful for planning purposes (Figure 8). While they are not likely to be used on a specific map-reach basis, together with the RMC-P map they will give an indication of the general areas and sub-catchments where restoration or management interventions might have the best effects in terms of increasing riparian functions.

We have used 8 classes and a range of GIS and other attibutes to map these classes. These attributes come from the REC, LENZ, and from field assessments (see Appendix 7.3 for definitions and examples). In our field assessment only one site was classed as Class 1, 2 of Class 2, 4 of Class 3, 2 of Class 8 and the rest between Classes 4 and 7, even though there is a reasonable distribution of stream reaches of each RMC-K class in the wider Motueka River catchment.

In general terms, factors that separate stream reaches in this classification relate to vegetation cover, land steepness, stream order, and source of river flow (mountains, hills or lowland). As indicated above, this approach uses a combination of objective attributes from spatial databases as well as expert knowledge of what controls the form and the function of riparian zones.

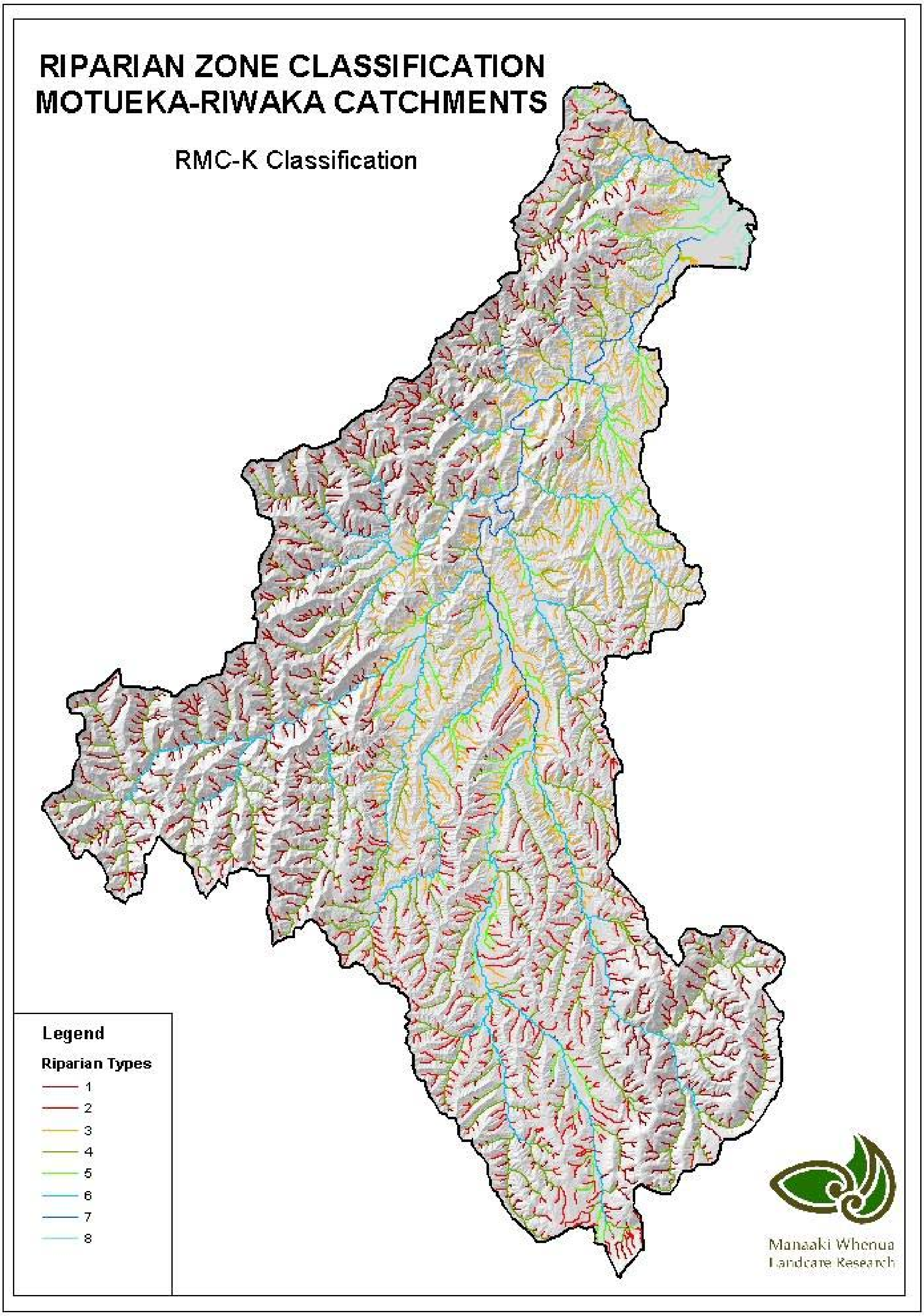

Figure 8 Map of RMC-K types for the Motueka-Riwaka catchments.

3.4 Selecting native species for riparian revegetation

The selection of appropriate plant species is a key factor in determining the success of any riparian management intervention. The nature of the issue that the riparian zone intervention is aimed at will determine the types of plants and pattern of planting. For example, if the issue of concern were contaminant removal then a low-growing grassy mix of plants that provides a high degree of filtering would be most beneficial. If dual roles of contaminant removal and stream shade were required then a planting pattern that had grassy plants on the outer margins of the riparian planting zone and taller vegetation closer to the stream would provide these two functions.

One of the other considerations deals with the issue of production crops in the riparian zone. If a key requirement is to gain production as well as other co-benefits of riparian re-vegetation then selection of plant species for nut or timber production or for livestock fodder will be a primary consideration. It is beyond the scope of this report to detail all possible alternatives here but information can be found through MAF or through the local Tree Crops Association. For this report we focus on the primary aim of improving indigenous biodiversity with the intention of utilising native plant species known to be successful in the local conditions. This focus is because native plants provide benefits to both terestrial biodiversity and to stream health and because, in contrast to exotic production plants, there is less information and experience on appropriate native plantings, though the latter is rapidly improving.

Planting recommendations need to consider pioneer plants that can become readily established in the open grassland conditions that exist at most sites, as well as mid- and late-succession species. The latter may be able to be planted under existing willow and poplar trees which has proven to be a highly successful method to transition traditional streamside planting to natives (C. Meurk pers. comm.).

It is possible to obtain some information from existing electronic databases to predict the potential natural vegetation cover that is likely to occur at a site. LENZ (ref) has some ability to do this based on data from surviving remnants of natural ecosystems. *Planterguide* is an electronic decision support tool for indigenous planting in New Zealand developed by Landcare Research and accessible via the internet at http://www.bush.org.nz/planterguide/. Planterguide is a procedure for choosing appropriate indigenous plants for landscaping, habitat and biodiversity restoration, revegetation for erosion control, and quarry and mine rehabilitation. Plant species recommendations for riparian habitats are nested within ecological regions. Details are also provided about the particular tolerances of individual species to various environmental factors by clicking on the species name.

This is a very accessible and and useful source of general information on native plant species suitable for planting in riparian areas (Table 6). Riparian areas though, contain many micro-habitats each with different combinations of soil fertility, moisture, and exposure to flooding. This heterogeneity is not explicitly dealt with in Planterguide but is addressed in the riparian microhabitat planting recommendations below (after Meurk pers. comm and Quinn et al 2000).

Eight main plant micro-habitats were identified in surveys of streams of stream riparian areas in Canterbury and the Waikato (Quinn 1999; Quinn et al 2000) and these micro-habitats are also similar to those found in the Motueka River catchment. Recommendations for native riparian plant species that are favoured by the conditions in these microhabitats are given in Table 7. Most of these microhabitats will support both pioneer, herbaceous types of vegetation and mature woody vegetation at different stages of development.

Table 6 PlanterGuide recommendations for Canterbury Plains/Motueka catchment riparian areas

Latin Name	**Common Name/s**
Blechnum minus	swamp kiokio
Blechnum novaezelandiae	Kiokio
Polystichum vestitum	prickly shield fern; puniu
Carex flagellifera	Glen Murray tussock
Carex geminata	cutty grass; rautahi
Cyperus ustulatus	giant umbrella sedge; toetoe upokotangata; coastal cutty grass
Juncus gregiflorus	leafless rush
Juncus planifolius	flat-leaved rush; grass-leaved rush
Phormium tenax	New Zealand flax; harakeke; flax
Schoenus pauciflorus	bog sedge; bog rush
Hebe salicifolia	Koromiko
Olearia virgata	twiggy shrub daisy
Cordyline australis	cabbage tree; ti kouka; ti
Coprosma repens	Taupata
Eleocharis acuta	spike sedge
Shoenoplectus validus	lake clubrush; kapungawha
Carex secta	pukio; niggerhead
Coprosma propinqua	Mikimiki

Carex virgata	pukio; niggerhead
Carex maorica	sedge, purei
Cortaderia richardii	Toetoe
Rorippa palustris	marsh yellow cress

Table 7 Recommendation for a selection of native plants suitable for planting in riparian microhabitats in Canterbury and also in Motueka River catchment. See Fig. 7 for position of microhabitats in the riparian sequence. N.B. those species indicated as requiring shelter initially may establish successfully under willow or other exotic pioneer species. This does not include instream aquatic species.

Microhabitat type	Canterbury native riparian plant species recommendations
1. Water margins (base flow level – continuously flooded)	*Carex secta, Typha orientalis, Schoenoplectus tabermontanei, Eleocharis acuta.* N.B. *Typha* may not be desirable if channel blocking is of concern.
2. Channels/banks (flooded during freshes – ca. 3–10 times per year)	*Phormium tenax, Carex secta, Carex virgata, Carex geminata, Cortaderia richardii, Polystichum vestitum, Hebe salicifolia, Coprosma propinqua, Blechnum novae-zelandiae* (including *B. minus*)
3. Levees (flooded in extreme events – every 1–3 years	*Sophora microphylla, Carpodetus serratus* (with shelter), *Cordyline australis, Pittosporum tenuifolium, Pseudopanax crassifolius, Hoheria angustifolia, Plagianthus regius, Melicytus ramiflorus* (with shelter), *Aristotelia serrata* (with shelter), *Coprosma robusta, Myrsine australis* (with shelter), *Lophomyrtus obcordata, Prumnopitys taxifolia, Podocarpus totara, Cyathea dealbata* (with shelter), *Dicksonia squarrosa* (with shelter), *Astelia fragrans* (with shelter).
4a. Wetlands & backswamps on peats (flooded for >6 months per year; permanently saturated or water table never lower than 60 cm)	**Pioneer** *Typha orientalis, Phormium tenax, Carex secta, Carex virgata, Carex geminata, Cortaderia richardii*, tall *Juncus* spp. **nursery** *Cordyline australis, Leptospermum scoparium* (suffers badly in lowland Canterbury from m~nuka blight), *Coprosma propinqua, Myrsine divaricata.* **swamp forest** *Dacrycarpus dacrydioides, Caprosma robusta, Pittosporum tenuifolium, Griselinia littoralis, Lophomyrtus obcordata, Gahnia xanthocarpa, Blechnumnovae-zelandiae, Asplenium bulbiferum.*
4b. Wetlands & backswamps on gleyed mineral soil/alluvium (flooded for >6 months per year; permanently saturated or water table never lower than 60 cm)	**pioneer & nursery** – as above in 4a **swamp forest** *Dacrycarpus dacrydioides, Elaeocarpus hookerianus, Prumnopitys taxifolia, Griselinia littoralis, Pseudowintera colorata, Lophomyrtus obcordata, Pennantia corymbosa, Cyathea dealbata, Dicksonia squarroa, Dicksonia fibrosa, Gahnia xanthocarpa, Astelia grandis, Blechnum novae-zelandiae, Asplenium bulbiferum.*
5a. Footslope of terrace scarp or hill (flooded in extreme events –	**pioneer & nursery** *Phormium tenax, Cortaderia richardii, Cordyline australis, Kunzea*

Microhabitat type	Canterbury native riparian plant species recommendations
every 1–3 years, soils brown to gleyed coluvium – permanently moist & fertile)	*ericoides, Pittosporum tenuifolium, Sophora microphylla, Coprosma robusta, Hoheria angustifolia, Plagianthus regius.* **mature forest** *Podocarpus totara, Prumnopitys taxifolia, Dacrycarpus dacrydioides, Elaeocarpus dentatus, Pseudopanax arboreus, Pseudopanax crassifolius, Pittosporum eugenioides, Lophomyrtus obcordata, Melicytus ramiflorus, Carpodetus serratus, Myrsine australis, Cyathea dealbata, Dicksonia squarrosa, Astelia fragrans.*
5b. Mid to upper slope of terrace scarp or hill (pallic-like soils)	**pioneer & nursery** – as above in 5a excluding *Phormium tenax* and *Cortaderia richardii* **mature forest** *Podocarpus totara, Prumnopitys taxifolia, Sophora microphylla, Pittosporum eugenioides, Griselinia littoralis, Hoheria angustifolia, Pseudopanax crassifolius.*
6. Lower tidal riparian salt marsh (flooded every tide)	*Selliera radicans, Sarcocomia quinqueflora, Schoenoplectus pungens, Juncus maritimus, Leptocarpus similes, Carex litorosa, Bolboschoenus caldwellii, Schoenoplectus tabermontanei* (the last two on brackish riverine banks).
7. Upper tidal riparian salt marsh (flooded only on spring tides)	*Phormium tenax, Cortaderia richardii, Carex virgata, Cyperus ustulatus, Plagianthus divaricatus, Muehlenbeckia complexa, Coprosma propinqua, Isolepis nodosa.*
8. Stopbanks & levees (seldom if ever flooded)	Same as for 7.

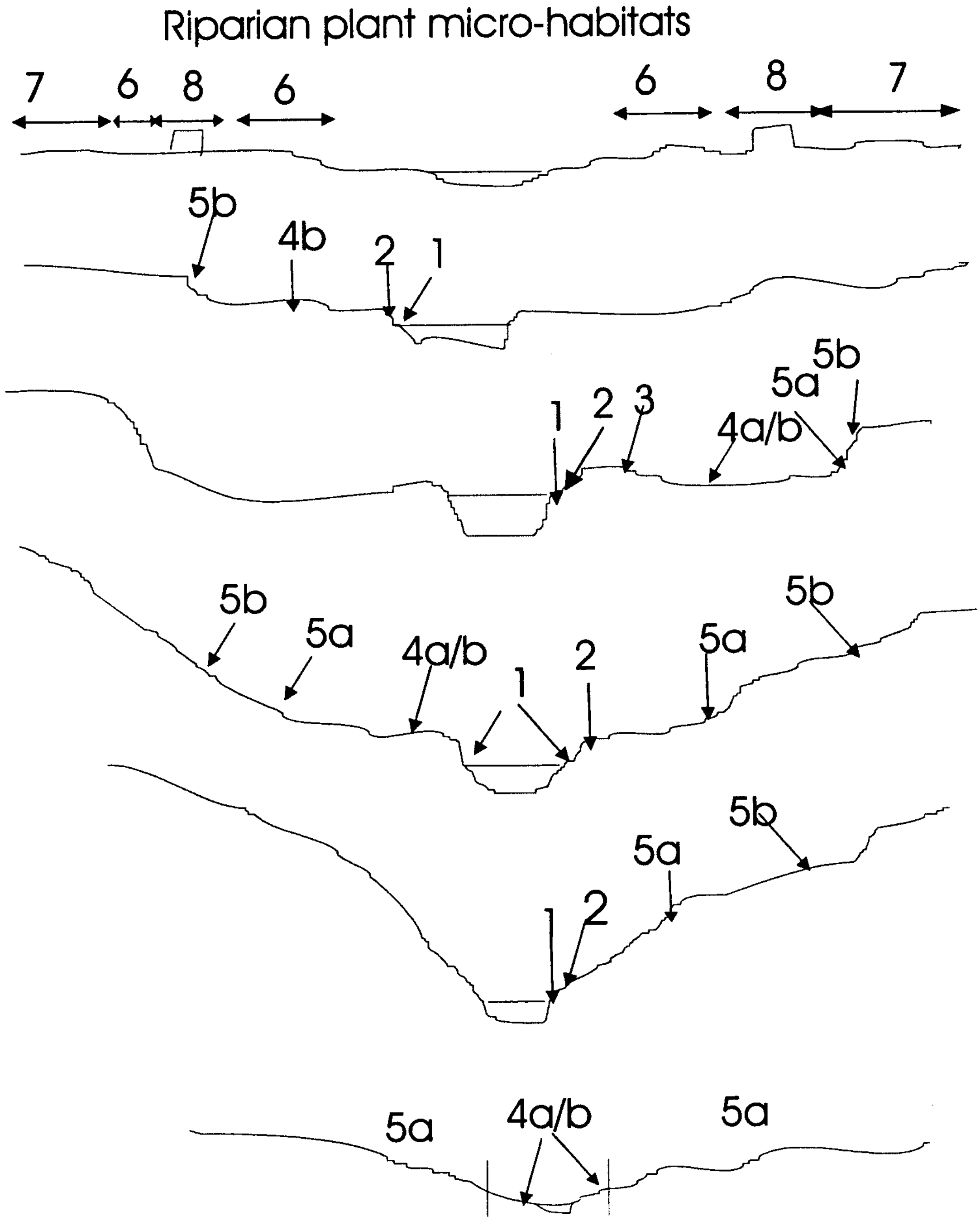

Figure 9 Representative stream/riparian cross-sections showing the location of the riparian plant micro-habitats (numbered 1 to 8) for which planting recommendations have been made (after Quinn et al. 2000). 1 = water margins; 2 = channel/banks; 3 = bankside levees; 4a = wetlands and backswamps on peats; 4b = wetlands and backswamps on gleyed mineral soils; 5a = footslope of terrace scarp or hill; 5b = midslope or crest of terrace scarp or hill; 6 = lower tidal riparian salt marsh; 7 = upper tidal riparian salt marsh; 8 = stopbanks and levees.

4. Application of riparian management classification in river and catchment management

The preceding sections of this report have outlined the development of approaches to a riparian management classification for streams in the Motueka catchment. How this information is used to assist resource managers in managing their catchments is highly dependent on the goals required of any intervention and the specific issue that intervention is trying to address.

For much of the Motueka catchment, particularly the areas to the west and south, there will be little opportunity for direct management intervention as these areas are in conservation estate and have a cover of native vegetation anyway. In addition, a large part of the catchment is under exotic forestry and riparian management usually only becomes an issue either at the time of new plantings on former scrub or pastoral land (of which there is little) or at the time of harvesting. For most of the forest rotation many of the riparian functions mentioned in this report are performed well by these exotic forests.

Areas that would gain some benefit from riparian management interventions are those under some form of pastoral farming and perhaps those currently under horticulture. Many of these areas are in the flood plains of the main rivers and their tributary streams. Many are on Moutere Gravel terrain in catchments such as the Dove, Orinocco, and Stanley Brook.

A framework, such as proposed in Fig. 10 (after Quinn et al 2000) provides one way in which the riparian management classification methods developed in this report can be used to assist in river and catchment management.

Once the specific goals are established for a river at the catchment and/or segment scale (step 1), predictions of current and potential RMC classes (RMC-C, RMC-P) can be made using the discriminant function models in Appendix 7.4. These classes indicate the activity of riparian functions currently and the potential functions that currently contribute to the river management goals and /or could be enhanced by riparian management (steps 2&3). Because of the need for field data for reasonably reliable predictions of RMC-C classes, i.e. to get 80% prediction, this step will involve surveys of a representative sample of sites and extrapolation to similar sites. If a lower level of prediction is required, such as a quick first cut, then just the GIS variables alone will give about 60% correct prediction. The various RMC classifications (RMC-C, RMC-P, and RMC-K) provide an improved basis for prioritising areas for riparian management to meet the goals outlined (step 4). This then feeds into a riparian management strategy, which in turn recognises other goals, pressures and resources (step 5), and then provides the context for the development of reach or farm-scale riparian management plans (step 6). Finally, the planting recommendations feed into this step by providing the detail needed to improve the success of any revegetation efforts at the site.

Riparian Management Classification	**River management**
	1. Identify specific goals for catchment and river segments
Evaluate current RMC classes from field survey and map information using discriminant models and infer riparian function ratings (Fig. 2) or make direct assessments	2. Identify how riparian functions contribute to goals currently
Evaluate potential RMC classes from field survey and map information using discriminant models and infer function ratings (Fig. 3) or make direct assessments	3. Evaluate potential riparian function ratings with best practicable riparian management
	4. Identify priority river segments for riparian management where riparian functions that contribute to goals are predicted to increase most in activity
Other relevant information e.g. Statutory obligations, M~ori perspectives, local interest/politics, terrestrial biodiversity goals, landscape ecology issues and available resources	5. Develop riparian management strategies recognising variations in priorities and riparian functions within the catchment or region
Farmer/landowners goals for their properties	6. Reach and farm scale riparian management plans

Riparian microhabitat-based native
species planting recommendations

Figure 10 Flow chart showing how Riparian Management Classification (RMC) and microhabitat-based native plant recommendations can contribute to river management planning (after Quinn et al. 2001b).

5. Summary and Conclusions

Riparian management is a potentially powerful tool for mitigating the damage that various land use activities can have, particularly on stream environments (e.g. Collier et al. 1995; Lowrance 1998). The riparian zone is the one place in a catchment that a management intervention can have a disproportionate benefit relative to the size of the area that gets treated. Often small interventions such as riparian fencing and excluding stock from streams can have a significant improvement on water quality.

Decisions on riparian management need to start with a clear understanding of how important this area is to stream health and the water quality of a catchment. From this, an understanding of the goals that an intervention will make in the riparian zone needs to be considered in some multi-objective manner. The riparian management classification provides such a framework for linking the management goals to the spatial variations in riparian buffering functions within the catchment and a way in which priorities can be set relative to the resources that might be available.

Using the field and GIS information the RMC is not a tool for defining a specific reach in need of intervention rather its' focus is more on the regional level. However, while the RMC is a fairly crude assessment tool with a limited number of classes, it can, in conjunction with local and expert knowledge, provide a means to prioritise areas within a catchment where the best gains can be made from any management intervention.

6. References

Abernethy, B.; Rutherfurd, I.D. 1999. Guidelines for stabilising streambanks with riparian vegetation. Cooperative Research Centre for Catchment Hydrology, Parkville, Victoria.

Basher, L. and others. (in press) Integrated catchment management for the Motueka River catchment. Technical report.

Boothroyd, I. K.G.; Langer, E.R. 1999. Forest harvesting and riparian management: A review. NIWA, Wellington.

Burckhardt, J.C.; Todd, B.L. 1998. Riparian forest effect on lateral stream channel migration in the glacial till plains. *Journal of the American Water Resources Association* 34: 179-184.

Collier, K.J.; Cooper, A.B.; Davies-Colley, R.J.; Rutherford, J.C.; Smith, C.M.; Williamson, R.B. 1995. Managing riparian zones: a contribution to protecting New Zealand's rivers and streams. Vol. 1: Concepts. Department of Conservation, Wellington, NZ.

Collier, K.J.; Halliday, J.N. 2000. Macroinvertebrate-wood associations during decay of a plantation pine in New Zealand pumice-bed streams: stable habitat or trophic subsidy? *Journal of the North American Benthological Society 19*:94-111.

Coon, W.F. 1998. Estimation of roughness coefficients for natural stream channels with vegetated banks. U.S. Geological Water Supply Paper 2441.

Cooper, A.B. 1990. Nitrate depletion in the riparian zone and stream channel of a small headwater catchment. *Hydrobiologia 202*: 13-26.

Davies-Colley, R.J.; Quinn, J.M. 1998. Stream lighting in five regions of North Island, New Zealand: control by channel size and riparian vegetation. *New Zealand Journal of Marine and Freshwater Research 32:* 591-605.

Gregory, S.V.; Swanson, F.J.;McKee, W.A.; Cummins, K.W. 1991. An ecosystem perspective on riparian zones. *Bioscience 41:* 540-551.

Howard-Williams, C.; Pickmere, S. 1999. Nutrient and vegetation changes in a retired pasture stream: recent monitoring in the context of a long-term dataset. *Science for conservation* 114. Department of Conservation, Wellington.

Knowles, R. 1982. Denitrification. *Microbial Reviews 46*: 43-70.

Leathwick, J. R., Wilson, G., Rutledge, D., Wardle, P., Morgan, F., Johnston, K., McLeod, M., Kirkpatrick, R. 2003. (in press). *Land Environments of New Zealand*. Bateman, Auckland. 183 pp.

Lyons, J.; Trimble, S.W.; Paine, L.K. 2000. Grass versus trees: managing riparian areas to benefit streams of central North America. *Journal of the American Water Resources Association 36:* 919-930.

Marden, M.; Phillips,C.J.; 2002. How do native riparian plants grow? Conservation Quorum, Issue 26, 14-15.

McKergow, L.A.; Weaver, D.M.; Prosser, I.P.; Grayson, R.B.; Reed, A.E.G. 2003. Before and after riparian management: sediment and nutrient exports from a small agricultural catchment, Western Australia. *Journal of Hydrology 270*: 253-272.

Mitchell, C.P.; Eldon, G.A. 1991. How to locate and protect whitebait spawning grounds. Freshwater Fisheries Centre Publication for the Department of Conservation.

Mitchell, C.P.; Penlington, B.P. 1982. spawning of *Galaxias fasciatus* Gray (Salmoniformes: Galaxiidae). *New Zealand Journal of Marine and Freshwater Research 16*: 131-133.

MFE 2000. Managing waterways on farms: A guide to sustainable water and riparian management in rural New Zealand. Ministry for the Environment, Wellington.

Mosley, M.P. 1989. Perceptions of New Zealand river scenery. *New Zealand Geographer 45*: 2-13

Nguyen, M.L.; Sheath, G.W.; Smith, C.M.; Cooper, A.B. 1998. Impact of cattle treading on hill land. 2. Soil physical properties and contaminant runoff. *New Zealand Journal of Agricultural Research 42*: 279-290.

Parkyn, S.; Davies-Colley, R.; Collier, K.J.; Reeves, P.; Cooper, A.B. 2001. Issues for riparian management in the Auckland region: Analysis of trade-offs between benefits and impacts. NIWA Client Report ARC01279. NIWA, Hamilton.

Phillips, C.J. 2001. Soil stabilising characteristics of native riparian vegetation in New Zealand. Paper presented at NZARM Annual Conference, Hamilton, 19-21 September 2001.

Phillips, C.J.; Marden, M.; Rowan,D.; Ekanayake, J.C. 2001. Stabilising characteristics of native riparian vegetation in New Zealand. In: Proceedings of 3rd Australian Stream Management Conference, Brisbane August 2001, 507—512.

Prosser, I.; Bunn, S.; Mosisch, T.; Ogden, R.; Karssies, L. 1999. The delivery of sediment and nutrients to streams. *In:* Price, P; Lovett, S., (*eds.*) Riparian Land Management Technical Guidelines. 1. *Principles of Sound Management.* Land and Water Resources Research Development Corporation (LWRRDC) Canberra. Pp. 37-60.

Quinn, J.M. 1999. Towards a riparian zone classification for the Piako and Waihou River catchments. Environment Waikato Technical Report TR99/16.

Quinn, J.M.; Burrell, G.P.; Parkyn, S.M. 2000. Influence of leaf toughness and nitrogen content on in-stream processing and nutrient uptake in a Waikato, New Zealand, pasture stream and streamside channels. *New Zealand Journal of Marine and Freshwater Research 34*: 255-274.

Quinn, J. M.; Brown, P. M.; Boyce, W.; Mackay, S.; Taylor, A.; Fenton, T. 2001a. Riparian zone classification for management of stream water quality and ecosystem health. *Journal of the American Water Resources Association 37*: 1509-1515.

Quinn, J. M.; Suren, A. M.; Meurk, C. D. 2001b: Riparian management classification for Canterbury streams. NIWA Client Report MFE01229/1, 50 p, Hamilton.

Quinn, J.M.; Stroud, M.J.; Burrell, G.P. 1997. Shade effects on stream periphyton and invertebrates: an experiment in streamside channels. *New Zealand Journal of Marine and Freshwater Research 31*: 665-683.

Rutherford, J.C.; Blackett, S.; Blackett, C.; Saito, L.; Davies-Colley, R.J. 1997. Predicting the effects of shade on water temperature in small streams. *New Zealand Journal of Marine and Freshwater Research 31*: 707-721.

Rutherford, J.C.; Davies-Colley, R.J.; Quinn, J.M.; Stroud, M.J. Cooper, A.B. 1999. Stream shade: towards a restoration strategy. Department of Conservation, Wellington, NZ.

Rutherfurd, I.; Abernethy, B.; Prosser, I. 1999. Stream erosion. *In:* Lovett, S.; Price, P., (*eds.*) Riparian land management technique guidelines. 1. *Principles of Sound Management.* Land and Water Resources Research Development Corporation (LWRRDC) Canberra. Pp. 60-78.

Simon, A.; Collison, A.J.C. in press. Quantifying the mechanical and hydrological effects of riparian vegetation on streambank stability. *Earth Surface Processes and Landforms.*

Smith, C.M. 1992. Riparian pasture retirement effects on sediment, phosphorous, and nitrogen in channelised surface run-off from pastures. *New Zealand Journal of Marine and Freshwater Research 23:* 139-146.

Snelder,T.; Weatherhead, M.; O'Brien, R.; Shankar, U.; Biggs, B.J.; Mosley, P. 1999. Further development and application of a GIS based river environmental classification system. NIWA Client Report CHC99/01, Christchurch.

Thorne, C.R. 1990. Effects of vegetation on riverbank erosion and stability. *In:* Thornes, J.B., (*ed*) Vegetation and erosion. Wiley, Chicester.

Watson, A.; Phillips, C.; Marden, M. 1999. Root strength, growth and rates of decay: root reinforcement changes of two tree species and their contribution to hillslope stability. *Plant and Soil 217*: 39-47.

Webster, J.R.; Benfield, E.F.; Ehrman, T.P.; Schaffer, M.A.; Tank, J.L.; Hutchens, J.J.; D'Angelo, D.J. 1999. What happens to allocthonous material that falls into streams? A synthesis of new and published information from Coweeta. *Freshwater Biology 41*: 687-705.

Webster, J.R.; Covich, A.P.; Tank, J.L.; Crockett, T.V. 1994. Retention of coarse organic particles in streams in the Southern Appalachian mountains. *Journal of the North American Benthological Society 13:* 140-150.

Wilcock, R.J.; Rodda, H.J.E.; Scarsbrook, M.R.; Cooper, A.B.; Stroud, M.J.; Nagels, J.W.; Thorrold, B.S.; O'Connor, M.B.; Singleton, P.L. 1998. The influence of dairying on the freshwater environment (the Toenepi study). Volume 2. Technical Report. NIWA, Hamilton.

Willems, H.P.L.; Rotelli, M.D.; Berry, D.F.; Smith, E.P.; Reneau, R.B.; Mostaghimi, S. 1997. Nitrate removal in riparian wetland soils: effects of flow rate, temperature, nitrate concentration and soil depth. *Water Research 31*: 841-849.