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RIVERCARE

Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation

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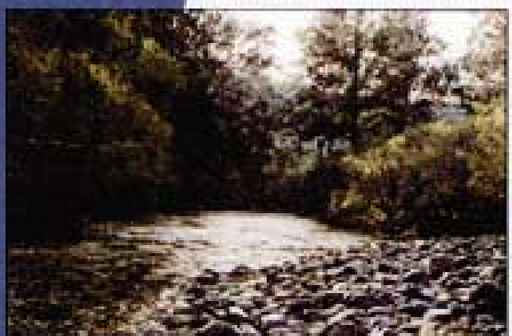

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Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation

A.W. Raine and J.N. Gardiner
NSW Department of Land and Water Conservation

Land and Water Resources Research and Development Corporation
Canberra 1995

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Preface

Riparian lands are those that lie along riverbanks or adjacent to lakes and streams. They include swamps and wetlands as well as riverbanks, and extend along small streams and tributaries that may carry water only intermittently. Riparian lands often have better soils and more moisture than other parts of a catchment and consequently are often highly productive and of special significance to rural industries and landholders. Riparian areas are also a distinctive part of our landscape, as they provide specialised habitat and corridors that link other components of the land, as well as a refuge for plants and animals in times of stress. Riparian lands are thus keystone habitats for conservation of biodiversity. They can exert a strong influence on rivers and lakes, with potential to affect water quality and quantity as well as the plants and animals which live in the water. How we manage riparian lands can also influence the position, shape and stability of river channels. Last but not least, these lands may also have special cultural, recreational and aesthetic value.

Australia's riparian lands have not been well managed since European settlement. They have been subject to particularly intense land use and clearing, and many are now showing signs of severe degradation. In several regions of Australia individual landholders and community-based groups now realise that active rehabilitation and management of riparian lands is needed urgently. The LWRRDC supports this view, and is keen to see these groups join together with State agencies and research organisations to work out practical and economic methods of rehabilitation and management that take account of the special characteristics and requirements of riparian lands.

Unfortunately, we know little about the processes which take place within riparian lands and of the close linkages between terrestrial and aquatic ecosystems. Consequently, it is difficult to predict just what management is required in particular situations in order to achieve our aims for more stable riverbanks, better water quality, or maintenance of intact ecosystems. The corporation has developed a national R&D program to begin to answer these questions. The purpose of the program is to develop guidelines and demonstrate practices for effective and economic management of riparian lands that is aimed at maintaining and improving the condition and values of streams, wetlands, lakes and their associated terrestrial ecosystems.

This Occasional Paper draws on the results of a LWRRDC-supported R&D project that aimed to develop and promote the use of native vegetation in rehabilitating and managing riparian land. The project was based on the coastal rivers of northern New South Wales, but much of the information gained can be modified and applied to other regions. This Paper gives a broad overview of the causes of land and river degradation since European settlement, outlines the interactions between rivers, land and vegetation in shaping the landscape, and describes Rivercare, a practical approach developed in NSW that can be used by landowners and community groups to assess the state of their rivers and, where necessary, to develop and apply management plans for their rehabilitation.

If you are interested in river and riparian management, you are sure to find interesting and provoking information in this Occasional Paper. It presents a historical perspective on the changes in land use and management that are driving what we see happening today to our rivers and riparian lands.

It provides a general overview of the relationship between river flow and channel characteristics—a relationship that reflects current catchment condition and climate—and some of the major causes of channel degradation. It discusses at length the role of native plants in river and riparian management, and how to select appropriate species and use them in revegetation projects. Finally, the Paper provides information on a practical process that can be used by any group of landholders to assess river condition and to work out what management actions may be required.

Phil Price
Executive Director, LWRRDC

1 INTRODUCTION

As a result of vegetation removal—both catchment-wide and within riparian lands—Australia's rivers have suffered since European settlement. The clearance of forests and woodlands for timber and agriculture has altered catchment hydrologies, and land–water interactions that were once stable are now no longer so. The evidence for this, from historical records and the current state of many of our rivers, cannot be refuted.

The widespread clearing of trees and other natural vegetation throughout catchments has meant that the land now responds differently to major rainfall events. Less rain is held up in plant canopies or infiltrates the soil, so that a greater proportion is shed as run-off and more quickly than in the past. At the same time, cropping and grazing activities as well as roads and other earthworks have provided huge sources of sediment that can be moved by run-off into our rivers and streams. Because the riparian lands adjacent to rivers are often especially productive, they have been extensively cleared of natural vegetation. This has left riverbanks unprotected and open to erosion, and has led to floodouts and loss of agricultural land during flooding, particularly when clearing has been combined with unrestricted access by hard-hoofed stock to the banks and river channel. The building of dams for water storage has led to major changes to the flow regimes of rivers, while sand and gravel extraction and other infrastructure works have often resulted in changes in bed level and headcutting of streams, leading to further sediment loads.

This has led in many parts of Australia, over just 200 years, to a dismal picture of degraded rivers, as evidenced by silted channels and filled-in pools, bare and eroded banks, and poor water quality. This is invariably accompanied by erosion and degradation of adjacent riparian lands, and floodplains supporting sparse vegetation showing little diversity or community structure. Yet, historical research tells us that these were once vibrant streams flowing in well-defined and narrower channels, often with a pool and riffle sequence that was vital to the fish and other biota within the streams. The adjacent banks and associated areas once supported rich and diverse plant communities. Research and engineering studies are unravelling the intimate relationships between river form and flow and vegetation, initially stimulated by the need to control bank erosion, but now also in the wider context of ecologically sustainable land use and river management. There is a growing realisation across Australia that riparian lands, in addition to their important relationship to rivers and stream channels, are a special component of the landscape and may need a management system that is different to the rest of the catchment.

Efforts have been made in the past to restore riparian lands and stabilise river channels, particularly following major flood events. The introduced willow (*Salix* spp.) and, in some instances, the poplar have played a big part in streamside revegetation programs to arrest bank and floodplain erosion. The main advantages of willows and, to a degree, poplars are their vigour and adaptability. Their disadvantages are that they are primarily cold climate trees and relatively short-lived in warmer areas, and that they produce homogenous vegetation not at all like the stable and complex communities of native plants that once occupied riverbanks and the riparian zone. The pros and cons of the use of willows and poplars in stream-restoration projects are being debated. Their once-a-year leaf drop is seen by some as environmentally undesirable. The ability of, for example, *Salix fragilis* to regrow from twigs and cuttings means that good management practices need to be in place in streams where such species occur. Recently, concern has arisen about the ability of willows to produce viable seed. *Salix nigra*, which commonly produces male and female flowers, is spreading aggressively in one North Coast river system. Cremer (1995) and Cremer et al. (1995) provide more detail on these issues.

Thus, there has been a need for some time to identify native species that can take the place of willows and poplars, at least in the short-term, in riparian restoration. Experience in the use of native vegetation for riverbank stabilisation is growing steadily, though much further work needs to be done. Research is showing that many native plants are potentially suited to bank stabilisation and other riparian restoration activities, and that they provide an added bonus in the form of ecologically sustainable habitat, both terrestrial and aquatic.

This Occasional Paper draws on the ideas and outcomes of a R&D project, 'Use and Management of Native Vegetation for Riverbank Stabilisation and Ecological Sustainability', undertaken on the New South Wales north coastal region, and jointly funded by the Land and Water Resources Research & Development Corporation and the then NSW Department of Water Resources (now the Department of Land and Water Conservation). A summary of the project's objectives, methods, and results, and a list of its reports, are given in Appendix 1.

Some of the information provided here is based specifically for New South Wales and for the northern coastal rivers of the State. However, much of the information and results can be adapted and applied elsewhere within New South Wales and in other States and Territories. The Paper outlines a wide range of general principles that could be applied widely, while the case studies of the Hunter, Manning and Nambucca show how the general principles and specific information can be applied to individual situations. The aim of this Paper is thus to give a broad overview of the theory and practice of river channel and riverbank stabilisation, and the crucial role of vegetation in these endeavours.

We look first in Chapters 2 and 3 at what is known about land and river conditions pre- and post-European settlement. Although there must be a degree of speculation in some of the historical perspective, the factual accounts help to give a clear picture of the changes that have occurred in the last 200 years and of the forces likely to have been the main drivers of those changes. It is important to gain this long-term perspective, as the changes taking place in catchments and river channels today may well be a reflection of events or actions many decades ago. Understanding the forces driving present-day changes, and their scale, is important background information for catchment management committees and Landcare groups as it provides a context for management objectives and decisions.

Chapter 4 discusses channel stabilisation, river training and the influence of riparian vegetation. There are different views and approaches to this topic, but this chapter tries to set out some of the broad principles that must be considered in any river/riparian management plan. Determining the characteristics for a stable river channel, and its possible location on the landscape, are crucial early steps in restoration work; there is no point in undertaking revegetation or other works until this has been done, as a relatively stable channel is a fundamental requirement. This approach of dealing first with channel characteristics and then with revegetation and restoration is widely used elsewhere [see, for example, 'Stream Analysis and Fish Habitat Design' by Bob Newbury and Marc Gaboury (1994), a summary of Canadian work].

The next section, Chapter 5, introduces the Rivercare approach which has been developed in New South Wales in the form of landholder and community-based management programs to halt or reverse degradation of riparian lands. Chapter 6 discusses the use and management of native vegetation in riverbank stabilisation and ecological sustainability, using results from the Manning catchment as a detailed case study. Information on preparing and implementing a Rivercare plan is provided in Chapter 7, and Appendixes 2 and 3.

This Occasional Paper has been developed with several audiences in mind. Some readers will be particularly interested in the historical perspective, others in the more technical aspects of geomorphology and channel requirements. Others will be interested primarily in learning some of the principles in selecting native species suitable for different positions adjacent to the river channel, and how best to propagate and replant them. Landholders and catchment groups may decide to turn directly to Chapters 5 and 7 in order to examine the practical methods of Rivercare. Much of the text deals with general issues and concepts. More specific information, including users guides arising from the project, are presented in an annex and appendixes.

Our overall objective for this paper is to promote the Rivercare concept by demonstrating that it is founded on solid principles and extensive research. We believe we can now say to land managers, land owners and community groups concerned with the poor state of our rivers and riparian lands, that we do have a basis for a readily-applicable technology to halt the decline, and to improve the condition of our streams and rivers through sustainable management.

2 THE SHAPE OF THE AUSTRALIAN LANDSCAPE

The condition of the land in Australia has changed for the worse since European settlement. It is only relatively recently that we have become painfully aware of the extent of the change, of the unsustainability of many current land practices, and of the need for urgent action to arrest environmental degradation. Even before European settlement, the activities of Aboriginal Australians, principally use of fire in land management, had influenced the vegetation, though generally in a sustainable way.

Barlow (1994) states that the history of Australian vegetation through the Tertiary period (65–0 million years before present) has been one of differentiation from the original Gondwanan flora under conditions of increasing geographic isolation until the Miocene contact with the Sunda plate.

During this time, falling mean temperatures, increasing intensity of atmospheric pressure systems, regionally decreasing precipitation, and increasing seasonality led to enhanced habitat differentiation. The pan-Australian Gondwanan flora diversified into two broad sub-elements known as the Autochthonas Sub-element and the Relict Sub-element (Barlow 1994). The former represents those members of the original flora that have evolved to produce typically Australian taxa, such as the eucalypts, while the latter contains those elements of the original flora that have changed little, as for example, *Nothophagus* and *Podocarpus* species.

One of the major features of the Autochthonous Sub-element is the tendency for many genera to exhibit scleromorphy (literally 'hard form') manifested by small, tough, closely-set leaves. According to Barlow (1994) it is now widely accepted that scleromorphy is an adaptive response to nutrient deficiency marked by physiological processes leading to a reduction in the number of cells formed. Many of the characteristics of the present flora were therefore already in place by the opening of the Quaternary period some 1.8 million years ago. By that time there was a host of scleromorphic species with an abundance of mechanisms to cope with fire and the nutrient-deficient ancient soils (Dodson 1994).

Dodson notes also that these same adaptations were useful in highly seasonal and often perturbed environments which were to mark Quaternary time. He points to three major Quaternary phenomena that have shaped the flortistics and distribution of the vegetation as we know it today:

- dramatic climate change;
- migration of people from Asia; and
- European settlement.

Others (e.g. Flannery 1994) argue that the extinction of the mega-fauna, large herbivorous mammals that used to roam the continent, also has influenced the vegetation. These animals, Flannery opines, were the main consumers of vegetation and likely ate sufficient plant material to moderate the severity of wildfires.

Yet other researchers, including Singh et al. (1981), have traced the fluctuations in vegetation distribution and composition through the Quaternary using pollen grain analysis. They note the expansion and contraction of rainforest elements (e.g. *Podocarpus*) during glacial and inter-glacial periods in the Lake George area near Canberra. Singh et al. found that fires had increased in frequency during the last as compared with earlier inter-glacials and, since the change in climate alone cannot explain the changes in the vegetation, suggest that this may have been associated with the arrival of humans in the area. They surmise that the use of fire by the Aboriginal people may have unwittingly caused the disappearance of tall, open-forest elements (*Cyathea*, *Lycopodium*, and *Podocarpus*) from the vegetation.

Singh et al. (1981) conclude that vegetation changes have been controlled predominantly by climate, except within the last 40,000 or so years when the additional factor–fire–and the possible association of humans have played an important role in the establishment and maintenance of unusually high levels of sclerophyll vegetation for the first time during the last 140,000 years.

Flannery (1994) also argues that, because of the El Niño Southern Oscillation (ENSO), coupled with factors such as fire and poor soils, the flora has adapted to retain and rapidly recycle nutrients. This has led to plant communities in which species have become efficient but inter-dependent. He points out that if key species are removed from these communities 'the entire co-evolved structure can collapse'.

From an examination of weather records, Flannery concludes that ENSO has functioned since at least the beginning of the nineteenth century and that floral and faunal indicators suggest that it has existed for very much longer, perhaps millions of years.

The environmental changes caused by uncontrolled fire must have had a severe impact on the lives of Aborigines. By lighting many small, low-intensity, controllable fires—a strategy dubbed 'firestick farming'—the Aborigines mitigated the drastic effects of wildfires. They also helped to prevent the loss of remnant patches of rainforest that provided critical resources at certain times in parts of northern Australia (Flannery 1994).

Flannery suggests that Aboriginal people may have adopted firestick farming initially as a response to the threat that the natural fire regime posed to the animals on which they depended for food. If so, it was a highly effective response, for it maintained an assemblage of more than 20 middle-sized mammal species over much of the continent for over 35,000 years. However, it was a management system entirely dependent upon the understanding and actions of a people who had coevolved with the landscape. Europeans, on the other hand, came with a supreme ignorance of their new environment. Their arrival was to prove the undoing of 35,000 years of conservation effort and sustainable land use.

By the time of European settlement, the fire-sensitive rainforest communities were restricted to more favourable sites which either precluded fire (e.g. scree slopes) or provided highly favourable growing conditions (e.g. fertile soils of high rainfall areas such as the Comboyne, Dorrigo, and Alstonville plateaus on the North Coast of New South Wales).

The alluvial flats of New South Wales North Coast rivers also provided an important refugia for rainforest communities, with fertile soils and access to ground water allowing survival during dry periods. The explorers of the northern rivers describe in detail the density and complexity of these forests, or 'brush', which were present along the lower sections of all the major rivers. Vernon (1987) describes the Hunter River in the Morpeth to Maitland area as having been lined right to the water's edge with dense brush containing red cedar (*Toona australis*), rosewood (*Dysoxylum fraserianum*), scentless rosewood (*Synoum glandulosum*), white cedar (*Melia azedarach*), lilly pilly (*Acmena smithii*), and figs (*Ficus* spp.). The brush extended two to three miles back from the river in places and was said to be almost impenetrable. Floyd (1990b) describes the floristics and structural diversity of riverine rainforest remants in the North Coast region, and classifies them into a number of rainforest suballiances that are uniquely riverine.

European Settlers and the 'Land of Plenty'

General

European settlers initially saw in Australia a land of plenty and treated it accordingly. They rapidly cleared the land for agriculture and pastoralism as if resources were unlimited and unrelated. They compared the woodlands, forests, and pastures around the new colony to those in their former homelands. The similarities were obvious but the differences escaped them. The earliest years of settlement were boom times, but the bust soon came, as Flannery (1994) relates:

> Disillusionment was inevitable, for those first impressions of Australian landscapes were mistaken. Australia's woodlands, which so impressed European explorers as being like an English gentleman's park, bear only the most superficial similarity to English woodlands. English woodlands grow in a seasonal climate on fertile soil. They are the result of generations of shaping. The trees are planted, and are kept in their place by intense grazing pressure exerted by a vast biomass of large herbivorous mammals. The grazers fertilise the grasses in a nutrient cycle that allows for tremendous productivity.

The effects of grazing and the end of firestick management rapidly changed the composition of the vegetation. Once open woodland areas became dense thickets of woody shrubs. The native fauna suffered too, from the combined effects of vegetation change, competition with introduced livestock and rabbits for food, and the arrival of an efficient predator—the fox.

Eclipsing all these, however, was the effect on the soil. In the words of Flannery (1994):

> But perhaps the greatest tragedy was the destruction of the soil itself, upon which everything depended for existence. By the early twentieth century, soil erosion had become a problem of such proportions that it could no longer be ignored, and by the 1930s most state governments were taking some action to assess the situation. In the 1930s, the CSIR (forerunner to the CSIRO) appointed the British scientist Francis Ratcliffe to investigate the problem in northern South Australia. He arrived when much of the state had had no or little useable rain for 12 years. But, as he astutely observed, the drought and its associated soil erosion were not solely a consequence of this lack of rain. As he travelled north, Ratcliffe found a courageous but deluded people struggling to maintain their dignity and economic viability in a land which had died under them.

Gross overestimates of the extent of forests encouraged overexploitation of the timber resource. In 1847, Commissioner Fry of the New South Wales Colonial Service told a commission of enquiry that it would take five or six centuries to clear the 'Big Scrub' of northern New South Wales. Clearing began in earnest in the 1880s and by 1900 the Big Scrub was gone. As recently as late last century it was being put about that half of New South Wales and over 90% of Victoria was timbered country.

Because of such views there was little concern about wastage of timber. Flannery writes that: 'In Victoria an official suggested that at a minimum, just one tenth of the useable timber cut was ever used. On the goldfields of New South Wales prime timber trees were destroyed for their bark, which was used to roof huts'.

In summary, treatment of the environment since the arrival of Europeans in 1788 has caused substantial degradation and changes to the landscape. Some effects on the environment have been more subtle. Many native plants, for example, have proven to be intolerant of the higher levels of phosphate in the soil that have followed broad-scale application of phosphate fertilisers.

Environmental degradation continues, as evidenced by, for instance, continuing soil and riverbank erosion and dying rivers. Efforts to halt this need to be redoubled. Rivers, like the land, probably settled into a stable regime for most of the past 15,000 years, driven by climate and other natural events, and firestick management.

The character of river systems when white settlers arrived can be reasonably accurately gleaned from the historical record. Excerpts from early accounts of the Hunter and Manning river valleys are given in the next section.

The historical record charts the progress of the ensuing degradation that was wrought on the land by early European land users. We can see how the land and rivers reacted to that usage, and today we face the problem of how to manage them to provide, at the minimum, physical stability and biological sustainability within the limits of current land management.

We mentioned earlier the sharp physical boundaries between fire-tolerant and fire-sensitive communities. We noted also the interdependence of native species and that the removal of a few key species from a system can cause collapse of a whole coevolved plant community. The species which occupied the rainforest communities of the alluvial flats of the rivers of the New South Wales North Coast had similarly evolved to be interdependent. With the loss of many key riparian species from the riverbanks, the succession process has been altered. Primary riverine colonisers such as river oak (*Casuarina cunninghamiana*) have flourished under post-settlement conditions, and the lack of seed sources for secondary and tertiary successional species, because of their clearing, has prevented continued succession to a stable, diverse riverbank flora [see Floyd (1990a) for a description of rainforest succession]. Site-specific microclimatic conditions have also changed following clearing, to the extent that—without the protection of a rainforest canopy and the succession of secondary successional species—many sensitive species are not regenerating from the few parent trees remaining.

The problem of excess phosphate in stunting or killing native vegetation growth has also been mentioned. We are probably seeing these symptoms along many of our river systems at present. The current spate of poor management practices including overgrazing, cultivation, inappropriate use of herbicides and fertilisers adjacent to streams etc. needs to be highlighted and corrected.

River managers are faced with the extraordinarily difficult task of trying to restructure a highly degraded system, using species of vegetation which are highly co-dependent on both one another and their management regime, one which has evolved for 40 to 60,000 years. This whole system has been largely destroyed in the last 200 years. Community perception in some areas is that rivers can be put back to the condition they were in when Europeans arrived. This is unrealistic, given the dramatic changes in land use that have occurred since then. We need to set our sights on goals that are achievable and sustainable within the context of current land use and socio-economic constraints.

We need to work out a river regime that is in tune with our current land use and management practices and which can provide the community with *stable, clean, healthy, productive rivers* but in the context of our current expectations and within the limits of the community's capacity to pay. To aspire to rivers that looked like those of 200 years ago is a pipe dream in light of the vast changes that have been wrought on them and their catchments. We need to set realistic, balanced goals and head for them. To see what goals might be realistic, we need to look first at where we have come from—how the rivers have changed since European settlement. We take the Hunter and Manning rivers as examples.

The Hunter and Manning Rivers

The Hunter and Manning valleys were amongst the earliest settled by Europeans in New South Wales.

The Hunter River (first called the Coal River) was discovered in 1797 and permanently settled in 1804 (King's Town) to provide a further convict settlement and a source of materials for Sydney and for overseas trade.

We know from the historical record that timber, especially red cedar, was cut in large quantities in the valley, along the floodplains and riverbanks (King and Woolmington 1960). The area was also heavily grazed. Rolls (1981) in his seminal account 'A Million Wild Acres' notes that 'By 1826 the Hunter was eaten out. Stock were taken up to the farthest branches of the river in search of grass'. Similar practices followed in the Manning Valley.

One of the earliest accounts recognising the importance of trees in maintaining riverbank stability is found in the *Sydney Gazette* of 1803, where orders from Governor King state:

> From the improvident method taken by the first settlers on the sides of the Hawkesbury and creeks in cutting down timber and cultivating the bank, many acres of ground have been removed, lands inundated, houses, stacks of wheat, and stock washed away by former floods, which might have been prevented in some measure if the trees and other native plants had been suffered to remain, and instead of cutting any down to have planted others to bind the soil of the banks closer, and render them less liable to be carried away by every inconsiderable flood ...
>
> As several settlers have been and are now fencing on the lower part of the Hawkesbury, along the Nepean, South Creek, and George's River, in situations where the above evils may be prevented, it is hereby directed that no settler or other person to whom ground is granted or leased on the sides of any river or creek where timber is now growing, do on any account cut down or destroy, by barking or otherwise, any tree or shrub growing within two rods of the edge of the bank, except for an opening one rod wide to have access to the water.

Settlers henceforth disregarding this regulation were to be fined fifty shillings for each tree cut down. In an effort to redress the damage already done, the Governor's proclamation concluded:

> It is earnestly recommended to those who already hold farms by grant situated on the side of any river or creek liable to floods, and which have been cleared of timber, to replant the banks with such binding plants and trees as they can procure.

King and Woolmington (1960) note that exploration and mining for coal was an early (1797–1804) activity in the Hunter that led to the discovery of scattered stands of cedar along the riverbanks:

> For the colony at that time this timber was a more valuable resource than coal, for in Sydney, where local hardwood timbers were difficult to work, a considerable demand existed for such fine timbers as cedar for both building and furnishing purposes. Thus, the search for cedar, which was carried out by the exploiters of Hunter River coal, provided a powerful incentive for upstream exploration, and indeed the real initial motive for the penetration of the interior.

The exploitation of coal and cedar later became the primary economic aims of permanent settlements established during the period 1804–1820. As timber cutting moved further from its base in Newcastle, subsidiary bases had to be established upstream. The demand for building material in a rapidly growing Sydney increased the tempo of exploitation.

The period 1820–1860 saw the opening of the Hunter lands to free settlers and led to the immediate and rapid rural development of the region. King and Woolmington (1960) note that the rivers played two key roles in this. First, the areas of alluvial soil, which were those most keenly sought by the agricultural settlers, were located along the river banks; and second, the rivers constituted the already established and only effective communication link, via Newcastle, with Sydney, which was initially the principal market for the agricultural products of the region.

Some idea of the rapidity of rural development is given by the growth in numbers of livestock: '... whereas in 1820 the domesticated animals of all kinds in the region numbered only 875, by 1827, the "cedar flats" alone supported 25,000 cattle and 80,000 sheep, and the region provided a nursery for sheep farming in the northern interior as squatters began driving Hunter River stock across the ranges northward' (King and Woolmington 1960).

The Hunter Valley had obviously been subject to large floods in pre-European times, though these seem to have caused relatively little permanent damage. The large flood of 1955 in the valley appears to have stimulated speculation and study on this issue, leading to the 'rediscovery' of accounts of even larger floods in the early days of the colony.

Leo Butler (1956) refers to one of these earlier accounts, by a Mr Loder, in his article 'Flood Threat Over a Promised Land':

> But Loder's words were not lost; forgotten they were for half a century or more, but they were not lost. After the 1955 flood, William Fitzgerald, then in retirement at Branxton, remembered them and told the story to scientists from Newcastle University College. And these scientists have been able to establish that, round about 1806, a big flood did occur at Singleton which was possibly (there is a great deal of research work yet to be done on the subject) far bigger than the 1955 flood.
>
> The 1955 flood, big as it was, did not overtop the saddle between Reservoir Hill and the bend of the river from Long Point into Singleton. ... it seems likely that [this flood] swept over this saddle, making it higher than any flood the white man has seen in the Hunter.

Robert Dawson, once Chief Agent of the Australian Agricultural Company, writes of his travels in the North Coast region in a book 'The Present State of Australia' published in London in 1830. The following extract gives a picture of the state of the rivers before large-scale degradation.

We crossed several very deep and wide streams, or rather channels, which proved the existence of heavy and rapid torrents of water at certain seasons. They were from ten to fifteen yards wide, and were now in the same state in which they are generally found during summer—perfectly dry perhaps for intervals of a quarter of a mile, then pools of still but pure water. The banks of most of them were steep, and frequently occasioned some difficulty to the horses in crossing them: at other places they were nearly flat, and overgrown by vines, intermixed with small trees, resembling, both in size and bark, the sapling ash, having, like the vines, a dark green foliage, and were growing under very large and lofty spreading trees, whose leaves resembled those of a laurel both in size and colour. These places sometimes extended half a mile, and were frequently a hundred yards or more in width, alternating with the steep banks on both sides; the high and low bank being almost invariably opposite on each side of the channel, so that the passing through the thick vines was sometimes as troublesome to the pack-horses as the ascending of the high banks on the other side. Small rich alluvial flats or meadows, lightly timbered, invariably attended these streams on the exterior of the brushes, which form a pleasing and interesting feature of the country. These low jungles or brushes are inhabited by a small bird, which is constantly making a noise resembling the filing of a saw heard at a distance [probably the restless flycatcher, *Myiagra inquieta*]. We were always warned by them of the existence of deep channels, long before we saw them: at first, they were extremely disagreeable to my ear: but as they became associated with pleasant scenery, rich soil, and good water, the opposite sensations were created.

Large brush areas of the type described by Dawson used to occur on the alluvial flats along most major streams of the NSW North Coast. The remnants of these are described in Floyd (1990b).

The Australian Agricultural Company was an important influence on the land and land development in the Hunter region, and in the Manning Valley in particular.

In his 'Historic Towns and Buildings of New South Wales—Hunter Region', Tony Crago (1979) writes:

Stroud was named in 1826 by Robert Dawson, who was struck by the similarity of the country to that of the Cotswolds in the west of England, two principal centres of which are the towns of Gloucester and Stroud. The town (Stroud) owes its origin to the Australian Agricultural Company, which was formed in London in 1824, with a capital of £1,000,000, and a grant of one million acres in New South Wales. Neither the grant nor the assignment of 1400 convicts to work the land were fully taken up as the company became dissatisfied with its 'slave labour', although its holdings did, in time, extend from Port Stephens as far north as Taree.

Dawson's association with the company was short-lived and he returned to England in 1828.

The company engaged in a range of agricultural and pastoral activities. Sheep raising was a primary objective, but after many failures it was finally realised that coastal areas of Australia are not suitable for this. According to Crago (1979):

The Company grew its most important and successful crops at the small settlement of Booral, a few kilometres south of Stroud, but these were eventually ruined by rust. Maize, barley, tobacco and silk were all tried with limited success.

In his book 'The Manning Valley', W.K. Birrell (1987) notes the passing of the Australian Agricultural Company and the extent of land degradation by the turn of the century.

The financial losses incurred by the Company in its pastoral activities during the economic depression, the loss of stock and the damage done to the pastures during the natural disasters of 1895–96 climaxed many years of disinterested management and a declining interest in the pastoral activities of the Gloucester Valley as the highly productive Liverpool Plains Estates were developed. For a number of years the pastures on the Gloucester Estate had been deteriorating through excessive and uncontrolled grazing, much of the ringbarked and cleared land had degenerated into scrub and secondary forest growth, and the once luxuriant native grasses along the Gloucester, Avon and Bowman River valleys had been succeeded by coarse and unpalatable blady grass (*Imperata* species). ...

In 1903 the Australian Agricultural Company disposed of the forested and infertile tracts of the Estate in the vicinity of Port Stephens for five shillings per acre and the Gloucester Cattle Station was sold to a land investment syndicate, Gloucester Estates Ltd. ...

The new management immediately began to effect improvements [sic] on the estate prior to its subdivision into small farm portions for private sale. This included the ringbarking or clearing of about 20,000 acres, the erection of fifty miles of fencing, the clearing and cultivation of part of the brush land which was then sown down to paspalum pasture to demonstrate its grazing potential, and the cultivation of a part of the river flats along the Gloucester River on which grain and fodder crops were grown to illustrate the agricultural possibilities of the soil.

The sale of the farm portions on the Estate was the beginning of a new phase in the land use and settlement pattern in the Gloucester Valley and the lower valleys of its tributary streams the Avon, Bowman and Barrington Rivers. Small farm settlements and a land use pattern of diversified agriculture and intensive grazing soon replaced the pattern of sparse settlement and extensive grazing which had dominated the area for seventy-five years.

Poor management and the resulting degradation of land and riverine vegetation did not pass totally unnoticed. The

Department of Public Works Annual Statement of 1906 notes:

> The time must come when tree planting will have to be resorted to throughout the catchment areas and the banks of all the coastal rivers, to counteract the bad effects resulting from the destruction of forests and scrubs by ringbarking and clearing, which have affected the velocity and scour of floods. The present is an excellent time to take action on these lines, because the silt being carried by floods will be vastly increased, owing to the clearing of the upper river flats and banks and their cultivation which in many cases is carried as close to the water's edge as possible; to allow this silt to be carried out to sea instead of assisting nature to deposit it on the low lands bordering the tidal water of the rivers is a very short sighted policy.

Summary

In this chapter, we have looked briefly at some of the forces shaping the Australian landscape in recent geological time. We have noted the changes wrought by the arrival of humans – Aboriginal and European – and the extinction of large herbivorous animals. Aboriginal 'firestick farming' was a sustainable land use strategy. European practices of clearing the land for agriculture and pastoralism, on the other hand, quickly proved to be unsustainable, as evidenced by changes in vegetation and the health and form of rivers and the riparian zone.

In the next chapter, we focus on catchment-wide changes in the Hunter Valley since European settlement, in particular changes in the incidence and damage caused by flooding of the Hunter River and resulting from the change in land use practice and vegetation management imposed by the early European settlers. This information provides further foundation for the development of realistically targeted riverbank rehabilitiation work and management that recognises the interdependence of riverbank vegetation and river channel form, and of the components of riparian zone plant communities.

3 THE IMPACT OF EUROPEAN SETTLEMENT ON RIPARIAN VEGETATION, AND RIVER FORM AND FLOW

From historical accounts we can identify three major changes in the Hunter River catchment since European settlement: the vegetation has changed; the impact of flooding on the land has changed; and the form, or morphology, of rivers has changed. The first two have been alluded to earlier. Here we look in more detail at all three, and at their interrelationships. As regards vegetation, we focus in particular on the vegetation associated with river and streambanks.

Riparian Vegetation

Local residents called before the Colonial Commission into 'Floods in Hunter' (NSW Colonial Government 1870) often reported on the denudation of riverbanks in the Hunter.

A Mr John Eckford examined by the Commission on 23 September 1869 reported that the banks of the river at Singleton had previously been thickly timbered except for small clearings. Also, there had been scrub in the bights of the river, he said, but not on the forest land. A Mr John Brown also reported that there had been thick scrub on the riverbanks. The scrub had disappeared leaving what he called false shelves on the banks. There had been no scrub on the river flats, which he described as like a park in their natural state, with a tree here and there. This same pattern of vegetation distribution is evident in other relatively incised North Coast streams, and probably typified most streams of the region. Floyd (1990b) indicates that gallery rainforest (or 'brush') grew (and in some instances continues to grow) along the stream banks, where access to ground water compensates for periods of low rainfall. Above this, on the floodplain, vegetation is reliant on rainfall alone and consists of scattered eucalypts and angophoras. Such examples can be found on the Richmond River on the North Coast of New South Wales.

In Helen Brayshaw's 'Aborigines of the Hunter Valley', published in 1986, there are some interesting insights into the river vegetation in the first part of the eighteenth century. She recounts that:

> Tall cedar trees once graced Patersons and Wallis Plains in the Maitland-Morpeth area where there were also lagoons, silted flood channels and open swamps. The vine brushes along the banks of the river were up to 2-3 miles deep in places. The Quaker missionary James Backhouse (1843:388,397)

> ... took a walk into one of the luxuriant woods, on the side of the Hunter, such as are termed Cedar Brushes, on account of the colonial White Cedar, Melia Azedarach, being one of the trees that compose them. Eugenia myrtifolia and Ficus Muntia are among the variety of trees in these brushes ... These Cedar Brushes are also thick with climbers, such as Cissus antarctica, the Kangaroo Vine, Eupomatia laurinae, a briary bush, allied to the custard-apple but with an inferior fruit, and several Apocineae.

In his book 'Dawn in the Valley', published in 1972, W. Allan Wood writes:

> Behind the mangroves bordering the lower reaches of Hunter's River were limited stands of Coal River Pine that were soon cut out. The rest of the low country was occupied by swamp oak and flooded gum trees, tea-tree scrubs, and wide open tracts of swamp land. A little further upstream the rich alluvial lands commenced, with their cedar brushes, vine entangled scrubs, and contrasting strips of open flooded country.

> When surveying at Wallis Plains in 1822, Henry Dangar frequently referred to dense brush which made the river bank inaccessible but he also found some open spaces of good flooded land. George Boyle White reported on 3 June 1833 that the northern bank of the Hunter from Lorn downward was lined with jungle or brush almost impenetrable, and to form a road from the Government township site (East Maitland) towards the Paterson River it would be necessary to cut through the brush for 2 or 3 miles from the Hunter River crossing.

Wood also recounts the explorations of Allan Cunningham in the Upper Hunter region. Of particular interest to us is Cunningham's description of the Upper Hunter River just above its confluence with the Goulburn River. Here, in 1825, the explorer and botanist found the river to be not above 50 yards wide, but too deep for pack horses to cross (Wood 1972, p. 47). We can pinpoint where Cunningham reached the river, and compare his description with aerial photographs taken in 1955 (Plate 1) and 1993 (Plate 2). These highlight the substantial change in the form of the river that has occurred since European settlement. In 1955, the river was some 300 yards wide at the point described by Allan Cunningham.

Another early traveller in the same region was Peter Cunningham, who described the Upper Hunter in its virgin state, and the progress of settlement, before his departure for England in 1826. It is also interesting to compare his description with Plates 1 and 2 which show agriculture as the dominant land use and an absence of trees along the river and on the alluvial flats.

> Twickenham Meadows consist of a series of the finest alluvial flats, dotted lightly over with trees, with good forest land behind. This rich and beautiful tract of country was but very lately discovered by Mr H. Dangar, and was all granted away in a few months after his first visit.
>
> One of the finest natural prospects that can be witnessed ... The flat alluvial lands spread out before you are matted with

Plate 1. Aerial photograph of the junction of the Upper Hunter and Goulburn rivers in 1955, showing the place at which explorer Allan Cunningham in 1825 described the Upper Hunter as 'deep and not above 50 yards wide'.

luxuriant herbage. Branching evergreens are scattered singly or in clumps, with the river winding through the midst; its steep and grassy banks with a deep green fringe of dark-foliaged swamp oaks. The gently rising hills beyond, thinly clothed with wide-spreading forest trees, extend in diversified magnificence as far as the eye can reach.

Wood, in 'Dawn in the Valley', also recounts that Lieutenant W.H. Breton, R.N. visited the Hunter in 1832, staying at Dalwood. On the creek bank opposite the Government Cottage he saw the brush, which he described as 'one of the thickest vine brushes in New South Wales; so thick that is it difficult to penetrate even a few yards'. There he also saw the great brush fig tree measuring 60 feet around its triangular butt. Today, these areas are mostly grassland and pasture, and devoid of trees.

Flooding

It was clear to the early settlers that at least one flood of enormous depth had passed through the valley in the not so distant past. As news of this spread, there was, understand-

Plate 2. Aerial photograph of the junction of the Upper Hunter and Goulburn rivers in 1993. Comparison with Plate 1 shows the results of extensive river training and realignment works undertaken after the 1955 flood.

ably, some alarm, particularly among the residents of Maitland, who had visions of their settlement being washed away. There was a perception that the threat of deep flooding receded with each year of land change in the catchment. On the other hand, the damage caused by relatively minor floods progressively increased.

Helen Brayshaw in her 'Aborigines of the Hunter Valley' (Brayshaw 1986), reporting on the explorations of Allan Cunningham in the region, writes:

> In April 1825 Cunningham saw 'the dark line of forest trees marking the Course of the River as also of the channels of a water discharged into it on its northside'–this was the junction of the Goulburn with the Hunter.
>
> In the branches of the large swamp oaks higher up the Goulburn there had been flood debris twelve feet above the ordinary level. Here on the lower Goulburn, however, Cunningham and his party 'could not but with awe remark: flood debris 50 to 60 feet above the river level'. Where he had first joined the Hunter on the 1825 expedition, north east of Mt Thorley, stubble high in the trees had indicated a great flood, 'such a deluging ... however having not taken place since the residence of Settlers on the lower part of the River or even since the settlement of Newcastle has been established'.

Much earlier, in 1802, Barrallier had said of the Pattersons River '... it is a stream which will never be of use to a New Settlement, if I may Estimate the degree to which floods rise by traces on trees of above 40 feet high'. Also, in his 'Account of the State of Agriculture and Grazing in New South Wales', James Atkinson (1826) quotes 'a Gentleman in the Colony, of long experience, and accurate observation' on the 1806 flooding of the Hawkesbury–Nepean River, to the south of the Hunter:

> The inundation which happened in March, 1806, carried away grain and live stock to the amount of £35,000. The waters on the Nepean rose ninety-two feet above the common level of the river, threatening to carry every thing away before it. At the Hawkesbury, houses, barns, stacks of corn, together with some thousands of hogs and other live stock, were swept away, leaving nothing but desolation and ruin behind.

It seems certain that this is the great flood of which evidence was found by Cunningham and many other early residents and travellers.

In the summary of the report of the Colonial Commission into 'Floods in Hunter' (Moriarty Report 1870), Commissioners Moriarty, Whitton, Pell, Bennett and Adams write:

> From Rev. Alfred Glennie we learn that his brother, Mr. James Glennie, was a witness of the flood of 1826, at Dulwich, about 8 miles above Singleton, and that its height at that place exceeded that of any subsequent flood. He saw also traces of some former and still higher flood. ... The condition of the channel was probably very different then from what it is at present. Mr. W.C. Leslie, who has resided at Singleton since 1841, and who appears to have been a close observer of everything relating to the river, and who is a most intelligent and trustworthy witness, is of opinion that within his own experience the channel has doubled in width, and been cleared of many obstacles to the free discharge of the flood-waters. From Mr. Alexander Munro also we have some valuable evidence as to the enlargement of the channel near Singleton within his experience, which extends back to the year 1830. It is quite possible then that the great rise at Singleton in 1820 may have been caused by a quantity of water which would now flow harmlessly within the banks.
>
> Mr. Moriarty, in his Report to the Minister for Works, has explained so clearly and satisfactorily that the great height of the flood of 1820 at Maitland is attributable probably to the obstacles presented to the escape of the water by the condition of the banks of the river and of the low lands at that time, rather than to the quantity of water which came down, that we have little more if anything to say on the subject. The banks of the river and portions of the adjacent flats were then covered with a dense and tangled scrub, greatly impeding the progress and distribution of the flood-waters. Now that the land is cleared the flood-waters when at their height escape with comparatively little impediment from the neighbourhood of Maitland, the point at which the river in such cases empties itself as it were into a basin. ...

The perception here is that the clearing of vegetation had actually been beneficial, because it had reduced the potential severity of future floods! But at what cost to the land and rivers?

In the body of the report, however, a Mr Alexander Wilson, who had lived in the district for about 36 years, was of the opinion: 'The flood of 1851 did more damage than that of 1840, owing to the cultivation being more extensive'.

Mr John Brown, some of whose comments on vegetation have been mentioned, said that he had observed driftwood high in oak trees that indicated that a flood as much as 12 feet deeper had occurred some time before the floods of 1857 and 1867. He said that the evidence 'was very noticeable, and from its appearance had not been long there'.

A Mr George Wyndham of Dalwood wrote on a number of occasions to the Hunter River Flood Commission in mid 1870, presumably at the time of publication of the Moriarty Report. In the following letter he was evidently concerned with, among other things, the fate of Maitland.

> Our good Parson Glennie has lately published in the Singleton Times (has been copied by the Mercury) extract of a letter from his brother, James Glennie, who witnessed the flood of '26 at Glendon–the flood which I have no doubt, deposited 'my drift-stuff'. The letter states that he went across to Mr. Dangar's

cottage (still in existence), and was shown the height the flood attained to; and Mr. Dangar showed him drift-stuff so many feet higher. I forget the figure, 9, 10, 12; but it is plain that the floods we have seen are mere babies. No doubt 'competent engineering skill' [and] any money enough might save Maitland, M. de Lesseps, and ten millions sterling; but practically the only way to save Maitland is to remove it to higher ground.

In a later letter he wrote:

... Many old residents–the late Mr. Larnach of Rosemount for one, and I believe old Mr. Howe and others–have been heard to say that when they came to Singleton there were drift and flood marks round the trees on the tops of both McDougall's and Howe's Hills at Singleton, as if the water had been several feet over the highest part of both of them, and see Mr. James Glennie's letter also, the log shown to him by Mr. Dangar at Neotsfield, 11 feet above 1826 flood.

and

... Lower down the river, near Corinda, was a drift log up in a large dead gum-tree, which Mr. Bell, M.L.A., tells of and he says this drift he is sure was about 15 feet above the highest 1857 flood.

The foregoing reports provide good evidence that there had been major floods of great magnitude before European settlement, with water reaching heights that have not since been repeated. It appears that the size of the 1806 flood was much greater than the 1955 flood, the latter considered to be a 1 in 75–100 year flow. The most interesting aspect from our point of view is that major floods before European settlement apparently did little damage to the riverine environment, while more recent floods–such as that in 1955–destroyed long sections of riverbank thereby lowering the natural levee and increasing the susceptibility to flooding of the adjacent land. Also, the 1955 flood sterilised large areas of the lower Hunter with deep sand and caused severe silting of the Newcastle port area.

River Form

Some of Mr Alexander Munro's evidence to the Colonial Commission on Floods in the Hunter has already been mentioned. We present here in greater detail some of his responses to questioning about changes in the form of the river.

Q. Was the flood of 1832 as high as the flood of 1857?

A. In some parts it was higher. It made the channel larger, so that the flood of 1857 had more room to get away.

Q. There was a change in the channel of the river between 1832 and 1857?

A. Yes, a great change.

Q. Whereabouts?

A. All along the banks.

Q. Do you think there has been such a change in the bed of the river since 1832 that the flood is enabled to get away more easily than in former years?

A. Yes.

Q. What change do you refer to more particularly–the clearing away of the timber?

A. Each flood making channels for itself.

Q. Have you seen yourself any considerable change of that kind?

A. Yes, I have gone up the bed of the river for a considerable distance when I could not get a drink of water, and the river was much narrower then. Even opposite here at Mrs. McDougall's the bank is cutting away on to the cultivation land, and the ford is also getting wider.

Q. Are not other places getting an increase–does not one man gain what another loses?

A. Not here.

Q. Does it not make ground in other places?

A. No. In back creeks, such as Fordwick Creek, where the land is flooded considerably, the floods have taken away a deal of land.

The observations of a Mr William Copeland Leslie supported the view that a substantial change in the form of the river had taken place.

Q. The water has now a better chance of getting off?

A. Yes. I am not at all afraid of floods. I believe that every flood makes room for itself. Opposite my own door half an acre of land has fallen in, and part of the bed of the river; near the opposite bank was a road where you could have driven horses and carts. There has been an immense increase in the size of the channel. The river was many years ago, full of stumps and debris, but the last two or three floods have washed it quite clean from about here. When I came here first, at the crossing there was a beautiful island, well grassed over, and covered with oak trees.

Q. Near Brown's?

A. Near Brown's bank. Everyone of those oak trees has been swept away, and feet and feet of the bank too.

He adds: 'The ground is trodden down by cattle and grass and dead timber have been cleared away, so that the water runs quicker off the land than it did formerly'.

J.H. Maiden, Government Botanist, in his presentation (Maiden 1902) on 'The mitigation of floods in the Hunter River' to the Royal Society of New South Wales, also noted the effects of stock on the land:

The innumerable sheep tracks are accentuated, and the ground everywhere is pulverised by the feet of the sheep wandering after the scanty herbage. When the rain falls much of this pulverised soil, carrying with it grass plants (latent) and seeds of grasses and various forage plants must be washed into the creeks and again into the Hunter, which becomes discoloured. As the country is nearly all wrung out it is to be hoped that many of these seeds will be arrested by the fallen timber. ...

The innumerable creeks will doubtless require to be dealt with in any effective remedy for the mitigation of floods. There is evidence everywhere of broadening streams, of banks breaking down and good soil washed away. Apple (*Angophora intermedia*), and River Oak (*Casuarina Cunninghamiana*), doubtless filled these flats, and they have been removed in order to cultivate the rich land to the fullest extent.

Outcomes

By the end of the nineteenth century in the Hunter catchment we thus have a picture of large-scale clearing of riverbanks and adjacent areas that previously supported a rich and diverse vegetation. The Hunter and associated rivers and streams were becoming wider and shallower as the banks and surrounding flood plains were eroded.

That these changes occurred so rapidly, well within half a century, highlights the fragility of the Australian landscape.

In 1903, the Parliamentary Standing Committee on Public Works, after assessing various schemes for flood mitigation in the Hunter, concluded:

That, while the carrying out of no one of the schemes under consideration can be recommended beneficial results may be attained by, as far as practicable, restoring the country around the sources of the river and its tributaries, and the banks of the river and its tributaries, to their original condition in regard to forests and vegetation, by replanting them with suitable shrubs, and grasses.

In 1948, the Report of the Hunter River Flood Mitigation Committee, known as 'the Huddleston report' commented on condition of the Hunter River and its tributaries at that time:

After one hundred years of misuse and neglect the Hunter River and its catchment area are in a deplorable condition and it is apparent that if widespread flood rains, such as have been experienced in the past, occur again, considerable inundation and damage will result.

Over the major portion of the catchment, but in particular on the Isis and Page Rivers and the upper part of the Hunter, where over 90 per cent of the land has been alienated, the country has been largely denuded of trees and, due also to over-grazing by stock and rabbits, there are great areas of active erosion. ...

... There is no doubt that the wholesale destruction of timber over the years has contributed largely to the erosion of the countryside and the breaking down of the river banks.

The disastrous flood of 1955 further brought home the extent of the deterioration of the Hunter River's condition, fulfilling the foregoing prediction (see Plate 3). A report (Parliament of New South Wales 1956) of the Committee of Advice on Flood Control and Mitigation that was subsequently established quotes the conclusions of Mr H.G. Strom, Divisional Engineer for Rivers and Streams, State Rivers and Water Supply Commission, Victoria, who was commissioned to investigate riverbank erosion along the Hunter River before and after the flood. Mr Strom reported, *inter alia*:

Plate 3. Sediment deposited by the Hunter River at Maitland following the 1955 flood.

- River erosion along the Hunter River and its tributaries has reached alarming proportions, and must have a serious effect on the economy of the valley.

- The quantity of material set in motion by this erosion is so great that it may well be the principal contributor to the siltation of Newcastle harbour. A provisional estimate of the material dislodged by river erosion along the Hunter and its tributaries in the recent flood would be 20,000,000 to 25,000,000 cubic yards [15–19 million m^3]. The total quantity eroded in previous years would be much greater than this.

- This erosion has other ill effects besides siltation. Large areas of highly fertile land are totally lost to production; communications and services are threatened or damaged; trees are dislodged and become dangerous floating timber; and natural levees are eroded, increasing the liability to flooding of adjacent lands.

- Sporadic execution of isolated works designed merely to meet immediate local needs is, in the long run, futile. Such works are likely to be destroyed by erosion on uncontrolled sections nearby, or else rendered useless by a change in river course.

Pressures of Development

The changes to the Hunter River and its tributaries are not unique, though the rapidity with which they have occurred may be. In North America, for example, the removal of riverbank timber consequent on the steamboat era had significant impact.

The following is an extract from an article entitled 'Restoration of the Middle Mississippi River', by the American Corps of Engineers.

> Timber, from along the banks of the Mississippi River, was used for fuel on the steamboats and lumber for construction of settlements.
>
> A new era in the life of the Village of St. Louis began in 1817 when the first steamboat arrived at the St. Louis levee.
>
> Also great forests of timber were cleared from the rich alluvial bottoms for agricultural purposes. In 1848, a traveler named Henry Lewis, wrote that the 'steamboats on the Mississippi all burn wood, and such are the immense quantities destroyed in this manner that, had not nature provided an inexhaustible [sic] supply, some other fuel would have had long since to take its place'.
>
> As the timber from the bank lines of the river was being removed, the banks became less stable and began to deteriorate rapidly. The river width increased from an average of 3600 ft. in 1821 to an average of 5300 ft. in 1888.

Maiden (1902) in his presentation on 'The Mitigation of Floods in the Hunter River' notes, inter alia, that: 'I do not think that truth has been sacrificed to fine writing and do feel that what has been taking place in the Mississippi has its counterpart in the Hunter Valley, New South Wales ... '.

The paddle steamers which used to ply the Darling River as far north as Bourke (Plate 4) could not do so today because the river is largely unnavigable. In the hey-day of the riverboats over 100 paddleboats, towing twice as many barges, would be steaming up the Darling to the outback ports of Wilcannia, Bourke, Brewarrina and Walgett. At Bourke, steamers from South Australia and Victoria unloaded provisions and building materials then loaded wool for England. A punt connected the north and south banks. A lifting span bridge, the 'Gateway to the Real Outback', at north Bourke was the first of this type in New South Wales. It was opened in 1883. In 1885 the railway reached Bourke tying it more closely to Sydney than before. The riverboats fed the railhead.

Plate 4. The paddle steamer *Excelsior* on the Darling River circa 1895, loading timber for fuel to fire the boiler.

On the Murray River, Echuca was the major river town. Indeed, in 1872 the 'Port of Echuca' was the second largest in Victoria in terms of goods landed and transported, with 240 boats per year cleared through it at that time.

The riverboats were powered by timber cut from the banks and adjacent flood plains. This timber was also used to build wharves, bridges, locks etc. and even to make the steamers and barges themselves.

The wash from the paddles and barges no doubt also contributed to undermining the river banks. Timber blockages and obstructions were cleared from the river systems, further downgrading the ecology of the river.

The coastal rivers of New South Wales have also likely been subject to similar development pressures, with a pattern of tree removal and exploitation of land that is oft repeated. The effects of land and vegetation destruction have had severe impacts on our waterways.

Comments such as those from Alan Barnes and Ted Stanton in the Gloucester and Barrington Landcare Groups are typical. They recall the period from the late 1940s until the 1960s when rabbits infested the riverbanks. After floods the wrack which lodged in the trees was burnt to discourage rabbit harbourage. Similarly, blackberries grew extensively along the river systems in the Gloucester area. They were sprayed extensively. Both these processes effectively destroyed the bank vegetation. During that period there was heavy stocking of properties with dairy herds and the vegetation that did grow on the banks was often trodden down or eaten. Gravel extraction took place, essentially without regulation.

Floods through this period caused much damage to the banks. Subsequently, in the 1960s and early 1970s extensive river training works were put in place in this area. These works rely largely on willows to effect bank stability. This is very slowly changing as the willows die out and are replaced by natural regeneration of native vegetation.

Des Daley, Stock and Station Agent at Wauchope, interviewed in November 1990, noted that the Hastings River had once been navigable to the old wharves about 2 km upstream of Beechwood, below Cameron's falls. Large ships used to sail up into this area, he said, but by 1913, the railway had come through and the shipping declined. Des grew up in the Upper Hastings and knew that the waterholes had been up to 40 ft deep. Those same holes today are silted up, and only about chest deep. One reason for this, said Des, was intensive dairying, particularly after the Second World War. Bulldozers were bought cheaply from the Americans in the islands, imported and used to clear large tracts of land–steep or otherwise. They had done it on their property, he said.

Stan Glyde, a long-term landowner in the Nambucca Catchment, provided in 1994 a detailed list of many waterholes which existed before the 1949–50 flood filled them in. He recounts in a 1995 report how 'The river which was previously a long, deep, slow meandering stream was in one stroke converted into a fast running, shallow drain ...'.

Summary

In this chapter we have dipped into the historical records on land-use changes and their impact on the Hunter River in particular. We have seen a rapidly changing picture of the effects of land clearing for agriculture and pastoralism on the river and its catchment. We can surmise that the river once flowed in a deeper and narrower channel with densely vegetated banks. Vegetation protected the banks and flood plains from erosion during both normal and flood flows. With land clearing, the speed of overland flood flows has changed, causing either scouring of flood plains or deposition. Remnant bankside vegetation became more prone to flood damage and less effective in reducing bank erosion. Banks have eroded, streams have become wider and shallower. The sequence of degradation culminated in the flood of 1955 which caused great damage throughout the whole Hunter catchment and saw tens of millions of cubic metres of soil and silt washed towards the sea.

This same pattern is repeated many times on the rivers of the North Coast of New South Wales and elsewhere in Australia.

In the next chapter, we begin to look at means of revegetating the riparian zone to halt streambank and flood-plain erosion and return rivers to something approaching a more stable form. River works to control flow and minimise erosion may take many forms: the key is the inclusion of vegetation in river rehabilitation programs to ensure the establishment of sustainable outcomes with a range of wider ecological benefits.

4 CHANNEL STABILISATION, RIVER TRAINING AND RIPARIAN VEGETATION

The main body of this paper covers theoretical and practical aspects of channel stabilisation techniques in general, and the use of native vegetation in the riparian corridor to maintain the health of waterways. In many cases it will be impossible to return streams to pre-European settlement condition. What we seek to achieve is to return them to a stable state that can be maintained within the constraints of current land management practices, though the latter clearly need modification in many instances.

The key to stabilising, managing, and restoring degraded rivers lies in an understanding of the interactions between river form and flow, and bankside vegetation. When this can be achieved for a particular river or stretch of river, manipulation of the interactions then becomes the basis for protection and improvement of the riparian zone (Figure 1).

As we have noted, the style of management in place when Europeans first came to Australia had evolved over many thousands of years through the native Australian management culture. Records show that burning of the country was a common practice as part of their hunter–gatherer life style.

Since European settlement, intensive agricultural practices, overstocking, introduction of exotic species (e.g. rabbits, vegetation), and other human activities have led to extensive changes to the Australian landscape. Alternate floods and droughts, and the failure to accommodate these in land management practices, have exacerbated these changes, particularly along the river channels. Forests have been destroyed, banks have eroded, and channels have widened and silted up.

Many rivers are now in a degraded state, with gravel bars that are being vegetated by pioneer species such as river oak and bottlebrush capable of colonising hostile environments and favoured by habitats in full light. These stands of vegetation create blockages which in turn lead to further bank erosion during flood flows. Note too, however, that these same species, because of their hardiness and vigour, are also important elements of riverbank revegetation programs. The key is to have the right plants in the right place.

The limited seed source of the original riverbank species in many catchments also inhibits the regeneration of diversity along the river, which is needed to produce a cohesive, stable system. Species such as privet, camphor laurel, and willow also tend to inhibit the propagation of the diverse range of species needed for a comprehensive self-sustaining system to re-establish itself.

From the hydrological viewpoint, the basic underlying requirement for improvement of flood control, navigation, and the like is a river channel that is stable, at least in the short term. Rivers that are not physically stable will not be environmentally stable. Despite the risks of scour and deposition which are inherent in natural river processes, any system which exhibits accelerated erosion processes–that is, is out of regime–will have little prospect of long-term stability unless management processes and strategies are applied to it.

In this chapter, we look at the roles of vegetation, and of physical or engineering aspects of river form, and begin to synthesise this information into a relatively simple approach to the use of riverbank vegetation for maintaining stable, non-erosive river courses. This is further developed in the Rivercare strategy outlined in the remainder of the paper.

Modern river management must take a multi-disciplinary approach, with engineers, fluvial geomorphologists, botanists and aquatic ecologists contributing to the development of strategies for stream restoration. This approach ensures that restoration projects yield both stream stability and ecological sustainability.

The Role of Vegetation in Bank and Bed Stabilisation

The use of vegetation as a medium for bank stabilisation in the river systems of New South Wales started in earnest after the 1955 flood and was extensively employed in the Hunter River. The principal vegetation type used for many years has been the exotic willow. In recent times there has been a growing resistance to its widespread use and there has been a concerted push to look for alternatives and, in particular, suitable native vegetation. At best, the outcome of use of native vegetation as an initial bank protection medium has so far been variable. This will improve as experience grows in the selection and use of appropriate species.

The extensive use of willow accompanied the introduction of the concept of *river training* (see Box 1). Before this time methods of direct bank protection such as groynes, bank battering and grassing and similar approaches had been tried with mixed success, but in most instances the systems eventually failed through structural collapse or outflanking (Plate 5).

In essence, the concept of river training looks to guiding flows through eroded sections of a river system from one stable section to another by the assistance of suitably located training works set to a stable alignment. The high velocity erosive flows are moved away from the eroding banks. These training works slow the flow between the alignment and the eroding bank and promote deposition of sediment adjacent to the erosion, thereby preventing the further undercutting of the bank.

The technique which has been commonly used for this purpose employs low wire mesh fences formed into paddocks to entrap the silt (Plate 6). Other structural means such as wooden jacks are also being trialled. These act to retard the flow of the river, causing silt to drop. Willow or some other suitable species is planted in the embayments to hold and bind the deposited silt. This vegetation takes over, in time, to become the means of protecting the bank from further erosion. The various zones of the bank–the toe, and the middle and upper zones–present different habitats and thus require

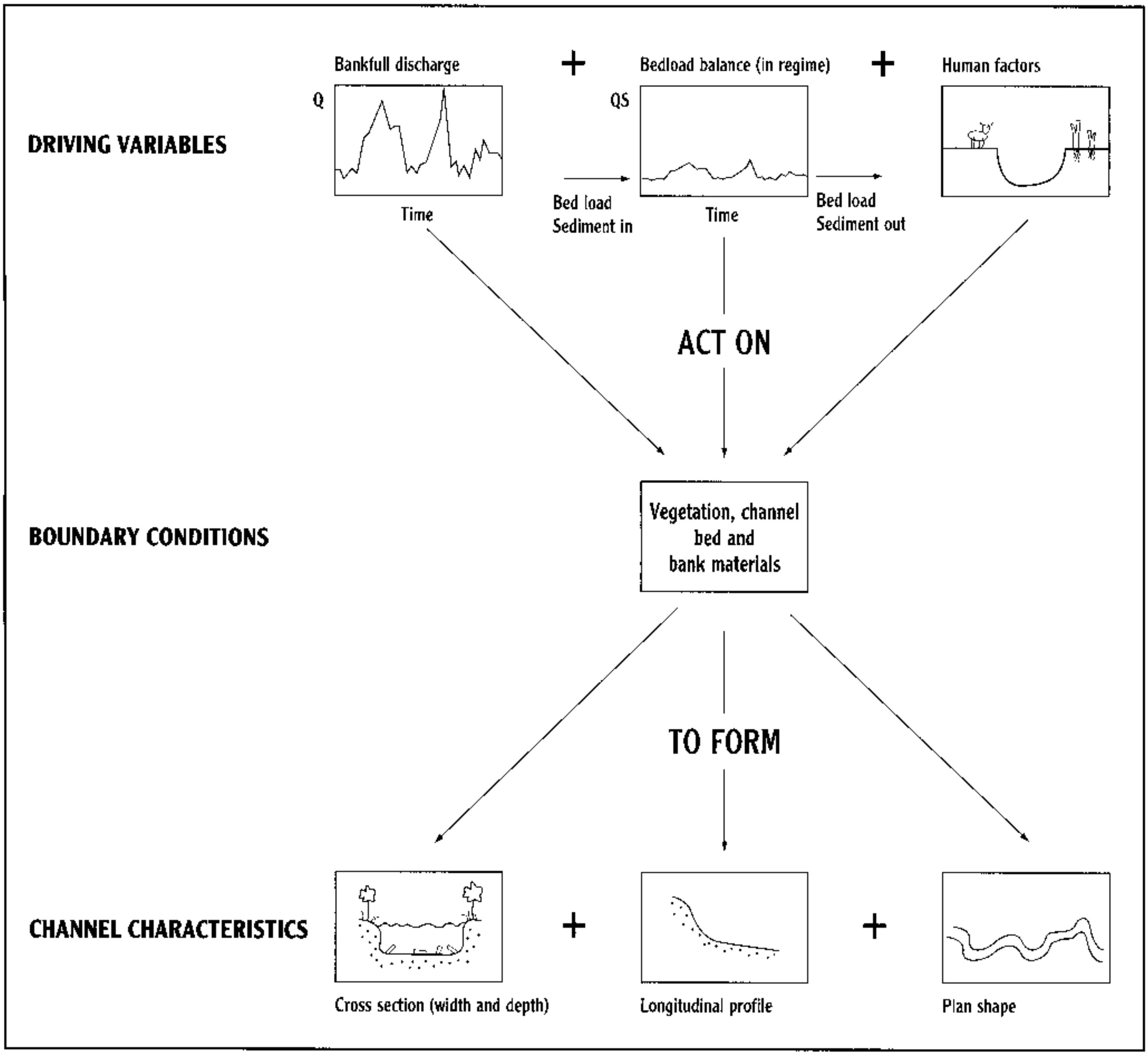

Figure 1. The interaction of discharge and sediment with vegetation in determining river channel characteristics (after Brookes 1992).

plantings of a range of species in stabilisation or revegetation projects. This aspect is covered in detail in Chapter 6.

In some situations, rock toe protection is used as a more suitable medium to hold the bank in place but, where possible, is accompanied by plantings to assist the stability of the rock and to enhance the environmental benefits from the work.

Appropriate riparian vegetation protects riverbanks from the erosive effects of the river in both its normal flow regime and during flooding. The root systems of trees, shrubs, grasses and other vegetation help to hold the soil together, stabilising the banks. An understanding of plant zonation–how the vegetation style and formations progressively change between the water's edge and the top of the bank– is important also. Loss of this zonation through stock grazing, flood damage and the like will weaken the banks. The toe of the bank is a critical area in channel stabilisation schemes. Vegetation that binds the toe provides the foundation for a stable bank and, combined with correct channel widths and alignments and stable riffles, is fundamental to sound river restoration programs.

Box 1. Development of River Training Works in New South Wales

Early types of riverbank protection works in New South Wales involved the construction of training walls and permeable and impermeable groynes.

A 15-foot high groyne built in the Hunter River at Singleton (see Plate 5) was destroyed by a large flow soon after it was constructed. It was replaced by one of an amended design, but this too was subsequently washed away. Fifteen feet was chosen as the height because records indicated that this level was exceeded, on average, on only two days per year.

On the Pages River a series of groynes made of river gravel enclosed in wire mesh was installed. During the flood flow of February 1955, some damage occurred to the river bank between these groynes and one groyne was outflanked, but remained in position and has now been repaired. Detail of this style of work, which is no longer cost effective, is set out in Reddoch (1957).

Other strategies attempted with little success involved the use of vegetation, but generally in 'structural' rather than naturalistic ways. For example, on high banks adjoining agricultural lands, large bushy-topped trees were anchored along the toe of the bank and the banks battered so as to partly bury their tops. Willows were planted among the tree tops to provide permanent protection for the bank when they had grown sufficiently.

A breakthrough in approach came with the realisation that protecting eroding river banks without also controlling the alignment of the stream would not reduce the amount of silt entering the river. The aim thus became to determine a suitable alignment on which the main flow channel could be controlled, and then to confine the flow on this alignment between two lines of suitable protective work.

The type of alignment sought was a series of regular curves conforming generally to the existing meander pattern of the stream in stable reaches, and accommodating fixed structures such as bridges or road crossings.

Key factors in determining the alignment were the minimum radius for the curves and the distance between protective works. The following engineering formula of Grant (1948) was adopted for determining the former:

$$\text{Radius (in chains)} = 1/6 \sqrt{\text{discharge (in cusecs)}}$$

Note here that the radius selected depended strongly on the particular discharge chosen. In these early applications of the formula, high discharge rates were selected. For work on the Pages River near Aberdeen, for example, the maximum recorded discharge for this section of the river was chosen. The selection of such high discharge rates has since been shown to be a fundamental error in that it produced 'flat' radii of curvature. Current applications of this type of formula generally adopt the 1 in 18 month flood, modified for bank vegetation effects, to more effectively take control of the stream path.

To determine the width between the two lines of protective work, the regime formula developed by Lacey (1930) was adopted:

$$P \text{ (in ft.)} = 2.66 \sqrt{Q} \text{ (in cusecs)}$$

Here P is the wetted perimeter of a regime channel in incoherent alluvium corresponding to a flow of Q cusecs. For practical purposes the width of the channel was taken as equal to P. When using this formula it was usual to adopt a discharge somewhat less than the maximum recorded for Q, but as it was intended in this case that the protective work should be developed away from interference by floods, as far as possible, a width equal to that which would be required for passage of the maximum recorded flow was adopted as the width between

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lines of protective work. The figure finally adopted was 8 chains. This has permitted excessive meandering of the stream between these over-wide alignments.

Forms of protective work were attempted, including concrete blocks secured with steel wire ropes, brush fencing, and stonework, all associated with planting of vegetation such as willows. Figure 2 outlines a typical plan for stream control and realignment.

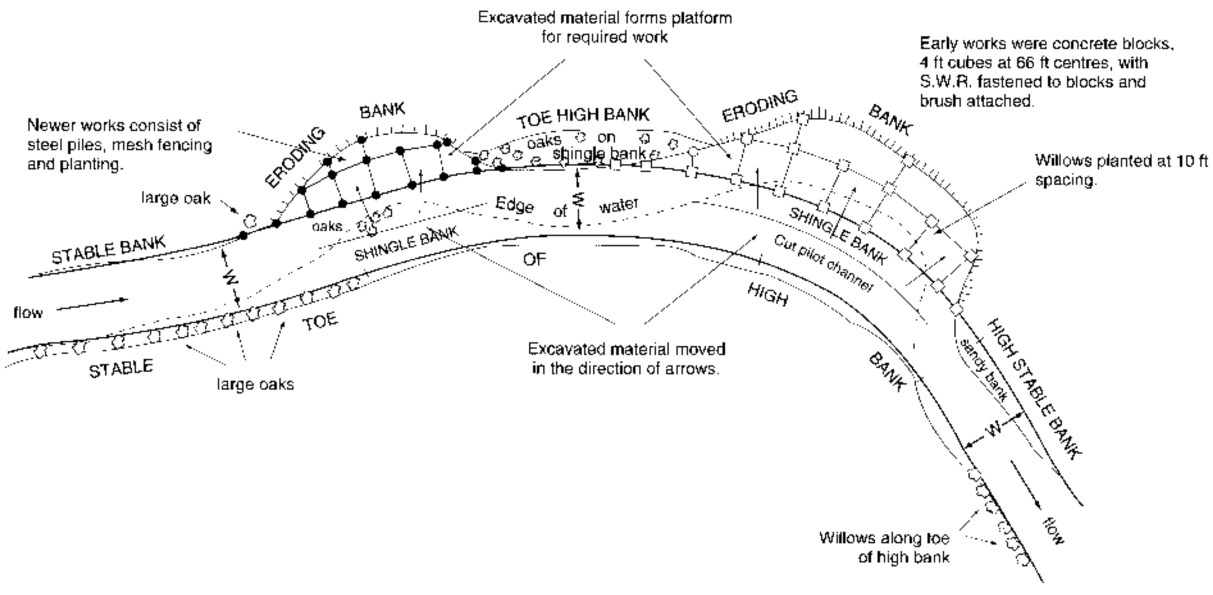

Figure 2. Stream control and realignment.

Shattock (1966) noted the importance in the design of river training and protective works of creating a waterway of appropriate width (W). The width needed to be sufficiently restrictive to encourage proper development of the central channel yet also promote satisfactory accretion of the area within the paddocks on which the protective work of fencing and tree planting has been constructed.

He further reported that experience had shown that, for practical purposes, W (see Figure 2) closely approximates P in the Lacey regime formula (see above). As most of the rivers on which works were carried out were relatively wide and shallow, P approximated the width of the water surface.

Shattock suggested that in using the formula to determine width, the 'dominant' discharge (the weighted mean of all discharges) should be employed. He noted that a check on the dominant discharge was made from observation of the more stable and well-defined sections of the stream in the vicinity and particularly leading to and away from the section being treated. In these sections the 'bankfull' discharge should approximate the dominant discharge.

Rankin (1982) also covers some of the more recent developments in river works. He notes that, since the mid 1950s:

> Instead of constructing isolated works of a sporadic nature at the eroding bank, comprehensive schemes were adopted for the overall control of the course of the river. The river is established on a suitable combination of alignment and with the damaging flows being guided away from, and past the eroding banks.
>
> In selecting a new alignment, the existing configuration of the river is followed as closely as possible. Only in exceptional circumstances, where the river alignment has deteriorated to the extent that it cannot be controlled between the banks, is a major change of course across the alluvial flood plain adopted.
>
> Guidance of the river is achieved by the development of plantations of dense tree growth in the river bed between the selected course and the eroding banks. Protection for the trees is required until they are established. This consists of installing retarding barriers with upper levels about 1 metre higher than the normal low flow level. These barriers generally consist of low flexible cylindrical wire mesh fences laid out on a 15 metre wide grid pattern to provide enclosed embayments in which trees are planted [see Figure 3]. The frontal fence conforms with the edge of the selected alignment, and the laterals (which are normal to the direction of the river) act as obstructions to flow. ...
>
> The main effect of these low barriers is to retard the flow outside the width and alignment selected for the river channel. Because of the reduction in velocities silt, sand, gravel and other debris are deposited in the embayments. The trees consolidate the deposits, and take over from the retarding barriers which ultimately deteriorate.

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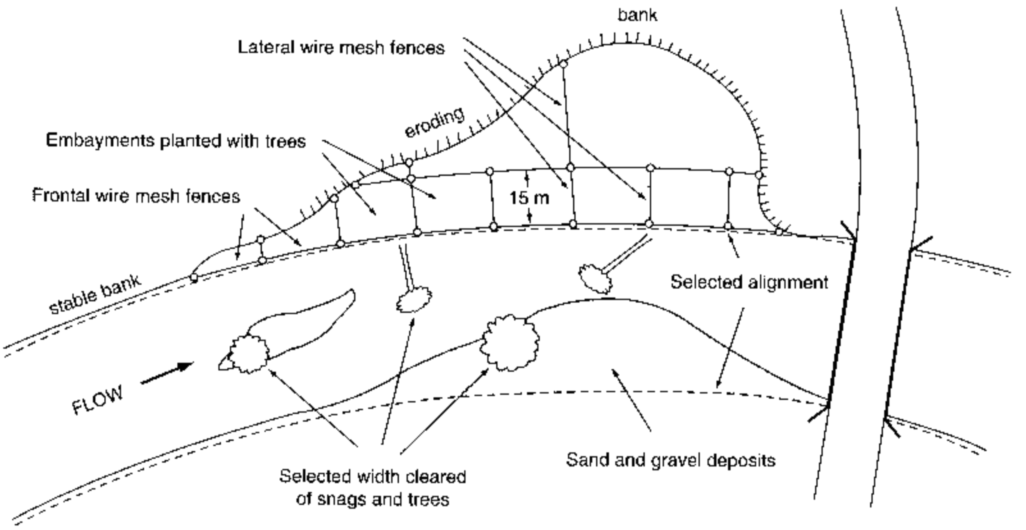


Figure 3. Typical plan for river training works.

Rankin stresses the effectiveness of retarding barriers in reducing flow velocities close to the bank.

> A surprising feature is that retarding barriers, only 1 metre high, installed in front of banks up to 10 metres high, can provide adequate protection to arrest bank erosion. During high floods their presence is not evident at the water surface, but they effectively retard the low level bed currents which otherwise would undermine the toe of the banks. The bank naturally develops a stable slope, and material which falls as minor subsidence, remains trapped in the embayments. Additional work is not needed on the face of the banks to prevent more erosion. This is contrary to the views of some engineers and most landholders, who are quite convinced that sloping and a protective cover, is also necessary.

He also notes that, irrespective of variations in bed slope, the type of material in the river channel and the frequency of flooding, Lacey's formula provides an excellent guide for determination of river channel width in riverworks programs, and moreover that the relationship outlined by Lacey appears to be applicable to a wide range of river systems in different physiographic settings. (Rankin used the 1 in 1 year flood.)

Rankin drew the following conclusions, which encapsulate the philosophy of river training and improvement of the riparian zone, from which current practices have been derived

> Rivers are constantly in a state of change. It is necessary to maintain and protect rivers by encouraging their desirable tendencies and resisting those changes which will have adverse effects on the environment, including man and his activities.
>
> River training methods, which have been developed to arrest bank erosion and reduce damage from flooding, consist of providing a stable, unobstructed channel conforming as closely as practicable with the existing course. Floodwaters can then be conveyed with a minimum of damage and the river channel is capable of coping with major variations in discharges, without excessive damage.
>
> Comparatively simple methods of river training have been devised, using fundamental engineering principles. The works are installed as an integral part of planned comprehensive schemes. They consist of retarding barriers at a low level to control the bed currents. Tree growth and vegetation is promoted on the edge of the selected river channel.
>
> These methods provide for guidance of the river and not confrontation. Flooding and velocities are not significantly increased and there is improvement to the environment, both within and adjacent to rivers.

For maximal reduction of soil erosion from banks, species with a dense network of fibrous roots are generally more effective than species with a sparse network of woody roots. On the other hand, overall bank stability and drainage may be enhanced by the presence of larger woody plants. For example, soil is strong in compression but weak in tension, whereas plant roots are the opposite. When combined, the soil-root matrix produces a type of reinforced earth conducive to bank stability. This reinforcement will extend to the depth of the deepest roots, affording some protection from slumping to banks at least this high.

Bank accretion depends on the deposition of sediment on the bank and at its base. Research results indicate that vegetation plays an important part in promoting sediment deposition on advancing banks (Hickin 1984). On natural banks, pioneer species colonise berms, enhancing their stability and accelerating their expansion.

For these reasons, among others, there is clearly a role for use of vegetation in protecting river banks against erosion and mass failure such as slumping. Moreover, if the banks are stable, this has a feedback effect on the form of the river, as outlined in the next section.

Vegetation also contributes to bed stability of rivers. Roots, and fallen timber and other debris, provide natural controls of bed level that help reduce bed degradation and, through scouring, maintain pools in particular sections of streams. These benefits can be captured in rehabilitation projects through 'rebuilding' stream riffles (see Box 3).

Plate 5. Upper: One of a series of groynes built in the Hunter River at Singleton in the early 1950s, to protect the flour mill and bridge abutment. **Middle**: The 'protected' area soon after the 1955 flood. Groynes were later abandoned as a means of bank protection in favour of 'river training' methods. **Lower**: A recent photograph of this area shows bank stability. A rock toe training wall and bank revetment has been used with success to replace the earlier groynes. Note remnants of the old groyne just left of centre at the bottom of the photograph.

Plate 6. A section of the Hunter River at Muswellbrook before (upper) and after (lower) treatment, looking downstream. The lower photograph shows the set out of the low wire mesh training fences secured to vertical railway track guiding flows away from the eroding high bank. The embayments have been planted with willows.

Plate 7. Constructing an experimental log sill in the Nambucca River. The geo-textile membrane reduces undersill seepage and raises the watertable level of the stream.

Plate 8. An experimental log sill built recently in the Nambucca River. The sill is recreating the pool-riffle sequence of the river and re-establishing the biological balance.

Plate 9. Photograph taken from the left bank of the Hunter River at Scotts Flat, looking downstream. It shows the river being trained past an extensive eroding bank from stable section to stable section. The river works are now well consolidated.

Vegetation and Stream Alignment and Flow

Rivers naturally meander and form outside and inside curves. Erosion usually occurs on the outside bends and deposition on the inside bends or bars. On many New South Wales rivers, vegetation colonisation takes place most frequently on the inside bars and in doing so narrows the channel onto the outside bend, thereby putting it under additional stress from the erosive effects of the fast outside currents. By removing this vegetative cover from the inside point bars the stress on the outside bends is reduced to the extent where the erosion can, in some instances, be stopped through the interplay of the natural forces in the river system. Where this is not possible, structural works are put in place to provide the degree of strength needed to allow the natural forces to come into play. In other words, if it is possible to make an eroding outside bend sufficiently strong the river will naturally adjust its width by erosion and deposition on the inside point bars. If these inside points are unduly consolidated with vegetation this process will most likely not occur and the state of potential instability of the outside bank will likely be activated into erosion; hence the need to keep the inside point bars free of vegetation to some extent. The management trick is to know what that extent is (see Box 2).

Box 2. River Training, Alignment Widths, and Vegetation

Following the 1955 flood in the Hunter River numerous approaches were taken to control the severe bank erosion existing at that time, the most successful method to date being that of river training. As was the practice at that time an alignment width was determined using the 1955 flood flow, which was said to be a 1 in 100 year event, and a formula derived by Lacey (1930).

This combination of formula and flood size gave an alignment width that was far too wide and led to problems of in-stream meandering. Current practice uses the 1 in 18 month flood flow and formulas which, although a modification of the Lacey approach, take into account bank vegetation density.

Regime equations (Lacey's theory and its variations) form a frame of reference to which observations on natural rivers can be related and correlated.

It is recognised that Lacey's theory is imperfect, but it is sufficiently accurate to provide first-order estimates of channel dimensions. By applying professional judgment to each situation, sufficiently accurate estimates can be made of the river parameters to allow rational designs and recommendations to be drawn up for the channel of concern.

Hey and Thorne (1983) note that the hydraulic geometry of gravel bed rivers can be defined by seven variables: width; average depth; maximum depth; slope; velocity; sinuosity; and meander arc length.

Each of these variables is free to adjust in response to discharge, bed load transport, bed and bank material, valley slope and bank vegetation. Theoretically, the simultaneous solution of seven governing equations defining continuity, flow resistance, bed load transport, bank erosion, bar deposition, meandering and riffle spacing would produce channel design equations. However, this is not currently possible because of lack of knowledge regarding the operation of all these process equations. Empirical approaches offer a solution to this problem, provided all of the variables that define and control channel dimensions are included in the analyses.

Regime type relations must reflect the nature of the seven governing equations responsible for the adjustment process. The hydraulic principles underlying the flow resistance and bed load transport equations have been established, but relatively little is known about the mechanics of channel width adjustment or meander development.

The factors controlling regime channel dimensions can either be justified in physical terms or used to identify the controlling processes. This is possible because of the interrelations between the designated dependent and independent variables within the governing process equations.

Hey and Thorne (1983) state that channel width is independent of bed material size and bed load discharge because width has insignificant influence in the flow resistance and the Parker et al. (1982) bed load transport equations. Discharge has a major effect on channel width, through the continuity equation, while bank vegetation appears to dominate the process of bank erosion. Consequently, grass-lined channels are significantly wider than tree-lined channels.

Following further studies, Hey and Thorne (1986) reiterate that bank vegetation has a major control on width, wetted perimeter and velocity, while width and wetted perimeter are unaffected by bed material size. They recommend the following formulas for channel width. W is the channel width in metres, and Q_b the dominant discharge in m^3/sec. The information on bank vegetation and density were used to identify four major vegetation categories.

$W = 4.33Q_b^{0.50}$	Vegetation Type I	Grassy banks with no trees or bushes
$W = 3.33Q_b^{0.50}$	Vegetation Type II	1–5% tree/shrub cover
$W = 2.73Q_b^{0.50}$	Vegetation Type III	5–50% tree/shrub cover
$W = 2.34Q_b^{0.50}$	Vegetation Type IV	Greater than 50% tree/shrub cover or incised into floodplain

These equations relate to width only, and for many river remediation projects it is sufficient to focus only on width. Where particular projects require advice or comment on attributes such as mean depth, maximum depth, meander arc length, riffle spacing, sinuosity, riffle width, riffle mean depth and riffle maximum depth, then specialist help will be needed. The aim of the methods developed in this paper is to provide a methodology that is widely applicable, can be put into practice by a large number of people, and will significantly improve the condition of waterways.

In Chapter 5 an approach to the management of streams in the project area is developed using a modified form of these equations.

Much consideration has been given to the mechanisms by which vegetation may exert control over river flow and form. Hickin (1984) lists five such mechanisms: flow resistance, bank strength, bar sedimentation, formation of log-jams, and concave-bank bench deposition. Cummins (1993), reviewing what is known about the ecology of riparian zones, hones these down to two: stabilisation of banks by root systems and the modification of channel structure by large woody debris. He also comments on practical aspects of the use of vegetation for riparian zone management:

> Given a functional view of riparian systems as the focus, a logical way to scale the riparian functional influences, and their management, is in terms of channel widths ... That is, riparian protection or management should be oriented in terms of set back distance from the bankfull discharge line (active channel) measured in channel widths. Bankfull discharge is approximately equal to the mean annual high flow at peak runoff and has a recurrence interval between one and two years ... The bankfull line, or average maximum annual floodplain inundation, can usually be readily determined by the zone of interface between annual (below bankfull) and perennial (above bankfull) vegetation.

Thorne (1990) notes that bank vegetation can dampen turbulence in river flow near the bank, thereby reducing the strength of the erosive forces impinging on the bank. He adds that the type of vegetation is very important in this regard. Grasses and shrubs are effective at low flow velocities, but not at high flow rates. The stems of woody species continue retarding the flow up to very high velocities, but may generate serious bank scour through the local acceleration of flow around their trunks. Thus, Thorne says:

> Also of importance is the spacing of trees or shrubs along the channel. Single trees or small groups of trees are impediments to the flow that generate large-scale turbulence and severe bank attack in their wakes. Hence, the flow is usually able to isolate and flank hard points in the bank resulting from the effects of widely spaced trees or groups of trees. For trees to be effective in reducing flow attack on the bank they must be spaced sufficiently closely that the wake zone for one tree extends to the next tree downstream, preventing re-attachment of the flow boundary to the bank in between. In this regard the effects of trees continue even after the death of the plant. An isolated, downed tree may generate local scour and, unless removed, can become a locus of serious channel instability. But a dense accumulation of downed timber on a bank can be quite effective in protecting the bank from flow scour.

He also comments on a point of contention:

> The extra flow resistance associated with a dense stand of vegetation on the banks of a river is seen as a disbenefit by many river engineers. This view is based on the assumption that by increasing roughness, bank vegetation significantly reduces channel capacity, thereby promoting flooding. On these grounds, bank vegetation is often removed in a 'clearing and snagging' operation, the stated aim of which is to increase the channel's conveyance. In fact, in most natural channels at high in-bank flows the contribution of bank roughness to total channel resistance is small. This is the case because in channels of high width-to-depth ratio (w/d>30) flow resistance depends mostly on bed roughness and channel shape, not bank roughness. For such channels any increase in conveyance achieved through clearing bank vegetation is more than lost when bank erosion due to reduced erosion resistance leads to widening, an increase in width-to-depth ratio, and a reduction in the hydraulic efficiency of the channel cross-section.

In New South Wales these concepts are now well understood among river engineers. Also, environmental legislation and activities are targeting practices such as tree clearing. Nevertheless, there remains a general need to convey concepts of ecologically sustainable land use to developers, landowners and other custodians of our land and rivers.

In practical terms, Thorne notes that for vegetation to be effective in protecting the riverbank it must extend down the bank to at least the average low water level, otherwise the flow will undercut the root zone during increased flows. On this part of the bank, therefore, plants which are tolerant of inundation are most effective and a mixture of plant sturctural types is recommended. He also remarks that slumping caused by the weight of trees at the edges of steep banks is generally associated with bands of trees only one or two deep, and may be overcome by planting wide stands of trees running some distance back from the bank. The planting guide for the Manning catchment given as an annex to Chapter 6 incorporates the concept of zonation of species for different parts of the bank.

This concept is discussed in a New South Wales context in Woodyer (1968), who points out that a definite zonation of vegetation occurs from waters edge to above the bankfull zone. In a wider context, Cummins (1993) discusses riparian zone dimensions in terms of stream widths.

Clearly, bank vegetation has complex effects on soil erosion and bank stability, and there is a wider interaction between the riparian zone and river dynamics. Overlying these interactions are catchment-wide events that have a bearing on streamflow and its variability over time. Riverbank revegetation projects need to take account of these interactions.

Erosion and River Training

Early attempts to control river erosion by processes such as direct protection using groynes, battering of banks etc. were largely unsuccessful (see Box 1 and Plate 5). These early failures stimulated development of the concepts of river training (Plate 6).

The object of river training is to guide the eroding flows away from the base of the bank onto a new suitable alignment which, if stabilised, will provide a new river course with inherently stable properties and which will require the minimum of attention to maintain it on its selected course (Figure 4).

The usual practice has been to protect only the outside bends. The fact that there is maximum turbulence in the flow at the outside bend, and that erosion occurs there, is capitalised on in river training work. Also, by protecting outside bends only, the costs to treat a length of river can be minimised. In a section of river to be stabilised an overall plan is devised to protect eroding outside bends. Once an outside bend is stabilised the corresponding inside bend will adjust its own width to match to the dominant discharge. Thus, no protection works are required on the inside bend.

The sections between major bends usually need little attention other than selective removal of obstructing vegetation if necessary, or lopping overhanging trees which are likely to be undermined and fall in, thereby promoting direct erosion problems. Habitat trees are retained, and sparsely vegetated banks may be fenced and replanted.

There are strength limitations to standard protection works on outside bends. Where the protection of an outside bend will involve radii of protection works which are considered too tight to succeed without excessive maintenance being carried out, then other methods are used. For tight bends a rock platform is substituted for the standard protection works or in some extreme cases a pilot channel is cut through to establish a desirable radius of curvature.

Research by Kwan (1976) based on Hunter River works shows that failures start to occur in mesh works on bends with a radius of less than 195 metres. Rock-based methods are better used on the tighter bends, to reduce maintenance costs (see Figure 4).

River training works have sometimes been accused of producing undesirable changes in river form and flow. Erskine (1990), in a paper entitled 'Hydrogeomorphic effects of river training', comments:

> The principles of river training were developed between 1950 and 1955 by DWR and have been applied to many rivers in NSW since then. Although these works are often criticised for inducing adverse hydrogeomorphic effects there are few well-documented examples in NSW.
>
> Although river training works have certainly resulted in some localised channel changes, in the case of the Allyn River they were mainly a response to, rather than a cause of, channel instability. Further studies of other DWR's river training schemes are needed to determine if this is a general result.

That these early works have performed satisfactorily, and our improved understanding of the effects of bank vegetation on channel dimensions, put us in a strong position to maximise the benefits of river training work and refute unfounded criticism.

River Training and Floods

What can be achieved by river training and associated work needs to be kept in perspective, and be reflected in the objectives of Rivercare projects

It is practically impossible, for example, to engineer for the effects of a major event such as a 1 in 100 year flood. Rather, the approach extends from the premise that,

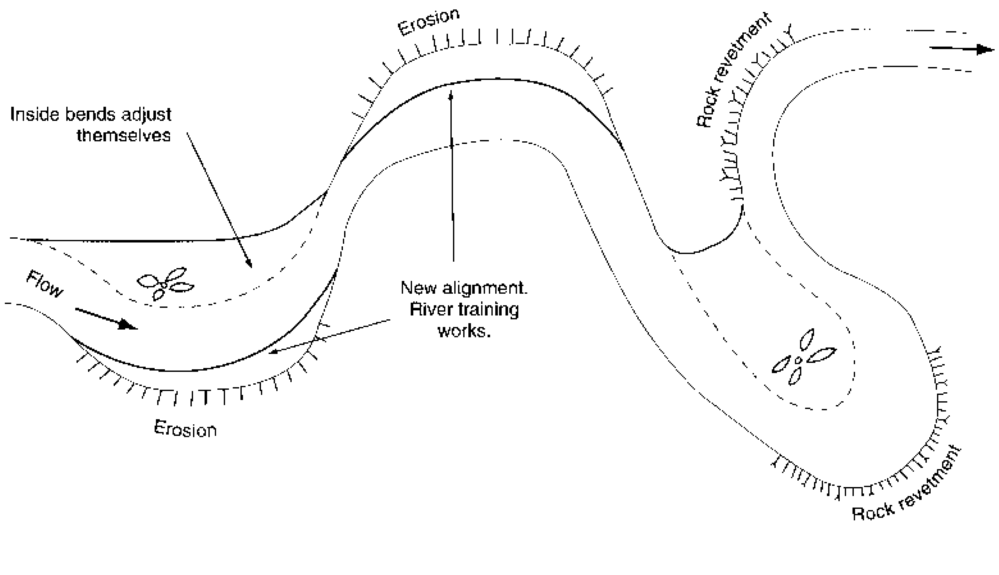


Figure 4. Establishing a stable alignment on a river with eroding bends. Rock has been used on bends with tight radii.

provided the system has been set up to cope adequately with inbank and overbank flows, then the effect of a 1 in 100 year flood, which borders on a catastrophic sequence, can be minimised. Expenditure or planning to cope with more than, say, a 1 in 20 year flood, other than to guard against loss of life or major infrastructure such as highways or railway bridges, is not cost effective.

The effects of large floods are unpredictable–money can be spent in the wrong areas. The best way to mitigate against these floods in physical and financial terms is to create an effective system which copes adequately with the more frequent situations. Thus, costs are minimised and benefits maximised on an annual basis and there is a long-term reduction in the costs of major floods. The parameters of such an approach, although empirical in the main, are well known.

Future Directions

Works to date have centred largely on the river training approach. This method has served us well, is appropriate to many river management situations and has a range of beneficial outcomes. Erskine (1992), for example, reports improvements in stream ecology consequent on river training works and channel stabilisation. He notes that where training works have been undertaken on the Hunter River they have created a better habitat for fish. Pool depths have increased, the proportion of unstable sand and substrate has been reduced and the length of vegetated banks has increased.

Nevertheless, the management practices outlined in this paper provide just part of the solution to integrated riparian zone management. Bed conditions, for example, must also be considered. In the Gloucester/Manning River system there are many rock bars across the bed which naturally help form a pool and riffle sequence and assist in the control of bed levels in the river. The same is true for many other river systems on the North Coast of New South Wales. In recent times, the importance in river works of retaining woody debris in the bed and of maintaining riffle areas relatively undisturbed has been recognised. Extra attention has also been focused on vegetation density and location.

There is thus a need to look at re-establishing sills in rivers, using timber, rock or other material to assist in controlling bad stability (see Plates 7 and 8). This is applicable to rivers or sections of rivers where those natural features have been destroyed by bank erosion and siltation. Details and methodologies are given in publications such as Newbury and Gaboury (1994) and the NSW Department of Land and Water Conservation 'Riverwise' advisory notes. Box 3 gives the principles involved.

In many modern river restoration programs both bed and bank erosion may be addressed at the one site.

Human Impacts on River Bed and Bank Geomorphology

There is little point in attempting remedial works when some of the major causes of instability remain unchecked. The impact of these on the river system since European settlement was outlined in earlier chapters. Many of them continue to cause damage to rivers and streams.

Major causes of instability in the larger catchments include the following:

- Clearing of riverbank vegetation.
- Loss of hydraulic roughness in bed, and bed lowering, because of removal of debris, etc.
- Clearing of catchments – increase in runoff and sediment transport.
- Gold mining by dredging or use of water jets – destruction of riverbanks and filling of river channel with sediment.
- Dams – reduction in natural sediment transfer, alteration of flood regime, creation of channel instability downstream.
- Sand/gravel extraction – loss of natural sediment transport and promotion of bank erosion. It may be beneficial to remove sediment slugs in a system.

At the landowner level, activities causing instability include:

- Inappropriate stock access, particularly to outside banks.
- New roadworks disrupting banks, causeways interrupting sediment and water flow patterns, runoff providing unwanted silt to river system.
- The placement or removal of obstructions in channels without due thought to the local flow regime and implications for instability.

Facing the Practicalities of Rivercare

It is apparent from discussions with many catchment management groups across the country that people will continue to work largely in the dark unless they have some understanding of past and present causes of river instability. Problems often relate to events long past. For instance, much of the gravel that was mobilised through bank erosion in the early to middle periods of this century is still moving through the river system.

In the section of this paper recounting the history of land management, we have tried to show the impact of early practices on the river systems. Many of these impacts are still with us, and if we understand that, we are better equipped to deal with the current problems.

Box 3. Some Simple Engineering Principles in River Rehabilitation

Newbury and Gaboury (1994) set out the following principles:

- River behaviour is similar in all parts of the world, and can be related to catchment landscape, stream placement within the catchment and seasonal water flow.
- As a result of catchment clearing, dam building or sand and gravel extraction, rivers can get out of balance with their channel. This lack of hydraulic equilibrium can lead to major problems in flooding, bank erosion etc.
- It is possible to bring many rivers back to a more natural state by using small, rock structures to restore a pool and riffle sequence, and by rebuilding meanders.
- These simple engineering works can be designed for a particular situation by using measurements from a river survey. They are relatively cheap to build and offer many ecological advantages (e.g. pools are retained even under low flow conditions).
- There is little point in revegetating stream banks if the river is out of equilibrium–*attend to the flow of the channel first.*

Steps in Restoring Channel Equilibrium

1. *Assessment.* Identification of the characteristics of the channel, noting the topographical, hydrological and land-use factors likely to affect restoration works.
2. *Measurement.* Sample measurements of stream geometry and vegetation from representative stream reaches are needed in order to establish the relationship between the channel geometry, drainage area and bankfull discharge.
3. *Survey.* Make detailed plans of the restoration sites, describing them in detail and showing the intended works.
4. *Reference areas.* Establish reference areas in undisturbed stream reaches which can be used as biological guides for the restoration sites.
5. *Identification.* Establish habitat requirements for fauna and flora present or likely to be present in the stream reach.
6. *Design.* Plan a rehabilitation scheme that is appropriate for the stream, according to the catchment and stream surveys. Planned new structures need to be reinforced by existing stream dynamics and geometry. The approach might opt for pools and riffles based on similar natural structures occurring elsewhere in the stream, rather than fixed structures.
7. *Supervision.* The restoration work should be supervised to ensure correct placement of structures such as riffles, and to provide ongoing information as required.
8. *Monitoring.* The restoration must be monitored, and adjusted over time as the stream reach evolves.

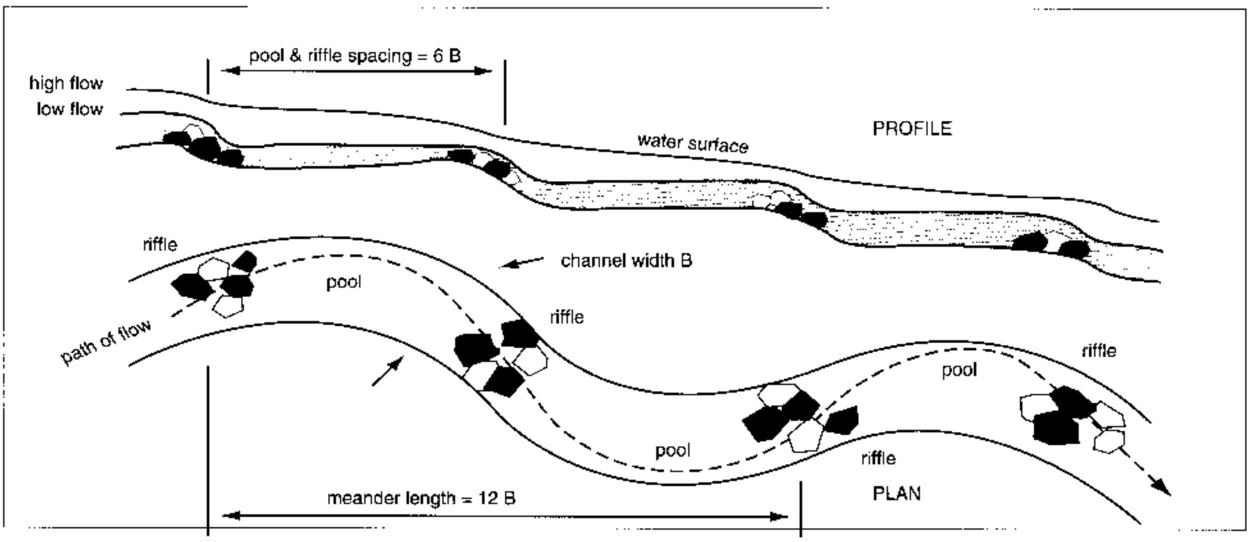


Figure 5. Diagram of pool and riffle sequence.

Difficult decisions will have to be made by catchment groups. First they have to decide if they wish their river to continue in its present state–degraded, and often further degrading–in the short to medium term or whether they wish to begin stabilising and reversing the process. Once they have decided on action, they need to determine the extent of that activity.

The planning activity set out in the Rivercare planning approach given in subsequent chapters provides a means of looking at the overall context of the problem and putting in place strategies which can, at the minimum, halt the degradation, and ideally provide a mechanism for rehabilitation of a river. Which route is chosen becomes a decision for the individual Catchment Committee or Landcare Group.

Activities undertaken by groups not having a catchment-wide perspective may be only marginally productive in tackling the overall problem. A catchment-wide perspective and proper planning will generally maximise returns for the effort involved, and provide much more meaningful results.

5 SIMPLE APPROACHES TO RIVER MANAGEMENT

Introduction

The following sections briefly set out some of the approaches being used in Rivercare projects, particularly those in the smaller catchments, to determine management style related to the geometric alignment and bankfull widths, while taking into account bank vegetation types and density. Different erosion types are examined and some simple treatments outlined. A pamphlet which sets out the concepts for community use is given as Appendix 2: 'A Users Guide to Effective and Inexpensive River Maintenance Practices, Community Programmes and Channel Stabilisation Techniques'.

Management Style

The management style needed for a particular section of river can conveniently be determined from an identification matrix (see colour fold-out, Appendix 2). The style is derived by colour coding RED-YELLOW-GREEN (traffic lights) for both stream morphological and vegetation condition. So, if a river can be described as being in a YELLOW-YELLOW state, the matrix is entered at the YELLOW (river) and again at the YELLOW (vegetation) and the appropriate condition and management options are read off and acted upon.

The photographs in the fold-out, showing the categories of river condition and bank vegetation cover, should be sufficiently explicit for a landowner to differentiate between them. In the overall management perspective a minor bias in identification of one of the states will not affect the end result to any significant degree.

STEP 1 – Pick the picture that nearest represents the *river condition*.

RED — represents a river that is out of regime, which means that there is an imbalance of sediment inflow and outflow.

YELLOW — represents a river that is starting to deteriorate. There is deposition in the channel and/or bank slump and erosion. Not as extensive as RED and is probably within the capacity of a landholder to do something about.

GREEN — represents a river system that is generally in balance with little or no erosion – a bankfull flow passes through it without any appreciable damage – it will recover readily.

STEP 2 – Pick the picture that represents the *bank vegetation cover* which most closely represents the river banks.

RED — means that 75% to 100% of the river's natural riverbank vegetation is missing, banks may be heavily stocked, and there is little binding vegetation.

YELLOW — means that there is up to 50% of native vegetation – but sparsely located – much of the understorey is missing, trees are tending to be undermined – a bankfull flood event creates further devastation.

GREEN — means that 50% or more of the natural bank vegetation is largely in place with good understorey. A bankfull flow will pass through the system and any damage will recover quickly.

STEP 3 – Enter the management *matrix* in the colour fold-out (Appendix 2) with the rating and *follow the management option offered*.

For example YELLOW-YELLOW gives the management option:

> Prepare a Rivercare Plan for the river channel and its vegetation and implement that plan.

Determining Suitable Alignment Widths — Examples of Present Practices

River flows that can impact on channel width and geometry vary widely between seasons and years. Nevertheless, to provide the basis for planning and works, some dimensions must be set.

Different approaches can be taken according to the situation facing the planner, and the data and resources available. It is important to know, for example, whether the stream being examined is braided, straight or meandering (Newbury and Gaboury 1994).

Empirical approaches based on the 'dominant' or 'bankfull' discharge have been used for many years. They provide relatively quick answers that are sufficient, in most cases, for assessments made during the large number of on-site discussions between the department and landowners. More sophisticated approaches may be needed where major works such as channel diversions, dams, gravel extraction , etc. occur in the river system.

This paper aims to provide sufficiently accurate detail for rational decisions to be made about the most commonly occurring problems. An explanation follows of the processes involved.

Woodyer (1968) found that the frequency of bankfull discharges for the high bench (present floodplain group) is in the range 1.24–2.69 years in New South Wales. D. McLaren (personal communication 1995) considered that a bankfull discharge frequency of 1.7 years gave good correlation to his own observations over a 6-year period in the 1980s when he was responsible for most of the river-related inspections on the North Coast of New South Wales. According to McLaren, the 'two year flood frequency was definitely too high'. However, methods used at that time did not take into account variations in vegetation style and density on the river banks. Also, better data and computerised methods of analysis have since become available.

Thus, based on the recommendations of Leopold et al. (1963), a flow frequency of 1.5 years (1 in 18 months) has been adopted as the dominant discharge. The cumulative experience of the present authors has shown that this value—when married with the Hey and Thorne (1983) formulas based on the regime equations of Lacey modified for bank vegetation density (see also Figure 6)—is reasonably reliable for streams on the New South Wales North Coast, though further research is needed to fine tune it.

Gordon et al. (1992) discuss the interdependence of channel width and catchment area, using the Acheron River in Victoria as an example. Also, Newbury and Gaboury (1994) note:

> Establishing the natural geometry relationships for a stream is an important step in understanding the stream's behaviour and characteristics. Based on the drainage area the channel geometry measurements may be linked to channel pattern and profiles and used to dimension stream rehabilitation works that mimic natural conditions.

Using probability-stream discharge data where they exist (e.g. Figure 7) it is possible to extract from the graph the 1 in 18 month or 67% flow and insert this into the equations as shown in the example below.

By using this approach with the Log-Pearson Type III Annual Series Analysis for fifty-three North Coast stations whose records date to before 1970 (LTR) and by selecting streams as shown in Table 1, Figure 6 was derived. This graph provides a stream width relative to catchment area for the eight catchment groupings, with an R^2 value of 0.66. The graph has given fair results in practice. An example of its application is given below.

Empirical formulas were used by D. McLaren and others on the North Coast for many years:

$W^2 = 2.5 \times A$ McLaren I

$W = (10 \times A)^{0.44}$ McLaren II

where W is width in metres and A is catchment area in square kilometres.

Table 1. Data for eight catchment groupings on the New South Wales North Coast.

Drainage Basin No	Name	Catchment Area km^2	Average Annual Discharge $m^3 \times 10^6$	Average annual rainfall mm	Distribution of catchment sizes used in Figure 6: 11–100 sq km	101–1000 sq km	1001–10,000 sq km	10,001–100,000 sq km	Number in each catchment
201	Tweed River	1110	418	1500–3000		1			1
202	Brunswick River	492	246	1600–1850	1				1
203	Richmond River	6940	1920	1000–1800	3	3	1		7
204	Clarence River	22,660	4920	820–1920	8	6	7	1	22
205	Bellinger River	3440	1150	1150–2000	1	3			4
206	Macleay River	11,450	2150	700–1550		4	2		6
207	Hastings River	4530	1450	1180–1840		2	1		3
208	Manning River	8420	2270	660–1840	2	3	4		9
				Total	15	22	15	1	53

Source: Water Resources Inventory, Water Resources Commission 1980.

These formulas, which do not take into account vegetation density, are plotted on Figure 6 for comparison.

Figure 7 gives flow data for the Gloucester River at Doon Ayre, catchment area 1610 km^2. The 18 month flood (67% probability of being exceeded) is 24,000 megalitres/day or 278 cubic metres per second.

Width = $4.33 \times (278)^{0.5}$ = 72 metres (see Chapter 4 for basis of formula) for a river with grassed or raw banks, or

Width = $2.34 \times (278)^{0.5}$ = 39 metres for a river with dense bank vegetation and trees.

For the purpose of the Bulliac River plan the widths were estimated as follows:

Gloucester River

Approximate river length (ARL) 4.0 km to ARL 29.2 km (Bowman R. confluence)

	Channel width needed to carry the 1 in 18 month maximum flow
Good vegetation both banks	40–45 metres
Good vegetation one bank	50–55 metres
No vegetation or grass only both banks	60–65 metres

These dimensions were derived from:

- Theoretical calculations (outlined earlier)
- Inspection and measurements from aerial photographs
- An on-ground check at strategic locations using an optical range finder (Plate 10).

Plate 10. By using an optical range finder, channel widths can be quickly compared with the ideal and an asessment made of the degree of degradation.

From this combination of information, widths were set. They are applied specifically to *critical channel dimensions* in such areas as rapids, diversions to outflow channels and channels downstream of these locations, bends in rivers and reaches demonstrating channel flow characteristics.

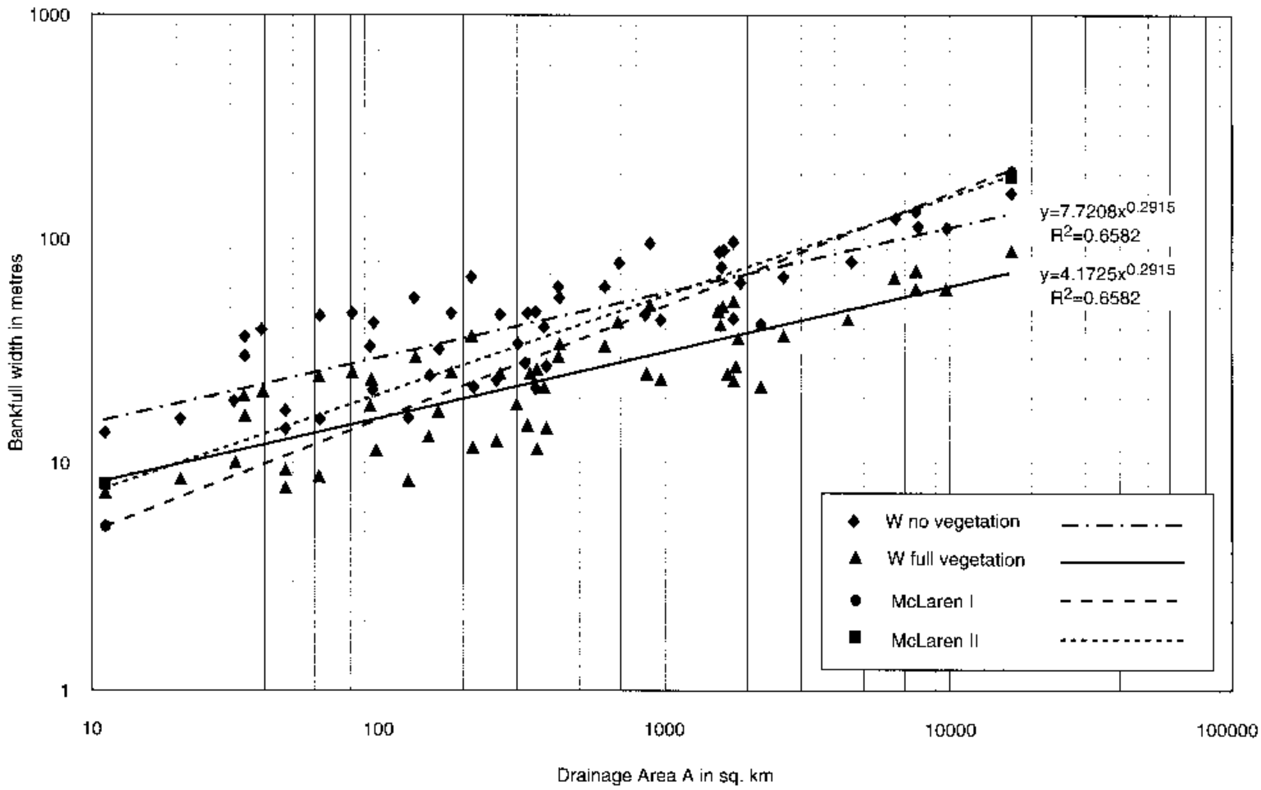


Figure 6. Drainage area versus bankfull width for 1 in 18 month flood LTR using DLWC data and formulas in text.

In the Hey and Thorne discussion earlier in this paper (see Chapter 4) four classifications of vegetation were postulated. For the purpose of Rivercare plans (detailed in Chapter 7) for river management in New South Wales, three classifications have been adopted: good vegetation on both banks; good vegetation on one bank; and no vegetation, or grass only, on both banks.

Alternative methods for determining alignment width can be compared.

From Figure 6 for 1610 km^2:

W (no vegetation) = $7.7208 \times (1610)^{0.2915} = 66.5$ metres

W (full vegetation) = $4.1725 \times (1610)^{0.2915} = 36$ metres.

D. McLaren's empirical equations for a catchment area of 1610 km^2 give:

$W_I{}^2 = 2.5 \times 1610$	$W_I = 63.5$ metres	McLaren I
$W_{II} = (10 \times 1610)^{0.44}$	$W_{II} = 71$ metres	McLaren II

Alternatively, stream parameters can be derived from direct survey as set out in Newbury and Gaboury (1994).

Good vegetation on both banks

Figure 8 represents a channel which is in regime and fully vegetated on both banks – it is stable and the channel runs relatively deep.

If such channels are allowed to narrow to below their critical width, then excessive scour of the vegetation can cause undermining and destruction of the integrity of the river banks. Also, or alternatively, the high flows can tend to bypass the choked section and cause damage to the floodplain. Such a process is often compounding unless remedial action is taken (Plate 11).

Good vegetation on one bank

Figure 9 represents a channel which has good vegetation on one bank but little or none on the other. Such situations exist at bends in the river where inside point bars form a means of temporary sediment storage as part of the river's geomorphic function. It is frequently necessary to keep these inside points free of vegetation to allow areas of temporary sediment storage to operate effectively during high flow events. This is particularly important where the outside bend is unstable.

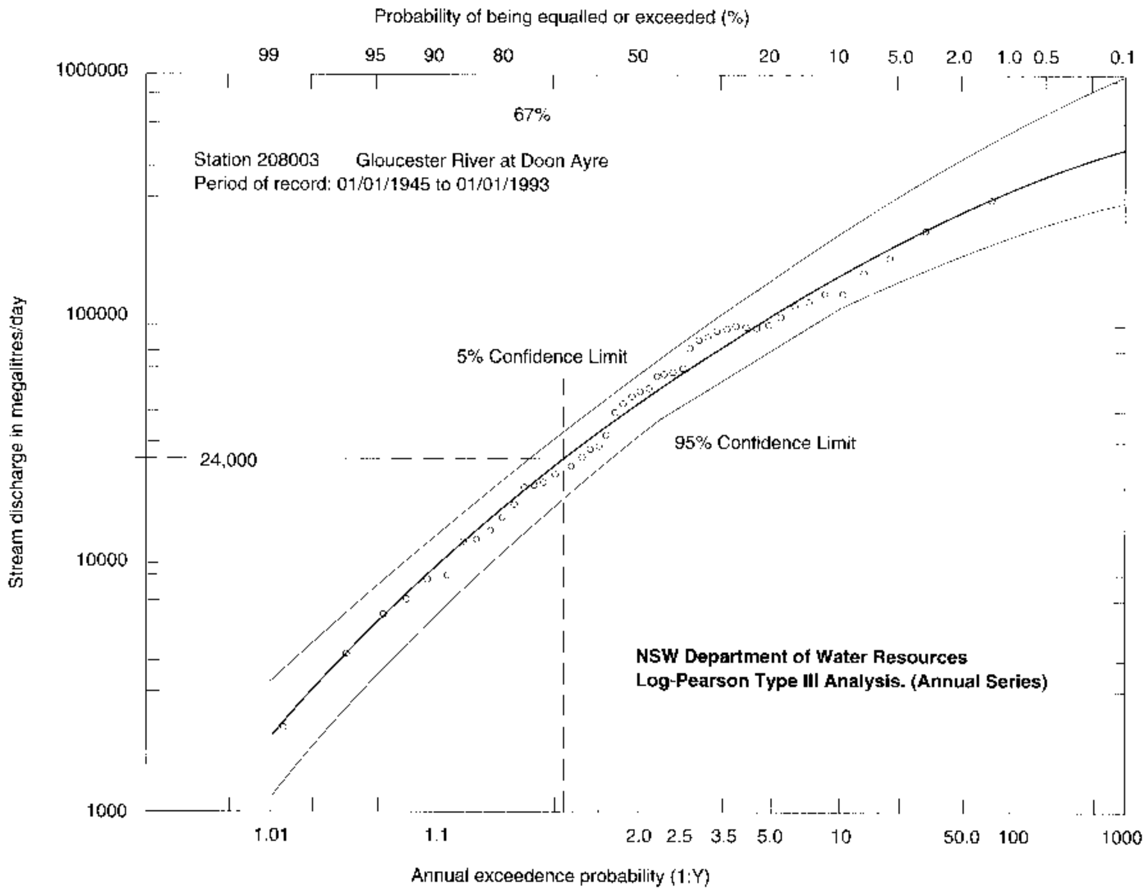


Figure 7. Probability–stream discharge for Gloucester River at Doon Ayre.

Keeping the inside bar free of vegetation to the determined width will increase the effectiveness of strategies to stabilise the outside bend.

No vegetation, or grass only, on both banks

This situation, depicted in Figure 10, can occur in badly degraded sections of the river. The aim here will be to reduce the width of the channel to either a 'good vegetation both banks' or 'good vegetation one bank' condition. The dimensions determined give the river planner a feel for how degraded or excessively wide the channel might be in a particular section of river relative to its pre-European or 'pristine' state.

Alignment Width Modifiers

The use of these alignment widths needs, in practice, a degree of first-hand experience in their interpretation: there are many situations along a river that cannot be equated to textbook examples.

Some of the variables to be considered are bank vegetation density, pool-riffle sequences, outflow areas and overland flow, rapids, rock banks and outcrops, and other geological and geomorphological features, such as stream confluence areas.

Apart from purely natural phenomena, the channel width is affected by developmental changes in flow regime which influence the dominant flow. Such changes can come from river diversion for irrigation, power generation, clearing of the catchment, or the construction of a dam on the river. If necessary, professional advice should be sought in any river planning activity on which they impinge.

Plate 11. The Williams River looking upstream from below Dungog showing how a choked channel has forced water onto the floodplain, scouring a new channel. Judicious clearing of the main river, particularly the inside points, has remedied this potential diversion.

Some Common Riverine Corridor Erosion Types and How to Prevent or Reverse Them

A number of common erosion types need to be dealt with in any degrading river system. Details of how the various types occur and how they are managed are set out below. It is not unusual to find more than one of them at play at any one site. Simple revegetation options are described, although in some cases other forms of protection such as structural works may be required.

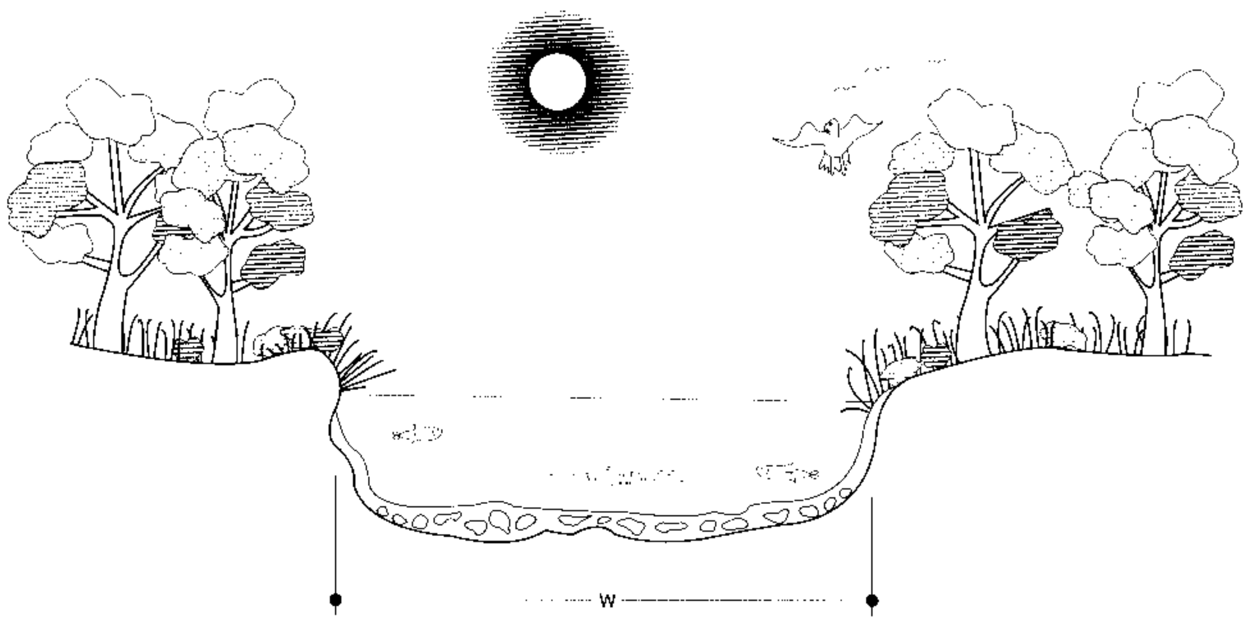


Figure 8. A fully vegetated channel — in regime.

Bank erosion

The process. Bank erosion is a natural process, contributing to the meandering movement of streams, and the creation of floodplains over geological time. Hurst et al. (1993) list various factors, natural or of human origin, that may accelerate or otherwise modify bank erosion, including:

- riverbed instability
- removal of protective and binding vegetation
- changes in the sediment or hydrologic regime (caused by catchment clearing and inappropriate gravel extraction, for example)
- bank saturation

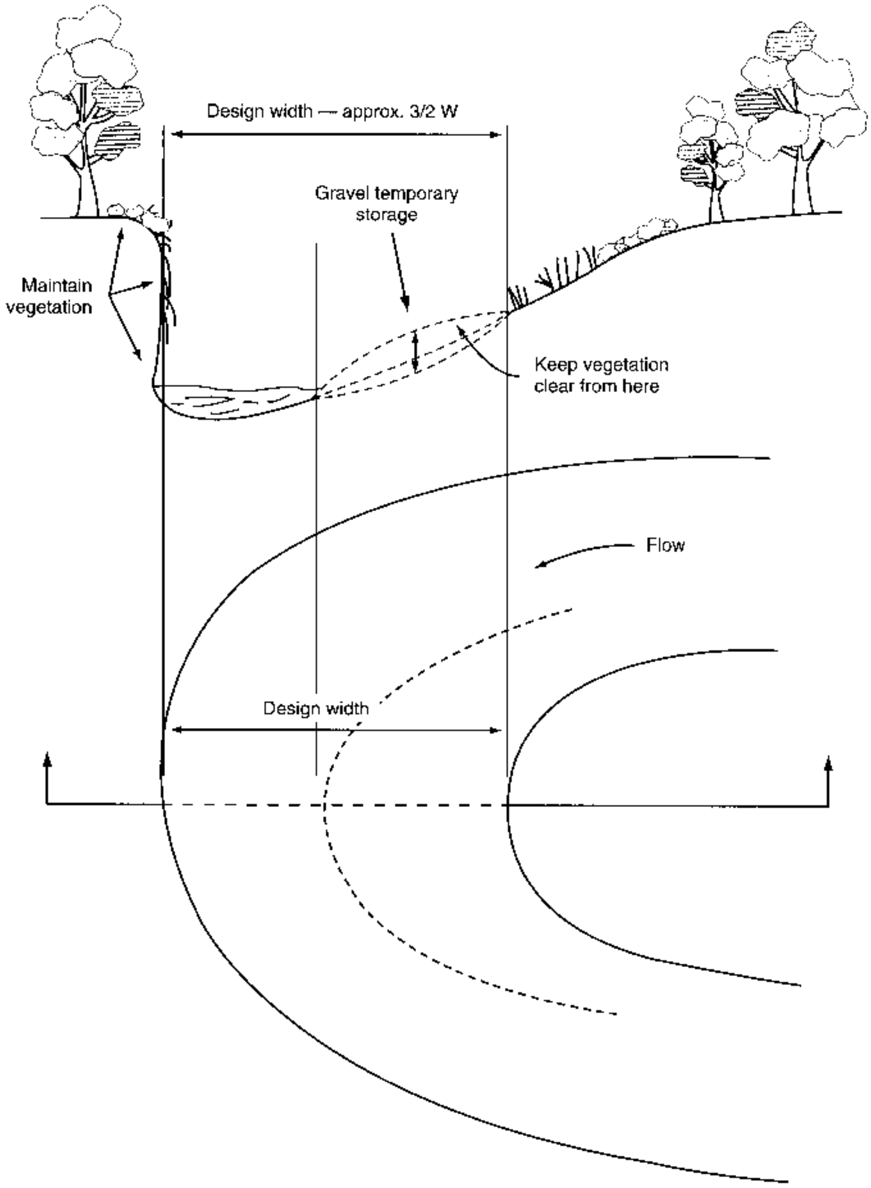


Figure 9. Cross-section of channel with good vegetation on one bank, and determination of design width.

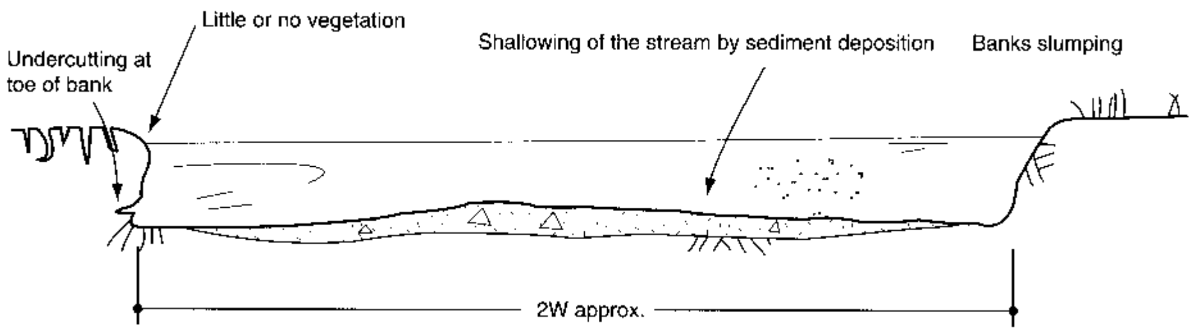


Figure 10. Cross-section of a badly degraded stretch of river, with no vegetation — or grass only — on both banks.

- trees falling from banks
- acceleration of flow around debris and instream blockages
- the construction of dams, causeways or bridges.

Generally, such erosion occurs on the outside of river meander bends (where the original vegetation has been damaged or is no longer present) as a result of processes such as undercutting and sloughing (Figure 11).

Figure 12 depicts the process of bank erosion around a series of curves. The erosion meanders, if left unchecked, will progressively migrate downstream as undercut basal material is removed and bank collapse continues.

As the water flows around a bend, because of centrifugal forces, the surface of the water at the outside of the bend is higher than at the inside. This increased elevation produces secondary currents which run down the bank and across the bed to the inside bend. These secondary currents, when combined with the normal flow currents, form a spiral component which travels both down and across the stream in the direction of flow (Figure 13).

These currents remove material from the outside bank of the bend, and deposit it on the inside bank where velocities are slower, thus forming a point-bar.

Study and experience of these processes have shown that, to control riverbank erosion, the toe of the bank must be protected, to stop undercutting. The development of river training works to achieve this was outlined in the previous chapter.

Management steps. Before starting a revegetation project to control bank erosion, an appropriate width and alignment

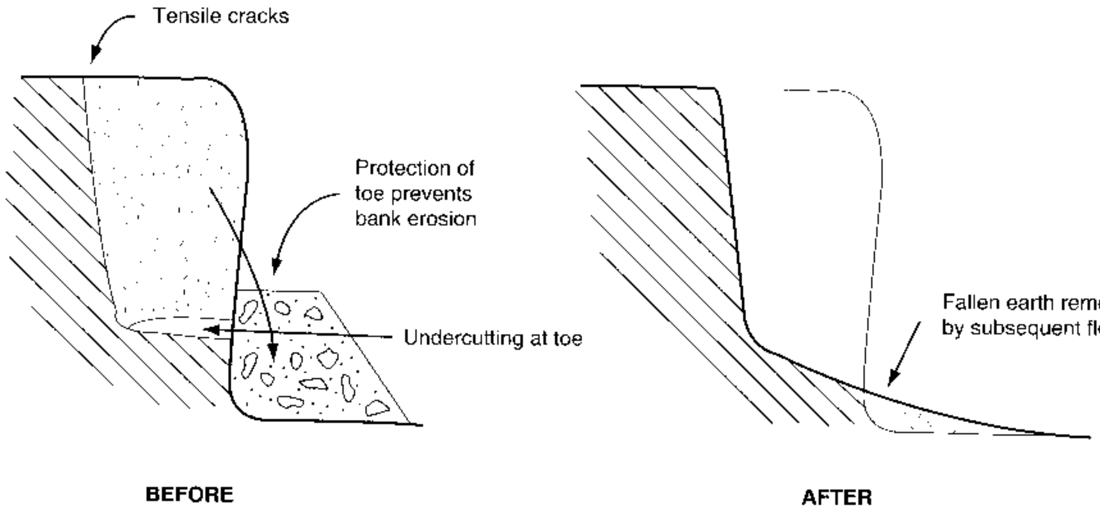


Figure 11. The process of undercutting, where material is scoured from the toe of the bank, resulting in loss of bank support and sloughing. The use of structural works, e.g. a rock toe, will prevent this erosion.

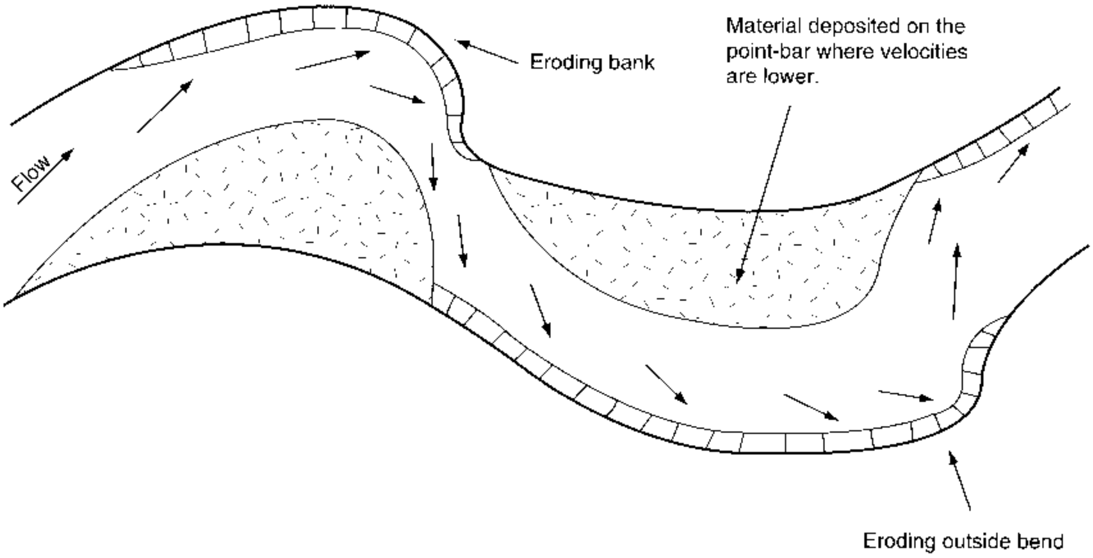


Figure 12. Outside-bend bank erosion. Arrows mark the direction of flow, showing that outside bends are the areas of greatest erosion potential — meanders migrate downstream.

for the river must be determined. Means of doing this were covered earlier in this chapter and in Chapter 4.

It is also important to look at the possible causes of bank erosion before commencing work. As outlined in preceding chapters, severe erosion may point to a catchment-wide problem requiring high capital input. Discuss the possible causes of erosion with an officer from the appropriate government department. Catchment-wide problems generally require catchment-wide solutions in addition to the development and implementation of a Rivercare plan. As mentioned previously, many North Coast streams have become wider and shallower with increases in the amount of silt, sand and gravel present due to bed and bank erosion. A lack of substantial vegetation on banks has also allowed more light to penetrate to the stream and many sites are now dominated by species such as river oak. These species are generally colonising or opportunistic plants and take advantage of the increased amount of light available and increased growth substrate in the form of moist gravel beds. The seed of these species is most commonly deposited on lower velocity areas such as point-bars. When undertaking work to control bank erosion it may be necessary to remove some of this regrowth from point bars, or mid-channel bars, until the bank has been stabilised, and natural processes remove excessive regeneration of these species. Clearing is undertaken to the calculated alignment width as outlined previously.

Where the erosion has resulted in a vertical bank, gravel from the inside of the bend or point bar can be pushed across to the outside of the bend and levelled as a bench for planting, usually in combination with structural works. To enable plant roots to obtain moisture, such benches should be no more that 300 mm above low-flow level. If the bank is battered with gravel, it dries rapidly and vegetation is difficult to establish. Remember that the aim is to protect the toe and that battering of the bank face is therefore unnecessary. Structural works are generally necessary on severe alignments (see Chapter 4). The various options for structural works are outlined in 'Riverwise Notes – Works to Control Stream Bank Erosion', available from the NSW Department of Land and Water Conservation. The costs of such works vary widely and depend on the availability of material, nature of the problem, finance available and so on.

Once the site is fenced to exclude stock, only those species indicated as suitable for planting along the toe of the bank should be used. Studies have shown that these species have the ability to grow in gravel and withstand the force of floodwaters once established. The planting guides (see annex to Chapter 6 for sample guide) identify those species suitable for particular applications and give suitable planting densities. Trees should be planted randomly and not in rows, to provide maximum slowing of the water flow by increasing bank and channel roughness. Where gravels are coarse, fine soil will need to be placed in the planting hole.

When planting for erosion control in high velocity sections, it is best not to use tree guards or stakes as they may trap debris and wash out the plants.

The use of non-native species (willows and poplars) should be considered only for large-scale erosion problems or severe alignments. These species are fast-growing,

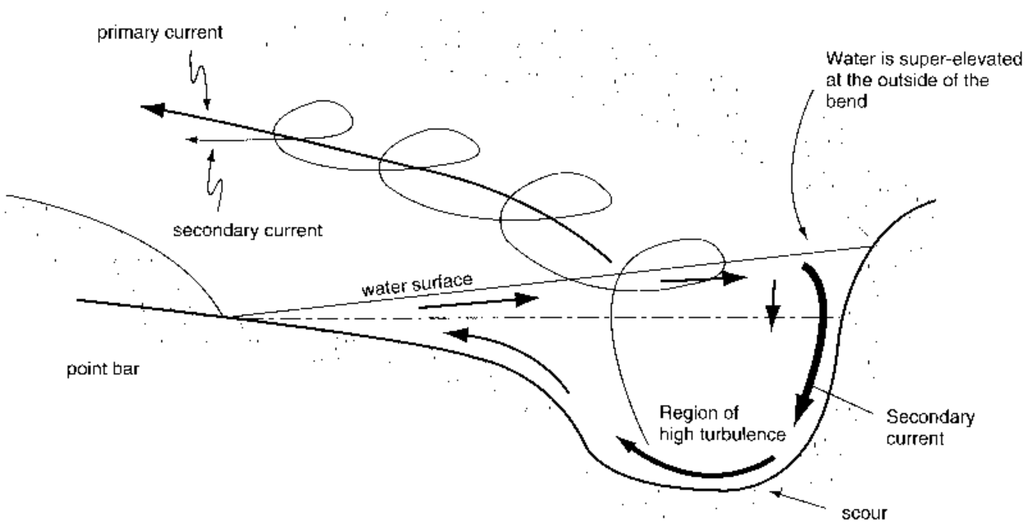


Figure 13. Simplified representation of secondary currents acting on the outside of a meander bend. Material is eroded from the toe of the bank, while deposition occurs on the inside bend. Bold arrows indicate areas of highest erosive potential.

and cuttings, usually two-year-old wood and up to 2.5 metres long, can be planted directly into the ground, providing rapid protection. For these reasons, willows are useful for large-scale stabilisation works where immediate bank protection is required on severely-eroding areas. Willows are generally short-lived (less than 20 years) on the North Coast of New South Wales, and native species should be planted behind willows to ensure long-term security of any works. Willows can be invasive in cold areas. If you want further information on willows and how to plant them, contact the NSW Department of Land and Water Conservation for advice. This is important, as some species can spread by seed.

When revegetating areas where structural works are used it is important to consider the purpose of the works. Works such as rock revetment, for example, are designed to provide immediate protection. These areas can be revegetated as soon as works are completed. Other works, such as wire meshing or timber jacks, are designed to slow water down and trap sediment, particularly the wash load, while vegetation becomes established. It is best to plant vegetation after a flood event, or plant willows initially and replace them with native species once the area is stabilised.

Bank slumping

The process. Bank material containing large proportions of poorly drained fine sediment such as clay, silt, or fine sand, tends to collapse by slumping, as shown in Figure 14.

A slump can occur without previous undercutting to the bank in response to:

- a rapid fall in stream water levels following prolonged flooding (called rapid draw down)
- reduced drainage capacity of the bank soil due to a lack of deep-rooted tree species
- a progressive increase in bank height and slope due to sediment build-up, to a point where, when waterlogged, the bank becomes unstable
- a weight being added to the bank (perhaps a building or the wrong species of tree)
- loss of structural support due to lack of vegetation.

Over the North Coast study area slumping most commonly occurs in the Richmond River catchment.

Management steps. It is important to determine the cause of slumping, as drainage works or diversion banks may be needed to reduce waterlogging due to seepage. The simplest method of controlling and preventing bank slumping is to fence the site to exclude stock and revegetate it with suitable species, as follows.

1. Replant the toe of the bank with species listed as suitable for this location. These species have mat-forming roots and can withstand high velocity flood-flows. They prevent undercutting and reduce water velocity along the toe of the bank. Plantings should be dense, with spacings no greater than 1 metre.
2. Replant the middle to upper bank areas with fast-growing, deep-rooted tree species. These species grow where velocities are lower. The deep roots of these species:
   - physically hold the bank together
   - provide drainage lines through the bank, preventing waterlogging
   - remove excess moisture in the bank by transpiration.

   Spacings in these areas can be wider (2–3 metres).
3. Use a variety of species to ensure differing root structures and densities within the bank.

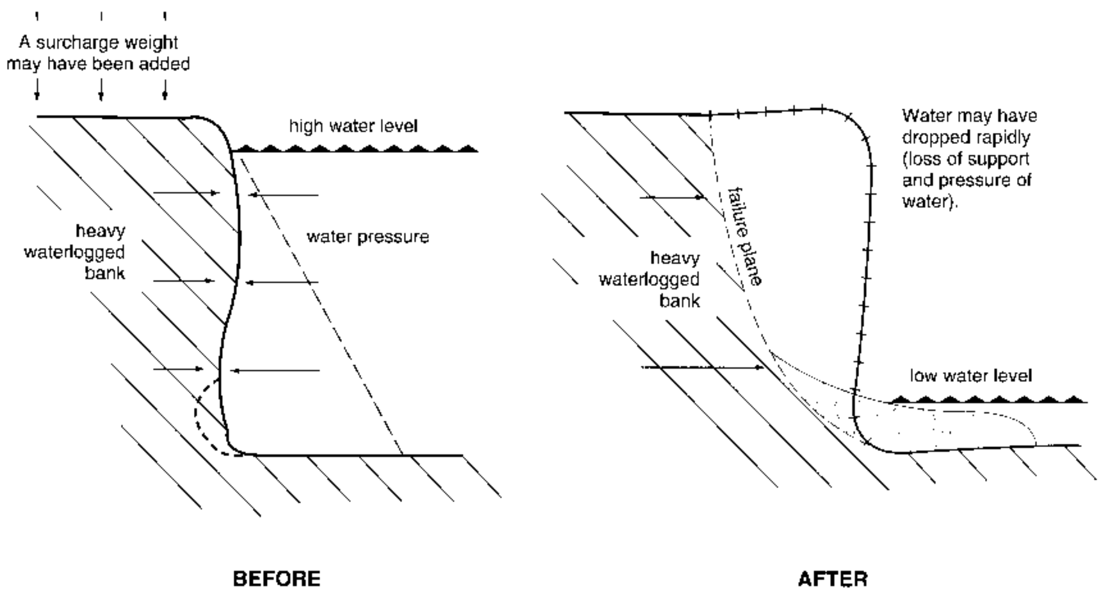


Figure 14. Bank slumping due to draw down.

4. If the area is stable, but with only one or two species such as river oak present, it is good practice to plant a variety of other species amongst these, to provide additional support and a variety of root structures in the bank.
5. Plantings need to extend from the toe to the floodplain. Too narrow a band of trees may serve only to increase the weight of the bank material and cause slumping. Areas of bank saturation caused, for example, by a dam on the adjacent floodplain, need to be treated. Drainage works and/or planting of recharge and seepage points adjacent to the riverbank will help reduce the chances of slumping.

Floodplain stripping

The process. The removal of topsoil from floodplains by overland flow is known as floodplain stripping. The events involved are depicted in Figure 15.

Floodplain stripping may be initiated by a combination of factors including:

- clearing of shrubs and trees from the adjacent floodplain allowing more flood-waters to move across it at a higher velocity, causing scouring of soil
- ploughing or cultivation of land on the floodplain making it vulnerable to erosion by overland flows.
- obstructions to flow in the main channel such as low-level bridges, debris blockages and excessive vegetation growth can reduce its capacity, causing overland diversions
- an influx of sediment into the stream.

On the North Coast, floodplain stripping occurs in the Manning, Hastings, Macleay and Clarence River valleys.

Management steps. Strategies to reverse the effects of floodplain stripping are generally as for its control: the use of flow-retards and revegetation. The aim is to encourage deposition of soil and sediments.

In conjunction with this, there is usually a need to remove some blockages from the main channel to reduce flows entering the floodplain at break-out points (Figure 15).

Types of flow retards vary, but often consist simply of a series of low fences placed across the direction of flow.

Once the site is fenced to exclude stock, vegetation is planted along the retards to ensure long-term stability of the site, an activity that brings supplementary environmental benefits. The same species as those suitable for planting along the toe of the bank can be planted in areas prone to floodplain stripping. Tree plantings should be dense (2 metre spacings) along the length of the retards on the downstream side, and at least 5 metres wide.

At sites where the topsoil has already been stripped and bare gravel is present, vegetation may be difficult to establish. Species recommended for planting along the toe will grow in gravel, but site preparation and watering may be necessary. To loosen gravel and allow easier planting and root penetration the planting area can be ripped. Bare gravel is a hot and harsh habitat, so to ensure success it is advisable to water seedlings until the roots have penetrated the gravel to ground water. If gravel is coarse, soil will need to be added to the planting hole. One of the simplest and most effective methods of maintaining seedlings on stripped areas is by a drip watering system which is linked to an existing watering system,

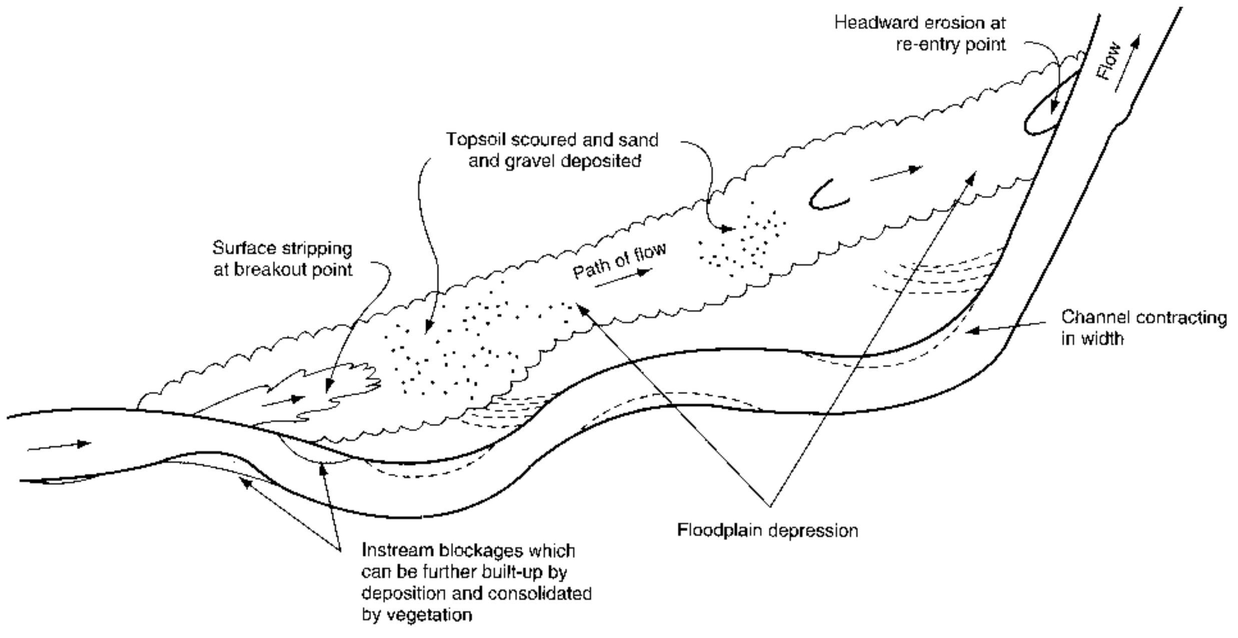


Figure 15. Planform view of the mechanics of floodplain stripping.

either irrigation or stock and domestic. This method will ensure watering each time the pump is used. The use of slow-release fertiliser and mulch is also recommended, as stripped sites are usually deficient in nutrients. Also, mulching will reduce temperature extremes in the gravel.

Another method which also allows establishment of seedlings in gravel is direct seeding using brush. A small area adjacent to flow retards is ripped (3–5 metres wide) to prepare the ground for seeding. Small branchlets of trees bearing woody fruits, such as tea-tree, bottlebrush and river oak, are harvested and pegged to the ground over the ripped area. As the fruits dry, the seed is released onto the prepared soil surface. The dead branchlets provide initial shade and protection during germination. In areas where gravels are coarse, supplementary irrigation may be required.

Floodplain stripping generally involves extensive areas. If the resources are not available to undertake a large replanting project over the entire area, it is best to concentrate on removing–to the calculated alignment width–blockages in the main channel near the break-out point and gradually revegetate in a downstream direction along the scour as resources become available.

Bed lowering

The process. A change in the sediment or hydrological regime, or in channel hydraulics, may lead to the bed of the stream eroding to a new, lower level (Figure 16). Events that may initiate bed lowering include:

- river flow regulation and water diversion
- flow concentration or restriction
- channel straightening
- inappropriate sand and gravel extraction
- excessing clearance of in-stream blockages
- an interruption to sediment movement, such as caused by construction of a dam or weir.

Severe bank erosion often follows bed lowering. As the riverbed falls, basal support of banks is removed and they collapse, resulting in a widening of the channel.

On many of the smaller North Coast streams, vegetation and bed stability are interlinked. Well-vegetated streams in their natural state contain relatively large amounts of woody debris contributing to bed roughness. Larger logs often generate riffles. Short-term activities such as desnagging may result in loss of riffles and a decrease in bed roughness, in turn increasing the tractive stress placed on the bed and leading to bed and bank erosion. Longer-term activities such as vegetation clearing from streambanks and adjacent land may result in a significant decrease in bed roughness and removal of the sources of larger debris contributing to bed controls.

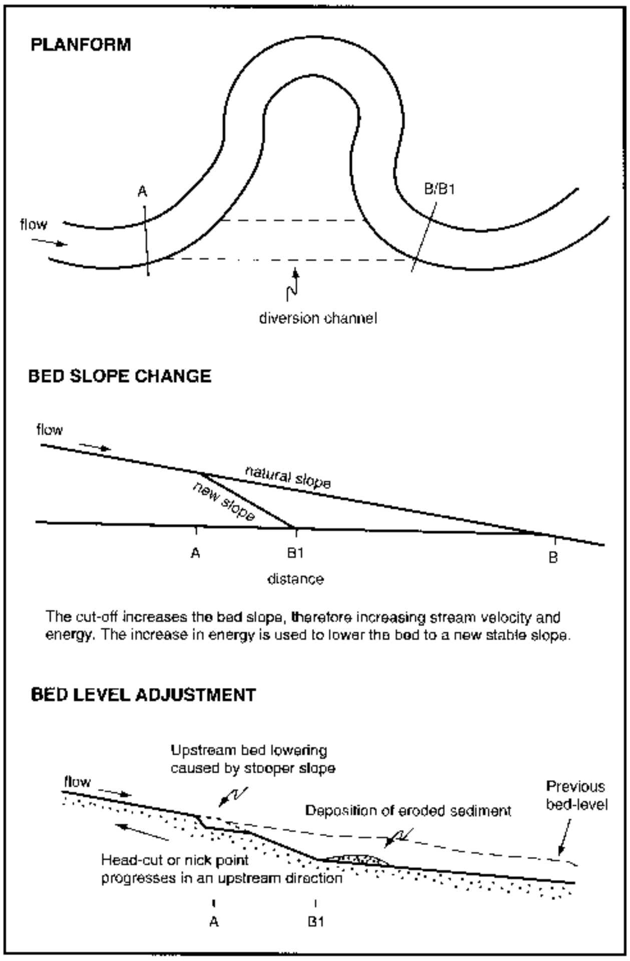


Figure 16. The mechanics of bed lowering, in this case induced by a meander cut-off. Adapted from Hurst et al. (1993).

Management steps. In the short term, bed lowering is combatted by controlling the upstream advance of head-outs, and by increasing bed height and roughness using bed control or grade control structures. These vary depending on the resources available and the type of stream. Some examples are illustrated in Chapter 4, and in Plates 12 and 13. More details can be found in 'Riverwise Notes – Works to Control Stream Bank Erosion', available from the NSW Department of Land and Water Conservation, and in 'Guidelines for Stabilising Waterways', published by the Rural Water Commission of Victoria (RWCV 1992).

Longer-term management options include:

- realignment of debris
- revegetation.

To maintain channel roughness, fallen logs causing erosion problems, rather than being removed, may be realigned parallel to the flow, or strategically secured to the bed. Advice on these procedures should be sought from an appropriate departmental officer.

Plate 12. The Cockburn River near Tamworth, New South Wales, looking upstream from the right bank. A rock-bed control weir and fishway are being used to prevent bed lowering in a stream on which sand and gravel mining has been excessive.

Plate 13. Bed/riffle control structure across the Great Forester River, Tasmania, made by the Springfield Landcare Group from truck tyres wired to pig netting fence.

Riverbank revegetation programs should, in the long term, incorporate native trees that contribute large, woody debris to the stream. In natural systems where banks are well vegetated and thus have high shear strength, such trees cause minimal damage if they fall into the stream. On streams of the North Coast of New South Wales, *Eucalyptus grandis* (flooded gum) is the most common contributor of woody debris of sufficient size to form controls in the stream bed.

Bankfull Width, Channel Geometry and Design

Newbury and Gaboury (1994) note that the: 'geometry of meanders and the pool and riffle profile for all river patterns in erodible materials may be related to bankfull width (see Figure 5). A full meander wavelength has been observed to occur between 7 and 15 times the bankfull width for rivers ranging from 0.3 to 300 m wide. The mean spacing of pools, half the meander wavelength, has been measured as 5.6 to 6.7 times the bankfull width for alluvial and bedrock streams by Roy and Abrahams (1980)'.

In a sample of natural meander bends in 50 rivers, the median value of the radius of curvature was found to be 2.7 times the bankfull width (Leopold et al. 1963).

From this it can be seen that, once the bankfull or 'dominant' width is established, the other channel geometry details can be quantified and used in the planning and implementing river works.

Management of Declining Vegetation and Maintenance of Existing Stable Areas

In many areas on the North Coast of New South Wales there is a lack of native plant regeneration and replacement due to grazing pressures. Evidence of this is an observation by one of the authors (AWR) of a lack of stems in the 0–10 cm size class. The solution of this problem should be recognised as a long-term management need. In many localities where trees and shrubs die through old age, fire, insect attack, etc, they are not being replaced. The slow removal of vegetation through this process will result in increased bank erosion and over-bank diversions, over a long period of time.

As part of a long-term plan to manage this type of degradation, whole-farm planning should incorporate rotational spelling of these areas from stock, to allow sufficient time for regeneration to occur. If insufficient natural seed source is available, a revegetation plan using appropriate species needs to be considered.

Summary of the Management Processes and Some Simple Management Options

The fold-out in Appendix 2, Section D illustrates and summarises key steps in the management process for a Rivercare plan and presents some simple management options.

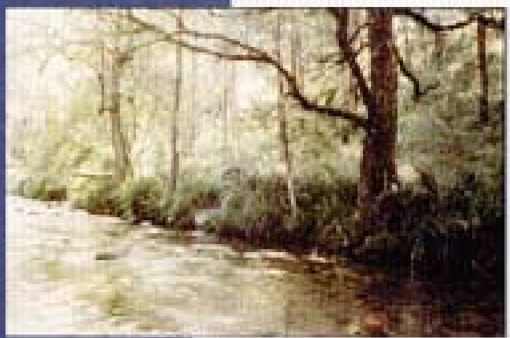
Land & Water Resources
Research & Development Corporation

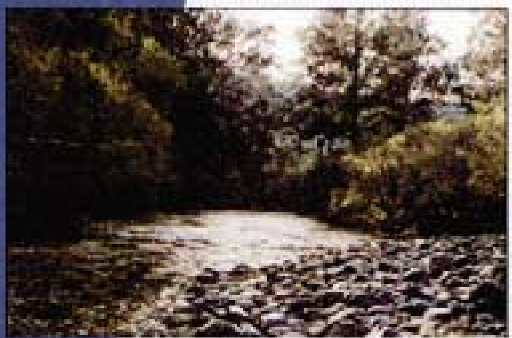
RIVERCARE

Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation

Occasional Paper No 03/95

Occasional Paper Series





6 USE AND MANAGEMENT OF NATIVE VEGETATION FOR RIVERBANK STABILISATION AND ECOLOGICAL SUSTAINABILITY IN THE MANNING RIVER CATCHMENT: A CASE STUDY

Background

As part of a long term commitment to the improvement of the riverine environment, the Department of Land and Water Conservation of New South Wales has undertaken inventories of riparian vegetation in catchments on the North Coast of New South Wales, with the aim of identifying and recommending suitable plant species for riverbank stabilisation and revegetation.

This chapter represents the results of the inventory of the Manning River catchment. This information is the basis for the practical methods described in users guides for landholders, Landcare groups, and others, presented in the Annex to this chapter and the Rivercare planning process described elsewhere in this paper.

The Importance of the Riparian Zone in Stream Ecology

The riparian zone may be defined as that component of land (including floodplains) adjacent to watercourses (Riding and Carter 1992). Riparian vegetation includes emergent aquatic and semiaquatic plants, and the terrestrial vegetation in the zone adjacent to the stream and dependent upon its presence (Parson 1991).

The biophysical functions of the riparian zone contribute to riverbank stability, channel integrity and ecological values, and may ameliorate flows of contaminants into streams from surrounding lands.

Bank stability and channel integrity

Bank erosion has been identified as one of the major land degradation issues on the New South Wales North Coast. For example, Reddoch (1957) records that between 1946 and 1955 a total of 250 ha of land was destroyed, equating to a volume of 23 million cubic metres of highly productive river flats, over the 85 km stretch of the Hunter River between Glenbawn Dam and Alcheringa.

Bank erosion is a natural process, contributing to the meandering movement of streams and the creation of floodplains over geological time, though it may be modified by both natural factors and human actions, as outlined in previous chapters.

Vegetation plays a significant role in influencing fluvial processes and channel morphology. Vegetation provides a resistance to flow (by increasing hydraulic roughness) and bank strength (through root systems binding the soil). Andrews (1984), for example, in a study of gravel bed rivers in Colorado, USA found that, on average, rivers with thick bank vegetation have approximately the same depth, but are 25% faster, 26% narrower, and nearly twice as steep as the rivers with sparse bank vegetation. Similar results were obtained by Hey and Thorne (1986). Charlton et al. (1978), in a study of British rivers with beds composed of non-cohesive gravel larger than 2 mm, found that the vegetation on the banks appeared to affect the width of the stream. Light vegetation (generally grass) led to widths about 30% greater than the average of the 23 rivers studied. Heavy vegetation (shrubs and trees) resulted in a width about 30% smaller than the average.

Ikeda and Norihiro (1990), in a study of self-formed straight gravel rivers (sinuosity less than 2) with vegetated banks, found that a thicker vegetation cover yields a greater depth and a smaller width, with increasing discharge increasing the effect of vegetation. Ferguson (1991) points out that binding networks of roots increase bank shear strength and that, during flood flows, resilient vegetation bends into erosion inhibiting mats. This appears to be true of riparian species such as *Callistemon viminalis*, *Leptospermum brachyandrum* and *Tristaniopsis laurina* on the North Coast of New South Wales. These and other riparian species are described later in this chapter. Where disturbance has led to the formation of mid-channel and point-bars, certain species (e.g. *Casuarina cunninghamiana* and *C. viminalis*) may colonise these, with the effect of 'over-narrowing' the channel, potentially leading to bank erosion.

Allen (1978) notes that the functions of vegetation in soil stabilisation, infiltration enhancement, filtering of soil particles, interception of precipitation and usage of soil water are also factors contributing to erosion control. The last has important consequences for areas subject to soil saturation and slumping where, as well as physical support, vegetation helps to control soil moisture levels [see Bell et al. (1990), for example].

Other important functions include natural bed level controls by roots and large woody debris. Such controls can help reduce bed degradation and also cause scouring, thereby maintaining pools in certain sections of streams (Cummins 1993) (see Plates 14 and 15). The hydraulic roughness of the bed is increased by logs and other large woody debris, thereby reducing the energy level of the stream.

Ecological values

Riparian vegetation is an important source of organic matter to streams.

Terrestrial insects falling from trees are a food source for instream fauna (Bunn 1986; Boulton and Suter 1986; Mason et al. 1984; Parson 1991 [all cited in Riding and Carter 1992]). Leaves and other woody debris provide habitat and food for instream invertebrates which are in turn eaten by fish. Pidgeon and Cairns (1981) indicate that plant detritus represents a primary food source for invertebrates. A high percentage of food eaten by fish living in well-vegetated riparian areas, particularly on smaller streams, consists of terrestrial insects (Riding and Carter 1992). Mason et al. (1984) [cited in Riding and Carter (1992)] found that canopy insects are as important as aquatic invertebrates as a food source on smaller streams.

Larger inputs from riparian vegetation, such as branches, logs, and overhanging roots, provide important habitat and feeding areas for fish and other instream fauna. Parson

Plate 14. Partly submerged log controlling the pool level upstream and forming a scour hole downstream (Hastings River at Lonely Point).

Plate 15. Partly submerged log controlling the pool level and riffle sequence. Sediment build-up on the downstream side has been colonised by *Lomandra* sp. (Orara River near Nana Glen).

(1991), for example, found that fish use this debris, and other habitat such as tree roots, to shelter from high velocity stream flow, predators, sunlight and competitors, and as spawning areas (Koehn and O'Connor 1990). Some native fish species are known to lay adhesive eggs on, or in, logs. Lloyd et al. (1991) in reporting on a study in the River Murray state that large woody debris 'create a complex and patchy environment that promotes the coexistence of many dissimilar plants and animals, including predators and their prey'. They also indicate that large woody debris plays an important role in productivity, particularly where the substratum is of sand or mud.

Another important effect of riparian vegetation is in moderating water temperature fluctuations, by shading streams. Small streams cleared of riparian vegetation may experience more rapid temperature fluctuations than shaded streams (Koehn and O'Connor 1990). Reynolds (1986) indicates that temperature changes of as little as 2°C can affect the breeding success of fish such as trout. Dappled shade from riparian vegetation also provides camouflage for fish and helps prevent predation (Reynolds 1986; Koehn and O'Connor 1990).

A range of terrestrial fauna frequents or relies on riparian forests for food. Birds observed in the riparian zone on the North Coast of New South Wales include the azure kingfisher, mangrove kingfisher, nankeen night heron, restless flycatcher and black bittern. A study of the Colo River valley in New South Wales found that, of the 20 non-flying mammal species likely to occur, 17 frequent the riparian vegetation areas (Riding and Carter 1992). Gregory and Pressey (1982) [cited in Riding and Carter (1992)] state that platypus and the water rat are particularly dependent on riparian habitat, and that nineteen species of bats may also occur in vegetation near streams. Floyd (1990b) also points out that, on the North Coast of New South Wales, flying foxes have a preference for riverine rainforest. Taylor (1986) reports that, as a result of a streamside revegetation program on Rainbow Creek in Victoria, there has been a return of platypus and a bird species, the white faced chat.

There has been much discussion on the role of vegetation corridors in facilitating the movement of fauna [see references in Saunders and Hobbs (1991)]. Research demonstrating the use and importance of linear vegetated areas for wildlife corridors includes that of Saunders and de Rebeira (1991) and Arnold et al. (1991) for birds and kangaroos, respectively. Research on the New South Wales North Coast by Date et al. (1991) indicates that corridors and relatively closely spaced areas of vegetation are important in facilitating the passage of certain tree-fruit-feeding pigeon species. They also state that passage for migrant species can be aided by retaining rainforest along features such as gullies, streambanks, fencelines, and road verges. However, little research has been done to assess the value of riparian areas as wildlife corridors linking larger vegetated areas.

Many riparian forests support rare plant species or vegetation associations. Floyd (1990b) lists three suballiances of the *Castanospermum–Waterhousea floribunda* dry rainforest alliance all of which are strictly riparian. These are:

- *Castanospermum–Grevillea robusta* suballiance
- *Streblus–Austromyrtus* suballiance
- *Waterhousea floribunda–Tristaniopsis laurina* suballiance

Floyd (1990b) indicates that two factors which may determine their distribution are groundwater and floodwater. The availability of groundwater in the riparian zone supplements inadequate rainfall during dry months, and relatively high velocity floodwaters necessitate species with flexible branches.

A number of Floyd's other subtropical rainforest suballiances are generally confined to alluvial areas. These are:

- *Toona–Flindersia* (lowland alluvium)
- *Cryptocarya obovata–Dendrocnide excelsa–Ficus* spp.–*Araucaria* (floodplain alluvium)
- *Elaeocarpus grandis* (streambank alluvium)
- *Castanospermum–Dysoxylum mollissimum* (moist, alluvial flats and benches).

On the New South Wales North Coast several riparian forests commonly contain fruit-bearing species such as those of the Lauraceae family, which are absent in the surrounding eucalypt dominated open forests [see Gilmour and Helman (1991), for example]. These areas provide important food sources for fruit-eating bird species, particularly fruit-doves.

Several plant species are also generally confined to riparian forests. Examples include:

- *Waterhousea floribunda* (weeping myrtle) – streams from the Williams River, New South Wales to Mackay, Queensland.
- *Tristania neriifolia* (water gum) – streams in the Sydney District.
- *Potamophila parviflora* (river grass) – streams from the Hastings River north into Queensland.
- *Tristaniopsis laurina* (water gum) – streams from Bairnsdale, Victoria, to Eumundi, Queensland.
- *Callistemon viminalis* (weeping bottlebrush) – streams from the Williams River north into Queensland.
- *Casuarina cunninghamiana* (river oak) – streams in New South Wales and Queensland.

There are also many plant species that are purely aquatic, living within the stream. Sainty and Jacobs (1981) provide details of these.

Buffer zones

Vegetated areas along watercourses may function as a buffer between the watercourse and adjacent agricultural land, aiding in the removal of sediment and attached and dissolved nutrients and pollutants from run-off by providing opportunities for filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilisation (Nieswand et al. 1990). Within a buffer strip, vegetation reduces the velocity of run-off by increasing the hydraulic roughness, causing sediment deposition and the trapping of particles around roots and stems. Ideally, a buffer zone should be comprised of grasses, shrubs, and trees, all of which aid in trapping sediment, and contribute to the structural stability of the bank and the uptake of trapped nutrients.

The effectiveness of buffer strips in protecting water quality is dependent on a number of parameters, including: slope length; slope angle; soil type; rainfall intensity and duration; vegetation type and degree of cover; buffer width; degree of water channelisation when passing through the buffer; degree of soil aggregation; and present form of land management.

Peterjohn and Correll (1984) in the United States showed that nutrient removal in riparian forest is of ecological significance to the receiving waters. Their research results indicated that some 4.1 Mg of particulates, 11 kg of particulate organic-nitrogen (N), 0.83 kg of ammonia-N, 2.7 kg of nitrate-N and 3.0 kg of total particulate-phosphorus (P) per ha per year were removed from run-off which passed over approximately 50 m of riparian forest. Run-off experiments by Dillaha et al. (1989) studied shallow, uniform flow over plots 9.1 m and 4.6 m long, with slopes of 11% and 16%, respectively. Their results indicated that flow over the longer plot removed, on average, 84% of incoming solids, 79% of incoming P and 73% of incoming N. The corresponding values for the shorter plot were 74%, 61% and 54%. Removal rates for phosphorus and nitrogen are similar to removal rates for sediment as most N and P were sediment bound.

Lowrance et al. (1984) found in a study of a small catchment in the United States that nutrient uptake and removal by soil and vegetation in a riparian forest prevented outputs from adjacent agricultural areas from reaching the stream.

McColl (1978) in a New Zealand study concluded that run-off water which flows directly from pasture to stream without the intervention of streambank vegetation poses the greatest risk to water quality.

Generally, where run-off is collected and confined in a channel or gully when passing through a buffer zone, the efficiency of sediment and nutrient trapping by the zone declines to almost zero (Norris 1993).

Other research (e.g. Haupt and Kidd 1965; Barling and Moore 1992) has also demonstrated the efficacy of buffers to remove nutrients and sediment.

Commenting on the use of grasses as sediment filters, Karr and Schlosser (1977) note that the species used should have the following characteristics:

- deep root systems to resist scouring in swift currents;
- dense, well-branched top growth;
- resistance to flooding;
- ability to recover growth after inundation by sediment; and
- if possible, they should also yield an economic return.

Another important factor in determining the efficiency of grass in trapping sediment is its retardance coefficient. Karr and Schlosser (1977), for example, point out that the retardance, and therefore the filtering capacity of a grass, falls to zero when it is completely submerged. For this and other reasons, a key to efficient functioning of buffer zones is their structural diversity. They should contain a range of grasses, groundcovers, sedges, shrubs, and trees. This is particularly important when buffers are used to protect the instream environment, as stream shading, input of terrestrial organic matter, and diversity of substrates are crucial in the maintenance of instream habitat. Further examples can be found in Riding and Carter (1992).

General Description of the Manning Catchment

Location and topography

The Manning River catchment occupies approximately 8400 km^2 on the mid North Coast of NSW between longitude 151°10'E and 152°45'E and latitude 32°10'S and 31°20'S (Figure 17). Major towns within the catchment are Taree and Wingham in the east, and Gloucester in the south.

WCIC (1968) recognises four main topographic zones within the catchment: plateau areas (tablelands), dissected uplands (escarpments), alluvial valleys and coastal riverine plains.

Most of the major streams in the Manning River catchment commence on plateaux or in dissected uplands, and flow in an easterly or south-easterly direction through alluvial valleys, before joining the Manning River, which traverses the coastal riverine plain. Exceptions are the Gloucester, Barrington and Avon rivers, which flow in a north-easterly direction.

The Manning River rises in a plateau of the Mt Royal Range north of Barrington Tops at a height of about 1570 m. From here it traverses relatively mountainous country with steep-sided valleys. Until its confluence with the Gloucester River, alluvial flats along the Manning are small and scattered.

Major tributaries of the Manning River are the Barnard, Nowendoc, Barrington and Gloucester rivers, all of which flow through mountainous or hilly country for much of their length. Southwest of Barrington township, the Barrington River enters an alluvial plain, as does the Gloucester River southwest of Gloucester township. Downstream of Gloucester, the Gloucester River passes through hilly to undulating country until its confluence with the Manning River, where the river is again flanked by larger alluvial flats.

Minor tributaries include the Avon River, which traverses a flat, broad floodplain upstream of its confluence with the Gloucester River; Dingo and Cedar Party creeks, which drain the Bulga and Comboyne plateaux, respectively, in the north-east of the catchment; and the Lansdowne River which drains the northern coastal section of the catchment, traversing large areas of flat alluvial land.

WCIC (1968) states that flat lands (slopes less than 3°) occupy only a very small proportion of the catchment (less than 9% of the total area), including the extensive swampy coastline areas. Land classified as undulating to hilly (slopes 3–8°) and hilly to steep (slopes 9–15°) comprises 13 and 11% of the total catchment area, respectively. Rugged to mountainous areas (slopes greater than 15°) make up 67% of total catchment area (WCIC 1968).

Climate

The following picture of the climate of the Manning catchment comes from Birrell (1987).

In general, rainfall in the Manning catchment decreases with increasing distance from the coast. The exceptions are the Comboyne Plateau and Barrington Tops areas which receive the catchment's highest annual average rainfalls. Average annual rainfall at Elands (Comboyne Plateau) is about 1735 mm, and is estimated to exceed 1750 mm a year on Barrington and Gloucester tops (Bureau of Meteorology 1988). Moving from east to west, annual rainfall at Manning Heads is 1369 mm, at Taree 1187 mm, at Wingham 1101 mm, at Gloucester 978 mm, and at Glenrock in the far west is 700 mm (Bureau of Meteorology 1988). Throughout the catchment, the wettest period is December to April inclusive. The driest periods generally occur during July to November.

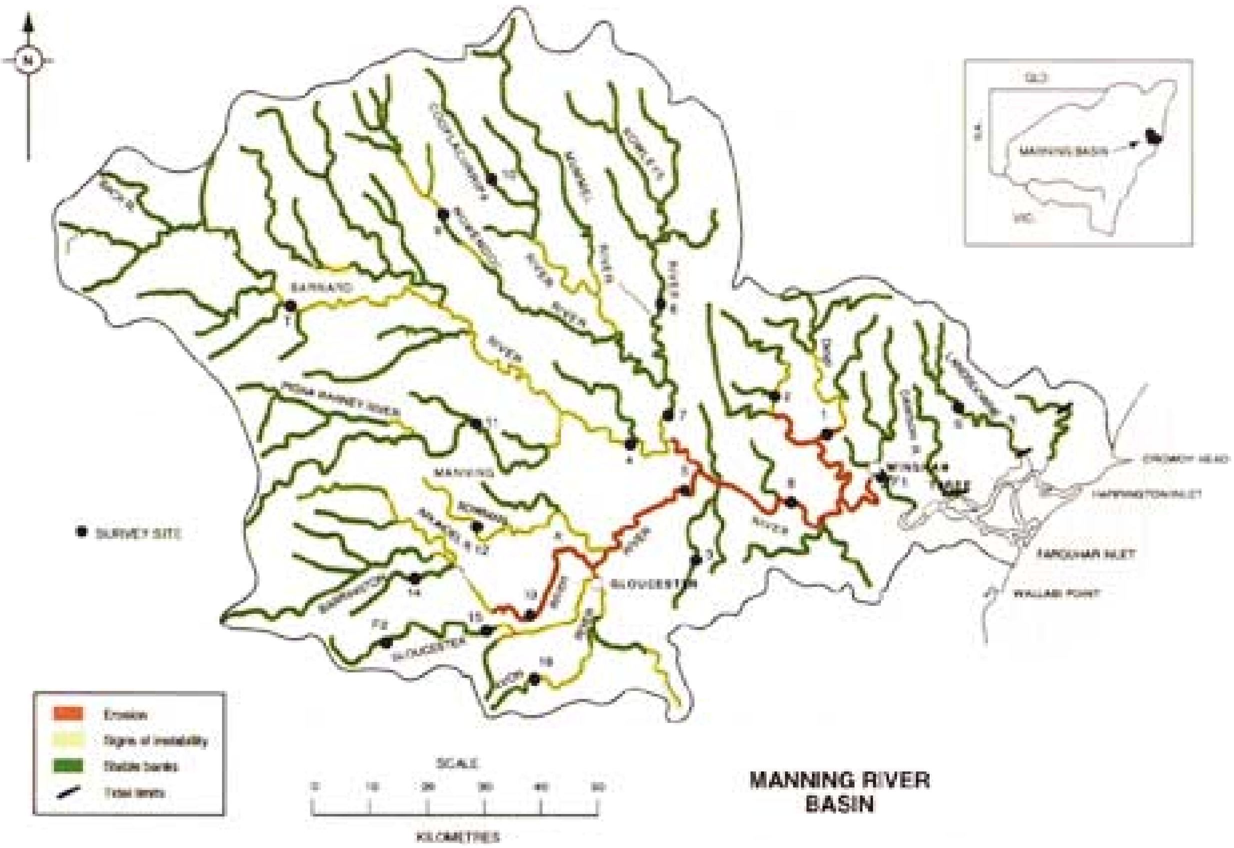


Figure 17. The Manning River catchment, showing locations of study sites.

As with other North Coast catchments, rainfall may vary widely from year to year. Gloucester, for example, which has an average annual rainfall of 977 mm, received only 498 mm in 1964, but 1875 mm in 1993.

In the lowland coastal areas, average maximum temperatures in January and February are between 25 and 28°C, and the average minimum temperature is 18°C. Inland, average summer temperatures are generally lower, but maximum daily temperatures may be much higher due to the increased distance from the ocean.

Similarly in winter, the influence of the ocean creates milder temperatures on the coast (6–8°C average minimum), with greater extremes experienced inland (average minimum temperatures are estimated to be as low as 0°C in high altitude areas). The frequency of frosts increases with distance from the coast. On the coast, severe frosts may be expected during June and July (2–5 per year frequency) and about 30 severe frosts may occur in the uplands between May and September. In high altitude areas such as the Barrington Tops and Nowendoc areas, there may be winter snowfalls.

Geology

The following picture of the geology of the Manning catchment draws heavily on SCS (1985).

Uplifting toward the end of the Tertiary period raised the New England region approximately 600 m. The effect of this is most evident in the western and north-western sections of the catchment. The large relief of these areas and dissection of the folded and faulted erosion-resistant Devonian and Carboniferous sedimentary rocks has led to the development of steep-sided narrow valleys which are drained by the Gloucester, Manning, Barnard, and Nowendoc rivers. The southern portion of the catchment is characterised by the folding of the Carboniferous sedimentary strata to form the synclinal valley of the Avon River.

The main geological zones recognised are:

Quaternary alluvium (river gravels, alluvium, sand and clay). These extend inland from the coast up the major river valleys of the Avon, Gloucester, Barrington, Manning, Nowendoc and Lansdowne rivers, and Dingo and Caparra creeks.

Tertiary igneous (volcanic) rocks (mainly basalt and dolerite). These form part of the Liverpool Range beds and occur in the elevated sections of the catchment, namely the Comboyne Plateau, sections of the Mt Royal Range including Barrington Tops, and parts of the Great Dividing Range in the north-west of the catchment between the headwaters of the Barnard and Rowleys rivers. Weathering and erosion from these basaltic areas have contributed to the relatively higher fertility of the alluvium supporting rainforest in the middle and lower sections of the catchment.

Devonian–Carboniferous sedimentary rocks. These include the Bowman beds in the south of the catchment, and the 'Sandon Association' in the north and north-west. The Bowman beds consist mainly of sandstones and siltstones and the Sandon Association includes sandstones, schists, phyllites and slates.

Early Palaeozoic sedimentary rocks. These include the Myra beds, which contain cherts, claystones, tuff and sandstones. They occupy the central and western parts of the region, including areas drained by the Barnard and Curricabark rivers.

Permian sedimentary rocks. These strata include the Giro beds, which overlie the Myra beds in the central part of the catchment and contain mudstones, conglomerates, siltstones, shales and sandstones.

In general terms, with the exception of those areas of alluvium influenced by basalts on the broader flats of the Gloucester, Barrington and lower Manning rivers, most riverbank areas are relatively infertile and composed mostly of coarse material derived from the sedimentary strata outlined above. The riverine vegetation reflects this.

Stream flows and erosion

The average annual discharge of all streams in the Manning catchment is 2270 million m^3, which is 40% greater than the average for coastal streams in NSW (WRC 1980), and represents about 23% of annual rainfall over the catchment. As with most North Coast catchments, stream flows are highest during February–April and lowest during September–November (see Figure 18), which corresponds to maximum and minimum rainfall distribution throughout the year.

Substantial variations exist in stream discharge from year to year, with some major streams (e.g. Gloucester and Barrington rivers) ceasing to flow in severe droughts. According to WRC (1980), the longest zero flow period recorded at any main stream is 90 days, during the summer of 1951–1952. On average, moderate floods occur every 5 years.

Erosion in the Manning catchment is detailed by Raine and Gardiner (1992). The main problems are:

- floodplain stripping;
- bank erosion; and
- lack of maintenance of old river works.

Floodplain stripping is the removal of alluvial soil during floods, as a result of processes such as *scouring*.

The fluvial processes causing floodplain stripping are basically a response of the river to changed hydrological and hydraulic conditions. Bank and floodplain vegetation, one of the major controlling variables, has been altered to the extent that dependent variables, including average bankfull width, and stream velocity and depth have had to adjust to the new regime. This is because vegetation removal from the floodplain has provided an easy path for flood flows, leading to a decrease in the competency of the main channel. In time, the main channel can overgrow thereby exacerbating the problem and leading to further floodplain stripping and erosion. Figure 19 and Plate 16 illustrate its occurrence at Charity Creek on the Manning River.

According to Nanson and Erskine (1988), during a series of eight floods of varying severity (recurrence interval 3.8–52 years) between 1968 and 1978, approximately half the 250 m width of the floodplain of the Manning River at Charity Creek was stripped to basal gravels for a length of over 600 m. From the results of carbon dating, they suggest that, while floodplain stripping probably occurred in the Manning before European settlement, it is now exacerbated by a lack of vegetation on the floodplain. Deposition and accretion of alluvial soil are unlikely to occur on the stripped areas while there is no vegetation to moderate flow velocities, and the main channel continues to overgrow.

Floodplain stripping is the main erosion problem for the Manning River, occurring from the Nowendoc River confluence to the tidal limit, and also along sections of the lower Barnard River.

Surveys of areas around the Avon and Gloucester rivers and Dingo and Caparra creeks, as well as some sections of the Barrington, Barnard, Little Manning, Nowendoc and Rowleys rivers, revealed bank erosion as the major riverine degradation problem in these areas (Plate 17). Generally, such erosion occurs on the outside river bends, as a result of processes such as *undercutting* and *slumping* (see Chapters 4 and 5).

As outlined in Chapter 5, bank erosion is a natural process, contributing to the meandering movement of streams, and the creation of floodplains over geological time. Factors, natural or of human origin, that may accelerate or otherwise modify bank erosion include riverbed instability, removal of protective and binding vegetation, changes in the sediment or hydrologic regime (caused by catchment clearing and inappropriate gravel extraction, for example), bank saturation, trees falling from banks and acceleration of flow around debris and instream blockages.

Instream blockages are obstructions within the river channel that may cause erosion by flow diversion due to constriction of the main channel. Within the Manning system, such obstructions usually occur as gravel bars and/or vegetation growth within the main channel. Colonising plant species such as *Callistemon viminalis* and *Casuarina cunninghamiana* appear to have become more common on North Coast streams due to habitat changes within the riparian zone. Such species colonise point- and mid-channel bars and, where the banks are unprotected, have the potential to cause bank erosion.

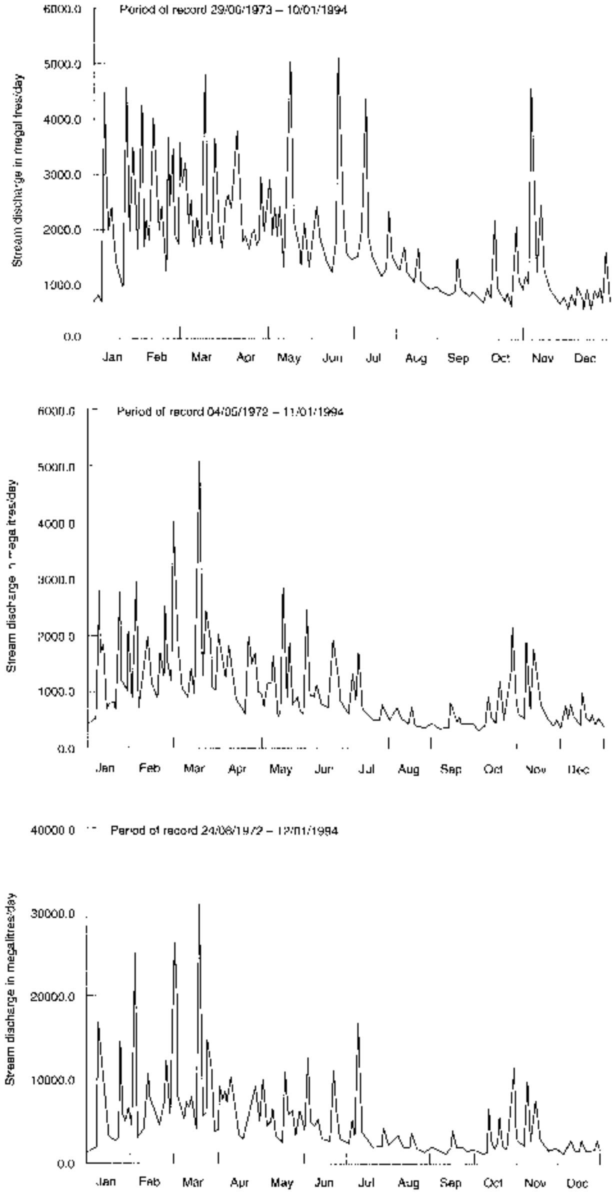


Figure 18. Average stream discharge (ML/day) for (top) the Nowendoc River near Nowendoc, (middle) the Barrington River at Forbesdale, and (bottom) the Manning River at Killawarra.

In pristine systems, on the other hand, large logs or snags, and vegetation growth within streams often act as bed controls, and assist in the creation of pools by processes such as scouring (see Plates 14 and 15). This process assumes greater importance in the narrower sections of streams such as the upper areas of the Gloucester, Avon, Bowman and Barrington rivers, and Dingo and Caparra creeks. There must thus be careful consideration before blockages are removed. In some areas strategies are now being developed to replace these natural bed controls to re-establish lost pool–riffle sequences.

Problems associated with old wire-mesh river works are evident around Gloucester and Barrington.

The concept underlying wire-mesh river works is that the meshwork protects the toe of the bank while vegetation planted becomes established. The wire mesh eventually disintegrates and the vegetation takes over the main role of bank stabilisation.

River works may fail if not properly maintained. Common problems include the following.

- Excessive growth of vegetation on the opposite point-bar causes the velocity of flood-flows against the works to exceed the original design load of the works. Maintenance involves the removal of these trees (in the Gloucester area, usually *Casuarina cunninghamiana*), to increase channel width and relieve the pressure of flood-flows against the works.
- In many cases the willows within river works are reaching the end of their life. These willows require lopping to maintain a bushy habit and to prevent trees from falling into the watercourse and further damaging the works (Plate 18). In many cases, where willows are becoming old and their protective function is reduced, the river may out-flank the works during floods and subsequently

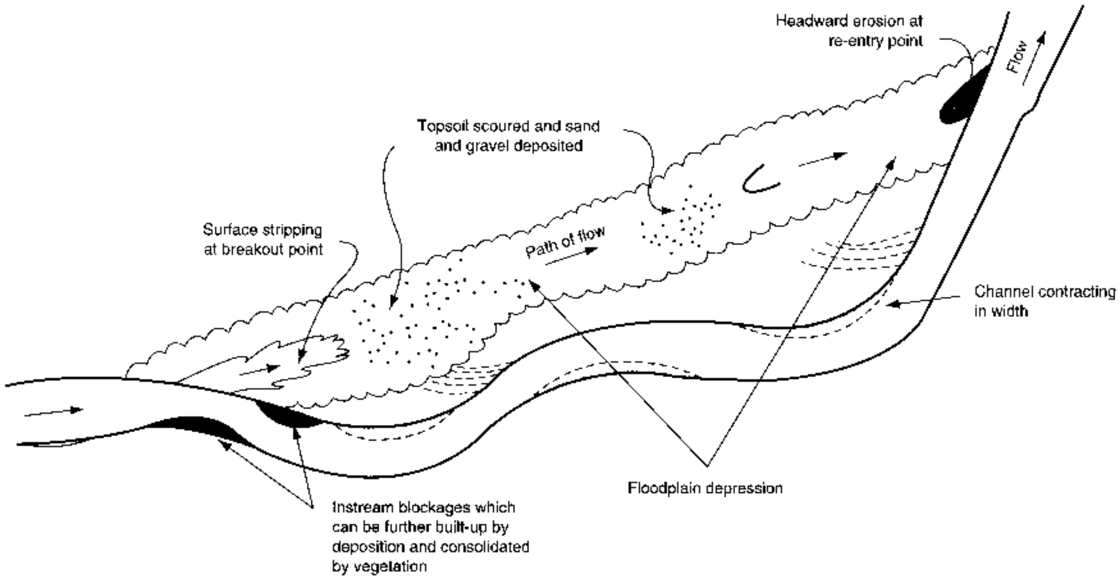


Figure 19. The mechanics of floodplain stripping at Charity Creek, Manning River.

Plate 16. View of floodplain stripping along the Manning River at Charity Creek. The horizontal rules to the left of the picture mark out the stripped area, the left arrow the break-out point, and the right arrow sedimentation and consolidation by vegetation on a mid-channel bar.

flow around them. At these sites the area should be heavily replanted (1 m spacings) with native species to encourage long-term stability, and the old willows lopped.

- Incorrect initial alignment of works.

Community identified water resource issues in the Manning River catchment

A report of the Manning Catchment Management Committee (MCMC 1990) uses total catchment management (TCM) principles to identify issues in the catchment. These views of the catchment community are presented in this section.

Major problems with the potential to impact on water resources, and which are relevant to riverbank stabilisation and ecological sustainability, include:

- streambank erosion and riparian issues;
- sedimentation and gravel build-up; and
- flood damage to infrastructure.

Streambank erosion and other riparian issues

The two major community concerns regarding streambank erosion in the Manning catchment are loss of highly productive farmland, and associated increases in the sediment load of the river.

To address these concerns the Manning Catchment Management Committee, the Department of Land and Water Conservation, and various Landcare groups have:

- completed a morphological survey of the Manning catchment to identify eroded areas (red), unstable areas susceptible to erosion (yellow), and stable (green) areas—the results of this survey are shown in Figure 17.
- developed Rivercare plans for the Gloucester, Barrington, Bulliac, and Mt George Landcare Groups; and
- demonstrated low-cost methods of erosion control.

The Manning Catchment Management Committee recognises the importance of well-maintained and managed vegetation growth in preventing further erosion of streambanks and floodplains, and has extended this concept into the Rivercare planning process.

Sedimentation and gravel buildup

Transport and deposition of sediment within river channels is a natural process. However, changes in the hydrologic regime of a river may alter the sediment regime. These changes may be both natural and human-induced. Inputs of sediment can be significantly increased by reworking of inactive floodplain/sediment through accelerated riverbank erosion and floodplain stripping.

Plate 17. Bank erosion along the outside of a meander bend along the Gloucester River at Gloucester.

Plate 18. View of the Gloucester River immediately upstream of the Gloucester Caravan Park. Willows used here for erosion control have reached the end of their life span and are falling into the stream (right of picture). The bank has migrated several metres from the original alignment of the works (the original piles can be seen amongst the debris within the stream).

Increased gravel loads within streams may contribute to increased flooding, floodplain stripping and streambank erosion by reducing the capacity of the main river channel to carry water during flooding and increasing the tractive stress. The problem may be further exacerbated when the deposited gravel is colonised by opportunistic plant species such as *Casuarina cunninghamiana* during extended low-flow periods. These consolidated gravel bars may constrict the channel, causing erosion on the opposite bank or out-flanking and subsequent soil stripping.

One of the major environmental effects of increased sedimentation is the loss of instream habitat and food sources, due to smothering by sediment.

The Manning Catchment Management Committee has stressed the need for river corridor planning, erosion mitigation, and planting to protect the river corridor and reduce sediment inputs from accelerated streambank erosion and floodplain stripping.

Flood damage to infrastructure

Damage to infrastructure such as bridges, culverts and roads has occurred in the Manning catchment during major floods. The cause of most damage has been debris build-up or streambank erosion. When problems of streambank erosion, and sediment and gravel build-up, are addressed, and riverland vegetation and the development of flood-prone land are properly managed, flood damage to infrastructure will be reduced.

Site Selection and Survey Methodology

Riparian zone vegetation of the Manning River catchment was surveyed, from the headwaters of streams to their tidal limits.

Aerial photos were examined to locate all significant sites of remnant vegetation. Having located such areas, the selection of sites for field survey was based on geology, altitude, climate, area of catchment, channel slope, and proximity to known erosion areas. At each site a general survey of vegetation was undertaken. A broad reconnaissance was made of riparian vegetation between survey sites. Where no remnant stands of riparian vegetation were present, larger stands of regrowth were surveyed.

Sixteen sites were surveyed (see Figure 17). At some of them, transects were employed to illustrate broad structure and the location of plant species with regard to channel and bank geomorphology. Transects were placed perpendicular to the channel and extended to the pasture–forest interface, or the boundary between riparian and hillslope species. All species which overhung or were intersected by the transect line were recorded, their position noted and height estimated using an Abney level. Channel and bank profiles along the transect lines were also recorded. Photographs were taken at each site.

Species and abundance were recorded using methods similar to those of Floyd (1990a,b) and Gilmour and Helman (1991). Although most species at each site were recorded, the surveys were not exhaustive and species lists should therefore be regarded as indicative only. The abundance ratings used were:

- vc = very common – top 1–6 most common species
- c = common – more than 5 individuals
- o = occasional – 1–5 individuals

Qualitative observations were made of the role of species in stabilising the bed and banks of the stream, particularly in potential erosion-prone areas such as the outside of meander bends.

Plant names used in this report follow Harden (1990, 1991, 1992, 1993) with the exception of *Daphnandra micrantha*, which follows Beadle (1982). Difficulty was experienced in identifying several species, particularly grasses, sedges and rushes, and especially where no fruiting bodies were present and/or stock damage had occurred. Specialist help was sought with species which could not be readily identified. For very common species such as *Lomandra longifolia* and *Lomandra hystrix*, cattle damage to plants had occurred at many sites and a species assessment was made based on the habitat. Both species, however, are common to all North Coast catchments, and can occur within the riparian zone on any particular stream.

Parameters that characterised the general environment at each site were recorded, using a method similar to that of Vernon (1987). These were:

- site description—a brief description of the overall site in terms of the stream and vegetation characteristics;
- grain-size of the bed load using the Wentworth–Udden scale (Whitten and Brooks 1977);
- land use in the surrounding area; and
- degree of disturbance.

Other measurements taken included:

- channel slope—as measured from topographic maps;
- elevation;
- geology; and
- approximate catchment area.

An extensive literature review (see Raine and Gardiner 1992) was undertaken to collect information on the use of native species for erosion control and on current vegetation management practices. Reference in the text to right and left riverbanks refers to the banks viewed in a downstream direction.

Vegetation Survey Results

Survey sites and factors that may influence the distribution of riparian vegetation

Most sites (see Figure 17) are around the more populous areas of the catchment, where most accelerated bank erosion is occurring, including areas along Dingo Creek (Sites 1 and 2), the Gloucester, Barrington and Avon catchments (Sites 11–16), Bakers Creek (Site 3), sections of the mid-Manning (Sites 4, 5, 7 and 8), and lower Rowleys River (Site 6). Other sites are representative of changes in geology, climate, altitude and physiography: Site 9 is on the Nowendoc River at a high elevation near Nowendoc township; Site 10 is located on the Cooplacurripa River and is representative of higher altitude streams in steep-sided valleys; Site 11 is representative of upper sections of the Manning River. Other streams, such as the Barnard, Pigna Barney, Myall and Mummel rivers, contain few vegetation remnants of substance along their middle to lower sections and/or are difficult to access. These rivers flow through steep-sided valleys in which there are very few, if any, erosion problems. They were therefore not suveyed.

Information on the upper Barnard River (Figure 17, Site T) was obtained from Turner (1981). Information collected during surveys by Floyd (1990b) at Wingham on the Manning River (Figure 17, Site F1) and the upper Gloucester River at Gloucester Tops Flora Reserve (Figure 17, Site S) was also recorded.

Various factors may influence the composition and structure of riparian vegetation along streams in the Manning catchment, including:

- elevation;
- geology and soils;
- past disturbance;
- floodwater velocity and inundation; and
- stream width.

Each of these factors is discussed in terms of its potential influence on vegetation, but note that under natural conditions they operate interactively rather than in isolation. Obviously, further research is required to determine the degree to which each of these factors influences the distribution of vegetation.

Table 2 gives scientific and common names of those plant species occurring on the catchment that are of particular significance in the context of riparian revegetation. Wrigley and Fagg (1988) give descriptions of the growth requirements of most of these and of most other species mentioned here.

Table 2. Scientific and common names of some of the more important plant species in the context of riverine revegetation of the Manning catchment.

Scientific name	Family	Common name
Acmena smithii	Myrtaceae	Small-leaved lilly pilly
Angophora subvelutina	Myrtaceae	Broad-leaved apple
Aphananthe philippinensis	Ulmaceae	Rough-leaved elm
Backhousia myrtifolia	Myrtaceae	Grey myrtle
Callistemon sieberi	Myrtaceae	River bottlebrush
Callistemon viminalis	Myrtaceae	Weeping bottlebrush
Carex gaudichaudiana	Cyperaceae	Tufted sedge
Casuarina cunninghamiana	Casuarinaceae	River oak
Cryptocarya spp.	Lauraceae	Laurels etc.
Elaeocarpus obovatus	Elaeocarpaceae	Hard quandong
Eucalyptus spp.	Myrtaceae	Gums, boxes, stringybarks, etc.
Ficus coronata	Moraceae	Creek sandpaper fig
Glochidion ferdinandi	Euphorbiaceae	Cheese tree
Leptospermum polygalifolium	Myrtaceae	Creek teatree
Lomandra hystrix	Lomandraceae	Mat-rush
Lomandra longifolia	Lomandraceae	Spiny mat-rush
Melia azedarach var. *australasica*	Meliaceae	White cedar
Podocarpus elatus	Podocarpaceae	Plum pine
Potamophila parviflora	Poaceae	River grass
Streblus brunonianus	Moraceae	Whalebone tree
Syzygium australe	Myrtaceae	Brush cherry
Tristaniopsis laurina	Myrtaceae	Water gum
Waterhousea floribunda	Myrtaceae	Weeping myrtle

Elevation

In larger catchments such as the Manning, which incorporate sections of the Northern Tablelands, elevation is a major determinant of vegetation types along streams, with tableland areas subject to much lower temperatures on average, and severe frosts and snow. The riparian forest on the tablelands is therefore dominated by cold-tolerant species such as *L. polygalifolium* and *C. sieberi*.

At Site 9, which is on the eastern escarpment, there are species characteristic of both tableland and lowland areas, including *L. polygalifolium* and *Eucalyptus pauciflora* (tablelands), and *C. cunninghamiana* and *Angophora subvelutina* (lowland areas).

Geology and soils

The geology and soils may influence the type of vegetation present, at both local and catchment-wide scales.

At a local scale, soil properties may change with increasing distance from the low-flow channel. For example, at Sites 11 and 13 the soils in frequently flooded areas consist of coarse-grained alluvial gravels with fines of sand and silt, and are of relatively low fertility. This area occurs within the bankfull zone and is characterised by species such as *C. cunninghamiana*, *T. laurina* and *C. viminalis*, which have low nutrient requirements.

Next to these coarse-grained, lower fertility soils, the alluvial benches and/or flats are made up of fine-grained alluvium (often contributed to by basalt which occurs upstream in the catchment) and, as a result, these areas support dry rainforest and are floristically diverse (see Figure 21).

On a catchment-wide scale the geology of each sub-catchment can have a significant influence on the vegetation present. For example, the alluvial soils adjacent to the lower sections of the Manning River are derived from a number of sources, including basalt from plateau areas, and are relatively fertile. These areas support, or previously supported, lowland subtropical rainforest (e.g. Sites 8 and F1).

In areas where alluvium is derived predominantly from sedimentary sources, riparian forests tend to be floristically simple.

Past disturbance

Since European settlement, much of the original riverine vegetation has been cleared from areas within the Manning catchment. This has led to an increase in light levels reaching the bed and banks of the streams and, as discussed in Chapter 4, the bedload. This has resulted, in turn, in an increase in the numbers of colonising, light-demanding species such as *C. cunninghamiana* and *C. viminalis* which require moist gravel and high light levels to germinate. Areas of even-aged *C. cunninghamiana* regrowth typically occur along sections of the Gloucester River near Gloucester, the Bowman, Cooplacurripa, Barrington rivers, and sections of the Little Manning River where past riverbank clearing was most intense.

The remediation of long stretches of the degraded Gloucester and Barrington rivers, and of parts of some other streams, was attempted during the 1960s and early 1970s using wire-mesh training works and willows. This was initially generally successful but, because of lack of attention, these works deteriorated and have now become part of the revegetation and maintenance program.

Floodwater velocity and inundation

Hey and Thorne (1983) describe the bankfull discharge as the main channel-forming flow. Those plant species which are wholly or partially inundated by such events are generally subject to the highest flow velocities and to greater periods of inundation than the surrounding vegetation. It is therefore these species which are most important in controlling streambank erosion, particularly those located along the toe of the bank (Rankin 1980).

Woodyer (1968) and Cummins (1993) point out that the zone of interface of the bankfull discharge is also an area where there is an identifiable change in vegetation. This also appears to be the case in the Manning catchment where plant species such as *C. viminalis*, *T. laurina*, *C. cunninghamiana*, *L. hystrix*, *P. parviflora*, *C. gaudichaudiana*, *C. sieberi*, *W. floribunda* and *L. polygalifolium* dominate the vegetation between the high banks (see, for example, Figure 20). Typically these species are multi-trunked, appear flexible under the weight of floodwaters, have root-systems which form erosion inhibiting mats and occur exclusively along streambanks.

On the upper bank and floodplain, where velocities are lower and the period of inundation is shorter, the vegetation changes to taller, less flood-tolerant species (see, for example, Figure 21).

A general indication of the velocity of floodwaters and the period and depth of inundation of riparian vegetation was determined from the channel slope and catchment area at each site.

Excluding the tablelands, within the catchment there is a general pattern of riparian vegetation distribution in little disturbed areas in which *T. laurina* dominates the upper sections of streams (e.g. sites 15, 16 and F2) and is gradually replaced by *C. viminalis* as catchment area increases. Further downstream where catchment areas increase significantly (e.g. sites 4 and 8) and riparian vegetation becomes wholly inundated for longer periods, and to greater depth, *C. viminalis* tends to be the sole dominating species, with species such as *T. laurina* occurring only as scattered individuals.

Stream width

A strong relationship has been noted between stream width and catchment area (Leopold et al. 1963; Gordon et al. 1992; Newbury and Gaboury 1994), and this appears to be the case for streams in the Manning catchment.

An increase in stream width allows greater light penetration to streambanks, thus allowing light demanding species such as *C. viminalis* to persist on wider streams. For example *C. viminalis* is absent at Sites F2 and 15 on the Gloucester River (where *T. laurina* dominates) and is co-dominant with *T. laurina* further downstream at Site 5. Further downstream, at the confluence with the Manning River, *C. viminalis* becomes the dominant riparian species. Similarly, on the Barrington River at Site 13 and along Dingo Creek at Site 1, *C. viminalis* occurs only in areas where light levels are assured, immediately fringing the low-flow channel, or where the original vegetation cover has been cleared. To determine whether it is stream width, or floodwater velocity and inundation, that primarily influences the distribution of *C. viminalis* and *T. laurina* needs further research.

Distribution of riparian vegetation in the Manning River catchment

Lower Manning River (including Lansdowne and Dawson rivers, and Pipeclay, Killabakh, Cedar Party, Dingo, Caparra, Bo Bo, and Burrell creeks)

On the section of the Manning River between Charity Creek bridge and Wingham, and on other streams in the lower catchment, the dominant riparian species is *W. floribunda*. This species tends to be confined to the coastal zone, and within the Manning catchment does not extend more than about 40 km inland. It occurs on both smaller, lower velocity, streams such as Caparra and Pipeclay creeks and larger, higher velocity streams such as the Manning River downstream of Charity Creek. The substrate ranges from sandy loam on the smaller streams, to gravel of cobble size on larger streams. This species appears to play a major role in limiting bed and bank erosion and controlling stream width and is worthy of further investigation to confirm this.

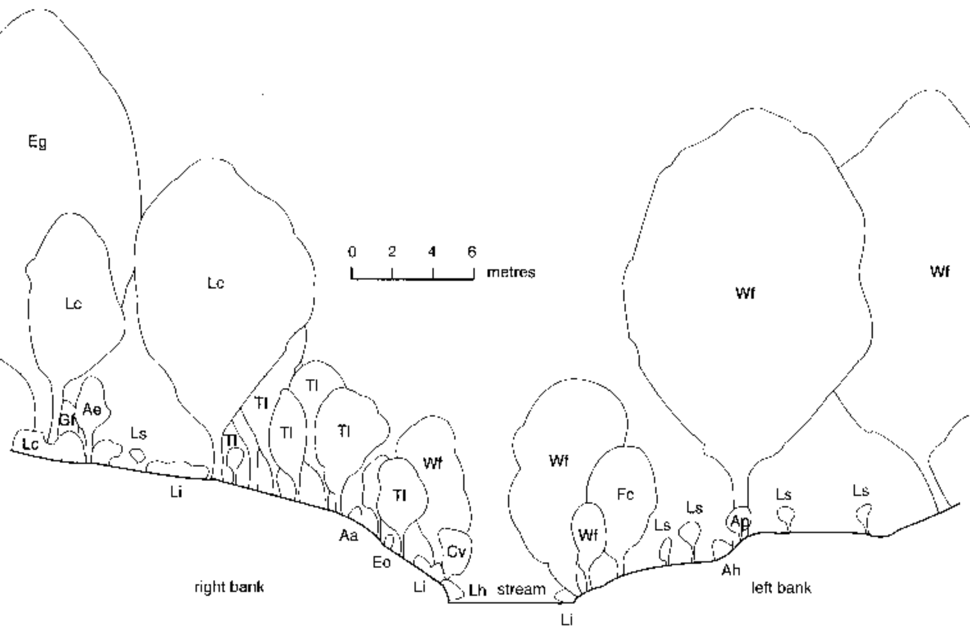


Figure 20. Representative transect diagram for Site 1 (Dingo Creek at 'The Duckbill'). Both *Waterhousea floribunda* and *Tristaniopsis laurina* dominate the frequently inundated area between the high banks, with *Callistemon viminalis* present immediately adjacent to the low-flow channel. Eg, *Eucalyptus grandis*; Lc, *Lantana camara*; Gf, *Glochidion ferdinandi*; Lc, *Lophostemon confertus*; Ae, *Alphitonia excelsa*; Ls, *Ligustrum sinense*; Ll, *Lomandra longifolia*; Tl, *Tristaniopsis laurina*; Aa, *Adiantum aethiopicum*; Eo, *Elaeocarpus obovatus*; Pr, *Pittosporum revolutum*; Wf, *Waterhousea floribunda*; Cv, *Callistemon viminalis*; Lh, *Lomandra hystrix*; Fc, *Ficus coronata*; Ah, *Adiantum hispidulum*; Ap, *Aphananthe philippensis*.

Other riparian species commonly present with *W. floribunda* include *T. laurina*, *C. viminalis*, *C. cunninghamiana*, *Ficus coronata*, *L. hystrix*, and *P. parviflora*. *C. viminalis* tends to be most common in areas along the stream which receive most light (i.e. immediate stream edge on wide sections of the channel) (Figure 20) and/or areas which are subject to higher flood-flow velocities such as rock-controlled riffle sequences (Plate 19).

C. cunninghamiana generally occurs as a scattered emergent species where *W. floribunda* dominates (see Plate 19), but can be a dominant regrowth species where the original bank vegetation has been cleared (e.g. upper areas of Dingo Creek). *L. hystrix* and *Lomandra longifolia* are common herb-layer components associated with riparian vegetation, and *P. parviflora* is a grass that grows scattered on the lower banks and within the bed of the larger streams such as lower Dingo Creek and the Manning River.

Other rainforest type species associated with *W. floribunda* dominated areas in the Manning Catchment include *Elaeocarpus obovatus*, *Glochidion ferdinandi*, *Syzygium australe*, *Cryptocarya glaucescens*, *Cryptocarya microneura*, *Endiandra discolor*, *Daphnandra micrantha*, *Backhousia myrtifolia*, *F. coronata*, *Acmena smithii*, *Rhodamnia rubescens*, *Alphitonia excelsa*, *Melicope micrococca*, *Eucalyptus grandis* (which is usually present as an emergent), *Guioa semiglauca*, and *Alectryon subcinereus*. *Cordyline stricta*, *Cryptocarya meisneriana*, and *Neolitsea dealbata* are common understorey species.

Floyd (1990b) classifies this type of plant association as dry rainforest belonging to the *Castanospermum–W. floribunda* Alliance, Suballiance No. 26: *W. floribunda–T. laurina*. He indicates that this type of rainforest forms a narrow fringe along riverbanks with two factors, groundwater and floodwater, possibly determining its distribution. He further points out that groundwater supplements inadequate rainfall during dry months (typically July to November), and strong-flowing floodwaters restrict vegetation to species with willowy, flexible branches.

This type of riparian forest is generally surrounded by open forest with species typically including *A. subvelutina*, *Eucalyptus tereticornis* and *Imperata cylindrica* (blady grass) in the herb-layer. Birrell (1987), who compiled a vegetation map of the catchment based on historical records, indicates that open forest of 'apple tree and blady grass' commonly occurred along Dingo, Caparra, Bo Bo, and Burrell creeks and sections of the lower Manning River.

Birrell (1987) presents a map of vegetation types and distribution in the Manning Valley in 1824, drawn using data from a number of sources. It indicates that 'brush' once extended intermittently from the tidal areas of the Manning River as far upstream as the Nowendoc River confluence

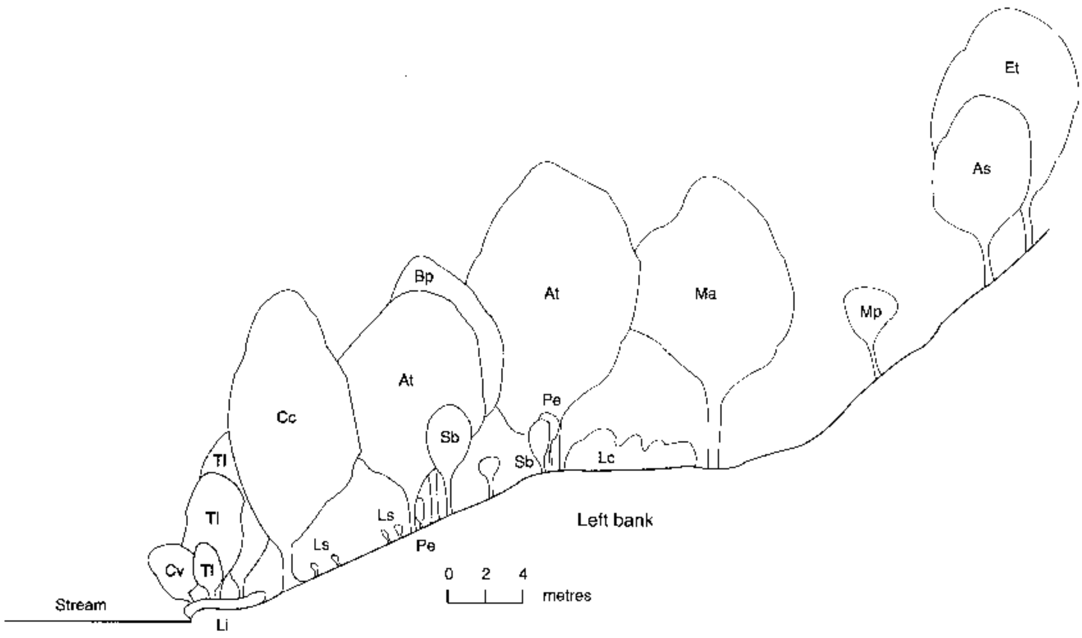


Figure 21. Representative transect diagram for Site 13 (Barrington River at Rocky Crossing), showing flood-tolerant species fringing the low-flow channel. These are replaced by dry rainforest species on the less-frequently flooded, more-fertile alluvial flats, and by open forest on the surrounding hillslopes. Cv, *Callistemon viminalis*; Tl, *Tristaniopsis laurina*; Ll, *Lomandra longifolia*; Cc, *Casuarina cunninghamiana*; Ls, *Ligustrum sinense*; At, *Alectryon tomentosus*; Pe, *Podocarpus elatus*; Sb, *Streblus brunonianus*; Bp, *Brachychiton populneus*; Lc, *Lantana camara*; Ma, *Melia azedarach* var *australasica*; Mp, *Mallotus philippensis*; As, *Angophora subvelutina*; Et, *Eucalyptus tereticornis*.

(interspersed by the open forest described above). A remnant of this type of 'brush' is present on the Manning River at Wingham and at Coocumbac Island. It is rainforest belonging to Floyd's *Heritiera trifoliolata* Alliance, Suballiance No. 3: *Cryptocarya obovata, Dendrocnide excelsa–Ficus* spp.–*Araucaria*. Floyd (1990b) describes this type of forest as 'the major suballiance on the well-drained, fertile, basaltically-enriched alluvial lowland flood plains north from the Manning River'. He states that the alluvial flats of the lower Manning River have been enriched by the basalts of the Comboyne and Bulga plateaux and the Barrington and Gloucester Tops.

The main canopy species present at the Wingham remnant are *D. excelsa*, *Melia azedarach* var. *australasica*, *Heritiera actinophylla*, *Planchonella australis*, *C. obovata*, *Dendrocnide photinophylla*, *Dysoxylum rufum* and emergent *Ficus macrophylla*. Common understorey species include *Alangium villosum*, *Capparis arborea*, *Streblus brunonianus* and *Aphananthe philippinensis*. Although no other substantial remnants exist upstream of Wingham there are large remnant trees scattered on the alluvial floodplains near Mt. George, including *F. macrophylla*, *Dysoxylum fraserianum*, *E. obovatus*, *A. philippinensis*, and *Toona ciliata* (Plate 20). As mentioned previously, this type of forest once extended discontinuously as far upstream as the Nowendoc River confluence. It would also likely have occurred on the lower velocity alluvial floodplain areas, adjacent to the *W. floribunda–T. laurina* Suballiance, the latter occurring in a narrow band fringing the stream where velocities are higher and soils (namely gravel) are poorer. This view is shared by Stockard (1992).

Southern tributaries (including Bowman, Barrington, Gloucester and Avon rivers, and Bakers and Belbora creeks)

Much of the original vegetation along these streams has been altered since European settlement. The dominant species on the middle to lower sections of these streams are *C. viminalis* and *C. cunninghamiana*, often in association with *T. laurina* which also dominates some areas. The last-named species generally dominates relatively undisturbed areas and tends to be replaced by *C. viminalis* and *C. cunninghamiana* in highly disturbed areas. For example, *T. laurina* is abundant at Sites 5 and 15 on the Gloucester River (Plates 21 and 22) but is rare or absent in disturbed intervening areas around Gloucester township where *C. cunninghamiana* now dominates with exotic *Salix* (willow) and *Ligustrum* (privet) species also common. It is also abundant at Sites 13 and 16, on the Barrington and Avon rivers, but is rare or absent in disturbed areas immediately downstream, where exotic species such as *Salix* and *Ligustrum* occur scattered amongst the dominant *C. cunninghamiana*. Further, in-depth studies focusing on life cycle stages (e.g. Harper 1977) are needed to determine the reasons for a lack of regeneration of *T. laurina* in disturbed areas. There is evidence that seedlings have difficulty establishing under changed conditions and are highly palatable to stock.

T. laurina is common along the Gloucester River, the upper sections of the Avon River, and the Barrington River downstream of Mackays Creek. Before European settlement, it probably occurred throughout the area, including the Bowman River and Bakers Creek and upper areas of the Barrington River.

Plate 19. Riparian community of the *Tristaniopsis laurina–Waterhousea floribunda* suballiance along Dingo Creek at the Wherrol Flat Road bridge crossing. Note the dominance of *Callistemon viminalis* and *Tristaniopsis laurina* between the high banks where flood-flow velocities are higher (front of photo), as compared to deeper, slower flowing areas which are flanked by *Waterhousea floribunda* (dark foliage) and large specimens of *Tristaniopsis laurina* (pale foliage). Scattered emergent *Casuarina cunninghamiana* can be seen in the background.

Plate 20. Remnant lowland subtropical rainforest on an alluvial flat adjacent to the Manning River at Mt George.

Plate 21. Riparian community dominated by *Tristaniopsis laurina*, with *Lomandra longifolia* dominating the herb-layer, along the Gloucester River at Site 15.

C. viminalis is a species which is almost exclusively riparian in its habitat. It generally grows in gravel within the bed of the stream, or along the bank on the immediate stream edge. As a light-demanding species, it is most common along larger streams where the width of the stream allows increased light to the bed and banks (see Plate 22). For example, it is absent from the upper Avon, Barrington, Gloucester and Bowman rivers, and from upper Bakers Creek. At Sites 3 and 12, on the middle to upper sections of Bakers Creek and the Bowman River, it is common and occasional, respectively. Downstream of these areas, along the larger streams such as the Barrington and Gloucester rivers, it becomes a dominant species, particularly where the site has been disturbed and light levels are high.

C. cunninghamiana is common on virtually all streams in the southern part of the catchment. In areas where most of the original vegetation has been cleared, it is often the only native riparian species present (e.g. Barrington River and tributaries upstream of Mackays Creek, the Gloucester River around Gloucester, and sections of Bakers and Craven creeks, and the Bowman and Avon rivers) forming dense even-aged stands. *C. cunninghamiana* appears to have become prevalent after the extensive clearing which began in 1945, following the end of the Second World War, and after the major floods of the early 1950s . In areas where disturbance is minimal on the upper sections of some streams (e.g. Kerripit River at Site 14) it occurs as scattered large trees along the stream bank (Plate 23).

Plate 22. Riparian community dominated by both *Tristaniopsis laurina* (dark foliage) and *Callistemon viminalis* (pale foliage), along the Gloucester River at Site 5.

Common herb-layer species along most of the streams are *L. hystrix* and *L. longifolia* (see Plate 21). *P. parviflora* is also common along the lower Gloucester River, and *C. gaudichaudiana* is a common herb-layer species along the upper Bowman River.

Other common rainforest-type species in the riparian forest of these areas include *Claoxylon australe*, *G. ferdinandi*, *M. azedarach* var. *australasica*, *Acacia irrorata*, *F. coronata*, *S. brunonianus*, *Rapanea howittiana*, *A. smithii*, *S. australe*, *Hymenosporum flavum*, *Pittosporum undulatum*, *A. excelsa*, *A. subcinereus* and *Hymenanthera dentata*. In areas dominated by *T. laurina*, there is commonly a fringing community of *B. myrtifolia* on the drier, rockier upper banks.

Apart from the headwaters, and higher elevation areas, the riparian forest is surrounded by open forest in which common species include *A. subvelutina*, *E. tereticornis* and *Eucalyptus amplifolia*. Typical understorey species include *Bursaria spinosa* and *I. cylindrica*. In less well drained soils around the Avon River (downstream of Wenhams Cox Road crossing), *Melaleuca linariifolia* is a common species. An early botanical survey undertaken by Maiden (1895) indicates that *Melaleuca styphelioides* was also common in these areas. According to Maiden, open country with scattered trees and grasses was common along many sections of these rivers.

Plate 23. Scattered trees of *Casuarina cunninghamiana* along the Kerripit River at Site 14, with *Lomandra longifolia* dominating the herb-layer. The smaller trees on the immediate stream edge are *Rapanea howittiana.*

In the more-confined protected areas upstream (e.g. Site 12 and F2), *Eucalyptus saligna* becomes increasingly common, with rainforest species in the understorey. At Site F2, where elevation and rainfall are higher, and the stream is protected by steep-sided valleys, the drier *T. laurina* dominated forest and surrounding open forest, are replaced by species typical of warm-temperate rainforest. Typical species include *Caldcluvia paniculosa, Schizomeria ovata, Sloanea woollsii, D. fraserianum, Pennantia cunninghamiana, Doryphora sassafras, Orites excelsa, D. micrantha* and *Tasmannia insipida.*

In the higher elevation areas around Gloucester and the Barrington Tops no surveys were undertaken, as the streams are stable and flow within State forest or national parks. Riparian species include *Nothofagus moorei, Leptospermum* sp. and *Callistemon pallidus.*

According to Birrell (1987) the alluvial flats on the Gloucester and Barrington rivers around the townships of Gloucester and Barrington were once occupied by 'brush' (rainforest). The small alluvial flat at Site 13 on the Barrington River supported a number of dry rainforest species including *Podocarpus elatus, Alectryon subcinerous, Alectryon tomentosus, Brachychiton discolor, E. obovatus, Ehretia acuminata, M. azedarach* var. *australasica, S. brunonianus, Mallotus philippensis, H. flavum, C. arborea, D. excelsa* and *H. dentata*. There are also some large remnant trees of *P. elatus* on the Gloucester River near Gloucester.

This riverine rainforest extended discontinuously from the confluence of the Barrington and Gloucester rivers to Mackays Creek on the Barrington River and Faulklands Road crossing on the Gloucester River (Birrell 1987). Riverine rainforest also appears to have been scattered along Craven and Copeland creeks. Maiden (1895) wrote of the botanically rich areas of brush along the Gloucester River, noting that *D. excelsa, Synoum glandulosum, P. elatus, H. dentata, B. myrtifolia, Adriana* sp., and *W. floribunda* were common. The record of *Waterhousea floribunda* appears doubtful as it is absent downstream of Gloucester until the Manning River near Charity Creek. As at Site 13 (see Figure 21) the brush areas would have been located on the finer alluvial soils, with flood-tolerant species such as *T. laurina, C. cunninghamiana* and *C. viminalis* dominating the stream bed and banks.

Central and northern tributaries (including Rowleys, Cooplacurripa, lower Nowendoc, lower Barnard, and Manning rivers)

Most of the forests along these streams are floristically very similar to those in the streams of the southern catchment area. *T. laurina, C. viminalis* and *C. cunninghamiana* are the dominant species along Rowleys, the lower Cooplacurripa, and the lower Nowendoc rivers (Plate 24). *T. laurina* is absent from the Manning River upstream of the Nowendoc River confluence (see Plate 25).

Associated species include *L. hystrix* and *L. longifolia* in the herb-layer, and *G. ferdinandi, M. philippensis, M. azedarach* var. *australasica, F. coronata, S. brunonianus, A. smithii, B. myrtifolia, A. excelsa, T. ciliata,* and *A. subcinereus.*

The riparian forests are generally surrounded by open forest, with species such as *A. subvelutina* and *E. amplifolia* common. On sheltered steep slopes the riparian forest is flanked by dry rainforest dominated by species such as *Backhousia sciadophora*. On upper Rowleys River near its confluence with Cells River, *C. viminalis* is absent, and the dominant riparian species, *T. laurina*, is often flanked by a narrow band of *B. myrtifolia*, much like Site 15 on the Gloucester River.

Along the Cooplacurripa and Mummel rivers upstream of the area around 'Glamis', both *C. viminalis* and *T. laurina* are absent and *C. cunninghamiana* is virtually the only riparian tree species present until the streams enter the steep-sided valleys upstream. It is accompanied by *L. longifolia* and *P. parviflora* in the herb-layer.

Birrell (1987) indicates that most of the surrounding forest was open and well-grassed. *A. subvelutina* is the only species present in any abundance on these grassed areas. The area has been subject to considerable clearing, and *T. laurina* and associated species probably extended beyond 'Glamis' before European settlement.

The far upstream ends of Walcrow, Mummel and Rowleys rivers are largely inaccessible and within State forest, and were therefore not surveyed. As with the upper Gloucester River, *T. laurina* is likely a common riparian species in these areas.

Plate 24. Riparian community dominated by *Tristaniopsis laurina* (right of photo) and *Callistemon viminalis* (left of photo) along Rowleys River at Site 6. Note how the trees are bent in alignment with flow.

Plate 25. Riparian community dominated by *Callistemon viminalis*, with emergent *Casuarina cunninghamiana*, along the Manning River at Site 4.

The top end of Cooplacurripa River (Site 10) is largely confined by steep-sided valleys and is subject to little or no streambank erosion. Tree species common along the banks include *Acacia melanoxylon*, *A. irrorata*, *A. smithii*, *Eucalyptus saligna*, *B. myrtifolia* and *B. spinosa*. The main species stabilising the immediate stream edge were *L. longifolia* and *C. gaudichaudiana* (Plate 26). The riparian zone is surrounded by open forest dominated by *E. amplifolia*, *A. subvelutina* and *Allocasuarina torulosa*.

T. laurina is absent from the Manning and Barnard rivers upstream of the Nowendoc River confluence. The riparian forest along these areas is dominated by *C. viminalis* and *C. cunninghamiana*, with *L. hystrix*, *L. longifolia* and *P. parviflora* common in the herb-layer.

Associated species are similar to most other areas and include *C. arborea*, *G. ferdinandi*, *M. philippensis*, *M. azedarach* var. *australasica*, *F. coronata*, *S. brunonianus*, *A. smithii*, *M. micrococca*, and *H. dentata*. Apart from protected steep slopes supporting rainforest dominated by *B. sciadophora* and *D. excelsa*, the riparian zone along the Manning and Barnard rivers is surrounded mostly by open forest, with *A. subvelutina* the most common species. Upstream of the Barnard River confluence, *C. viminalis* becomes less frequent on the Manning River and *C. cunninghamiana* is the dominant species. At Site 11 on the Manning River, a small section of rainforest occurs next to the stream with species typical of alluvial 'brush' forest present. Also, large specimens of *P. elatus* and *S. brunonianus* are present on the Barnard River upstream of 'Bretti', indicating that, before European settlement, pockets of rainforest with floristics similar to those once found in the Gloucester area probably occurred on the alluvial flats of the lower Barnard River.

Plate 26. Riparian community along the Cooplacurripa River at Site 10. Species include *Carex gaudichaudiana* (lining the low-flow channel in the herb-layer), *Acacia* spp. (small trees along stream) and *Eucalyptus amplifolia* and *Angophora subvelutina* (furthest from stream).

It is likely that *C. viminalis* is absent further upstream on the Barnard, Curricabark, Manning and Pigna Barney rivers, with *C. cunninghamiana* dominating, though these areas, because of relative inaccessibility, were not surveyed. Turner (1981) in a survey of vegetation on the upper Barnard River around Schofields and Orham Creeks indicates that *C. viminalis* is absent.

Far western area of the catchment (including the higher reaches of the Barnard and Nowendoc rivers)

These areas are influenced by both lower rainfall and higher altitude. Only two sites were surveyed (Sites 9 and T).

On the upper Nowendoc River downstream of Nowendoc, the main riparian species are *L. polygalifolium* subspecies *montanum* and *C. cunninghamiana*. This site was very close to the point at which the river leaves the tablelands and begins its descent to the lowlands. *C. cunninghamiana* is absent upstream from the site. Most of the original streambank vegetation has been cleared upstream toward Nowendoc township, but it is likely that *L. polygalifolium* was once a common riparian species along the immediate stream edge, with *L. longifolia* in the herb-layer. Reed species such as *Typha orientalis* and *Phragmites australis* are common in large slow-flowing pools along the stream edge. *C. gaudichaudiana* is a common stream edge species in faster-flowing areas. Shrub species along the stream include *B. spinosa* and *Lomatia arborescens*. Surrounding tree species include *A. subvelutina* (which is absent upstream) and *E. pauciflora*. Although absent at this site, species which would be expected to occur upstream include *Eucalyptus stellulata*, *Eucalyptus nova-anglica*, *Eucalyptus acaciiformis* and *Eucalyptus bridgessiana*. These species are common along tableland streams in the Macleay catchment to the north.

Vegetation communities similar to those at Site 9 would be present on the Barnard River, and tributaries, around Barry, with the exceptions of *E. nova-anglica* and *E. acaciiformis* which reach the southern limits of their ranges in the Nowendoc area. Downstream of Barry, at Site T, *C. cunninghamiana* is the dominant species, with *C. sieberi* common in rocky, faster-flowing sections of the river (Turner 1981). Other species present in the riparian zone are *F. coronata*, *Acacia implexa*, *B. myrtifolia*, *Alectryon forsythii*, *Ficus rubiginosa*, and *Angophora floribunda*. Some species in the surrounding forest, such as *Eucalyptus laevopinea*, *Eucalyptus melliodora*, *Notelaea microcarpa*, and *Dodonaea viscosa*, are more typical of tableland forest, whereas others, such as *E. tereticornis*, *A. torulosa*, *P. undulatum*, *Rapanea variabilis*, *F. rubiginosa*, and *Clerodendrum tomentosum*, are more typical of lower elevation areas.

Native Successional Species

Many of the native species present at each site (Table 3), although rainforest trees, would normally qualify as successional or second or third stage regeneration species in another rainforest community. Succession is defined by Buchanan (1989) as the slow, orderly progression of changes in community composition during development of vegetation in any area, from initial colonisation to the attainment of the climax typical of a particular area. In general, most early successional species exhibit traits typical of weed species, such as high light demands, rapid growth, short life-cycle, and excellent dispersal mechanisms.

The existence of rainforest species along streams in most areas of the Manning catchment generally rests on access to groundwater and lack of fire. Streambanks are typically a harsh environment in which, among other things, flooding, debris accumulation, erosion, and often poorer growth media all have a degree of influence on the vegetation present. The presence of the stream itself allows greater light penetration to the banks, and floods often create canopy gaps. Therefore, only the hardier, fast-growing, light-demanding rainforest species are present along the frequently-flooded areas of most streams. Beyond this on the floodplain, where conditions allow, rainforest communities tend to be more diverse.

Table 3. Common successional species of the Manning catchment riparian zone.

Species	Regeneration stage[a]
Acacia irrorata (green wattle)	3
Acacia melanoxylon (blackwood)	3
Alphitonia excelsa (red ash)	3
Commersonia fraseri (brush kurrajong)	3
Claoxylon australe (brittlewood)	3
Croton verreauxii (native cascarilla)	3
Dendrocnide excelsa (stinging tree)	3
Glochidion ferdinandi (cheese tree)	3
Guioa semiglauca (guioa)	3
Mallotus philippensis (red kamala)	3
Melicope micrococca (white euodia)	3
Neolitsea dealbata (white bolly gum)	3
Omalanthus populifolius (bleeding heart)	2
Pittosporum undulatum (native daphne)	3
Rubus rosifolius (wild raspberry)	1
Trema aspera (poison peach)	2

[a] Regeneration stages are (Floyd 1990a): 1, herbs and soft-wooded shrubs (0–2 years old); 2, soft-wooded secondary shrubs or pioneers (2–15 years old); 3, short-lived trees that are early secondary trees or nomads; 4, long-lived mature-stage trees aged up to 100 years or more.

The floristic composition and relative abundance of successional species at many sites are often also a reflection of past disturbances such as clearing, logging and selective grazing, rather than the pre-European flora. Nevertheless, sufficient remnants of the original vegetation, or regrowth of it, are usually present at highly disturbed sites to allow an assessment of the original flora to be made. Stage 2 species (see Table 3) are quick growing and produce large quantities of seed of long viability (Kooyman 1991). They do not regenerate in the shade and are replaced by Stage 3 species. Stage 3 species are fast growing, light demanding, produce seeds of long viability, and have effective dispersal mechanisms using wind and animals (Kooyman 1991). The rapid growth rates of these species, their effective seed dispersal mechanisms, seed longevity, and high light requirements are characteristics which made these plants suitable for streambank revegetation. Speed of growth is particularly important, as most North Coast streams are subject to frequent floods and short establishment time is therefore critical.

Other successional species such as *C. cunninghamiana* also appear to be much more common now than they were in pre-European, riparian forests. In little-disturbed areas studied, *C. cunninghamiana* tends to exist as an emergent species with large trees scattered throughout the riparian forest (e.g. Sites 1, 2, 5, 7 and 15; Plate 19). However, where vegetation has largely been cleared, and/or active erosion is occurring, it becomes dominant, often forming monospecific, even-aged stands (Plate 27). Such areas exist on Caparra and Bakers creeks, and the Avon, upper Barrington, Gloucester, Bowman, Cooplacurripa and Mummel rivers.

Plate 27. Even-aged stands of *Casuarina cunninghamiana* along the Gloucester River near Gloucester. An older stand can be seen lining the left bank, with a younger stand present on recently deposited alluvium on the right of the photo.

C. cunninghamiana is an opportunistic species which rapidly colonises recently deposited alluvium where high levels of light are available. In riparian ecosystems it is a primary colonising or regeneration species. When initially colonising a site, there may be up to 10–50 seedlings per square metre of alluvium. Plants are relatively fast-growing (up to 3 m per year) and quickly thin through natural attrition. It is a nitrogen-fixing species (Wrigley and Fagg 1988) and this, in combination with its shading ability, provide conditions suitable for the establishment of secondary colonisers such as *T. laurina*, *W. floribunda*, *S. australe*, *F. coronata*, *G. ferdinandi*, *G. semiglauca* and *A. excelsa* in otherwise hostile habitats such as gravel. In time, the first two species may dominate the site, with *C. cunninghamiana* being left as a scattered emergent, providing the seed bank for future distribution.

Rare, Endangered, and Critical Habitat Species of the Riparian Zone

The *W. floribunda–T. laurina* and *C. obovata–D. excelsa–Ficus* spp.*–Araucaria* suballiances are both rainforest communities, the former confined to the narrow riparian zone and the latter to basalt-enriched alluvium. The Manning River valley is notable in that it retains many *W. floribunda* dominated remnants in the lower part of the catchment. Floyd (1990b) describes this community as poorly conserved within New South Wales. The remnants of the *C. obovata–D. excelsa-Ficus* spp.*–Araucaria* suballiance at Wingham Brush and Coocumbac Island are the only two within the Manning catchment and are the southern-most occurrences of this rainforest type. Floyd (1990b) describes preservation of this rainforest type within New South Wales as adequate.

Riparian rainforest remnants along the streams of the Manning catchment provide a refuge for native plants and animals that cannot survive in the adjacent cleared floodplain areas. Many plant species provide habitat values to wildlife: as habitat trees and sources of food, and as nesting, roosting, and social interaction sites for both endemic species and seasonal visitors. For example, the riparian forests of the lower Manning (e.g. Dingo, Caparra, Bo Bo and Pipecky creeks) contain a large number of species of the Lauraceae family. These species are an important food source for frugivorous pigeon species. Such plants are absent from the surrounding cleared land or eucalypt-dominated forest.

The general ecology of the river and streamside vegetation may be enhanced if forethought is given to the choice of species for a riparian revegetation project. For example, the use of trees known to provide food for birds aids the spread of these trees. Trees that provide food for insects encourage insectivorous birds which are useful in controlling some agricultural insect pests. Studies at the University of New England (Ford, undated) suggest that birds may take up to 50% of the insects produced in healthy eucalypt woodland. This figure is in the order of 30 kg/ha/year. Falling insects are also a major component of the diet of many fish species. Reynolds (1986) reports that experiments have shown that the bulk of food eaten by fish living in small well-vegetated streams consists of terrestrial insects.

Cummins (1993) discusses a number of important influences of riparian vegetation on stream ecology: degree of shading; instream primary production rates; litter inputs; shredder utilisation of litter inputs; inputs of large woody debris; and provision of habitat via root systems and maintenance of pools by the interaction between vegetation and fluvial processes. Structural and floristic diversity of riparian plants is a critical factor in maintaining all of these functions in an aquatic ecosystem.

Cummins (1993) also discusses the influence of land-use patterns on leaf litter breakdown rates. As with most developed catchments, the riparian vegetation once reflected the mature phase community, or climax, interspersed with infrequent patches of earlier successional plant communities that developed due to disturbances such as lateral channel migration or bank erosion. In much of the Manning catchment, and many other areas, this situation is now reversed, with colonising species such as *C. cunninghamiana* now dominating areas that once supported diverse forest. Cummins (1993) states that the implications of this are the replacement of dispersed patches of early successional communities that were colonised readily by naturally mobile pioneer invertebrate species, with dispersed mature systems inhabited by riparian and stream invertebrate species less well adapted for dispersal and colonisation.

Exotic Weed Species

At many of the sites studied within the Manning River catchment large numbers of exotic weed species were present. Once weeds are established they may impede the natural succession process and, under certain circumstances, may eventually replace native species. Weed species are a particular problem in riparian forests, as seeds and other vegetative parts may be carried downstream to new sites during flood-flows. High densities of exotic species also have the potential to change water quality, habitat, and shade characteristics of the environment (Reynolds 1986).

Exotic weeds of particular concern include *Ligustrum sinense* and *Ligustrum lucidum* (privets), *Lantana camara* (lantana), *Rubus fruiticosus* (blackberry) and *Anredera cordifolia* (Madeira vine).

Ligustrum sinense had invaded areas along the banks of Caparra and Big Run creeks near Site 2, Dingo Creek at Site 1, Barrington River at Site 13 and in extensive areas near Barrington township, the Gloucester River near Gloucester, and lower sections of the Avon River. *Ligustrum lucidum* was also common at Site 1.

Buchanan (1989) outlines characteristics of both *Ligustrum* species that allow them to successfully compete with, and often replace, native species. These include:

- lack of predatory (phytophagous) species;
- ability to grow in low light (1 to 5% of full sunlight);
- prolific seed production (e.g. *L. lucidum* produces 10 000 to 10 000 000 seeds per tree with an average of 400/m^2 of canopy, while *L. sinense* averages 1300 fruit/m^2 of canopy);
- seed spread by birds (e.g. in a study on pied currawongs the average number of seeds per regurgitated pellet was 36, with a maximum of 167);
- seed germinates readily in heavy shade under existing trees, with samples in one study showing 624 and 349 plants/m^2 of *L. sinense* and *L. lucidum*, respectively;
- fully developed plants produce a dense mat of roots near the soil surface and appear to exploit soil moisture and nutrients with greater efficiency than some competitors;
- both species can coppice readily if damaged, and *L. sinense* is capable of suckering from roots; and
- both species can grow in a range of soil types.

The scrambling shrub *L. camara* was common to very common at nearly all sites examined, generally forming large thickets adjacent to riparian forests. In some areas, these form an almost impenetrable barrier, blocking access to sections of the stream.

Buchanan (1989) points out that *Lantana* can alter the turnover of nutrients in the litter/soil system to its advantage and the detriment of native species. Loss of nutrients by leaching is far higher in a *Lantana*-dominated vegetation community and soil organic carbon and nitrogen, in the form of nitrate, increase dramatically (Buchanan 1989). The heavy shade created by a *Lantana* canopy also appears to inhibit the regeneration of native species beneath it.

At several sites within the catchment, the exotic groundcovers *Tradescantia albiflora* (wandering Jew) and *Ageratina riparia* (mist flower) are common. Buchanan (1989) and Floyd (1990a) indicate that the former species, where prolific, forms a dense carpet over the forest floor, preventing light from reaching the ground, and inhibiting seedling establishment. It is suspected that *A. riparia* behaves similarly. Both species can reproduce vegetatively and are readily spread during floods.

Ricinus communis (casteroil plant) is common around the lower Gloucester and Nowendoc rivers near their confluence with the Manning River. *Solanum mauritianum* (wild tobacco) is common at many sites, but is not considered a threat to the riparian environment. At higher altitude localities (Sites 9 and 10), *Rubus fruiticosus* was very common growing next to streams.

The area most affected by weeds is the remnant at Wingham Brush (Site F1) where exotic vine species, most importantly *Anredera cordifolia*, *Macfadyena unguis-cati* (catsclaw creeper), and *Cardiospermum grandiflorum* (balloon vine) have invaded.

A. cordifolia and *C. grandiflorum* are common in riparian forests on more fertile soils. *A. cordifolia* is considered by Dunphy (1991) to be one of the most destructive weeds of rainforest remnants in north-eastern New South Wales. It is a fast-growing, aggressive species with the potential to smother the canopy of remnants, causing collapse of branches and ultimately the death of heavily infested trees. The species reproduces vegetatively through aerial tubers which are produced in large numbers and readily spread downstream during flood-flows. Dunphy (1991) indicates that it prefers edges and gaps, which places riparian remnants at a higher risk due to their narrow, linear nature, resulting in a high edge to area ratio.

C. grandiflorum also prefers the edges of remnants and has seed that is readily dispersed by water. Dunphy (1991) states that, although remnant edges can be totally dominated by this species, its short-term destructive ability is not as great as heavier species such as *A. cordifolia*.

A bush regeneration team has been working to control weed invasion at the site for a number of years with great success and using a variety of methods. Buchanan (1989) and Stockard and Hoye (1990) provide further information.

Species with Potential for Use in Erosion Control

This section describes the species listed in Table 4, which were assessed as having the potential for use in erosion control projects in the catchment. Assessment was based on:

- qualitative observations of the root system;
- ease of propagation by seed or division, and growth rates;
- ability to withstand and rapidly recover from inundation by floodwaters and battering by bedload and gravel;
- growth habit;
- appropriateness to various locations and problems within the catchment; and
- dominance of the species in the riparian zone.

Along undisturbed streams, there is a diversity of riparian species present, ranging from groundcovers and shrubs to trees, all of which have differing habits and root structures and contribute in various ways to stream stability. Riparian floristics also vary at catchment-wide and local scales. This needs to be considered before undertaking any erosion control work, so that those species best adapted to a particular site and indigenous to that part of the catchment are used. Locally collected seed should be used, where practicable, to maintain genetic integrity.

Callistemon viminalis (weeping bottlebrush)

A shrub or small tree growing to about 6 m high with a dark furrowed trunk. The leaves are alternate, linear to narrow elliptic, 3 to 7 cm long and 3 to 7 mm wide, with an acute apex, and obscure lateral veins. Red flowers are produced in spring to early summer on spikes 4–10 cm long and 30–60 mm wide with the filaments fused into a ring at the base. Seed from the woody fruits can be stored once collected. Source: Harden (1991).

C. viminalis is a species confined to streambanks, generally occurring on larger streams and most commonly dominating the frequently flooded areas on the banks of the stream immediately adjacent to the low-flow channel. With increasing stream size and period of inundation, it replaces species such as *T. laurina* and *C. cunninghamiana* as the dominant species.

Table 4. Plant species assessed as having potential for streambank erosion control in the Manning River catchment.

Species	Family	Common name
Callistemon viminalis	Myrtaceae	Weeping bottlebrush
Tristaniopsis laurina	Myrtaceae	Water gum
Waterhousea floribunda	Myrtaceae	Weeping myrtle
Casuarina cunninghamiana	Casuarinaceae	River oak
Lomandra hystrix	Lomandraceae	Mat-rush
Lomandra longifolia	Lomandraceae	Spiny mat-rush
Potamophila parviflora	Poaceae	River grass
Carex gaudichaudiana	Cyperaceae	Tufted sedge
Callistemon sieberi	Myrtaceae	River bottlebrush
Leptospermum polygalifolium	Myrtaceae	Creek teatree

C. viminalis has a weeping, multi-branched habit and flexible branches which bend under the weight of floodwaters (Plate 28). On larger streams, trees are usually flood-battered and permanently bent in alignment with the direction of flow. The species has a spreading mat-like, adventitious root system (Plate 28) which extends below low-flow water level and stabilises the toe of the bank in substrates ranging from sandy loams to cobbles.

Plate 28. An example of *Callistemon viminalis*, with its multiple-trunked habit and spreading mat-like root system, stabilising an alluvial bench on the Orara River (Clarence catchment).

C. viminalis is fast-growing and has no special growth requirements other than full sun and access to groundwater and, as a result, frequently colonises moist, unconsolidated gravel bars within the streambed.

In the Manning catchment, *C. viminalis* occurs along most larger and some smaller streams. It is absent from higher elevation areas and densely vegetated smaller streams.

Tristaniopsis laurina (water gum)

> A shrub or small to medium-sized tree growing up to 30 m high, though generally much smaller. The bark is pale grey to cream, and sheds in strips or flakes. The leaves are alternate, oblanceolate to narrow-oblanceolate, 6.5–12 cm long and 15–30 mm wide, with an obtuse to acute apex. The upper surface of the leaf is dark green and glabrous, and the lower surface greyish white and felty in texture. Yellow flowers are produced from December to January and are followed by oval capsules. The seed can be stored once collected.
> Source: Harden (1991).

T. laurina is a species generally confined to stream banks, often occupying the area from the toe to the floodplain. On wider streams it often fringes a more flood-tolerant species such as *C. viminalis* (Plate 29).

On larger, faster-flowing streams it adopts a multi-trunked habit and, like other riparian species, is flexible under the force of floodwater, with older specimens permanently bent in alignment with flow. In such areas, trees rarely exceed 4 m high (see Plate 24).

T. laurina has a spreading adventitious root system which, from qualitative observations, tends to run along the bank parallel to stream flow, binding gravel and making it more resistant to stream transport. It occurs on substrates ranging from clays to cobbles. *T. laurina* tolerates a range of light conditions, though does not appear to regenerate well after clearing, and in such cases is often replaced by *C. cunninghamiana*. More-detailed studies focusing on life-cycle stages (see Harper 1977) and dispersal potential are needed to determine the reasons for poor regeneration in disturbed areas. It has been observed that seedlings are highly palatable to stock.

In the Manning catchment, *T. laurina* occurs along almost all streams. It is absent from the Manning River upstream of the Nowendoc River confluence, and the higher elevation areas.

Waterhousea floribunda (weeping myrtle)

> A small to medium-sized tree growing to about 30 m and with dark, furrowed bark. Leaves opposite, lanceolate to narrow-elliptic, 5.5–16 cm long and 1.5 to 5 cm wide, with an acuminate apex. The upper surface of the leaf is glossy dark green and the lower surface is dull and paler. The margins of the leaves are undulate. The occurrence of senescent bright-red leaves amongst the dark green crown is a distinctive feature of this species. White flowers produced from November to January are followed by round, pale green, fleshy fruits which ripen from January to April. Seed of this species cannot be stored and is best sown fresh.
> Source: Harden (1991).

W. floribunda is a species confined to streambanks, usually occupying the bank toe and face. On larger streams it often fringes more flood-tolerant species such as *C. viminalis* or *T. laurina*.

W. floribunda is similar in habitat to the exotic willow (*Salix* spp.) and has weeping pendulous branches that bend with floodwaters. Like willows, it forms extensive mats of fine roots (Plates 30 and 31) which have the ability to grow over recently deposited sediment and have been observed at distances up to 8 m from the tree. On smaller streams, the roots of this species often act as a bed control, extending to a metre below low-flow water level.

Plate 29. Plants of *Tristaniopsis laurina* (dark green foliage) fringing more flood tolerant species such as *Callistemon viminalis* and *Leptospermum brachyandrum* (adjacent to the low-flow channel) along the Orara River (Clarence catchment).

Plate 30. Fine, mat-like root system of *Waterhousea floribunda* growing over a log along the Stewarts River (Camden Haven catchment).

Plate 31. Mat-like root system of *Waterhousea floribunda* extending for a distance of about 5 m from the base of the trunk and consolidating a gravel bar (the fine black roots can be seen protruding from the gravel adjacent to the low-flow channel) along the Kalang River (Bellinger catchment).

Along streams where it dominates and where bedrock is absent, the low-flow channel tends to be relatively incised, with the surface of steep vertical banks being almost wholly composed of fine roots. Thus, there appears to be less potential for lateral migration of the low-flow channel in these areas, where the bed is stable.

W. floribunda is fast-growing and has no special growth requirements other than access to groundwater. In the Manning catchment, *W. floribunda* occurs along streams east of Caparra Creek.

Casuarina cunninghamiana (river oak)

Small to large tree varying in height from 8 to 35 m with fissured grey-brown bark. The leaves are reduced to 8 to 10 teeth in whorls, and are 0.3–0.5 mm long. The articles (portion of branchlet between whorls of teeth) are 6–9 mm long and 0.4–0.6 mm wide, with the edge of furrows often marked by a slight ridge. The species has both male and female plants. Male trees have a rusty appearance when in flower, and female trees produce cones. Seed from the woody fruits can be stored once collected.
Source: Harden (1990).

C. cunninghamiana is probably the most common riparian plant on the New South Wales North Coast. It grows as a straight-trunked tree in a diverse range of soils and climates, provided it has access to groundwater. It is the primary colonising species of disturbed riparian areas and readily colonises moist, unconsolidated gravel bars, forming dense, even-aged stands. It is a nitrogen-fixing species and is regarded as the first stage in riparian succession, as it traps sediment, fixes nitrogen, and provides shade for secondary colonising species in otherwise hostile environments such as bare gravel.

C. cunninghamiana is a useful erosion control species along streams with a stable bed-form. Where the bed is actively lowering or scouring, the shallow root-system may often become undermined, causing larger, heavier specimens to dislodge from the banks. In such cases, it is therefore common practice by many landholders to lop such trees, to reduce the above-ground mass, and interplant with a range of other riparian species with differing root structures.

Where *C. cunninghamiana* colonises gravel bars it may contribute to erosion problems by constricting the main channel and redirecting flood-flows.

In the Manning catchment, *C. cunninghamiana* occurs on all streams, apart from the far upstream reaches and those at high elevations.

Lomandra hystrix (mat-rush) and *L. longifolia* (spiny mat-rush)

> Robust, tussock-forming plants, usually up to 1.5 m high. The leaves of *L. hystrix* are dark green, flat, rather thin, 90–130 cm long and 5–10.5 mm wide. The apex is acute with 2–4 lateral teeth usually located well below it; the laterals rarely longest. Inflorescences up to as long as the leaves, branched usually twice with usually four major primary branches per node. The leaves of *L. longifolia* are flat or slightly concavo-convex, occasionally rolled, usually 50–100 cm long and 5–7.5 mm wide. The apex is 2–3 toothed with the central tooth in a pronounced sinus or longer than the laterals. Inflorescences simple or branched; all branches, or when many, the larger branches, often 2 per node. Seed can be stored for a limited period but is best sown fresh.
> Source: Harden (1993).

Lomandra spp. are herb-layer plants which commonly occur along the toe of the bank, particularly where the roots have access to groundwater (see Plates 21 and 23). The flower spikes have pungent thorns, hence the common name. Along many streams *Lomandra* forms an almost continuous cover over the ground and appears to reduce flow velocities at the soil–water interface by increasing the hydraulic roughness. The root systems of both species appear relatively dense.

Both species have no special growth requirements, although *L. longifolia* is more common on drier sites and prefers full sun. They will grow in substrates ranging from silt and clays to cobbles and boulders, and are easily propagated by division of large clumps.

In the Manning catchment, *Lomandra* spp. occur on virtually all streams.

Potamophila parviflora (river grass)

> Tall, erect, tussocky, rhizomatous perennial growing to about 1.5 m high. Leaves are ligule membranous, 5-15 mm long, the blade rolled in bud, erect, flat or loosely inrolled and 4-6 mm wide. The plant's small flowers are produced in summer. No information is available on seed storage, though it is expected to have storage characteristics similar to those of other grass species.
> Source: Harden (1993).

P. parviflora is a semi-aquatic grass (Plate 32) which generally grows within the bed and along the banks of larger streams, with its roots partly submerged. It usually occurs as scattered clumps, though in some areas it may form a relatively dense colony.

Its presence reduces the velocity of flood-flows adjacent to the bank, by increasing the hydraulic roughness at the soil-water interface. It has a fine, mat-like root system (Plate 33) which extends to at least 1 m below low-flow water level, making it a useful species for the prevention of bank undercutting where plants are dense.

Plate 32. Plants of *Potamophila parviflora* growing in a high velocity section of the Little Manning River near Gloryvale Reserve.

Plate 33. The fine, mat-like root system of *Potamophila parviflora*.

Like most grasses, *P. parviflora* can be propagated readily by division of existing plants, with large clumps having the potential to be divided into over 500 new plants. Vertical rhizomes cut from the plant and pushed into moist gravel will resprout at the node to form a new plant.

Apart from requiring ample light and moisture, *P. parviflora* has no special growth requirements and generally occurs in gravel or cracks in bedrock.

In the Manning catchment, *P. parviflora* occurs along most larger streams.

Carex gaudichaudiana (tufted sedge)

Small, tussocky rhizomatous sedge growing to about 80 cm high. The culms are triquetrous, scabrous, 10-90 cm long and 1 mm diameter. The leaves exceed the culm and are 2-4 mm wide. The inflorescence is erect, 7-18 cm long, with 3-8 spikes solitary at nodes. No information is available on seed storage. Source: Harden (1993).

C. gaudichaudiana is a semi-aquatic plant commonly found growing within the bed, or along the toe of the bank where access to moisture is assured (Plate 34). It usually occurs as scattered clumps, though in some areas it may form a relatively dense colony. It is most often found on the smaller, narrower streams or those at higher elevations, and sometimes replaces *Lomandra* spp. as the dominant riparian herb. Its presence reduces the velocity of flood-flows adjacent to the bank, by increasing the hydraulic roughness at the soil-water interface. Its root system appears relatively dense.

C. gaudichaudiana has no special growth requirements provided moisture is assured. Growth substrate is usually gravel, and it is easily grown by division of large clumps.

In the Manning catchment, *C. gaudichaudiana* is most common along the higher elevation streams or the upper sections of smaller streams such as the Bowman River.

Callistemon sieberi (river bottlebrush)

A shrub or small tree growing to about 3 m in height with a dark, furrowed trunk. The leaves are alternate, narrow-oblanceolate, 2-5 cm long and 2-5 mm wide, with mucro, midrib and marginal veins prominent. Cream to pale pink flowers produced from November to January are followed by woody capsules. Seed can be stored once collected. Source: Harden (1991).

C. sieberi is a species confined to streambanks and on the North Coast generally occurs at higher elevations. It usually dominates larger streams and is common where bedrock outcrops occur and stream gradients are relatively steep, tending to replace *L. polygalifolium* ssp. *montanum* as the dominant species in such areas, particularly along sections of stream where plants become wholly inundated during flood-flows (Plate 35).

C. sieberi has a multi-branched habit and flexible branches which bend under the weight of floodwaters (Plate 35). Plants are usually flood-battered and permanently bent in alignment with flow. It has a spreading adventitious root system and stabilises the bed and the toe of the bank where access to moisture is assured. Growth substrates range from gravel to cracks in bedrock.

C. sieberi has no special growth requirements other than full sun and access to groundwater.

In the Manning catchment, *C. sieberi* has been found only on the upper reaches of the Barnard River, but probably also occurs on other higher elevation streams.

Plate 34. Plants of *Carex gaudichaudiana* (tussocky plant on left of photo) growing along the Tia River near Tia. The shrub species present is *Leptospermum polygalifolium*.

Plate 35. *Callistemon sieberi* growing along a high velocity section of the Chandler River (Macleay catchment). *Lomandra longifolia* can be seen in the herb-layer (left of photo). *Eucalyptus nova-anglica* can be seen adjacent to the riparian zone (top of photo).

Leptospermum polygalifolium subspecies *montanum* (creek teatree)

> Shrub or small tree up to about 3 m in height, with greyish, finely fissured bark. The leaves are alternate, oblanceolate to elliptic or linear-elliptic, 5–20 mm long and 1–5 mm wide; usually glabrous with the apex broad to narrow acute or obtuse. The leaf tip is often recurved with a blunt point. A profusion of white flowers is produced from August to January followed by round woody fruits. The seed can be stored once collected.
> Source: Harden (1991).

L. polygalifolium ssp. *montanum* is generally found at higher elevations and is largely confined to stream banks, usually growing along the toe where access to water is assured. It is the dominant riparian species on most tableland streams, often in association with *C. gaudichaudiana* (see Plate 34).

Like most species adapted to riparian environments, it has a multi-stemmed habit and is flexible under the force of floodwaters (see Plate 34). It has a relatively extensive root system which extends below low-flow water level, and performs a stabilising role in substrates ranging from heavy basalt-derived soils to sand and river gravel.

L. polygalifolium ssp. *montanum* has no special growth requirements other than adequate sunlight and access to groundwater and, as a result, frequently colonises moist unconsolidated gravel bars within the stream bed.

In the Manning catchment, *L. polygalifolium* ssp. *montanum* occurs along the upper, higher elevation sections of the Nowendoc River and probably along other higher elevation streams.

Methods for Regeneration of Riparian Areas in the Manning River Catchment

Regeneration of riparian areas poses special problems due to stream flooding and the resultant potential for native trees to be severely damaged, buried, or washed away before they establish. This is further exacerbated by changes to the planting environment: plants must now also cope with unstable beds, high light levels, frosts and exposure. For erosion control, the species identified in the previous section should be used.

Structural works

In most cases, where active accelerated streambank erosion is occurring, structural works of some form are generally necessary as the first step in rehabilitation. Types of structural works vary considerably depending on site constraints and capital available. The various types of erosion control works used in Victoria and New South Wales have been documented (Standing Committee on Rivers and Catchments, Victoria 1991; Hurst et al. 1993) and can be referred to for further information. Recent work carried out in the Nambucca River has relied largely on the use of low-cost bed-control structures. The basis of this restoration program is outlined in DWR (1995).

Traditionally, there have been two types of works: those that provide a direct barrier to erosion (e.g. rock revetment), and those that act to encourage deposition along the toe of the bank by increasing the hydraulic roughness (e.g. river training wire-mesh works). In both cases, the aim of the works is to stabilise the toe of the bank. In the former, vegetation is planted among the rocks where practicable, and behind the rockwork. In the latter type, vegetation plays a major part and is used to provide long-term stability of the improvements achieved by the structural works. Trials are currently being conducted with a third type of work aimed at controlling bed degradation using low-cost structures. The aim of these is to re-establish the pool–riffle sequence (see Newbury and Gaboury 1994). In practice, all three types may be used on a particular stretch of stream.

Before any structural works are built, a suitable width and alignment are chosen (see Chapters 4 and 5). Most types of works designed to trap sediment require the creation of a bench (usually by relocation of gravel from the opposite point-bar) on which the works are built and vegetation is planted (see Figure 22). In some cases, this may involve removal of regrowth on the opposite point-bar.

Revegetation

Seedling trees are planted on the gravel bench, preferably in conjunction with some form of slow-release fertiliser, as sand and gravel are very poor in nutrients. Where coarse gravel is present, finer material such as sand and silt may need to be placed around the plant to prevent transplant shock due to air pockets. This should be sourced from an area where no weed seeds are present. Dense plantings (1 m spacings) will afford greater protection than scattered trees as, under natural conditions, many riparian species colonise recently deposited sediment at the rate of hundreds per square metre (Plates 36 and 37), with ultimate spacings determined by natural attrition. In severe alignments or highly eroding areas, willows are often used to provide initial protection, and then gradually replaced by natives.

Plate 36. Dense colonisation of freshly deposited alluvium by *Waterhousea floribunda* seedlings along Caparra Creek (Manning Catchment).

Plate 37. Seedlings of *Lomandra hystrix* (black arrow), *Leptospermum brachyandrum* (blue arrow), and *Tristaniopsis laurina* (red arrow), colonising gravel alluvium along the Orara River (Clarence Catchment).

Trials carried out on the MacIntyre River by the Department of Water Resources indicate that riparian species such as ***Melaleuca bracteata*** and ***C. viminalis*** planted amongst heavy-duty wire mesh fencing can withstand significant periods of inundation with no major losses of plant numbers.

Any revegetation scheme should try to mimic natural systems and needs to incorporate understorey species such as ***Lomandra*** spp., ***P. parviflora*** and ***C. gaudichaudiana*** to reduce scouring. All these species have been proven in trials by one of the authors (AWR) to grow easily by division, and large clumps can be divided and directly planted on site.

A new revegetation technique developed by Bill Hicks, chairman of the Wollombi Landcare Group, is currently being assessed. It involves growing plants in forestry tubes in a nutrient solution. Roots are air-pruned and plants are encouraged to develop stems up to 2 m long. Sediment-tolerant species are used. The plants are jetted into the ground to a depth of 1-1.5 m using a water lance, in a fashion similar to that used with willows. The method allows quick root establishment and thus the potential for more rapid stabilisation. Several trees per minute can be planted. Various species, including ***C. viminalis***, ***T. laurina*** and ***W. floribunda***, are to be tested.

Direct seeding

Plants that produce fine woody seeds, some of which are commercially available, such as ***C. cunninghamiana***, ***T. laurina***, ***C. viminalis*** and ***Lomandra*** spp. have the potential for use in direct seeding, as an option for revegetation.

Direct seeding has advantages over the planting of seedlings for a number of reasons including:
- it is less laborious and time-consuming;
- it is less costly (1 kg of seed can contain up to 2 million seeds for fine-seeded species such as ***M. bracteata***);
- because of more natural root development, seedlings established by direct seeding techniques require less follow-up care; and
- a more natural spatial distribution of established seedlings results.

Disadvantages of direct seeding include predation of seed by ants, losses due to poor post-seeding weather, and specific germination requirements of some species.

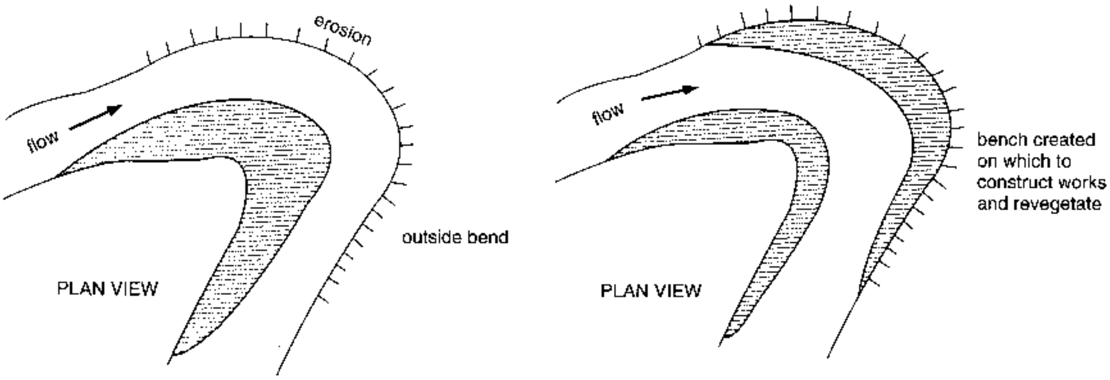


Figure 22. Eroding stream bank (a) before and (b) after stabilisation work.

Brooks (1987), in a case study on the use of native plant seed by the mineral sands industry, states that plant counts in rehabilitated areas of age 2 years or more have densities of upper canopy species which are ten-fold greater than the pre-mining densities. He further points out that this provides ample seedlings for attrition due to competition and suppression of slower-growing individuals.

Trials carried out on the MacIntyre River by the Department of Land and Water Conservation using *C. viminalis*, *M. bracteata* and *C. cunninghamiana* have employed seed sowing rates of 0.28, 0.31, and 0.16 g/m^2 of riverbank, respectively. In order to ensure an even spread of the fine seed over the moist sand/gravel bench and prevent loss of seed by wind, seed at the trials was mixed with moist, coarse sand and hand broadcast (hand operated broadcasters could also be used). In most cases, access prevents the use of mechanical broadcasters in riverbank areas and costs associated with other means, such as hydromulching, are often prohibitive. Further monitoring will be carried out at the site to determine the seedling establishment rate per square metre of riverbank.

Other species whose seeds are not commercially available, such as *W. floribunda*, produce large seeds and are relatively prolific seeders. Trials carried out by one of the authors (AWR) on these species indicate that they have no special germination requirements apart from adequate moisture. Their seed has potential to be harvested and directly placed into the growing medium using a rod to create a planting hole. This method has been used in sand-mining rehabilitation for species with large seeds (Brooks 1987). Spacings need to be dense (10–20 cm) to compensate for lack of viability and other causes of losses.

From observations of regenerating riparian species, it is apparent that moisture levels within the sand/gravel substrate are critical for germination and early seedling establishment. Riparian species such as *C. viminalis*, *C. cunninghamiana*, *T. laurina*, *L. hystrix*, and *W. floribunda* have been observed densely colonising sand and gravel recently deposited immediately adjacent to the low-flow channel, where moisture levels are assured for a considerable period (see Plates 36 and 37). The seed of these species is transported by water and appears to be deposited during receding floods.

The chances of success of a direct seeding program will be enhanced if the following matters are attended to.

Site preparation

For seed to germinate and seedlings to successfully establish, the ground surface must first be prepared. In areas where erosion control is being undertaken, this generally involves relocating gravel to the toe of the eroding bank to form a bench at a level no greater than about 300 mm above normal low-flow conditions. This will ensure adequate moisture for seed germination and seedling establishment and allows direct seeding to be carried out at virtually any time of the year (except winter in frost-prone areas), although the likelihood of seed being washed away by minor rises in stream level is increased in late summer/autumn.

Further away from the stream, where trees are to be established in soil, different preparation is needed. In lowland areas where many streambank species are rainforest, planting of tubestock is more desirable as seeds are usually large, fleshy and short-lived. Alternatively, larger seeds such as those of *W. floribunda* can be placed individually into prepared soil. In tableland areas, where the vegetation is dominated by eucalypts, Curtis (1991) describes a number of methods to improve direct seeding results, including:

- grading – removing the topsoil with a grader and then scarifying with a ripper or chisel plough;
- cultivation – generally only successful in native pasture where excessive weed growth is not a problem;
- burning – removes grass and creates an ash-bed, but again successful only in native pasture; and
- ripping – generally used in combination with the above, aids root development of seedlings, particularly in heavy soils.

Weed control

Weed control is critical for the successful establishment of seedlings. Both knockdown and residual herbicides have been used successfully. If residual herbicides are used, the infected surface soil is scraped away immediately before sowing. Weed control is essential within the first year of establishment and desirable during the second year. Residual herbicides should not be used in sand or gravel areas, or near the water.

Sowing

Most literature on direct seeding recommends a sowing depth of two to three times the width of the seed. On gravel benches, this generally involves raking the surface to expose fines, broadcasting the seed (mixed with moist coarse sand) and then tamping the surface with a hoe to ensure burial. Curtis (1991) has also successfully used a hessian bag half-filled with sand, which is dragged over the site.

A similar procedure can be followed in other areas, although in most cases where broad-acre revegetation is required, mechanical seeders are used. Such machines, after expelling the seed onto the prepared surface, follow-up by burying the seed by tamping (using a wheel or other device) or by dragging a chain or other implement over the seeded soil.

Species selection and sowing rates

Species best suited to direct seeding are those that produce woody fruits. In lowland areas these include *C. viminalis*, *T. laurina*, *C. cunninghamiana*, *L. hystrix*, *L. longifolia* and *P. parviflora*. In tableland areas, suitable species include *L. polygalifolium* spp. *montanum* and *C. sieberi*.

Department of Land and Water Conservation trials have used seed sowing rates of 0.28, 0.16, and 0.31 g/m^2 for *C. viminalis*, *C. cunninghamiana*, and *Melaleuca bracteata*, respectively, when sowing directly into a gravel bench for erosion control. These high-density sowing rates are recommended to establish a dense sward of vegetation for erosion control.

For broad-acre direct seeding the number of seeds required per hectare is calculated using the formula:

> Weight of seeds required (g) = Number of plants required/ (Number of seeds per gram × Survival rate)

For broad-scale direct seeding, Curtis (1991) recommends that *Acacia* species be used in conjunction with other species on the tablelands, as they have the best survival rates. He estimates that survival rates of acacias are around 5%, compared with 0.1% for eucalypts. Information on the number of viable seeds per gram is given by Boland et al. (1980) and Langkamp (1987), or can be calculated by undertaking germination trials.

Timing

For most erosion control works, the gravel bench is levelled so that moisture levels are maintained in the substrate without relying on rainfall. Sowing can therefore be undertaken in spring, summer or autumn.

Curtis (1991) indicates that September to mid October is the best time to sow on the tablelands, after frosts have finished, soil moisture is usually high, and the temperature is right for germination.

Other management issues

Willows

As well as their use in structural works, as a direct erosion control method, the Department of Land and Water Conservation has successfully planted willow cuttings using a backhoe or jet-rod, with plantings of native species behind. The aim is to replace the willows with native species once stabilisation has occurred. Willows are used for large-scale stabilisation work where immediate bank protection is required, as they are fast-growing in early life and cuttings up to 3 m can be rooted directly on site. However, without careful management, willows may cause partial channel blockages, thereby increasing the potential for erosion at the site. Also, they are not as ecologically beneficial as native riparian species. The Department of Land and Water Conservation uses willows only on those streams where they are already present, and selects species known not to spread by seed or to propagate readily by vegetative means.

The hope is that further trials by both planting and direct seeding, using the species identified in this report, will lead eventually to the substitution of willows by native species.

Floodplain stripping and revegetation

Floodplain stripping requires erosion control strategies different to those for bank erosion.

Various management strategies have been identified to help reduce the occurrence of floodplain stripping and to help rejuvenate degraded areas. These entail the removal of encroaching vegetation from within the main channel to a suitable width, and introducing strategies to reduce the velocity of flood-flows over the floodplain and at 'breakout' points (points where high volume/velocity flows divert from the main river channel and onto the floodplain [see Figure 19). Plate 38 illustrates the dramatic effect on bed level of the cutting back of encroaching vegetation. With the canopy of trees removed, the hydraulic roughness is reduced and the resultant flood flows provided a controlled removal of bed material around the roots of dead trees, thereby increasing the effective capacity of the main channel adjacent to the breakout point, and resulting in decreased flows through it.

Plate 38. Example of a site where vegetation has been trimmed at a break-out point and the decrease in hydraulic roughness resulted in removal of bed material, thereby increasing the main channel capacity. The folder marks the original bed level. The remaining roots control the process.

Revegetation is the means to reduce the velocities of flood flows across the eroding floodplain, either on its own, or in combination with mesh fencing, brush or other retards.

Vegetation establishment on the floodplain encourages deposition by increasing the hydraulic roughness, thereby reducing the sediment carrying capacity of that section of the stream. Vegetation is planted along the retards, or in rows at dense (1 m) spacings at a width of up to 5 m or more, between the high bank of the stripped area, and the low-flow channel, or the natural levee adjoining it (see Plate 39). Where the topsoil is still present, a range of species comprising those described earlier and others indigenous to that section of the stream, can be planted.

Where the topsoil has already been stripped, vegetation establishment is more difficult as bare gravel holds little water and nutrients, contains large air-pockets, and is subject to large temperature fluctuations. Only those species described earlier as suitable for control of erosion should be used (with the exception of *C. gaudichaudiana* and *P. parviflora* which have high water demands) as they have the ability to grow in gravel alluvium. Where the soil has been stripped, the gravel may become armoured and attention to soil preparation will reduce losses. Preparation can include ripping (to bring fines to the surface), application of herbicides where appropriate (to reduce weed competition), and amelioration of the soil by the addition of mulches, organic material, and nutrients (to increase the moisture retaining capacity of the soil). Even with such preparation, losses may still be considerable, particularly during times of low rainfall, and supplementary watering may be required until plants are established. Other methods to reduce losses include use of water-retaining polymers and mulch. Once plants are established and their roots reach groundwater (which is close to the surface in these areas) they require very little or no maintenance.

Direct seeding of stripped areas

As for bank erosion, direct seeding is a cheaper and more effective method of revegetating stripped areas. Areas in which floodplain stripping occurs are generally more accessible than those subject to bank erosion, and mechanical methods are appropriate, in addition to hand broadcasting. These include the following.

- *Mechanical spreaders*, which can be attached to conventional tractors and allow seed, and soil/sand/fertiliser mixtures to be spread to a width of up to 8 m. Such devices can also scarify the soil surface, and cover the seed after it has been broadcast.
- *Hydromulching*, which involves spraying a slurry mixture containing the seed, using a pump and hose unit. Slurry mixtures include hammer-milled waste cardboard or tar mixtures.
- *Hay or straw mulch*. This method employs a straw mulcher to blow chopped straw or hay through a mist of bituminous binder to a depth of up to 30 mm over the area. Seed and fertiliser can be applied at the same time or later. This method may have greater moisture retention properties than hydromulching (Buchanan 1989).
- *Brush matting*, which entails harvesting seed-laden branches of woody-fruited species and pegging them to the area to be seeded. The seed is released on to the prepared soil surface when the branch dries. The branches provide shade and help retain soil moisture until the seed has germinated.

Trials are needed to determine the relative effectiveness of each of the four methods, which are described in further detail in Langkamp (1987). Direct seeding of stripped areas is best carried out in autumn when rainfall is highest. Seed may require watering during dry periods to maintain gravel moisture.

Plate 39. View of a riverbank revegetation trial. The gravel bench between the low-flow channel and a rock revetment has been densely planted with seedlings of *Waterhousea floribunda*.

Control of stock grazing

Stable natural systems exhibit considerable diversity in terms of vegetation floristics and structure. In a natural riparian community, vegetation ranges from ground covers such as *Lomandra* spp. and *C. gaudichaudiana*, to small trees such as *C. viminalis* and *T. laurina*, to large trees such as *W. floribunda*.

The range of species in riparian communities contributes to stabilisation of river banks in various ways through differing growth habits and root structures. Relatively undisturbed, natural communities are also generally self-sustaining. Trees which senesce or are removed by floods are replaced by regeneration of seedlings.

At many sites surveyed within the Manning catchment, including areas that are stable, grazing of stock is preventing regeneration of native plants. This should be recognised as a long-term problem. In many localities, where trees and shrubs die through old age, fire, insect attack, or removal by floods, they are not being replaced. The slow removal of vegetation through this process will result in an increased potential for bank erosion and river diversions over the long term.

As part of a long-term plan to reduce this type of degradation, whole farm planning should incorporate rotational spelling of such areas from stock for a sufficient time to allow regeneration to occur. If insufficient seed trees are available, a revegetation plan may need to be implemented.

Options to reduce fencing costs, and fence losses due to flooding, include the erection of temporary electric fences. Tax concessions may be available for fencing carried out to stop land degradation.

Outhet (1995) gives further information on livestock control near rivers.

General revegetation where banks are stable

For general riverland revegetation, or where previously active eroding areas are becoming stabilised, standard regeneration principles can be implemented. In dry riparian forests that are surrounded by open eucalypt dominated woodland this involves planting the dominant riparian species (e.g. *T. laurina*, *C. viminalis*, *Lomandra* spp. and *C. cunninghamiana*) at spacings from 1 to 2 m. Interspersed between these, in less flood-prone areas, pioneer or dry rainforest trees are planted, with ultimate spacings 1 m. Examples of suitable hardy species are listed in Table 5.

Using this method, the dominant, faster-growing riparian species provide shade and shelter for the other rainforest species and a degree of flood protection. The surrounding drier areas away from the stream are replanted with *E. tereticornis*, *E. amplifolia* and/or *A. subvelutina* at wide (5–15 m) spacings.

On the tablelands, riparian forests are less diverse, and replanting generally involves *L. polygalifolium* and/or *C. sieberi*, with *C. gaudichaudiana*. This type of regeneration is carried out in flood-prone areas. The surrounding drier areas are replanted with *Eucalyptus* species indigenous to the area (e.g. *E. stellulata*, *E. nova-anglica*, *E. pauciflora*, and *E. bridgessiana*) and understorey species such as *Acacia* spp., *B. spinosa*, and *Lomatia arborescens* at 5 to 10 m spacings. The above examples include tree, shrub and groundcover species, as structural diversity also increases the habitat value for native fauna.

Rainforest regeneration

Where rainforest has been cleared and replaced by pasture, the environmental conditions to which newly planted seedlings are exposed often change dramatically. Such changes include greater temperature fluctuations, increased sunlight, frost and wind exposure, loss of topsoil rich in organic matter and competition from grass. Many rainforest trees exhibit poor growth when planted in the open and it is general practice to protect slower growing, more sensitive species with hardier pioneer species. For example, they can be planted under a cover of fast-growing eucalypts, which can be harvested in the future for posts and rails when their protective role is completed (Cremer et al. 1990). Information is readily available on rainforest regeneration (e.g. Thorpe 1978; Sankowsky and Schaul 1983; Jones 1986; Kooyman 1991).

Where revegetation involves rainforest regeneration (e.g. around Gloucester, Barrington, and on the Manning River at Charity Creek) rainforest regeneration principles apply (flood-prone areas are first planted as per the above description). As most sites where rainforests were once present are now dry and exposed, a number of additional steps may be required. Exposed sites may require a windbreak of edge species to protect the regeneration plot (Kooyman 1991). Suitable species would include *M. philippensis*, *P. undulatum*, *B. spinosa*, *A. excelsa*, *A. subcinereus*, *B. myrtifolia*, *Hibiscus heterophyllus*, *M. azedarach* var. *australasica*, and *Acacia* spp. Use of water-retentive compounds (e.g. Gro-gel) and/or follow-up watering have also been recommended for dry rainforest sites, as have mulching of trees and 'clump' planting techniques that bring advantages of rapid canopy closure and moisture retention (Kooyman 1991). 'Clump' planting involves using a combination of faster-growing Stage 2 and 3 species with a dense planting of more shade tolerant, slow-growing species including shrubs.

In most recognised rainforest regeneration methods, the initial stage (Stage 1) of regeneration, involving prolific growth of weeds, woody shrubs and vines can be by-passed. Kooyman (1995) outlines *four basic models.*

- *Model 1. Late succession planting – mixed species.* This planting design bypasses the early stages of succession, with the emphasis on rapid development of a Stage 3 and 4 canopy with multi-layering and subsequently low light conditions in the understorey (see Figure 23). Site domination is achieved quickly (12–24 months), and therefore follow-up maintenance is reduced to very low levels. ***This model is ideally suited to sites which have small seed sources or are far away from seed source forest, and therefore recruitment is expected to be low.*** Bird and bat attractant species form part of the mix, as the intention is to maximise natural recruitment and attract additional species.

Table 5. Examples of rainforest plant species suitable for planting in riparian areas.

Scientific Name	Common Name	*Tristaniopsis/ Callistemon/ Casuarina* dominated forest	*Waterhousea* dominated forest
Acacia irrorata	Green wattle	+	+
Acacia melanoxylon	Blackwood	+	+
Acmena smithii	Small-leaved lilly pilly	+	+
Alectryon subcinereus	Wild quince	+	+
Alphitonia excelsa	Red ash	+	+
Aphananthe philippinensis	Rough-leaved elm		+
Backhousia myrtifolia	Grey myrtle	+	+
Bursaria spinosa	Blackthorn	+	
Cassine australis	Red olive-berry	+	+
Claoxylon australe	Brittlewood	+	+
Cordyline stricta	Narrow-leaved palm lilly		+
Cryptocarya glaucescens	Jackwood		+
Cryptocarya meisneriana	Thick-leaved laurel		+
Cryptocarya microneura	Murrogun		+
Cryptocarya obovata	Pepperberry tree		+
Daphnandra micrantha	Socketwood		+
Ehretia acuminata	Koda	+	+
Elaeocarpus obovatus	Hard quandong	+	+
Endiandra discolour	Rose walnut		+
Ficus coronata	Creek sandpaper fig	+	+
Glochidion ferdinandi	Cheese tree	+	+
Guioa semiglauca	Guioa	+	+
Hibiscus heterophyllus	Native hibiscus	+	+
Hymenanthera dentata	Tree violet	+	
Hymenosporum flavum	Native frangipani	+	+
Mallotus philippensis	Red kamala	+	+
Melia azedarach	White cedar	+	+
Melicope micrococca	White euodia	+	+
Neolitsea dealbata	White bolly gum		+
Pittosporum revolutum	Hairy pittosporum	+	+
Pittosporum undulatum	Native daphne	+	+
Rapanea howittiana	Smooth muttonwood	+	+
Rhodamnia rubescens	Scrub turpentine	+	
Streblus brunonianus	Whalebone tree	+	+
Syzygium australe	Brush cherry	+	+
Toona ciliata	Red cedar	+	+

- *Model 2. Early succession planting – mixed species.* This model uses a mixture of predominantly light demanding species from Stage 2 and early to late Stage 3, with a scattering of Stage 4 (or mature phase) species (see Figure 24). The objective of this strategy is to stimulate the rapid development of the canopy via the use of Stage 2 and 3 species, interspersed with bird and bat attractant species to maximise recruitment. *This planting model is recommended for sites directly adjacent to larger seed-source forest (>200 ha) where recruitment should rapidly enrich the site.*

- *Model 3. Pioneer plantings.* These may consist of single species plantings or a mixture of Stage 2 (or pioneer) species (see Figure 25). *This method is useful where sites are subject to heavy frosts, and some pioneer species (e.g.* Commersonia *spp.,* A. melanoxylon, Mallotus *spp.,* P. undulatum*) can act as a protective 'nurse' crop.* Later successional species are planted under the protective canopy after 12 to 24 months, with the pioneers later culled or pruned to allow these to develop. Pioneer plantings are also used on sites bounded by large seed-source forests (>200 ha) where recruitment levels would be expected to be high. Kooyman (1995) points out that these plantings are totally reliant on recruitment to add diversity and allow succession to mature phase forest, and that they are particularly vulnerable to weed invasion. They should therefore be used only where there is an ongoing commitment to maintenance and supplementary planting.

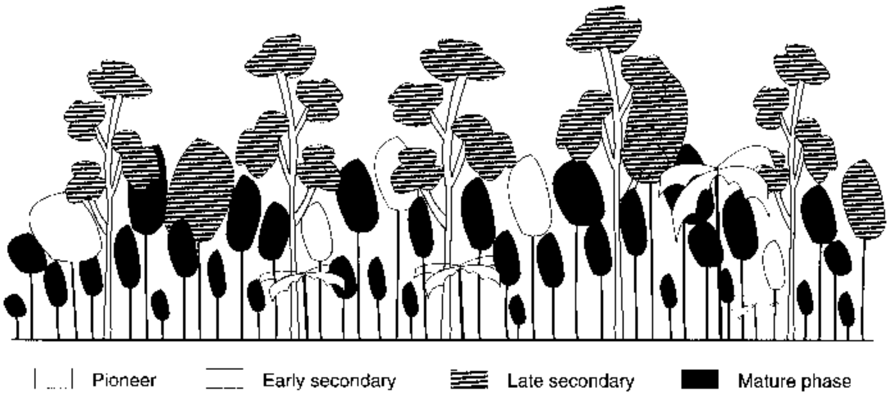


Figure 23. Example of late successional model—accelerated succession, mixed species—for revegetation (adapted from Kooyman 1995).

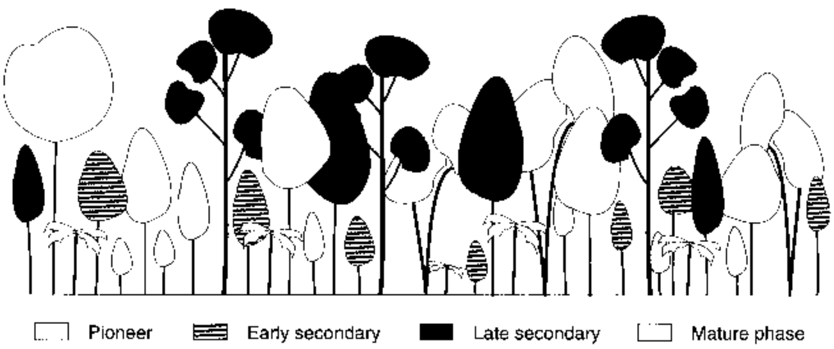


Figure 24. Example of early successional model—mixed species—for revegetation (adapted from Kooyman 1995).

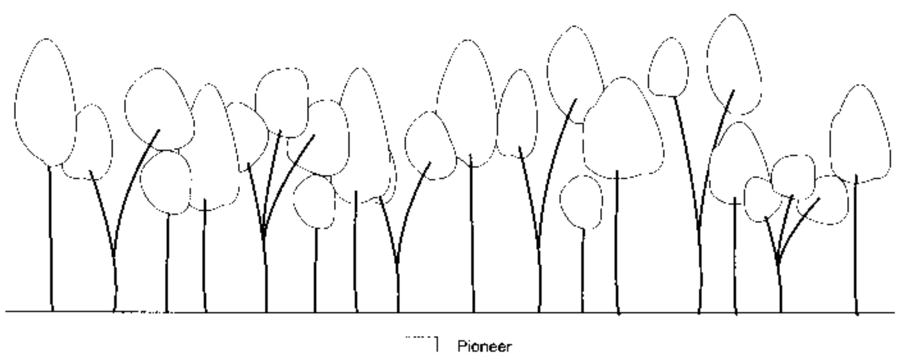


Figure 25. Example of pioneer model—single species or multi-species—for revegetation (adapted from Kooyman 1995).

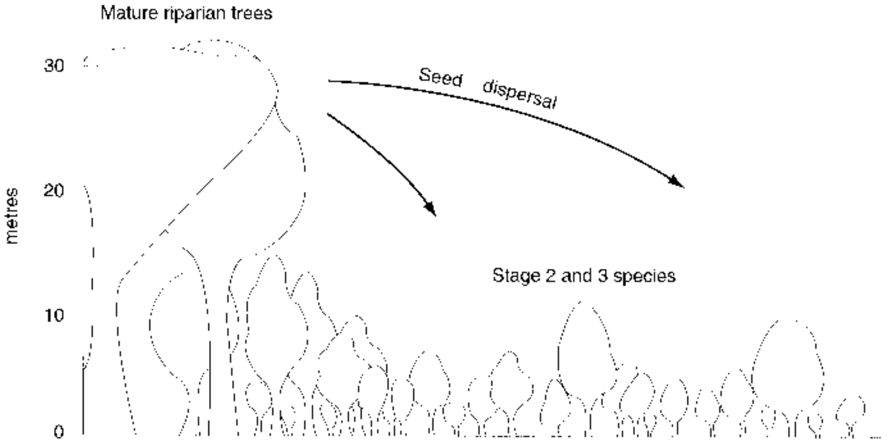


Figure 26. Plant-out of successional stage 2 and 3 species adjacent to mature riparian forest. This method relies on dispersal mechanisms such as seed fall from the adjacent forest and spread by frugivorous birds, to increase diversity of other species planted among stage 2 and 3 species (adapted from Kooyman 1995).

- *Model 4. Augmentation of remnant vegetation.* In many riparian areas within the Manning catchment patches of remnant vegetation remain. Such areas act as a seed source for a variety of species, and in such cases it may be necessary to plant only Stage 2 and Stage 3 species adjacent to these areas, so that natural seeding and regeneration of Stage 4 species can occur (see Figure 26). Most species still occur in sufficient numbers to act as a viable source of seed. Provided weed species are kept out of replanted sites, re-established riparian areas can become potentially self-sustaining due to seed spread by water, frugivorous birds and other dispersal methods. It is important that such remnants are protected in the long term, as they may be critical future seed source areas for riverine species.

Listings of the various stage 2, 3 and 4 successional species can be found in Kooyman (1995).

Other considerations

Generally, maximum success is achieved when rainforest species are planted at dense spacings (1 to 1.5 m, or 4000 to 5000 trees/ha), as this allows rapid canopy cover and therefore fewer maintenance problems. However, for large-scale regeneration the costs of such dense spacings may be prohibitive, and 2–3 metre spacings (1100 to 2500 trees/ha) will generally suffice. Wider spacings usually require more follow-up maintenance. Kooyman (1991) also suggests that clump plantings may provide better success through rapid canopy closure. The use of clump plantings can also reduce costs by concentrating on small areas at a time.

The following general steps are recommended to enhance chances of success of revegetation projects (Kooyman 1991, 1995):

- exclusion of stock;
- planting in autumn (unless irrigation is available or the site is prone to frosts);
- exclusion of fire;
- use of herbicide around individual trees and clumps to a one metre diameter and follow-up weeding for 3–5 years (N.B. herbicide should be used only in strict accordance with the manufacturer's instructions);
- mulching;
- sun-hardening of seedlings;
- fertilising during establishment;
- if contemplating a mixed aged/species planting, aim to have all plants established within 1–5 years so that the competitive advantage gained by earlier pioneer plantings does not overly suppress the growth of supplementary plantings.

Land & Water Resources
Research & Development Corporation

RIVERCARE

Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation

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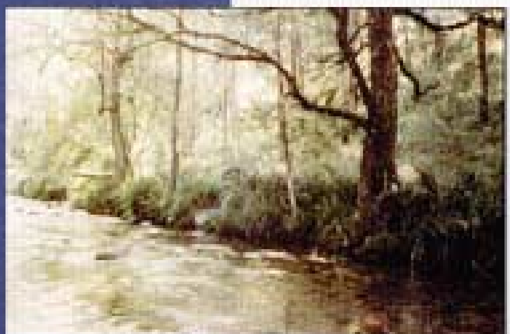

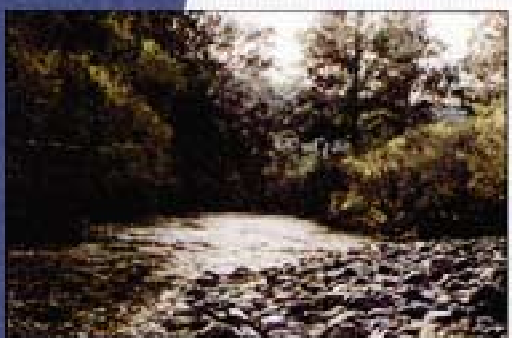

ANNEX

A Guide to Revegetating Streams in the Manning River Catchment

REVEGETATING STREAMS IN THE MANNING CATCHMENT

A GUIDE TO SPECIES AND PLANTING METHODS

LAND & WATER CONSERVATION

Land & Water Resources Research & Development Corporation

Prepared by: A. Raine
J. Gardiner

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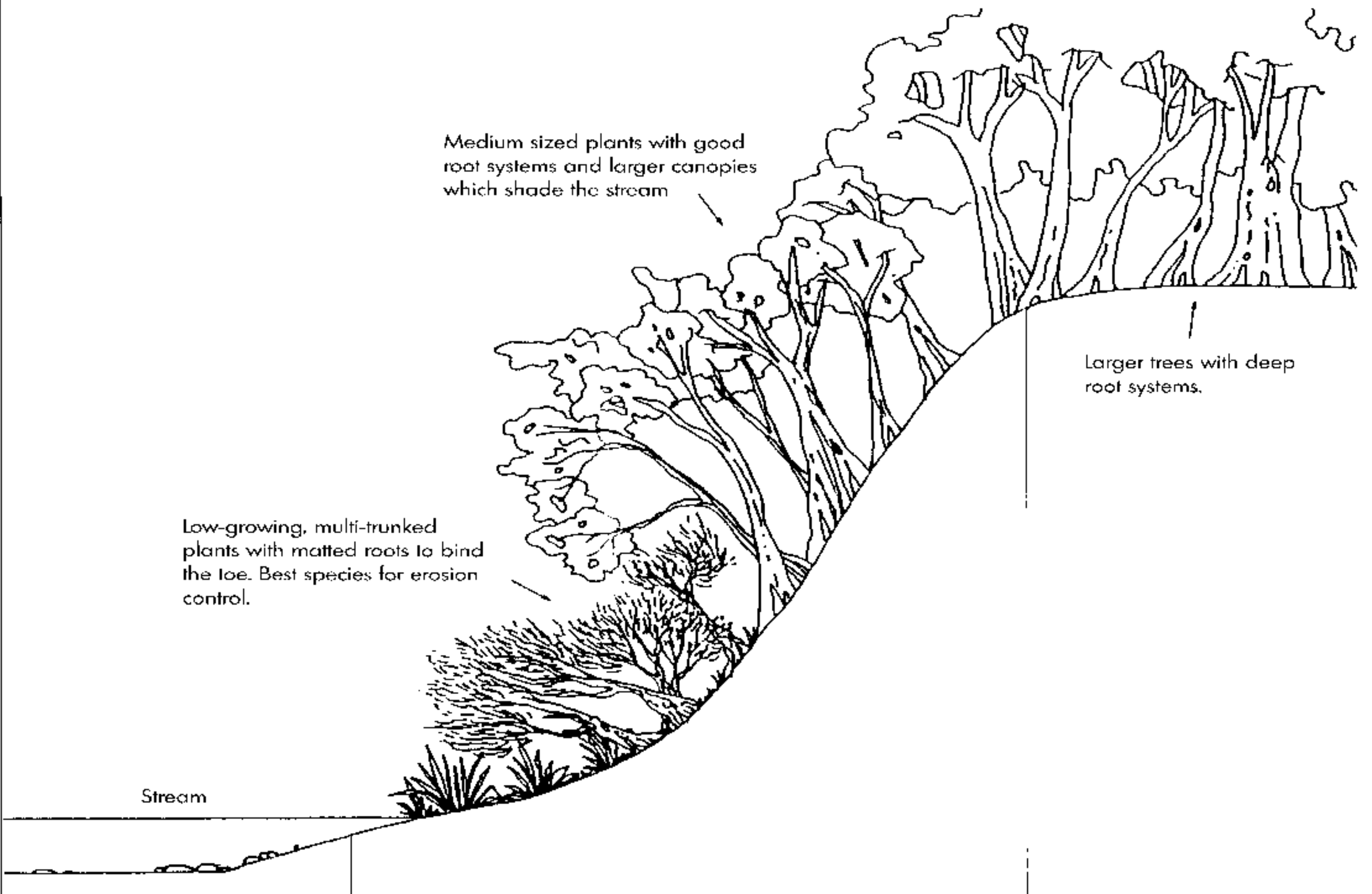
SPECIES BY STREAM AND LOCATION



STREAM	TOE	MIDDLE	UPPER
Tableland and higher elevation streams	*Callistemon sieberi* *Carex guadichaudiana* *Leptospermum polygalifolium* *Lomandra longifolia*	*Acacia filicifolia* *Acacia rubida* *Acacia siculiformis* *Bursaria spinosa* *Grevillea juniperina* *Hakea microcarpa* *Lomatia arborescens*	*Bursaria spinosa* *Eucalyptus bridgessiana* *Eucalyptus laevopinea* *Eucalyptus melliodora* *Eucalyptus pauciflora* *Eucalyptus stellulata* *Lomatia arborescens*
Lower Manning River downstream of Charity Creek (including Lansdowne and Dawson rivers, and Pipeclay, Killabakh, Dingo, Cedar Party, Caparra, Bo Bo, and Burrell creeks	*Callistemon viminalis** *Lomadra hystrix* *Lomandra longifolia* *Potamophila parviflora* *Tristaniopsis laurina* *Waterhousea floribunda*	*Acacia melanoxylon* *Acmena smithii* *Alectryon subcinereus* *Aphananthe philippinensis* *Backhousia myrtifolia* *Casuarina cunninghamiana* *Cordyline stricta* *Cryptocarya glaucescens* *Cryptocarya meisneriana* *Cryptocarya microneura* *Cryptocarya obovata* *Daphnandra micrantha* *Diploglottis australis* *Ficus coronata* *Glochidion ferdinandi* *Guioa semiglauca* *Hymenosporum flavum* *Mallotus philippensis* *Melicope micrococca* *Neolitsea dealbata* *Pittosporum undulatum* *Planchonella australis* *Streblus brunonianus* *Syzygium australe* *Tristaniopsis laurina* *Waterhousea floribunda*	*Acacia irrorata* *Acacia melanoxylon* *Alphitonia excelsa* *Angophora subvelutina* *Aphananthe philippinensis* *Callistemon salignus* *Cryptocarya obovata* *Diploglottis australis* *Dysoxylum fraserianum* *Ehretia acuminata* *Elaeocarpus obovatus* *Eucalyptus amplifolia* *Eucalyptus grandis* *Eucalyptus tereticornis* *Mallotus philippensis* *Melia azedarach*

STREAM	TOE	MIDDLE	UPPER
Southern tributaries (including Bowman, Barrington, Gloucester, and Avon rivers, and Bakers and Belbora creeks	*Callistemon viminalis** *Lomandra hystrix* *Lomandra longifolia* *Tristaniopsis laurina*	*Acacia melanoxylon* *Acmena smithii* *Alectryon subcinereus* *Alectryon tomentosus* *Alphitonia excelsa* *Backhousia myrtifolia* *Brachychiton discolor* *Casuarina cunninghamiana* *Ehretia acuminata* *Elaeocarpus obovatus* *Ficus coronata* *Glochidion ferdinandi* *Guioa semiglauca* *Hymenosporum flavum* *Mallotus philippensis* *Pittosporum undulatum* *Planchonella australis* *Podocarpus elatus* *Streblus brunonianus* *Syzygium australe* *Tristaniopsis laurina*	*Acacia irrorata* *Acacia melanoxylon* *Angophora subvelutina* *Callistemon salignus* *Ehretia acuminata* *Eucalyptus amplifolia* *Eucalyptus grandis* *Eucalyptus tereticornis* *Mallotus philippensis* *Melia azedarach*
Central and northern tributaries (including Rowleys, Cooplacurripa, Manning, Little Manning, lower Barnard, and lower Nowendoc rivers)	*Callistemon viminalis** *Lomandra hystrix* *Lomandra longifolia* *Potamophila parviflora* *Tritaniopsis laurina*	*Acacia melanoxylon* *Acmena smithii* *Alectryon subcinereus* *Alectryon tomentosus* *Alphitonia excelsa* *Backhousia myrtifolia* *Brachychiton discolor* *Casuarina cunninghamiana* *Ehretia acuminata* *Elaeocarpus obovatus* *Ficus coronata* *Glochidion ferdinandi* *Guioa semiglauca* *Hymenosporum flavum* *Mallotus philippensis* *Pittosporum undulatum* *Planchonella australis* *Podocarpus elatus* *Streblus brunonianus* *Syzygium australe* *Tristaniopsis laurina*	*Acacia irrorata* *Acacia melanoxylon* *Angophora subvelutina* *Callistemon salignus* *Ehretia acuminata* *Eucalyptus amplifolia* *Eucalyptus grandis* *Eucalyptus tereticornis* *Mallotus philippensis* *Melia azedarach*

* This species should be planted only of it already present along the stream.

Now go to the next page for the common names and plant descriptions.

DESCRIPTION OF RIVERBANK PLANTS NATIVE TO THE MANNING CATCHMENT

HEIGHT – refers to maximum height in an OPEN situation. Some species may grow taller in protected areas.
FROST RESISTANT – refers to the frost resistance of newly planted seedling. 1 = definite resistance; 2 = some resistance (light frosts); 3 = none or very little frost resistance.
PROTECTION WHEN YOUNG – 1 = requires no protection; 2 = may require some watering and protection on exposed sites; 3 = plant requires watering and protective cover of taller plants.

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Acacia irrorata, green wattle	Small, fern-leaved wattle with pale yellow flowers. Very hardy.	6	+	1	1	Good canopy species for protecting rainforest plantings	Attracts insect-eating birds
Acacia filicifolia, fern-leaved wattle	Medium-sized, fern-leaved wattle with golden flowers. Very hardy.	8	+	1	1	Useful middle-storey species for tableland or higher elevation plantings	Habitat tree for tablelands
Acacia melanoxylon, blackwood	Medium-sized bushy wattle with pale yellow flowers. Very hardy.	10	+	1	1	Useful buffer tree for planting on the outer edges of streamside plantings	Seeds attract birds
Acacia rubida, red-leaf wattle	Small, shrubby wattle with reddish leaves and pale yellow flowers	2	+	1	1	Understorey shrub for tableland plantings	Understorey habitat
Acacia siculiformis, dagger wattle	Small, shrubby wattle with spiny, sickle-shaped leaves and pale yellow flowers	1.5		1	1	Understorey shrub for tableland plantings	Understorey habitat
Acmena smithii, lilly pilly	Medium-sized rainforest tree with a dense habit and pink to purple fruit	10		2	2	Some forms make useful windbreaks if given sufficient water	Fruit attracts birds
Alectryon subcinereus, wild quince	Medium-sized rainforest tree with a dense crown, often bushy to the ground	8		2	2	Useful rainforest regeneration species, timber suitable for small turnery	Fruit attracts birds
Alectryon tomentosus, hairy alectryon	Medium-sized rainforest tree with a dense crown and hairy leaves	8		2	2	Useful regeneration species for dry rainforest sites	Fruit attracts birds
Alphitonia excelsa, red ash	A medium-sized tree with some drought tolerance. Leaves have a white underside. Hardy	12	–	1	1	Timber suitable for building or cabinet work. Stock forage tree. Good rainforest regeneration tree	Seeds attract birds
Angophora subvelutina, broad-leaved apple	A medium-sized tree with a sparse canopy and characteristic twisted branches. Very hardy	15		1	1	Useful shade and shelter tree	Attracts insect-eating birds
Aphananthe philippinensis, rough-leaved elm	Small to medium-sized rainforest tree with stiff, elm-like leaves and dense, dark crown. Hardy	12		2	2	Timber hard and suitable for handles. Edible fruit. Useful rainforest regeneration species	Fruit attracts birds
Backhousia myrtifolia, grey myrtle	Slow-growing bushy rainforest tree with some drought tolerance. Usually found on steep rocky banks. Hardy	8		2	2	Screen plant. Wood hard and tough, and suitable for handles	Good host for orchids and ferns
Brachychiton discolor, lacebark	Medium-sized deciduous rainforest tree with large hairy leaves and large pink, bell-shaped flowers. Hardy	12		2	2	Hardy regeneration species for dry rainforest sites. Used as a street tree in some areas	
Bursaria spinosa, blackthorn	Dense, bushy shrub with spiny branches and small, white, perfumed flowers	2.5		1	1	Useful understorey tree for revegetation projects on the tablelands. The spines afford protection for birds	Excellent habitat tree for tablelands
Callistemon salignus, willow bottlebrush	Small to medium-sized tree with papery bark, pink new growth, and cream-coloured bottlebrush flowers. Hardy	6	+	1	1	Useful windbreak species for exposed sites, or clayey, waterlogged soils	Flowers attract birds

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Callistemon sieberi, river bottlebrush	Small, multi-stemmed tree or shrub with pale, furrowed bark and cream to pink bottlebrush flowers. Hardy	3		1	1	Floor-tolerant species suitable for rocky, higher elevation streams. Useful erosion control species once established. Used for direct seeding.	Flowers attract birds
Callistemon viminalis, weeping bottlebrush	Multi-stemmed tree with hard furrowed bank and red bottlebrush flowers. Very hardy	5	+	1	1	Excellent erosion control species. Used for direct seeding	Flowers attract honeyeaters
Carex gaudichaudiana, tufted sedge	Small, tussocky sedge with dark green leaves and dark brown flower spikes	1		1	1	Good erosion control species for planting along the toe of the bank. Plants are easily grown by division	Good stormiest habitat species
Casuarina cunninghamiana, river oak	Tall, pine-like species. Very common on the North Coast. Hardy. Needs management as may contribute to erosion	20		1	1	Fixes nitrogen. Good canopy cover species for rainforest regeneration. Direct seeding.	Larger, older trees used as roosting sites
Cordyline stricta, slender pal-lilly	Slender shrub often forming clumps	2		3	3	Landscaping, understorey plant in shaded areas	Fruit attracts birds
Cryptocarya glaucescens, jackwood	A medium-sized, dense-crowned rainforest species producing wrinkled black fruit in autumn	10		3	2	Cabinet timber species	Fruit attracts birds
Cryptocarya meisneriana, thick-leaved laurel	Shrub to small tree with thick, dark, glossy leaves and black fruits	6		3	3	Understorey rainforest species	Fruit attracts birds
Cryptocarya microneura, murrogun	A medium-sized rainforest species producing shiny black fruit in summer/autumn	10		3	2	Reasonably hardy species for rainforest plantings	Fruit attracts birds
Cryptocarya obovata, pepperberry tree	Medium to tall densely-crowned rainforest tree with hairy new growth and dark leaves	18		3	3	Good shade tree	Fruit attracts birds
Daphnandra micrantha, socketwood	Medium-sized, straight-stemmed rainforest tree with compact, dense canopy and horizontal branches	12		3	3	Sometimes used for ornamental rainforest plantings	
Diploglottis australis, native tamarind	Attractive tall rainforest tree with large leaves and rusty hairy new growth	15		3	3	Attractive tree for landscaping. Edible fruit	Fruit attracts birds
Dysoxylum fraserianum, rosewood	Medium to tall rainforest tree with shady spreading crown. Needs water to establish	18		3	3	Timber is rose scented and used for cabinet work	
Ehretia acuminata, koda	Medium-sized rainforest tree. Deciduous, with grey, fissured bark and masses of orange fruits in summer/autumn	10		2	2	Fruits are ornamental	Fruit attracts birds
Elaeocarpus obovatus, hard quandong	Tall rainforest tree tolerant of wet soils. Hardy. Produces masses of small blue fruits	15		2	2	Useful timber tree for interior work. Shade tree	Fruit attracts birds
Eucalyptus amplifolia, cabbage gum	Tall tree of alluvial flats. Belongs to the red gum group and has large distinctive leaves. Very hardy	18		1	1	Useful timber tree for construction and fencing. Medium importance as a pollen source for bees	Attracts insect-eating birds
Eucalyptus bridgessiana, apple box	Medium-sized tree with box-type bark. The crown is large, spreading and heavily branched. The bark is grey, soft and fibrous and persistent to outer branches. Very hardy	15		1	1	Useful shade and shelter tree for the tablelands. Less valuable than other boxes for timber. Good honey and pollen tree for bees	Attracts insect-eating birds
Eucalyptus grandis, flooded gum	Very tall eucalypt with smooth white bark. Mostly found at lower elevations	35	+	1	2	Hardwood timber. Good pollen tree	Koala food tree
Eucalyptus laeropinea, stringybark	Medium to tall stringybarked tree. Very hardy	20		1	1	Useful timber tree for general construction work. Good honey tree and of major importance for pollen	

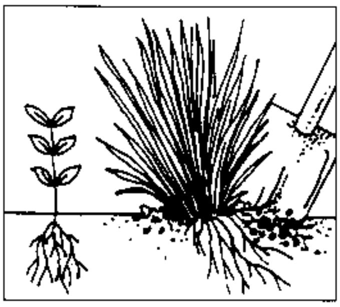
BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
***Melia azedarach* var *australasica*, white cedar**	Very hardy deciduous tree. Drought tolerant	15	+	1	1	Cabinet timber species	Fruit attracts birds
***Melicope micrococca*, white euodia**	Small rainforest tree with light-green foliage. Leaflets arranged in threes	10	+	3	2	Useful rainforest regeneration species on protected sites	Fruit attracts birds
***Neolitsea dealbata*, white bolly gum**	Small bushy tree with large drooping leaves that are vivid white underneath	10		3	3	Landscaping plant. Understorey tree	Fruit attracts birds
***Pittosporum undulatum*, native daphne**	Small bushy tree with fragrant flowers in spring. Hardy	8	+	1	1	Landscaping plant. Low windbreak tree. Good for rainforest regeneration	Fruit attracts birds
***Planchonella australis*, black apple**	Medium-sized rainforest tree with dark glossy leaves and large black fruits in spring/summer	12		3	3	The large black fruits are edible	Fruit attracts birds
***Podocarpus elatus*, brown pine**	Slow growing, dense crowned tree with dark-green leaves and brown scaly bark. Fruits are dark bluish/black	14		2	2	A valuable softwood timber species with a wide range of uses. The fruits are edible	Fruit attracts birds
***Potamophila parviflora*, river grass**	A grass species forming dense tussocks within the bed and along the banks of larger streams. The root mass is tough and dense	1.5		1	1	An excellent erosion control species if planted in sufficient density. Can be grown easily by direct transplant	Good stream-side habitat species
***Streblus brunonianus*, whalebone tree**	Small to medium-sized rainforest tree with glossy, toothed leaves, wiry branches and small green fruits. Hardy. Slow growing	8		2	2	Good understorey species for stream-side rainforest plantings	Fruit attracts birds
***Syzygium australe*, brush cherry**	Small, dense crowned rainforest tree with dark green leaves and red fruits from summer to early winter	10		2	2	Edible fruit. Good riparian rainforest regeneration species	Fruit attracts birds. Good host for ferns
***Toona australis*, red cedar**	Large rainforest tree with large leaves and spreading canopy. Semi-deciduous. Hardy	20	+	2	2	Good shade tree. Valuable timber tree. Subject to attack by tip moth	
***Tristaniopsis laurina*, water gum**	Medium-sized tree with flaky bark and yellow flowers produced in summer. Hardy	12	+	2	1	Useful erosion control species and some value for cabinet work. Useful nectar and pollen species. Used for direct seeding	Roots provide habitat for stream-dwelling animals. Good riparian shade species
***Waterhousea floribunda*, weeping myrtle**	Medium to large tree. Densely crowned with weeping foliage and round green fruit in summer/autumn. Hardy	15	+	2	2	Excellent erosion-control species with extensive mat-like root system	Roots provide habitat for stream-dwelling animals. Good riparian shade species

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Eucalyptus melliodora, yellow box	Medium-sized tree with yellowish to grey, box-type bark. Bark highly variable. Crown is often spreading and drooping. Hardy	20		1	1	Good shade and shelter tree for the tablelands. The timber is strong and durable and useful for fencing and heavy construction. Excellent honey tree for bees	Attracts insect-eating birds
Eucalyptus pauciflora, snow gum	A small, often multi-trunked tree with smooth white to dark grey bark which sheds in irregular patches. Very hardy	1-		1	1	Good shelter species for sites subject to very heavy frosts and snow. Useful pollen tree for bees	Attracts insect-eating birds
Eucalyptus saligna, Sydney blue gum	A very tall eucalypt with smooth white bark and a small 'sock' of flaky, dark grey bark	35	+	1	2	The timber is light, easy to work and durable when used above ground. Medium importance as a pollen source	Attracts insect-eating birds
Eucalyptus stellulata, black sallee	A small, often multi-trunked tree, with smooth, greenish brown bark. Base of the tree has dark, flaky bark. Very hardy	10		1	1	Minimal value as a timber tree. Produces useful pollen supplies. Excellent shelter tree for frost hollows	Attracts insect-eating birds
Eucalyptus tereticornis, forest red gum	A medium-sized to tall tree with blotched, whitish-grey bark. Often grows on alluvial floodplains. Very hardy	28		1	1	Timber suitable for heavy construction and fencing. Good shade tree. Good pollen species for bees	Koala food tree
Ficus coronata, creek sandpiper fig	Small bushy tree with sandpapery leaves	6		2	2	Excellent riparian species with edible fruit	Fruit attracts birds
Glochidion ferdinandi, cheese tree	Tree has spreading canopy with attractive foliage. Fruit looks like small cheeses	8		2	2	Excellent riparian regeneration species and small shade tree	Fruit attracts birds
Grevillea juniperina, prickly spider-flower	Small shrub with spiked leaves, spreading habit and red flowers	1		1	1	Good understorey species for tableland plantings. The spiked leaves afford protection for smaller birds	Flowers attract birds
Guioa semiglauca, guioa	Small rainforest tree. Leaves with silvery underside. Hardy	10		2	2	Attractive tree for landscaping. Useful for rainforest regeneration	Fruit attracts birds
Hakea microcarpa, small-fruited hakea	Shrub with bluish, spine-tipped leaves and small, two-seeded woody fruits	2		1	1	Good understorey species for tableland plantings	Habitat for small birds
Hymenosporum flavum, native frangipani	Small rainforest tree producing numerous yellow and white flowers in spring. Hardy	10	+	1	1	Useful species for rainforest regeneration	Fruit attracts birds
Leptospermum polygalifolium, creek tea tree	Multi-branched shrub with small dark-green leaves, white flowers and woody capsules. Common on tableland streams. Hardy	3	+	1	1	Good streambank stabilisation species for the tableland. Can be used for direct seeding	Habitat for small birds
Lomandra hystrix, spiny mat-rush	Small, tussocky rush, forming thick clumps. Hardy	1		1	1	Good for erosion control if planted in sufficient density. Large spreading root system	Good stream edge habitat species
Lomandra longifolia, spiny mat-rush	Small, tussocky rush forming thick clumps. Hardy on exposed or high elevation sites	1		1	1	Good for erosion control if planted in sufficient density	Good stream edge habitat species
Lomatia arborescens, smooth lomatia	Shrub with stiff, toothed leaves and fragrant cream-coloured flowers	5		2	1	Understorey species for high elevation areas and tablelands	
Mallotus philippensis, red kamala	Small bushy, dense-crowned rainforest tree producing hard red capsules in spring/summer. Very hardy	8		2	2	Useful rainforest regeneration plant. Fruit can be used for dye. Wood suitable for tool handles	

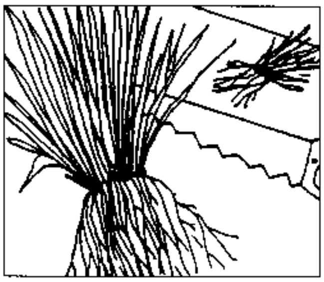
HOW DO I PLANT MY SELECTED SPECIES?

1. DIVISION OR DIRECT TRANSPLANT – MOST SUITABLE FOR TOE OF BANK

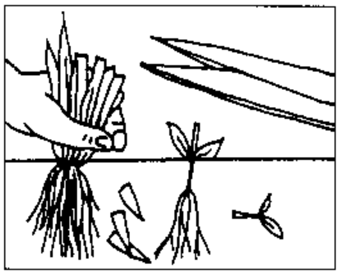
Mature clumps of lomandra or river grass can be dug up, divided and directly transplanted to moist soil or gravel. Seedlings of bottlebrush or tea tree can also be directly transplanted from site to site.



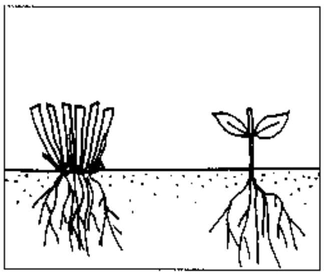
1 *Dig up clump or seedling.*



2 *Divide clump with saw, mattock or tomahawk*



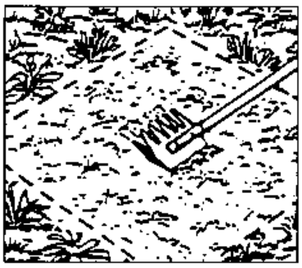
3 *Cut off tops of leaves or stem to reduce transplant shock.*



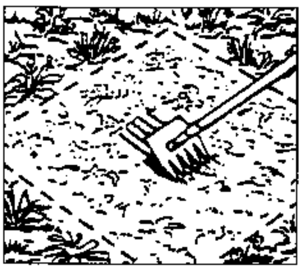
4 *Plant in moist soil or gravel.*

2. DIRECT SEEDING – MOST SUITABLE FOR TOE OF BANK

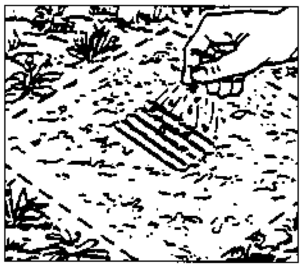
The seed of some species (e.g. bottlebrush, tea tree, lomandra, and water gum) can be directly sown on site. **Seed must be sown in moist, weed-free sand or gravel.** The gravel is levelled no higher than 100 mm above water level against the bank toe. Using this method we can reproduce the natural conditions that allow plants such as river oaks, tea tree, and bottlebrush to densely colonise gravel bars. The aim is to achieve dense colonisation, so sowing rates of up to 0.5 grams per square metre of gravel can be used.



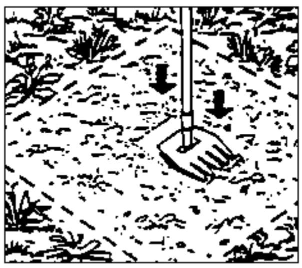
1 *Scrape the surface to remove any weeds or weed seed.*



2 *Rake to prepare the seed bed and bring fines to the surface.*



3 *Mix the seed with moist sand and broadcast over the surface.*



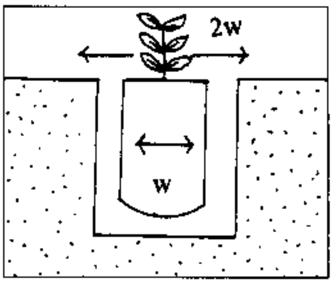
4 *Tamp the surface for fine seed, rake then tamp for coarse seed.*

3. TRUNCHEON CUTTINGS – MOST SUITABLE FOR TOE OF BANK

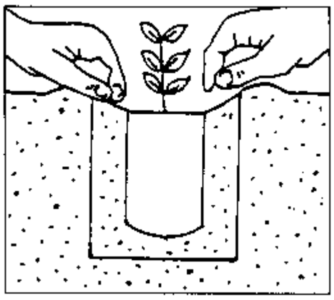
Branches or cuttings up to 3 metres long can be taken from mature trees and planted directly on site. Half the stem is buried into moist gravel using a crow-bar or water jet. At present this method is used mainly for non-natives such as willows and poplars. See your DLWC adviser before using these species as they may cause problems in your stream.

4. STANDARD TUBESTOCK – SUITABLE FOR TOE (0.5–1 metre spacings), MIDDLE BANK (2 metre spacings) and UPPER BANK (spacing 2 metres or wider)

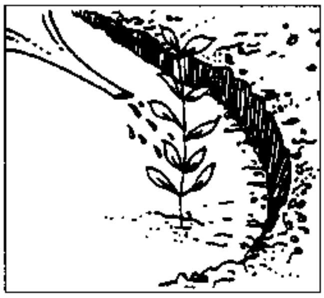
1 *Plant when soil is moist and there is no danger of frost.*



2 *Dig hole twice the width of the pot.*



3 *IMPORTANT: after planting, firm the soil to remove air pockets. If planting in coarser materials, place some fine soil in the planting hole.*



4 *Water in. A slight depression left around the plant will allow water to get where it is needed.*

5 *Give follow-up water and weed control where needed. (Weeds slow growth by taking water and nutrients.)*

6 *Check trees regularly for damage by animals. Stake and guard where needed.*

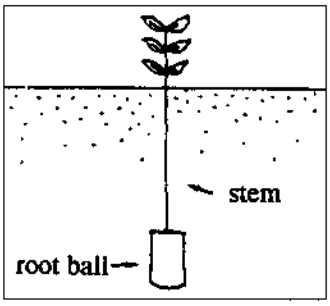
7 *Mulching helps conserve water.*

5. BROADACRE PLANTINGS – MOST SUITABLE FOR UPPER BANK/FLOODPLAIN (flat to undulating land)

Involves the use of specialised equipment and tubestock for mass plantings on a large scale. See your DLWC adviser for detailed information.

6. OTHER SPECIALISED METHODS – SUITABLE FOR TOE, MIDDLE BANK AND UPPER BANK

The use of specialised long-stem tubestock is currently being trialled. This method was developed by Wollombi Landcare Group. It involves the growth of seedlings in standard forestry tubes in a nutrient solution, and encouragement of stem elongation. Trees are planted using a water lancing jet to a depth of one metre or more. Root growth is achieved much more rapidly. Species tolerant of sediment build-up around the stem are used.



Long-stemmed tube is planted in sand. Root growth occurs from the nodes located along the stem.

RATING YOUR RIVER'S VEGETATION

RATING	ASSESSMENT	MANAGEMENT
RED 	VEGETATION ON THE BANKS IS MISSING, BANKS ARE BARE, OR TREES ARE FALLING INTO THE CHANNEL. BANKS MAY BE UNSTABLE.	THERE IS A NEED FOR EXTENSIVE GENERAL REPAIR OF THE CHANNEL AND ITS VEGETATION AND TO APPLY THE **RIVERCARE** PLANNING METHOD WITH FOLLOW UP DESIGN PLANS. STRUCTURAL WORKS MAY BE NECESSARY WHERE ALIGNMENTS ARE SEVERE. THERE ARE VARIOUS OPTIONS HERE AND YOUR DLWC ADVISOR CAN DISCUSS THEM WITH YOU.
YELLOW 	VEGETATION ON THE BANKS IS EITHER SPARSE, OF THE WRONG KIND, OR ONLY SINGLE SPECIES PRESENT. MOSTLY OLDER, LARGER TREES ARE PRESENT, WITH FEW SEEDLINGS OR YOUNG PLANTS. BANKS BECOMING UNSTABLE.	UNDERTAKE SUPPLEMENTARY PLANTINGS WHERE NEEDED. AIM TO INCREASE PLANT DIVERSITY. SPELL AREAS FROM STOCK IF REQUIRED, TO ALLOW NATURAL REGENERATION. PREPARE A **RIVERCARE** PLAN FOR THE RIVER AND ITS VEGETATION AND IMPLEMENT THAT PLAN.
	VEGETATION GROWTH WITHIN THE BED OF THE STREAM HAS CONSTRICTED THE MAIN CHANNEL EXCESSIVELY. NO VEGETATION IS PRESENT ON THE BANKS TO RESIST EROSIVE FORCES.	SET AN ALIGNMENT WIDTH BASED ON RIVER PARAMETERS (SEE YOUR DLWC ADVISOR). CUT BACK OBSTRUCTING OR EXOTIC VEGETATION. LEAVE THE ROOT SYSTEM INTACT TO REDUCE THE IMPACT OF THE RIVER ON THE BANK. KEEP INSIDE POINTS AND BARS CLEAR OF OBSTRUCTING VEGETATION WITHIN THE ALIGNMENT WIDTH WHERE NEEDED. PLANT THE ERODED BANK WITH VEGETATION.
GREEN 	VEGETATION ON THE BANKS IS IN GOOD CONDITION WITH A GOOD DIVERSITY OF NATIVE TREE, SHRUB, AND GROUNDCOVER SPECIES.	PRESERVE THE EXISTING STATE SPELL THE AREA FROM STOCK IF REQUIRED. KEEP FREE OF NOXIOUS WEEDS AND EXOTIC SPECIES. KEEP UP THE GOOD WORK!

7 PREPARING AND IMPLEMENTING A RIVERCARE PLAN

Total Catchment Management and River Management Planning

Preparing a Rivercare plan is a consultative process between the landowners and the Department of Land and Water Conservation.

The plan forms the basis for property planning and river management by the members of a Landcare Group in conjunction with the Department of Land and Water Conservation and the particular Catchment Management Committee as part of its total catchment management (TCM) initiatives.

The plan brings together the collective expertise and experience of departments and landowners to achieve solutions to problems of common concern on a whole stream rather than individual site basis. In the case of Rivercare plans, the problems targeted are extensive riverbank and floodplain erosion and management of the lands adjacent to the river – the riverine corridor.

Rivercare Planning

What is a Rivercare plan?

A Rivercare plan is a document that provides landowners with a basic scheme for managing their river corridor land. The plans also ensure that the Rivercare activities of neighbours are coordinated, and that river and bank erosion and other land degradation problems are identified and treated, so that productivity of the land and a reduction in land loss is maintained or improved over the long term.

What do Rivercare plans look like?

A Rivercare plan generally includes one or more base aerial enlarged photographs and a number of clear plastic *overlays* (see Figure 27) and a booklet 'Landowner Participation Activity Guide' (see Appendix 3). The number of overlays may vary according to the requirements of the plan but there are generally four to six. The following example describes a four-layer overlay plan.

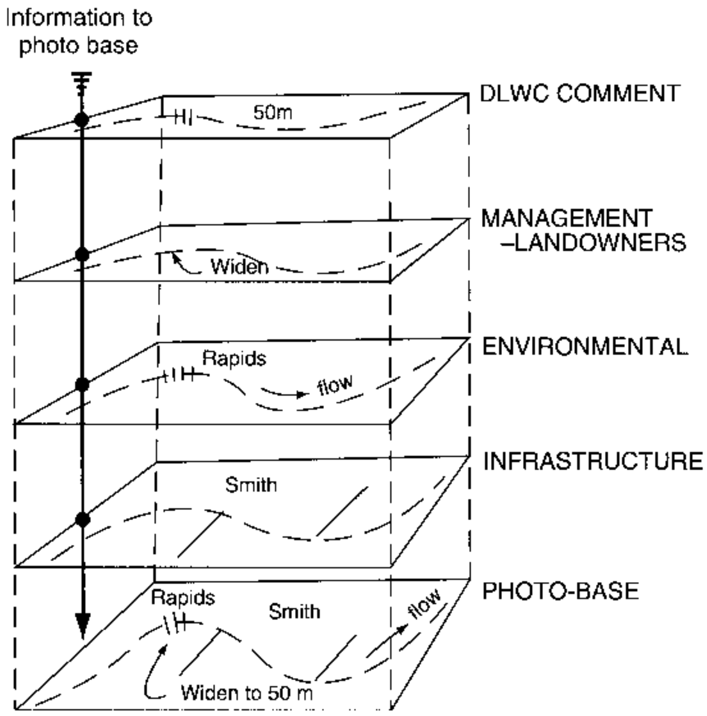


Figure 27. Graphical representation of the Rivercare planning process.

The *first overlay* shows improvements such as roads and tracks, fences and watering facilities, paddock boundaries, and problem types and areas.

The *second overlay* shows features that are there at present, such as bank erosion, rapids, pump locations, stock watering points, nesting sites, remnant vegetation, and other items of interest. Essentially, this layer picks up matters of environmental significance.

A *third overlay* provides the planning layer and shows the proposed works. It is initially prepared by the landowners.

A *fourth overlay* is used by the Department to combine the information. This information is then transferred back onto the aerial photograph and submitted to the Rivercare group for agreement.

An optional layer–the geomorphic layer–is used to describe pertinent geomorphic features such as gravel pits, log controls, erosion control works and the like.

Figure 28 shows the style of a completed plan. This is in a reduced size so the scale marked is not correct. The full-size plan is a laminated A1 size (841 × 594 mm) photograph.

What qualities do landowners need to start a Rivercare plan?

Landowners need to have:

- a desire to stay on the land by implementing stable productive techniques
- a knowledge of the property and its relationship to other properties within the catchment
- an understanding of the land and its management
- increased appreciation of catchment problems and their resolution
- a desire to adopt wise land management
- the time, labour and capital resources to implement the Rivercare plan.

How are Rivercare plans produced?

A Rivercare planning kit contains pens, ruler, rubber, a backing board, clear plastic overlays–usually between four and six–to suit each aerial photograph enlargement and an explanatory booklet, entitled 'Attribute Details Activity Guide' or 'Landowner Participation Activity Guide'.

The booklet provides information on producing the overlays which result in the final property plan. A copy of a typical booklet is given in Appendix 3.

Department of Land and Water Conservation personnel will provide assistance with the production of the Rivercare plan. There will be guidance through the planning steps with an on-farm visit and/or through workshops.

The outcome of the implementation of Rivercare plans will be *stable, clean, healthy, productive rivers*.

Legislative Controls

Action in or about rivers is controlled by many Acts of Parliament including:

Rivers and Foreshores Improvement Act
Soil Conservation Act

These New South Wales Acts prescribe that certain procedures must be followed and/or permits etc. obtained before works are undertaken.

There are many situations where these and other Acts and associated regulations may or may not be applied. This is drawn to the attention of readers, to alert them to the need to meet such legal obligations as may be associated with river-care activities.

Use of the Rivercare planning process allows Departmental officers to guide landowners through the legislative processes involved, which in some instances may be quite complex.

Tax Concessions

The *Income Tax Act* provides concessions for expenditure on river-care activities.

Two booklets have been published on the topic:

- *Landcare Taxation Arrangements* – a guide to section 75D.
- *Income Tax Deductions for Landcare Related Activities* – a guide to sections 51(1), 53, 54, 75B and 75D.

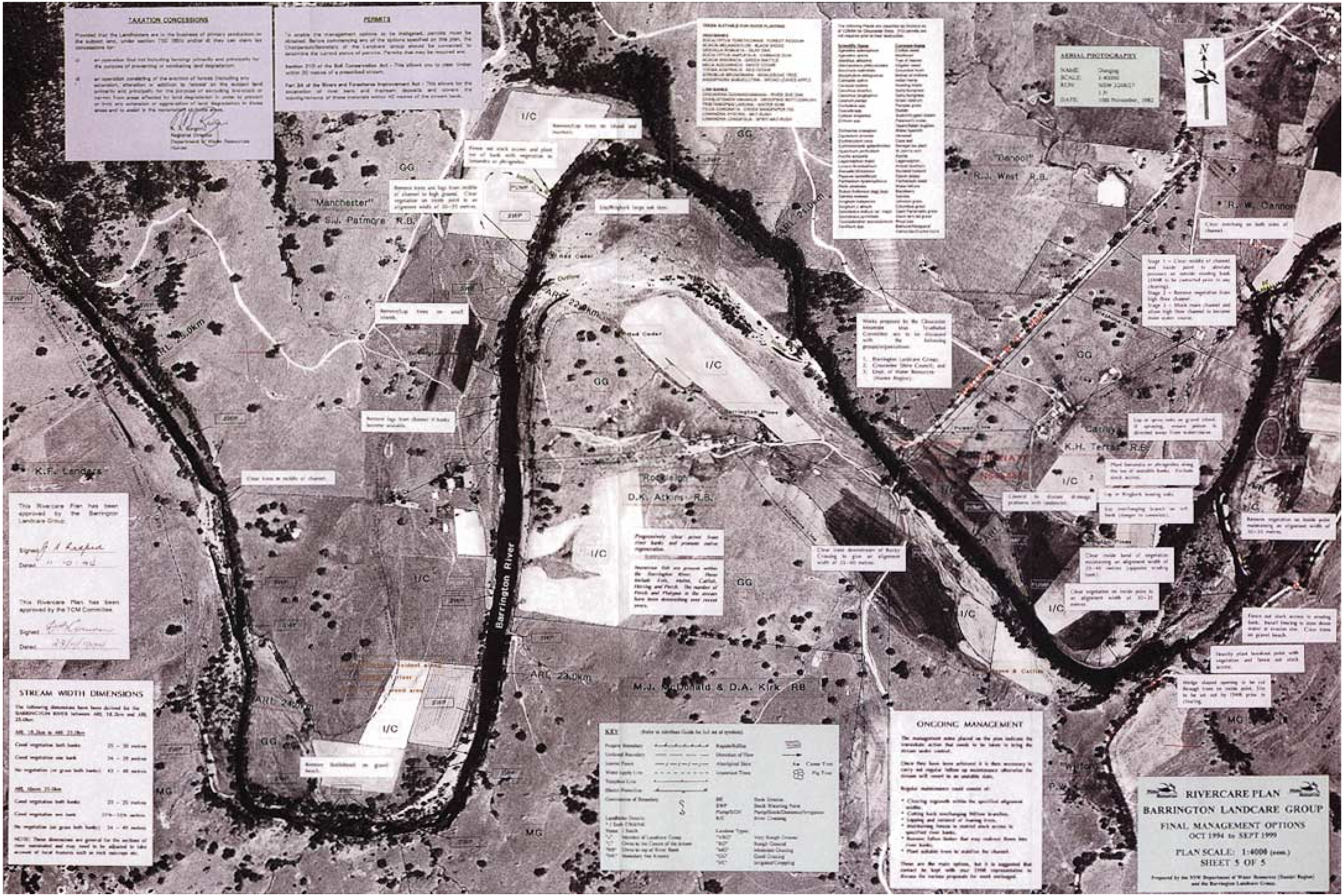
Copies can be obtained through your DLWC representative or from:

National Landcare Policy Branch
Department of Primary Industries and Energy
GPO Box 858
Canberra ACT 2601
Phone (06) 272 5838

The Australian Taxation Office can also provide information on tax concessions. The telephone number for general inquiries is listed in the White Pages.

Also, the matter can be discussed with your Accountant

Figure 28 (on facing page). A typical Rivercare plan. This is for a section of the Barrington River.



TAXATION CONCESSIONS
PERMITS
AERIAL PHOTOGRAPHY
I/C
GG
"Manchester"
S.J. Patmore R.B.
"Danpol"
R.J. West R.B.
R.W. Dannor
ARC 22.0km
ARC 23.0km
Barrington River
K.F. Landers
Rockleigh
D.K. Atkins R.B.
K.H. Terrar R.B.
M.J. McDonald & D.A. Kirk RB
This Rivercare Plan has been approved by the Barrington Landcare Group.
This Rivercare Plan has been approved by the TCM Committee.
Signed
Dated
STREAM WIDTH DIMENSIONS
KEY
ONGOING MANAGEMENT
MG
RIVERCARE PLAN
BARRINGTON LANDCARE GROUP
FINAL MANAGEMENT OPTIONS
OCT 1994 to SEPT 1999
PLAN SCALE: 1:4000
SHEET 5 OF 5

Procedure for Undertaking a Rivercare Plan

The steps involved in preparing a Rivercare plan, and the approximate times involved, are given in Table 6. It is assumed that five (5) aerial enlargements with four overlays will be used for the plan. At a scale of 1:5000 the plan will cover 25-30 km of river.

Implementing the Plan

Preparing a Rivercare plan is a consultative process between the landowners and the Department of Land and Water Conservation. The plan is intended to form the basis for property planning and river management by the members of a Landcare group in conjunction with the Department and the particular Catchment Committee as part of its TCM initiatives. It is a collective approach – using collective experience to fix the problem.

In summary, to produce a Rivercare plan the landowner(s) need to:-

- Decide that there is a reason to manage the river as part of their property management.
- Approach their neighbours about forming a Landcare Group, and the local TCM Committee for advice and assistance on how to establish a group.
- Form a Landcare Group to undertake a Rivercare Plan.
- Seek Departmental assistance.
- Start the Rivercare planning process.
- Implement the Rivercare Plan.
- Maintain the river for its long term health and viability and for the long term sustainability of the farming land.
- Strive for *stable-clean-healthy-productive rivers.*

The plan sets up a series of works to be implemented progressively over a period of usually five years. The Landcare Group may need assistance in the management of this project-based approach.

Table 6. Steps in preparing a Rivercare Plan.

STEP	ITEM	APPROX DEPARTMENTAL TIME (HOURS) PLUS TRAVEL WHERE REQUIRED	
STAGE 1	INITIAL DISCUSSION		
1.	Landcare Group advises DLWC or relevant body they require a Riverplan.	1	
2.	DLWC talks to chair of committee and explains the procedures that are involved.	1	
3.	DLWC may be asked to give a talk at a Landcare meeting. Preparation of information.	4	
4	DLWC representative gives a talk to Landcare group, which includes video, funding options, etc. Length of stream to be studied is determined at the meeting.	7	
5.	Cost of Plan is determined by DLWC after checking prices of materials, travelling, size of plan etc. and notifies Landcare group or Chairperson.	7	20
STAGE 2	FUNDING APPLICATION AND SETTING UP PLAN BASE		
6.	Landcare group applies for funding, e.g. NLP.	1	
7.	Once funding is obtained, DLWC orders flight run information.	3	
8.	While waiting for information, set up Project Folder. Job Number is obtained for costing.	2	
9.	From flight information, aerial contact prints are ordered. In addition, topographic maps and property maps.	4	
10.	While waiting for maps and prints to arrive, order the following: backing boards (A1 plus 5 mm), clips, film, stickers, sample bags, pens, rulers, erasers and make up Attribute Books.	4	
11.	Assemble sample bags to go with enlargements.	1	
12.	Check the scale of contact prints by comparison with topographic map. Mark out the extent of enlargements, taking into consideration the size of the final plan and that the final scale is workable.	4	
13.	Order aerial enlargements, to A1 size.	2	
14.	Cut and make storage folders.	2	
15.	Access HYDSYS for stage discharge curves and flood frequency curves. Get catchment areas from Hydrographic Data Books, and store in Project Folder.	4	
16.	On receipt of photographs check enlargements for scale.	1	

Continued on next page.

Table 6. Steps in preparing a Rivercare Plan.

STEP	ITEM	APPROX DEPARTMENTAL TIME (HOURS) PLUS TRAVEL WHERE REQUIRED	
17.	Cut enlargements and overlays to suit backing boards and mount on boards.	3	
18.	Prepare, print and place stickers on overlays.	2	
19.	Work out theoretical river widths and check from enlargements using stereoscope. Note any unusual features in river. Place details into Attribute Guides and Project Folder.	5	
20.	Place boundaries, landholder details, AMG co-ordinates, ARL's and overlaps on overlay one	14	52
STAGE 3	INITIAL HANDING OVER OF PLANS TO THE GROUP AND COLLATION OF INFORMATION		
21.	Arrange and talk at Landcare meeting with group, to show what is required (information workshop).	7	
22.	Landholders carry out items as per the Attribute Guide.		
23.	DLWC then assesses information on plans (landowner comments on the three layers).	14	21
STAGE 4	SITE DISCUSSION, FINALISE INFORMATION, PERMITS		
24.	Site inspection between DLWC and landholders, arrange through Landcare Group.	60	
25.	Transfer essential information onto the aerial enlargements, by way of clear adhesive stickers.	50	
26.	Transfer management options onto the enlarged photograph by way of white stickers. Place all key information including: Title Block, Photo Details, Keys to symbols, North Point, Alignment Widths etc.	50	
27.	Organise approvals for clearing of vegetation and works involving moving of bed material.	10	170
STAGE 5	FINAL ACCEPTANCE OF PLAN		
28.	Arrange Landcare Group to view the final plan and make comments. Present at the meeting should be representatives of Fisheries, NP&WS, and TCM.	7	
29.	Add any changes or information to the final plan, and then laminate.	23	
STAGE 6	HAND OVER COMPLETED PLAN		
30.	Present plan and associated materials to Landcare Group.	7	37
	TOTAL HOURS		300

The following strategy is suggested for implementing the plan.

a) Details of activities proposed by the DLWC facilitator and their timing during the first six months after receipt of the management plan by the Group.
   - i) Contact the Landcare Group(s) involved.
   - ii) Set up meetings to draw up:-
     - works programs and priorities
     - costing – estimates
     - liaison requirements (government departments, inter-landowner, environmental groups etc.)
     - set targets, check permits
     - aim to complete 50% of the works on the Rivercare Plans within 2 years.
   - iii) Put in place recording procedures, take photographs.
   - iv) Commence works.

b) Details of next years work activities and objectives
   - i) Continue with surveying, setting out of works, marking out areas to be planted, or trees removed.
   - ii) Assist groups in appraising best methods of achieving their goals listed on the Rivercare Plans.
   - iii) Keep photographic records of works and document progress.

c) The following six months – during this period the facilitators gradually hand over their activities to the Groups and:-
   - i) Start running workshops, field days and meetings to promote the outcome, methods, and procedures determined during the previous 18 months.
   - ii) Draw up programs for the next three years work, for each Landcare Group.
   - iii) Assess successes of the past 2 years work and compare with goals set on the first 6 months of the project, for the Group.
   - iv) Writes and distributes summary report.

Once the initial five-year plan has been achieved maintenance of the improvements made needs to be considered. In some cases, maintenance will begin during the implementation of the plan.

Project Maintenance to Year Four

Once the project has commenced, it is essential that a maintenance program to be undertaken by the landowners concerned be put in place. It is suggested that follow-up be yearly for the first four years, then every three years till ten years have elapsed. At this stage, it would be wise to have the overall progress of the project assessed and an ongoing maintenance program devised for the next ten years.

During the first four years of the project it is recommended that each year about five person days be spent on each kilometre of the river finalised to ensure that regrowth in the main channel is removed and that nominated regrowth areas continue to vegetate without hindrance from grazing stock. It is essential that during this critical period islands cleared as part of the original project remain free of obstructing vegetation, and the channel width designated does not narrow beyond the limits specified. It is also essential to ensure that plantings of trees be tended to the extent that fencing is maintained, stock excluded and weed control and any supplementary plantings required are undertaken up to the ten year assessment of the project, after which some relaxation of such procedures may be considered.

Project Maintenance to Year Ten

Experience has shown that once a project is established it is usually sufficient to undertake the maintenance activities described above at 3-5 yearly intervals. The interval will be determined by striking a balance between achievements and cost efficiency.

From Year Ten

After year ten it is advisable to review the progress of the project and set future goals against achievements based on the original project plan.

8 REFERENCES

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APPENDIX 1 Summary of LWRRDC Project: Use and Management of Native Vegetation for Riverbank Stabilisation and Ecological Sustainability

Project Reference Number: NDW1

Report Date: 30 September 1994

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Tony Voller (Dept. of Land and Water Conservation - Scone)

Statement of project objectives

The objectives of the project were to:

1) Provide resource managers/community with:
   - a list of species suitable for replanting for bank stabilisation and ecological sustainability of riparian corridors along each catchment;
   - a photographic record and easy key for plant identification in the field to be used in assessing various channel management activities such as tree destruction, channel modification and water abstraction;
   - a guide to planting, maintenance techniques and suitability of species to certain situations and locations;
   - a list of species potentially suitable for agroforestry.

2) Increase the knowledge base of riparian vegetation along the North Coast.

3) Provide information/education to landowners, schools, TCM Committees, Landcare groups, TAFE Colleges etc by:
   - the production of a video outlining problems and presenting possible solutions;
   - the production of a valley specific kit and complementary documentation;
   - organisation of field days.

Summary of methods

1) Undertake an inventory of the North Coast Rivers to identify existing native/riparian vegetation.
   - Identification of remnant riparian vegetation in each catchment using aerial photo interpretation.
   - Selection of survey sites across each catchment based on differences of geology, elevation, climate, catchment area, channel slope and proximity to known erosional areas. A general vegetation survey was then undertaken at each site.

2) Investigate different approaches to riverine corridor vegetation management.
   - Extensive literature review on the various approaches to riverine vegetation management including its effect on stream width and other channel characteristics.

- Apply this to the development of the 'RIVERCARE' planning process with the production of a number of plans using the concepts derived.
- Assessment of the suitability of the methodology and its community acceptance.

3) Research the soil binding capacity/stabilising potential of each species through observation, literature review, review of existing revegetation works, and planting trials.
   - Qualitative observations made on the role of various species in stabilising the bed and banks of the stream. (Transects were used to show the variation in floristics from waters edge to the top of the bank.)
   - Planting trials undertaken in a number of North Coast catchments using species identified.
   - Observation as part of the RIVERCARE planning process of the binding capacity of riparian vegetation and how to manipulate it to influence stream dynamics.
4) Research growth requirements of each species through observation, consultation and literature review.
5) Prepare a list of species suitable for bank revegetation projects, and techniques for planting and management.
6) Develop a photographic record and easy key for each species.
7) Combine obtained data to produce management and information kits for specific river valley areas and/or erosion problems.
   - Development of guides to river management practices and revegetating streams in specific catchments.
   - Development of an interactive RIVERCARE planning process.
8) Produce a 16-minute video 'RIVERCARE – For the good of your country' illustrating management procedures, to be widely distributed to TCM committees, landcare groups, landowners, schools, TAFE colleges, etc. demonstrating methods of managing erosion problems, suitable vegetation and the ecological benefits of revegetating river banks.
9) Organise field days for demonstrating the various techniques.
   - Development of visual display for use at field days, conferences etc.
   - Wide dissemination to a broad audience.

Results of the project

The project has achieved the following results (as at 30 September 1994).

a) The production and finalising of three RIVERCARE plans (15 sheets) embodying the methodology (Manning Valley-Bulliac, Gloucester & Mt. George) with another seventeen plans in various stages of production. This covers about 600 km of badly degraded sections of rivers in New South Wales.
b) There has been wide acceptance of the process by the farming community for the plans as they are practical, understandable and useable.
c) It is too early yet to state the on-ground outcomes, other than to say, there is a lot of 'will' to make the system succeed to produce *stable-clean-healthy-productive rivers*.

The results have exceeded the objectives by a considerable margin.

The information provided has been transformed into an interactive management process now being adopted Statewide by the NSW Department of Land and Water Conservation.

The video produced has been widely acclaimed and has been used as the base for documentation, displays, field days etc.

Public documents can be used as part of valley specific kits.

The distribution of riparian vegetation communities has been determined for all catchments on the North Coast of New South Wales–from Manning to Tweed.

Factors affecting the distribution of various riparian vegetation communities have been determined for each catchment.

- Weed species of the riparian zone have been identified in each catchment.
- Changes in the floristics of riparian vegetation since European settlement have been examined, and the importance of this on stream dynamics has been discussed.
- Rare, endangered, and some of the critical habitat species within the riparian zone have been identified.
- Species with potential for use in erosion control within each catchment have been identified and described.
- The various approaches to regeneration of riparian areas have been reviewed and discussed.

There have been numerous meetings presentations, workshops etc. during the development of the process. There are further field days planned using the documentation produced in this project. It is ongoing.

Interpretation of results has found the following:

- The distribution of riparian vegetation communities and species is influenced by a range of parameters at each site examined. These may include geology, climate, elevation, stream width, rainfall, floodwater velocity, inundation and disturbance history.

- The vegetation in most cases appears to differ significantly from that present before European settlement.
- Information gained from discussions with property owners indicates that following catchment clearing and the intense agricultural practices of the post war era (1945) and the floods of the 1950s, there was extensive erosion and mobilisation of river sediments. It appears that colonising species such as river oaks have proliferated since that time, to the extent that they now exert a significant influence on the stability of the river banks and bed.
- Management of these rivers has now become a process of controlling the extent of colonisation during periods of extended low flow. The report sets out a methodology to do this and to assess channel dimensions based on expected dominant flows and existing vegetation densities.
- Long term planning needs to address this by encouraging the re-establishment of species diversity along the streams and re-establishing a balanced, sustainable riparian ecosystem.

This could be achieved by accelerating the natural successional process by:

- thinning colonising species.
- planting the range of secondary colonising species identified in the research report. Such a process is similar to recognised rainforest regeneration techniques.

- The results of the project have been brought together and used in the development, educational material in the form of:
  - A video: 'RIVERCARE – for the good of your country'.
  - 'A Users Guide to Effective and Inexpensive River Maintenance Practices, Community Programmes and Channel Stabilisation Techniques'.
  - 'Revegetating Streams: a Guide to Species and Planting Methods'. Valley-specific kits outlining regeneration techniques listing suitable native species for the various streams in each catchment.
  - A visual display for use at field days, conferences etc.

Adoption of results

The RIVERCARE planning process has allowed the interactive adoption of results with landowners and provides a vehicle for their dissemination by way of the planning process and associated activities such as field days, group meetings etc.

In the case of the four plans in the Manning Catchment, an Implementation Officer will assist the groups in their project management and with the aim of achieving 50% of planned works in two years and 100% in five years. This will involve planning, review and recording procedures.

The results are now being used by some Councils through their planning process and the use of various planning instruments to ensure correct species of vegetation and procedures are being adopted in the riverine corridor. This could include conditions of consent on development approvals and other instruments such as development control plans.

The results of the project are used in the day-to-day extension activities of the DLWC staff.

Communication and technology transfer and adoption

Activities to date have included:

- Videos
- Promotion – cross country
- Development of a promotional display
- Attendance and participation in conferences, as well as presentation and reports.
- Rivercare plans – currently in production.
- Distribution of videos, promotional material and 'How to' booklets has been to:
  - catchment management committees
  - numerous Landcare groups
  - other government agencies
  - appropriate libraries
  - schools and other learning institutions
  - individual landowners.

Some Landcare groups have already started to adopt the results. These include:

Armidale/Dumaresq Landcare Group (Macleay Catchment)
Barrington River Landcare Group (Manning Catchment)
Bulliac Landcare Group (Manning Catchment)
Ellenborough River Landcare Group (Hastings Catchment)
Gloucester River Landcare Group (Manning Catchment)
Hollisdale Landcare Group (Hastings Catchment)
Kangaroo Creek Landcare Group (Clarence Catchment)
Medlow Landcare Group (Nambucca Catchment)
Mt George Landcare Group (Manning Catchment)
Paddy's Line Rivercare Group (Nambucca Valley)
Plains Station Landcare Group (Clarence Cachment)
Upper North Arm Landcare Group (Nambucca Catchment)
Upper Taylor's Arm Catchment Protection Landcare Group (Nambucca Catchment)

Also there are many groups outside the project area involved, including many west of the Great Dividing Range.

List of publications arising from the project

a) Milestone Report for the Project – published October 1992 – Provides a literature review of sources referred for the project up to October 1992.

b) A Users Guide to Effective and Inexpensive River Maintenance Practices, Community Programmes and Channel Stabilisation Techniques. ISBN 0 7310 2274 2

c) Milestone and Final Report for the Project
Volume 1 – Channel Stabilisation Techniques and Assessment. ISBN 0 7310 2277 7

d) Volume 2 – Use and Management of Native Vegetation for Riverbank Stabilisation and Ecological Sustainability in:
   i) The Manning River Catchment ISBN 0 7310 2278 5
   ii) The Hastings and Camden Haven River Catchments ISBN 0 7310 2279 3
   iii) The Macleay River Catchment ISBN 0 7310 2281 5
   iv) The Nambucca River Catchment ISBN 0 7310 2282 3
   v) The Bellinger River Catchment ISBN 0 7310 2283 1
   vi) The Clarence River Catchment ISBN 0 7310 2284 X
   vii) The Richmond River Catchment ISBN 0 7310 2285 8
   viii) The Brunswick River Catchment ISBN 0 7310 2286 6
   ix) The Tweed River Catchment ISBN 0 7310 2287 4*

e) A Guide to Revegetating Streams in:
   i) The Manning River Catchment ISBN 0 7310 2308 0
   ii) The Hastings and Camden Haven River Catchments ISBN 0 7310 2306 4
   iii) The Macleay River Catchment ISBN 0 7310 2305 6
   iv) The Nambucca River Catchment ISBN 0 7310 2304 8
   v) The Bellinger River Catchment ISBN 0 7310 2303 X
   vi) The Clarence River Catchment ISBN 0 7310 2302 1
   vii) The Richmond River Catchment ISBN 0 7310 2301 3
   viii) The Brunswick River Catchment ISBN 0 7310 2300 5
   ix) The Tweed River Catchment ISBN 0 6310 2299 8

Videos

'RIVERCARE–for the Good of Your Country' – 16 minutes. ISBN 0 7305 7896 0

'The State of the Rivers' (1991) – 19 minutes. ISBN 0 7305 7921 2

Project Award

The project won the Federal Water Environment Merit Award of the Australian Water and Wastewater Association for 1995.

Obtaining further information

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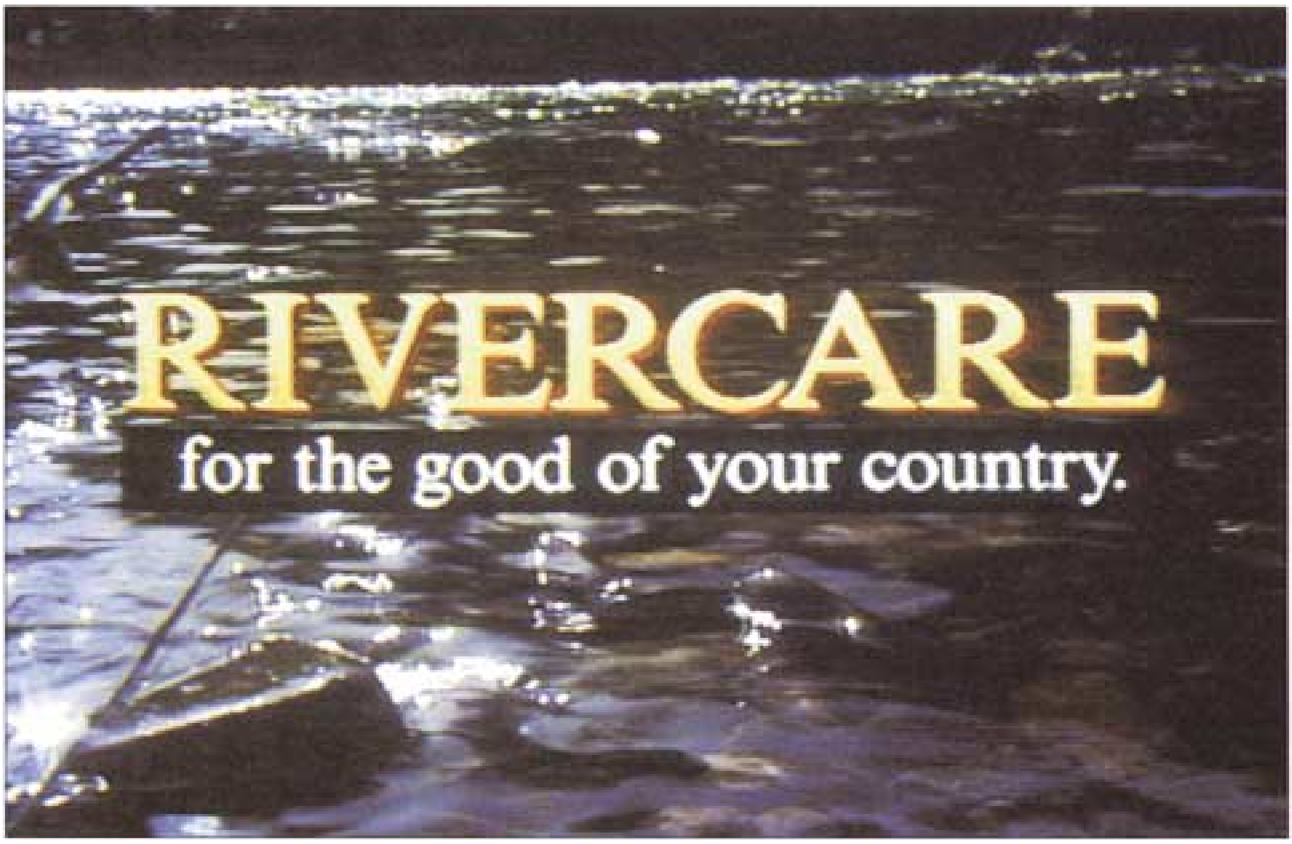
* Currently in final draft format.

APPENDIX 2 A Users Guide to Effective and Inexpensive River Maintenance Practices, Community Programs and Channel Stabilisation Techniques



A Users Guide to Effective and Inexpensive River Maintenance Practices, Community Programs and Channel Stabilisation Techniques

LAND & WATER
CONSERVATION

ISBN 0 7310 2274 2

This document is part of the project
'USE AND MANAGEMENT OF
NATIVE VEGETATION FOR RIVERBANK
STABILISATION AND ECOLOGICAL
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of NSW.

See the report: 'CHANNEL STABILISATION
TECHNIQUES AND ASSESSMENT' – Milestone
and Final Report, Volume 1, February 1994 for
background information to this document.

Prepared by: J. Gardiner
A. Raine

May 1994

THE RIVERCARE USERS GUIDE

CONTENTS

A. INTRODUCTION

EROSION AND FLOODPLAIN STRIPPING — A PERSPECTIVE

Prior to European settlement some 200 years ago, our rivers maintained themselves in a state of balance through the long time established natural ecosystems.

The banks of our streams supported a diverse range of native flora and fauna. This included essential native shrubs and trees, which maintained river bank stability by reducing the velocity and erosive power of seasonal floodwaters.

As was European practice at the time, the early Australian pioneers cleared catchments, often right up to riverbanks, and flood plains for intensive farming purposes.

The effect of this extreme clearing in Australia's harsh flood and drought cycles caused many rivers to dramatically change.

Without the protective covering of native vegetation, the streams, rivers and floodplains were open to attack.

As the velocity of floodwaters and runoff began to build, prime agricultural and grazing land was being lost on an ever increasing scale.

This erosion and stripping is still happening today.

Whether a major river system or a local stream it's time for the community to begin river maintenance practices.

THE RIVERCARE USERS GUIDE

The aim of this Guide is to show you how to begin looking after and maintaining your river.

This Guide provides the means of sorting through some of the more common problems encountered by landowners and points the way with practical suggestions and methods.

The solutions suggested are derived from practices and procedures currently being used by the Department of Land and Water Conservation (DLWC) in the development of RIVERCARE PLANNING.

For a greater understanding of the practices and procedures embodied in this Guide, please contact the Department for various guidelines and references that are available to cover your particular case. An explanatory video "RIVERCARE — for the good of your country" is also available upon request.

Although the ideas and procedures that follow have largely been developed from experience on the North Coast of NSW and Manning and Hunter Regions, it is considered that these procedures can be adapted to include most river catchments with some local variation.

B. MAKING A START

ASSESSING YOUR RIVER STABILITY AND RIVERBANK VEGETATION

To begin we need to review what is right and what is wrong with our section of the river.

The Department of Land and Water Conservation has developed a simple but effective way to rate the general health of a river system.

It is similar to "TRAFFIC LIGHTS". You rate your river corridor and bank vegetation as RED – YELLOW – GREEN depending on the immediate condition.

The following RIVERCARE FOLDOUT shows six management states:

Red River
Yellow River
Green River

Red Vegetation
Yellow Vegetation
Green Vegetation

The photographs depicted are representative of the six basic "TRAFFIC LIGHT" conditions.

LET US EXAMINE FIRSTLY THE CONDITION OF THE RIVER.

RED RIVER: The river is unstable, there is an imbalance of sediment inflow and outflow passing through the system with every chance of further degradation and land loss.

YELLOW RIVER: The river is tending towards becoming unstable, deposits are building within the channel, or erosion is likely to occur during flood.

With local maintenance much can be done.

GREEN RIVER: The river is generally stable and after flooding will recover quickly.

NOW, TO THE CONDITION OF RIVERBANK VEGETATION

RED VEGETATION: There is already massive loss as over 75% of the natural vegetation is missing, the banks may be stocked and there is little binding growth to protect against erosion.

There is an urgent need to begin planting.

YELLOW VEGETATION: Some 50% of the native vegetation cover is missing and what's there is sparsely located. Much of the understorey is non existent and trees are tending to get undermined. There may be excessive growth within the river itself.

With planting and maintenance this can be easily rectified.

GREEN VEGETATION: There is a good diversity of native growth, shrubs, bushes and trees. The natural ecosystem is in place and damage from flooding will recover quickly.

LETS BEGIN:

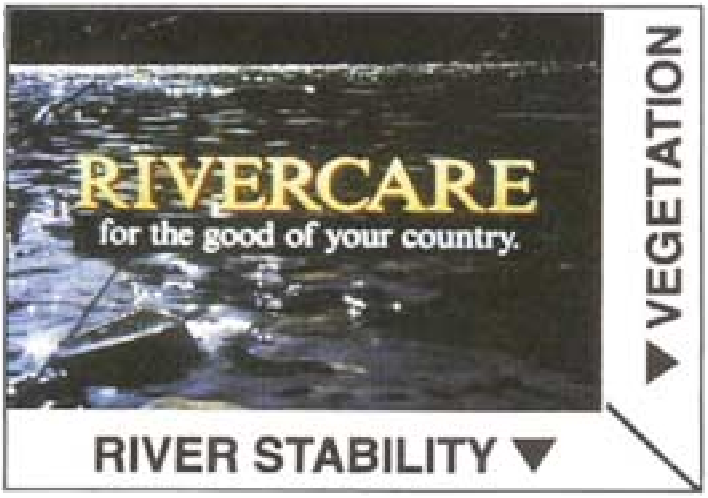
It is a good idea to TAKE SOME PHOTOGRAPHS along your river and stream sections and make a start by rating your river with this RED – YELLOW – GREEN system.

THE RIVERCARE FOLDOUT (see following) offers nine management options based upon these ratings.

The option might be obvious and advice sought from your DLWC adviser can then be easily and inexpensively put into practice. For example, a green river – yellow vegetation assessment.

However, the solution may not be so simple.

There may be a need for a community approach and action through a LANDCARE GROUP to produce and implement a RIVERCARE PLAN as in the red river – red vegetation situation.



RATING	MANAGEMENT
* River channel is in an advanced stage of disintergration. * Vegetation on the banks is either missing, banks are bare, or are falling into the channel.	* There is a need for extensive general repair of the channel and its vegetation and to apply the **RIVERCARE** planning method, with follow up design plans. Check to see if this plan needs to be part of a **TOTAL CATCHMENT PLAN.**
* River channel starts to enter a state of decline and physical instability. * Vegetation on the banks is either missing, banks are bare or are falling into the channel.	* Prepare a **RIVERCARE** plan. Later probably also a design plan for capital works. Check to see if this plan needs to be part of the **TOTAL CATCHMENT PLAN.**
* River channel is stable from erosion. * Vegetation condition is degraded, maybe contains exotics, or noxious weeds for example.	* Inspect after flood events and rectify any minor instability. * Get advice on bank and channel vegetation, planning and management.

RATING	MANAGEMENT
• River channel is in an advanced stage of disintergration. • Vegetation on the banks is sparse, or the wrong kind or has excessive growth within the river channel.	• There is a need for extensive general repair of the channel with extensive replanting of its vegetation. Apply the **RIVERCARE** planning method. Detail design plans needed in some areas. Check to see if this needs to be part of the **TOTAL CATCHMENT PLAN.**
• River channel starts to enter a state of decline and physical instability. • Vegetation on the banks is either sparse, or the wrong kind or has excessive growth within the river channel.	• Prepare a **RIVERCARE** plan for the river channel and its vegetation and implement that plan.
• River channel is stable from erosion. • Vegetation on the banks is sparse, or the wrong kind or has excessive growth within the river channel.	• Inspect after flood events and rectify any minor instability. • Get advice on bank and channel vegetation, planning and management.

RATING	MANAGEMENT
• River channel is in an advanced stage of disintergration. • Vegetation on the banks is generally sound with good species diversity.	• Although there is good bank cover an unstable channel points to a wider catchment problem which may need an **OVERALL CATCHMENT MANAGEMENT PLAN.**
• River channel starts to enter a state of decline and physical instability. • Vegetation on the banks is generally sound with a good species diversity.	• Undertake a **RIVERCARE** plan for the channel and retain existing vegetation management style. Check for wider catchment degredation.
• River channel in good stable state. • Vegetation on the banks in good condition with a good diversity of Australian native species.	• Seek extension advice on maintaining existing condition. - Keep up the good work!

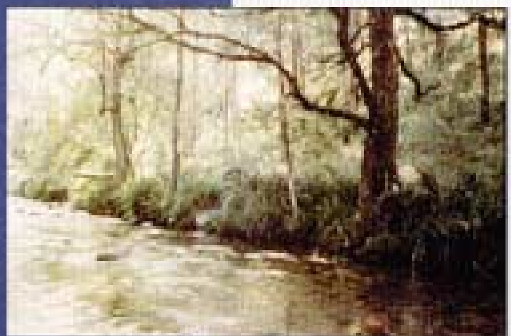
Land & Water Resources
Research & Development Corporation

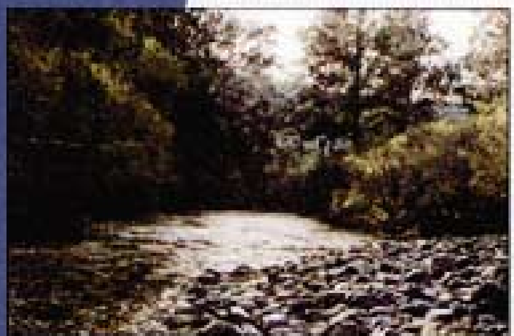
RIVERCARE

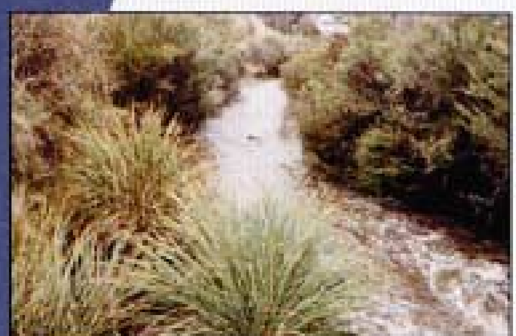
Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation

Occasional Paper No 03/95

Occasional Paper Series







C. LANDCARE AND RIVERCARE GROUPS

SOLVING LOCAL PROBLEMS THROUGH COMMUNITY COOPERATION AND INVOLVEMENT

Where management plans are called for, these will be best implemented and undertaken as a member of a LANDCARE or RIVERCARE GROUP.

Essentially, these Groups work as a community team to tackle common problems shared by a number of landowners along a section of river.

The idea is to provide an interactive forum with your river neighbours to work together on joint projects. LANDCARE and RIVERCARE GROUPS work particularly well to fix erosion, floodplain stripping and silting problems in the river valleys. The many interests, skills and ownerships available within these communities can together evolve long term management outcomes.

Once the Group has established its common resolve, an approach is made to the DEPARTMENT OF LAND AND WATER CONSERVATION for assistance in the preparation of a RIVERCARE PLAN.

The planning process can include meetings with the Group, the funding application, setting up a plan base, preparation of the aerial photograph plan and overlays, inspections, advice on permits and final recommendations.

The Department's standard procedure for the implementation of RIVERCARE PLANS is set out in Section G following.

As EVERY RIVER SYSTEM IS UNIQUE this standard RIVERCARE planning procedure can vary and it is best discussed with your local Departmental Officer. The process devised by the Department is very much an interactive one. For example, you need to provide property details and preferred management options. The Department's role is one of advice, consultation and facilitation in such matters as permits and technical data.

THE LANDCARE AND RIVERCARE GROUP is the cooperative way to firstly fix your river system and then secondly to regularly maintain it.

LANDCARE AND RIVERCARE GROUPS DO WORK

So talk to your neighbours and get them involved.

D. THE MANAGEMENT PROCESS

LOOKING FOR THE CAUSE OF EROSION

Erosion commonly occurs on the outside of bends during floods.

What we want to do is to make these outside bends strong enough to resist these erosive forces.

We can make the outside bends strong enough by planting and maintaining vegetation, preferably native species.

In severe situations, a preferred option could be to install structural devices such as Jacks or Rock.

The river flows are thus guided past the potential erosion site from one stable section of the river to another.

The inside bends or point bars provide a temporary storage area for sediments passing through the river system. We need to recognise this when considering our management options, as it may be necessary to remove consolidating vegetation and bushes from these point bars to allow the river processes to operate freely.

This guide does not go into the causes of riverbank erosion except in its simplest meaning. Your DLWC adviser has further references and more detailed information.

CHANNEL WIDTH AND ALIGNMENT

THIS IS CRITICAL

If the width of the river channel is too narrow or overgrown, the river flow becomes choked in a flood. This in turn causes the velocity of the flow to increase, producing a scouring effect — particularly on vulnerable outside bends.

In some instances, a badly blocked channel is bypassed, leading to overbank flow.

The extreme case can occur during prolonged flooding. This causes floodplain stripping and headward erosion of the floodplain itself when hectares of prime land can end up in the river estuary.

When channel widths are too wide, then the problem of instream deposition occurs.

This allows for the creation of sandbars and rapids, which if consolidated by vegetation and bushes then exert erosive forces on the adjacent banks.

GETTING THE BALANCE RIGHT

The whole physical management of a river system is about getting the correct balance between:

WATER FLOW

SEDIMENT MOVEMENT

BANK VEGETATION DENSITY.

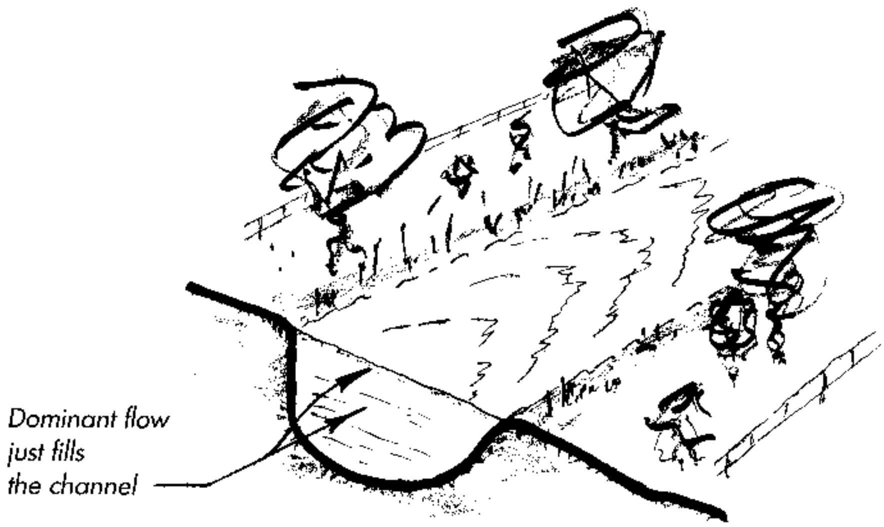
Of the seven factors which have been identified to affect general channel stability, there are two in particular which have a major influence.

These are the DOMINANT FLOW and the BANK VEGETATION DENSITY.

How do I know how big my river channel should be?

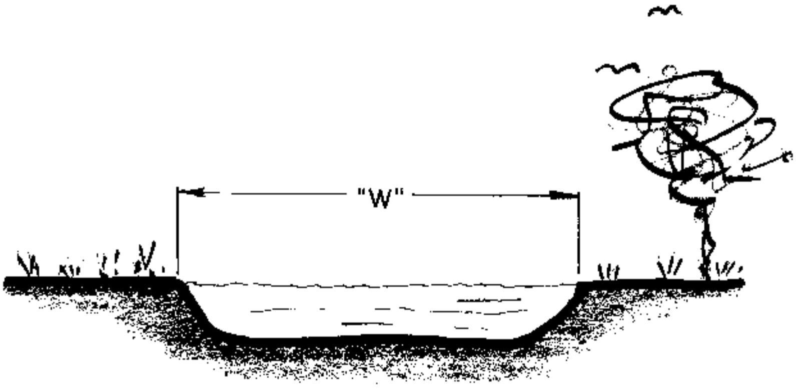
The size of the river channel has been found to be dependent on the river flow.

This flow, THE DOMINANT FLOW is the one that usually just fills the channel without overflowing its banks and occurs on average once every 18 months. This can vary up to 3 years.

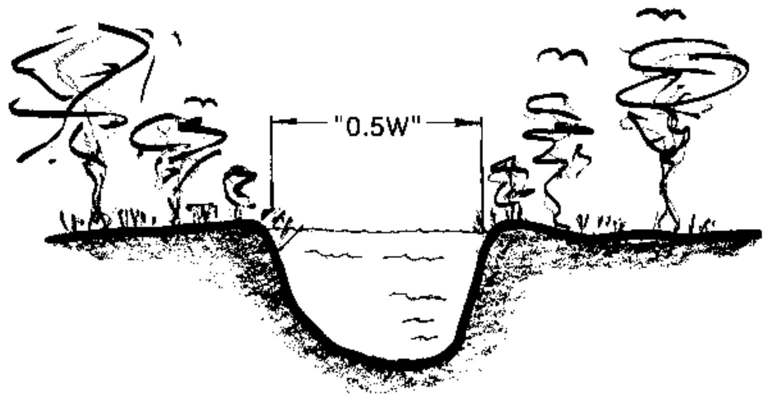


How does vegetation density impact on the channel size?

NO VEGETATION

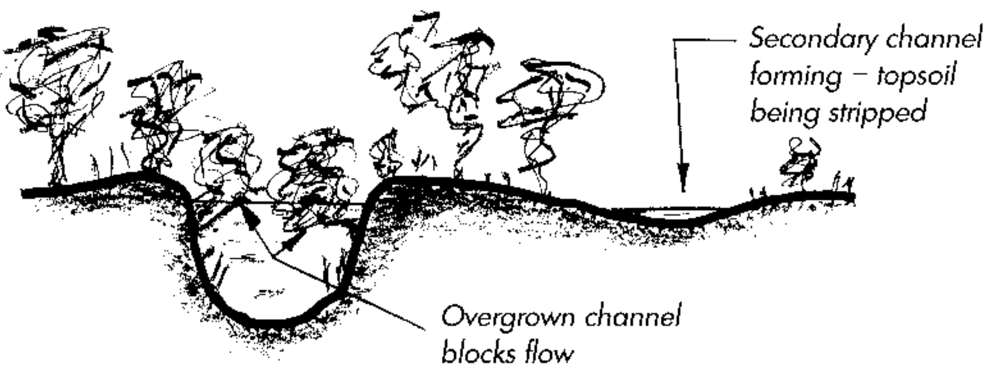


GOOD VEGETATION



Good vegetation will contract the channel width by about 50% and also deepen it. If vegetation is destroyed the channel will widen and become shallow.

OVERGROWN WITH VEGETATION



Of course there are other factors to take into consideration in the on site situation. The adoption of a RIVERCARE PLAN and its procedures will take into account the many and varied anomalies that can occur along your particular river system.

MANAGING YOUR RIVER

Having assessed the general health of your river system, and formed a LANDCARE GROUP you should now be in a position to review the options available to start managing your river.

THE MANAGEMENT PROCESSES (see following foldout) sets out a visual methodology based upon a real situation and the sort of RIVERCARE PLAN and recommendations that would apply. This is only one situation and will probably differ from yours. It does, however, demonstrate how you can bring back a very degraded river to a balanced river.

Certainly, it is possible to contain a river system that is starting to deteriorate, whilst pristine rivers are about future management.

SIMPLE MANAGEMENT OPTIONS (see following foldout) shows some of the simple options and practices that are available to you.

This RIVERCARE Users Guide addresses the more common problems usually encountered by landowners.

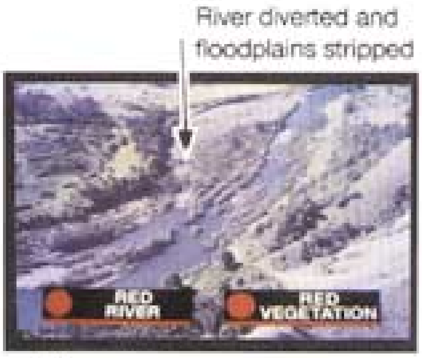
Where more complicated problems such as:

ACCRETION
BANK SLUMPING
BED DEGRADATION
FLOODPLAIN STRIPPING
HEADWARD GULLYING

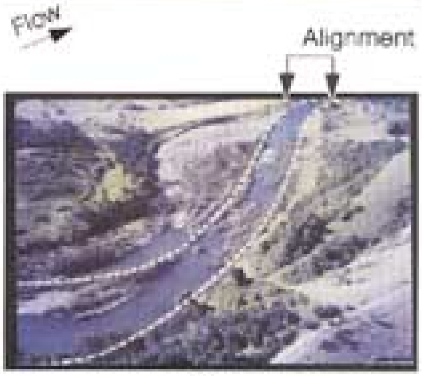
are occurring specialist advice is called for and should be sought from your local DLWC adviser.

MANAGEMENT PROCESSES

FORM A RIVERCARE GROUP and start a collaborative **RIVERCARE** plan with your neighbours.

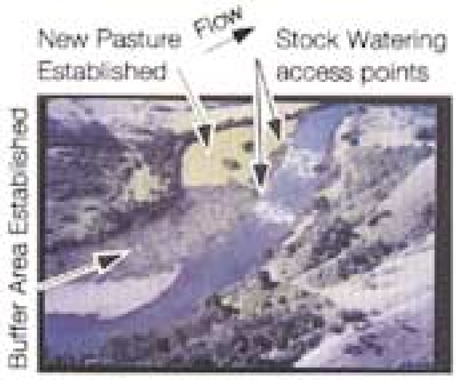


THIS SHOWS A RIVER WHICH HAS OVERGROWN in the main channel and has forced flood flows over the flood plain and is removing topsoil from the flood plain and back to raw gravel. The channel continues to overgrow with vegetation.



TO REVERSE THIS TREND:-

i) Set an alignment based on river parameters — see your DLWC advisor
ii) Start planting out eroded banks and breakout points.
iii) Start clearing within set alignment taking into account environmental factors.
iv) Permits are needed.



CONSOLIDATE THE PROGRAM:-

i) Ensure good buffer strips at upstream end.
ii) Plant up and fence out pasture area.
iii) Provide stock access to the river downstream of the rapids.

MAINTAIN THE RIVER BY:-

i) Fencing out stock from vulnerable locations.
ii) Removing regrowth from the river channel.
iii) Replanting and repairing damaged areas after floods.

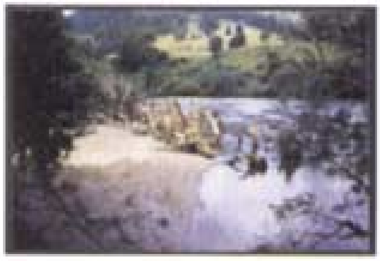
SIMPLE MANAGEMENT OPTIONS

A RIVER IN CONTROL - WITH GOOD BANK VEGETATION

i) Preserve the existing state and
ii) Ensure stock are excluded from banks.
iii) Keep free of noxious weeds and exotic species
iv) Preserve this environment, maintain a 30 metre wide buffer zone.

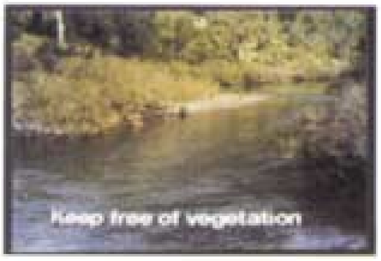
A RIVER WHERE THE CHANNEL IS BLOCKED

i) Cut back obstructing or exotic vegetation.
ii) Leave root system intact to reduce the impact on the banks of the rivers.



A RIVER WHERE OBSTRUCTING VEGETATION HAS CREATED EROSION ON OUTSIDE BENDS

i) Keep inside points and bars clear of obstructing vegetation within the alignment width - where needed.
ii) This can be done by cutting back and/or the judicious use of an approved herbicide such as Round-up. (R).



Planting Australian Natives

PLANTING VEGETATION

Where the channel is of adequate width and the alignment is not severe (straight) plant up the toes of the eroding banks using **NATIVE VEGETATION**. Where there is severe erosion use Poplars or Willows - jetted or backhoed into the riverbed, to act as the initial stabilising medium. Aim to replace them with natives as a long term goal.

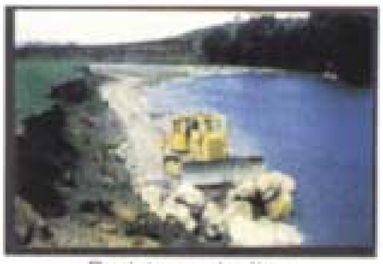
Jet planting Willow cuttings

Jacks planted with Willows

STRUCTURAL WORKS may be necessary where alignments are severe.

There are various options here and your DLWC advisor can discuss them with you

Their costs can vary widely and depend on local availability of materials.



Rock toe protection

GETTING THE VEGETATION RIGHT

A second booklet in this series:

"Revegetating Streams: a Guide to Species and Planting Methods"

sets down some suggestions on the correct species of trees to plant along your riverbanks. It provides a guide to planting techniques and sets out the locale to get the best results for erosion control given the growing potential of each species. This guide also covers other environmental considerations

Remember, the aim of any RIVERCARE project is about putting your river back into balance and this includes the maintenance of the natural ecosystem.

For further detail or information please contact your local DLWC adviser.

E. LEGISLATIVE CONTROLS

Action in or about your river is controlled by many Acts of Parliament including:

THE RIVERS AND FORESHORES IMPROVEMENT ACT

This Act amongst other matters controls the removal/excavation of materials in the riverbed or within 40 metres of the top of the riverbank.

THE SOIL CONSERVATION ACT

This Act controls the removal of timber, shrubs etc. within 20 metres of the top of the riverbank.

These Acts prescribe that certain actions, permits, etc must be undertaken or obtained before works can begin.

There are many situations where these and other Acts may or may not be applied. It is not intended, here, to set these situations out in detail other than to advise of their existence and the need to meet the statutory requirements.

The use of the RIVERCARE planning process allows Departmental Officers to guide landowners through the necessary requirements as defined by the particular management options adopted by that LANDCARE or RIVERCARE GROUP.

F. TAX CONCESSIONS

The Income Tax Act provides concessions for this kind of work.

There are two information booklets for further reference:-

LANDCARE TAXATION ARRANGEMENTS — A GUIDE TO SECTION 75D.

INCOME TAX DEDUCTIONS FOR LANDCARE RELATED ACTIVITIES — A GUIDE TO SECTIONS 51(1), 53, 54, 75B, 75D

Copies of these can be obtained through your DLWC representative or from:

National Landcare Policy Branch
Department of Primary Industries and Energy
GPO Box 858
CANBERRA ACT 2601
Telephone (06) 272 5838

The AUSTRALIAN TAXATION OFFICE can also provide information on tax concessions. The telephone number for general inquiries is listed in the White Pages.

Lastly, discuss the matter with YOUR ACCOUNTANT.

G. THE RIVERCARE PLAN

THE DLWC PLAN — AN OVERVIEW

STEP ONE — INITIAL DISCUSSIONS

LANDCARE GROUP advises DLWC they require a Riverplan.

DLWC talks to the group and explains the procedures that are involved.

DLWC adviser gives a talk to the LANDCARE GROUP, which includes screening of the video, funding options available etc. The length of the stream or river to be studied is determined at this meeting.

Cost of the plan is estimated by the DLWC adviser in consultation with the LANDCARE GROUP.

STEP TWO — FUNDING APPLICATION AND SETTING UP PLAN BASE

LANDCARE GROUP applies for funding e.g. NLP.

Once funding is obtained, the DLWC orders the flight run information.

From the flight information, aerial contact prints are ordered. In addition, topographic and property maps are ordered as required.

On receipt of the contact prints, the scale is checked and the extent of the enlargements needed is marked out. Consideration will be taken to the size of the final plan and the final scale.

The aerial enlargements are ordered and on receipt are prepared for presentation to the LANDCARE GROUP.

STEP THREE — INITIAL PRESENTATION OF THE PLANS TO THE LANDCARE GROUP AND COLLATION OF INFORMATION

Arrange and talk at LANDCARE GROUP meeting, to show what is required. This is an Information Workshop.

Landowners provide information and their ideas as set out in the LANDOWNER PARTICIPATION ACTIVITY GUIDE.

DLWC then assesses this information on the plans.

STEP FOUR — SITE DISCUSSION, FINALISE INFORMATION AND PERMITS

Site inspection and discussion between DLWC and landowners. This is arranged through the LANDCARE GROUP.

Transfer essential information onto the aerial enlargements and set up plans.

Organise approvals for clearing of vegetation and moving of sand and gravel.

STEP FIVE — FINAL ACCEPTANCE OF THE RIVERCARE PLAN

Arrange for the LANDCARE GROUP to view the final plan and make final comments.

Present plans at a meeting of the appropriate CATCHMENT COMMITTEE.

Add any changes or information to the final plan.

STEP SIX — THE COMPLETED RIVERCARE PLAN

Final presentation of the plan and all associated permits and approvals is made to the LANDCARE GROUP.

H. TO SUMMARISE

MAKE THE DECISION TO MANAGE YOUR RIVER AS PART OF YOUR OVERALL PROPERTY MANAGEMENT.

RATE THE STATE OF YOUR RIVER AND ITS BANK VEGETATION.

APPROACH YOUR NEIGHBOURS AND YOUR LOCAL CATCHMENT COMMITTEE FOR ADVICE AND ASSISTANCE ON HOW TO FORM A LANDCARE OR RIVERCARE GROUP.

FORM A LANDCARE GROUP TO UNDERTAKE A RIVERCARE PLAN.

SEEK DEPARTMENTAL ASSISTANCE.

BEGIN THE RIVERCARE PLANNING PROCESS.

IMPLEMENT YOUR RIVERCARE PLAN.

MAINTAIN YOUR RIVER FOR ITS LONG TERM HEALTH AND VIABILITY.

WITH RIVERCARE PLANNING, WATCH AS YOUR FARMS FUTURE SUSTAINABILITY IS GREATLY IMPROVED.

For further detail or information contact your nearest DEPARTMENT OF LAND AND WATER CONSERVATION Office listed in your WHITE PAGES and referenced through the INDEX of STATE GOVERNMENT DEPARTMENTS, AUTHORITIES or SERVICES.

APPENDIX 3 Nambucca River and Missabotti Creek Rivercare Plan: Landowner Participation Activity Guide

RIVERCARE

RURAL FORMAT

DEPARTMENT OF LAND & WATER CONSERVATION

NAMBUCCA RIVER
AND MISSABOTTI CREEK
RIVERCARE PLAN

LANDOWNER PARTICIPATION
ACTIVITY GUIDE

JULY, 1995

CONTENTS

Originally produced in MUSWELLBROOK by

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The document was revised by the NAMBUCCA CATCHMENT MANAGEMENT COMMITTEE RIVER STABILISATION SUB-COMMITTEE on 4 July 1995

A) “RIVERCARE” – A Landowner Driven Riverine Corridor Management Process

1) BACKGROUND

The need for the better management of our RIVERS and STREAMS to stem bank erosion, improve water quality, improve habitat, and reduce the effects of flooding, has been apparent for many years.

The HUNTER REGION of the Department of Land and Water Conservation (DLWC) in conjunction with the MANNING VALLEY CATCHMENT MANAGEMENT COMMITTEE has devised a system of river management which allows for *DEPARTMENTAL* and *LANDOWNER* inputs to produce “**RIVERCARE**” management plans on a collaborative basis.

2) MANAGEMENT

These “**RIVERCARE**” plans form the basis of the management of a particular section of river under the jurisdiction of a particular Landcare Group.

The plans allow for a **group permit** process. Permits which currently require individual applications, now can be a single application by the Landcare Group based on the agreed ‘**RIVERCARE” plan.**

3) RIVERCARE PLANNING

Some important features and advantages of Rivercare plans are:

- **consultation** between neighbours, DLWC, other government bodies, including local and State, and river users.
- **technical advice** is provided.
- **flexibility** — the plan is adapted to a particular stretch of stream to meet the needs of river users.
- **long and short term goals** can be set.
- **permits** for tree destruction and other river works cover the length of stream in the plan.
- **funding** to carry out works can be applied for on the basis of a planned approach.
- **tax concessions** for fencing and other works.

A **Landcare/Rivercare** Group is needed to create a **Rivercare plan**.

Broader catchment problems, such as gullying, can impact on channel stability. In these cases, a **catchment plan** is probably needed. A **Rivercare plan** would be an integral part of a **catchment plan**. It can also provide a continuity base for whole farm plans along the river.

4) THE PROCESS

Using enlarged aerial photographs with a series of overlays, all relevant riverine corridor information such as the physical, environmental, and the managerial can be recorded by the Landowners and DLWC. Most of the data is collected by the Landowners with the Department's role being one of co-ordination, guidance and technical input.

This information forms the basis of a Rivercare management plan.

B) METHODOLOGY – Summary

This manual has been developed to assist you in the preparation of a Rivercare plan. The plan consists of a number of layers that will help you develop a workable management plan for your area. The initial plan is usually developed for what can be achieved by your group over the next five years.

The pages have been colour coded to aid you in completing each section/ layer of the plan. The pens provided correspond to the colour code. Mistakes can be erased using the white correction pen, or special rubber.

The following sets out a brief outline of the process and the diagram shows a graphical representation of the procedure.

1) AERIAL PHOTOGRAPHS

The aerial photographs have been enlarged to enable features of the area to be easily identified and to permit clear depiction of the final management options. The photographs are to a standard scale so that direct measurements can be taken from them.

2) BOUNDARY AND PROPERTY OWNER – INFRASTRUCTURE

This is the first layer and is closest to the aerial photograph. A black pen has been provided with your kit and all information on this layer should be marked with this pen. See Grey section of this manual for requirements here.

3) ENVIRONMENTAL LAYER

This is the second layer and this is for noting all features of the existing environment that are there at present, such as bank erosion, aboriginal sites, vegetation details, existing riverworks, items of interest, etc. Features on this layer should be marked with the green pen.

4) GEOMORPHIC FEATURES and PERMITS/AUTHORITIES GRANTED

This layer is arrived at by looking at the dynamics of the river i.e. whether it is aggrading, degrading, the history of water holes, nature of any modifying works done on the river e.g. tree removal, gravel extraction etc. Information such as rock outcrops or bars in the river etc. is needed to assist in the design of the stable channels. An orange pen is provided for use on this layer.

5) LANDOWNERS' MANAGEMENT OPTIONS AND PREFERENCES FOR THE NEXT FIVE YEARS

This layer shows proposed works. This is the planning layer and is prepared by the Landowners. A red pen is provided for use on this layer.

5_i) CHANNEL DIMENSIONS

This is not a layer on the plan, but gives you an idea of the optimum channel widths for the river. It is an addendum to the Landowners Management Options Layer.

6) FINAL MANAGEMENT PROPOSAL/TCM DETAIL

For this layer, DLWC advisory staff go along the river and discuss the various options, attributes, environmental factors, etc, and put together with you, the Landowners, a workable management plan to be implemented over (say) the next five years.

Note areas that are of specific interest to discuss — as shown in blue pen.

Final management options are developed and areas of competing interests are examined and resolved. A blue pen is used for this.

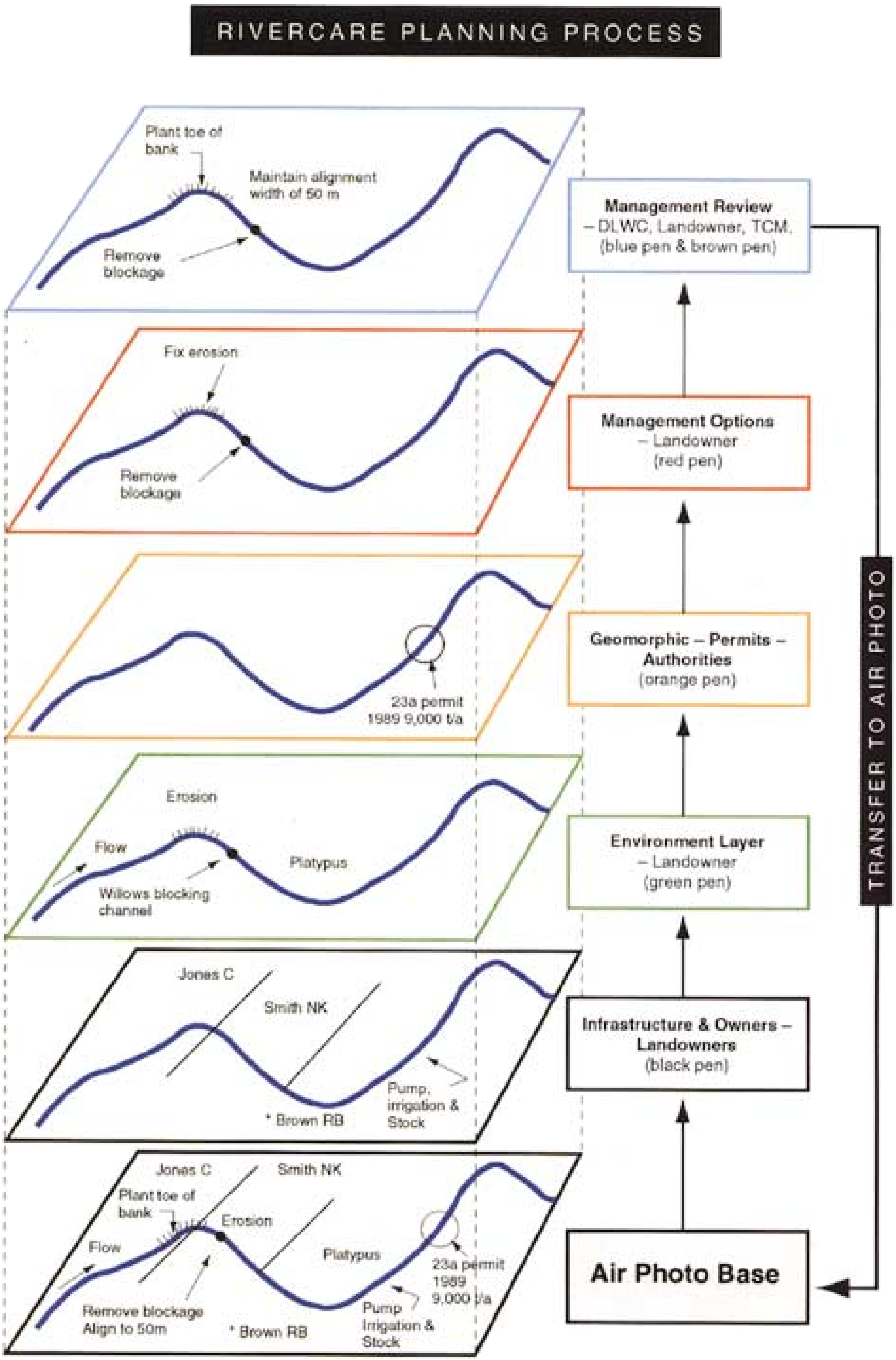
A brown pen is provided for you to mark down supplementary information that you consider to be important to the overall management of the catchment.

7) FINAL ACCEPTANCE AND APPROVAL

The essential information is transferred onto the Aerial Photographs and laminated after final assessment and endorsement by the Rivercare Group and Catchment Management Committee.

Permits for works are arranged and then presented to the group with the plan.

WORKS CAN NOW COMMENCE.


RIVERCARE PLANNING PROCESS
Plant toe of bank
Maintain alignment width of 50 m
Remove blockage
Management Review – DLWC, Landowner, TCM. (blue pen & brown pen)
Fix erosion
Remove blockage
Management Options – Landowner (red pen)
23a permit 1989 9,000 t/a
Geomorphic – Permits – Authorities (orange pen)
Erosion
Flow
Platypus
Willows blocking channel
Environment Layer – Landowner (green pen)
Jones C
Smith NK
Pump, irrigation & Stock
* Brown RB
Infrastructure & Owners – Landowners (black pen)
Jones C
Smith NK
Plant toe of bank
Erosion
Flow
Platypus
23a permit 1989 9,000 t/a
Remove blockage Align to 50m
* Brown RB
Pump Irrigation & Stock
Air Photo Base
TRANSFER TO AIR PHOTO

C) BOUNDARY AND PROPERTY OWNER, INFRASTRUCTURE

This layer shows the boundaries of the various properties in the LANDCARE GROUP as well as the owners name/company.

There are two methods that are used:

METHOD 1 – Where Owner/Property Details have been shown, please check that they are correct. If not, then please make the appropriate amendments.

METHOD 2 – Details have not been placed on this layer due to the lack of information. Owner/Property Details are to be placed on the layer.

Please indicate in black pen, the following information for each holding:-

1) Is this particular holding represented in the LANDCARE GROUP?

Please mark against name thus "*" if a member, e.g.

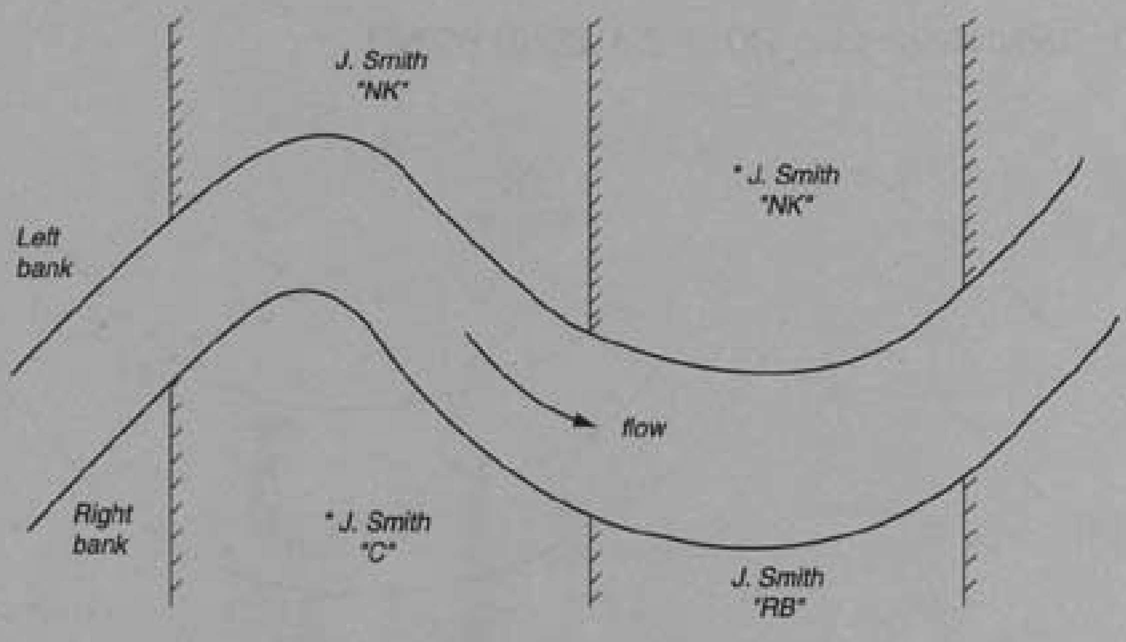
*	J. Smith	(is a member)
	J. Smith	(is not a member)

Please mark Landcare/Rivercare Group boundaries.

2) Indicate whether the property boundary is to the centre thread of the river "C", to the river bank "RB", or not known "NK"

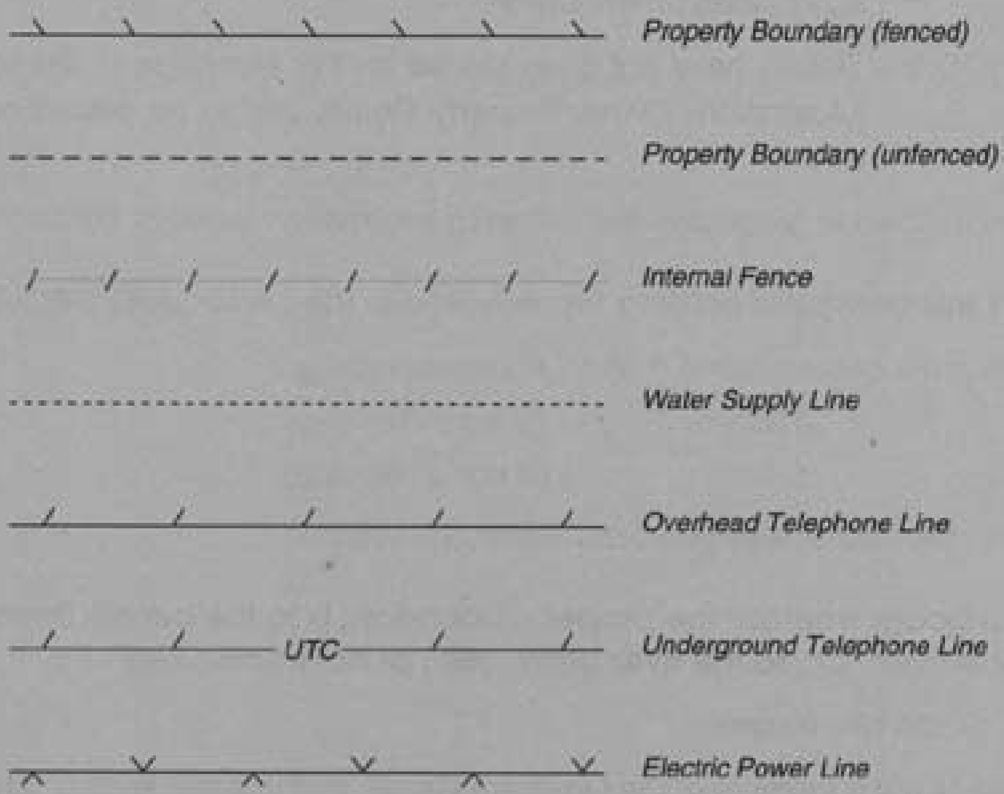
e.g. J. Smith NK, means:-

J. Smith is not a member of the Landcare Group, and it is "not known" whether his property boundary is the centre thread of the river or at the river bank.

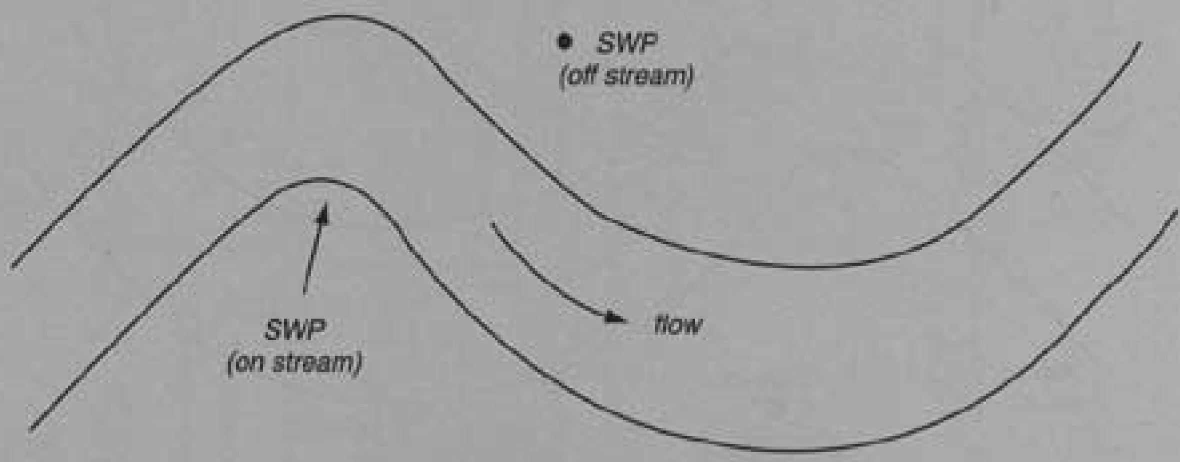


3) **Indicate by way of sketching on the layer any IMPORTANT FENCE needed in the management of the river area of the property, for example a boundary fence with a neighbour. Also indicate water supply pipe lines, power and telephone lines.**

Symbols are:

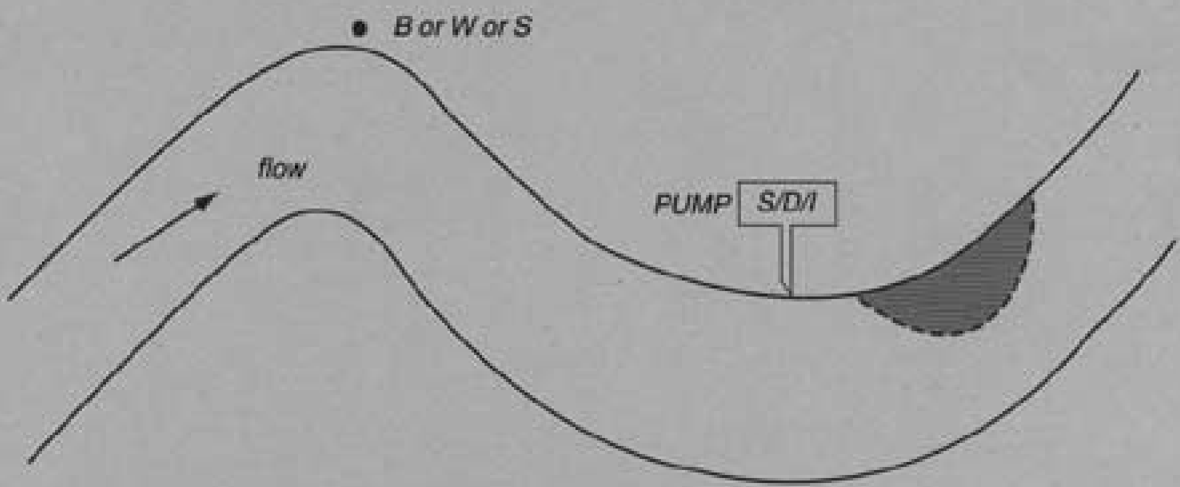


4) **Indicate existing <u>STOCK WATERING POINTS</u>**



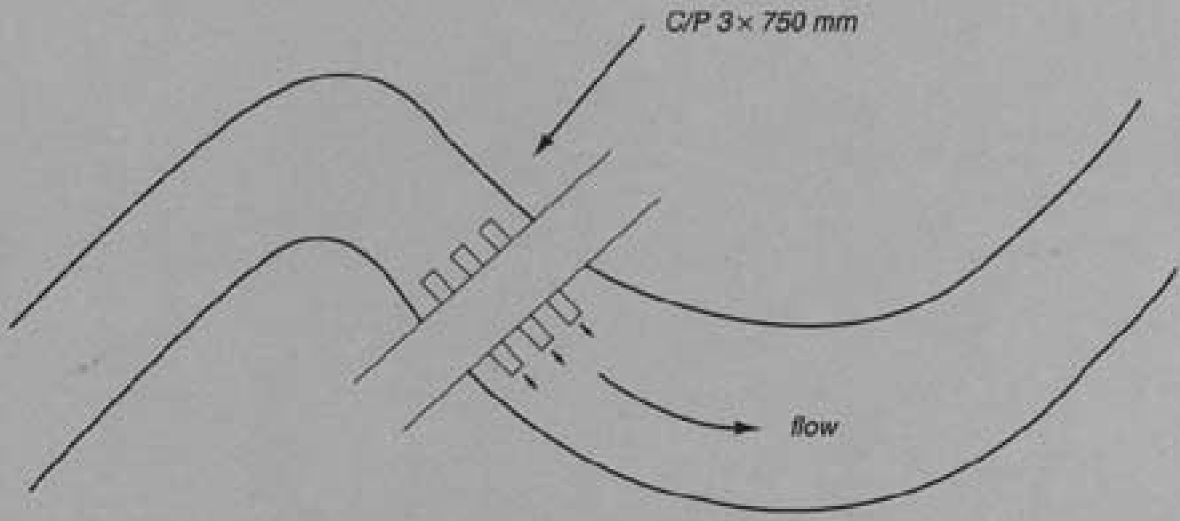
5) **Indicate river pump locations and show whether they are for stock, domestic, or irrigation, or a combination. Also show any bore, well/windmill, spring or seepage close to the river.**

e.g. PUMP/S/D/I is PUMP/Stock/Domestic/Irrigation or B/D is a bore with a domestic pump.



6) **Indicate essential RIVER CROSSINGS that need to be retained in the final management proposal, and give detail of type**

R/C	River Crossing
C/P	Concrete Pipe/s
C/C	Concrete Causeway
Bridge	Bridge (Wooden, Concrete etc. give dimensions)



D) ENVIRONMENTAL LAYER

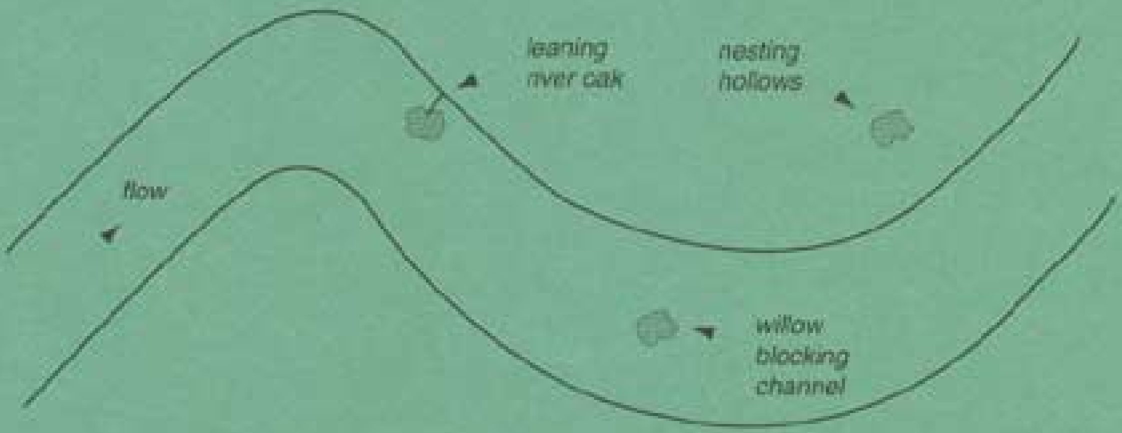
The purpose of this layer is to identify the various environmental factors which need to be taken into account as part of the final management plan. Any work carried out should not have any adverse effect on the stream stability or the environment as a whole. Please mark with green pen provided.

1. VEGETATION

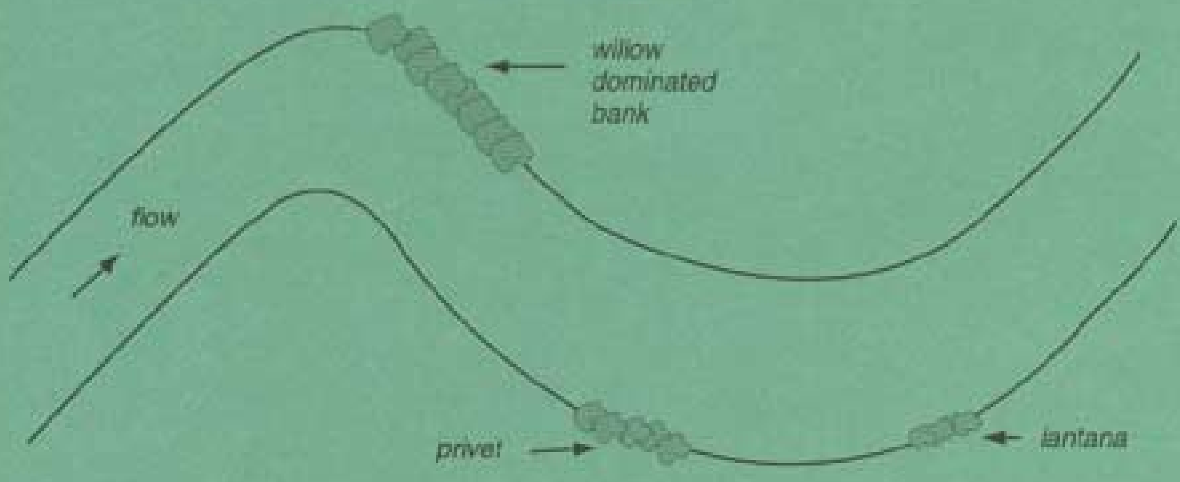
(a) Important trees — try and specify why.

(i) Habitat trees — **large old native trees provide nesting hollows for birds and animals.**

(ii) Problem trees — **large trees, such as leaning River Oaks or Willows, causing or potentially causing bank erosion.**



(b) Exotic vegetation —banks dominated by exotic vegetation (privet, lantana, willows, camphor laurel) at the expense of native vegetation diversity are undesirable for the long term.



If possible specify weed infestation. See list in Appendix.

(c) Aged vegetation

Indicate specific trees or sections of the river where vegetation is aged and loosing its bank binding properties e.g. no understorey vegetation or no recolonisation.

(d) Vegetation change

Please write a short note showing the nature of changes in riparian vegetation cover.

Provide photos or other records to illustrate this change for copying.

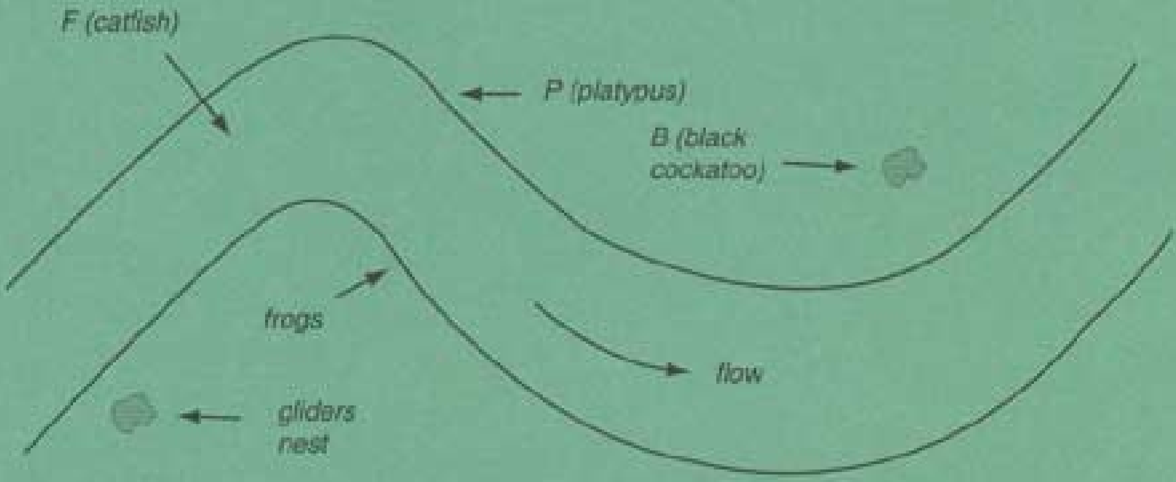
In this we are looking at the dynamics of that change.

e.g.
- i) pre 1880 flats covered by rain forest species.
- ii) 1880–1910 timber cleared for extensive agriculture/ grazing.
- iii) 1920–1940 willows planted to overcome bank eorsion problems.
- iv) 1950–1955 ageing willows destroyed by floods particularly 1950.
- v) 1960–present diebacks of riparian vegetation — invasion of channel by tea tree or river oak.

2. FAUNA (BIRDS, MAMMALS, FISH, REPTILES AND AMPHIBIANS)

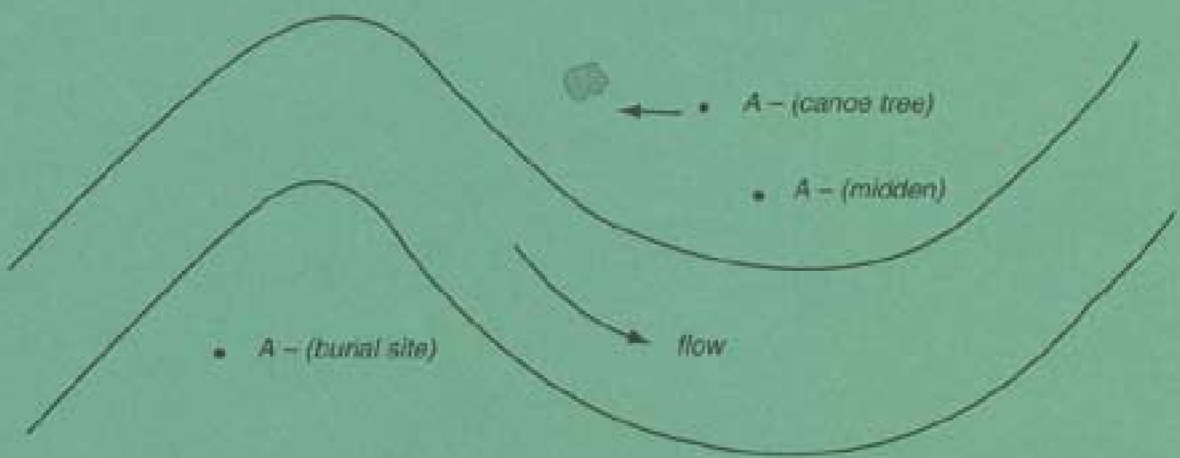
If possible, specify the type of bird, animal or fish.

(a) Presence of fish (F)
(b) Presence of platypus (P)
(c) Presence of birds (B)
(d) Presence of other fauna (e.g. gliders, frogs)



3. ABORIGINAL SITES

If possible, specify the type of site, e.g. canoe tree, midden, burial site, stone tools.

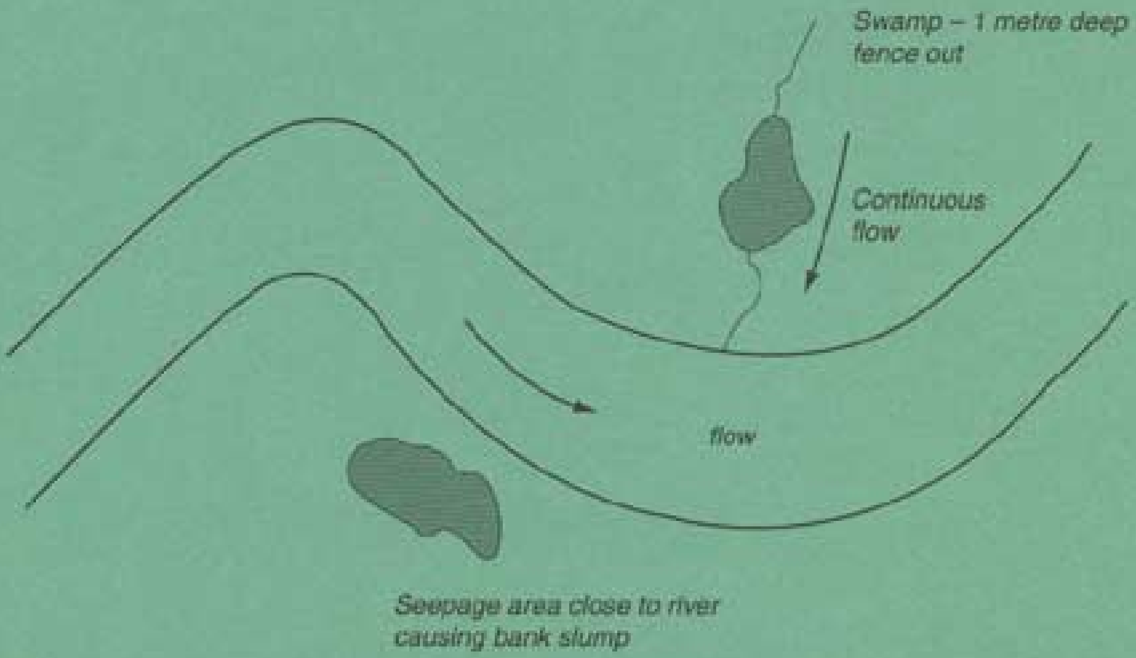


4. OTHER FEATURES

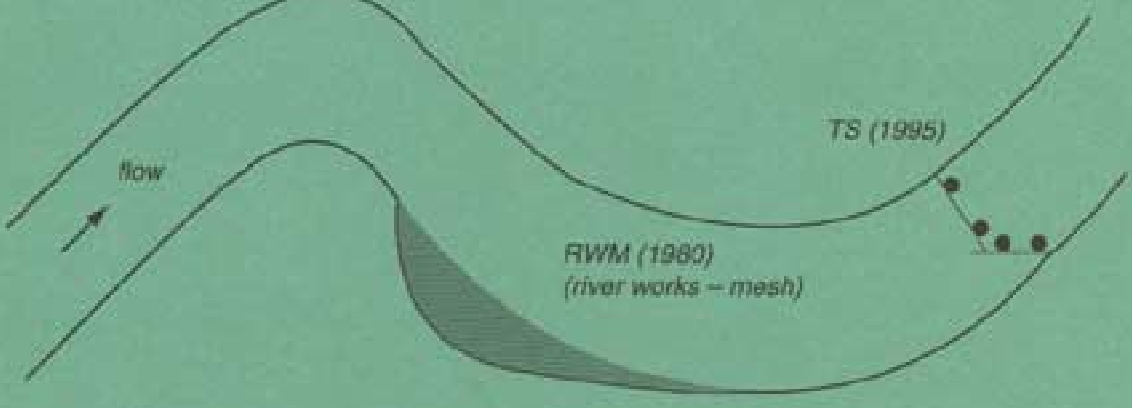
Caves close to the river, areas of diverse habitat are of interest, e.g. remnant rainforest areas adjacent to the river.

5. STREAM AND FLOODPLAIN FEATURES

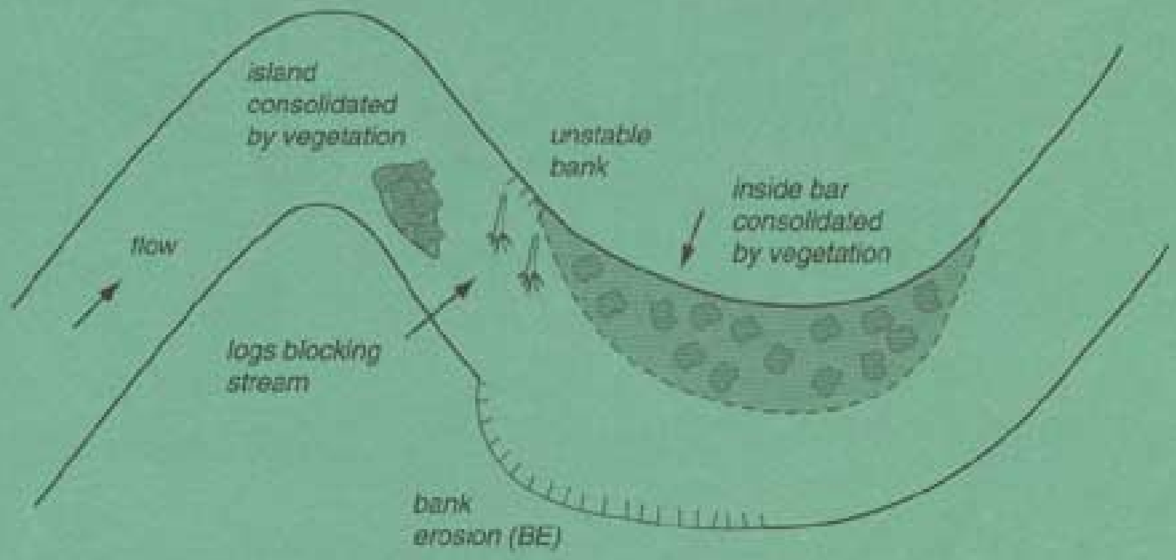
(a) <u>Important off-river valley or wetland</u> — mark out these areas thus:-



(b) <u>Existing river works</u> specify type, i.e. "M" for Mesh, "R" for Rock, "G" for Gabions or "P" for Plant, "TS" for timber sills, "RS" for rock sills, etc.



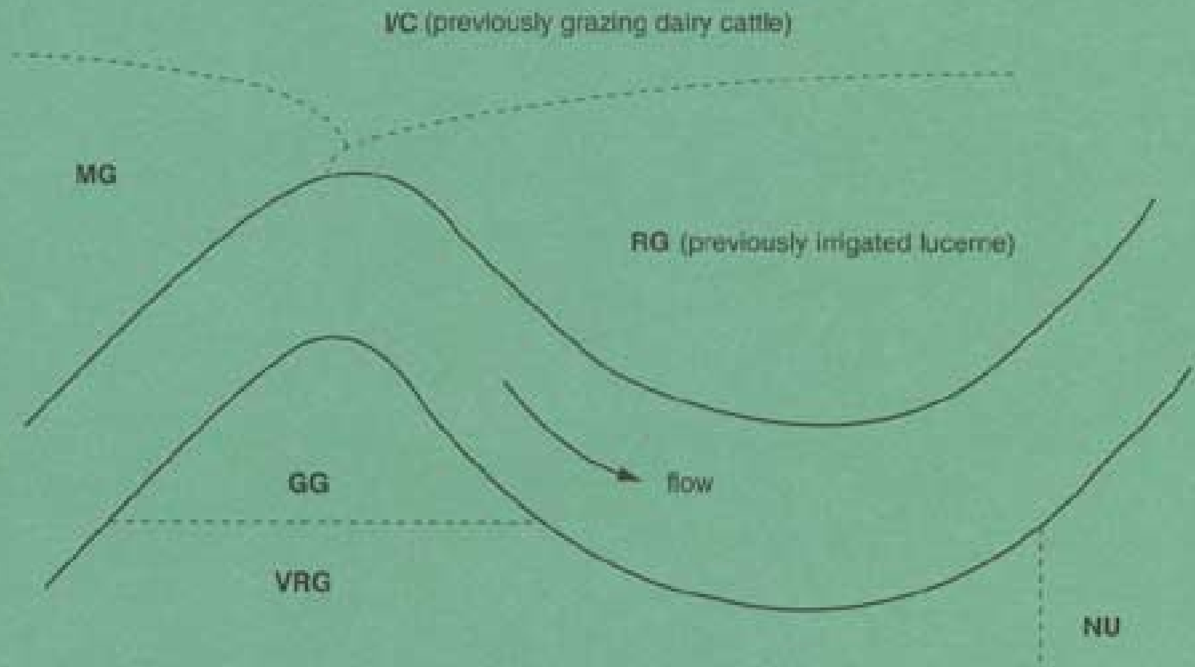
(c) Bank erosion and instream blockages caused by vegetation



(d) Land use types

Please indicate Land Use types adjacent to the river channel as below:

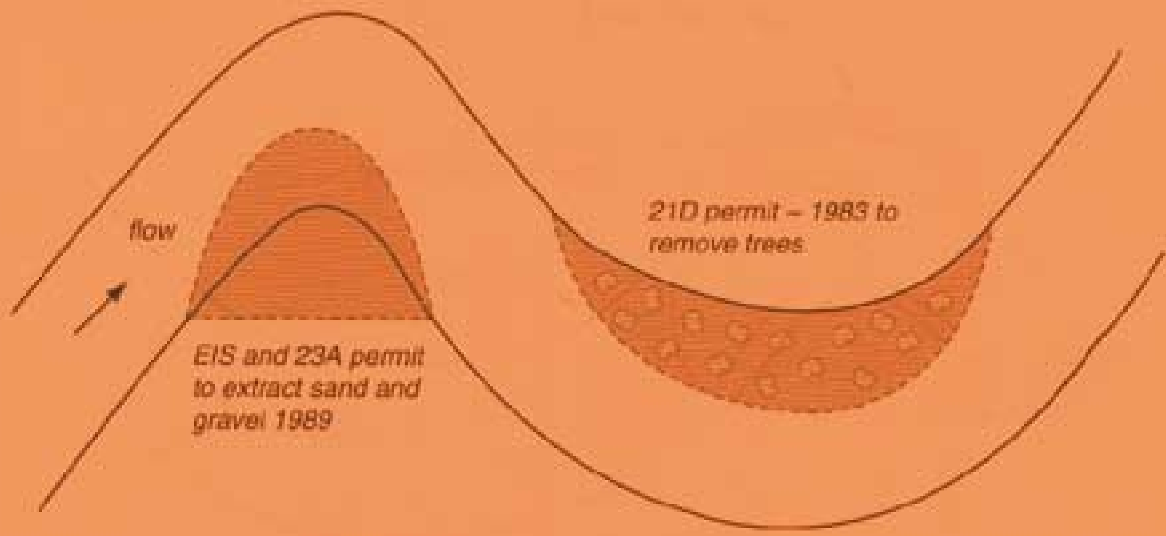
i)	Very Rough Grazing	VR
ii)	Rough Grazing	RG
iii)	Moderate Grazing	MG
iv)	Good Grazing	GG
v)	Irrigated/Irrigable or cropping	I/C
vi)	Not used	NU



If land use has changed in the last 20 years please indicate previous land use as above.

E) GEOMORPHIC FEATURES and PERMITS/AUTHORITIES granted

(a) WITH THE ORANGE PEN PROVIDED IDENTIFY ANY AREA THAT IS OR HAS BEEN THE SUBJECT OF AN ENVIRONMENTAL IMPACT STATEMENT OR PERMIT APPLICATION UNDER PART 3A (23A PRIOR TO APRIL 1992) OF THE RIVERS AND FORESHORES IMPROVEMENT ACT, OR SECTION 21D OF THE SOIL CONSERVATION ACT, thus:-



Give history of extraction sites thus:-

Extracted 3 times between 1989 and 1993 — approx 20,000 tonnes removed (total)

(b) <u>Instream features</u> — that have changed over time.

i) Where pools have been lost — indicate details and location e.g.

Buller's hole — length 300 m up to 50 m wide — "bottomless' habitat for platypus, mullet, perch, eels, herring and catfish. This hole existed pre 1949/1950, now a gravel bed.

ii) Is the river aggrading (bed coming up) — show over what length and by how much — what are the signs — how long has this taken?

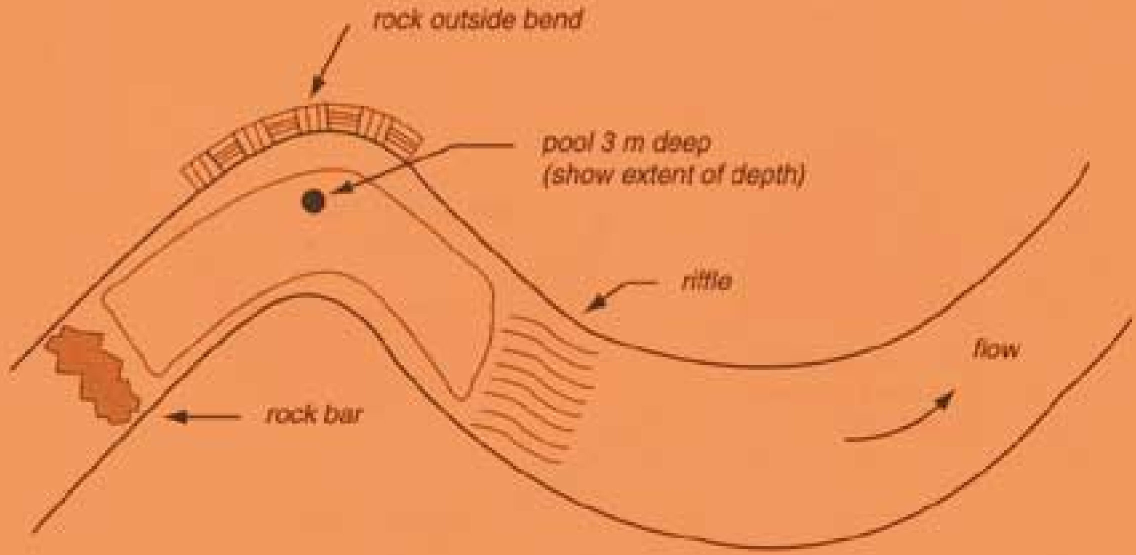
iii) Is the river degrading (bed dropping) — show over what length and by how much — what are the signs — how long has this taken?

iv) If you consider there is a sediment slug in the river — designate extent — when did you first notice it?

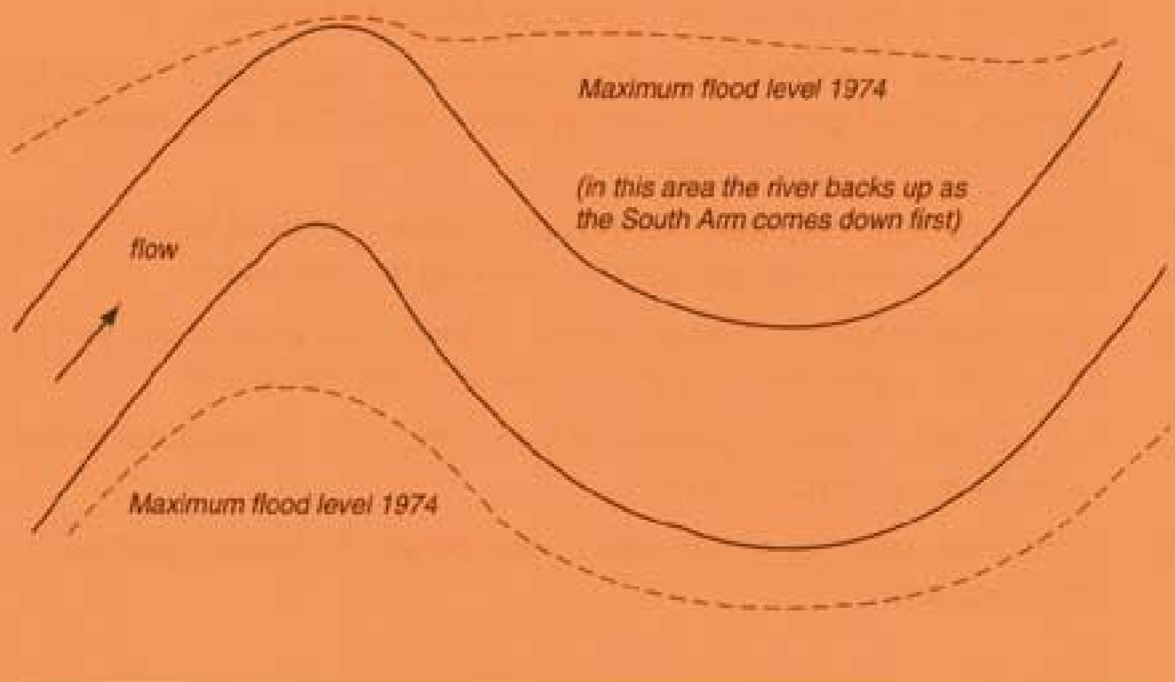
v) Is the river widening or narrowing? give details if possible, particularly times, locations, etc.

(c) <u>Instream features</u> — at the present time.

i) Rock bars or logs important to control the level of the stream bed.
ii) Rock banks or logs which control lateral migration of the channel.
iii) Important gravel bars and riffles which control pools.
iv) Detail of existing pools.

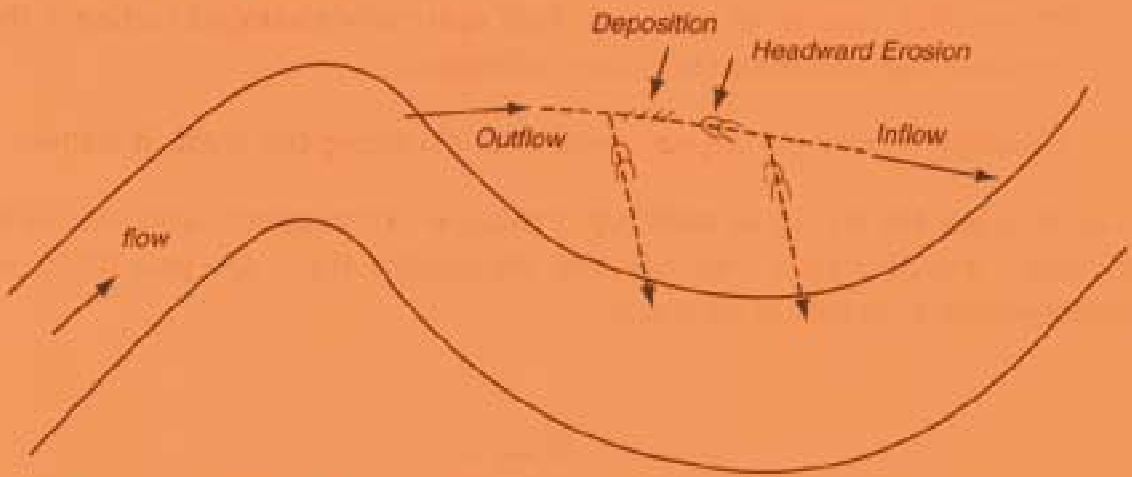


(d) <u>Highest known flood level</u> — make a comment about different types of flood or sequence of flooding.



(e) Floodplain features — that have changed over time — also floodplain composition

i) Major outflow and inflow channels — headward erosion — has the river been artificially or deliberately straightened? — show old course and date



ii) Composition of the river flats — show nature and extent e.g.

"Quartz underlying silts deposited over — silt 4 metres deep — quartz 2 metres over bed rock."

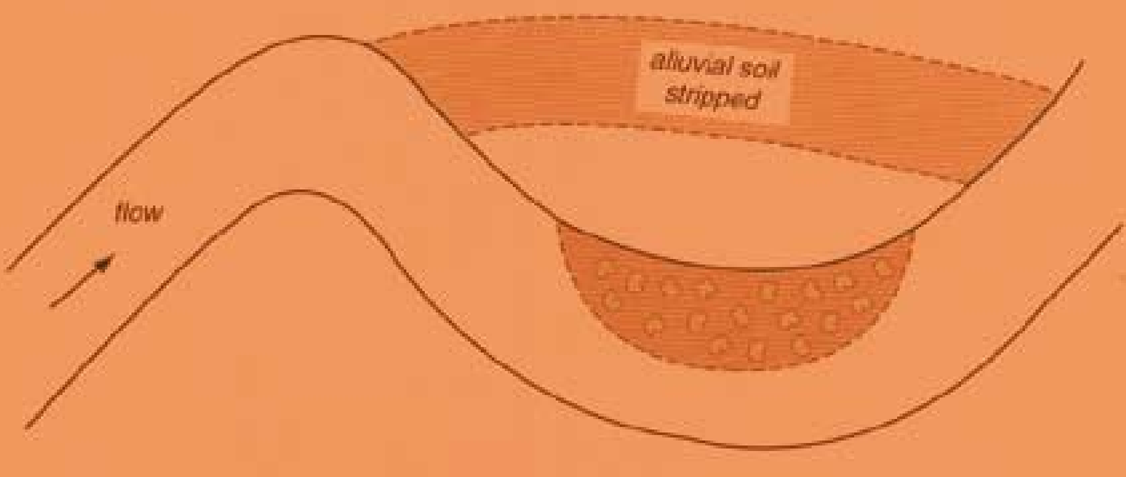
or

"Top flat —silt over clay base" — give profile if known.

iii) Benches on the floodplain — the history, composition and timing of these, if known.

Please mark extent and write detail in note form.

iv) Floodplain stripping or aggradation.



v) Other important details to note

- If there has been excessive floodplain stripping or soil deposition (e.g. sand) on the river flats please indicate.
- Indicate any buried fences/fencelines.
- Where the course of the river has naturally changed indicate the old channel and when changes occurred.
- Location of any surveyed cross-section along the river, if known.

In all this we are trying to build up a picture of the processes that have occurred through your memory and documentation. Do you have old photographs that would be useful?

F) LANDOWNER'S MANAGEMENT OPTIONS AND PREFERENCES FOR THE NEXT FIVE YEARS.

This layer allows you to list your preferred options for the management of your stretch of the river. It provides a means of discussion with Department of Land and Water personnel and your neighbours about your best management options, taking into account the condition of the river, constraints imposed by land useage, environmental considerations and similar issues.

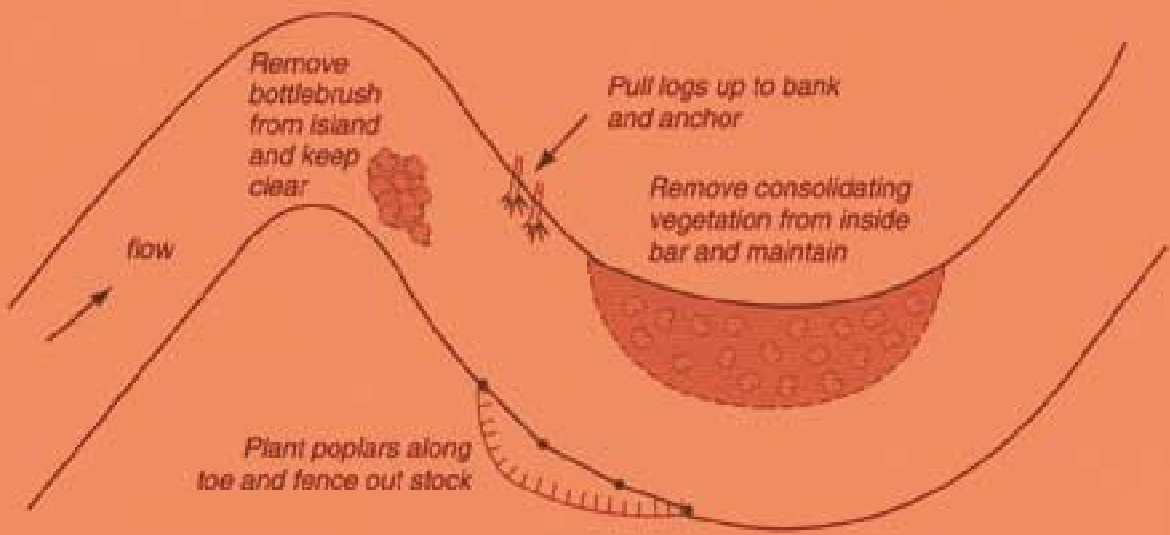
Perhaps the best way of starting this layer is to look at the features such as bank erosion, instream blockages, floodplain stripping, etc., marked in the environmental layer and start to devise simple solutions to these problems, within the resources available to manage them. See foldout sheet on "Management Processes and Simple Management Options"*.

Draw on the layer with the red pen provided your ideas, and signify next to those ideas what you feel is necessary to effectively manage the river and adjacent area, e.g. remove oak trees from the centre of the river, or plant bank to stop erosion, etc. Look at what might be achievable in a five-year time frame.

It is also necessary for you to know the 'dominant width' or optimum channel width of the river through your property. This is set out on the following pages titled "Channel Dimensions".

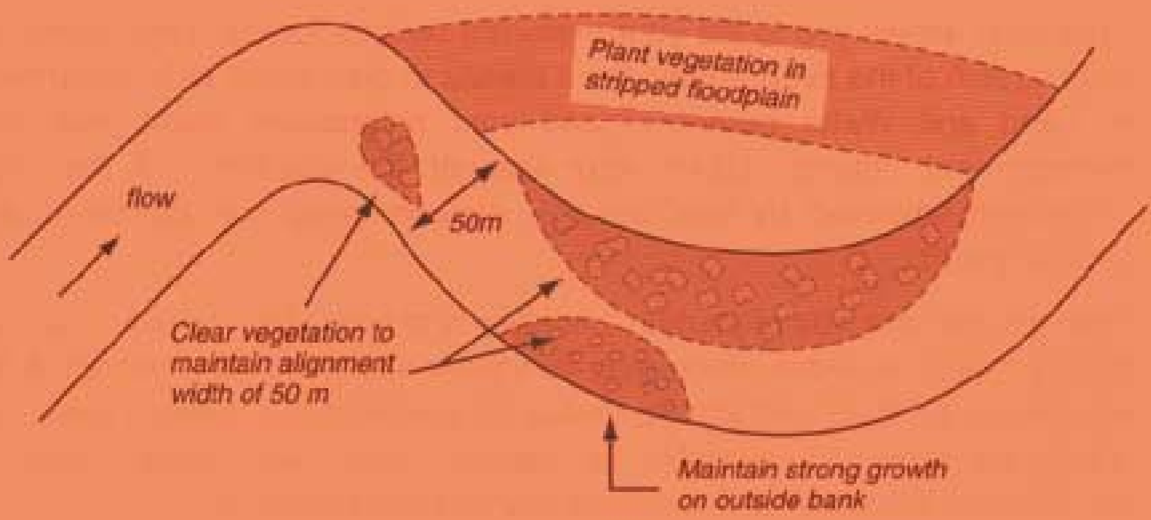
Examples of how to mark in Landowner's management options

Example a)



* This is given in Appendix 2 of this LWRRDC Occasional Paper.

Example b)

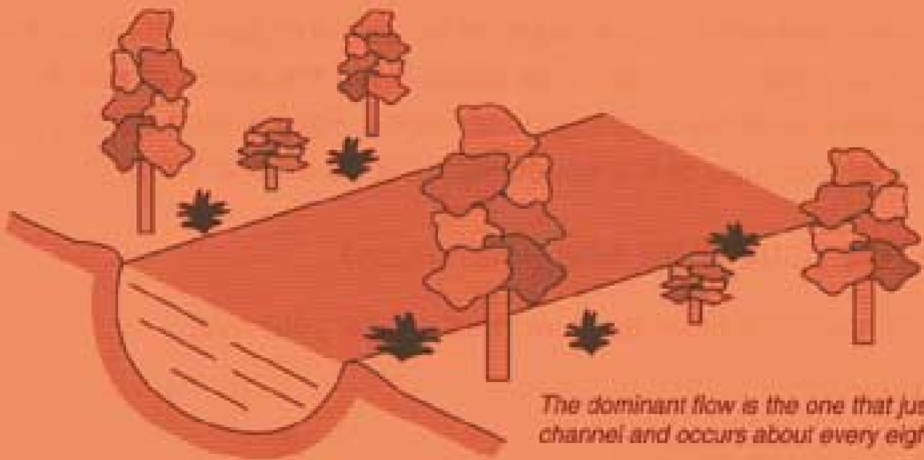


When you have completed all the steps return the plans to the Department of Land and Water Conservation for preliminary assessment.

CHANNEL DIMENSIONS (CRITICAL*)

How do I know how big my river channel should be?

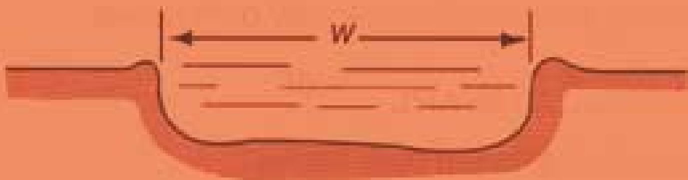
The size of the river channel has been found to be dependent on the 1 in 18 month river flow. This flow is the one that fills the channel without overflowing its banks.



The dominant flow is the one that just fills the river channel and occurs about every eighteen months.

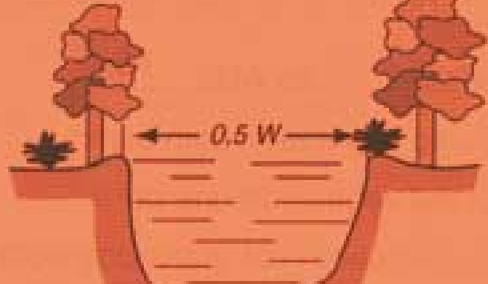
How does vegetation impact on the channel size?

No vegetation



Good vegetation

Good vegetation will contract the channel width by about 50% and also deepen it. If vegetation is destroyed the channel will widen and become shallow



* Critical channel dimensions — are in areas such as rapids, diversion to outflow channels and channels downstream of these locations, bends in rivers, reaches demonstrating channel flow characteristics.

CHANNEL DIMENSIONS

How do I work out the size of my river channel?

There are mathematical formulas which can be used. Your Department of Land and Water Conservation adviser can show the details of these.

A simpler way is to look at a stable section of a river and derive your section from this.

In looking at on-ground widths, one needs to be aware of any outflow or inflow points of minor channels or streams, as these have the effect of altering the "bankfull" flow and hence the channel dimensions. Rapids also decrease the width of a channel because of the speed water flows across them.

DIMENSIONS FOR YOUR RIVER ARE! (*Preliminary*)

The following dimensions have been worked out for your river.

Missabatti Creek

ARL 0.0 **to ARL** 8.0

Good vegetation both banks	19–23 metres
Good vegetation one bank	26–30 metres
No vegetation or grass only both banks	34–38 metres

ARL 8.0 **to ARL** 9.85

Good vegetation both banks	15–19 metres
Good vegetation one bank	22.5–26 metres
No vegetation or grass only both banks	30–34 metres

ARL 9.85 **to ARL** 13.0

Good vegetation both banks	13–15 metres
Good vegetation one bank	18–22 metres
No vegetation or grass only both banks	25–30 metres

ARL 13.0 **to ARL** 17.5

Good vegetation both banks	10–13 metres
Good vegetation one bank	14–18 metres
No vegetation or grass only both banks	19–23 metres

ARL *17.5* to ARL *For discussion*

Good vegetation both banks 5sq km	*6.0* metres
Good vegetation one bank	*8.5* metres
No vegetation or grass only both banks	*11.0* metres

Nambucca River (*Preliminary*)

ARL *28.5* to ARL *39.0*

Good vegetation both banks	*27.5–32.5* metres
Good vegetation one bank	*37.5–42.5* metres
No vegetation or grass only both banks	*50–55* metres

Junction Missabotti Creek (39.0 km)

ARL *39.0* to ARL *55.0*

Good vegetation both banks	*21–25* metres
Good vegetation one bank	*31–35* metres
No vegetation or grass only both banks	*40–45* metres

ARL *55.0* to ARL *70.0*

Good vegetation both banks	*20–24* metres
Good vegetation one bank	*29–33* metres
No vegetation or grass only both banks	*37.5–42.5* metres

ARL *70.0* to ARL *80.0*

Good vegetation both banks	*15–19* metres
Good vegetation one bank	*22.5–26.5* metres
No vegetation or grass only both banks	*30–35* metres

ARL .... to ARL ....

Good vegetation both banks	..........metres
Good vegetation one bank	..........metres
No vegetation or grass only both banks	..........metres

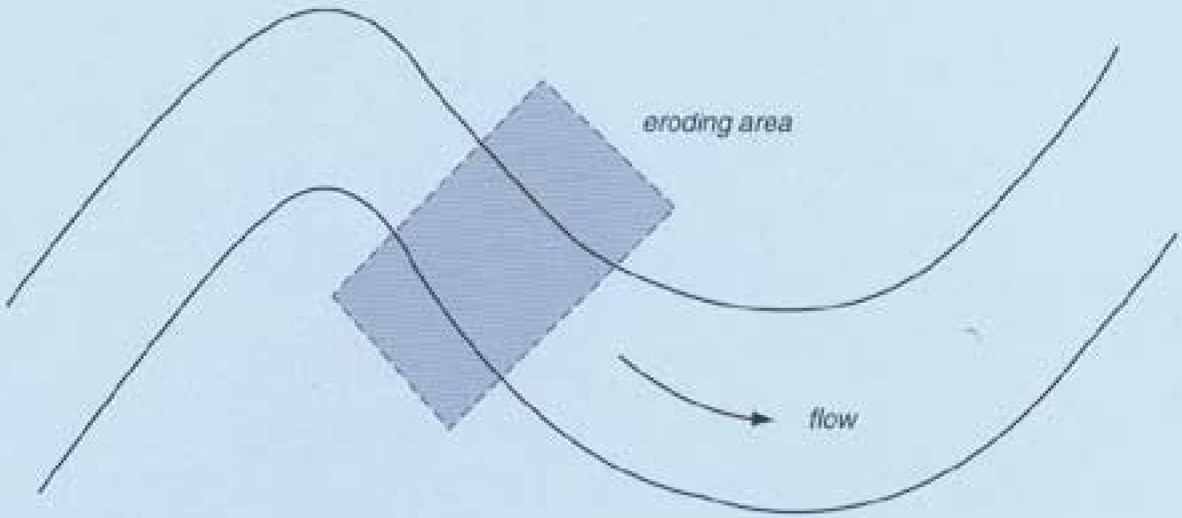
G_i) FINAL MANAGEMENT PROPOSAL

In this layer, your DLWC Advisors go along the river and discuss the various options, attributes, environmental factors, etc., and put together with you a workable management plan to be implemented over (say) the next five years.

Final management ideas are developed and areas of competing interests are examined and resolved.

This layer is completed in the **blue pen** provided.

Eroding or degraded areas or areas of special interest — mark out areas for discussions with your DLWC advisor as shown using the **blue pen** provided.



G_{ii}) TCM DETAIL

Please note down, using the **brown pen** provided, any supplementary information or comments that you consider to be important to the overall management of the catchment.

– – – – – ❁ – – – – –

H) FINAL ACCEPTANCE AND APPROVAL

The management options accepted by the **Rivercare Group** as a whole will be transferred to the aerial enlargement/s.

Errors located on the plan will be corrected.

Approval of the **DRAFT MANAGEMENT PLAN** will be sought as required from Local Council and State Government Bodies (e.g. NSW Fisheries, National Parks and Wildlife Service).

Any variations sought will be discussed with the **Rivercare Group** before the plan is varied and presented to the Catchment Committee for final endorsement.

On endorsement the **DRAFT MANAGEMENT PLAN** becomes the **MANAGEMENT PLAN**. The photographic plan is now **LAMINATED**.

Permits associated with any works proposed will be obtained and provided to the Group, with the **RIVERCARE MANAGEMENT PLAN**.

WORKS CAN NOW COMMENCE.

APPENDIX "A"

The following plants are classified as Noxious as of 10th June, 1993 for Nambucca Council Area. 21d permits are not required prior to their destruction.

NOXIOUS PLANTS

Botanical Name	Common Name	Category
Acacia karoo	Karoo thorn	W1
◆ *Ageratina adenophora*	◆ Crofton Weed	W3
◆ *Ageratina nparia*	◆ Mistflower	W3
Alternanthera philoxeroides	Alligator Weed	W1
Baccharis hahmifoiia	Groundsel Bush	W2
Cannabis saliva	Indian Hemp	W1
Cenchrus Incerlus	Spiny Burr Grass	W2
Cenchrus longispinus	Spiny Burr Grass	W2
Cestrum parqui	Green Cestrum	W2
Chromolaena odorata	Siam Weed	W1
◆ *Cortaderia selloana*	◆ Pampas Grass	W2
◆ *Eichhornia crassipes*	◆ Water Hyacinth	W2
Equisetum arvense	Horsetail	W1
Eythrnxyhtm coca	Coca Leaf	W1
Gymnocoronis spilanthoides	Senegal Tea Plant	W1
Kochia scoparia	Kochia	W1
Lagarostphon major	Largarosiphon	W1
◆ *Lantana camara*	◆ Lantana (Red flowered)	W3
Papaver somnifterum	Opium Poppy	W2
Parthenium hysterophorus	Parthenium Weed	W1
Pistia stratiotes	Water Lettuce	W1
Rubus fruticosus (aggl spp.	Blackberry	W2
◆ *Salvinia molesta*	◆ Salvinia	W2
Seneclo Madagascariensis	Fire Weed	W3
Sorghum halepense	Johnson Grass	W2
Sorghum x almum	Columbus Grass	W2
Sporobolus indicus var. *major*	Giant Parramatta Grass	W3
Sporoboluspyramidalis	Giant Rat's Trail Grass	W2
Toxicodendron succedaneum	Rhus Tree	W2
Xanthium spinosum	Bathurst Burr	W2
◆ *Xanthium Occidentale*	◆ Noogoora Burr	W2
Xanthium spp.	Californian & Cockle Burrs	W2

◆ are the weeds commonly found near or in the river systems of the Nambucca.

W1 Notifiable W2 Need to fully and continually suppress and destroy W3 Must prevent spread and reduce numbers

For more information contact Noxious Weeds Inspector Mr. John Ennis – phone 015-457-231

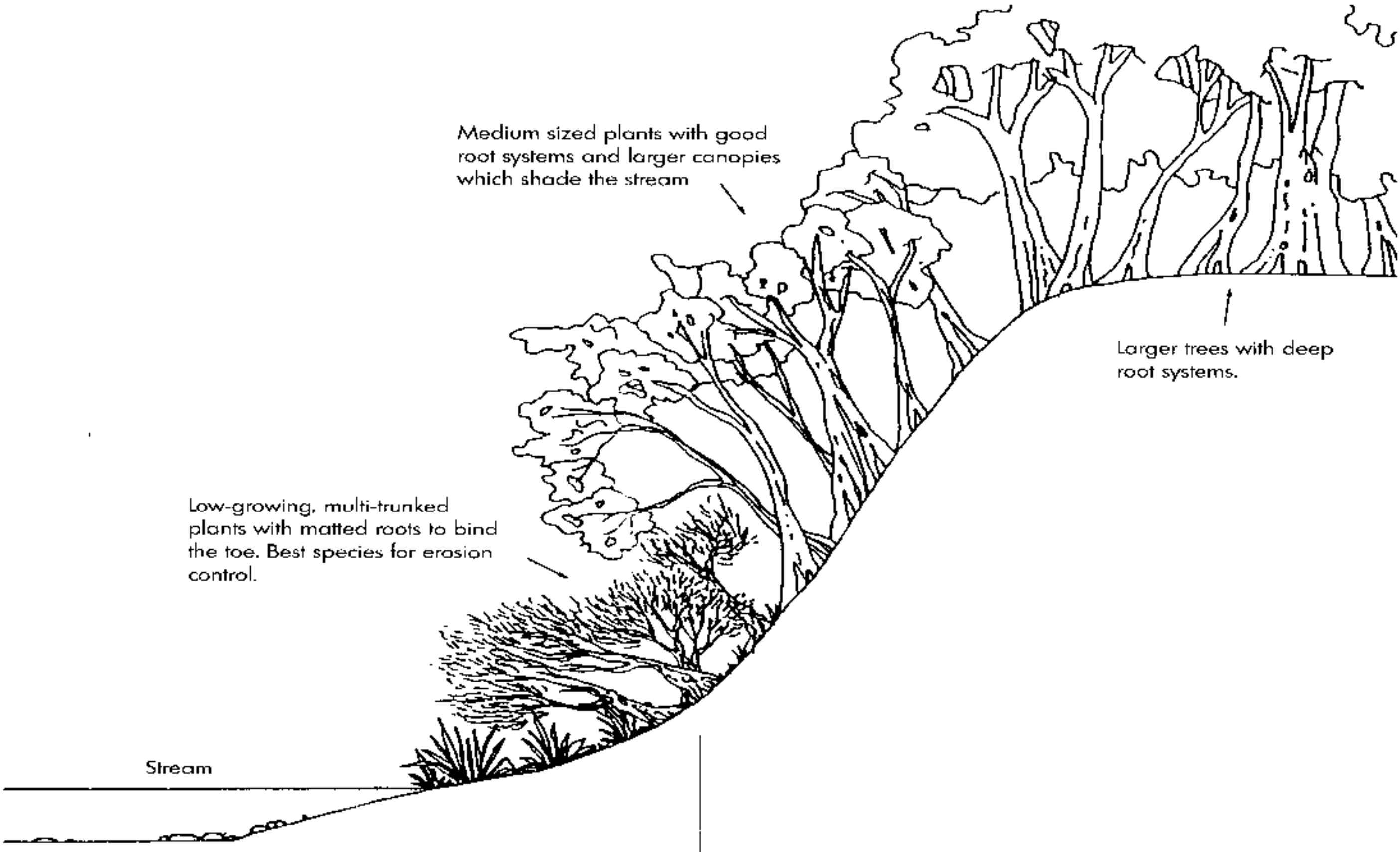
APPENDIX "B"

Trees for River Planting

Species by Stream and Location

Prepared by Allan Raine
Senior Catchment Management Officer
Department of Land and Water Conservation
GRAFTON – Phone (066) 42 7799

SPECIES BY STREAM AND LOCATION



STREAM	***TOE***	***MIDDLE***	***UPPER***
ALL (including Warrell Creek)	*Leptospermum brachyandrum* *Lomandra hystrix* *Tristaniopsis laurina*	*Acmena smithii* *Alectryon subcinereus* *Aphananthe philippinensis* *Archontophoenix cunninghamiana* *Austrosteenisia* sp. *Backhousia myrtifolia* *Callicoma serratifolia* *Capparis arborea* *Ceratopetalum apetalum* *Cordyline stricta* *Cryptocarya glaucescens* *Cryptocarya microneura* *Cryptocarya obovata* *Daphnandra micrantha* *Endiandra meuelleri* *Ficus coronata* *Glochidion ferdinandi* *Gmelina leichhardtii* *Guioa semiglauca* *Hymenosporum flavum* *Jagera pseudorhus* *Mallotus philippensis* *Melicope micrococca* *Milletia megasperma* *Neolitsea dealbata* *Pittosporum undulatum* *Planchonella australis* *Rhodomyrtus psisioides* *Syzygium australe* *Tristaniopsis laurina*	*Acacia irrorata* *Acacia maidenii* *Acacia melanoxylon* *Alphitonia excelsa* *Aphananthe philippinensis* *Cryptocarya obovata* *Diploglottis australis* *Ehretia acuminata* *Elaeocarpus obovatus* *Eucalyptus grandis* *Flindersia schottiana* *Grevillea robusta* *Jagera pseudorhus* *Lophostemon confertus* *Mallotus philippensis* *Melia azedarach*
TAYLORS ARM	*Callistemon viminalis*	*Bosistoa floydii*	
BUCKRA BENDINNI		*Backhousia anisata*	
ALL (except Warrell Creek)		*Amorphospermum whitei* *Caldcluvia paniculosa* *Cuttsia viburnea* *Sloanea australis* *Sloanea woollsii* *Waterhousia floribunda*	*Agyrodendron actinophyllum* *Dysoxylum fraserianum* *Ficus* spp. *Elaeocarpus grand* *Toona australis*

DESCRIPTION OF RIVERBANK PLANTS NATIVE TO THE NAMBUCCA CATCHMENT

HEIGHT – refers to maximum height in an OPEN situation. Some species may grow taller in protected areas.
FROST RESISTANT – referes to the frost resistance of newly planted seedling. 1 = definite resistance; 2 = some resistance (light frosts); 3 = none or very little frost resistance.
PROTECTION WHEN YOUNG – 1 = requires no protection; 2 = may require some watering and protection on exposed sites; 3 = plant requires watering and protective cover of taller plants.

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Acacia irrorata, green wattle	Small, fern-leaved wattle with pale yellow flowers. Very hardy.	6	+	3	1	Good canopy species for protecting rainforest plantings	Attracts insect-eating birds
Acacia maidenii, Maidens wattle	Medium-sized, bushy wattle with pale yellow flowers. Very hardy.	8	+	3	1	Good canopy species for protecting rainforest plantings	Attracts insect-eating birds
Acacia melanoxylon, blackwood	Medium-sized bushy wattle with pale yellow flowers. Very hardy.	10	+	3	1	Useful buffer tree for planting on the outer edges of stormiest plantings	Seeds attract birds
Acmena smithii, lilly pilly	Medium-sized rainforest tree with a dense habit and pink to purple fruit	10		2	2	Some forms make useful windbreaks if given sufficient water	Fruit attracts birds
Alectryon subcinereus, wild quince	Medium-sized rainforest tree with a dense crown, often bushy to the ground	8		2	2	Useful rainforest regeneration species, timber suitable for small turnery	Fruit attracts birds
Alphitonia excelsa, red ash	A medium-sized tree with some drought tolerance. Leaves have a white underside. Hardy	12	+	1	1	Timber suitable for building or cabinet work. Stock forage tree. Good rainforest regeneration tree	Seeds attract birds
Amorphospermum whitei, rusty plum	Medium-sized rainforest tree with large fruits that are rusty-hairy beneath. Large black fruits in spring. Rare	10		1	3	Feature tree for rainforest plantings	
Aphananthe philippinensis, rough-leaved elm	Small to medium-sized rainforest tree with stiff, elm-like leaves and dense, dark crown. Hardy	12		2	2	Timber hard and suitable for handles. Edible fruit. Useful rainforest regeneration species	Fruit attracts birds
Archontophoenix cunninghamiana, bangalow palm	Single-stemmed, feather-leaved palm. Needs plenty of water. Best for upper catchment	8	+	1	3	Landscaping	Fruit attracts birds
Argyrodendron actinophyllum, black booyong	Tall rainforest tree with dense, dark canopy and fan-shaped leaves. Needs plenty of water	18		1	3	Attractive feature tree. Useful timber tree for indoor work	Seeds eaten by scrub turkeys
Austrosteenisia spp.	Large vine species with red flowers. Blood red sap produced from freshly cut trunk	Vine		1	2	Riparian vine species	
Backhousia anisata, ringwood	A tall, dense-crowned rainforest tree. The crushed leaves have a distinct aniseed smell	15		1	2	Leaves can be used for their aniseed odour. Timber durable	
Backhousia myrtifolia, grey myrtle	Slow-growing bushy rainforest tree with some drought tolerance. Usually found on steep rocky banks. Hardy	8		2	2	Screen plant. Wood hard and tough, and suitable for handles	Good host for orchids and ferns
Bosistoa floydii, five-leaved bonewood	Small to medium sized rainforest tree with dense, dark crown. Slow growing. Needs water to start. Rare	15		1	3	Ornamental tree	
Caldcluvia paniculosa, soft corkwood	Medium sized rainforest tree which produces small, showy cream flowers in November	15		1	3	Suitable for cabinet timber	Good host for orchids and ferns

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Callicoma serratifolia, callicoma	Shrub or small rainforest tree with distinct toothed leaves and white underside. Usually on shaded rocky banks. Needs water to esatblish	8		1	3	Useful understorey species in protected, shady areas	
Callistemon viminalis, weeping bottlebrush	Multi-stemmed tree with hard furrowed bank and red bottlebrush flowers. Very hardy	5	+	3	1	Excellent erosion control species. Used for direct seeding	Flowers attract honeyeaters
Casuarina cunninghamiana, river oak	Tall, pine-like species. Very common on the North Coast. Hardy. Needs management as may contribute to erosion	20		3	1	Fixes nitrogen. Good canopy cover species for rainforest regeneration. Direct seeding.	Larger, older trees used as roosting sites
Ceratopetalum apetalum, coachwood	Medium sized rainforest tree with attractive pale trunk with prominent rings	12		1	2	Cabinet timber species	
Cordyline stricta, slender pal-lilly	Slender shrub often forming clumps	2		3	3	Landscaping, understorey plant in shaded areas	Fruit attracts birds
Cryptocarya glaucescens, jackwood	A medium-sized, dense-crowned rainforest species producing wrinkled black fruit in autumn	10		3	2	Cabinet timber species	Fruit attracts birds
Cryptocaria microneura, murrogun	A medium-sized rainforest species producing shiny black fruit in summer/autumn	10		3	2	Reasonably hardy species for rainforest plantings	Fruit attracts birds
Cryptocarya obovata, pepperberry tree	Medium to tall densely-crowned rainforest tree with hairy new growth and dark leaves	18		3	3	Good shade tree	Fruit attracts birds
Cuttsia viburnea, cuttsia	Small, soft-leaved rainforest species producing showy white flowers in spring/summer. Usually on shaded, rocky banks. Dislikes drying out	6		1	3	Useful understorey species for shaded, rocky sites	
Cyathea spp., tree fern	Tall, single-trunked fern	4		1	3	Useful understorey species for protected, shaded areas	
Daphnandra micrantha, socketwood	Medium-sized, straight-stemmed rainforest tree with compact, dense canopy and horizontal branches	12		3	3	Sometimes used for ornamental rainforest plantings	
Diploglottis australis, native tamarind	Attractive tall rainforest tree with large leaves and rusty hairy new growth	15		3	3	Attractive tree for landscaping. Edible fruit	Fruit attracts birds
Dysoxylum fraserianum, rosewood	Medium to tall rainforest tree with shady spreading crown. Needs water to establish	18		3	3	Timber is rose scented and used for cabinet work	
Ehretia acuminata, koda	Medium-sized rainforest tree. Deciduous, with grey, fissured bark and masses of orange fruits in summer/autumn	10		2	2	Fruits are ornamental	Fruit attracts birds
Elaeocarpus grandis, blue quandong	Tall, buttressing rainforest tree with sparse canopy and large blue fruits in spring/summer	30	+	2	3	Valuable timber tree for interior work. Shade tree. Edible fruit	Fruit attracts birds
Elaeocarpus obovatus, hard quandong	Tall rainforest tree tolerant of wet soils. Hardy. Produces masses of small blue fruits	15		2	2	Useful timber tree for interior work. Shade tree	Fruit attracts birds
Endiandra muelleri, green-leaved rose walnut	Bushy tree with pink new growth and black fruits in Autumn	12		1	3	Landscaping	Fruit attracts birds.

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Eucalyptus grandis, flooded gum	Very tall eucalypt with smooth white bark. Mostly found at lower elevations	35	+	1	2	Hardwood timber. Good pollen tree	Koala food tree
Ficus coronata, Greek sandpiper fig	Small bushy tree with sandpapery leaves	6		2	2	Excellent riparian species with edible fruit	Fruit attracts birds
Ficus spp., other figs	Large trees with buttress roots and spreading canopy	20		1	3	Excellent shade tree. Edible fruit	
Flindersia schottiana, cudgerie	Tall tree with open canopy. Very hardy	20	+	2	2	Very fast growing tree which is ideal for rainforest regeneration. Useful timber for indoor work	
Glochidion ferdinandi, cheese tree	Tree has spreading canopy with attractive foliage. Fruit looks like small cheeses	8		2	2	Excellent riparian regeneration species and small shade tree	Fruit attracts birds
Gmelina leichhardtii, white beech	Medium sized rainforest tree with spreading canopy and large purple fruits in summer/autumn	15		1	3	Valuable timber species. Good shade tree	Fruit attracts birds
Grevillea robusta, silky oak	Tall, sparse canopied species with golden flowers. Drought tolerant. Very hardy	15	+	3	1	Excellent species for rainforest regeneration. Cabinet timber. Minor to medium value for bees	Flowers attract honeyeaters
Guioa semiglauca, guioa	Small rainforest tree. Leaves with silvery underside. Hardy	10		2	2	Attractive tree for landscaping. Useful for rainforest regeneration	Fruit attracts birds
Hymenosporum flavum, native frangipani	Small rainforest tree producing numerous yellow and white flowers in spring. Hardy	10	+	1	1	Useful species for rainforest regeneration	Fruit attracts birds
Jagera pseudorhus, foambark	Small rainforest tree with attractive ferny foliage and hairy yellow-brown fruits. Hardy	12		2	2	Very attractive tree for landscaping. Useful for rainforest regeneration	Fruit attracts birds
Leptospermum brachyandum, thin-fruited tea tree	Small, multi-trunkde tree, common in the catchment. The bark peels in spring, turning from a copper colour to white. Very hardy	4	+	3	1	Good erosion control sepcies. Can be used for direct seeding	Good habitat species for shading the stream edge
Lomandra hystrix, spiny mat-rush	Small, tussocky rush, forming thick clumps. Hardy	1		1	1	Good for erosion control if planted in sufficient density. Large spreading root system	Good stream edge habitat species
Lophostemon confertus, brush box	Tall tree with spreading growth when grown in the open. Hardy	25	+	2	2	Good hardwood timber. Shade tree. Good quality nectar and pollen for bees	Useful habitat tree when large
Mallotus philippensis, red kamala	Small bushy, dense-crowned rainforest tree producing hard red capsules in spring/summer. Very hardy	8		2	2	Useful rainforest regeneration plant. Fruit can be used for dye. Wood suitable for tool handles	
Melia azedarach var *australasica*, white cedar	Very hardy deciduous tree. Drought tolerant	15	+	1	1	Cabinet timber species	Fruit attracts birds
Melicope micrococca, white euodia	Small rainforest tree with light-green foliage. Leaflets arranged in threes	10	+	3	2	Useful rainforest regeneration species on protected sites	Fruit attracts birds
Milletia megasperma, native wysteria	Large vine species producing large pods similar to black bean tree	Vine		1	3	Riparian vine species	

BOTANICAL/COMMON NAME	BRIEF DESCRIPTION	MAX. HEIGHT (m)	FAST GROWING	PROTECTION WHEN YOUNG	FROST RESISTANT	OTHER USES	WILDLIFE
Mischocarpus pyriformis, yellow pear-fruit	Small rainforest tree with dark green foliage. Fruits yellow and pear-shaped	10		1	3	Landscaping. Understorey plant	Fruit attracts birds
Neolitsea dealbata, white boly gum	Small bushy tree with large drooping leaves that are vivid white underneath	10		3	3	Landscaping plant. Understorey tree	Fruit attracts birds
Pittosporum undulatum, native daphne	Small bushy tree with fragrant flowers in spring. Hardy	8	+	1	1	Landscaping plant. Low windbreak tree. Good for rainforest regeneration	Fruit attracts birds
Planchonella australis, black apple	Medium-sized rainforest tree with dark glossy leaves and large black fruits in spring/summer	12		3	3	The large black fruits are edible	Fruit attracts birds
Sloanea australis, maiden's blush	Spreading, shady canopy rainforest tree with large glossy toothed leaves. Likes plenty of water	15		1	3	Useful timber tree for interior work	Fruit attracts birds
Sloanea woollsii, yellow carabeen	Spreading, shady canopy rainforest tree with large glossy toothed leaves. Likes plenty of water	15		1	3	Useful tomber tree for interior work	Fruit attracts birds
Syzygium australe, brush cherry	Small, dense crowned rainforest tree with dark green leaves and red fruits from summer to early winter	10		2	2	Edible fruit. Good riparian rainforest regeneration species	Fruit attracts birds. Good host for ferns
Toona australis, red cedar	Large rainforest tree with large leaves and spreading canopy. Semi-deciduous. Hardy	20	+	2	2	Good shade tree. Valuable timber tree. Subject to attack by tip moth	
Tristaniopsis laurina, water gum	Medium-sized tree with flaky bark and yellow flowers produced in summer. Hardy	12	+	2	1	Useful erosion control species and some value for cabinet work. Useful nectar and pollen species. Used for direct seeding	Roots provide habitat for stream-dwelling animals. Good riparian shade species
Waterhousea floribunda, weeping myrtle	Medium to large tree. Densely crowned with weeping foliage and round green fruit in summer/autumn. Hardy	15	+	2	2	Excellent erosion-control species with extensive mat-like root system	Roots provide habitat for stream-dwelling animals. Good riparian shade species