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Use of willows and natives for stream bank control in New Zealand: a survey of regional councils

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Willows or natives for stream bank control: a survey of usage in New Zealand regional councils

Motueka Integrated Catchment Management (Motueka ICM) Programme Report Series

by

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Cover Photo: Exposed willow roots in Motupiko River bed following Easter 2005 flood.

PREFACE

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

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

Contents

Introduction

Stream bank erosion is a natural geomorphic process which occurs in all channels. It is one of the mechanisms by which a channel adjusts its size and shape to convey the discharge and sediment supplied to it from the surrounding land. Bank erosion becomes problematic when it potentially influences or places at risk land adjacent to the stream channel or infrastructure that might be in the vicinity of the stream or river (e.g., bridges).

Where bank erosion is required to be controlled, it is achieved with either structural measures (concrete structures or rip rap (large boulders)) or by planting trees at the river edge or on the banks. Vegetation is widely accepted as a key factor in contributing to a stream's bank stability. In general terms, vegetation roots increase bank stability by protecting soils against entrainment from flood flows, and root mass and density provide soil shear strength and thereby protect against gravity collapse of undercut banks.

River control is both a widespread and costly practice across New Zealand and several earlier reviews have documented these costs (e.g., Acheson 1968; Williman & Smart 1987). Of the works carried out by catchment boards of the day, the proportion involving some form of vegetation management (removal or planting) ranged from 15-20% of the total costs across 81 schemes (1985 dollars, total costs were $750 million). Even then however, there was considerable variation across the country in the use of tree planting for bank protection.

The most commonly used species used to control bank erosion in New Zealand is *salix* or willow (e.g., van Kraayenoord & Hathaway 1986). However, in the last two decades, there has been interest in moving away from introduced species to using more native species, particularly on smaller streams (Stanley 2002). There are however, concerns that native plants will not perform as well as well as willows and the information to allay these concerns does not yet exist or is sparse (e.g., Collier et al., 1995; Czernin & Phillips 2005; Marden et al., 2005). Further, some willow plantings are at risk from the arrival of the willow sawfly (*Nematus oligospilus*) in New Zealand, which has, and continues to cause damage to plantings in some regions. There is also a growing realisation of the long-term risk of pests in using a single species for river bank plantings.

This report complements papers and reports developed for the ICM Motueka research programme on riparian typology (Phillips & Marden), bank erosion (Watson & Basher), riparian vegetation enhancement (Langer & Rodgers 2003), and root development of native plants (Marden et al., 2005). Its primary aim is to present the results of a survey of regional and unitary councils in New Zealand of the use of willows and native plants in stream and river protection work. We have not made a distinction between restoration activities on small streams and river training efforts on larger rivers.

Our aim was to collate information to produce an annotated bibliography of the use of willows and natives for river stabilisation in New Zealand. While there is a considerable body of literature on the uses of willows in other countries for river control (e.g., Coppins & Richards 1990; Gray & Sotir 1996; Stott 1992), as an introduced and now well-established species, we felt that nationally there was not an up-to-date accessible resource that brings together information and knowledge about the use of willows and natives for stream bank stabilisation – their benefits, disadvantages and so on. And further, based on conversations with a number of people around the country, there is a current need to provide such a resource.

Background

Since the turn of the 20th century much of New Zealand's indigenous riparian vegetation has been cleared for pastoral use, for the development of an exotic forest industry, and for urban development associated with European settlement. In more recent years, in hill country areas, the regeneration of indigenous species has been suppressed by continual grazing, while remaining stands of riparian vegetation have been further decimated largely through state-assisted land development encouragement loans or subsidies. The loss of buffering and ecosystem services provided by this riparian vegetation has led to the progressive degradation of waterways through increased sedimentation and nutrient pollution. The consequence has been a loss of in-stream habitat and inferior water quality in many streams and lakes throughout rural New Zealand (Phillips et al., 2001 and others).

Channel widening by bank collapse is now a common occurrence along many kilometres of stream throughout New Zealand. The loss of primary agricultural land and physical property adjacent to eroding stream banks is very costly and the need for their protection against erosion has long been recognised (Acheson 1968; Eyles 1983). An increase in awareness of the poor health of New Zealand's water bodies and a genuine willingness to redress this situation have increased the public's desire to become involved in restoring riparian areas by planting indigenous rather than exotic species such as willows (*Salix* spp.). Though the role of the latter in improving stream habitat and bank stability and in preventing erosion is well-recognised (Van Kraayenoord & Hathaway, 1986), information on the nature, and more importantly on the performance, of New Zealand's indigenous riparian species is generally descriptive, with much of our knowledge anecdotal. In the case of below-ground growth performance and functionality, there are relatively few published studies on root system architecture and biomass of individual native tree species (e.g., Watson et al., 1999; Czernin & Phillips 2003; Marden et al., 2005).

A further need to address this information gap has arisen as a result of the increased risk to many riverbank protection works posed by the introduced willow sawfly (*Nematus oligospilus*), which has caused widespread defoliation and mortality among New Zealand's willow trees (Baker et al., 1997; Cowley & Whyte 1997; Charles & Froud 1997; Charles & Allan 1998). Historically, effective structural stream bank protection has been expensive to install and maintain, and as riverbank protection using only willows is no longer practical, other options are needed. This includes combining the proven capability of willows with the untested ability of native species with the view to reducing the longer-term reliance on willows.

Increasingly, societal considerations have become an integral part of riparian stabilisation projects. These may include incorporating the aspirations of Maori in plant selection for use in traditional medicine, as fibre for weaving, and for other uses. Other multiple goals may include increasing New Zealand's plant diversification and maximising plant performance for carbon accrediting. New Zealand ratified the Kyoto Protocol (IPCC, 2000) in 1997 (New Zealand Climate Change Office 2003), and since then the trading of carbon credits by organizations and companies at local, regional and national levels has become an integral part of the country's economy. It is important therefore, that a measure of biomass accumulation, particularly during the early years following the establishment of new plantings of woody species, including indigenous plants, is based on verifiable data.

With public and government pressure to maintain and enhance the indigenous biodiversity of New Zealand, river engineers and land managers are seeking to use more indigenous plants for streamside planting but are often faced with a dilemma – will natives work as well as willows which have been the mainstay of river bank protection works for decades in New Zealand.

History and role of willow plantings

Much of the following section comes from an unpublished report prepared by DL Hicks for Environment Waikato and is hereby acknowledged as well as from the proceedings of a willow control workshop held in 1993 (West 1994).

Willows were first introduced into New Zealand around the 1840's as ornamental specimens in the gardens of early settlers (for more information see Thompson & Reeves 1994). Cuttings were soon planted on riverbanks, in a similar manner to their use in Britain and Europe. The willow were intended to confine channels, prevent them from eroding land cleared for farming, and protect roads and bridges from flood damage. Willows continue to be used to the present day by land owners and resource management agencies. Willows are also our most abundant and widespread exotic tree after pine trees.

Willows belong to the family Salicaceae together with its other main genera, *populus* (poplars). Almost all species of poplars and willows are deciduous, dioecious (separate main and female plants), and the insect-pollinated flowers are grouped into compact, usually pendulous, catkins. Seeds are small, often minute, and very adapted to wind dispersal. While all poplars are trees, willows show a remarkable range of form from large trees to shrub forms (sometimes called sallows) and osiers (smaller multi-stemmed stature, sometimes called basket willows). Hybrids are common, relatively easy to develop artificially, and many can reproduce sexually (Thompson & Reeves 1994).

Figure 1 Willow stabilising river bank. Note bank erosion upstream of tree.

Willows are beneficial in a wide range of situations, e.g., as bank stabilisers (Acheson 1968, Collier et al., 1995); as cover for trout (Latta 1974; Green et al., 1989); as habitats for birds (can be detrimental, e.g., in braided rivers Robertson et al., 1983, 1984); as a canopy beneath which regeneration of natives can occur (Meurk pers. comm.); as a source of pollen (and honey) for bees (van Kraayenoord 1979); and often as supplementary stock fodder during dry periods (van Kraayenoord et al., 1995; Milligan 2005). Conversely, willows are detrimental in a wide range of situations, e.g., as silt traps (could also be positive); as blockages within a channel that then promotes local scour or reduces the carrying capacity of the floodway; as cover for predators of native birds; affecting freshwater ecosystems (both positive and negative – Green et al., 1989; Collier 1994; Glova & Sagar 1994; Lester 1992; Maloney et al., 1999) and as invaders of native vegetation or ecosystems (West 1994). In terms of the impacts on willows on aquatic ecosystems it appears that dense plantings of willows are generally detrimental to stream health but that moderately spaced plantings generally improve stream health relative to open pasture (Collier 1994). Unfortunately, no studies have examined the impacts of willows on aquatic habitats relative to the effects of native tree species. Current and future beneficial uses of willows also include phytoremediation and biomass production for both fuel and fibre (e.g., Kuzovkina & Quigley 2005).

Generally, willows are well adapted to New Zealand's climatic conditions. While most willows are typically associated with water and wet ground, some species are also tolerant of dry soils. This level of adaptation often reflects genetic variation or "clones" from the same taxa, e.g., *Salix purpurea* now contains enough genetic variability for clones to stabilise river banks on one hand and counter steepland soil erosion on the other. *Salix matsudana* is recognised as having the widest site tolerance among the tree willows in New Zealand (van Kraayenord et al., 1995).

One of the issues with some of the early willows was that they often cracked and branches would float downstream and then re-grow where they lodged. While this was a plus in terms of enabling willow to be easily established, it caused problems with dense infestation of willows in places that resulted in obstruction of floodwater often causing local erosion and increased flood levels and durations (Russell 1994 – in West 1994). Where trees have fallen across channels, debris accumulates, and log jams or dams can form. Control or maintenance of willows in waterways is a continuing problem. However, willow management rather than willow removal is a preferred option as complete removal (or killing willows with no follow up work) tends to create a cycle of extremes – congestion to denudation often with a 5-10 year cycle of erosion after the willows have been removed (Green et al., 1989; Russell 1994).

Willows have also "invaded" wetlands. While species in use today are non-cracking and sterile varieties, the progeny of earlier plantings remain throughout most rivers and regions and most councils have programmes to remove these problem willows. In addition, where female plants occur and can be recognised these should be removed and any engineering and soil conservation work should normally employ only male clones and, ideally, these should be sterile.

Willows were also used in small tributary channels for soil conservation, particularly where gully erosion was a problem in pumice alluvium or mudstone hill country. In the eyes of many landowners, willows improve the aesthetic appeal of a farm landscape. However in the eyes of some environmentalists they are an exotic weed.

Willows have been used extensively in New Zealand to control both small and large rivers and provide stability to river banks but there is a dearth of information about the stability and effectiveness of willow plantings (Oplatka & Sutherland 1995). However, anecdotally, willows are deemed to be effective by river engineers and there use is widespread as front line defences for river control works. It is the weedy characteristics of willows (suckering, coppicing and rapid growth) "that make them so useful and cost effective (in the short term) for stabilizing banks" (Stanley 2002). However, willows can create problems in smaller, lower energy rivers by blocking channels and reducing flood capacity. Tree willows possess an extensive mat-like root system which can provide considerable cohesion to erodible soils. This soil-binding capacity is strongest when a think mat of tough, pliable fibrous roots is produced before the trees reach maturity. During maturity these roots become larger, more scattered and smooth, and much of the soil reinforcing action is lost (van Kraayenoord et al., 1995). Large willows also become top-heavy and liable to windthrow. In river bank protection planting, these problems are prevented by rejuvenating the trees at least once every 10-15 years. Rejuvenation is usually achieved by layering or lopping.

Figure 2 Willows stabilising stream bed (left) and stream banks (right)

Features that make willows a useful biological tool in river protection work, particularly in rural based flood protection schemes, include their fast growth rates, ability to be grown vegetatively (i.e., rooted cuttings, wands, stakes or poles, usually taken from existing stands), and they can be layered when they become old or ineffective. Layering involves partly cutting the trunk so that the tree lays in the edge of the river flow protecting the base of the bank but also reducing flow and allowing silt to build up along the river edges which in turn allows them to sucker new root systems and re-establish themselves - an advantage for bank edge protection. Willows are also cheap to propagate and can be used as sacrificial bank edge protection that can be replaced relatively quickly (in contrast, natives tend to cost more per plant, cost more to establish, grow more slowly and if lost or damaged would be more costly to replace). Willows are also often used to complement the protection of other structures such as rock groynes, gabion baskets, and rip rap. All these attributes combine to make the modern hybrid willow the least expensive and the most effective plant for river edge erosion control (Porteous 2001).

Figure 3 Willows planted as poles (left) and shrub willows with rip rap (right).

Willows as invaders of waterways and wetlands

Willows colonise river and stream beds by vegetative or sexual reproduction, with potentially severe environmental and biological effects through formation of dense stands of structurally unstable trees or shrubs with extensive, dense, root mats. Impacts include:

- modification of stream morphology, hydrology and stability, causing blockage/obstruction, avulsion, increased erosion and sedimentation and increased flooding.
- increased water-use in streams resulting from higher transpiration rates than indigenous vegetation.
- severe damage to infrastructure where willow debris obstructs stream channels during floods (e.g., loss of bridges and roads).
- alterations to ecological processes in streams (e.g., Lester et al., 1996; Collier 1993), including energy fluxes and nutrient cycling (timing, quality and consistency of organic matter inputs), water temperature modifications (through intense shading) and water quality via anoxic conditions produced (biological oxygen demand) during breakdown of the massed autumn leaf fall.
- dense shading by willow canopies alter (or decrease) primary production, impacting on higher order consumers such as invertebrates and fish.
- destruction of instream and streambank indigenous vegetation communities and dependent faunal communities by intense shading.
- destruction of significant flora and fauna species and populations of streams and streambeds.
- reduction in amenity values associated with streams, for example reduced access for fishing, canoeing and rafting on streams densely vegetated with willows.

Crack (*Salix fragilis*) and grey willow (*Salix cinerea*) are listed for inclusion in the Auckland Regional Council's 2007 to 2012 RPMS (ARC 2006) as 'surveillance' plant pests. Horizons Regional Council's proposed RPMS (Horizons 2006) lists grey willow as a 'containment' pest plant whilst crack willow is listed under Horizon's 'site-led programme'. In conjunction with DoC, Environment Waikato is seeking the ability to conduct control work on crack and grey willows in the region on an as needs basis. No landowner compliance rules/obligations are proposed. Environment Waikato are proposing that the crack willow is included in its RPMS as a 'containment' plant pest.

In summary, there are still misconceptions and misunderstandings regarding the New Zealand willow flora – simply because naturalised taxa of this genus have been little studied, even though they are one of the most important influences on our modern lowland wetland and riverine ecosystems (Thompson & Reeves 1994).

Role and use of natives

While vegetation in general provides a level of reinforcement to stream and river banks, there are many factors that influence its success. Indigenous vegetation (natives) can, and does play a useful role in stabilising stream and river beds throughout New Zealand's landscapes. However, while this can be seen in many "natural" environments such as national parks or reserves, in many of our pastoral landscapes where stream channels and banks may still be adjusting to geomorphic thresholds related to post-forest removal some 100 years ago, their performance often is, or is perceived to be, wanting in light of elevated levels of bank or bed erosion.

In general terms, the knowledge base on the effectiveness or performance of native plants for erosion and sediment control is limited and there has been little produced in recent years (e.g. Pollock 1986). Information on natives recommended for bank erosion is included in the appendix of the Plant Materials Handbook for Soil Conservation Volume 3 (Pollock 1986). Those listed specifically for bank erosion were grasses and herbs (*Cortaderia*, and *Phormium*). However, some of the species listed for use in gully control might also prove useful.

Lack of knowledge on the effectiveness of native plants for erosion control is both a function of the sparse information on the below-ground characteristics of New Zealand's native plants (roots – structure, biomass etc) and monitoring of native plantings in erosion-prone situations. Root studies (e.g., Cameron 1963; Phillips & Watson 1994; Watson et al., 1999; Phillips et al., 2001; Wardle 2002; Czernin & Phillips 2003; Watson & Marden 2005; Marden et al., 2005; Phillips 2005) mostly involve one or just a few specimens and are usually of a limited age range. To a large degree this paucity of data is a reflection of the time-consuming nature of root system extraction, particularly for large shrubs and trees, as well as the fact that root systems are often influenced by soil conditions, making statistical comparisons difficult. In addition, growth modelling for species typical of productive systems such as crops or forests, cannot readily be done without good data from which empirical allometric relationships are made possible. As part of the ICM Motueka research programme, trials of native plants up to the age of 5 years are beginning to yield useful quantitative data on the below-ground attributes of some of the more common native species used in streamside plantings (see http://icm.landcareresearch.co.nz/research/research.asp?theme_id=1&research_id=15).

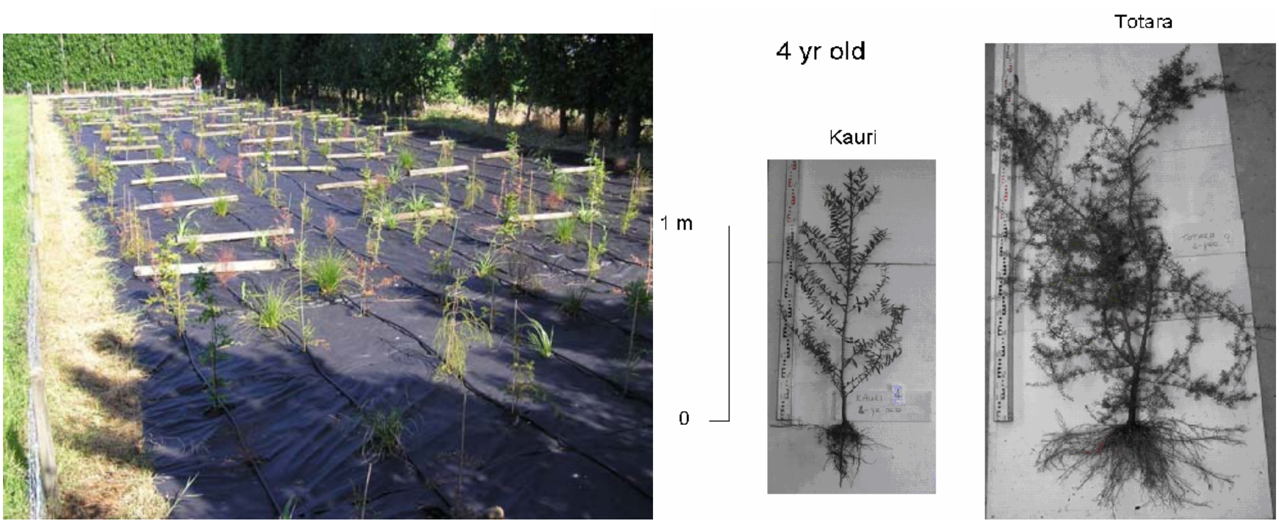

Figure 1 Native plant trial site and 4-year-old kauri and totara from trial 2.

Methods

A literature review was carried out to determine the use and performance of plant materials for controlling stream bank erosion. The focus of the review was on the use of willows and natives in New Zealand.

A simple survey, together with follow-up phone calls to appropriate people in regional and unitary authorities (river engineers and/or land management officers), aimed to provide information not able to be gleaned from the formal literature search. This also helped determine the currency of information and knowledge as well as an estimate of the amount of money being spent using plant materials for river control.

Specific survey questions included:

- Are willows still used for river bank stabilisation works? What proportion of the annual budget is for vegetative (soft control) vs. hard control (rip rap etc)?
- What varieties of willows are used now? Have the policies on varieties changed in the last 5 years? Why?
- Are natives being used? What sized streams or rivers are they being used on? Do you have any success stories using natives that you'd be prepared to share with us?
- Is there a move in council to try and use more natives, and what are some of the issues in terms of adoption?
- Is maintenance of old plantings an issue for your council? How are you dealing with it? What is the proportion of the asset management budget spent on this activity vs. establishing new works?
- Do you know of any papers, reports, file notes that deal with willows, their use, removal, effectiveness etc. that we could see (even getting the citation will be useful – we suspect that lot of material is in the grey literature or in officers filing cabinets in the form of project files).

Results

Literature review

Formal publications related to the use of willows and natives (and other plant materials) for river and/or bank control are generally limited, but more specifically from New Zealand. Widening the search produced a number of references related to the ecological effects of river bank plantings on either in-stream or terrestrial ecosystems – they too are limited for New Zealand. Further, there has been little written in recent years with most literature over 20 years old. In addition, a number of sources indicated that much earlier information on willows is, or was contained in the grey literature, particularly as file notes or brief reports, within regional councils or their former catchment boards. Much of that explicit information is now either lost or difficult to access or resides as tacit knowledge within the minds of a dwindling number of resource management practitioners who have been involved in this area for two or more decades.

All regional councils, unitary authorities and some district and city councils have varying degrees of information on willows and natives available on their websites (as text or contained within publications, newsletters or reports)(e.g., Gibbs 2007). This information is contained either in riparian management, biodiversity enhancement, or weed management guidelines or strategies. These usually contain lists of recommended species for a range of applications, notes on how to establish and maintain plantings, or notes on removal of pest plants.

Survey

Responses to the mail survey across resource management agencies were variable in terms of the level of detail of information supplied to the questions asked. Thirteen of sixteen councils responded to the survey with two councils providing responses from within different parts of the same council. Responses were not received from Northland Regional Council, West Coast Regional Council and Environment Canterbury. General results are summarised in Table 1. Key points to emerge included:

- Councils are spending anywhere from 10 to 90% of their river protection budget on soft measures, e.g., use of vegetation.
- Some councils such as Gisborne and Otago mostly use hard measures.
- General consensus among river engineers that there are currently no proven species that are as effective as willows for front line river protection.
- A variable use of native plants for stream side planting, but in all cases their use is confined to situations away from front line defences, and they are more used for biodiversity enhancement projects.
- Significant issues persist around continued use of crack and grey willow and the need to meet compliance with bio-security needs for their eradication.
- Wide range of species of willows used - both tree willows and shrub willows.
- Many moving away from crack and grey willow to shrub willows as easier to manage by mechanical means for layering etc.
- General feeling is that vegetation and hard measures are necessary but local conditions prevail and “one size does not fit all” across the country.
- Some confusion around costs of soft measures – maintenance vs. active control or replacement but generally vegetation management is not considered capital works.
- There is an increasing preference for using natives, particularly in small streams and closer to urban areas
- Most cannot see that there would be a shift to natives because they are slow to develop, cost more, can’t be managed in the same way, and don’t provide the level of protection needed.

Table 1 – Results from survey

	%	%	$x1000	$x1000		
Council	**Hard**	**Soft**	**Hard**	**Soft**	**Natives used**	**Willow varieties used**
GW	51	49	180	171	Yes	Moutere, Tongoio, booth
Southland	53	47	530	470	Yes/no	Pohangina, Glenmark, Kumeti, Moutere, crack
ARC					Yes	Banned but still problems with crack and grey
EW		10 - 90			Yes	Matsudana, Holland, Irette, Pohangina, booth, crack
Nelson City					Yes	Rule controlling planting of willows in city, permitted in rural but not certain varieties
Taranaki					Yes	Matsudana, Irette, Booth
Marlborough			300	40	No	
Hawkes Bay	33	66			Yes/no	
Gisborne	85	15			No	Matsudana
Otago	90	10			No/yes	
Tasman		50				

Notes Doesn't include costs for capital works
Crack willow discouraged by most councils
Natives generally not used for front line defense - secondary, smaller streams or amenity/urban
Both tree and shrub willows used

Implications of using more native plants for riparian restoration and management

The results of our survey suggest that willows are likely to remain a key component of river control into the future. However it is clear that there will continue to be more natives being planted adjacent to streams and rivers. While the driver for their establishment is largely for biodiversity enhancement there will be an added benefit for stream bank stabilisation. Much of these planting efforts, however, will continue to be on the smaller lower order streams rather than the medium to large rivers. However, some councils are using a multi-tiered approach combining willows for front-line defences and then using natives further away from the active channel (e.g. Environment Bay of Plenty has been trialling this approach). Further, in some situations particularly in urban areas, willows are retained to provide bank reinforcement with natives underplanted. Once native are well established the willows are slowly removed.

The net result of these activities is likely to be a significant improvement in riparian slope and bank stability for the smaller streams more typical of unmodified, upland stream reaches where current channel form, slope characteristics and hydraulic conditions are better representative of what existed before forest clearance and where the performance of riparian vegetation has proven effective. For these streams, it is not the physical limitations of root system depth, spread and density of individual riparian species to provide effective soil reinforcement that determines the key to successful slope and bank stabilisation but rather the density of plantings and the species mix present.

Treatment options that promote the quickest canopy closure and root development at all levels of the soil profile are likely to be the most effective in promoting site stability (Phillips et al., 2001). Where a native seed source already exists, and if animal stock could be excluded from riparian areas, many of these areas would regenerate naturally and at little cost. Excessive vegetative growth may, however, encroach on these channels, and without proper management may create drainage and local flooding problems by clogging the stream and constricting the channel. As a consequence of their relatively shallow-rooted habit, however, many of New Zealand’s indigenous plants will have limited effectiveness in floodplain reaches of higher order streams modified by the building of stopbanks (levees) and where channel hydraulic conditions are likely to undercut stream banks to a very steep and unstable slope >2 m high. If the potential for bed degradation exists, additional protection in the form of structural materials will be required along the toe of the bank and to some depth below the normal streambed. Similarly, bank materials such as alluvium are prone to undermining, thus riparian plantings must be protected by structural means (e.g., gabion baskets, rip rap, etc.) and/or by bank reshaping until growth is sufficient to achieve effective bank stability.

The limitations of root depth aside, New Zealand’s indigenous riparian vegetation is sufficiently diverse to meet most of the requirements for slope and bank restoration, particularly of the lower order streams. The selection of suitable plant materials must take into account both the degree of overbank inundation contemplated and the ability of plant materials to provide year-round protection, have the capacity to become well-established under adverse soil conditions, be long lived, develop a root system that will withstand the drag of stream flow on the above ground portion, have multi-stem and branch characteristics with many stems emerging from the boundary surface, have tough, resilient stems and branches, and require minimum maintenance.

Where stability is required to a known depth, such as to a potential failure plane that lies within the rooting depth of plants being considered to restore stability, the species selection must include those with root systems capable of reaching the specified depth. Failure to meet this goal will undoubtedly be the result of insufficient roots crossing the failure plane as it is below the vertical limit of root growth of the species selected. For many rehabilitation/restoration sites the strategy should be to select a mix of species with different rooting habits. To appreciate fully the potential use of indigenous vegetation for the stabilisation of riparian slopes and streambanks in New Zealand, further studies are needed for other riparian plant species that may better meet the slope and bank stability requirements for drainage systems in different soil types, geology and with differing hydraulic characteristics.

Conclusions

While there is a desire to meet a growing need expressed by the general public for more indigenous plantings alongside stream and river banks it is clear that where there are bank erosion issues or a requirement to control rivers, native plants will not be used because they are regarded as slow growing, do not have extensive root systems, nor can they be managed in ways that willows can (e.g., vegetative cuttings, layering etc). However, plantings of natives along smaller streams in both rural but especially in urban and peri-urban environments are likely to be effective where stream banks are less than about 2m in height and where there is no active bank erosion. The increases in native plantings happening around the country are driven more from meeting biodiversity needs than for necessarily improving stream bank stability.

Willows are likely to remain the primary bioengineering tool in flood protection and river control because their attributes combine to make them the most cost-effective biological solution to riverbank protection. However, the key to keeping willows beneficial rather than becoming a pest lies in continuing to use the right kinds of willows in the right places and a continual eye on maintenance.

Recommendations

- There is an on-going need to continue to share knowledge and experiences both within and between councils. Many councils are separated internally on functional lines, e.g., flood control from biodiversity enhancement or “land/stream care”. Enhancing the information flow between groups such as the Willow and Poplar Research Collective, the Regional Council River Managers group, the Regional Council Land Managers’ forum would improve the general level of understanding of the use of plant materials across the country. In addition, much of the current knowledge base is tacit and anecdotal and resides within a limited group of individuals. It would be beneficial to capture this knowledge from individual within these groups and produce a report or document on what is known and what opportunities exist for further research.
- There is also a need to conduct further trials of natives and exotic alternatives (non-invasive) to willows and perhaps even further trials of willows to expand the very limited quantitative data base. Such field trials need to quantify growth rates, coppicing ability and root structure alongside willows. Investigations into enhancing growth rates by using growth promoters or micorrhyza and determining which species can be used for vegetative reproduction and/or establishment would also be desirable. In addition, trials that aim to use a mix of exotic willows together with natives either from establishment or using established willows as nurse crops might yield useful information relevant for future management.
- Development of river bank stability models that incorporate vegetation together with visualisation models that can be used to illustrate a range of vegetation scenarios over time are also needed to provide the necessary information to convince resource managers of future alternative strategies for river and stream control.
- Future models, be they deterministic process-based models, economic models, or spatial-temporal models will increasingly require quantitative data to run them and these data can only be obtained from trials.

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