Shelley McMurtrie

Hill Waterways

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View of the Avon-Heathcote Estuary/Ihūtai from Mt Vernon (top), view of the Port Hills from Lyttelton Harbour (bottom)

7.1 Port Hills Values

The Port Hills, known to Māori as K̲a Kōhatu Whakarak̲arak̲a o Tamatea Pokai Whenua (the flaming rocks of Tamatea Pokai Whenua), are among the best-loved areas of Christchurch. Visitors and residents alike go there to enjoy panoramic views of the city and the Canterbury Plains. Hill properties with such views are highly sought after. Moreover, the Hills themselves are prominent landmarks, visible both within the city and from well beyond.

The variety of values associated with the Port Hills accounts for much of their appeal; an impressive range of landscapes can be observed, including prominent geological formations such as Castle Rock and the volcanic Multiple Dykes. Rocky outcrops are a well recognised sight at the summit and the heads of valleys. Tussock grasslands extend throughout the Hills, tending to greater density at higher altitudes and on south-facing slopes.

Native forest is more extensive in the higher rainfall south-west than in the sparsely vegetated and drier east. Small pockets of native bush abound in gullies and on shadier slopes, ranging from small remnant patches of ancient podocarp (e.g. totara, matai, and kahikatea) to areas of regenerating bush.

Wildlife values are also significant. Native birds were once plentiful; during the 1850s ornithologists reported that old growth forests supported some of the most prolific bird life found anywhere in New Zealand (Crossland 1996). Unfortunately, since that time bird numbers have declined dramatically. Today, with revegetation projects underway in several areas and natural regeneration occurring in others, it is hoped that native birds will recover their numbers and thrive in the future.

Numerous invertebrates and at least three species of native lizard are found throughout the Port Hills. Little is known about the invertebrates but, as with native birds, much can be done to increase their diversity and numbers.

The Port Hills are recognised not only for these values that relate to the physical environment, but also for values associated with human activity (Figure 7-1). The area contains an intricate web of sites that are important to people. Recreational opportunities are plentiful and include walking, tramping, running, mountain-biking, horse-riding, parapenting, and rock climbing. Much of the essence of the Port Hills' heritage has been captured by Gordon Ogilvie (Ogilvie 2000).

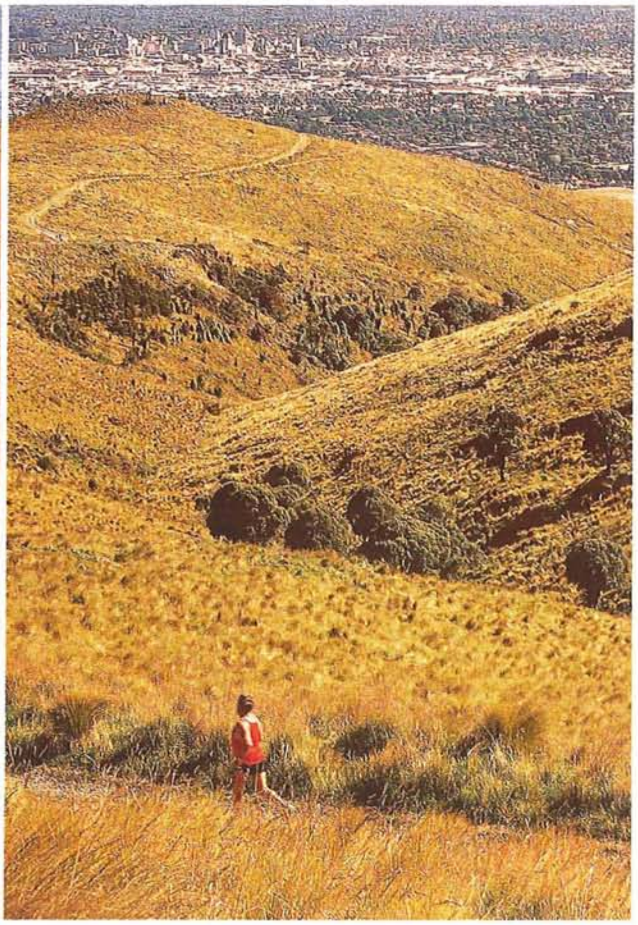

Figure 7-1: The Port Hills are among the best loved areas of Christchurch. The panoramic views of the city and recreational opportunities, including walking and mountain biking, are only some of the values the Port Hills offer.

Figure 7-2: Ephemeral hill waterways are a distinctive feature of the Port Hills landscape. Glenstrae Stream at Drayton Reserve (top), Bridle Path Stream in a private garden, upper Heathcote Valley (above).

7.2 Waterways and Wetlands Natural Asset Management Strategy for the Port Hills

During the past ten years a major shift has taken place in the management of Port Hills waterways and wetlands. The change has emphasised working with nature as well as protecting and restoring the natural qualities of the Port Hills environment.

The Christchurch City Council's Waterways and Wetlands Natural Asset Management Strategy (Christchurch City Council 1999) identified the objective of restoring forested valleys throughout the area. The Strategy envisions the Port Hills as "a breathing place of forested gullies, clear water, and open tussocklands; a refuge for wildlife and an immediate space for people to enjoy".

Important components of the vision include:

- managing soil conservation (Trangmar in press)
- grazing management (McCombs et al. 2001)
- establishing ecological and recreational links
- mapping residential area flood hazards
- identifying and protecting secondary flow paths
- naturalising waterways
- ensuring that future development is sustainable
- developing a sea-level rise strategy.

Working in partnership with landowners and the many interest groups of the Port Hills is vital to the success of implementing such a vision.

While the majority of the Port Hills waterways are ephemeral, they are a distinctive feature of the landscape (Figure 7-2). Runoff from the 25 main catchments within the City feeds into the Halswell River/Huritini, the Heathcote River/Ōpāwaho, or directly into the Avon/Heathcote Estuary (Ihūtai) or Pegasus Bay. Much sediment, including loess, is washed into the rivers during heavy rainfall storm events and causes the rivers to become muddy-brown in colour.

It is worth noting that several springs, ponds, and wetlands are found throughout the Port Hills, while a few waterways with year-round flows are located in the south-western end of the Hills.

7.3 Loess Deposition and Erosion Characteristics

The Port Hills mainly consist of volcanic colluvium with varying levels of loess deposition. Loess found on the Port Hills has been carried on the wind from flood plain deposits, and began arriving at the Port Hills around 30,000 years ago, as the major river flood plains extended eastward. As time has progressed three distinct loess depth zones have developed; known as S (surface), C (clay), and P (parent) zones (Table 7-1).

Loess soils are highly erodible and are an important consideration when dealing with hill waterways and development on the Port Hills. Loess is dispersive when wet and prone to shallow seated landslides or tunnel gullying (under runners). Studies of this process support a desiccation crack origin due to wet and dry cycling. The control of surface and sub-surface water is a key factor in maintaining stability of loess slopes.

The problems with loess arise because it tends to be single-sized, and so is open and permeable. The dispersive characteristic of loess is due to electrostatic repulsion of wetted particles caused by the presence of sodium ions. However, this dispersion can be overcome by treating with hydrated lime (CaOH; of which calcium is the active ingredient), after which significant cohesiveness develops. Hydrated lime is not to be confused with garden lime, which is crushed calcium carbonate ($CaCO_3$).

It has been observed that if the slope reduces to 35° (or less) then surface slippage ceases, but surface vegetative protection along with redirection of surface water must also be carried out to prevent rilling and general surface erosion.

7.4 Design Considerations for Hill Waterways

Design of hill waterways presents special challenges because of their sensitivity to high intensity storms of short duration, with consequent high runoff per unit area (Figure 7-3). Steep slopes make control of runoff difficult, owing to high water velocities and the erosion-prone loess soils that are found in many hill gullies and on valley floors.

The major concern for most hill waterways is the stabilisation of bank and channels in the erosion prone loess soils, and to contain within the channels the high intensity flows that can often occur during periods of rain. While these factors can be achieved using heavily artificial solutions, it is important to create an environment that is as natural as possible, and that is harmonious with the surrounding landscape.

Figure 7-3: Port Hill waterways can experience short duration floods of high flows, usually of brown colouration due to the presence of loess. Richmond Hill waterway, October 1989.

Table 7-1: Basic characteristics of the three basic loess zones.

Loess Depth Zone	Characteristics
S (surface zone)	Dispersive. Generally 0.3 to 1.5 meters deep. Often contains organic matter. Prone to shallow 'rabbit hole' under-runners.
C (clay zone)	Clay has been carried downwards from the S zone by percolating water to form a relatively hard and stable layer. Tends to be a lighter colour because of the clay content.
P (parent zone)	Weak, soft, highly dispersive. Prone to deep under-runners. Density typically only 80% of standard compaction due to deposition by wind transportation.

Basic Considerations

Where the channel invert is on rock or volcanic colluvium, there is no need for any bank and channel stabilisation as such. The main concern is to retain the flow within the natural boundaries of the channel. See *Section 7.4.1: Reducing the Erosive Power of Water.*

Where the predominant soil type is loess, the main concern is for bank and channel stabilisation. There is a need to armour the surface and limit subsurface seepage, while also limiting velocities. Refer to *Section 7.4.2: Bank and Channel Stabilisation.*

Bridge crossings over hill waterways are strongly preferred to culverts to satisfy landscape criteria and minimise the risk of blockage. Where culverts are used, they are required to be over-sized in terms of hydraulic capacity with the invert partially buried (see *Chapter 13.2: Bridges and Culverts*).

A wide range of measures to reduce the erosive power of water, and stabilise banks and beds, has been used on Port Hills waterways. These measures include planting as well as harder engineering solutions, and sometimes combinations of both. Some measures and their purposes are described in the following sections, with a summary provided in Table 7-2.

Many hillside waterways discharge into pipe systems upon arriving on the valley floor. Inlets at this point are susceptible to debris related blockage, leading to downstream property flooding and damage. For example, most property damage sustained in Sumner and Redcliffs during the October 2000 storm resulted from pipe inlet blockages and consequent surcharges or overflows. Such pipe systems, especially those terminating on flat grades with tidal outfalls, also have sedimentation related maintenance problems.

Discharge of hill waterways into piped systems is undesirable; it is preferable that flow be kept in an open waterway. Where discharge into a pipeline is unavoidable, then the entry area must incorporate sedimentation retention, a heading up area, a pipe entry grill, a debris trap, the identification and protection of a secondary flow path, and assessment of likely pipeline sedimentation, along with ongoing maintenance provisions. See Chapters *13.4: Grills in Waterways; 14.6: Pipe Inlet Structures; 14.2.4: Longitudinal Gradients (Minimum Gradients).*

Table 7-2: Summary of typical measures for soil conservation and erosion mitigation of Port Hills catchments and waterways, with examples of their application.

Measure	Examples of Application					
	Richmond Hill	Dry Bush/ Mt Vernon Farm Park	Avoca Valley	Whites Drain	Mt Pleasant Stream	Glenstrae Valley
Grazing Management	■	■	■			
Slope Dewatering						
native vegetation		■		■	■	
exotic vegetation			■	■	■	
contour cutoff drains				■		■
control at source				■		
Vegetation						
for control of riparian sediment/ water delivery to stream	■	■	■			
Bank or Bed Lining						
unprotected bank/bed	■	■	■			
grassed channel on stabilised base				■		■
tree roots for bank/slope stability		■	■	■	■	
rock lining	■		■			■
stepped cascade						■
concrete lining	■		■	■		
baffled concrete				■		
concrete and cemented rocks	■					■

7.4.1 Reducing the Erosive Power of Water

Increasing channel bed roughness slows or breaks up water flow, and reduces the erosive power in the channel. Reducing the erosive power of water flow is a major factor for contributing to the stabilisation of the banks and channels of hill waterways.

Features such as cascading steps and extensive use of embedded rocks and margin planting should be included to keep otherwise high and unmanageable velocities within a manageable range (for example, less than 2.5 m/s). Additionally, weepholes should normally be provided. Methods for increasing bed roughness are detailed below.

Structural Methods

- baffles on the base of concrete channels
- placeing rocks on the banks and in the channel (Figure 7-4)
- super elevation on the outside of bends
- a controlling wall on the outside of bends
- the inclusion of a series of cascading drops and pools (Figure 7-5). Cascading drops are the preferred method for implementing changes in the flow direction in a hillside channel. They dissipate energy and can also become landscape features if designed properly. The crest line of the drops must be square to the channel downstream, but may be angled relative to the channel upstream. For stepped cascade design, refer to Chanson (1994).

Vegetative Methods

- planting of vegetation in and across the stream channel (Figure 7-6, see over page)
- the use of planter mats with grasses sown into the channel
- refer to *Section 7.4.2.1: Planting for Bank and Channel Stabilisation*, for planting techniques.

7.4.2 Bank and Channel Stabilisation

Bank and channel stabilisation can be achieved by the following methods:

Structural Methods

- concrete lining (now discouraged as a method)
- rock lining of the waterway channel, bank, or both (Figure 7-4)
- placement of rip rap of an appropriate size and roughness. In areas where rip-rap is used, voids beneath should be filled to protect the underlying strata, and to minimise the possibility of hydraulic uplift forces mobilising the rocks.

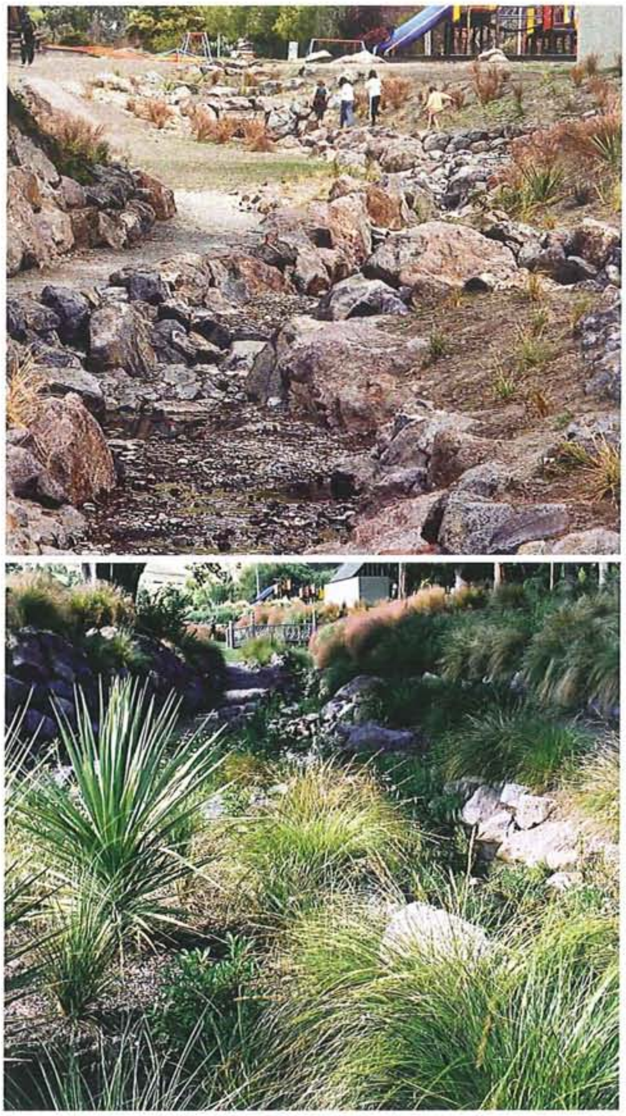

Figure 7-4: Structural methods for dispersing water flow include the secure placement of rocks within the channel and along the banks. Bridle Path Stream at Heathcote Domain before (top) and after (above) plant growth.

Figure 7-5: A series of properly designed cascading drops and pools will dissipate water flow energy and so reduce the erosive power of the flow. The growth of vegetation along the waterway banks will help to soften an otherwise hard structure. Unnamed Stream, Augusta Street.

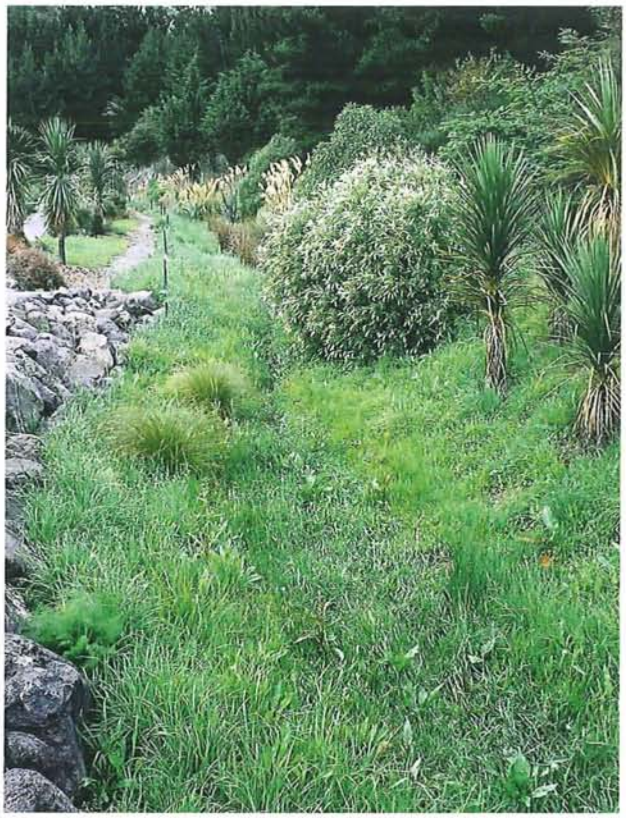

Figure 7-6: Planting grass in the waterway channel and vegetation on the bank is a soft alternative for bank and channel stabilisation. Glenstrae Stream at Drayton Reserve.

Figure 7-7: Smooth, steep, concrete cast channels result in fast, unmanageable water flows that are not acceptable for hill waterways.

Vegetative Methods

- planting of vegetation in and across the stream channel (Figure 7-6)
- the use of planter mats with grasses sown into the channel, or grassed channels
- refer to *Section 7.4.2.1: Planting for Bank and Channel Stabilisation*, for planting techniques.

Previous Methods Used for Channel Stabilisation

Past channel stabilisation methods were structural, including concrete lining or piping of waterways:

- Concrete-lined channels were designed to quickly remove peak flows during intermittent high flow periods. However, smooth steep channels such as these can lead to excessive and unmanageable velocities (Figure 7-7) and are now discouraged except for small systems.
- In the past some hill waterways have been piped, This is now strongly discouraged because piping destroys the natural character of the waterway, and pipe inlets on hill waterways are very prone to blockage and bypass by high velocity storm flows. This has frequently led to property damage on poorly protected secondary flow paths.

7.4.2.1 Planting for Bank and Channel Stabilisation

The establishment of vegetation along Port Hills waterways can be expected to improve general soil and channel stability. This might be best applied in the upper catchments, ephemeral feeder channels, and in gentler, confined, and accumulating swampy channels of the mid-catchment. In steep, eroding channels where there is high velocities, the emphasis should be on establishing plants on the channel banks and floodplain rather than on the channel beds (where vegetation could result in sedimentation and channel aggradation that might reduce bank stability). Where sediment trapping is contemplated, it may be appropriate to densely plant stream channels, beginning at the headwaters and moving down.

Tussock rushes, New Zealand flax, cabbage tree, toetoe, and ribbonwood are suggested as the principal restoration species. Grass swards could be more appropriate in downstream channels (Figure 7-6), seepage zones or discharge points. Consider using tussock species, as a native alternative to grass.

Vegetation increases slope stability by reducing water content in the soil and binding soil within the root zone. Large, fast growing trees use the most water and will therefore be most effective at dewatering saturated soils. In particular, dewatering seepage slopes can be achieved by dense plantings of lowland ribbonwood, cabbage trees, karamu, kohuhu and New Zealand flax, and eventually by large trees. Headwaters and channel margins may be stabilised with New Zealand flax, tussock rushes and sedges, toetoe, cabbage trees, and koromiko (margins).

Tree and shrub establishment on loess-mantled hill slopes should improve slope stability. Dense native forest plantings can be contemplated where there is sufficient space along wandering channels on the lower fan sections of catchments, and around seepage zones or discharge points. Table 7-3 shows a suggested concentric zoning of faster growing indigenous species away from a waterway or point source of stormwater discharge.

After establishment, some level of grazing can sometimes be used to control weeds around plantings of browse-tolerant plants. However, stock access to waterway banks can cause considerable bank damage, and stock will consume palatable native plants. If grazing is not used, plantings may need to be fenced off and alternative weed management used initially.

The following publications have further information on native planting for erosion protection:

- Meurk et al. (1998): outlines stabilisation and enhancement options for Port Hills' waterways
- Van Kraayenoord & Hathaway (1986): discusses the requirements of soil conservation plants
- Pollock (1986): discusses the selection of suitable native plants and specific requirements of over 70 natives for soil conservation.

Rooting Systems

The shallow, fibrous roots of densely growing species, especially sward grasses, are important stabilisers of surficial rill erosion. The roots of toetoe, rushes, and New Zealand flax (harakeke), while still shallow, are tougher and more strongly binding, with the ability to tie in large slabs of topsoil. Many native small trees and shrubs have relatively shallow roots, but their contribution to slope stability is enhanced by high density of stems and the interlocking of individual root systems.

The lateral and deep anchoring tap and sinker roots of some trees have the greatest potential for inhibiting slumping on hills. These include cabbage trees among the natives (Figure 7-8) and selected non-invasive introduced species. Vertical (tap or sinker) roots develop best in a well-drained, deep, loamy soil. Rooting depth will be limited by the high water table associated with riparian zones, but if trees or tussocks within this zone are contiguous with trees growing in deep, loamy soil that is better drained, then the interlocking of root systems is likely to enhance the stability of riparian planting.

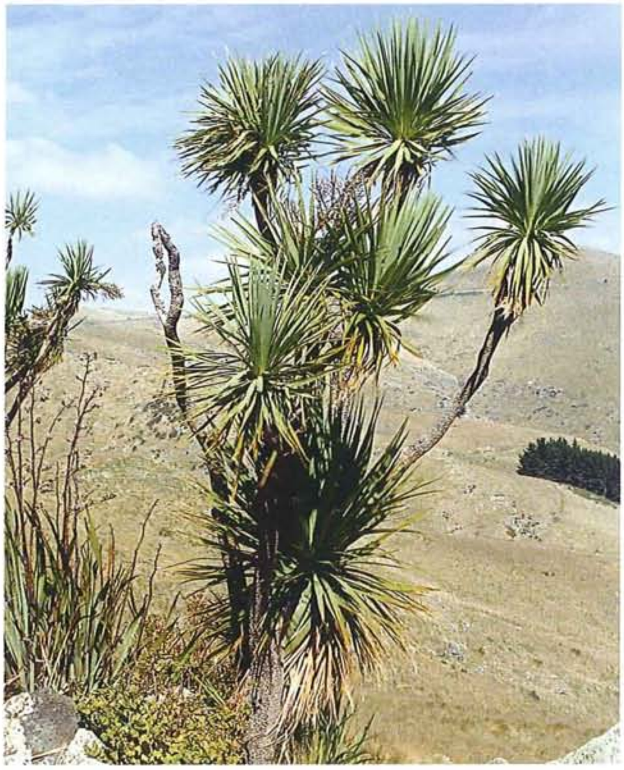

Figure 7-8: Cabbage trees (Cordyline australis, tī kōuka) are efficient at dewatering seepage slopes, and have deep anchoring tap and sinker roots that have great potential for inhibiting slumping on hills.

Table 7-3: Concentric zoning of plants away from a stormwater discharge or waterway. Also refer to Lucas et al. (1997).

Planting Zone	Species
Closest Zone Channel edge, seepage slopes and part floodplain	A gradient of tussock rushes, New Zealand flax, toe toe, and cabbage trees.
Middle Zone Part floodplain and moist bank	Lowland ribbonwood, karamu, kohuhu, cabbage trees, kahikatea, pokaka, five finger, broadleaf, and kowhai.
Upper Zone Dry slope forest (well drained)	Ngaio, akeake, narrow-leaved lacebark, lemonwood, totara, matai with an understory of hounds tongue fern, wind grass, bush lily (damper places).

7.4.3 Determining the Best Solution for Hill Waterways

The options that have been outlined in this section are relevant for different situations; no single measure can be applied universally. The appropriate measure(s) to use in any given waterway (or section of waterway) will depend on several factors, including:

- objectives of stream bank/bed management (e.g. water removal, bank erosion control, ecological, historic, landscape or recreational values)
- reaching a balance between the structural and vegetative solutions, that takes into account future management options and issues (Figure 7-9)
- flooding potential for the waterway, including the frequency, size and erosive power of the flood, and projected costs of flood damage
- the costs of bank/bed management measures at the site
- the source of funding for any work, for example, the Christchurch City Council, developer or landowner.

The aesthetic and ecological values of the waterway must always be taken into account irrespective of other objectives.

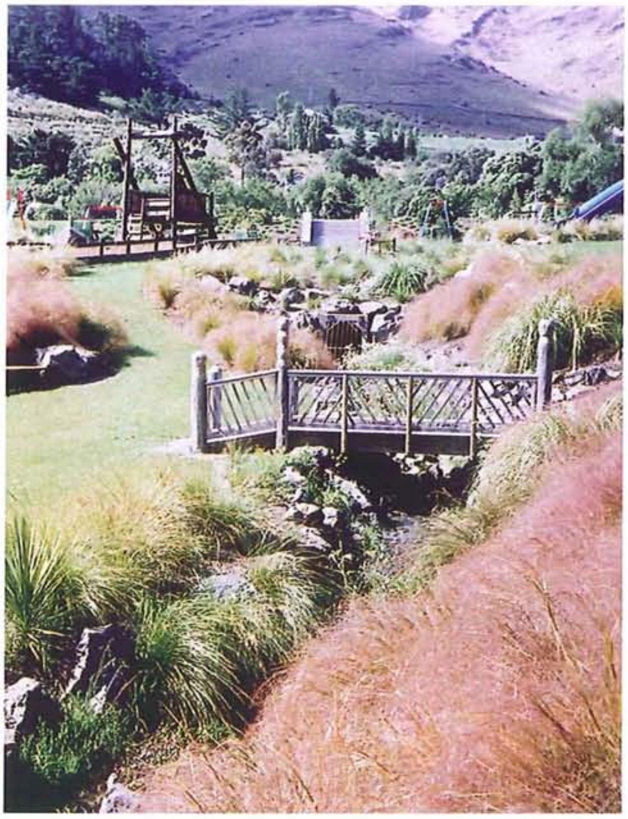

Figure 7-9: The combination of structural methods of bed and bank stabilisation (rockwork) with softer vegetative methods have created a natural looking hill waterway, structurally able to withstand flood flows. Bridle Path Stream at Heathcote Domain.

7.5 Guiding Principles for Designers

Stormwater Discharges on the Port Hills

- Ensure that all discharges are controlled at the source. Proper design of stormwater disposal into approved outfalls is of paramount importance.
- Intercept or cut off potentially uncontrolled stormwater discharges.
- Provide energy dissipation at all points of discharge to natural slopes or waterways.
- Spread, rather than concentrate discharges. The 'leaky hose' concept, coupled with the use of energy dissipaters and maintenance of a mix of multi-storey vegetation, has great potential as an effective method of source control, that involves dispersion of water disposal over a wider area. Inspection of outlets from time to time is essential where discharge is not onto bedrock, and maintenance must be undertaken as required to maintain the spread discharge. Beware that continuous discharge over extended periods can saturate and destabilise a slope. A smaller diameter base flow pipe capable of safely conveying a trickle flow will be preferable in such situations with higher flows discharged overland.
- Do not discharge stormwater onto slopes that are unstable or contain under-runners. In these circumstances it is safer to capture and divert the stormwater, so as to reduce the down-slope hazard.
- Consider installing rainwater retention tanks.

Slope and Channel Stabilisation

- Always design for both water control and soil conservation.
- Treat each site on its merits, but use knowledge gained with methods adopted at existing sites.
- The feeder, gentle accumulation, steep eroding, and lower fan sections of a catchment should be treated differentially as recommended.
- Plant appropriate indigenous vegetation where possible in order to maximise values such as landscape, heritage, and ecology.
- Always adopt a multi-disciplinary design approach. For example, landscape architecture, ecology, hydraulic and geotechnical engineering.

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