Forest harvesting and riparian management guidelines: a review

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Abstract

Boothroyd, I. K. G. & Langer, E. R. 1999: Forest harvesting and riparian management guidelines: a review. ***NIWA Technical Report 56.*** **58 p.**

Riparian zones are often advocated as a suitable protection or environmental management tool for reducing impacts of land use activities on aquatic resources, and there is a long history of riparian zone use in New Zealand. However, there has been little research on the effectiveness of these zones in managed production forests with the result that there is little information on which to base decisions for riparian zone management.

As part of a larger research programme to develop decision-making tools which can be used to develop riparian zone management plans in production forests, a literature review was undertaken and a database of reference material established. This review of literature on the use and benefits of riparian zones and overseas and local approaches vs riparian zone management to minimise the impacts of forest harvesting on freshwater environments results from a search of 10 major international databases.

This review documents the current state of knowledge of the effects of riparian management zones on freshwaters, with particular focus on water quality management (nutrients, sediments, temperature), instream biodiversity, and coarse woody debris. It summarises international and current regulatory and non-regulatory approaches in New Zealand. Guidelines and regulations from Canada, USA, South Africa, Australia, and Great Britain are summarised.

Although riparian management guidelines developed overseas have limited direct application within New Zealand, several themes were common amongst them all: waterbody classification (size and/or use), riparian width prescriptions, and additional narrative guidelines. In New Zealand, forest industry guidelines generally comprise narrative guidelines for riparian management zones, while most regulatory authorities (regional councils) have favoured non-regulatory approaches (education, promotion, consultation) for managing riparian zones and forestry effects on waterbodies. The use of these mechanisms acknowledges the need for further research and information, as well as the need to be site-specific in determining riparian management decision support requirements for forest harvesting.

1. Introduction

New Zealand is rapidly becoming a major forestry nation with over 7.9 million hectares (29%) of the land area covered in forest (MfE 1997). Of this, 6.4 million hectares are indigenous forests (most of them protected) and 1.5 million hectares are planted forests, the latter dominated by radiata pine (91% of total planted forests) but also with Douglas fir and eucalyptus species. In total 17.3 million cubic metres of wood was harvested from New Zealand's production forests in 1996 and by 2010 it is anticipated that wood supply from New Zealand production forests may be up by 73% of current levels (MfE 1997). As well as achieving economic outputs, the forestry industry needs to operate within current resource legislation that is dependent on maintaining a high quality environment, particularly the essential soil and water resources.

The recent State of New Zealand's Environment report (MfE 1997) considered the pressures that forestry can exert on the environment. Water yield and water quality are generally foremost in discussion on the effects of forestry, and tree felling and road construction are held as the two main activities that can degrade waterbodies through additions of sediment and nutrients. The effects of forestry on freshwater ecosystems can be short-term (sediment additions), medium-term (changes to light and temperature regimes), or long term (streambed substrate changes, instream woody debris changes) (Campbell & Doeg 1989).

Riparian zones or buffer zones are often advocated as a suitable protection or environmental management tool for reducing impacts of forestry (and other land use activities) on aquatic resources. There has been little research into the effectiveness of riparian zones in managed forests in New Zealand, although there has been a long history of using riparian areas for stream protection (Gilliam *et al.* 1992). When the state forests were planted several decades ago the riparian areas of many streams were left unplanted. The reasons for this are unclear today but it may have been due to difficulty of terrain as well as an early recognition of the benefits of excluding riparian areas from production. The Waikato Valley Authority retained the riparian areas along the margins of many of the rivers and streams entering Lake Taupo recognising the potential impacts of land use activities within the basin. Gilliam *et al.* (1992) believed this to be the among the first examples of the use of riparian zones for water quality protection.

The introduction of the Resource Management Act (1991) added emphasis to the need for suitable tools and means of stream protection, as well as the need for well researched quantitative information on riparian zones, their locations, and their scale. As a result the Ministry for Research, Science and Technology has funded NIWA, Forest Research, and LIRO to develop decision support tools that can be used to plan activities and management in riparian areas to minimise impacts on high value aquatic ecosystems. This review forms a part of the research programme with the aim of summarising information on the use and benefits of riparian zones and international and national riparian management guidelines in a form that can be used by the forestry sector, government authorities, conservation groups, non-government organisations, and science and technology researchers.

2. Scope of the review

Purpose

The literature on the effects of forestry and riparian zones on freshwater ecosystems is vast and it is beyond the scope of this document to cover all the aspects involved. Numerous reviews have been undertaken of the general effects of forestry on streams (Bell *et al.* 1974, Campbell & Doeg 1989, Binkley & Brown 1993) and of the benefits of riparian zones (Howard-Williams 1991, Gilliam *et al.* 1992, Murphy 1992a, Quinn *et al.* 1993).

Similarly, management activities within production forests are many (planting, silviculture, pest and fire control, felling, processing, extraction) and it is not within the realms of this exercise to review all of the information for each phase of the life cycle of a production forest. Instead this review will focus on the use of riparian management during harvesting (including felling and extraction) and roading as these have been identified as two activities with a high potential to impact on freshwater environments. Additional aspects of forestry (economic cost/benefits, comparisons with other land uses, soil and land issues) are not covered by this review. A comprehensive ecological, economic, and social assessment of forest ecosystem management was provided by FERAT (1993), and MfE (1998) produced a directory of available information on better land management practices.

This document will therefore focus on the potential use and benefits of riparian zones to minimise the impacts of forestry harvesting on freshwaters. The main emphasis will be on small streams and moderate sized rivers, largely because production forests in New Zealand are generally located in the upland regions where these stream and rivers systems occur, and not on the low-lying floodplains where land-use is dominated by pastoral, horticultural, and urban activities. Many of the principles of riparian zone management are equally relevant for lakes, wetlands, and coastal areas. While the review may make reference to additional elements of riparian zone management (e.g., wildlife or biodiversity) the main emphasis will be on management for water quality, aquatic biota, and aquatic habitat protection.

Method

A literature search of identified computer databases was undertaken. TREECD was first used to identify key literature, followed by searches of the LIRO Ltd. library database and Forest Research library database (Horizon). A smaller and more inclusive set of key words was then used to search the following databases.

Database	Contents	Dates searched
TREECD	Forestry, Agroforestry, and Forest Products Abstracts etc.	1939–October 1997
BIOSIS	Biological Abstracts	1991–September 1997
Current Contents	Agriculture, Biology, Environment; Engineering and Applied Science; Physical and Chemical Sciences; Social and Behavioural Sciences etc.	July 1995–March 1998
GEOREF	American Geological Institute's Geoscience Database	1785–February 1998
Environment CD	OCLC Environment Library	1960–1996
Water Resources Abstracts	Selected water resources abstracts	1967–April 1996
Dialog	Biosis Previews	1969–February 1998
Dialog	Agricola	1970–January 1998
Dialog	Life Sciences Collection	1982–December 1997
Dialog	Geobase	1980–January 1998
Dialog	Scisearch	1974–February 1998
First Search	Environmental Sciences and Pollution Management	October 1994–June 1998
Spectrum	New Zealand and Technology STIX database (former DSIR & CRI publications)	about 1920s–1993
Horizon	National Forest Library database	–December 1997

Additional reference material was obtained from the NIWA library, colleagues' personal literature databases, and key reference material. Much of the material viewed relates to overseas forest practices, in particular the USA and Canada, but almost all of the literature cited is available within New Zealand or from the world wide web (Internet). Several forestry companies were approached to obtain information on riparian management guidelines they advocate and use, and existing and proposed policies developed by regional councils were examined for common themes and approaches.

3. What is a Riparian Management Zone?

Riparian zones and their management often mean many things to many people and there are often conflicting expectations about their use and benefits. The Shorter Oxford Dictionary defines riparian as 'of, pertaining to, situated on, or inhabiting the banks of a river; riverine', but this has been broadened in the literature to include the banks of other freshwater bodies such as lakes, reservoirs and wetlands (Murphy 1992a). Similarly, different terms and interpretations are used in the scientific and forestry management literature — buffers, zones, strips, streamside management zones, exclusion zones, etc. This section aims to better define the terms for the purpose of this review.

Within a catchment the stream or river can be divided into three zones: channel, flood plain and hillslope or upslope (Collier *et al.* 1995a, Figure 1). In Idaho, USA, Belt *et al.* (1992) considered similar zones as aquatic (stream and streambed normally under water), riparian (between aquatic and upland zone), and upland areas (vegetation and soils different from riparian area). Thus a riparian zone is essentially a strip of land bordering a stream, lake, or wetland (Williams & Brickell 1983), or a strip of land which separates upland soils (e.g., forested and agricultural land) from streams, rivers, lakes, and wetlands (Gilliam *et al.* 1992, Large & Petts 1996). In New Zealand, Quinn *et al.* (1993) followed the functional definition of riparian zones as three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems (from Gregory *et al.* 1991). In most parts of the world this intimate relationship between land and water has been interrupted, degraded, or, often, destroyed.

However, while the riparian zone exists along the margins of a watercourse, the entire zone may not be essential for the prescribed management purposes. As a result the terms "buffer zones" or "buffer strips" often occur in the literature. Buffer strips can be defined as strips of vegetation left bedside a stream, lake or wetland and also may be referred to as filter strips or protection strips. The term buffer is often loosely applied to a variety of administratively designated protection zones e.g., Stream Protection Zone (SPZ), Streamside Management Zone (SMZ), or Riparian Management Zone (RMZ) (Belt *et al.* 1992). Swift (1986) identified a buffer zone as "any area where management is modified to isolate an activity from some sensitive area. .....provides space between a soil disturbance (e.g., road, logging) and other site (e.g., stream) needing protection". A buffer zone also may be designed to have a specific management function. The terms buffer and riparian zone have generally been used interchangeably in New Zealand, and generally refer to a vegetated or protected (e.g., fenced off) area alongside the watercourse.

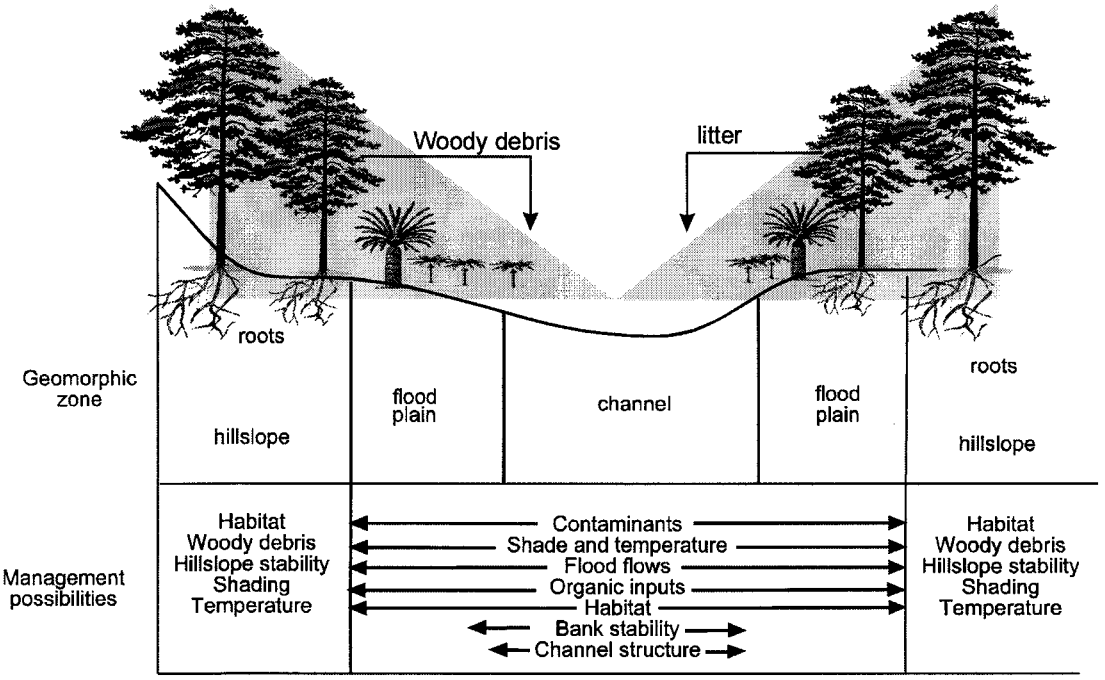

***Figure 1*: Conceptual diagram of a stream and its riparian zones with management influences (from Collier *et al.* 1995a).**

For the purposes of this review the following definition will apply:

Riparian zone, area, or strip: a strip of land which separates an upland or hillslope area from streams, lakes, and wetlands, and where activity is modified to prevent adverse effects on the water quality, biota and habitat within the watercourse.

Riparian zones are themselves particularly dynamic areas of the landscape with their own microclimate influenced by land practices and disturbances upslope, such as fire and windthrow, and by the stream channel and disturbances, e.g., floods. As well as the characteristics and functions outlined below, riparian zones are commonly environments with heterogeneous vegetation and soil and diffuse but non-uniform upslope source areas (Hairsine 1996), and are an important habitat for terrestrial and semi-aquatic organisms (birds, insects, amphibians, plants). Numerous features define riparian zones; vegetation type, root strength and continuity contribute to the stability and longevity of the riparian areas and influence the flora and fauna within the zones. Many of these aspects are also important in defining the use of riparian zones for environmental management.

4. Why riparian zone management?

General

The benefits of riparian zone management have long been recognised in New Zealand and it is generally agreed that such zones can serve a number of functions (Gilliam *et al.* 1992). Large & Petts (1996) considered that the case for including riparian zones in river management rested on four key functions:

- water quality management
- instream habitat enhancement and management
- biodiversity and nature conservation
- recreation and amenity

In a summary of views of industry, regional councils, and riparian zone researchers Gilliam *et al.* (1992) outlined the perceived values and disadvantages of riparian management in New Zealand (Table 1).

Several questions arise: "Which streams need protection?", "What size streams need to be protected?", "How wide should a riparian zone be?". Perhaps the most important question is "What is the expected purpose of the riparian zone and what are the expectations for the waterway?". It has generally been agreed that there are no specific answers to these questions and the solutions lie in an appraisal of the watercourse in question, the stream and site conditions, and management objectives (Brosofske *et al.* 1997). Nevertheless, Gilliam *et al.* (1992) concluded that reasonable guidelines must be developed, and so it is imperative that more research be undertaken. The focus of this report is on benefits of riparian zone management for freshwaters and these are outlined in the following sections.

***Table 1*: Advantages and disadvantages of riparian zones in New Zealand (from Gilliam *et al.* 1992)**

Advantages	Disadvantages
Protection of water quality	Increased costs of logging if riparian zones treated as exclusion zones
Aesthetic beauty of native vegetation adjacent to streams	Loss of productive land
Better habitat for fish and wildlife: greater biodiversity	Growth of pests and weeds
Better food sources (organic inputs)	
Delineation of no-go area for heavy machinery, no tree felling	Who is responsible for maintenance of riparian Zone, e.g., tree regeneration
Better public image for forestry industry	Problems associated with spraying herbicides/burning

Water quality management — nutrients and sediments

In temperate conditions, at least, it has been demonstrated that riparian zones can significantly reduce the concentrations of sediment and nutrients in surface water and groundwater entering streams. Much of this research has been based on agricultural systems with a considerable amount of research being undertaken in New Zealand (Howard-Williams *et al.* 1986, Cooke & Cooper 1988, Smith 1989, Schipper *et al.* 1991, 1993). In grassed riparian zones sediment-bound phosphorus and nitrogen inputs to streams can be reduced by up to 80–87%, and groundwater nitrate inputs by more than 90% from pasture (Smith *et al.* 1989, Cooper 1990). Less research has been undertaken on nutrient removal by forested riparian zones in New Zealand, but it is generally believed that nitrate removal within riparian zones occurs less from plant uptake and more from microbial denitrification (Schipper *et al.* 1989, 1991, Gilliam *et al.* 1992, Quinn *et al.* 1993). Riparian zone conditions are conducive to the development of the appropriate environmental conditions for the denitrification process, but it appears that a suitable residence time within the riparian zone is necessary (Cooper 1990, Quinn *et al.* 1993).

Native forests are also known to improve diffuse-source pollution. Up to 99% nitrate removal has been recorded from small streams in the Sierra Nevadas from native riparian forests and wetlands (Rhodes *et al.* 1985), and in New Zealand O'Loughlin (1980) recorded up to 50% less nutrient input to streams from logging activities in evergreen mixed forests where a riparian protection strip was retained than where it was absent. However, in the same study, the retention of the riparian strip did not prevent large quantities of sediment entering the stream (although large amounts of sediment were derived from track surface and construction residues). Gilliam *et al.* (1992) believe that nutrient additions are not a significant issue for water quality in forested streams in New Zealand, and that, with one exception, at any time during the rotation, only small amounts of nutrients enter watercourses from forests. Only where nutrient-rich treated wastewaters are sprayed in forests for treatment purposes are riparian zones likely to be effective in significantly reducing excessive nutrients reaching watercourses (Schipper *et al.* 1989, 1993). Neary & Leonard (1978), however, found that applications of fertiliser to production forests resulted in increases in nutrients in the watercourse and suggested that inputs to waterways could be reduced by using 20 m buffer strips along stream edges. Nutrient effects in freshwaters are generally well understood and can result in greater plant growth and thus changes to the habitat and biological communities. Large & Petts (1996) concluded that three primary processes are active in controlling nutrient quality in areas of semi-natural riparian vegetation along rivers:

1. retention through interception of sediment-bound nutrients, pesticides and other contaminants transported by surface runoff;
2. uptake by vegetation or microbes of soluble nutrients (and denitrification — see above);
3. absorption by organic and inorganic soil particles.

Sediment intrusion to watercourses, on the other hand, is often held as the major potential impact from forest harvest and forest road activities (Winterbourn 1986, Murphy & Milner 1996), and the benefits of riparian zones have become evident largely following forest harvesting exercises. Sediments in watercourses are usually classified into two categories: suspended sediment in the water column (typically clay and silt less than 0.1 mm diameter), and bedload sediment in the streambed (typically over 1 mm) that can move during floods (Murphy & Milner 1996). Suspended sediment influences the visual clarity of the water which affects the aesthetic values, fish feeding, and light penetration. Suspended sediment can also clog intakes, and settles and fills in pools and reservoirs. When fine sediments settle they also can fill the interstitial spaces of the stream bed and reduce the habitat for the benthic biota. Sediment intrusion into waterways has significant impacts on the stream biota and often results in lower species diversity and productivity, and can continue long after harvesting has been completed through redistribution and transport of deposited material (Minshall 1984, Campbell & Doeg 1989). The environmental effects of sediment on New Zealand streams were reviewed by Ryan (1991). The amount of sediment lost from a catchment depends on site factors such as slope, soil type, and harvesting operations, but the general consensus appears to be that the major source of increased sediments from forests comes from roading and particularly from logging road construction (Campbell & Doeg 1989, Murphy & Milner 1996). Hicks & Harmsworth (1989) found that the sediment regime of a mature New Zealand production forest changed after landing-area construction, and that the harvesting period contributed an estimated 70% of the total suspended sediment yield over a 32 year period. Hairsine (1996) found that grass filter strips were marginally more effective for sediment trapping than near-natural riparian conditions, and the sediment trapping efficiencies of both types diminished slightly with increasing water inflow.

Water temperature

Water temperature is a fundamental factor influencing both chemical and biological characteristics of streams (Binkley & Brown 1993, Quinn *et al.* 1993) and has a significant influence on life cycles, growth, reproduction, and survival of aquatic animals and plants (Sweeney 1984). Most aquatic organisms have optimal temperature functioning, and forestry practices that significantly change temperatures may alter the ecology and functioning of freshwater ecosystems. Quinn *et al.* (1994) concluded that high summer temperatures in many New Zealand streams and rivers may limit the distribution and abundance of some macroinvertebrate taxa.

Table 2 shows the changes in temperature recorded in predominantly North American studies, from a variety of streams where forestry harvesting has been undertaken. It should be noted however that stream size (width, depth, and velocity) has not been recorded but can have a substantial influence on stream temperatures. Nevertheless stream temperatures were generally higher by 2–6 °C where riparian zones have not been retained in harvested streams, whereas retention of riparian zones keeps the maximum increase to less than 2 °C (Binkley & Brown 1993). In Australia, Davies & Nelson (1994) found significant differences in stream temperatures at forested sites with less than 10 m riparian buffer widths than over 10 m riparian buffer widths, and concluded that logging with under 10 m buffers caused a 10% increase in water temperatures. In contrast stream temperatures at harvested forests with riparian buffer zones of 10–30 m and 30–50 m were not significantly different from control sites. In Alaska, forest harvest has been shown to increase the maximum summer water temperature as much as 5 °C, and monthly maximum temperature by 2.2 °C. In a study in Washington, USA, however, Brosofske *et al.* (1997) found that although harvesting affected near-stream riparian zone microclimate, there was no relationship between water temperature and buffer width (except at one site where little or no buffer existed and where stream temperature was higher than at all other sites), and concluded that water temperature was strongly affected by soil temperature in the surrounding (riparian) area. Similarly, Gilliam *et al.* (1992) do not believe stream temperature to be a major problem in New Zealand forest harvesting activities, citing a lack of instream problem identification and that streams from harvested areas enter unharvested areas fairly quickly.

Studies of streams in New Zealand have shown that wood covering the channel following harvesting can play a major role in reducing both the magnitude of daily water temperature fluctuations and temperature maxima in summer. Thus, in small streams where wood remained stable over the channel, water temperatures fluctuated by less than 2 °C during the course of a day and maximum temperatures rarely exceeded 17 °C, compared with daily fluctuations of up to 9 °C and daily maxima up to 27 °C in a stream where the wood had been washed away by a storm (Collier *et al.* 1997). These maxima are of a magnitude considered stressful to aquatic life if maintained for long periods (Quinn *et al.* 1994). We know little about the effects of fluctuating temperatures on aquatic life, though Richardson *et al.* (1994) concluded that New Zealand freshwater fish are able to thrive within a wide temperature range.

Instream biodiversity

Numerous studies have been undertaken on the effects of forestry on stream biota (Graynoth 1978, 1979, Newbold *et al.* 1980, Murphy & Hall 1981, Silsbee & Larson 1983, Davies & Nelson 1994). Riparian zones can have significant effects on production and composition of stream animal and plant communities (Quinn *et al.* 1993). The type, diversity, composition, and scale of riparian zones can influence stream energy inputs and animal feeding, habitat, stream temperatures and oxygen levels, breeding, refuges, and adult habitat.

Table 2: **Effects of forestry harvesting on stream temperature maxima. C, control; H, harvesting, Δ, change in temperature; CC, clearcut with portion of watershed indicated where known (modified from Binkley & Brown 1993)**

Location	Temperature (°C)			Measure	Treatment type	Reference
USA	C	H	Δ			
Georgia	21.1	25.0	3.9	Avg. daily hottest month	CC + riparian zone (12 m)	Hewlett & Fortson 1982
North Carolina	18.3	21.7	3.4	Avg. daily hottest month	CC, no riparian zone	Swift & Messer 1971
West Virginia	14.4	16.1	1.7	Avg. weekly for growing season	95CC, thin riparian zone	Aubertin & Patric 1974
New Hampshire	16.0	20.0	4.0	Avg. daily hottest month	100% CC, no riparian zone	Likens *et al.* 1970
Pennsylvania	19.4	20.6	1.2	Avg. daily hottest month	44% CC+riparian zone (30m)	Rishel *et al.* 1982
Pennsylvania	17.8	25.0	7.2	Avg. daily hottest month	85% CC, no riparian zone	Rishel *et al.* 1982
Oregon	14.4	15.0	0.6	Day in July	CC + riparian zone	Brown *et al.* 1971
Oregon	16.7	18.3	1.6	Day in July	CC + thin riparian zone	Brown *et al.* 1971
Oregon	22.2	24.4	2.2	Day in July	CC, no riparian zone+reveg.	Brown *et al.* 1971
Oregon	13.3	15.6	2.3	Day in July	CC, no riparian zone	Brown *et al.* 1971
Oregon	13.5	16.0	2.5	Avg. daily for hottest 3 weeks	25% CC + thin riparian zone	Harr & Fredriksen 1988
Oregon	12.0	15.0	3.0	Avg. daily for hottest 3 weeks	25% CC + thin riparian zone	Harr & Fredriksen 1988
Oregon	13.9	18.3	4.4	Day in July	CC, no riparian zone	Brown *et al.* 1971
Oregon	14.4	18.9	4.5	Day in July	CC, no riparian zone	Brown *et al.* 1971
Oregon	15.6	21.7	6.1	Avg. daily for hottest month	100% CC, non riparian zone	Levno & Rothacher 1969
Oregon	16.1	23.3	7.2	Day in July	CC, no riparian zone	Brown *et al.* 1971
Oregon	20.6	28.3	7.7	Day in July	CC, no riparian zone	Brown *et al.* 1971
Oregon	14.4	22.8	8.4	Avg. daily for hottest month	100% CC, no riparian zone	Levno & Rothacter 1969
Oregon	12.2	22.2	10.0	Avg. daily for hottest month	100% CC, no riparian zone	Brown & Krygier 1970
Alaska			5.0	Max. summer	CC, no riparian zone	Murphy & Milner 1996
Canada						
British Columbia	17.0	22.0	5.0	Day in July	66% CC, no riparian zone	Feller 1981
Australia						
Tasmania			1.0	Median - day in summer	Various	Davies & Nelson 1994
New Zealand						
Maimai			0.8	Mean	CC+5-20 m riparian zone	Rowe & Taylor 1994

As early as 1978, Fisheries and Environment Canada identified the advantages of an adequate buffer zone or green strip along each side of a stream as:
(a) shade for the stream to maintain cool water temperatures;
(b) cover for rearing salmonids;
(c) nutrient source from leaf drop aiding the production of aquatic food organisms;
(d) an important food source for rearing fish in the form of terrestrial insects;
(e) stabilising banks and adjacent soils from soil loss to the stream.

In Australia, Davies & Nelson (1994) found that all effects of logging, including decreased macroinvertebrate abundance, were dependent on riparian buffer width, with small riparian zones (10 m or less) insufficient to provide adequate protection, and larger buffers (30 m or over) more suitable. Newbold *et al.* (1980) studied the impact of logging in Californian streams, and found that reaches without riparian zones had higher densities of tolerant macroinvertebrate taxa, and lower overall diversity than control sites, but no impacts in reaches with riparian zones of 30 m and over. Murphy & Milner (1996) attributed higher periphyton (benthic algae) densities to the variable riparian zone (0 to over 100 m) widths encountered in Alaskan salmonid streams. In the UK, Ormerod *et al.* (1993) found that riparian areas of pure conifer species had significant benefits on faunal communities, even after accounting for the more dominant influence of stream acidity.

In New Zealand, Graynoth (1979) found that numbers of some native fish species decreased as a result of logging, but it was not clear whether this was a result of sediment concentration, lack of cover, stream temperature, food resources, or a combination of all of these. On the other hand, Cowie (1984) attributed the lack of impact from logging operations on macroinvertebrates in Nelson forests to riparian zones alongside the perennial streams.

Riparian vegetation has been shown to influence the aquatic biotic communities in a variety of land uses in New Zealand. Glova & Sagar (1994) found that the abundance and biomass of brown trout and diversity of macroinvertebrates was greater in streams with riparian willows, but Lester *et al.* (1994) found that macroinvertebrate densities and biomass in two Central Otago streams, were lower in willow-lined sections of the streams. They concluded that this resulted from a decrease in average substrate size and/or a lower food production as a result of stream shading. In Southland pastoral streams, Quinn *et al.* (1992) found that shading by riparian vegetation was the main factor influencing macroinvertebrates where the vegetation reduced light, and thus temperature change, as well as periphyton growth.

Organic matter in the form of carbon is essential for food webs of running water ecosystems (Hildrew 1994), and the influence of riparian zones on food resources of watercourses has been summarised by Quinn *et al.* (1993) as:
- inputs of particulate organic matter
- control of dissolved and particulate carbon inputs
- retention of instream detritus
- control of shade
- contributing terrestrial prey for carnivorous fish

The influence of each of these factors can be expected to decline with increasing stream size, increasing stream power (flow variability), reduced coarse woody debris supply and retention, as well as influence aquatic biotic assemblages around New Zealand (Quinn *et al.* 1993). Linkages between riparian vegetation and fish distributions are known (McDowall 1980, West 1989, Hanchet 1990, Swales & West 1991), as is the importance of terrestrial insects from riparian vegetation in the diet of native and introduced fish (Edwards & Huryn 1995, 1996, Sagar & Glova 1995, McDowall *et al.* 1996). While many of the New Zealand aquatic macroinvertebrates are regarded as generalist feeders, riparian vegetation influences on instream food sources has direct effects on the feeding communities, e.g., litter retention and shredder abundance — invertebrates that obtain food by shredding leaves and coarse material (Winterbourn *et al.* 1981, 1984, Quinn *et al.* 1992, Linklater & Winterbourn 1993).

Coarse woody debris

Coarse woody debris (CWD) is often an important determinant of structure and complexity of stream morphology and ecology (Harmon *et al.* 1986, Sedell *et al.* 1988, FERAT 1993). The presence or absence of CWD can alter hydraulic conditions (Gippel *et al.* 1996, Abbe & Montgomery 1996), influence sediment storage and transport in streams (Keller & Swanson 1979, Mosley 1981), and change stream morphological characteristics such as the area of pool habitat (Bilby & Ward 1989, 1991, Trotter 1990, Hildebrand *et al.* 1997, Quinn *et al.* 1997). Aquatic biota and habitat can be influenced indirectly by increasing organic matter retention and morphological diversity in streams (Wallace *et al.* 1995, Culp *et al.* 1996), and directly by providing food and stable surfaces for invertebrates, especially where benthic habitats are unsuitable (Wallace & Benke 1984, O'Connor 1991, 1992). Macroinvertebrate densities have been shown to increase at logged sites where CWD is greater (Carlson *et al.* 1990). Research has indicated that this also occurs in New Zealand, and that some taxa show a preference for CWD over more mobile substrates in pumice streams due to wood providing both habitat and a food resource (Collier *et al.* 1997).

Stream size and hydrology are regarded as important factors determining the amount of CWD accumulation in streams, and greater amounts of CWD have been recorded from streams in old native forests than in streams from young native and pine forests in New Zealand (Evans *et al.* 1993), and Quinn *et al.* (1997) found that CWD was more abundant in more established pine forest than in native forest streams. Quinn *et al.* (1997) also found that the total CWD surface area at the pine forest site with a riparian zone of native forest vegetation was 20% of that at sites where pine trees were planted to the stream edge. Compared to other parts of the world, New Zealand native forest streams have lower amounts of CWD, which is thought to occur as a result of the vegetation characteristics and poor retention in streams with highly variable flows (Winterbourn *et al.* 1981, Harmon *et al.* 1986, Evans *et al.* 1993). Research in New Zealand has indicated that the turnover time for submerged *Pinus radiata* wood in cool water pumice stream beds is about 25 years (Collier, unpublished results), while Murphy & Koski (1989), in studies in Alaska, found that CWD was up to 226 years old. Models of changes in CWD in these Alaskan forest streams have indicated that 90 years after clear-cut logging without a streamside riparian zone, large CWD would be reduced by 70%, and recovery to pre-logging levels would take more than 250 years (Murphy & Koski 1989).

5. Frameworks for the development of riparian guidelines

While research has continued on the effects of forestry and the use of riparian zones in stream management, it is also important to construct a framework for developing, implementing, and monitoring stream management strategies. No single strategy exists for developing riparian management zones, and as the literature suggests that the research is at different stages of understanding of riparian zone functions, it is unlikely that a single strategic methodology will ever be appropriate.

New Zealand

Gilliam *et al.* (1992) indicated that riparian management in New Zealand is not new. Early settlers variously retained riparian zones around New Zealand, but the reasons, obligation, and commitment varied. One of the earliest attempts at riparian zone management can be found in the Lake Taupo catchment. Primarily implemented through concerns for soil erosion conservation and water quality under the Soil and Water Conservation Act (1967) by the Waikato Valley Authority (antecedent authority to the Waikato Regional Council), the works included swamp retention, hillside retirement, protection of selected perennial and ephemeral waterways, provision of alternative water supplies where required, and even the selection of vegetative species compatible to trout fisheries and wildlife conservation (WVA 1973). This was implemented with remarkable foresight at the time, and the high quality of the waters of Lake Taupo and its tributaries today affirms these early decisions.

Today, statutory responsibilities for resource management are provided in the Resource Management Act (1991) and for conservation management within the Conservation Amendment Act (No. 2) 1993. Before this, statutory provision for any form of riparian zone implementation was through Section 34 notices of the Soil and Water Conservation Act (1967).

Resource Management Act

The purpose of the Resource Management Act (RMA) is to "promote the sustainable management of natural and physical resources", and various sections implicitly require that riparian zone management strategies be considered as a means of managing freshwaters. In the current guidelines for managing riparian zones in New Zealand, Collier *et al.* (1995a) summarised the legal framework and detailed the sections of the RMA and Conservation Act relevant to riparian zone management.

Notwithstanding the Purposes and Principles of the Act (Part II, Sections 5, 6, 7), the functions of regional councils under the RMA, Section 30 (1) (c) allows (amongst other things) for the control of land use for the purpose of soil conservation and for the maintenance and enhancement of the quality of water in water bodies and coastal water. Restraining sections of the Act (Section 32, Duties to consider alternatives; Section 85, controls on land), however, may limit the power of councils to implement and enforce riparian management strategies.

In addition to specific provisions within the RMA the Act also requires the development of regional policy statements and allows for regional plans. Schedules I–III of the Act then provide a framework for plan development, matters to be considered, and classifications of waterways, while Schedule IV provides a framework for assessments of environmental effects for resource users.

With considerable foresight, the Taranaki Regional Council initiated much debate on riparian zone management in Taranaki and New Zealand in general with the publication of a discussion document on "Management of riparian margins in Taranaki" (Taranaki Regional Council 1992). This document presented (amongst other things) general guidelines for riparian management and options for implementation of riparian management, as well as a preferred strategy, and called for debate on the issues. The result has been an implementation strategy that details the preferred strategies for riparian management in Taranaki (Taranaki Regional Council 1993). In 1996, the Otago Regional Council produced a riparian management document for Otago, containing information on best management

practices, riparian guidelines, riparian planting, and monitoring and assessment (Otago Regional Council 1996). Further details of regional council plans, rules, and initiatives are given in Section 7.

International

As in New Zealand, no single framework for the development of riparian zone management guidelines exists in any one country. However, the Food and Agricultural Organisation of the United Nations (FAO) has developed a "Model code of forest harvesting practice" (Dykstra & Heinrich 1996) which aims to promote forest harvesting practices that improve standards of utilisation and reduce environmental impacts. The code highlights the wide range of environmentally sound harvesting practices and makes these available to policy-makers to develop national, regional, or local codes of practice. While the FAO model code is intended as a general model code it provides some guidance on how to write a code of practice. The code makes reference to buffer strips (as exclusion zones), but does not suggest any framework for establishing appropriate buffer widths or options.

The Forest Resources Commission of British Columbia established a framework for developing a Forest Practices Code (FRC 1992), which details 34 recommendations. The framework does not make explicit mention of riparian zones but describes a series of steps to be undertaken in developing codes, including auditing and public participation. Earlier the Ministry of Forests, Province of BC (Moore 1980) developed a decision-making procedure for streamside management on Vancouver Island. The site specific guide was developed as an aid for field personnel and details two decision-making procedures: a steep gradient stream procedure (streams with gradients over 20%), and a low gradient stream procedure (streams gradients less than 20%). However, this guide is primarily for operational testing and use.

Ice (1995) argued that forest practice rules (cf. codes) provide only the "floor" for watershed management, and suggested that additional initiatives such as internal company standards, stream enhancement programmes, environmental audits, watershed management needs, and stream habitat surveys are also required and cited examples from the Pacific Northwest states.

6. Existing riparian zone guidelines: International

Numerous riparian zone guidelines have been developed in countries and states around the world. Most are compiled within forestry Codes of Practice, Guidelines or State rules and regulations. This section summarises a selection of existing riparian zone guidelines and rules from international sources and within New Zealand.

United States

Washington

The Washington Forest Practices Rules and Regulations make reference to Riparian Management Zones (RMZs) and are included within the section headed Timber Harvesting (Washington State Forest Practices Board 1973, 1988). The rules outline all practices to be undertaken and include State Environmental Policy Act Guidelines, application and notification procedures, policy and organisation, timber harvesting, reforestation and enforcement. As part of the application procedure streams must be identified on maps and placed into one of five classes:

- Type 1: shorelines of the state
- Type 2: high use waters — important fish, wildlife, recreational and water supply use
- Type 3: moderate use waters — moderate fish, wildlife, recreational and water supply use
- Type 4: not type 1, 2, or 3 and over 2 m wide, may be perennial or intermittent
- Type 5: all other waters (intermittent streams, ponds, seepage areas)

RMZs are established along all Type 1, 2, and 3 waters and are measured from ordinary high-water mark and extend to a line where the vegetation changes from wetland to upland plant communities (Table 3). A minimum RMZ width of 25 feet (7.5 m) and a maximum width as specified is required, provided that the RMZ width shall be expanded as necessary to include swamps, bogs, marshes, or ponds adjacent to the stream. RMZs may be established at Type 4 streams in order to preserve small trees and other vegetation to help prevent debris torrents.

The requirements of RMZs vary according to stream class, stream width, and substrate, and the RMZs are further defined by width, ratio of coniferous to deciduous trees, and minimum number of trees of a minimum size for each 1000 ft (300 m) of stream. Required RMZ widths vary from 7.5 m to about 30 m.

***Table 3*: RMZ specifications for Washington, USA (Washington State Forest Practices Board 1973, 1988)**

Water type (average width)	RMZ max. width	Ratio of conifer to deciduous/size of leave trees	No. of trees per 1000 ft (300 m) each side	
			Gravel/cobble	Boulder/bedrock
Water Type 1 & 2 (> 23 m)	100 ft (30 m)	representative of stand	50	25
Water Type 1 & 2 (< 23 m)	75 ft (23 m)	representative of stand	100*	50*
Water Type 3 (> 1.5 m)	50 ft (15 m)	2 to 1	75*	25*
Water Type 3 (< 1.5 m)	25 ft (7.5 m)	1 to 1	25	25

* except NE Washington

RMZs are primarily focused on maintaining a supply of large organic debris for western Washington streams and for wildlife habitat in eastern Washington. The rules also provide for within the RMZ, whereby 50% or more of the trees shall be live and undamaged on completion of the harvest. These "leave" trees are required to be randomly distributed where feasible but some clumping is allowed to accommodate operational considerations. The number, size, species, and ratio of deciduous to conifer leave trees, is specified by the bed material and average width of the water type within the harvest unit (Table 3).

The rules also consider stream bank integrity (WAC 222-30-30), whereby in the RMZ along all Type 1, 2, and 3 waters, the operator is required to:

- avoid disturbing brush (understory vegetation),
- avoid disturbing stumps and root systems,
- leave high stumps,
- leave trees with root systems embedded in the bank.

The Washington Forest Practices Rules and Regulations also requires specific management of temperature sensitive streams (WAC 222-30-030). Determination of temperature sensitive Type 1, 2, and 3 waters is based on field/recorded data or modelling that demonstrate significant adverse water temperature impacts following any proposed timber harvest and shade removal. If streams are designated as temperature sensitive the operator is required (unless a waiver is granted) to:

(a) leave all non-merchantable vegetation which provides mid-summer and mid-day shade of the water surface; and

(b) leave sufficient merchantable timber, if any, to retain 50% of the summer mid-day shade.

Montana

Streamside Management Zones (SMZs) in Montana are a mandatory 50 feet (15 m) minimum from a stream, lake, or other water body that must be protected because of its special importance. The SMZs are not a "keep out" zone, but timber harvesting should be considered with care in them. Streamside Management Zones are covered in the Forestry BMPs: Best Management Practices (Logan & Clinch 1991) and the following BMPs with regard to SMZs have been adopted by the State of Montana.

SMZ boundaries:

- Designate SMZs to provide shading, soil stabilisation, sediment and water filtering effects, and wildlife habitat.
- Stream means a natural water course of perceptible extent with definite beds or banks which confine and conduct continuously or intermittently flowing water.
- Definite beds are defined as having a sandy or rocky bottom which results from the scouring action of water flow.
- The SMZ encompasses a strip at least 50 feet (approx. 15 m) wide on each side of a stream, measured from the ordinary (yearly mean) high-water mark or definable bank.
- The width of the SMZ extends beyond the 50-foot minimum to include wetlands along the stream bottom and to provide additional protection in areas of steep slopes or erosive soils.
- Consult with forestry professionals, soil and water conservation specialists, or biologists if assistance is needed in setting appropriate SMZ boundaries.

Within the SMZ:

- Leave the following adjacent to streams: hardwoods, unmerchantable conifers, and shrubs.
- Maintain or provide sufficient ground cover to trap sediment.
- Use directional falling for harvest operations within the SMZ or wetlands. Avoid falling trees in streams or water bodies.
- Consider hand-scalping and planting within the SMZ.

Site preparation near SMZs:

- Steep slopes containing material that could roll down slope and fall into a stream during burning should receive special attention.
- Protect the SMZ with a slash free strip along the border.
- High stumps along the SMZ border keep debris from rolling down steep slopes and reaching the stream.
- Retain trees necessary for bank stabilisation and as a future source of large woody debris to the stream channel.

The Forestry BMPs provide additional advice and notes on the benefits of SMZs as well as the effects of forestry practices.

The 1991 Streamside Management Act prohibits the following activities in SMZs:

1. Broadcast burning.
2. The operation of wheeled or tracked equipment except on established roads.
3. The forest practice of clearcutting.
4. The construction of roads except when necessary to cross a stream or wetland.
5. The handling, storage, application, or disposal of hazardous or toxic materials in a manner that pollutes streams, lakes, or wetlands or that may cause damage or injury to humans, lands, animals, or plants.
6. The side-casting of road material into a stream, wetland, or watercourse.
7. The deposit of slash in streams or other water bodies.

Alaska (modified from WRG 1998)

In Alaska the intent of the legislation is to protect riparian areas from significant adverse impacts of timber harvesting. The focus is on water quality and avoidance of mass erosion and there is no reference to recreation, domestic water supply, wildlife or aquatic life. Similar to other states, waters are classified into one of three main types (Table 4).

***Table 4*: Classification of water for riparian areas in Alaska (from WRG 1998)**

Water classification	Size	Average gradient (%)	Channels	Banks	Substrate	Other
Type A	Any size	< 8	Not incised	Held by vegetation	Rubble, gravel, sand or silt	Wetlands, lakes & outlets, estuarine areas
Type B	Any size	< 8	Incised and geomorphological		Rubble to bedrock	Fish stream or river
Type C	Width < 6 m	> 8	Incised > 55%		Rubble & bedrock	Mountain slope stream

The width of established riparian areas varies depending on the water type, whether it is used by anadromous or other fish, the administrative forest region, and whether the land is private or state-owned, and the restrictions on operations within riparian areas also differ. Specified widths vary from 50 feet (15 m) to 300 feet (100 m) on each side of a stream. For example, in coastal regions, riparian areas on private land are required to be: 20 m wide for Type A waters, 30 m wide for Type B waters, and 15 m wide for Type C waters. Timber harvesting is prohibited within Type A waters, and is restricted for riparian areas of Types B and C waters. Standards differ for other regions and for state-owned lands, e.g., for Type B (30 m) and Type C (15 m) waters the set-back relates to slope stability and not riparian management.

Vermont

The Department of Forests, Parks and Recreation, State of Vermont, produced a document describing acceptable management practices for maintaining water quality on logging jobs in Vermont (DFPR 1987). This was produced following changes to Vermont's water quality statutes. While these changes generally required permits to be sought for discharges, individual permits for discharges caused by logging operations are not required if "acceptable management practices" (AMPs) are in place. AMPs (similar to Best Management Practices) are the proper method for the "control and dispersal of water collecting on logging roads, skid trails and log landings to minimise erosion and reduce sediment and temperature changes in streams of Vermont" (DFPR 1987). A total of 24 AMPs are detailed, with AMP No. 14 describing protective strips as follows.

"Except for necessary construction of stream crossings, a protective strip shall be left along streams and other bodies of water in which only light thinning or selection harvesting can occur so that breaks made in the canopy are minimal and a continuous cover is maintained. Log transport machinery must remain outside a 25 foot margin along the stream or water body. Including this 25 foot margin, the width of the protective strip shall be according to Table 5."

***Table 5*: Protective strip width guide for Vermont (DFPR 1987)**

Slope of land between roads or landings and stream banks or lake shores (%)	Width of strip between roads or landings and stream (feet along surface of ground)
0–10	50
11–20	70
21–30	90
31–40*	110

* Add 20 ft for each additional 10% side slope.

In addition AMP No. 16 states "Landings shall be located in protective strips", and No. 17 states "Silt fencing, haybale erosion checks or water diversions shall be used to prevent sediment from landings from entering streams and other surface waters". Enforcement is undertaken by the Environmental Conservation Investigator of the Agency of Natural Resources.

Oregon

Under the Oregon Forest Practice Rules, riparian strips are termed Riparian Management Areas (RMAs). Streams are classified into one of three types according to size and use (as water supply, fisheries, or recreation):

Stream size		Stream use	
Type	**Definition**	**Type**	**Definition**
Small	Flow < 2cfs (0.45 $m^3 s^{-1}$)	F	Streams that have fish and may also have domestic use
Medium	Flow 2–10 cfs (0.45 -2.3 $m^3 s^{-1}$)	D	Streams that have domestic use but not fish use
Large	Flow > 10 cfs (2.3 $m^3 s^{-1}$)	N	Other streams

Table 6 shows the riparian management area widths for the three stream sizes. RMAs are usually measured as slope distance from the high water level of the main stream level. RMAs are generally not reserved no-go areas. The amount and type of vegetation retained in the RMAs varies with stream width, size and location. Previous legislation required that in special protection waters (cf. Type F and D), 50% of tree canopy and all snags not hazardous must be left, and 75% of shade present before harvest must be left. Leave tree requirements are specified and vary with stream width (specified as conifers per 1000 feet of stream). Riparian management areas for lakes and wetlands are shown in Tables 7 and 8 respectively.

Table 6: **Riparian management areas (RMAs) widths for specified stream types in Oregon (from WRG 1998)**

Stream size	Stream type		
	Type F	Type D	Type N
Large	100 ft (30 m)	70 ft (21 m)	70 ft (21 m)
Medium	70 ft (21 m)	50 ft (15 m)	50 ft (15 m)
Small	50 ft (15 m)	20 ft (6 m)	Variable

Table 7: **Riparian management areas (RMAs) widths for specified lake types in Oregon (from Oregon Water Protection Rules 1994)**

Lake classification and protection		
Classification	RMA	Protection (lake and RMA)
Large (> 8 acres)	100 ft	Leave understorey plants, snags, down wood, ½ of trees by species and size. Don't drain lake or cause sedimentation.
Other (½ acre> < 8 acres)	50 ft	Same as for Large
Other (< ½ acre)	No RMA	Don't drain lake or cause sedimentation. If > ¼ acre leave snags and down wood.

Table 8: **Riparian management areas (RMAs) widths for specified wetland types in Oregon (from Oregon Water Protection Rules 1994)**

Wetland classification and protection		
Classification	RMA	Protection (wetland and RMA)
Significant (>8 acres, estuaries, bogs)	Varies from 50–200 ft	Leave requirements same as for large lakes. Don't drain wetland or cause sedimentation.
Stream associated (next to a stream)	Stream RMA applies around wetland	Included in stream RMA
Other (< 8 acres)	No RMA	Don't drain lake or cause sedimentation. If > ¼ acre leave snags and down wood.

Canada

Manitoba

Manitoba Natural Resources have produced a "Consolidated Buffer Management Guidelines" document (MNR 1996) with the objective "To provide field managers and the forestry industry with the minimum standard buffer zone widths and the conditions for operating within buffers that maintain the integrity of sensitive areas or natural features". The forest industry is expected to adhere to these guidelines, timber harvest planning and operations, while the guidelines provide flexibility to accommodate the various resource values and site conditions in Manitoba (Table 9).
Additional guidelines are provided for other significant resource values (e.g., colonial waterbird nests, special habitats, MNR 1996).

Ontario

The Ministry of Natural Resources in Ontario produced a "Code of Practice for Timber Management Operations in Riparian Areas" (OMNR 1991). The Code applies to all headwater lakes, lakes over 10 ha or which possess significant fisheries values, permanent streams, and intermittent streams which provide spawning habitat for fish. Riparian areas are termed "Areas of Concern", and must be established on both sides of watercourses, but the code focuses on slope, width, spoil, season of operation, equipment, and other specified practices (Table 10). Other practices include the following.

- Trees must not be felled into waterbodies at any time of the year. No debris of any description is to be deposited in waterbodies.
- No logging debris is to be left on the banks of streams, rivers, or lakes.
- Equipment operating adjacent to waterbodies shall not cause destruction or slumping of banks.
- Equipment is not to travel within streams or rivers during harvest or renewal operations so as to cause damage to banks or beds. Stream crossings are to be kept an absolute minimum.
- Establishment of tertiary roads within riparian areas is only permitted in exceptional cases, where no reasonable alternative exists.
- A narrow filter strip of approximately 3 metres of undisturbed forest floor or vegetation (not necessarily tree species) is to be left on the banks of waterbodies except where necessary to cross a stream.
- Equipment is not to be refuelled or lubricated in riparian areas. Gasoline and oil for such equipment are not to be stored in riparian areas.

Table 9: **Buffer management guidelines for Manitoba (MNR 1996)**

Waterbody classification	Riparian zone buffer width	Roads and landings	Conditions for operating within buffers
Class 1 & 2 streams Productive lakes, small lakes and ponds	• No disturbance or timber removal within 100 m of the normal high water mark* • May be wider if recreational values are high	• None within 100 m of the normal high water mark	Where buffer management is approved • selected harvest only • heavy machinery not permitted within 15 m • cutting restricted to well drained or frozen ground • no trees to be felled into the watercourse • slash not to be left within 15 m • slash landing within watercourses to be removed manually
Wetlands	• Established by government agency for special site wetlands	• None within 100 m	• minimise machinery operations within the non-woody vegetated area surrounding wetlands • machinery use should be limited to frozen ground conditions
Landscapes	• 200 m or view to horizon or viewing distance	• Preservation of viewscapes in Parks or other scenic locations	• year round or seasonal

* High water mark is defined as:
(i) sharply defined bank: the top of the bank is the high water mark
(ii) gently sloped bank: the point where there is a change in aquatic and terrestrial based vegetation is considered the high water mark.

Table 10: **Timber management practice guidelines for Riparian Areas of Concern for the protection of fish habitat in Ontario (from WRG 1998)**

Fish habitat	**Slope**	**Width (m)**	**Modifications to timber management operations within Areas of Concern**			
	(%)		Roads	Landings	Harvesting options	Mechanical site preparation
Trout lakes	0–15 16–30 31–45 46–60	30 50 70 90	Nil	Nil	No harvesting. Selection cutting restricted. No damage to banks. No debris. No erosion	Nil
Other lakes	as above	as above	Nil	Nil	No harvesting. Selection cutting restricted. Limited clearcutting.	Restricted. Minimise exposure of mineral soil. Orientate furrows.
Coldwater streams	as above	as above	Stream crossings only	Nil	No harvesting. Selection cutting restricted. No damage to banks. No debris. No erosion. Maintain shade on both sides.	Nil
Coolwater and warmwater streams	as above	as above	Stream crossings only	Nil	No harvesting. Selection cutting restricted. Limited clearcutting. No clearcutting upstream of critical fish habitats.	Restricted. Minimise exposure of mineral soil. Orientate furrows.

British Columbia

The Forest Practices Code of British Columbia has four components: Forest Practices Code of British Columbia Act, Guidebooks, The Regulations, and The Standards. The Forest Practices Code of British Columbia Act is the legislation authorising the Code's other components and enables the Code to exist, establishes mandatory requirements, sets enforcement and penalty provisions, and specifies administrative arrangements. Riparian Management Areas described in this section are taken from the Riparian Management Area Guidebook (BC Environment 1995).

Forest Practices Code Guidelines have been developed to support the regulations but are not part of the legislation. In general they describe procedures, practices, and results that are consistent with the legislated requirements to the Code. This discussion on riparian management in British Columbia is drawn largely from The Riparian Management Area Guidebook (BC Environment 1995).

RMAs are implemented to:

- minimise or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands,
- minimise or prevent impacts of forest and range use on the diversity, productivity, and sustainability of wildlife habitat and vegetation adjacent to streams, lakes, and wetlands with reserve zones, or where high wildlife values are present,
- allow for forest and range use that is consistent with the above objectives.

RMAs usually consist of a reserve zone immediately adjacent to a stream, lake, or wetland, and a management zone. No harvesting is permitted within reserve zones (except in special approved circumstances). No road construction is allowed within the RMA (except stream crossings in special circumstances), and any harvesting within a management zone must not increase the risk of damage to the reserve zone (WRG 1998). Livestock use of the RMA is allowed only with an approved plan.

In British Columbia, streams, lakes, and wetlands are classified for RMA purposes. Stream classifications are outlined in Table 11 and specified RMA distances in Table 12. Definitions and measurement of terms are given in the Guidebook (BC Environment 1995).

Streams

For streams and rivers, the entire RMA generally ranges from 20 to 70 m. The management zone extends from the outer edge of the reserve zone, where one is present or from the top of the streambank where no reserve zone is required. The RMA adjacent to streams is measured from the top of the streambank to the greater of:

- a slope distance as specified in Table 12, or
- the top of the inner gorge, or
- the outer edge of the active floodplain, or
- the outer edge of non-classified wetlands.

Table 11: **Stream classification for Riparian Management Areas in British Columbia (BC Environment 1995)**

Is stream a fish stream or community watershed?			
NO		YES	
Average channel width	Riparian class	Stream width	Riparian class
		> 20 m	S1
> 3 m	S5	> 5–20 m	S2
< 3 m	S6	1.5–5 m	S3
		< 1.5 m	S4

Table 12: **Specified minimum Riparian Management Area slope distances for stream riparian classes in British Columbia (BC Environment 1995). Shaded area indicates fish stream or community watershed**

Riparian class	Average channel width(m)	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
S1 large rivers	≥ 100	0	100	100
S1 (not large rivers)	> 20	50	20	70
S2	> 5 ≤ 20	30	20	50
S3	1.5 ≤ 5	20	20	40
S4	< 1.5	0	30	30
S5	> 3	0	30	30
S6	≤ 3	0	20	20

Wetlands

The guidelines define wetlands to include open water, swamps, marshes, fens, and bogs. There are five riparian classes of wetlands (W1 to W5) in British Columbia based on whether a wetland is a simple wetland or a complex wetland, wetland size, and biogeoclimatic unit. Complex wetlands consist of two or more individual wetlands with overlapping RMAs and a combined wetland area of 5 ha or more. Classification of wetlands in British Columbia is given in Figure 2. with minimum slope distances for wetland riparian management areas in Table 13.

Table 13: **Specified minimum Riparian Management Area slope distances for wetland riparian classes in British Columbia (BC Environment 1995)**

Riparian class	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
W1	10	40	50
W2	10	20	30
W3	0	30	30
W4	0	30	30
W5	10	40	50

Lakes

There are four riparian classes of lakes (L1 to L4) in British Columbia determined by lake size and biogeoclimatic unit. Classification of lakes is given in Figure 3 and minimum slope distances for riparian management areas in Table. 14. The outer edge of the lake is measured from the high-water mark or the edge of an immediately contiguous wetland.

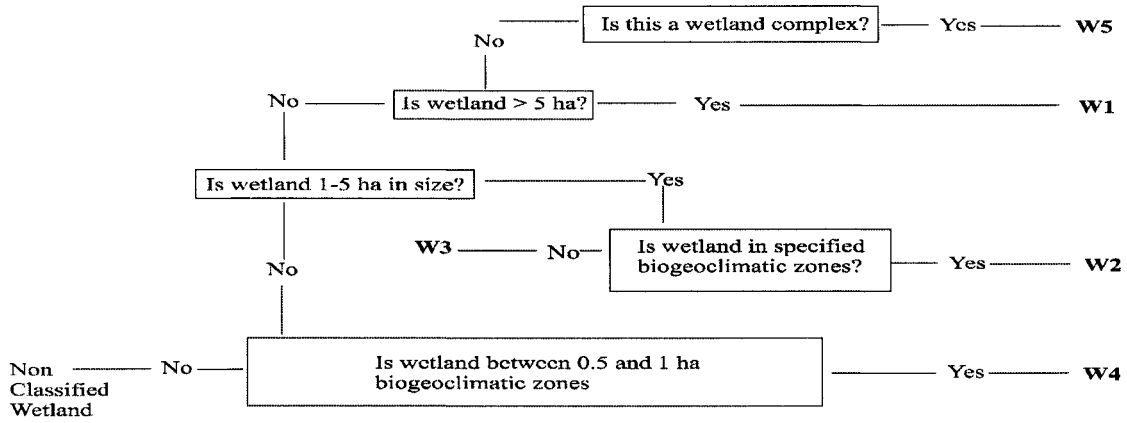

Figure 2: **Wetland classification system for Riparian Management Areas in British Columbia (BC Environment 1995).**

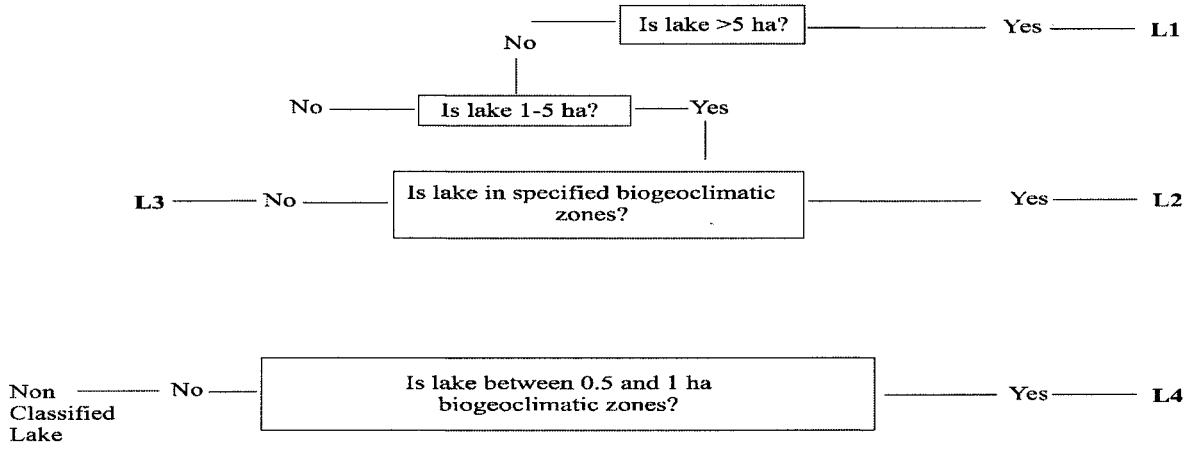

Figure 3: **Lake classification system for Riparian Management Areas in British Columbia (BC Environment 1995).**

Table 14: **Specified minimum Riparian Management Area slope distances for lake riparian classes in British Columbia (BC Environment 1995). NB L1 lakes under 1000 ha have a 10 m reserve zone and a lake shore management zone; L1 lakes over 1000 ha have only a lake shore management zone**

Riparian class	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
L1	10	0	10
L2	10	20	30
L3	0	30	30
L4	0	30	30

In addition to these classifications and minimum riparian management area widths, the guidelines also provide recommendations regarding silviculture, harvesting, and road construction practices within the RMA. These particular recommended forest practices were developed with consideration of their potential to impact on timber supply. The guidelines recommend site-specific decisions regarding the appropriate level of retention within RMAs and the types of trees to be retained. Maximum overall levels of basal area retention within the RMA are provided, as well as general guidelines on roads and crossings within RMAs, falling and yarding within RMAs, activities within streams and wetlands, stream clean-out, fisheries- and marine-sensitive zones, and windthrow hazard management. Fisheries-sensitive zones (FSZ), for example, are identified as side and back channels, ponds, swamps, seasonally flooded depressions, lake littoral zones, and estuaries that are seasonally occupied by overwintering fish. Fisheries-sensitive zones are to be identified and protected by:

- maintaining a 5 m exclusion zone
- retaining nonmerchantable conifer trees, understorey trees, shrubs, etc. within 5 m
- felling and yarding away from FSZs
- not introducing sediment and debris into FSZs
- not restricting natural water patterns associated with FSZs
- avoiding road construction through FSZs
- timing operations so as to minimise effects on FSZs
- not restricting fish passage to or from FSZs

In addition to general guidelines, the Riparian Management Area Guidebook (BC Environment 1995) details specific measures for each riparian class, active floodplain, and large rivers. A particularly useful appendix to the guidelines, "Instream work window for provincial fisheries zones", provides approximations for particular fish species over a specified area or region when instream work might be permitted at a time of reduced risk to the protection and viability of the species.

Yukon

Yukon regulations give significance to riparian areas for wildlife purposes, and suggest that, as a rule of thumb, a 100 m buffer on both sides of the water for fish and wildlife protection. Riparian zone widths are managed by a minimum width identified from general guidelines, with the remaining width within 100 m managed to meet desired objectives. Yukon standards and guidelines are given in Table 15.

Table 15: **Standards and guidelines for operating beside watercourses in Yukon Territory, Canada**

Watercourse classification	Roads, landings, and bared areas	Watercourse protective buffers	Operating conditions within buffers and watercourse areas where operations are approved	
			Tree felling	**Equipment operation**
Large permanent	• Not permitted within 60 m or from water-source area within buffer. • May be permitted within 60–100 m with approval.	• No disturbance or removal of merchantable timber within 60 m except where approved in Annual Operating Plan.	• Trees not to enter watercourse • No slash or debris in watercourse • If slash/debris in watercourse, immediate removal but no machines in watercourse • No felling in 30 m closest to water	• Where removal of timber within 60 m is approved, no machinery within 30 m of water. • Where possible, topographic breaks should be used as protection strip barriers.
Small permanent	• Not permitted within 30 m or from water-source area within buffer. • May be permitted within 30–100 m with approval	• No disturbance or removal of merchantable timber within 30 m except where approved in Annual Operating Plan.	• Trees not to enter watercourse • No slash or debris in watercourse • If slash/debris in watercourse, immediate removal but no machines in watercourse • No felling in 15 m closest to water	• Where removal of timber within 30 m is approved, no machinery within 15 m of water. • Where possible, topographic breaks should be used as protection strip barriers.
Intermittent	• Not permitted within 30 m or from water-source area within buffer.	• Buffer of brush and lesser vegetation to be left undisturbed along channel. • Width of buffer will vary according to soils, topography, water-source areas and fisheries. • Reed buffer not required unless requested by forest officer.	• Trees not to enter watercourse unless otherwise approved. • If slash/debris in watercourse, immediate removal but no machines in watercourse	• Heavy equipment may operate within 20 m only during frozen or dry periods. • No random skidding through watercourse channels. • Crossings must be planned with adequate crossing structures, and removed at end of operations. • Where fish and spawning movements identified, special crossings that do not obstruct upstream passage or cause siltation may be required.

Ephemeral	• Construction not permitted within a watercourse or a water-source area.	• Buffer of lesser vegetation in wet gullies to be left undisturbed.	• Large accumulations of slash or debris must be removed progressively.	• Random skidding through watercourse permitted only during frozen or dry conditions. • 15 m machine free zone during snow free period. • Temporary crossings are to be removed on completion of operations.
Lakes (little or no recreation, waterfowl or sport fishing potential)	• Not permitted within 100 m without approval.	• On lakes > 16 ha in area, no disturbance of timber within 100 m unless approved in Annual Operating Plan.	• Trees within these areas shall be felled away from watercourse. • No slash or debris to enter waterbody. • No felling in 50 m closest to water.	• If timber removal is approved, no machinery is to operate within 50 m of the water.
Lakes (recreation, waterfowl or sport fishing potential)	• For shorelines not located within reserved areas, no disturbances permitted within 200 m unless approved.	• On lakes > 4 ha in area, no disturbance or removal of timber within 100 m unless approved in Annual Operating Plan.	• Trees within these areas shall be felled away from watercourse. • No slash or debris to enter waterbody. • No felling in 50 m closest to water.	• If timber removal is approved, no machinery is to operate within 50 m of the water.
Water source areas and areas subject to normal seasonal flooding	• Construction not permitted unless approved in Annual Operating Plan. • No log decks permitted. • Number of stream crossings must be minimised. • No disturbance of organic layers or removal of lesser vegetation.	• Treed buffers of at least 20 m on all streams. • No harvest of merchantable trees or disturbance of lesser vegetation unless approved in Annual Operating Plan. • Buffer widths may be altered according to its potential to produce surface water, provided it is approved in Annual Operating Plan.	• Heavy machinery not permitted in the water-source areas during unfrozen soil conditions. • Minimal disturbance or removal of duff or lesser vegetation. • Timber may be harvested if sedimentation is the only resource concern, provided there is no disturbance of the organic soils and lesser vegetation during harvesting. • On unstable areas subject to blowdown, merchantable trees should be carefully harvested for water-source areas to minimise root disturbances of duff layers and watercourse damming.	• Road construction, timber harvest, reforestation and reclamation shall be done with equipment capable of operating without causing excessive disturbance to organic soil layers. • Heavy equipment is not permitted during moist or wet soil conditions. • No dirt caps or depositing of soil on roads in water-source areas, unless a separation layer is incorporated or the road is designed to provide adequate surface and subsurface drainage away from the road-bed.

Alberta

Alberta has similar standards and guidelines to the Yukon.

United Kingdom

The Forestry Commission and Forestry Authority have produced "Forests and Water Guidelines", now in its third edition, since 1988. The guidelines advise both native and planted production forest owners on how operations should be carried out and apply equally to government forest enterprises and the private sector. The guidelines have no formal legal status, but forest owners are required to meet legal obligations under the Control of Pollution Act (1974) (as amended by the Water Act 1989 (Scotland) and the Water Resources Act 1991 (England and Wales) and other relevant legislation when carrying out forest operations. The guidelines detail specific recommendations for all forest operations, including buffer areas.

The guidelines recommend that the width of the buffer area should be determined by the risk of sediment movement, and indicate average widths as follows:

- for a headwater stream with a channel up to 1 m wide, a buffer at least 5 m wide on either side;
- for a stream with a channel 1–2 m wide, a buffer about 10 m wide on either side;
- for a stream with a channel over 2 m wide, a buffer about 20 m wide on either side.

For very erodible soils the guidelines recommend that these widths be doubled. The guidelines recommend that riparian vegetation management should:

- apply to all features which are characteristic of riparian land;
- maintain open or partially wooded conditions — to minimise bank erosion;
- maintain about half the length of a stream open to sunlight — to maintain a sensible balance of light and shade.

Additional aspects discussed in the guidelines include choice of species, riparian wildlife management, and landscape design, and conclude with the statement "Imaginative management of the riparian zone will make a vital contribution to multipurpose forestry".

South Africa

A South African Harvesting Code of Practice has been developed by the Forest Engineering Group of South Africa (FESA 1995). The code was developed with reference to similar publications in other countries, but was modified for South African conditions. The aims of the document are to:

- avoid potential detrimental environmental impacts, and
- enhance product quality and productivity by
- applying improved harvesting practices.

The code refers to stream side management zones and requires special management to be applied to all stream side management zones, and to conserve water quality. Relevant legislation is cited. Management tactics for water values are listed as:

- identify hydrologically sensitive areas
- prevent up-slope soil disturbance by proper drainage control
- minimise the extent of the area disturbed
- avoid contamination of streams, especially with regard to fuel and oil
- situate extraction routes, landings and depots outside the riparian zone
- ensure roads and drainage systems are well planned
- minimise the number of river crossings
- do not disturb stream side management zones by harvesting operations
- make stream crossings at right angles to the stream
- avoid or minimise the felling and dragging of trees through waterways
- use suspension skyline methods to extract across a riparian zone or river where necessary
- avoid depositing debris in streams
- if debris in streams, remove with minimum damage to the stream bank and riparian zone
- the use of machines for removing slash from river beds is not recommended
- adhere to slash management prescriptions

Australia

Tasmania

The Forest Practices Act was passed in 1985 to ensure that forest operations are conducted in an environmentally acceptable manner on Crown and private forest lands. The Forest Practices Code (Tasmania Forestry Commission 1993) forms part of a process of progressively improving forest practices. The code contains both 'general principles' and a 'basic approach' for particular forest practices. The code contains mandatory practical operations covered by the Forest Practices Act 1985, as well as desirable but non-statutory operations.

Water quality and stream protection forms an important component of the code. General principles are:

- protect water quality by reducing soil disturbance near watercourses;
- in town water supply, fish farm, and in domestic water supply catchments particular attention to soil and water care is needed when roading and logging;
- timber harvesting plans will identify town and known authorised domestic water supply intakes within 2 km downstream of the proposed harvesting area, and will specify measures to protect water quality.

Minimum streamside reserve widths for native forests in Tasmania are given in Table 16, and the code also specifies a series of basic approaches (e.g., logging slash shall not be pushed into streamside reserves). No similar minimum widths are required for plantation forests but a series of basic approaches are suggested. Those relevant to riparian zones are as follows:

Harvesting of plantations where land has been planted up to the streambanks prior to the introduction of the Forest Practices Code in November 1987.	Establishment of second rotation plantations and new plantations with previously cleared streamside reserves.
• On high soil erodibility, vegetation within • 20 m of a streambank should not be removed unless approved in Timber Harvesting Plan • On other soils: - dry season conditions only - trees to be felled away from streams and remnant native vegetation to be retained - excavators may only enter to within 5 m of a streambank on slopes < 20 °C in dry conditions. Stems removed to at least 10 m from bank - other logging machinery not to enter within 10 m of streambank except at designated crossing points - substantial debris resulting from logging should be removed from stream causing as little damage as possible. • Selective logging or felling of the planted streamside reserve at a different time to the remainder of the coupe should be considered on sensitive sites.	• native vegetation should be established and future logging excluded on streamside reserves: - with soils in the high to very high erodibility category - with slopes in excess of 19 °C irrespective of soil erodibility class. - within 20 m of any Class 1 or Class 2 watercourse - of a special nature as specified (e.g. adjoining water supply intakes). • on other streamside reserves, native vegetation, or other high value species or the same species as the adjoining plantation may be established and logged as for existing plantations.

Table 16: **Minimum streamside reserve widths required in native forests in Tasmania (Tasmania Forestry Commission 1993)**

Watercourse type		Minimum horizontal width (m) from streambank to corresponding outer edge of reserve	Total stream reserve protection (m)
Class 1.	Rivers and lakes - waters which are important for town water supplies or recreational use	40	80
Class 2.	Creeks, streams and other watercourses from the point of where their catchment exceeds 100 ha	30	60
Class 3.	Watercourses carrying running water for most of the year between the points where their catchment is 50 and 100 ha	20	40
Class 4.	All other watercourses carrying water for part or all of the year for most years	No logging machinery within 10 m of the streambank except at defined crossing points	

The Tasmanian Forest Practices Code Forestry Commission (1993) also details a basic approach for swampy ground and surface seepage areas.

- Machines will not be taken within 10 m of the border of any swamp or area with obvious surface seepage except at properly corded crossing points.
- Conventional harvesting in production swamp forests should be in dry conditions.

Queensland

The Queensland Department of Forestry produced logging guidelines (QDOF 1988) and include buffer strips for watercourse protection that need to be total exclusion zones from logging operations. The Queensland guide includes a spatial as well as area guide, whereby buffer strips should be retained below the point on the watercourse where the catchment exceeds the areas specified in Table 17.

***Table 17*: Buffer strip guidelines for Queensland, Australia**

Erosion hazard rating	**Catchment area (ha)**	
High/moderate	> 60	
Low	> 100	
then the following shall be adopted as a guide to buffer width:		
Watercourse type	**Average grade of catchment**	
	Undulating to moderate (<15°)	*Steep to very steep (>15°)*
Temporary stream	10 m	20 m
Permanent stream	20 m	30 m

The entry of logging machinery into any part of the buffer strip is not permitted except for specified watercourse crossings. Trees must not be felled into watercourses but those that are must be removed with as little soil disturbance as possible. Unloggable slopes (those that cannot be logged in an environmentally sensitive manner) are also specified: low erosion hazard soil types, areas with slopes over 58% for more than 50 m are classed as unloggable (except where log extraction can occur without earthworks or significant soil disturbance); medium to high erosion hazard soil types, logging is not permitted on steep terrain over 33%.

Victoria

Harvesting operations in Victoria are regulated in state forests through the Timber Harvesting Regulations 1989 made under the powers of the Forests Act 1958. Forestry operations on private land are regulated by local government (municipal councils) through the Planning and Environment Act 1987. In 1989 Victoria established a Code of Forest Practices for Timber Production which was reviewed in 1996 (VNRE 1996). The latest code has benefited from significant developments in research information, field experience, and forest planning in Victoria in recent years. The purpose of the code is to ensure that commercial timber growing and timber harvesting operations are carried out on both public land and private land in a way that:

1. promotes an internationally competitive forest industry;
2. is compatible with the conservation of the wide range of environmental values associated with the forests;
3. promotes the ecologically sustainable management of native forests proposed for continuous timber production.

Water quality and aquatic habitat is protected by classifying stream types within and near forests, and maintaining buffer and filter strips on both sides of the stream as detailed in Table 18. Buffer strips are defined as a protective margin of vegetation abutting a stream, spring, wetland, body of standing water, swampy ground, or an area of rainforest, which protects it from potentially detrimental disturbances in the surrounding forest. Buffer width is defined as horizontal distance from which various operations are excluded. Filter strips are defined as a narrow strip of ground retained either side of a drainage line or temporary stream.

Table 18: **Minimum width (m) for buffer strips (B) and filter (F) to be applied to various stream categories, in relation to soil type and slope in Victoria, Australia**

Stream class	High permeability soils and low overland flow potential	Low permeability soils and high overland flow potential	
Slope	0–30°	0–20°	21–30°
1. Permanent streams (flow > 90% of year)	20B	30B	40B
2. Temporary streams (defined stream-bed, incision, riparian vegetation and flow at wetter times of year	10F	10B	20B
3. Drainage lines (periodically flowing water and /or channel > 30 cm depth, flow after heavy rain)	10F	10F	15F
4. Wetlands (permanent spring, swampy ground)	20B	30B	40B

Slope is determined as the average slope of the forest area in the vicinity of the water body and within the catchment. Additional specifications are as follows.

The width of buffer and filter strips must be:

- set locally in relation to water pollution hazard, having reference to the statewide minimum width, and having reference to additional specific factors mentioned in the guidelines (e.g., erodibility of soils, topography)
- measured in the horizontal plane
- measured from the edge of the saturated zone for streams and drainage lines, or if no evidence of such a zone, then from the edge of the channel
- measured from the edge of the current saturated zone for swamps, wetlands, springs and other bodies of standing water.

Operations within buffer strips:

- trees must not be felled from within buffer strips unless approval is obtained
- trees located in filter strips may be felled but care must be taken to direct them out of the strip. Slash accumulation and soil disturbance in the filter strip should be minimised
- buffers must be protected from damage caused by trees felled in adjacent areas. Tress accidentally felled into buffers may be removed if significant damage and disturbance to vegetation and soils of the buffer can be avoided
- machinery must not enter a buffer strip except for construction and use of approved stream crossings
- machinery must not enter filter strips except at agreed crossing points, and soil disturbance must be minimised.

The code also recognises the dual role of streamside buffers in water quality protection and in creating wildlife corridors.

Other guidelines

Riparian Road Guide

The guidelines detailed above have generally been developed to maintain or enhance water quality and habitat in rivers and streams as a result of native forest harvesting. Some of the guidelines discuss extraction, and make reference to river crossings, but only a few make special provisions for road building. Conventional road building practices focused on ease of travel, convenience, and safety, and roads were often located alongside waterbodies and through riparian areas. Little attention was given to environmental effects, but conventional approaches to road building sometimes cause undesirable environmental changes: alteration of flow patterns, riparian areas dried out, erosive force of water increased, water quality changes, and loss of plant and wildlife habitat (Terrene Institute 1994). The Terrene Institute in Washington D. C., in cooperation with the U. S. Environmental Protection Agency and the USDA Forest Service, have produced a "Riparian Road Guide" to enhance riparian areas (Terrene Institute 1994). The guide provides advice on the design, location, and operation of culverts, fords for stream crossings, bridges for stream crossings, wetland crossings, and road alignment, but does not specify riparian buffer zone widths. Swift (1986) discussed filter strip widths for forest roads, and concluded the strip widths on forest roads in the southern Appalachian Mountains were greater than necessary after finding that sediment movement downslope of newly constructed roads was less than previously reported. Guidelines have generally been based on the distance of soil movement related to slope steepness and Table 19 summarises a range of recommendations for filter strip widths for forest roads.

Pest management

As for most land management practices, forest management activities also include pest management, but rules, regulations, and guidelines for the use of herbicides and pesticides in production forests were difficult to source. However, the Forest Pest Management Institute of Canada has produced some estimates for buffer widths around streams during the use of permethrin (Payne *et al.* 1985) and glyphosphate (Payne *et al.* 1987). Groundwater and aerial applications were studied separately, and to avoid problems of the multiplicity of riparian zones with different meteorological conditions, worst case scenarios were modelled. Downwind buffers of 15 and 230 m for groundbased and aerial applications of permethrin were recommended to limit water shrimp (indicator species) mortality to 10% for a given permethrin concentration, and crosswind buffers of 5 and 25 m were recommended (Payne *et al.* 1985). Off-target measures of glyphosphate (Roundup Monsanto) were measured at various downwind distances from a crosswind swath aerial application. Results indicated that a riparian buffer zone of 25 m around water bodies was adequate to protect salmon, rainbow trout, and aquatic invertebrates from significant direct effects of the application of glyphosphate (Payne *et al.* 1987).

***Table 19*: Comparison of recommended filter strip widths for forest roads (after Swift 1986)**

Guideline	Percent slope								
	0	10	20	30	40	50	60	70	80
	Slope distance (m)								
General forest area management[1]	8	14	20	26	32	38	44	50	
Municipal watersheds[1]	15	27	40	52	64	76	88	101	
Slight erosion hazard soils[2]	9	17	25	34	43	53	64		
Moderate erosion hazard soils[2]	12	23	31	46	56	68	84		
Severe erosion hazard soils[2]	15	28	41	54	69	85	103		
Finished roads with brush barriers[3]	10	11	12	13	15	16	17	18	20
Finished road without brush barrier[3]	13	17	22	26	30	34	38	43	47
Unfinished road in winter[3]	26	32	43	52	60	68	77	85	94

[1] (Trimble & Sartz 1957); [2] USDA Forest Service (1973); [3] Swift (1986)

7. Existing riparian guidelines: New Zealand

Forest industry guidelines

The New Zealand Forest Code of Practice (LIRO 1993) was developed "to provide forest owners, managers and planners with a procedure that can be incorporated into their planning process to ensure that important environmental values are identified prior to the start up of operations, and that appropriate practices are selected to carry out different forest operations." The aims and objectives of the code are as follows.

Aim: To plan and manage forest operations with regard to their effect on environmental and commercial values.

Objectives:

(i) Soil and water values — To safeguard soil and water values by the appropriate management practices.
(ii) Scenic values — To recognise the effect of forest operations on visual amenity.
(iii) Cultural values — To identify and protect sites of high traditional, historical and archaeological value.
(iv) Recreational values — To recognise the effect of forest operations on existing recreational values and provide new opportunities as appropriate.
(v) Scientific and ecological values — To safeguard areas of high scientific and ecological value.
(vi) Forest health — To maintain the health of the forest.
(vii) Site productivity — To maintain the productivity of the site and adopt practices that ensure sustainable use.
(viii) Off-site impacts — To consider the effects of forest operations on people.
(ix) Safety - To ensure forest operations are carried out safely and comply with the requirements of Safety Codes.
(x) Commercial values — To ensure forest operations are carried out in a cost-effective manner and consider both short-term and long-term implications.

The code includes an impact appraisal process followed by a code of practice or best options, and environmental guidelines. The operations code includes techniques for the following:

- ACCESS: Stream crossing; access roading and tracking
- LAND PREPARATION: Herbicide application; hand felling; tracking; firebreaking; burning; grazing
- ESTABLISHMENT: Planting; releasing; grazing; fertilising
- TENDING: Pruning; waste thinning
- PROTECTION: Disease control; animal control; fire control; road maintenance; firebreaks; weed control; grazing
- HARVESTING: Roading; landing formation; tracking; felling; processing; extraction; stream crossings; transportation

Where appropriate, these techniques aim to reduce impacts on waterbodies; harvesting techniques consider the protection of streamside vegetation, but no guidelines are available in the code to indicate how much or which components of the streamside vegetation should be protected.

Industry guidelines

Further to the New Zealand Forest Code of Practice, many forestry companies have developed, or are in the process of developing, their own riparian or streamside management zone guidelines. Commercial sensitivity prevents them being detailed here, but it is evident that considerable thought and effort has gone into them. One advantage of individual industry or company guidelines is that they can be tailormade to the respective forests and forest conditions, and can include environmental and commercial realities. This has been done in some of the guidelines viewed by the authors. Others have followed the New Zealand Forest Code of Practice, and others are still in development.

Regional council guidelines

Provision for riparian management strategies in New Zealand are provided for in the Resource Management Act (1991) (see Section 5 of this review). Regional councils have now produced a variety of documents, plans and guidelines for resource management. Provisions specific to riparian management or land use near waterbodies developed by regional councils are detailed in Appendix I. Despite the proposed or draft status of many of the plans, few councils have opted for regulations on riparian management, and most favour an approach that uses a variety of non-regulatory or alternative methods rather than prescriptive rules. Most common amongst these methods have been a greater provision of information on riparian zones, and education programmes aimed at the industry and public alike. Alongside this was a recognition of the need for greater consultation with parties involved and a desire to prepare and/or implement non-regulatory guidelines on riparian management. It is not clear who will develop the guidelines, and how. Other methods include a greater liaison with territorial authorities, the use of economic instruments, and an understanding of best management practices. Anticipated outcomes from implementing this variety of methods are focused on improved water quality and habitat, recognising the benefits of riparian management outlined earlier in this review.

Other

An early attempt to present guidelines for riparian management were provided by Hicks & Howard-Williams (1990), and Visser & Fenton (1994) suggested a framework for developing guidelines in four steps:

Step 1: Identify the important values in your stream and streamside areas.
(i) Water quality
(ii) Aquatic habitat
(iii) Wetland areas
(iv) Soil quantity
(v) Streamside vegetation

Step II: Divide waterways into classes.
e.g., Class A waterways — width 1.5 m or more; well defined streambed; important native fish populations; trout or salmon spawning; wetland areas over 20 m^2.
Class B waterways — continuous or intermittent streams; small gullies; wetland over 5 m^2.

Step III: Establish Streamside Management Zone (SMZ) width.
e.g., To reflect the region that can significantly impact the values in each class of waterway.
Class A streams — 30 m SMZ
Class B streams — 10 m SMZ

Step IV: Determine SMZ requirements.

Focusing on the protection of the five identified values, a series of precautions and guidelines can be established to protect these values.

The most comprehensive guidelines for riparian management were published in 1995 by NIWA and the Department of Conservation (Collier *et al.* 1995b). Established primarily for agricultural environments, the guidelines are aimed at regulatory authorities, management agencies, and the Department of Conservation, and provide an overview of the significance and importance of riparian zones. The guidelines are in two volumes: Concepts and Guidelines. Guidelines for riparian management are provided for the following.

- Increasing channel and bank stability (STABILITY)
- Protecting streambanks by planting trees and shrubs (STABILITY: TREES)
- Managing remnant vegetation on streambanks (STABILITY: REMNANT)
- Managing stock grazing on damaged streambanks (STABILITY: STOCK)
- Reducing inputs to watercourses via overland flow (CONTAMINANT)
- Reducing inputs to watercourses in subsurface flow (NITRATE)
- Improving the light climate of streams (LIGHT)
- Improving watercourse temperature regimes (TEMPERATURE)
- Improving inputs of terrestrial carbon to watercourses (CARBON)
- Improving the supply of terrestrial carbon to watercourses (CARBON: SUPPLY)
- Improving the quality of terrestrial carbon in watercourses (CARBON: QUALITY)
- Increasing the retention of terrestrial carbon inputs (CARBON: RETENTION)
- Attenuating flows (FLOW)
- Increasing terrestrial habitat diversity (HABITAT)

Where appropriate, each guideline contains information on the following.

- The nature of the problems addressed by the guideline
- Ways in which riparian management can help solve the problem
- Objectives and targets for management
- What data are required to help select the most appropriate management practice
- Field investigations necessary to collect data and information
- Predictive methods to help in assessment of what riparian management might achieve
- Methods of implementation
- Justifications and assumptions associated with each guideline
- Potential side effects and limitations of the proposed management
- Confidence limits associated with the proposed methods
- Using the guidelines

No guidelines were presented for forestry or forest harvesting, but estimates of optimal width and performance riparian zone widths for reducing contaminants in overland flow from pastures are provided.

In the Whangapoua Forest on the Coromandel, Murphy (1989) identified the main hazards from forest harvesting as floods and siltation associated with the high-intensity localised rainstorms, and suggested the following guidelines.

- Logging by hauler operating upslope to ridgetop landings on slopes of 12° or steeper
- Riparian strips of 20 m or more on all watercourses draining 50 ha or more
- Coupe size to be determined by landing site and use of riparian reserves as boundaries
- Initial logging to use existing roads; new roading to follow ridgetops where possible
- Harvesting to be restricted in any one major catchment to ensure that adequate cover is maintained
- Harvesting to break up large age-class plantings in steep headwater areas to reduce the impact of streams coalescing on the floodplain

As a final conclusion to his review of riparian zone management in New Zealand, Murphy (1992a) suggested the following strategies for riparian zone management:

1. Identify those parts of catchments where land use and activities near streams are likely to make careful riparian zone management particularly important for the control of water quality.
2. Within those parts of the catchment where special riparian zone management is important, identify and map areas where overland flow commonly occurs after rain and where soils become waterlogged.
3. In those parts of catchments requiring special conservation measures, delimit riparian zones that cover as much of the streamside area generating saturation overland flow as possible, bearing in mind both the claims and likely impacts of competing land uses.
4. Take opportunities to acquire reserve land along streams and around the edges of lakes and estuaries.
5. Encourage the growth of dense vegetation, especially a thick ground cover. Fence the vegetation to exclude stock where its maintenance is particularly important. Introduce ordinance provisions in district schemes if necessary to protect important riparian lands and vegetation.
6. Discourage artificial drainage and reclamation of riparian lands.
7. Use riparian zone designation flexibly as a tool to help control land development impacts.

These strategies have focused largely on improving or maintaining water quality and are not restricted to forestry, but apply to all land uses.

8. Effectiveness of riparian buffer zones in production forests

Monitoring

Despite the literature available on the effects and benefits of riparian zones for protecting water quality and instream values, and the guidelines detailed above, there have been few long-term studies of the effectiveness of riparian zones in forests. Wissmar (1993) discussed the need for long-term stream monitoring programmes in the forest ecosystems of the Pacific Northwest and highlighted some of the problems and shortcomings of poorly stated objectives and plans as:

- coordination between disciplines
- definition and understanding of the time constraints for accomplishing objectives
- accommodation of probability and uncertainty
- utilisation of predictive methods
- evaluation of indirect and direct cumulative effects

Wissmar (1993) regarded long-term monitoring as the key for bringing together management organisations, researchers and decision-makers to improve the management of natural resources and suggested procedural requirements for developing monitoring programmes.

A number of guidelines and techniques are available for monitoring forest practices (Platts *et al.* 1982, Grant 1988, NCASI 1988, MacDonald *et al.* 1991, Ralph *et al.* 1991, Pentec Environmental 1991). MacDonald *et al.* (1991) attempted to define the key elements that lead to a successful monitoring project, depending on the forest activities (i.e., forest harvest, road building, fertilisation). Grant (1988) proposed the RAPID (Riparian Aerial Photographic Inventory of Disturbance) technique as a method for using measurements made from aerial photographs of riparian canopy disturbance to evaluate changes in channel conditions through time and to link changes with possible upstream causes. The RAPID technique can also be used for scoping or identifying sensitive stream reaches and basins.

Compliance

Lord *et al.* (1992) reported on the results of voluntary compliance with Best Management Practices in east Texas. Overall, 88% of the representative sites sampled received a fair or better overall compliance rating, and varied as follows.

Highest compliance on sites	Lowest compliance on sites
• managed under public ownership	• owned by non-industrial private landowners with < 1000 acres
• where a forester was involved	• where a forester was not involved
• with low soil erodability	• where soil was highly erodible
• where the landowner was familiar with BMPs	• where the landowner was unfamiliar with BMPs
• where the logger or contractor was familiar with BMPs	• where the logger or contractor was unfamiliar with BMPs
• where the activity was supervised by the landowner or a representative	• where work was unsupervised
• where the activity was site preparation or commercial thinnings	• where the activity was clearcutting

The east Texas study found that SMZs were most common on perennial streams (89%) as required by the BMP guidelines. What is notable is that while SMZs were not required for intermittent streams as part of the BMP guidelines, several major forest companies were found to be delineating SMZs (encountered on 68% of the intermittent streams) on intermittent streams. When SMZs were present, it was found that width recommendations were generally followed, with 93% of the sites having them of adequate width (18 m or more). The integrity of the SMZ was protected 86% of the time and indicates that an effort was made to stay out of the SMZ. Stream sedimentation (and high incidence of debris in streams) remained a problem in the east Texas study, but debris and sedimentation were less of a problem in streams with SMZs. Stream crossings had the most significant effect on water quality.

Economic impacts

Little research has focused on the economic impacts, if any, of riparian management in production forests. Olsen *et al.* (1987) undertook a case study on a 1336 acre catchment in Oregon to determine the harvesting and transport requirements of three riparian management scenarios. They concluded that the more restrictive the regulations (i.e., greater riparian management requirements) the greater the costs incurred, which they attributed to restrictions on conifer harvest within riparian zones. FERAT (1993) made an overall economic and social assessment of forest ecosystem management but did not refer specifically to riparian management.

9. Summary

This review has considered some of the benefits of managing riparian zones in production forests and detailed some aspects of riparian guidelines for forestry activities both overseas and in New Zealand. The benefits of riparian zone management have long been recognised in New Zealand and overseas, and the advantages and disadvantages of riparian zone management are generally well known. However, while the effects of forestry and riparian zones on the environment, particularly streams, have been documented, it appears that the detailed processes and pathways by which riparian vegetation and its management influence waterbodies and aquatic biota is still poorly understood. These gaps have significant implications for the development and implementation of riparian zone guidelines for forestry practices in New Zealand. Nevertheless, existing research has shown that riparian zone management within both native and production forests has benefits for water quality, instream habitat (sediments, temperature, woody debris) and biota, and biodiversity.

Riparian guidelines developed overseas appear to have limited direct application in New Zealand. First, they have been developed from very different legislation, generally quite unlike the New Zealand Resource Management Act. Second, these guidelines have occurred largely in the absence of detailed research information, and, as a result, are often heavily prescriptive and may overburden the forestry industry with unnecessary regulations that add no benefit to the environment. Third, New Zealand has a diverse and unique environment which many of the existing guidelines have not had to consider. Furthermore, many international guidelines deal with harvesting of native forests, whereas in New Zealand harvesting activities centre on exotic production forests. The implications of exotic forest plantations and harvesting on aquatic environments are less understood than in native forests.

These elements are reflected in existing and proposed planning documents being produced by the regulatory authorities (regional councils) who have, on the whole, favoured non-regulatory and educational methods to manage riparian zones and forestry effects on waterbodies (summarised in Table 20). The use of these mechanisms acknowledges the need for further research and information, as well as the need to be site-specific in determining riparian management requirements.

Several themes are apparent in the existing guidelines (summarised in Table 21); many have been developed from a waterbody classification system, and have generally favoured a system based on the use of the water (e.g., fishery, water supply), or waterbody size (e.g., channel width, lake area). The classifications are generally followed by riparian width prescriptions often linked with additional narrative standards or guidelines. These narratives often include guidelines to recommend appropriate activities within the defined riparian zone. This is in keeping with the definition of riparian zones (Section 3) which acknowledges that activities within a riparian zone are modified to prevent adverse effects on water quality, biota, and habitat within the watercourse.

Despite the variety and number of existing guidelines, it appears that few are subject to any monitoring, although many of the guidelines are periodically reviewed, either as legislation is reviewed, or as information and research is updated. It will be important that any riparian zone decision-support tools developed for New Zealand allow for knowledge and understanding of the functions and effectiveness of riparian management zones to be incorporated on a regular basis.

Table 20: **Summary of regional council rules, methods, and anticipated outcomes with reference to riparian management as detailed in regional plans. Documents viewed were the most recent available at time of writing. A number of documents are proposed or discussion documents only and therefore detail included within this table may be subject to change before final adoption by the respective councils**

Council	Otago Regional Council	Canterbury Regional Council	Northland Regional Council	Environment Bay of Plenty		Wellington Regional Council		Taranaki Regional Council	Hawke's Bay Regional Council	Environment Waikato
Plan type	Water	Land and Vegetation	Water and Soil	Water	Land	Water	Soil	Water	Water	Water
Plan status	Proposed	Operative	Proposed variation	Consultative Draft	Proposed	Proposed	Proposed	Proposed	Proposed	Consultative Draft
Year	1998	1997	1997	1997	1993	1997	1997	1998	1996	1997
Policies	✓	✓	✓	discussion topics	✓	✓	✓	✓	✓	✓
Rules				unspecified	specified	unspecified		unspecified	unspecified	unspecified
RMZ width										
Within RMZ activities			✓							
Effects on waterways		✓	✓				✓			
Effects on soil & vegetation			✓				✓			
Other methods										
Promotion	✓						✓	✓		
Information and education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Liaison/advocate with district councils/plans	✓						✓	✓	✓	✓
Develop codes/guidelines	✓		✓	✓		✓	✓	✓		
Implement codes/guidelines	✓			✓				✓		
Consultation		✓		✓	✓	✓	✓	✓		
Rules/enforcement		✓	✓	✓				✓		✓
RMZ zones management/BPO			✓	✓			✓	✓	✓	✓
Monitoring									✓	
Water quality standards			✓							
Landcare/community schemes/ property plans							✓			✓
Incentives/economic instruments				✓	✓			✓	✓	✓
Inventory	✓	✓							✓	
Other	✓	✓	✓	✓	✓	✓	✓		✓	
Anticipated environmental outcomes				unspecified						
Water quality maintained/enhanced	✓	✓	✓					✓	✓	✓
No increase in sedimentation	✓	✓	✓		✓		✓	✓	✓	
No increase in eutrophication	✓		✓		✓			✓	✓	
No degradation		✓					✓	✓		
Soil conservation							✓			
Slope/bank stability		✓	✓				✓			✓
Natural amenity values						✓				
Identify/retain RMZ					✓		✓	✓	✓	✓
Other									✓	✓

***Table 21*: Summary of riparian management rules, guidelines, and codes of practice from various international guidelines for forestry management**

Country/State	Year	Classification							Riparian Management Zones			Requirement		Other
		Streams					Lakes	Wetlands						
		Catchment/ Stream Size	Use/Type	Gradient and/or Slope	Flow	Channel type and/or width			RMZ or equivalent widths	Within RMZ rules and/or guidelines	Legislation /Rules	Guidelines /Best Management Practices	Voluntary Codes	
USA														
Washington	1988		✓			✓			✓	✓				Temperature sensitive streams
Montana	1991		✓				✓	✓	✓	✓	✓	✓		
Alaska	1998		✓	✓		✓			✓		✓			
Vermont	1987								✓		✓	✓		
Oregon	1998		✓		✓				✓		✓			
Canada														
Manitoba	1996		✓						✓	✓		✓		for significant resources
Ontario	1991			✓			✓	✓	✓	✓			✓	
British Columbia	1995		✓			✓	✓	✓	✓	✓			✓	Identifies Fishery-sensitive zones
Yukon		✓					✓	✓	✓	✓		✓		
United Kingdom	1993					✓						✓		
Australia														
Tasmania	1993	✓	✓	✓					✓		✓	✓		
Queensland	1988	✓		✓					✓	✓				
Victoria	1996		✓		✓			✓		✓	✓		✓	
New Zealand									✓	✓			✓	

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Appendix 1: **Policies, rules, outcomes, and methods of implementation with reference to riparian management areas detailed in regional plans prepared by regional councils in New Zealand. Documents viewed were those most recently available as at time of writing. A number of documents are only proposed or discussion documents and therefore detail included within this table may be subject to change before final adoption by the respective councils. Further detail is available in the respective documents**

Council	Document	Policy	Rules	Other methods	Anticipated environmental results
Otago Regional Council	Proposed Regional Plan: Water Feb. 1998	7.8.1 To recognise and support the development of appropriate codes of practice and management guidelines for land use activities where those activities could lead to contaminated runoff entering surface water. 7.8.2 To promote the avoidance, remediation or mitigation of the adverse effects of the increased runoff of nutrients and sediments by: (a) Agricultural land uses; (b) Urban development; and © Forest harvesting. 8.7.1 To promote the creation, retention and enhancement of appropriate riparian vegetation.	No rules specific to riparian management – see other methods	15.5.1.1 Assist preparation of codes of practice for land use activities 15.5.1.2 Encourage implementation of codes of practice 15.2.6.1 District Plan provisions 15.4.2.1 Promotion and education 15.4.2.2 Provide information 15.2.7.1 Liaison with territorial authorities 15.4.3.2 Support protection of indigenous biota and habitat 16.6.1.1 Identify and seek to enhance waterbodies degraded by land use activities.	7.9.1Water quality is enhanced so that it is suitable for contact recreation or aquatic life 7.9.2 Existing water quality is maintained 7.9.7 Land use practices that are sustainable in terms of water quality requirements are utilised 7.9.9 There is no increase of sediment or nutrient loads in surface water bodies resulting from agriculture, urban subdivision or forest harvesting.
Canterbury Regional Council	Land and Vegetation Management Regional Plan Part 1. Earthworks and Vegetation Clearance: Kaikoura East Coast	1. Promote land use management that avoids undue soil disturbance or vegetation removal. 2. Control earthworks and vegetation clearance so as to avoid, remedy or mitigate induced erosion and slope instability. 3. Pursue, in conjunction with other agencies and individuals, the identification of areas of natural character, outstanding natural features and landscapes, areas of significant indigenous vegetation and significant habitats of indigenous fauna, mahinga kai areas and sites of importance to Tangata Whenua; and protect them from adverse effects of earthworks and vegetation clearance.	Developed according to mapped areas. Rule 1: Permitted: 1. Vegetation clearance & earthworks - except within incised watercourses - and must meet Schedule 1. 3 Rule 2. Discretionary: Vegetation clearance & earthworks within incised watercourses - and must meet Schedule 1. 3 Rule 3. Permitted: 10. Earthworks where - the distance from a watercourse is greater than 15 m - and must meet Schedule 1. 3 Schedule 1.3: No disturbed soil or vegetation shall be discharged into a watercourse where it is likely to give rise to: (a) the diversion or obstruction of a continually flowing river or stream; or (b) any significant induced erosion of the banks of any stream. (c) any significant adverse effects on any aquatic ecosystem.	1. Regional Rules 2. Public information and education 3. Consultation with agencies and individuals to create regional inventory.	1. A reduction in erosion induced by human activities. 2. Reduced risk of slope instability. 3. Reduced risk of degradation of the natural character of the environment. 4. Reduced risk of the degradation of water quality in streams, lakes and coastal waters.

Northland Regional Council	Variation to the Proposed Regional Water and Soil Plan Aug. 1997	12.6.1 To promote soil conservation as an integral part of all land use and development activities.. 12.6.2 To avoid, remedy or mitigate adverse effects of land use activities on water bodies and their margins, particularly on water quality, water flows and levels, aquatic ecosystems and riparian habitats. 12.6.3 To avoid or reduce the discharge of sediment to all surface waters and to minimise soil losses from land use activities, particularly on land which has a high erosion risk. 12.6.4 When assessing applications for resource consents for land disturbance activities adjacent to water bodies, to have regard to.....(g) the amount of shading the existing riparian vegetation provides. 12.6.7 To promote streamside management along the margins of lakes, rivers and streams, and coastal waters by: (i) recognising the benefits of streamside vegetation (ii) protecting or enhancing existing streamside vegetation, particularly indigenous vegetation, (iii) encouraging the planting of new streamside vegetation, (iv) encouraging the rehabilitation or the creation of wetlands, ...such that the discharges from non-point sources into water bodies are reduced, and river systems are buffered against extremes of high and low flows. 12.6.8 To support industry base training programmes and the development of Codes of Practice for Northland.	35 Rules for land disturbance activities within the Streamside Management Area. 35.1 Permitted if: -visual clarity of river wetland < 40%; visual clarity of lake < 20%. - Riparian veg. Not removed if it does not: impede flood flows, cause bank erosion, and contributes to shade, food, habitat, bank protection (except earthworks but no debris in watercourse). 35.4 Permitted/controlled - crossings if: (a) exposed soil<100m^2 & < 50m^3 (b) Veg. removal <10m along sides of water & < 100m^2. (d) No veg. soil or debris in water or in place where may enter water. 35.8 Access for extraction if: (a) Exposed soil<100m^2 & 50m^3 on each side of water body. 35.3 Discretionary - 1. Vegetation clearance 2. Earthworks not permitted elsewhere 3. Land preparation in SMZ	5.2 Education, provision of information and advice 5.3 Codes of practice and guidelines 5.4 Rules and environmental standards 5.5 Water quality guidelines 5.6 Streamside management 5.8 Integrated catchment management	40.4 The natural character of Northland's wetlands, rivers and lakes and their margins preserved. Surface water to be of a quality that allows aquatic ecosystems to survive in a healthy state. 40.6 Streamside vegetation retained where that would assist the prevention of sedimentation and eutrophication of water 40.6 Streamside vegetation enhanced where that would mitigate soil loss from stream bank erosion and from intensive land uses adjacent to water bodies.
Environment Bay of Plenty	Water Plan Consultation Draft Nov. 1997 Proposed Regional Land	4. Proposed Discussion Topics: 4.1 Water Quality: water quality of surface and groundwater bodies; effects of land use development on water quality; downstream effects of water quality; 4.4 Wetlands: effects of human activities and land development. 4.5 Margins of Rivers, Lakes and Wetlands: appropriate development which has minimal effects in these margins; effects on water bodies from inappropriate development; public access issues; drainage schemes. 4.8 Aquatic habitats and indigenous vegetation: effects of development and land use practices on aquatic flora and fauna; protection of habitats of significant or endangered species. 6.5.3(a) EBOP will maintain a plan that addresses the adverse effects of the discharge of sediment onto land and into water.	Unspecified in Consultative Draft Water Plan Rules specified by land category and activity, with discretionary criteria (flexible and stringent) dependent on factors (e.g.	3.0 Discussion topics 3.1 Regulation (Regional Plans and Rules) 3.2 Transferable water permits 3.3 Best practicable option 3.4 Transfer of powers 3.5 Operational and service activities 3.6 Economic instruments 3.7 Education and information 3.8 Non-statutory guidelines 3.9 Advocacy 3.10 Self-regulation through Codes of Practice 3.11 Cleaner Production 3.12 Environmental Management systems 3.13 No-action 9.2 Education/Involvement 9.3 Incentives 9.4 Soil Conservation 9.5 Soil Conservation Property Plans 9.6 Covenants	Unspecified in Consultative Draft Water Plan 6.5.4(a) Minimisation of the production/loss of sediment and nutrients and

	Management Plan Sept. 1993	6.5.3(b) EBOP will address with relevant industries the methods of mitigating the movement of sediment and nutrients into streams and water bodies. 6.5.3© EBOP will address with relevant industries methods of mitigating adverse on-site effects caused by combinations of farmed animals and grazing regimes on specific susceptible land classes. 6.6.3(a) EBOP will identify significant riparian areas (with landowners and relevant organisations) - regionally and locally 6.6.3(b) EBOP will identify and ensure, with landowners and relevant organisations, appropriate management for the riparian areas identified in 6.6.3(a) through a balanced mix of promotion and rules.	water quality/quantity, erosion/sediment).		movement/deposition onto land and into water bodies. 6.5.4(a) Identification and appropriate management of riparian areas.
Wellington Regional Council	Proposed Regional Freshwater Plan Jan. 1997	7.3.1 To manage fresh water in its natural state in identified water bodies. 7.3..3 To manage fresh water for trout fishery and fish spawning in identified rivers, or parts of rivers. 7.3.4 To manage fresh water for contact recreation purposes in identified water bodies. 7.3.5 To manage fresh water for water supply purposes in identified river 7.3.6 To manage fresh water for aquatic ecosystem purposes in all surface water bodies in the region.	No rules specific to riparian management - see other methods	7.6.10 Organise a forum/workshop on riparian management in the region, involving relevant people and organisations, to identify issue and priority areas. 7.6.11 Provide technical support and advice to landowners 7.6.12 Prepare a booklet detailing the benefits and costs of riparian management techniques, adverse effects of sediment runoff, enhancing in-stream habitat. 7.6.13 Investigate other means for providing riparian management zones in severely degraded areas. 7.6.14 Implement appropriate riparian management practices in areas managed or owned by WRC. 8.1 Co-ordinate development of sustainable land management guidelines	10.4 The natural and amenity values of wetlands, lakes and rivers and their margins are maintained.
	Proposed Regional Soil Plan April 1997	6.1 To promote land management practices that recognise the inherent susceptibility of landforms to erosion 6.1 To encourage the implementation of planned soil conservation initiatives on a whole catchment, sub-catchment or single property basis 6.4 To promote and facilitate the adoption of sustainable land management practices 6.13 To avoid, remedy or mitigate the adverse effects of vegetation disturbance by promoting: • the maintenance and enhancement of vegetation in erosion prone areas; and/or • the conversion of erosion prone areas to forestry or soil conservation woodlots or reversion to native bush; and/or • riparian management; and/or • compliance with industry recognised standards and procedures such as "Forestry Code of Practice" • the maintenance and retention of erosion	Rule 4 Vegetation disturbance on an erosion prone site greater than one ha, is a permitted activity subject to conditions incl: (4) For vegetation disturbance located adjacent to a river, stream, lake or wetland, but outside of areas in rule 6, either: (a) any vegetation, slash and other debris is left on site but in a position where that material cannot enter any surface body, or (b) a windrow of vegetation, slash and other debris must be established Rule 6 Damage or destruction of shrubs and trees by: livestock, handcutting, spraying, burning, mechanical methods in identified areas is a discretionary activity.	8.2 Implement a publicity and education programme 8.3 Convene and run workshops and seminars 8.4 Initiate investigations to determine indicators for sustainable land use 8.5 Monitor sustainable land use 8.6 Promote sustainable land management programmes 8.7 Promote and support development of Landcare and community catchment control schemes	10.1 The potential adverse effects of erosion are controlled, and positive soil conservation initiatives are in place 10.2 The life supporting capacity of soils is maintained 10.3 The adverse effects from soil erosion are reduced because • recognised soil conservation practices are carried out where identified • riparian buffer strips are retained or developed • activities which have a high potential to cause erosion are controlled.

		control plantings 6.14 To regulate soil disturbance activities to ensure that the activity is unlikely to have significant adverse effects.			
Taranaki Regional Council	Proposed Regional Fresh Water Plan Feb. 1998	DIFFUSE SOURCE DISCHARGES 6.3.1 Land use practices which avoid, remedy or mitigate adverse effects on water quality will be encouraged and promoted including: (d) land development and restoration of disturbed land to reduce diffuse source discharge of contaminants to water (f) land management practices, including the discharge of contaminants to land, that avoid or reduce contamination of surface water; (g) land management practices that retain riparian buffer zones. 6.3.2 Existing riparian vegetation along the margins of Taranaki's rivers, streams and lakes will be protected and enhanced, as far as practicable, for the purpose of maintaining or enhancing water quality and the effective functioning of riparian zones. 6.3.3 The Taranaki Regional Council will promote the restoration of riparian margins where riparian vegetation will provide net water quality benefits. 6.3.4 The retirement and planting of riparian margins will be promoted, where appropriate, on all or parts of specified ring plain catchments. USE OF RIVER AND LAKE BEDS 6.6.1 The placement or maintenance of structures within river and lake beds will be managed so as to avoid, remedy or mitigate: (a) adverse effects on the habitat of aquatic and terrestrial flora and fauna, including the passage of fish; (b) erosion or accretion of river and lake beds or banks; (c) the exposure or destabilisation of existing structures within the bed; (d) the effects of flooding and erosion; (e) adverse effects on water quality and aquatic life. WETLANDS 6.8.1 TRC will prohibit the diversion of water, the discharge of contaminants and the drainage or reclamation of specified regionally significant wetlands. 6.8.2 TRC will manage the diversion of water, the discharge of contaminants and the drainage or reclamation of specified regionally significant wetlands. 6.8.3 TRC will promote the protection of all wetlands in the Taranaki region from inappropriate use and development and the adverse effects of appropriate use and development. 6.8.5 The enhancement and creation of wetland	No rules specific to riparian management - see other methods	DIFFUSE SOURCE DISCHARGES 6.3 METH 1 Promote sustainable land management programme 6.3 METH 2 Promote planting and appropriate management 6.3 METH 3 Support the preparation and adoption of codes of practice 6.3 METH 6 Preparation of a Regional Soil Plan for Taranaki 6.3 METH 7 Advocate to territorial local authorities 6.3 METH 8 Advocate and promote the retention and planting of riparian vegetation 6.3 METH 9 Prepare guidelines on principles and practices of riparian management USE OF RIVER AND LAKE BEDS 6.6 METH 3 Promote the retirement, establishment or planting of riparian margins as an appropriate method for avoiding, remedying or mitigating the adverse effects of erosion on the banks of rivers and lakes. WETLANDS 6.8 METH 1 Apply regional rules 6.8 METH 2 Promote protection of remnant wetlands 6.8 METH 3 Promote wetlands through education, provision of information and advisory services 6.8 METH 4 Provide advice, information and technical assistance 6.8 METH 5 Prepare guidelines on: (a) principles and practices of riparian management; (b) mechanisms for protecting wetlands. 6.8 METH 6 Advocate use to relevant agencies, use of legislation 6.8 METH 7 Consider use of economic instruments	DIFFUSE SOURCE DISCHARGES 6.3 ER 1 Adverse effects of diffuse source discharges avoided, remedied or mitigated 6.3 ER 2 Protection, restoration and enhancement of riparian vegetation USE OF RIVER AND LAKE BEDS 6.6 ER 1 Avoidance or mitigation of adverse effects on the environment of uses of river and lake beds 6.7 ER 2 Provision of fish passage past new and existing structures 6.6 ER 3 Avoidance or mitigation of adverse effects of flooding and erosion. WETLANDS 6.8 ER 1 Reduced loss of natural character of wetlands and their margins 6.8 ER 2 Avoidance of modification of natural character of regionally significant wetlands 6.8 ER 3 Enhancement and creation of wetlands

		areas will be encouraged where appropriate. 6.8.6 TRC will promote the integrated management of the effects of land uses on wetlands.		6.8 METH 8 Advocate to territorial local authorities	
Hawke's Bay Regional Council	Proposed Regional Water Resources Plan Nov. 1996	10-1 To support and encourage measures to preserve and enhance the natural character of the margins of wetlands, lakes and rivers and to protect them from inappropriate subdivision, use and development. 10-2 To promote the retention of remnant indigenous riparian vegetation on the margins of wetlands, lakes and rivers. 10-3 To promote the establishment of appropriate riparian vegetation on the margins of wetlands and rivers where there is an identified need to provide a buffer against the effects of runoff from land use activities, and the establishment of a buffer is likely to provide a net long term benefit.	No rules specific to riparian management - see other methods	• Investigation 10-1 Identify areas for retention and/or establishment of riparian areas 10-2 Determine riparian widths in appropriate areas • Education 10-3 Prepare and distribute educational material • Advocacy 10-4 Advocate to landowners and territorial authorities 10-5 Investigate methods of assistance 10-6 Advocate retention of riparian areas • 10-7 Advocate BMPs top the forestry industry on the margins of wetlands, lakes and continuously flowing rivers, including: (a) Avoiding or minimising the use of heavy machinery (b) Avoiding or minimising the establishment of tracks © Felling trees away from water, or minimise adverse environmental effects (d) Avoiding or minimising soil disturbance • Incentives 10-8 Rate relief 10-9 Make funding available • Services 10-10 Identify whitebait spawning and assist with fencing • Monitoring and Review 10-11 Monitor water quality and land use activities to assess effectiveness of methods	11.1 (a) Surface water quality allowing aquatic ecosystems to survive 11.2 (b) Groundwater quality 11.3 (f) Public access along wetland, lake and river margins 11.4 (g) Riparian vegetation established or retained adjacent to wetlands, lakes and rivers where that would assist in preventing the sedimentation and eutrophication of water.
Environment Waikato	Regional Water Plan: Consultative Draft Plan Dec. 1997	Policy 1: Land Use Effects To ensure that the following adverse effects caused by inappropriate landuse practices are minimised: the leaching and run-off of contaminants such as fertilisers, faecal matter, agrichemical residues, and sediment into waterbodies bed and bank erosion and instability. Policy 2: Streamside (Riparian) Management To promote streamside management as a means of managing: cumulative effects of point source and non-point source discharges of contaminants land uses which affect the margins and beds of waterbodies.	No rules specific to riparian management - see other methods	• Good Management P10-5 practices • Advocacy and Education • Support Care and Community Groups • Integration with District Councils • Mitigation • Economic Incentives • Streamside Enhancement Fund • RMA Part XII Enforcement	• Net improvement in water quality across the region • Net characteristics of streamside areas in the Region enhanced • Maintenance of bed and bank stability • establishment of care and Community