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# TALES OF THE RIVERBANK – EXAMPLES OF BANK RESTORATION ON URBAN RIVERS

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## ABSTRACT

Some of the practical issues in restoring riverbanks in urban areas are examined and projects carried out on the Avon and Heathcote Rivers in Christchurch City are described. In many cases the emphasis is on amenity values within which ecological aspects can be incorporated. Extensive experimental bankworks and revegetation were needed after salt water spread upstream in the Heathcote and included the use of timber terraces, gabions and wool and coconut fibre matting, all of which were sown with grasses and planted with predominantly native species. On the Avon River, restoration in the freshwater environment is easier, and reno mattresses have been used on the more gentle slopes. In a recent residential sub-division, the stormwater from streets flows into a new "stream" before passing through a pond and being discharged into the nearby Styx River. A set of guidelines has now been prepared for use on all the City's rivers to encourage the integration of ecological considerations into bankworks. The need to clarify the philosophy behind restoration projects is discussed. While the Resource Management Act gives a lead towards more sustainable river management in urban areas, the lack of appropriate staff may be a constraint. Opportunities include development of rapid revegetation techniques using native species and extension of these ideas into rural waterways management.

## INTRODUCTION

In urban New Zealand, waterways have been considered in a functional manner. They have been thought of as either problems, being the source of floods, smells or dangers to small children, or as disposal systems for stormwater, sewage or rubbish. Management of these waterways has generally been through the engineering or parks departments of local authorities, and has resulted in a utilitarian approach to both bank and water treatments. In the histories of many areas, there is a record of canalisation, drainage, modification to banks, and clearance of bank vegetation (e.g. Auckland Regional Water Board 1983, Wilson 1989).

The loss of vegetation and animal numbers and diversity associated with these physical changes have not often been documented. Descriptions of riverbanks from the time of early European settlement tend to be qualitative rather than quantitative. Photographs and paintings provide the main source of information. Through these we have gained an indication of the extent of habitat loss, from which the loss of species can be inferred (e.g. Wellington Regional Council 1989).

Christchurch City was built on drained swampland, and its two main rivers (the Avon and Heathcote) and their tributaries have been the subject of intensive management and control since the middle of last century. Until local government reorganisation five years ago, this work was carried out by the independent Christchurch Drainage Board, but more recently has been taken over by the Drainage and Waste Management Unit of the City Council.

In Christchurch, there is little native vegetation along the river or stream banks – and only near the Avon-Heathcote Estuary is any of this likely to be remnant of former communities. In keeping with the City's "Garden City" image, the Avon and Heathcote banks are regularly mown and planted. Those parts which flow through private properties receive similar treatment. Mallard are found in large numbers along most waterways. There is a growing brown trout population in the Avon, but not in the Heathcote. Galaxiids occur in both river systems in low numbers, with some evidence of attempts at spawning by whitebait species.

Many features of urban riverbank structure and management now make them inappropriate as habitats for riparian or semi-aquatic species. These include steepened and closely-mown grassy slopes, vertical margins directly above water level, dominance of introduced grasses and trees, mowing regimes which have no regard for nesting times, clearance of emergent vegetation, use of herbicide sprays near trees, disposal of stormwater, and run-off from roads and parking areas.

In Christchurch, Boffa Miskell have been working with the Drainage and Waste Management Unit of the City Council on seeking a solution to salination problems on the Heathcote River, as well as on a range of other aspects of environmental enhancement of the urban waterways. This paper reviews some of this work and draws some conclusions about the future of bank restoration in New Zealand.

## BANK RESTORATION CASE STUDIES

### The Heathcote River

The Heathcote is the lesser known of the two larger Christchurch rivers – the Avon which flows through the city centre is the focus of the City's image. The Heathcote flows along the foot of the loess-covered Port Hills, from which it receives stormwater run-off (which often carries sediment), and passes through suburbs such as Beckenham, Opawa, Woolston and Ferrymead (Fig. 1). These include both industrial and residential areas, and influence the visual and ecological characteristics of the riverbanks. Following the installation of an industrial sewer, the Heathcote River's water quality is improving, although stormwater run-off remains. In the lower reaches (i.e. Opawa to the sea) the banks are now characterised by:

- gentle to steep slopes,
- width ranging from 2 m to 10 m, but generally at the narrow end of the range,
- introduced grass cover, intensively mown and managed,
- willows (predominantly *Salix babylonica)* and other northern hemisphere deciduous trees,
- compacted soils and rubble forming stopbanks for much of the length,
- river paralleled by roads on both banks, as well as underground services.

**Figure 2 Bank collapse on Heathcote River**

**Figure 1 Location of Heathcote River and Woolston Cut.**

Before European settlement, the river meandered through a large wetland which extended from Lake Ellesmere in the south to the Amberley hills in the north (some 40 km). From 1850 onwards, as the City of Christchurch developed, the wetland has been drained, and all the rivers confined and modified.

The Heathcote has a gentle gradient, and at times of high tides and heavy rainfall there is a backing up of water which can cause extensive flooding in the Beckenham and Opawa suburbs. Downstream of these places is the Woolston Loop, a two kilometre long meander through which water flows slowly, adding to the flood back-up. Flooding has been a problem since early this century, and many solutions have been considered. In 1986 the Woolston Cut was opened – a canal which cut off the Loop and effectively formed a large island.

An environmental impact assessment on the proposal to build the Cut, and its associated bankworks, was carried out in the mid-1970's. This was a relatively short document, focussing on the physical aspects of reduction of flooding. No significant impacts on the river ecology were predicted.

However, within a short time of the Cut being commissioned, it was noted that willow trees upstream were dying. It became apparent that on each incoming tide salt water was penetrating almost two kilometres further upstream than it had done previously. Over the next four years the tree death spread slowly upstream. In addition, the banks in the same reaches became very unstable, with large blocks falling into the river (see Figs. 2 and 3)

In 1991, when the bank collapse started to threaten the roads, houses and services along the Heathcote, the City Council initiated a programme of investigations. The aims were:

- to find out exactly what was happening to the banks,
- to determine what the prognosis for the large trees was,
- to decide what action should be taken to remedy the matter.

A "think tank" of people with expertise in the geomorphology, soils, ecology, and hydrology of rivers was formed, and this group quickly recognised the processes which were occurring. With the intrusion of salt water into the banks three distinct things were having a synergistic effect:

1. There was a sodium/calcium exchange in the clay molecules of the soil. Sodium forms weaker molecular bonding than calcium, so the soils "collapsed".

2. The willows had always grown with their roots in a freshwater environment. Put simply, they started to take up chloride (and probably other elements) from the salt water; this was accumulated and affected transpiration ability, leading to moisture stress and death. Following death, their roots rotted and thus weakened bank strength.

3. The mud crab, *Helice crassa*, expanded its range upstream, digging tunnels into the banks. This added to the instability as well as facilitating the penetration of salt water further into the banks. Ecologically speaking, the process is one of expanding the estuary.

**Figure 3 Dying willows and eroded banks, Heathcote River.**

**Figure 4a Filter cloth and gabion baskets before replacement of soil and vegetation.**
**Figure 4b Wire mesh holds coconut matting in place over gabion basket.**

**Figure 4c Timber terraces planted with native species.**

A larger group of people, including Council staff and representatives of the local residents, then looked at ways of dealing with the consequences of the changes. From the outset, the Council insisted that the solution be environmentally driven – that is, the group would set an objective for the river environment and the engineers would seek a technical method for achieving it. There were long debates about whether there should be a return to willow-lined banks, or if the "new" riparian areas should be planted in natives; should the salt regime remain in its altered state, with impermeable structures used to stop further collapse, or should a return to some former state be sought? Wide public consultation indicated that most of the people who live along the upper reaches of the affected river (e.g. Opawa, Aynsley) preferred to see the vegetation typical of "English" landscapes, while those in some other areas wanted native species (e.g. Woolston).

The chosen solution was to:

1. Restore the river to its "pre-Cut" flow regime (recognising that this might not lead to the same overall state due to changes in soil conditions). This is being done by building a set of gates across the top of the Cut; water will flow down through the Loop under normal conditions, while the gates can be opened during floods.

2. Use emergency bankworks to protect the banks until the new flow regime operates.

3. Develop more permanent, vegetation-based bank treatments as the new regime becomes established.

4. Plant predominantly native species in the lower, more saline reaches of the river (where it flows through commercial and industrial areas) and restore deciduous trees over native ground covers in the upper reaches.

The photographs in Figures 4a, 4b and 4c illustrate some of the bank treatments used. They are based on use of artificial matting or covers (geotextiles) to stabilise the banks in the shorter term, while allowing vegetation roots to become established and form longer term cover. Differences in slopes and heights, bank soils, position on river bends, activity of people or stock, climate, desired appearance and habitat needs contribute to the decision about what to use where. Along the Heathcote a number of combinations have been used in a series of informal trials.

There is now a range of geotextile materials commercially available in New Zealand, most of which have been developed under overseas conditions. In places where a permanent solution is sought, without the need for later planting or earthworks, biodegradable matting has been used to hold soil in place until vegetation becomes established. Wool and coconut matting have been used in different places. These mats are simply layers of either woven coconut fibre or felted wool of varying thicknesses, dependent on site conditions. To use them, the earth is cut back to the desired shape and matting is pegged over the surface. Under water it can be held in place by stones or gravels, depending on the habitat or visual criteria as well as flow regimes in the river. Pockets can be cut or left in the matting for direct planting of larger plants, including trees. Alternatively, turves can be laid over the top. A finer mesh cloth may also be used to retain finer silts.

Where the bank is too steep or narrow to allow shaping to be stable, or where extra reinforcement is needed, gabion baskets can be used in combination with geotextiles. A gabion basket is a wire mesh enclosing boulders or stones. In this case the matting is used to hold imported soil in place. The soil can be pre-treated with seed or oversown once in place.

On some of the steeper, outside bends of the river, where more protection from the erosive force of the river is needed, timber has been used to form terraces, with the lowest step at about mean high-water mark. A mixture of flax (*Phormium tenax*), sedges (e.g. *Carex virgata*) and rushes (including *Juncus gregiflorus*) have been planted at the lower levels, while coastal ribbonwood (*Plagianthus divaricatus*) and bachelors buttons (*Leptinella dioica*) are on the upper level. After one year all these species have survived, but there has also been invasion by aggressive weed species, such as tall fescue (*Festuca arundinacea*). To ensure that the native species (both planted and later colonisers) become established, there will be a need for selective and careful maintenance.

Together, these two new types of banks have added to the physical and vegetation bank habitat diversity of the river. The gabions on the Heathcote provide small spaces into which fish and invertebrates can retreat during flood flows or freshes, as well as to escape predators. The margins of the lower river are otherwise uniform muds and silts. Ledges on the gabions have been planted with flax *(Phormium tenax)* and small herbs (including *Mimulus guttatus* and *Mentha* sp.) which occur elsewhere on the river, to enhance natural revegetation.

All this reconstruction work on the Heathcote River has been carried out during the 1991-1993 period, so its long-term effects are unknown. The wool matting was tested in conjunction with the Wool Research Institute of New Zealand. Preliminary results indicate that it produces better initial establishment of grasses, with taller growth and slower drying out, than the coconut matting. At other sites, initial plant establishment has been good. Success rates have been adversely affected by poor maintenance (e.g. accidental killing of small native shrubs during mowing). This appears to result from poor communication between staff of different sections of the Council.

**Avon River**

Erosion and slumping have also occurred along some freshwater reaches of the Avon River, particularly along Locksley Avenue and around the Hagley Park/Botanic Gardens areas. These have been caused by a variety of factors, including heavy traffic close to banks, natural erosion, and intensive mowing and bank-cutting removing the supportive root mat. Where the road runs close to the river, the erosion poses a potential threat to services; through the high-use public areas there is a danger of people falling into the river when edges collapse.

**Figure 5a Freshwater reach of Avon River showing reconstructed bank and gravel toe support.**

**Figure 5b Coconut matting exposed after herbicide application started erosion.**
**Figure 6 "New" waterway linking Regent's Park sub-division to existing drain.**

**Figure 7 Wildflower mix around pond, Regent's Park subdivision.**

Bank restoration here has been much easier in the freshwater environment than for the tidal reaches of the Heathcote. Figures 5a and 5b show a steep area which was cut back to about one metre from the water and then reshaped with coconut matting around a soil and gravel mix. At the water line, a heavier gravel was used for stability. A grass mixture ( including *Festuca* spp., *Trifolium* spp. and *Dactylis glomerata*) was seeded and growth was quick; native emergent plants (including *Carex virgata*) have been planted in the heavier gravel at the base. Unfortunately, due to a breakdown in communication between restoration and maintenance groups, there has been weed spraying around the bases of trees in the reach, so that some bare pieces of matting are now subject to erosion and trampling.

The Avon banks have been intensively managed for a number of years. Long reaches have had Reno mattress banks since the mid-eighties. A Reno mattress consists of stones sandwiched between two layers of wire mesh. It is flexible and suited to gentle slopes. Plant growth out from the mattress, especially as silts and gravels fill the cracks, is dense and diverse, especially where the flows are slower. However, intensive mowing can still prevent good establishment of plants.

Reno mattresses which were put in place in the mid-eighties are now difficult to distinguish from the banks because of good vegetation growth. Mowing tends to have maintained only low plant species diversity – predominantly common species such as tall fescue, jointed rush (*Juncus articulatus*) and monkey musk. However, there is a spring and summer growth of these plants as emergents along a gentle slope into the water providing a habitat not found elsewhere on the freshwater reaches of the river. Whitebait spawning has been recorded in one of these areas; however, there is no evidence of whether this occurred before the bank works or not.

The Avon River is a high value amenity river for the City and much of this value comes from the introduced plants, such as weeping willows, along the banks. Any changes to the river landscape are made only with careful consideration of their visual impact. The challenge is to diversify plant and animal habitats while maintaining the generally accepted landscape character. Habitat changes have thus been only minor, through use of flax and some native sedges at the water margins, rather than through replacement of trees and shrubs. Management and maintenance changes are likely to have greater effects on vegetation diversity. A River Management Plan is in preparation, and this may set directions for habitat enhancement.

**Regent's Park Stormwater Drain**

Regent's Park is a new residential sub-division close to the Styx River which flows through residential and rural land to the north of Christchurch. The developer originally proposed that the stormwater from the sub-division would be collected by conventional kerb and channelling and piped directly into the Styx Drain, which leads into the river. However, the Drainage and Waste Management Unit of the City Council refused to accept such plans and instructed the developer to look for a more environmentally sensitive solution. In 1990, the Council had carried out a resource assessment of the Styx River which had outlined ecological, visual and recreational values on the River. It had also made general recommendations about improvement of stormwater inputs and agricultural run-off upon which the Council staff's decision was based. The Council believed that piping of stormwater directly into the drain would have allowed silt and litter to be carried into the river. This stormwater could have included oil, lead and other materials from cars and residential parking areas. The Council also recognised that there was an opportunity for some habitat creation within the site which would not be taken if piping were used.

The steep sides of the open drain were regraded to produce gentle slopes, and planted with deciduous trees. These were selected for their amenity values and included silver birch (*Betula pendula*) and alder (*Alnus glutinosa*). The new slopes were seeded with a grass/clover mix to give rapid ground cover. This included:

Subterranean clover (*Trifolium subterraneum*)
White clover (*T. repens*)
Red clover (*T. pratense*)
Rye grass (*Lolium perenne*)
Cocksfoot (*Dactylis glomerata*)
Tall fescue (*Festuca arundinacea*)
Browntop (*Agrostis capillaceum* )
Dogstail (*Cynosurus cristatus*)
Lotus major (*Lotus major*)
Californian poppy (*Eschscholzia californica*)
Foxglove (*Digitalis purpurea*)
Lupin (*Lupinus polyphyllus*)

The "wildflower" species were chosen because of their colourful appearance and their ability to thrive in the urban residential environment. These species are commonly available in commercial seed mixes.

A new waterway was built leading from the existing drain into the subdivision (see Fig. 6). It led though a series of pools through the site, then back into the drain. Stormwater from the residential area is now taken along grass swales into this new stream. The pools act as settling ponds for sediments and have been designed to accommodate 1 in 50 year flooding. Both native and exotic plants have been planted around the margins. Monkey musk (*Mimulus guttatus*), flag iris (*Iris pseudacorus*), water cress (*Rorippa* sp.) and *Myosotis* spp., collected from nearby parts of the Styx system, were used (Fig. 7). Small weirs add variety and oxygenation. These weirs effectively prevent fish movement through the pond system – fish movement up and down the main drain system is unaffected. A general survey of fish in the freshwater reaches of the Styx River in 1989-90 recorded short and long-finned eels, inanga, common and upland bully, lamprey, common smelt and brown trout.

This project has now been handed over to the client, so that continued maintenance of the "new" stream depends on the developers and the new home owners. To date five of the seven sections which have sold are stream-side sections, which may indicate a spin-off for the developer from the work that has been carried out. The ecological benefits from this project are indirect rather than immediate. The ponds do add a further habitat type to the area, although they are isolated from the main stream. However, they are protecting the values in the Styx River. The action of the Council in making the developer recognise those values, and carry out protective actions sets a precedent for other developments in and around the City.

## BANKWORKS GUIDELINES

Following the different projects carried out for the Christchurch City Council, Boffa Miskell were asked to prepare a handbook for use by their staff and the public when contemplating any work along the local riverbanks. Working with engineers and a landscape architect from the Council, we prepared a series of "Bankworks Guidelines for the Avon, Heathcote and Styx Rivers, and Avon-Heathcote Estuary".

An analysis of existing bank protection work found over 120 different types, ranging from concrete coastal protection to solid timber and to home-made crib walls. There had been almost no attempt in the past to get a co-ordinated approach to works (to avoid use of unsightly or dangerous materials), and certainly no attempt to build ecological principles

**Figure 8 Example of guidelines page for bankworks on Avon River.**

into design or construction.

The Guidelines include general information about the range of techniques possible, as well as river-specific maps, landscape and ecological descriptions, recommended bankworks treatments, suggested species lists and examples of possible cross-sections. Figure 8 is an example of one page of the guidelines, illustrating the information provided for a reach of the Avon River.

**Types of bank work techniques, emphasising soft engineering or bio-technology approaches.** This section comprised a brief review of published material, with ideas developed for Christchurch use. A summary of techniques included:

1. **Earth shaping** i.e. where the riverbank is wide enough, shaping the soil into a self-supporting gradient, which may or may not need geo-textiles or wire meshes for initial soil retention or erosion protection.

2. Use of **vegetation only**.

3. **Timber** – either as horizontal or vertical posts or planks, in terraces for higher banks.

4. **Rock work** – in natural form, such as "dry" stone walls; or as large boulders placed on exposed shore lines.

5. **Gabions** – large rocks wrapped into cubes; earth and plant material can be placed in the rock interstices.

6. **Reno mattress** – placed over gentle slopes and extending underwater; again plants can grow up through the structures.

**Maps showing reaches of each river which have similar landscape ecological character** (see Fig. 8). The river sections were determined through a rapid site survey where vegetation cover, adjacent community character (e.g. residential, commercial), riverbanks topography (which is a reflection of underlying geology or soils as well as modifications), water characteristics (e.g. flow, salinity), and existing bankworks were recorded. These were used to identify reaches, varying in length from about 150 m to over a kilometre, which had sufficiently similar characteristics to warrant similar bankworks treatments. A number of "special sites" were identified within each river, which have particular features which warrant individual consideration when any treatment is being planned. In this category are, for example, historic wharf sites, known whitebait and trout spawning reaches, and canoe launch areas.

There were 17 sections on the Avon, 19 on the Heathcote, 9 on the Styx, and 11 around the Estuary.

**Table 1 Species list for the Avon-Heathcote Estuary.**

**Figure 9 Examples of sketches of desirable cross-sections, from Christchurch Bankworks Guidelines.**

**Descriptions of the ecological and other values of each reach** (see Fig. 8). Brief descriptions were prepared for each reach, using information from the site survey, published material and discussions with people with local expertise.

**Recommendations for each reach.** These comprised general directions about habitat and landscape improvement. For example, in the City centre noting opportunities to manage the whole river to protect trout spawning habitats while maintaining the "Garden City" image viewed by thousands of tourists each year. More specifically, a recommendation was made on whether earthworks, planting, timber etc was appropriate (see Fig. 8).

**Suggested species lists for planting in different areas.** These included both alien and native species, but had an emphasis on the latter. This recognises the existing character of the Christchurch rivers and the strong feelings of the community (voiced on other occasions) that the European tree species and mown grass berms should be retained in many places. However, the guidelines also sought to encourage the use of native species, particularly grasses, sedges, herbs and ferns in the immediate river margins and inter-tidal zones. A series of species lists were drawn up, bringing together proposals made by City conservation groups, the Department of Conservation, City Council landscape architects and other groups or organisations. The lists attempt to recognise the existing and historic character of the different rivers. An example of a species list, for the Avon-Heathcote Estuary, is shown in Table 1.

**Drawings to show possible cross sections.** For different reaches some sketches and plans were provided, as examples rather than prescriptions, encouraging the formation of gentle slopes to allow natural river processes such as flooding to occur. An example of this is shown as Figure 9.

## PHILOSOPHICAL CONSIDERATIONS

Working with urban rivers re-enforces the need to be sure of what values are being managed; and what the objective of restoration is. The concentration of people in urban areas also raises the importance of community perceptions of the natural environment.

These are usually heavily modified environments – the form, bed and cross-section of urban rivers are likely to have been changed, and may be subject to further change through dredging or bankworks. The water quality is not likely to be high, and the whole catchment may have been changed by European development.

For urban rivers then, it does not seem appropriate to aim for the pristine, pre-European settlement ecosystem as a goal – maintenance of this "New Zealand-1850" condition would frequently require high inputs of energy, through planting, earthworks, water management and animal control. This reflects the fact that the environment has probably been modified to an extent that species from that period would no longer survive. For example, to what extent can kahikatea be sustained on the Christchurch floodplains when the City's water-management regime has changed the water table?

Instead, we can try to create a more sustainable "New Zealand-2000" system, with a mix of native and alien species suited to the existing conditions, and planted to provide habitats for the mix of birds, fish and invertebrate species which are able to survive in these conditions. Rather than see urban rivers as places for **restoration** we should use them as places for **creation** of new, sustainable habitats, responding to existing conditions and providing food and shelter for sustainable populations of urban plants and animals. The urban environment as a whole is where most New Zealanders have their day to day contact with "nature". It is a place where ecological and social factors interact to shape the landscape – where the landscape comprises buildings, parks, roads, trees, rivers etc. It seems appropriate to create river and riverbank habitats which reflect the underlying conditions, and will develop "naturally", that is sustainably as conditions change. Given the changes in physical and social environment in urban areas, in most cases it will not be possible to manage restored systems in a sustainable manner. The areas will be in danger of becoming "ecological specimens" in need of intensive care and management.

Conflicts continue to arise between those wanting to use purely native plant species and those favouring exotics in urban areas. These have to be resolved on a case by case basis, and the community view must be considered. There is a tendency to focus on plants *per se*, rather than on the habitats and ecosystems of which they are part.

That is not to say that if there are remnants of pre-European vegetation, or sites used by rare or unusual species, these should not be protected and managed for the benefit of those values. But managers must recognise that the small remnant may not be ecologically viable, and thus possibly of low ecological value – the historic, representative, or educational values must be clearly articulated.

Other values must be identified, and objectives for their restoration considered as part of wider ecosystem management practices. For example, in the Heathcote River there is a healthy whitebait population, apparently thriving in the absence of trout which do not use the silt-laden river. On the other hand, the spring-fed Avon River has a good trout population and fewer whitebait. We need to ask: what will happen to the whitebait if we are ever successful in controlling stormwater run-off from the Port Hills and thus reduce sediment levels in the Heathcote? Following on from this we must consider the value of a trout-free river system in an urban environment.

Although riverbank restoration work is becoming more common in New Zealand, projects are still usually "engineer-driven". Habitat creation or restoration plans are often incidental to river management projects, rather than being the primary goal. The experience of riverbank work in Christchurch suggests that there are opportunities for ecologically valuable areas to be created and managed, providing that these are considered early enough in the programme. There is still heavy dependence on the project leader being aware of the opportunities, bringing together a range of expertise to provide sustainable solutions and having the courage to promote what are still considered by many as being "alternative" solutions.

## FUTURE DIRECTIONS

There **is** a growing awareness of the values of the natural parts of the urban environment, and waterways are an important feature of almost every town and city in New Zealand. However, one of the greatest constraints on recognition of ecological values and opportunities in rivers (and other ecosystems) is the lack of appropriate expertise within many local and regional authorities. These bodies have wide-ranging responsibilities for water management. Until in-house staff attain greater understanding of the ecological aspects (matching that of physical processes developed under the former catchment boards) there will not be an integrated approach to river engineering or management. The Resource Management Act should give Councils the direction, but many have been slow to follow.

New district and regional planning processes should contribute to the clarification of environmental objectives for urban rivers. Through the background investigations and public consultation processes, it should be possible to develop strategies and practical opportunities for sustainable management.

With respect to projects for bankworks restoration, there are likely to be developments in materials and methods. The work in Christchurch described earlier in this report was viewed very much as trialling. Almost all the technological developments in bank restoration materials have taken place overseas, and in the future these will have to be adapted to New Zealand conditions and resources. The wool matting is a good example of such a step. Developments are now needed in the use of New Zealand native plants for rapid revegetation, to replace quick growing species such as lotus (*Lotus major*). Expertise in the propagation of native sedges, rushes and riparian herbaceous species, for example raupo (*Typha orientalis*), would assist by widening the options for vegetation cover.

Rural waterways, including drains, and their values as habitats for aquatic animals are still neglected. However, the need to recognise their significance as habitats of local value (under S. 6 of the Resource Management Act) means that more research and inventory should be carried out. Rural water courses continue to be damaged by annual maintenance programmes, as well as by a range of land and water uses, even though they constitute significant sites for native species in many areas.

Finally, the multi-disciplinary approach, using the physical sciences to create the right conditions for sustainable plant and animal communities, must be developed. There has been a traditional separation of geomorphologists, hydrologists, ecologists, landscape architects and social scientists into separate organisations. In turn, these have often been distant from community views. The Resource Management Act, local government reorganisation, changes in Crown Research Institute structures and a general growing environmental awareness should all contribute to better management of urban waterways in the future.

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