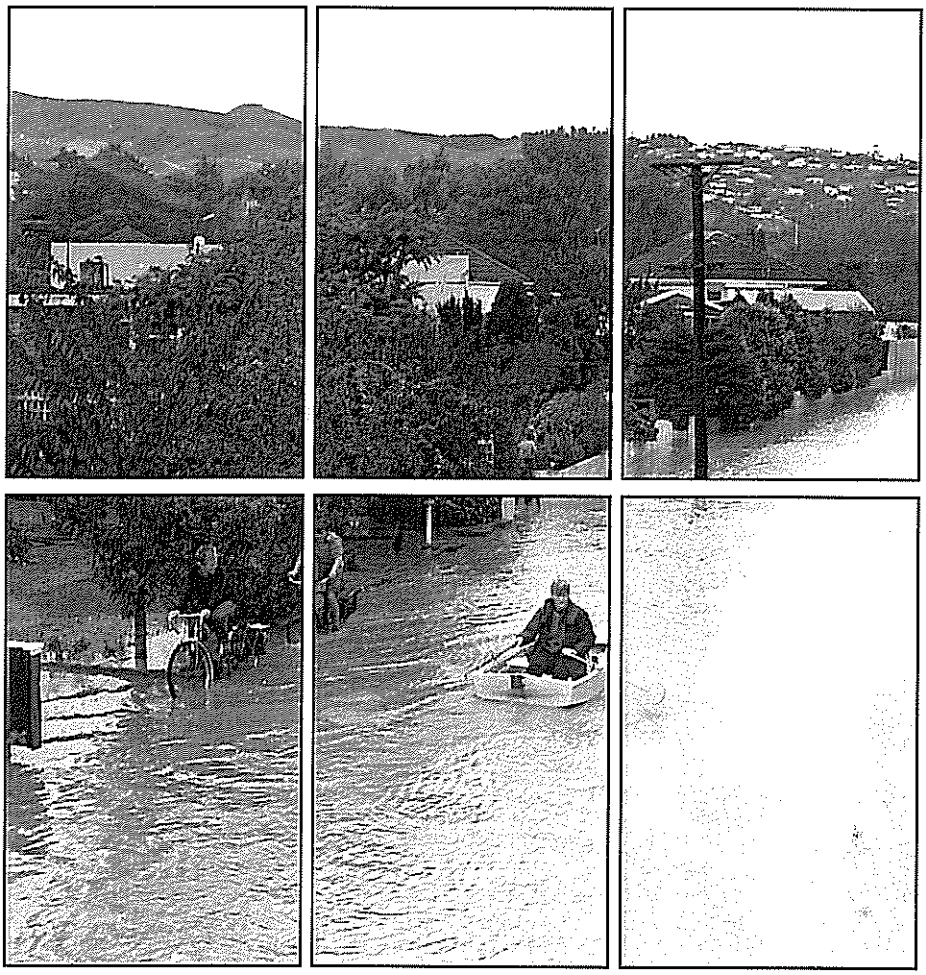
Heathcote River Floodplain Management Strategy



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Christchurch City Council

Heathcote River Floodplain Management Strategy

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Executive Summary

Background

The Heathcote River is susceptible to flooding. Over time the modification and development of the Heathcote River catchment and floodplain has resulted in the exposure of significant assets to the natural occurrence of flooding and has altered the pattern of flood events. Future development and modification of the floodplain and catchment will expose further assets to the effects of flooding and continue to impact on the natural flood process. A major flood could cause significant flood damage.

In response to the existing and future flood damage potential, the Christchurch City Council and Canterbury Regional Council have jointly prepared the Heathcote River Floodplain Management Strategy. The purpose of the strategy is to:

> *to achieve an acceptable level of flood damage on the floodplain of the Heathcote River by integrating the management of the use, development and protection of natural and physical resources.*

The strategy represents a non-statutory response to the flood damage issues of the Heathcote River floodplain. It provides a strategic overview of the management issues and develops solutions. This strategy will guide policy and operational decisions of both the councils.

Heathcote River Catchment

The Heathcote River drains a catchment of approximately 100 km^2 in the area above the Ferrymead Bridge, flowing into the Avon-Heathcote Estuary. It flows in a channel incised into the Waimakariri River gravel outwash fan, which is estimated to be able to accommodate up to a five year flood. Spring fed headwaters sustain the base flow of the river. The largest tributary is the Cashmere Stream, which drains the western Port Hills. The River is subject to tidal influences in its lower reaches.

While the catchment traditionally supported large swamp systems, it is now extensively developed for both urban and rural purposes. It is estimated that the catchment is 40% urbanised overall, with the upper catchment (upstream of Heathcote River/Cashmere Stream confluence) being only 29% urbanised. Further urbanisation of the catchment is anticipated in response to population increase. This urbanisation is expected to take two forms; the intensification and redevelopment of those parts of the catchment that are already urban, and the development for urban purposes of some parts of the catchment that presently are not urban (particularly the upper part of the catchment, including the Cashmere Stream sub catchment). However, it is not for this strategy to determine the amount, and location, of this urbanisation, but rather to provide guidance on how any resulting increases in flood damage can be mitigated.

Floodplain Management Issues

A number of Heathcote floodplain management issues have been identified. These are:

Floodplain Area	Present Day Issues	Future Issues
Lower[1]	Potential tidal flood damage	Increase in potential tidal flood damage due to sea level rise and new development
Middle[2]	Potential flood damage as a result of significant rainfall events	Increase in potential flood damage as a result new development and redevelopment in the middle of the Heathcote River catchment
		Increase in potential flood damage as a result new development in the upper part of the Heathcote River catchment in areas of relative pervious soils
		Increase in potential flood damage as a result new development in the Cashmere Stream sub catchment in areas of relative impervious soils
Upper[3]		Potential flood damage as a result of inappropriate development of the Waimakariri River overflow channels

Management Principles

The following 6 principles have been be developed to guide this strategy:

1. *Integrated land and water management on a catchment wide basis*
2. *Development and redevelopment should minimise, as far as practical, flood damage*
3. *Over time the number of existing buildings subject to flood damage should be reduced*
4. *Choices between floodplain management measures should favour those that are environmentally (including people and the community) sensitive where the floodplain management measures are roughly comparable*
5. *Individuals should be provided with adequate information to make informed decisions*
6. *The selection of the bundle of floodplain management measures should be guided by the economic consequences of their implementation.*

[1] Generally described as that part of the floodplain from the Estuary of the Avon and Heathcote Rivers to Woolston

[2] Generally described as that part of the floodplain from Woolston to the confluence of the Heathcote River and Cashmere Stream

[3] Generally described as that part of the floodplain above the confluence of the Heathcote River and Cashmere Stream

The Strategy

The Heathcote River floodplain management issues identified are to be managed as follows:

Floodplain Area	Issue	Management Measures
All	All	Development and implementation of information and education programmes Continuation of adequate warning and emergency procedures and programmes Requiring financial contributions from developers Encouragement of minimisation of hard surface areas
Lower	Potential tidal flood damage	Maintenance of the existing floodplain management measures Localised stopbanks to protect individual properties in and around Woolston Loop Minimum floor levels
	Increase in potential tidal flood damage due to sea level rise and new development	Maintenance of the existing floodplain management measures Restriction of development on the tidal floodplain area that has yet to be developed Localised stopbanks to protect individual properties in and around Woolston Loop Minimum floor levels
Middle	Potential flood damage as a result of significant rainfall events	Maintenance of the existing floodplain management measures Minimum floor levels
	Increase in potential flood damage as a result new development and redevelopment in the middle of the Heathcote River catchment	Maintenance of the existing floodplain management measures Enhancement of the Cashmere/Worsleys Valley ponding area Maintain river setbacks Minimum floor levels
	Increase in potential flood damage as a result new development in the upper part of the Heathcote River catchment in areas of relative pervious soils	Maintenance of the existing floodplain management measures Community soakage Swale systems Roof water directly into soakage
	Increase in potential flood damage as a result new development in the Cashmere Stream sub catchment in areas of relative impervious soils	Maintenance of the existing floodplain management measures Community retention through 'green corridors' Swale systems
Upper	Potential flood damage as a result of inappropriate development in the Waimakariri River overflow channels	Avoid high risk/high damage development (e.g. industry and hospitals) in Waimakariri River overflow channels

Taken as a whole, these measures will:

- manage development in areas particularly susceptible to flood damage;
- provide localised mitigation for the industrial and other areas associated with Woolston Loop;
- over time mitigate flood damage caused by the development and redevelopment of the middle of the catchment;
- significantly reduce the effects on flood damage from development in the upper part of the catchment (including the Cashmere Stream sub catchment); and
- reduce potential damage caused by the flooding of high risk/high damage development in the Waimakariri River overflow channels within the upper part of the catchment.

Implementation of the Strategy

The various measures will need to be implemented as:

- capital works (e.g. land modification, purchase and river control measures) incorporated in the Christchurch City Council's Financial Plan and Budget;
- statutory resource management responsibilities of Christchurch City Council (e.g. City of Christchurch City Plan). This may require variations or changes to the City Plan;
- yearly activities (e.g. community preparedness measures) incorporated in the Christchurch City and Canterbury Regional Councils financial plans and budgets.

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1 Introduction

1.1 Purpose

The purpose of the Heathcote River Floodplain Management Strategy is:

> *to achieve an acceptable level of flood damage on the floodplain of the Heathcote River by integrating the management of the use, development and protection of natural and physical resources.*

The Heathcote River is susceptible to flooding, and within the context of Christchurch City is thought of as a 'rogue' unlike its 'well behaved sisters' the Avon and Styx Rivers (Canterbury Regional Council and Christchurch City Council 1993). Over time the modification and development of the Heathcote River floodplain and wider catchment has resulted in the exposure of significant assets to the natural occurrence of flooding and altered the pattern of the flood events. Future development and modification of the floodplain and catchment will expose further assets to the effects of flooding and continue to impact on the natural flood process. While where floodwaters flow over roads, grassed berms, or reserves, relatively minimal damage occurs, inconvenience becomes flood damage where the silt laden, and saline tidal, floodwaters of the Heathcote River enter garages, houses and other buildings. There is a long recorded history of such events. A major flood could cause significant flood damage within the Heathcote River floodplain.

The study area is defined in Figure 1 page 6, being the Heathcote River catchment.

1.2 Strategy Status

The Christchurch City Council and Canterbury Regional Council have jointly prepared the Heathcote River Floodplain Management Strategy. The strategy represents a non-statutory response to the flood damage issues of the Heathcote River floodplain. It provides a strategic overview of the management issues and solutions. This strategy will guide policy and operational decisions of both the councils.

To be successful the strategy relies upon the commitment of the Canterbury Regional Council and Christchurch City Council to implement its findings. In the main, the implementation of the strategy is reliant on the Christchurch City Council responding through a range of its planning processes - resource management, asset management and financial.

The strategy represents a culmination of technical work and the bringing together of institutional and community knowledge. It is designed to be a living document. Therefore, as our understanding of the Heathcote River floodplain management issues and the range of potential solutions change, so the strategy will need to be revisited. It is anticipated that, at a minimum, the strategy should be reviewed in advance of each statutory review of the Christchurch City Plan – every ten years.

1.3 Strategy Preparation Process

The preparation of this strategy has occurred over a number of years. Key steps include:

- Computer modelling and assessment of flood damage scenarios in 1993 (Oliver and Peters 1993);
- Publication of a discussion document in 1993 (Canterbury Regional Council and Christchurch City Council 1993);
- Analysing the submissions to the discussion document (Taylor Baines 1993);
- Remodelling and assessment of flood damage scenarios and the effectiveness of measures by the Christchurch City Council in 1997;
- Reassessment of the economic value of flood damage (Brown Copeland, 1997);
- Preparation of a Draft Heathcote Floodplain Management Strategy (Canterbury Regional Council and Christchurch City Council, 1998);
- Analysing the comments to the Draft Heathcote Floodplain Management Strategy (Canterbury Regional Council, 1998b); and
- Consultation with the tangata whenua through the Canterbury Regional Council's Iwi Liaison Manager.

During the preparation of this strategy a number of significant events occurred that have affected its outcome. These include:

- The Canterbury Regional Policy Statement being operative on 26 June 1998; and
- The public notification of the Proposed Christchurch City Plan in 1995 (Christchurch City Council, 1995).

Both the Regional Policy Statement and Proposed City Plan contain direction on how flood damage issues are to be managed. Further, the City Plan is one of the implementation mechanisms for this strategy. Also, the notification of the Proposed City Plan provides for, and a number of the resulting submissions seek, development opportunities in parts of the Heathcote River catchment that potentially exacerbate the present floodplain management issues.

Finally, the Optimax Research Associates (1996) report prepared for the Water Services Unit of the Christchurch City Council has been an important resource document for the preparation of this strategy. The report investigates matters of resource management significance to the tangata whenua in the upper part of the Heathcote River catchment.

1.4 Statutory Context

The Canterbury Regional Council and the Christchurch City Council have wide ranging powers, functions and duties with respect to the management of the Heathcote River floodplain. The Christchurch City Council's powers include those prescribed in the Building Act 1991, Resource Management Act 1991 and Local Government Act 1974, while, in this context, the Canterbury Regional Council's powers principally relate to the Resource Management Act.

The City Council has the power to control building work and the use of buildings in terms of the Building Act 1991. Section 36 of this Act prescribes the circumstances

where the Christchurch City Council must refuse to grant a building consent when land is subject to inundation. The Building Code also prescribes that new residential activities must be protected from a 2% Annual Excedence Probability[4] (50 year) flood event.

The purpose of the Resource Management Act 1991 (section 5) is:

> *(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.*
>
> *(2) In this Act, "sustainable management" means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while -*
>
> *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
>
> *(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
>
> *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.*

The New Zealand Coastal Policy Statement 1994 provides that *in relation to future subdivision, use and development, policy statements and plans should recognise that some natural features may migrate inland as the result of dynamic coastal processes (including sea level rise)* (Policy 3.4.4).

Both councils have natural hazard management functions in terms of the Resource Management Act 1991. Two functions are particularly relevant to the Regional Council, being *the control of the use of land for the purpose of the avoidance or mitigation of natural hazards* (section 30(1)(c)(iii)) and *in relation to any bed of a water body, the control of the introduction or planting of any plant in, on, or under that land, for the purpose of the avoidance or mitigation of natural hazards* (section 30(1)(g)(iv)). The Christchurch City Council has similar functions with respect to land, being *the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazard* (section 31(b)).

It is also note worthy that section 62(1)(ha) of the Resource Management Act provides for the Regional Council, through its Regional Policy Statement, to delineate responsibilities between itself and the City Council for the development of objectives, policies and rules to control the use of land for the avoidance or mitigation of natural hazards. The Regional Policy Statement does this. In short, the responsibility for the management of natural hazards lie where they fell on 1 January 1994, and where the responsibility is not clear, the Regional Council retains primary responsibility. The

[4] The chance of a flood occurring is defined in the same way as any other statistical event. For example, a 2% Annual Excedence Probability flood (50 year flood) is one that has a 2% chance of being equalled or exceeded in any one year. As time passes without such an event occurring, statistically the probability of the event occurring increases.

Regional Policy Statement also provides that the Regional Council, in consultation with the territorial authorities, will review these responsibilities.

Further, section 74(2)(a) of the Resource Management Act 1991 states that *when preparing or changing a district plan, a territorial authority shall have regard to any proposed regional policy statement or regional plan on a matter of regional significance in respect of its district.* Section 75(2)(c) requires the *a district plan shall not be inconsistent with the regional policy statement, or any regional plan of its region in regard to any matter of regional significance or for which the regional council has primary responsibility under Part IV.*

The key objectives in the Regional Policy Statement are to:

> *Within urban areas and settlements, avoid or mitigate the actual or potential costs (both monetary and non-monetary) of natural hazards to the community* (Chapter 12 Objective 4);
>
> *Avoid or mitigate the actual or potential costs of loss or damage to life, property, or other parts of the environment from natural hazards* (Chapter 16 Objective 1); and
>
> *Avoid or mitigate significant adverse effects on the environment as a result of methods used to manage natural hazards. This applies especially to habitat and amenity values, heritage places, mahinga kai, and other taonga* (Chapter 16 Objective 2).

Volume 2 of the Proposed Christchurch City Plan contains objectives, policies and methods. Of particular relevance to flood damage is:

- Section 2: Natural Environment and particularly Objective 2.5;
- Section 6: Urban Growth, Objective 6.3; and
- Section 10: Subdivision and Development, Objectives 10.1 and 10.4.

These objectives are:

> *Identification and minimisation of the impacts of natural hazards on public safety and investment in infrastructure* (Objective 2.5).
>
> *Peripheral urban development of a scale and character consistent with the primary emphasis on urban consolidation, which avoids, remedies or mitigates adverse impacts on water, versatile soils and other natural resources, and which makes efficient use of physical infrastructure* (Objective 6.3).
> *That subdivision is not permitted to occur in localities where there are significant natural hazards, unless these can be adequately mitigated, and that any such mitigation measures not have significant adverse effects on the environment* (Objective 10.1).
>
> *Before new certificates of title are issued for land that has been subdivided, or land use development proceeds, the effects of the anticipated land use*

> *activities for which the subdivision or development is undertaken shall be taken into account, and the necessary supporting framework of services and contributions shall be provided* (Objective 10.4).

Policy 6.3.6 (hazards) is directly relevant. It is:

> *To ensure that development is avoided, or limited in scale or density in areas subject to natural and other hazards, particularly flooding, erosion, or potential sea level rise, unless these hazards can be adequately remedied or mitigated.*

Further, Policy 6.3.16 (long term development) is:

> *To promote the Wigram-Halswell-Kennedy's Bush area as the preferred area for the City's long term urban development, subject to further investigation and assessment of this area, including the future of Wigram Airfield.*

The Christchurch City Council is empowered to manage the land drainage system for the City principally though its powers under the Local Government Act 1974.

1.5 Strategy Structure

The strategy is divided into seven principal chapters, including this one. Chapter 2 will set out the background to the Heathcote River catchment, its historical and present development and the floodplain management measures presently being implemented. Chapter 3 will identify the Heathcote River floodplain management issues. These will be identified in two parts – present and future. The range of floodplain management measures available to address the identified issues, and which of these measures are worthy of further consideration, will be detailed in chapter 4. Chapter 5 will further assess the floodplain management measures identified in chapter 4, and four policy approaches to managing the issues will be identified and discussed using the selected measures. These approaches will be based on different evaluation systems – individual responsibility, social equity, economic efficiency and environmental values. The advantages and disadvantages of each option will be examined. Finally, in this chapter six key principles will be developed upon which the strategy will be based. The strategy to manage the issues identified in chapter 3 will be set out in chapter 6. Chapter 7 will discuss the implementation of the strategy and its individual components.

2 Heathcote Floodplain River Management

2.1 Introduction

The Heathcote River catchment supports a diverse range of land uses and activities. These activities have been imposed upon the original catchment resulting in it being significantly modified from its natural state. It is the interaction between the influence of humans on the catchment, and the impact of flooding within the catchment on humans, which results in the floodplain issues of today.

The purpose of this chapter is to provide the context for this strategy. It will describe the catchment and the human influence upon it. The historical attempts to manage flood damage within the floodplain will be briefly discussed. Following this, the present management of potential flood damage will be detailed.

2.2 The Heathcote Catchment

The Heathcote River drains a catchment of approximately 100 km^2 in the area above the Ferrymead Bridge, flowing into the Avon-Heathcote Estuary (see Figure 1, page 6). It flows in a channel incised into the Waimakariri River gravel outwash fan, which is estimated to be able to accommodate up to a five year return period flood (Canterbury Regional Council and Christchurch City Council 1993). Spring fed headwaters sustain the base flow of the river. The largest tributary is the Cashmere Stream, which drains the western Port Hills. The river is subject to tidal influences in its lower reaches.

The catchment contains four distinct geohydrological regions that respond differently to rainfall events. These are described in Table 1 (page 8).

While the catchment traditionally supported large swamp systems, it is now extensively developed for both urban and rural purposes. Oliver and Peters (1993) estimate that the catchment is 40% urbanised overall, with the upper catchment (upstream of Heathcote/Cashmere Stream confluence) only being 29% urbanised. Further urbanisation of the catchment is anticipated in response to population increase. This urbanisation is expected to take two forms; the intensification and redevelopment of those parts of the catchment that are already urban, and the development for urban purposes of some parts of the catchment that presently are not urban (particularly the upper part of the catchment, including the Cashmere Stream sub catchment). However, it is not for this strategy to determine the amount, and location, of this urbanisation, but rather to provide guidance on how any resulting increases in flood damage can be mitigated.

The Heathcote River floodplain is part of an area that was of great importance to tangata whenua for mahinga kai in pre-European times. The tangata whenua have identified that there is an obligation for the management of the floodplain and surrounding catchment to recognise and provide for these values.

HEATHCOTE RIVER CATCHMENT

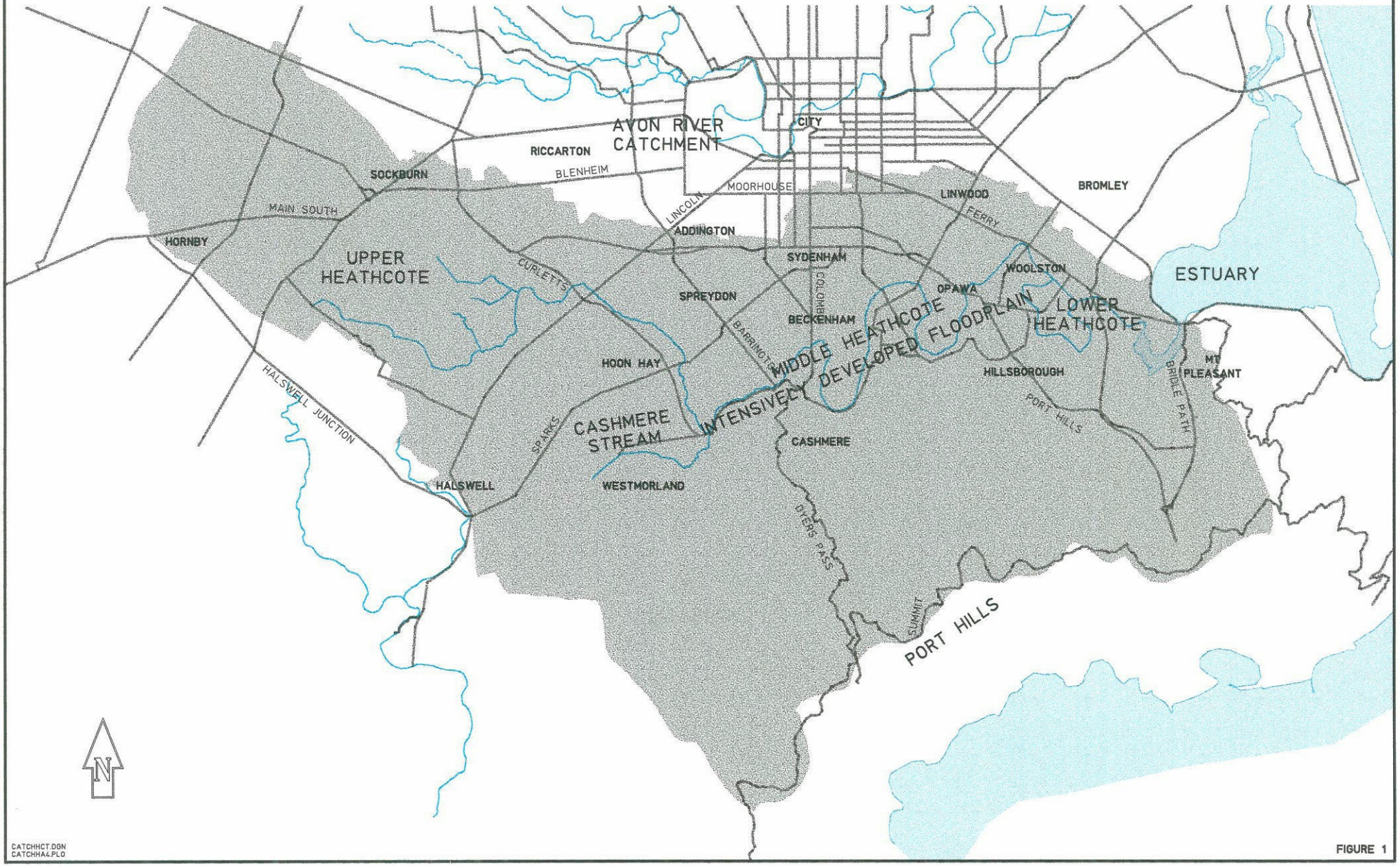

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FIGURE 1

Table 1: Summary of the characteristics of the Heathcote River catchment[5]

Region	Characteristics
Western Hills	Steep impermeable soils; no developed impervious areas; rapid storm runoff into natural ponding areas on the valley floor; slow release to Cashmere Stream; relatively high storm rainfall.
Eastern Hills	Steep impermeable soils; limited developed impervious areas; rapid storm runoff direct into Heathcote River; relatively high rainfall.
Western Plains	Flat high permeable soils, significant developed impervious areas, slow release to Heathcote River directly or via Hendersons Road ponding area.
Urban Plains	Flat with high proportion of developed impervious area; rapid storm runoff to Heathcote River via storm water drainage system.

2.3 Historical Management

Flood damage on the Heathcote River floodplain is well recorded. The Christchurch City Council has records of the flooding of 73 houses (water above the floorboards) over the years (Canterbury Regional Council and Christchurch City Council 1993). Since the 1960s floodwaters have reached heights above house floor levels on at least four different occasions (1968, 1975, 1977 and 1980) with the most affected areas being Waimea Terrace, Richardson Terrace, Aynsley Terrace, Clarendon Terrace, Riverlaw Terrace and Eastern Terrace (Canterbury Regional Council and Christchurch City Council 1993).

Physical works to the Heathcote River have been undertaken as early as the 1920s, and have included widening and deepening of the river channel and dragline operations (Hicks 1993). The Woolston Cut was completed in 1986. The Cut is designed to reduce flooding in the Woolston Loop and upstream by providing for the more efficient flow of water than could otherwise be achieved in the Woolston Loop. In response to the unforeseen effects upstream of the Cut due to salt-water intrusion, the Woolston Tidal Barrage was completed in 1994.

From the late 1960s the management focus shifted towards a catchment orientated management philosophy resulted in the adoption of "Scheme VB" (Wilson 1989). This scheme incorporated structural and non-structural means. The components include the now built Wigram East Retention Basin, and the raising of total of 19 houses since 1983.

2.4 Present Management

The present management of the potential flood damage associated with the Heathcote River floodplain reflects the past management initiatives. Initiatives such as the

[5] Based on Canterbury Regional Council and Christchurch City Council (1993).

Wigram East Retention Basin and house raising programme have considerably reduced flood damage when compared to the level predicted in 1993 (Brown Copeland, 1997).

The present floodplain management measures (summarised in Figure 4, page 48) consist of:

Woolston Cut

Reduces potential flood damage around the Woolston Loop industrial area and reduces potential residential flood damage upstream of the Cut to Opawa Road.

Wigram East Basin

This flood retention basin is situated at the downstream end of the large Paparua Drain catchment (1230 ha). The basin has a permanent wet pond area of 3.5 ha and a potential pond area of 30 ha before water is discharged over the spillway during significant flood events.

Discharges into the upper part of the Heathcote River from the basin are more than halved, resulting in significant downstream benefits (e.g. flood levels downstream of the Heathcote River/Cashmere Stream confluence are reduced by up to 150 mm in a 2% AEP event under future land use).

Natural Ponding Basins

Significant low lying areas (historically Raupo swamps) exist in the Cashmere Stream catchment. These form large natural ponding basins (i.e. Cashmere/Worsleys Basin (45 ha), Hendersons Basin (185 ha) and Hoon Hay Basin (27 ha)) during significant rainfall events and are responsible for the slow release of floodwaters from the Cashmere Stream catchment.

These natural ponding basins are currently in private ownership (zoned Rural 2) but are specifically identified in the Proposed City Plan as ponding basins where filling is a non complying activity except for building platforms. These basins play an important part in alleviating downstream flooding.

Setback Distances

The Proposed City Plan contains rules relating to minimum setback distances from the edge of the Heathcote River for development. From the estuary upstream to the Heathcote River/Cashmere Stream confluence the minimum setback is 30 metres, while for the upper parts of the Heathcote River and Cashmere Stream it is 20 metres in the rural zones and 15 metres in the urban zones. These setbacks are important for maintaining floodplain storage capacity as well as the river environment.

Minimum Floor Levels

New residential buildings being constructed on the floodplain, outside the above setback distances, are required under the Building Act to be built to a minimum floor level equivalent to the 2% Annual Excedence Probability (AEP) flood event. This helps to reduce future potential flood damage.

Flood Warning and Emergency Plans and Procedures

Current flood warning in the Heathcote catchment consists of Meteorological Services Heavy Rainfall Warnings, telemetered rain gauge sites throughout the catchment and telemetered water level recorders on the Heathcote River and at the Wigram East Retention Basin. Interpretation of this information is used to advise residents, the Police, and the Christchurch City Council's roading unit of the potential flood risk. If necessary streets are closed and the at risk public evacuated. Sandbagging may also be carried out.

2.5 Summary

The Heathcote River catchment is not uniform in its characteristics. This diversity is a result of both natural and human induced processes. The natural processes include climate, tide and geohydrological conditions. The human influences result from the settlement of the catchment, and include settlement patterns and measures taken to protect parts of the floodplain from the effects of flooding. All these characteristics work together to define the floodplain management issues. These issues will be the focus of the next chapter.

3 Heathcote Floodplain Management Issues

3.1 Introduction

This chapter will define the floodplain management issues associated with the Heathcote River. It will do so by firstly focusing on those issues that exist at present (existing potential flood damage), and then those that are predicted to result from any continued development and redevelopment of the catchment (future potential flood damage). With respect to the existing potential flood damage the chapter will examine the influences of tidal events on the lower part of the floodplain and rainfall events on the middle of the floodplain. In terms of future development, potential flood damage will be discussed with respect to the influences of sea level rise (lower part of the floodplain), rainfall events (middle part of the floodplain) and overflow of the Waimakariri River (upper part of the floodplain).

The identification of issues is based on a number of past and present studies. These include; the Draft Waimakariri River Floodplain Management Plan (Griffith, 1991), detailed computer modelling investigations (Oliver and Peters, 1993), an 'issues and options' discussion document (Canterbury Regional Council and Christchurch City Council, 1993), the resultant public response (Talyor Baines, 1993), an updated 1997 modelling study undertaken by the Christchurch City Council, an economic assessment of flood damage undertaken by Brown Copeland (1997) the responses to the Draft Heathcote River Floodplain Management Strategy produced in 1998 (Canterbury Regional Council and Christchurch City Council, 1998) and the consultation undertaken with tangata whenua in June and July 1998 (Smith, 1998).

The avoidance, remedying or mitigation of the floodplain management issues identified in this chapter will form the focus of this strategy.

3.2 Existing Flood Damage

3.2.1 Background

There is a recorded history of flood damage in the Heathcote floodplain. Based on the current management regime the average annual damage[6] of flooding is estimated as $0.09 million and the net present value of damage[7] as $0.9 million (Brown Copeland, 1997). Table 7 (page 18) provides an indication of potential present and future

[6] The term Average Annual Damage refers to a value that is equivalent to the average yearly flood damage for all flood events in the future. It is necessary to calculate Average Annual Damage because in some years there will be no flood damage and in other years there will be very high damage, and we need to know what we can expect in terms of damage on average over time. Average Annual Damage is effectively a calculation of all the expected damage for all possible flood events multiplied by the probability of their occurrence in any one year (in practice we calculate the damage for only a few events, and interpolate the damage for the other events).

[7] Net Present Value refers to a present day value that is equivalent to costs and benefits in the future. It is calculated by converting the values in the future to their present day equivalent using an annual discount rate. Thus for instance a cost of $1,100 in one year's time is equivalent to a cost of $1000 in the present day at a 10% discount rate, and a benefit of $1,610 in five years is equivalent to a benefit of $1,000 in the present day again at a 10% discount rate. In calculating the Net Present Value these streams of costs and benefits in the future are discounted back to the present day, and summed to determine their total value in present day terms.

(assuming no additional mitigation measures) flood damage costs. The location of the residential houses that contribute to these costs can be seen from Figure 2 (page 20).

Damage is influenced by two separate natural events – rainfall and tide. While these are discussed in separate sections below, they can coincide to increase the magnitude of flood events and hence flood damage.

3.2.2 Rainfall Events

Oliver and Peters (1993) describe the catchment response to rainfall. They state:

> *Due to the varied topography, land use, and soil type in the catchment, response to storm rainfall is quite complex for such a small catchment.*
>
> *Historically, significant flooding within the catchment is associated with low intensity (higher on Port Hills) long duration (48-72 hour) rainfall events, generally from a southerly direction with an associated low pressure system off the east coast. During a significant storm, Cashmere Stream and its tributaries which rapidly drain the Port Hills overflow into Cashmere Valley/Worsleys Valley, Hoon Hay Valley and Hendersons Road ponding areas, which slowly drain into the Heathcote River (high downstream water levels also contribute to this slow release).*
>
> *In the upper Heathcote catchment (i.e. upstream of the Heathcote/Cashmere Stream confluence, but not including the Cashmere Stream) the majority of the precipitation falls on undeveloped land and is transferred to soakage, interflow and groundwater. Interflow eventually reaches the drainage system, but because of the time lag does not contribute to peak runoff.*
>
> *The combined effects of natural ponding areas and the pervious soils result in relatively long critical storm duration (16 hours) at the Upper Heathcote/Cashmere Stream confluence.*
>
> *Flooding of the urban reaches of the floodplain generally occurs in flood events greater than the 20% Annual Excedence Probability (5 year return period).*

Oliver and Peters (1993) indicate that rainfall events are the critical determinant for flooding, and hence flood damage, in the upper and middle parts of the floodplain (i.e. above Opawa Road Bridge).

It is also noted that significant rainfall within the Waimakariri River catchment can also
potentially lead to overflow into the Heathcote River catchment. This is discussed in section 3.3.3 below.

3.2.3 Tidal Influences

The damage on the lower parts of the floodplain are aggravated by the tidal influence on the Heathcote River, and in particular the portions below Opawa Road (Canterbury Regional Council and Christchurch City Council 1993). This influence is significant.

Critical flood levels downstream of the Opawa Road Bridge for a given Annual Excedence Probability (AEP) event are a result of extreme tides (Oliver and Peters 1993). It is these extreme tides that can result in significant flood damage in the Woolston Loop area (Canterbury Regional Council and Christchurch City Council 1993). Flooding in extreme tidal events is generally associated with low barometric pressure and strong winds.

The tidal influence will be further aggravated in the event of a Tsunami. While Oliver and Kirk (1992) state that in probability and damage terms Tsunami is extremely difficult to evaluate, they concluded that with respect to the Avon-Heathcote Estuary it is reasonable to adopt a Tsunami water level rise of +1.5m. There is no recorded instance of such damage occurring.

3.3 Future Flood Damage Issue Definition

3.3.1 Background

Urbanising parts of the plains in the upper catchment is one option for accommodating a significant proportion of the growth of Christchurch City (Christchurch City Council 1995). As such, a 50 Year Development Scenario has been used to assess the likely effects on flood damage. This development scenario is based on a 50 year time scale and has been developed under the guidance of the Christchurch City Council's Environmental Policy and Planning Unit. In brief it is based on a population within Christchurch City of 375,000 people. This is compared with a population 309,000 in 1996 and a forecast of 352,000 by the year 2021. Sixty percent of the population increase is assumed to be accommodated within the Heathcote River catchment. To accommodate this population the 50 Year Development Scenario assumes 700ha of new residential development, including 400ha within the upper catchment, and 250ha of new industrial development. Further, the scenario assumes an additional 180ha of infill residential development within the existing urban areas. As a consequence it is assumed that within the catchment the total area of impervious surfaces will increase from 1690ha (17%) to 2290ha (23%). The extent of this development scenario is depicted in Figure 3, page 21. Table 7 (page 18) shows, in economic terms, the increase in flood damage under this scenario with no additional flood mitigation measures in place.

3.3.2 Existing Development Opportunities

Development opportunities are provided for in the Transitional and Proposed City Plans. These opportunities are in the form of the potential to develop presently vacant land for urban purposes (i.e. zoned for urban development but the opportunity has not been taken up), or through the present urban areas being redeveloped to higher densities.

Of relevance to this strategy is that the Proposed City Plan provides for the redevelopment and intensification of the middle part of the Heathcote River catchment and the development of some of its tributaries. Modelling of the catchment shows that additional development in this area will lead to an increase in flood damage in this part of the floodplain, generally between Radley and Colombo Streets. Table 2 (page 14) shows the predicted extent of the increase in residential building inundation,

noting that this does not account for all the increase in flood damage due to the development and redevelopment in this location.

Table 2 : Flooding potential of residential buildings as a result of development and redevelopment of parts of the middle of the catchment

	House Flooding		Garage Flooding	
	Present	Predicted	Present	Predicted
2% AEP	2	6	87	96
Extreme[8]	79	109	195	255

3.3.3 Development of the upper part of the Catchment

The upper part of the Heathcote River catchment is identified as the preferred area for long term development of Christchurch City in Policy 6.3.16 of the Proposed Christchurch City Plan. Without additional mitigation the 1997 modelling predicts that this will result in increased flood damage mainly in the middle parts of the Heathcote River floodplain. The predicted increase in terms of residential buildings flooded is set out in Table 3 (page 14). Again, this does not account for all the increase in flood damage due to development in this location.

Table 3: Flooding potential of residential buildings as a result of development in the upper part of the catchment

	House Flooding		Garage Flooding	
	Present	Predicted	Present	Predicated
2% AEP	2	6	87	102
Extreme	79	98	195	323

While it is not reflected in Table 3, the upper part of the catchment can be divided into 2 geohydrological areas, being those areas with relatively pervious soils (generally west of Sparks Road) and the areas with relative impervious soils (generally being within the Cashmere Stream sub catchment). These areas of the upper part of the catchment respond differently to rainfall events, with more rainfall entering ground water through the soil in the relatively pervious soil areas than in the relatively impervious soil areas. Therefore, the floodplain management issues, and consequently potential range of flood damage management measures, for these two areas differ.

Further, development in the upper part of catchment is potentially subject to damage from an extreme flood in the Waimakariri River. Overflow from the Waimakariri River may flow through Haytons Road drain, the dry watercourse between Wigram Road and St John of God Hospital and the Heathcote River headwaters into the Heathcote River. In the event an overflow did occur the flooding would be similar to the extreme event in the Heathcote River catchment itself, but with higher flood levels in the upper catchment and lower levels in the lower reaches (Canterbury Regional Council and Christchurch City Council, 1993).

[8] Extreme event is defined as a 0.2%AEP (500 year) rainfall event combined with a 0.2% AEP tidal event.

3.3.4 Sea Level Rise

As stated above, the Heathcote River floodplain is subject to tidal influences, and in particular the reaches below the Opawa Road Bridge. This tidal influence is likely to increase with sea level rise. Historic records show that sea level rise has been occurring at a rate of approximately 2mm per year since 1900 at Lyttelton (Oliver and Kirk, 1992). Recent estimates indicate that the sea level is likely to increase in the order of 230mm by the year 2050.

Both the 1993 modelling (Oliver and Peters, 1993) and the Christchurch City Council 1997 modelling have been undertaken allowing for a 100mm rise in sea level, which is based on the historic rate of the rise. The extent of the likely rise in sea level will need to be continually reviewed in light of world wide trends and predictions and this strategy reviewed accordingly.

3.3.5 Combined Effect

Assuming a 100mm rise in sea level over the next 50 years, the combined effect of potential flood damage resulting from the existing development and redevelopment opportunities, and the development of the upper part of the catchment, can be expressed both in terms of the economic cost and buildings flooded. Table 4 below summarises the potential average annual damage and the net present value of damage.

Table 4: Cost of potential flood damage under the 50 Year Development Scenario[9]

	Present ($million)	Future ($million)	Difference ($million)
Average Annual Damage	0.09	0.12	0.03
Net Present Value of Damage	0.9	1.2	0.3

[9] Based on Brown Copeland (1997)

Table 5 summarises the expected extent of residential buildings flooded.

Table 5: Flooding potential of residential buildings under the 50 Year Development Scenario

Property	AEP Event	Buildings Flooded		Additional
		Present	Future	
Garages	2%	87	109	22
	0.5%	129	175	46
	Extreme	195	320	125
Houses	2%	2	6	4
	0.5%	26	42	16
	Extreme	79	109	30

As can be seen, while there are a number of additional residential buildings flooded under the 50 Year Development Scenario, due to the overall small numbers involved the economic cost of the additional flood damage is also small. However, the Brown Copeland (1997) report states that this assessment of economic cost does not include an assessment of intangible and unquantifiable damage, which includes factors such as physical injury, fear, anxiety, ill health (physical and psychiatric problems), inconvenience, and the loss of memorabilia. The report comments that *on the evidence which is available, the intangible costs are often valued at equal to the structural and contents damages associated with floodwaters entering residential housing affected* (pg. 11).

3.4 Summary

Using the above analysis the potential flood damage issues identified for the Heathcote River floodplain can be summarised as in Table 6.

Table 6: Heathcote River floodplain management issues

Floodplain Area	Present Day Issues	Future Issues
Lower	Potential tidal flood damage	Increase in potential tidal flood damage due to sea level rise and new development
Middle	Potential flood damage as a result of significant rainfall events	Increase in potential flood damage as a result of new development and redevelopment in the middle of the Heathcote River catchment
		Increase in potential flood damage as a result of new development in the upper part of the Heathcote River catchment in areas of relative pervious soils
		Increase in potential flood damage as a result of new development in the Cashmere Stream sub catchment in areas of relative impervious soils
Upper		Potential flood damage as a result of inappropriate development of Waimakariri River overflow channels

In the next chapter, the range of available measures to manage the floodplain issues will be explored and assessed. From these, a number of measures will be identified for possible inclusion within the strategy to manage flood damage in the Heathcote River Floodplain.

Table 7: Existing and future potential flood damage in the Heathcote River floodplain[10]

		Damage ($000)									
										Houses	
Development	Event	Total	Industrial	Traffic	Roads	Access	Agricult.	Sections	Garages	0-100mm	>100mm
Present Day	5% AEP	302	0	0	0	41	60	152	49	0	0
	2% AEP	877	266	3	79	56	95	210	68	100	0
	0.5% AEP	3255	1215	8	81	79	100	245	103	776	648
	Extreme	10749	5325	27	93	128	100	384	161	1123	3408
Future	5% AEP	359	0	0	0	50	60	188	61	0	0
	2% AEP	1224	266	8	70	70	95	268	87	93	267
	0.5% AEP	4432	1215	15	85	102	100	337	142	779	1656
	Extreme	13157	5325	45	152	191	100	642	270	1058	5374

[10] Based on Brown Copeland (1997)

HEATHCOTE RIVER POTENTIAL HOUSE FLOODING

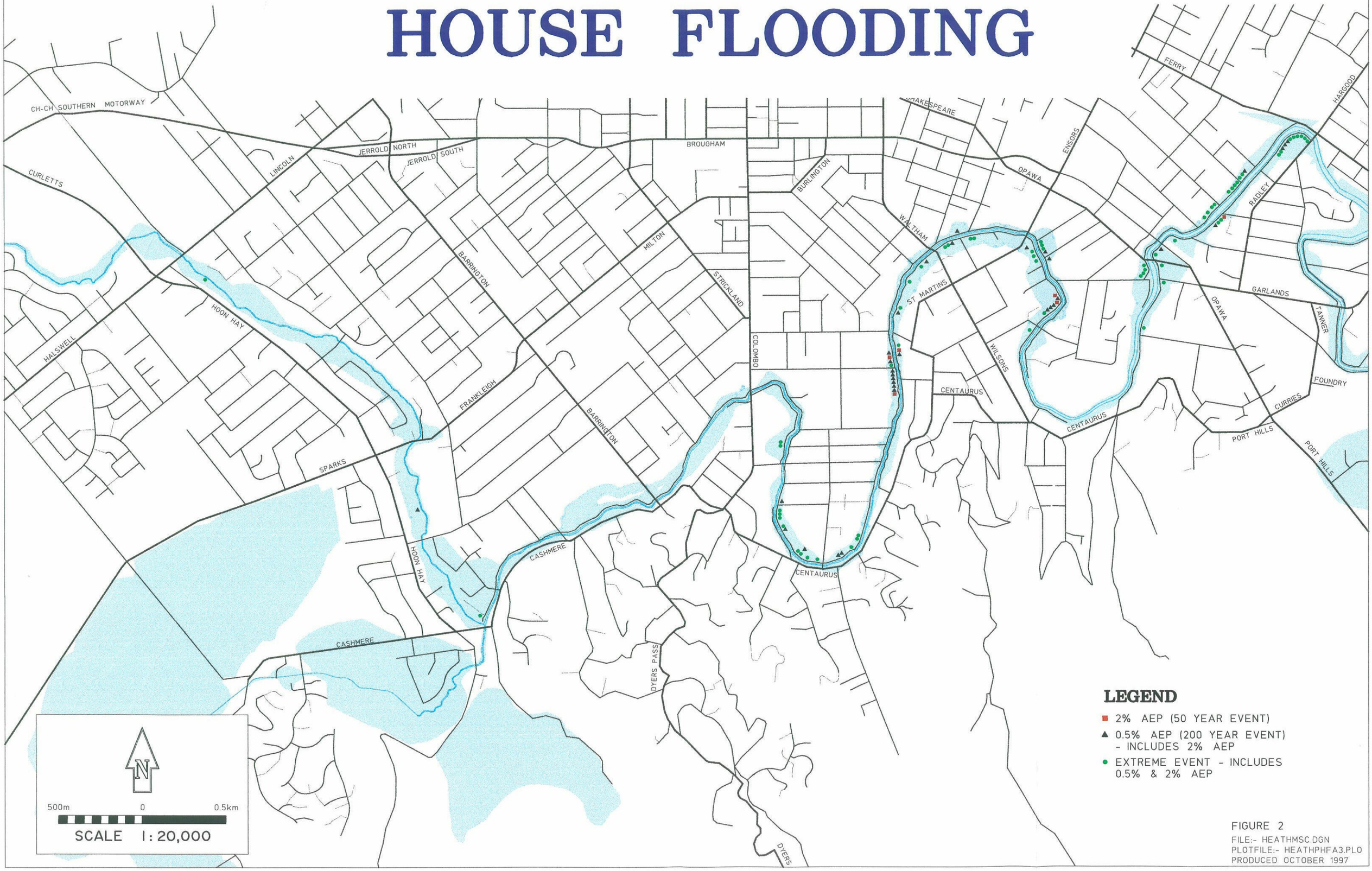

FIGURE 2

FILE:- HEATHMSC.DGN
PLOTFILE:- HEATHPHFA3.PLO
PRODUCED OCTOBER 1997

HEATHCOTE FLOODPLAIN STRATEGY LANDUSE SCENARIO

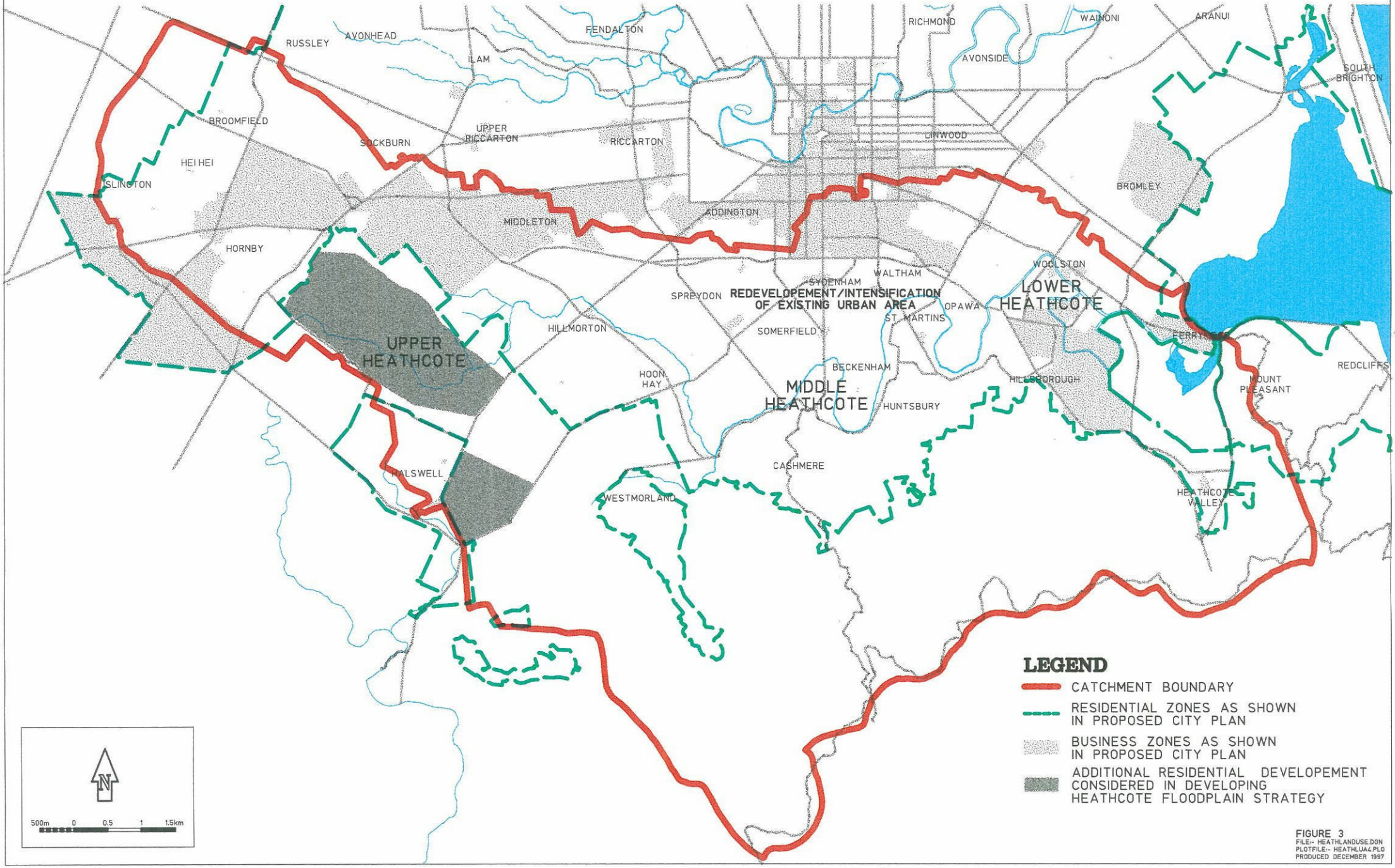

FIGURE 3
FILE:- HEATHLANDUSE.DGN
PLOTFILE:- HEATHLUA4.PLO
PRODUCED DECEMBER 1997

4 Selection of Possible Floodplain Management Measures

4.1 Introduction

A system of floodplain management measures to reduce flood damage within the Heathcote River floodplain already exists. The flood damage presently experienced is predicted to increase if the catchment further develops and redevelops for urban purposes.

There are a range of measures available to reduce flood damage. These floodplain management measures can be broadly categorised in accordance with the classification system in Appendix 1. This classification system provides a useful basis for identifying the range of possible measures available.

The purpose of this chapter is to scope the range of potential floodplain management measures available and determine which of these are worthy of further investigation. To do this the range of floodplain management measures available will be identified using the classification system in Appendix 1. Each measure will be assessed against the physical, economic, social, environmental and legal criteria set out Appendix 2. Based on this evaluation, the measures that warrant further investigation will be identified.

4.2 Range of Measures

The range of Heathcote River floodplain management measures can, in general, be identified from the significant body of work that has been undertaken since the mid 1980s on the reduction in damage caused by the flooding of the Heathcote River floodplain. This body of work includes:

- Heathcote River catchment investigations - stage 2 (Christchurch Drainage Board, 1985);
- NIWA report on sedimentation and erosion in the Avon-Heathcote catchment and Estuary (Hicks, 1993);
- 1993 discussion document (Canterbury Regional Council and Christchurch City Council, 1993);
- submissions to the 1993 discussion document (Taylor Baines, 1993);
- Royds Consulting draft Heathcote River floodplain Management Strategy (Royds Consulting, 1996);
- Christchurch City Council memorandum (Oliver, 1997);
- Submissions to the Draft Heathcote River Floodplain Management Strategy as summarised in Canterbury Regional Council (1998b).

Using Appendix 1 as a guide to ensure completeness, 91 measures have been identified and are described in Appendix 3.

4.3 Possible Measures

In order to determine the overall acceptability of each of the 91 measures, the advantages and disadvantages of each has been assessed under the headings; physical, economic, social, environmental and legal. The results of this assessment are set out in Appendix 4. This assessment has been carried out using the factors identified in Appendix 2 as a guide. Based on the assessment a judgement has been made as to which measures warrant further exploration. Twenty-six floodplain management measures are identified as falling within this category. Each of these measures is detailed in Table 8 below. A description of each of these measures can be found in by referring to Appendix 3.

4.4 Summary

Over time a significant amount of work has occurred on the options to manage flood damage within the Heathcote River floodplain. Based on this work 91 floodplain management measures were identified that potentially could manage flood damage. These measures have been qualitatively evaluated against physical, economic, social, environmental and legal criteria. Using this evaluation, 26 floodplain management measures have been selected as worthy of further consideration. Based on these selected floodplain management measures, the next chapter will assess the possible measures in the context of different policy approaches to develop a series of principles upon which the strategy will be based, enabling choices to be made between the 26 different measures, and combinations thereof.

Table 8: Selected flood mitigation measures

Classification of Floodplain Management Measures		No.	Measure
Category	Type		
Modify Flood Events	Land Treatment	2	Stormwater discharge of roof runoff to soakage from new development
	(Soakage)	7	Stormwater discharge of paved areas runoff to soakage from new development
	(Retention)	9	Develop Curletts Retention Basin
		10	Develop Wigram South Retention Basin
		12	Control outlets of Cashmere/Worsleys Basin
		17	Control runoff with local retention and green corridors within developments from new development on plains
	(Channel)	26	Remove local constrictions in downstream River Channel (i.e. Colombo Street Bridge)
	(Sedimentation)	27	Retain channel maintenance programme
	(Stopbanks)	34	Construct localised stopbanks/bunding
	(Local Drainage)	47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)
		48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system
Modify Flood-Loss Suspect.	Land Use Management (Location)	52	Control development in natural ponding areas, including agricultural development
		54	Control development in waterway corridors (e.g. setback distances)
		55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels
		64	Control development on tidal floodplain
		69	Site audit by Trade Waste personnel
		70	'Fail safe' chemical storage facilities
	(Tenure)	79	Public purchase all ponding land and manage for flood retention purposes
		80	Protect ponding areas through voluntary covenants, designations and similar
	Floodproofing	84	Set floor levels for new development above flood levels
		85	Raise level of riverside roads
	Community Preparedness	86	Manage an effective public education programme
		87	Maintain emergency plans and procedures
		88	Maintain flood warning systems
Modify Flood-Loss Burden		90	Impose financial contributions to offset the cost of additional floodplain management measures
		91	Flood Insurance

5 Strategy Philosophy

5.1 Introduction

The purpose of this chapter is to determine what combination, or bundle, of floodplain management measures selected in chapter 4 is appropriate to address the issues identified in chapter 3.

This chapter will assess the effectiveness, efficiency and environmental effects of each of the possible 26 management measures. This assessment will form the basis of an evaluation of the different approaches to the strategy that would result if alternative policy frameworks were used - individual responsibility, economic efficiency, social equity and environmental values. Comparison will then be made between the different policy frameworks to highlight the implications of each for the management of flood damage on the Heathcote River floodplain. Finally, based on this comparison, six principles will be developed to guide the strategy that will be set out in chapter 6.

In undertaking the evaluation within this chapter the scope of this study is an important consideration (i.e. managing flood damage). This means that any evaluation must be undertaken using this as the reference point, as opposed to the wider context of considering the advantages and disadvantages to the community of the development and redevelopment of parts, or all, of the Heathcote River catchment *per se*. However, the strategy can be used as a tool in assessing development options within the catchment.

5.2 Assessment of the Possible Measures

5.2.1 Background

This section builds on that assessment undertaken in chapter 4 by further assessing each of the possible 26 measures against the following criteria:

Effectiveness: measured in terms of the reduction in flood damage using the 50 Year Development Scenario;

Efficiency: measured in terms of economic efficiency (net benefit); and

Environmental Effects: measured in terms of both adverse and positive effects on the environment, and includes people and communities.

While in isolation some of the measures may not appear effective, when implemented in combination with other measures their effectiveness may markedly improve. This is recognised in the modelling that has been undertaken.

Not all the selected floodplain management measures have been subject to the same detail or type of assessment. The assessment reflects the nature of the measures and

also the strategic focus of this strategy. Therefore, in some instances the appraisal in this section will rely upon the earlier assessment described in chapter 4.

5.2.2 Effectiveness

In the context of this study, effectiveness has been determined on a three-point scale:

Positive: reduces flood damage;

Minor: has a small positive effect on flood damage, but this effect is insignificant; and

Neutral: has no direct affect on flood damage.

The evaluation is based on the results of the Christchurch City Council 1997 modelling exercise and qualitative analysis. The results are presented in Table 9 below.

Table 9: Effectiveness of floodplain management measures

No.	Measure	Effectiveness	Comment
2	Stormwater discharge of roof runoff to soakage from new development	Minor	Benefit is in conjunction with retention or soakage
7	Stormwater discharge of paved areas runoff to soakage from new development	Positive	In areas of relatively pervious soils it neutralises the effect of development
9	Develop Curletts Retention Basin	Positive	Particularly in combination with 7 and 10
10	Develop Wigram South Retention Basin	Positive	Particularly in combination with 7 and 10
12	Control outlets of Cashmere/Worsleys Basin	Positive	Directly contributes to damage reduction in the middle of the floodplain
17	Control runoff with local retention and green corridors within developments from new development on plains	Positive	In relatively impervious soil (e.g. Cashmere Stream sub catchment) areas it neutralises the effect of development
26	Remove local constrictions in downstream river channel (i.e. Colombo Street Bridge)	Minor	Constrictions are not significant
27	Retain channel maintenance programme	Minor	Maintains present conveyance capacity due to sedimentation (limited)
34	Construct localised stopbanks/bunding	Positive	Depends on design. Can be highly effective but carries the risk of breaches and overtopping
47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Minor/Positive	Depends on design and location
48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system	Minor	Benefit is in conjunction with retention or soakage

No.	Measure	Effectiveness	Comment
52	Control development in natural ponding areas, including agricultural development	Positive	Areas relatively undeveloped. Avoids risk of reduction in the functioning of natural ponding areas and maintains future options
54	Control development in waterway corridors (e.g. setback distances)	Minor	Corridors typically developed. Benefit is in terms of redevelopment
55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Positive	Likelihood of the event is small, but flood damage may be significant
64	Control development on tidal floodplain	Positive	Significant parts of the tidal floodplain are yet to be developed
69	Site audit by Trade Waste personnel	Minor/Positive	Effectiveness dependent on voluntary actions
70	'Fail safe' chemical storage facilities	Minor	Manages risk
79	Public purchase all ponding land and manage for flood retention purposes	Positive	Areas relatively undeveloped. Avoids risk of reduction in the functioning of natural ponding areas and maintains future options
80	Protect ponding areas through voluntary covenants, designations and similar	Positive	Areas relatively undeveloped. Avoids risk of reduction in the functioning of natural ponding areas and maintains future options
84	Set floor levels for new development above flood levels	Positive	Ensures that upon future development and redevelopment flood damage is maintained at the current level or reduced
85	Raise level of riverside roads	Positive	Act as stopbank
86	Manage an effective public education programme	Minor/Positive	No certain outcomes. Long term effectiveness only
87	Maintain emergency plans and procedures	Minor	Maintains present arrangements. Can limit some flood damage by short term reactive floodplain management measures
88	Maintain flood warning systems	Minor	Maintains present arrangement. Limited warning time can be provided due to the nature of the catchment
90	Impose financial contributions to offset the cost of additional floodplain management measures	Neutral	Process as opposed to mitigation measure, but ensures adequate funding is available
91	Flood Insurance	Neutral	Reacts to flood damage as opposed to avoiding damage. Presently in New Zealand there is not a distinction between high flood risk, and other areas

5.2.3 Efficiency

Brown Copeland (1997) has assessed, from an economic perspective, a range and combination of floodplain management measures based on the Christchurch City Council 1997 floodplain modelling results. The results of this assessment are set out in Appendix 5.

Efficiency is expressed as the net benefit of the measure, or bundle of floodplain management measures. As the current, and 50 Year Development Scenario, predicted annual average damage and net present damage is both relatively small, and similar, any measure with significant implementation costs will have a negative net benefit.

'Average Damage' and 'Net Present Value of Damage' is expressed as tangible benefits and costs only. The intangible benefits and costs are not included.

In the context of this study, efficiency (assuming land costs are included) has been ranked on a four-point scale:

Positive: the net benefit of the mitigation measure is positive;
Neutral: the net benefit is $0;
Negative: the net benefit of the mitigation measure is negative;
Not Determined: the net benefit has not been determined.

The results of this assessment are presented in Table 10 below.

Table 10: Economic efficiency of floodplain management measures

No.	Measure	Efficiency	Comment
2	Stormwater discharge of roof runoff to soakage from new development	Not Determined	Likely to be neutral but will have a positive impact on the efficiency of soakage and retention floodplain management measures
7	Stormwater discharge of paved areas runoff to soakage from new development	Negative	Requires capital works
9	Develop Curletts Retention Basin	Negative	Requires capital works
10	Develop Wigram South Retention Basin	Negative	Requires capital works
12	Control outlets of Cashmere/Worsleys Basin	Negative	Assuming land purchase required
17	Control runoff with local retention and green corridors within developments from new development on plains	Not Determined	Will be similar for soakage, although the implementation costs are likely to be less
26	Remove local constrictions in downstream river channel (i.e. Colombo Street Bridge)	Not Determined	The implementation cost is anticipated to be the marginal cost of the different designs when replacement occurs
27	Retain channel maintenance programme	Not Determined	Only occurs on a judged 'as needed' basis at present
34	Construct localised stopbanks/bunding	Negative	Magnitude depends on height of bunding
47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Not Determined	Could be positive where redesign results in lesser areas of hard surfaces (e.g. narrower roads)

No.	Measure	Efficiency	Comment
48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system	Neutral/Positive	Expected to have a similar cost to traditional 'hard' reticulation system but with reduced maintenance and replacement costs
52	Control development in natural ponding areas, including agricultural development	Not Determined	Development opportunities do not presently exist as of right
54	Control development in waterway corridors (e.g. setback distances)	Not Determined	Development opportunities do not presently exist as of right
55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Not Determined	Loss of some private development opportunities. Some offsetting of this cost may occur by using this, as opposed to another area, for community purposes
64	Control development on tidal floodplain	Not Determined	Cost to individuals who lose development rights
69	Site audit by Trade Waste personnel	Not Determined	Process orientated measure, the benefits are hard to determine
70	'Fail safe' chemical storage facilities	Not Determined	Will reduce damage caused by contamination
79	Public purchase all ponding land and manage for flood retention purposes	Negative	Transfers cost from one party to another
80	Protect ponding areas through voluntary covenants, designations and similar	Not Determined	Development opportunities do not presently exist as of right
84	Set floor levels for new development above flood levels	Positive	Cost to the individuals developing and redeveloping are outweighed by flood damage benefit
85	Raise level of riverside roads	Not Determined	The implementation cost is anticipated to be the marginal cost of the different designs when replacement occurs
86	Manage an effective public education programme	Not Determined	Process orientated measure, the benefits are hard to determine
87	Maintain emergency plans and procedures	Not Determined	Process orientated measure, the benefits are hard to determine
88	Maintain flood warning systems	Not Determined	Process orientated measure, the benefits are hard to determine
90	Impose financial contributions to offset the cost of additional floodplain management measures	Neutral	Process orientated measure, the benefits are hard to determine
91	Flood Insurance	Neutral	Reacts to flood damage as opposed to avoiding damage. Presently in New Zealand there is not a distinction between high flood risk and other areas

5.2.4 Environmental Effects

The environmental effects can be both positive and negative, and includes those effects on people and communities. As set out in Appendix 2 these effects include the following:

- ecology (plant and animal communities and habitat, including mahinga kai species);
- visual or aesthetic amenity; and
- water quality.

These matters were qualitatively evaluated as part of assessing the measures in chapter 4. The relevant parts of this assessment, with additional comment, are summarised in Table 11 (page 31). The environmental effects have been determined on a three-point scale, being:

Positive:	direct positive enhancement of the environment;
Neutral:	no direct effects on the environment; and
Negative:	direct negatively effects on the environment.

Table 11: Environmental effects of floodplain management measures

No.	Measure	Effect	Comment
2	Stormwater discharge of roof runoff to soakage from new development	Positive	If the system is sealed it reduces the size of retention and soakage areas required, and provides for the replenishment of groundwater at a relatively low risk of contamination
7	Stormwater discharge of paved areas runoff to soakage from new development	Positive	On balance, by providing enhancement opportunities while noting the risk of groundwater contamination
9	Develop Curletts Retention Basin	Positive	On balance, by providing enhancement opportunities
10	Develop Wigram South Retention Basin	Negative	Changes river environment
12	Control outlets of Cashmere/Worsleys Basin	Neutral	Additional ponding area has marginal effect
17	Control runoff with local retention and green corridors within developments from new development on plains	Positive	Provides enhancement opportunities
26	Remove local constrictions in downstream river channel (i.e. Colombo Street Bridge)	Neutral	Assumes that modified design has a neutral effect
27	Retain channel maintenance programme	Neutral	Short term water quality effects only
34	Construct localised stopbanks/bunding	Negative	Changes river environment, and in particularly adversely affects amenity values. Industrial uses may be less sensitive
47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Positive	Provides for reduced hard surfaces thereby providing the opportunity to enhance amenity values
48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system	Positive	On balance, by providing enhancement opportunities while noting the risk of groundwater contamination
52	Control development in natural ponding areas, including agricultural development	Positive	Protects habitat from alternative development (supported by the tangata whenua), but reduces the options of individual landowners
54	Control development in waterway corridors (e.g. setback distances)	Positive	Protects river environment
55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Neutral	Assumes development will occur regardless (i.e. is not a location determinant), but can contribute to a 'green' network

No.	Measure	Effect	Comment
64	Control development on tidal floodplain	Positive	Protects habitat from alternative development (supported by the tangata whenua), but reduces options of individual landowners
69	Site audit by Trade Waste personnel	Positive	Process that may lead to reduced environmental contamination
70	'Fail safe' chemical storage facilities	Positive	Reduces environmental contamination
79	Public purchase of all ponding land and manage for flood retention purposes	Positive	Protects habitat from alternative development (supported by the tangata whenua) and provides for enhancement, and enables existing landowners to be compensated
80	Protect ponding areas through voluntary covenants, designations and similar	Positive	Protects habitat from alternative development (supported by the tangata whenua)
84	Set floor levels for new development above flood levels	Neutral	Assumes development will occur regardless (i.e. is not a location determinant)
85	Raise level of riverside roads	Negative	Changes river environment, and in particularly adversely affects amenity values
86	Manage an effective public education programme	Positive	Process, but provides for community ownership of the issues and empowerment
87	Maintain emergency plans and procedures	Positive	Process that provides for management of the intangible costs to the community in the event of a flood
88	Maintain flood warning systems	Positive	Process that provides the community with the opportunity to minimise flood damage and ensure their health and safety
90	Impose financial contributions to offset the cost of additional floodplain management measures	Neutral	Process based on exacerbater pays principle
91	Flood Insurance	Positive	Process that provides individual members of the community with the ability to re-establish following a flood event

5.3 Different Policy Approaches

5.3.1 Background

The previous section assesses each floodplain management measure against three criteria. This assessment provides the detail necessary to enable the measures to be evaluated in terms of a policy framework. However, in this situation there is no clear single policy approach. At least four different approaches can be identified from the existing statutory and policy imperatives. Determining what emphasis to place on which approach is important to establish the basis on which the different possible measures will be given priority.

While in reality these different approaches are not mutually exclusive, exploring each will clarify the effects of different emphases in the policy making process. The four alternative approaches identified are:

- Individual responsibility (IR) - empower individuals to make decisions affecting them through education and information provision while ensuring they internalise any adverse effect caused;
- Economic (Econ) - focus on floodplain management measures that are economically efficient ('positive efficiency' in Table 10);
- Social Equity (SE) - avoid any additional flood damage ('positive effectiveness' in Table 9); and
- Environmental values (Envir) - based on mitigation measure(s) that enhance the environment ('positive' in Table 11, page 31)

Table 12 below illustrates that each of these policy frameworks would result in a different set of floodplain management measures being implemented.

It is important to recognise that each of these policy approaches is subject to a number of pre-existing constraints. These include the requirement to obtain resource consents under the Resource Management Act 1991.

Table 12: Alternative possible strategies based on the different policy approaches

No.	Measure	IR	Econ	SE	Envir
2	Stormwater discharge of roof runoff to soakage from new development				✔
7	Stormwater discharge of paved areas runoff to soakage from new development			✔	✔
9	Develop Curletts Retention Basin			✔	✔
10	Develop Wigram South Retention Basin			✔	
12	Control outlets of Cashmere/Worsleys Basin			✔	
17	Control runoff with local retention and green corridors within developments from new development on plains			✔	✔
26	Remove local constrictions in downstream River Channel (i.e. Colombo Street Bridge)				
27	Retain channel maintenance programme				
34	Construct localised stopbanks/bunding			✔	
47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)			✔	✔
48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system		✔		✔
52	Control development in natural ponding areas, including agricultural development			✔	✔
54	Control development in waterway corridors (e.g. setback distances)				✔
55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels			✔	
64	Control development on tidal floodplain			✔	✔
69	Site audit by Trade Waste personnel	✔		✔	✔
70	'Fail safe' chemical storage facilities				✔
79	Public purchase all ponding land and manage for flood retention purposes			✔	✔
80	Protect ponding areas through voluntary covenants, designations and similar			✔	✔
84	Set floor levels for new development above flood levels		✔	✔	
85	Raise level of riverside roads			✔	
86	Manage an effective public education programme	✔		✔	✔
87	Maintain emergency plans and procedures				✔
88	Maintain flood warning systems				✔
90	Impose financial contributions to offset the cost of additional floodplain management measures	✔			
91	Flood Insurance	✔			✔

5.3.2 Individual Responsibility

This approach assumes that individuals will be responsible for managing flood damage in two ways:

- making personal choices about the level of risk they are willing to be exposed to and acting accordingly; and
- internalising the effects of their own actions by mitigating additional flood damage caused.

The enabling provisions within section 5(2) of the Resource Management Act (see chapter 1) support this policy approach. Further, Chapter 16 Objective 1 Policy 5 of the Regional Policy Statement provides that *responsibility for costs associated with management of natural hazards, as well as these can be determined, should fall on those who benefit in proportion to that benefit.*

The floodplain management measures selected under this policy approach seek to ensure adequate information is available for rational decision making, and leave the widest range of possible mitigation options available to the individual to select from. Therefore, the implementation of public community based floodplain management measures is not likely under this framework due to timing and management differences between development and redevelopment projects.

5.3.3 Economic Evaluation Framework

The economic policy approach places priority on the economic benefit of the protection gained by the implementation of a measure, or bundle of measures, in relation to the cost of doing so. Using this principle the merit of any floodplain management measures can be determined. The approach assumes that where the cost of mitigation outweighs the benefit of reducing flood damage, mitigation is not required.

This policy approach is again supported by Chapter 16 Objective 1 Policy 1 of the Regional Policy Statement. In the explanation of the policy 'net benefit' is defined as the sum of the net monetary benefit and net non-monetary benefit.

Brown Copeland (1997) conclude that a positive net benefit accrues to society only for a limited number of measures, and then only in the absence of land cost being incurred. The option of passing runoff into soakage produces a net benefit of between $0.1 and $1.2 million if land costs are not incurred. This is because there is at the lower end of the design options a large saving in cost, and at the upper end no difference in cost, if compared with a conventional stormwater system. However, when the cost of land is included this position is reversed, and this measure produces a net benefit of between -$0.9 and -$2.2 million. The enhancement of Cashmere/Worsleys Retention Basin provides a net benefit of $0 million, provided that there is no cost incurred for the land, which increases to $0.1 million when this option is combined with the runoff to soakage option. Similarly, the Curletts Basin, when combined with the runoff to soakage option, produces no net benefit ($0million). The stopbanking and bunding options to 2% and 0.5% AEP levels provide net benefits of -$0.1million and -$0.2million respectively. The combination of the three enhanced retention basins produces a net benefit of -$0.4million in the absence of land costs. All the other

options that were analysed produce larger net negative outcomes in monetary terms, particularly when land costs are included in the calculations.

The only measure analysed in the Brown Copeland (1997) that provides a consistent positive net benefit is the imposition of either 0.5% AEP or Extreme event minimum floor levels for all development and redevelopment of houses ($0.2 and $0.4million respectively). This result recognises that over time (the average life span of the existing houses likely to be flooded in all events has been assessed as approximately 25 years) the number of houses flooded could be significantly reduced using this measure. Brown Copeland (1997) comment that *this measure would provide a greater reduction in flood damages than any other mitigation measures studied here other than extensive stopbanking, and it is likely that for a majority of houses a positive financial return to society, allowing for the transfer of costs and benefits associated with insurance, can be expected from its implementation* (pg. 20).

5.3.4 Social Equity

This option places emphasis on people and the community when considering the issue of flood damage and the appropriate floodplain management measures, and particularly focuses on the principle of equity. Based on this principle 'zero' flood damage is the desired outcome.

In Chapter 16, Objective 1 Policy 4 of the Regional Policy Statement it is stated that *in discharging their responsibilities for natural hazard management, the Regional Council, and territorial authorities in the Canterbury region should ensure that an appropriate combination of measures is used to modify occurrences, modify susceptibility to damage, and deal with the consequences of disaster.* 'Appropriate' is defined in the explanation of the policy as the combination of measures that deliver the desired level of protection, being a community choice, while incurring the lowest total monetary and non-monetary cost to the community.

The Proposed Christchurch City Plan has as its natural hazard objective (2.5) the *identification and minimisation of the impacts of natural hazards on public safety and investment in infrastructure.*

As the middle part of the catchment is already extensively developed, this option places emphasis on modifying flood events (structural measures) in combination with ensuring the new development and redevelopment in the floodplain is designed to provide the desired level of protection.

Modelling shows that only stopbank option can effectively reduce flood damage caused by the inundation of buildings, and in some cases, other private and public property. In all but the extreme event, two of the alternative options explored neutralise the effects of future development under the 50 Year Development Scenario, and provide an improvement to present flood damage (the first option provides the greatest benefit). These are:

- Soakage with Cashmere/Worsleys, Curletts and Wigram South Basins; and
- Cashmere/Worsleys, Curletts and Wigram South Basins.

The minimum floor level measure (extreme event) also has the potential to reduce flood damage caused by the inundation of buildings to the same extent as the stopbank measure. However, this measure will require a considerable implementation time before being totally effective.

5.3.5 Environmental Values

This framework places emphasis on:

- adverse environmental effects (including on people and the community) of the floodplain management measures; and
- environmental benefits, or opportunities, presented by the floodplain management measures.

The environmental effects can include visual, changing natural systems, surface water and groundwater contamination, changes in amenity values, and other impacts on people and communities. Where there is the opportunity, amenity values, water quality and other valued environmental systems (e.g. wetlands) may be enhanced.

Chapter 16, Objective 2 Policy 7 of the Regional Policy Statement provides that *in implementing measures to protect assets from natural occurrences, adverse effects of those measures on the environment, including loss of wildlife habitats or amenity values, heritage places, mahinga kai, and other taonga, are to be avoided, remedied, or mitigated.* Policy 2.5.7 of the Proposed City Plan is similar. However, this policy in the Proposed City Plan goes further by indicating the preferred stormwater disposal methods (retention of open waterway systems and promoting the use of ground soakage) both to avoid adverse effects on the environment and because of the opportunities presented to enhance environmental quality.

The floodplain management measures selected are generally those that provide opportunity for environmental enhancement. As such, there is an emphasis on physical measures that are of a scale that lend themselves to habitat establishment or restoration or the enhancement of amenity values. By far the majority of the floodplain management measures can be placed in either the positive or neutral category.

5.3.6 Implication of the Different Policy Approaches

As stated, the distinction between the four different approaches is somewhat artificial, but nevertheless it forms a useful guide to the implications of different approaches in the policy formulation process. To determine these implications, the purpose of this strategy, as set out in chapter 1 must be referred to (*to reduce to an acceptable level the extent of flood damage on the floodplain of the Heathcote River by integrating the management of the use, development and protection of natural and physical resources*). The different approaches will address the issues identified in chapter 3 to varying degrees. The implications of the different policy approaches are set out in Table 13.

The statutory and resulting policy frameworks place emphasis on integrating the four approaches identified. There is emphasis in the Resource Management Act 1991 on enabling people and communities to provide for their social, economic, and cultural well-being, and for their health and safety while avoiding, remedying, or mitigating adverse effects on the environment. The Regional Policy Statement and Proposed City Plan reflect this imperative. The Canterbury Regional Policy Statement emphases the concept of economic efficiency while enabling the community to determine what level of protection from flood damage is appropriate. The City Plan seeks to minimise the impact of natural hazards on public safety and investment in infrastructure, and recognises the environmental benefits of the soakage, retention and swale measures.

The public perception of these alternative approaches in policy is also important. This can in part be gauged by the responses to the Canterbury Regional Council and Christchurch City Council (1993) discussion document. The Taylor Baines (1993) report identified that the general thrust of the submissions is *that continued land development in the Heathcote River catchment is leading to increased risk of flooding - more extreme, more frequent, and with higher sediment loadings. Also identified was that a number of residents submissions took the view that people who live in the flood-prone areas chose to do so with the knowledge of the risks involved at the time of purchase. However, they see more recent developments, particularly in the upper catchment areas as imposing significant additional flood risks on them, while not bearing any of the associated costs* (page 7). Further, it stated that if *taken overall, these responses suggest a definite priority for measures to manage the social and environmental causes and effects, rather than have decision making influenced simply by $ costs and benefits* (page 16).

Table 13: Implications of different policy approaches

Policy Approach	Implications
Individual Responsibility	The primary advantage of this approach is that it places the capital expenditure responsibilities on the private sector allowing it to make an assessment of economic viability while ensuring no additional flood damage is experienced. In doing so it is possible that a more efficient use of resources will be achieved. However, this may be offset by the lack of ability to development integrated responses benefiting from 'economies of scale'. The disadvantages include the need to ensure that there are appropriate mechanisms available to require adverse effects to be internalised. This is particularly the case for areas where there are already development and redevelopment opportunities available (e.g. the middle of the catchment). Furthermore, the approach implies that the present level of flood damage is acceptable.
Economic Efficiency	The principal advantage of this framework is that the greatest net economic benefit will be obtained. However, the disadvantages include increased flooding of existing development due to further development within the catchment until redevelopment occurs at appropriate floor levels (assumes land costs are included) and does not address all flood damage (e.g. road flooding). Therefore, existing downstream development, particularly in the middle of the floodplain, is adversely affected under this approach. Furthermore, the lower part of the floodplain would become increasingly vulnerable to the effects of sea level rise.
Social Equity	The principal advantage of this approach is that it addresses flood damage as far as practicable. However, in doing so it requires a level of expenditure that is in excess of the value of the existing and predicted future flood damage. Furthermore, the stopbank measure is clearly shown to have adverse effects on the environment, and

Policy Approach	Implications
	in particular on amenity values in predominately residential areas.
Environmental Values	The primary advantage of this option is that it ensures that the implementation of the bundle of floodplain management measures positively contributes to environmental quality. Implementation of the floodplain management measures will neutralise flood damage caused by the development of the upper part of catchment under the 50 Year Development Scenario. However, the flood damage caused by the development and redevelopment of the middle of the catchment will not be addressed in any significant way without implementing a number of the neutral environmental measures. This option does not address flood damage in the lower floodplain.

5.4 Strategy Principles

The four different policy approaches lead to different outcomes. In some cases these are similar in flood damage reduction terms (e.g. individual responsibility when compared with social equity), and in other cases, widely divergent outcomes (e.g. economic efficiency when compared with social equity, individual responsibility, and environmental values).

The most robust approach is to attempt to maximise the consistency between all different policy approaches – that is selecting those measures that perform well no matter what policy approach is applied. The statutory and policy context can be interpreted as supporting this action (this was reinforced by the tangata whenua who identified the need for a holistic approach to management of the floodplain). However, this requires that a trade off is made between the different policy approaches and therefore the floodplain management measures. To achieve this, six principles can be identified from the previous discussion that integrate the four different policy approaches. These are:

1. *Integrated land and water management on a catchment wide basis;*
2. *Development and redevelopment should minimise, as far as practical, flood damage;*
3. *Over time the number of existing buildings subject to flood damage should be reduced;*
4. *Choices between floodplain management measures should favour those that are environmentally (including people and the community) sensitive where the floodplain management measures are roughly comparable;*
5. *Individuals should be provided with adequate information to make informed decisions; and*
6. *The selection of the bundle of floodplain management measures should be guided by the economic consequences of their implementation.*

5.5 Summary

Within this chapter the 26 possible floodplain management measures identified in the previous chapter were assessed for their effectiveness, efficiency and environmental

effects. Using this assessment each measure was evaluated using four different policy approaches. This highlighted the different forms the final strategy may take depending on what emphasis is placed on which policy approach. In order to ensure the strategy is 'robust' six principles were identified to integrate the four policy approaches, recognising that this integration requires a trade off to be made between them. These strategy principles will be used in the next chapter to develop the Heathcote River Floodplain Management Strategy.

6 Strategy to Manage Flood Damage

6.1 Introduction

The purpose of this chapter is to detail the strategy to manage the flood damage issues in the Heathcote River floodplain. It will do this using the assessment and evaluation undertaken, and the six strategy principles identified, in chapter 5. The strategy will consist of a bundle of measures to address the floodplain management issues identified in chapter 3. Finally, this chapter will examine the implication for the long term management of the Heathcote River floodplain (i.e. 50 years from now and beyond).

By necessity, each of the individual floodplain management measures must be viewed as part of the total solution. It is not possible to partially implement the solution or partially implement any one chosen measure. To do so would result in a significant decrease in the benefits of the strategy itself.

6.2 Selected Bundle of Management Measures

The chosen bundle of floodplain management measures and the anticipated benefits are set out in Table 15, page 45. These floodplain management measures address the identified issues by:

- taking a holistic catchment based approach;
- recognising the importance of community understanding and ownership of flood damage issues;
- localised stopbanking around industrial, and other, properties in Woolston Loop area to address present flood damage and potential sea level rise;
- controlling the location of future development to ensure the immediate environs of the Heathcote River and the tidal floodplain, and the Waimakariri River overflow paths are not developed inappropriately;
- setting minimum building floor levels on the floodplain to ensure no new building will be flooded, and over time, reduce the number of existing buildings that will be flooded;
- enhancing Cashmere/Worsleys Basin to in part, mitigate the present and future flood damage in the middle of the floodplain; and
- ensuring that development of the upper part of the catchment (including the Cashmere Stream sub catchment) does not result in an increase in flood damage in the middle part of the floodplain by implementing soakage and retention options.

6.3 Long Term Considerations

6.3.1 Background

The focus of this strategy has been on the effects of present flood damage and the damage under the 50 Year Development Scenario. However, beyond this time further development of the Heathcote River catchment can be expected. Such development will also give rise to flood damage issues within the Heathcote River catchment that will require mitigation.

The nature and location of development over the next 50 years will impinge on the options available to manage flood damage caused by the development and redevelopment of the catchment occurring after this period ends. Therefore, consideration must be given to the potential range of floodplain management options available and what actions are reasonable at this time to ensure these options remain available to benefit future generations.

6.3.2 Long Term Options

This strategy is based upon the assumption that development in the upper part of the Heathcote River catchment generally has a neutral effect on down stream flood damage, particularly in the middle part of the floodplain. Local community soakage and retention achieve this. However, two significant retention options were identified in the Heathcote River Catchment Investigation – Stage 2 (Christchurch Drainage Board 1985) that have been further explored, but not adopted, as part of this strategy. These are the:

- Wigram South Retention Basin; and
- Curletts Retention Basins.

As shown in Figure 4, page 49, these are located in the upper part of the catchment that is not currently developed for urban purposes. Significant development is anticipated to occur in the sub catchment above Curletts Basin. The modelling results indicate that, in combination with other measures, these basins effectively mitigate flood damage. Consequently, while these measures are not required at this time, it is prudent to maintain the option of developing the basins in the future.

The Wigram South Basin option is likely to remain available notwithstanding development. This is due to the incised nature of the Heathcote River in this location. No further action is viewed as being warranted at this time to retain this option for the future.

The Curletts Basin site does not have the same natural protection as the Wigram South Retention Basin site. Therefore, it remains vulnerable to development for other purposes notwithstanding its current zoning in the Proposed City Plan. As such, the long term protection of this site needs to be considered. Options available include land purchase and negotiated protection. It is strongly recommended that these options are explored and protection achieved over the short term.

Further, another floodplain management measure identified relates to the removal of structures constricting the water flow over the Heathcote River floodplain. While not recommended in this strategy, this matter is worthy of further consideration as and when these structures are being replaced. The Colombo Street Bridge represents one such structure.

6.4 Summary

Table 14 below summarises the specific measures to manage the issues in the Heathcote River floodplain as identified in chapter 3.

Table 14: Summary of the Heathcote River Floodplain Management Strategy

Floodplain Area	Issue	Management Measures
All	All	• Development and implementation of information and education programmes • Continuation of adequate warning and emergency procedures and programmes • Requiring financial contributions from developers • Encouragement of minimisation of hard surface areas
Lower	Potential tidal flood damage	• Maintenance of the existing floodplain management measures • Localised stopbanks to protect individual properties in and around Woolston Loop • Minimum floor levels
	Increase in potential tidal flood damage due to sea level rise and new development	• Maintenance of the existing floodplain management measures • Restriction of development in the tidal floodplain area that has yet to be developed • Localised stopbanks to protect individual properties in and around Woolston Loop • Minimum floor levels
Middle	Potential flood damage as a result of significant rainfall events	• Maintenance of the existing floodplain management measures • Minimum floor levels
	Increase in potential flood damage as a result of new development and redevelopment in the middle of the Heathcote River catchment	• Maintenance of the existing floodplain management measures • Enhancement of the Cashmere/Worsleys Valley ponding area • Maintain river setbacks • Minimum floor levels
	Increase in potential flood damage as a result of new development in the upper part of the Heathcote River catchment in areas of relative pervious soils	• Maintenance of the existing floodplain management measures • Community soakage • Swale systems • Roof water directly into soakage
	Increase in potential flood damage as a result of new development in the Cashmere Stream sub catchment in areas of relative impervious soils	• Maintenance of the existing floodplain management measures • Community retention through 'green corridors' • Swale systems
Upper	Potential flood damage as a result of inappropriate development of Waimakariri River overflow channels	• Avoid high risk/high damage development (e.g. industry and hospitals) in Waimakariri River overflow channels

Taken as a whole, these measures will:

- manage development in areas particularly susceptible to flood damage;
- provide localised mitigation for the industrial and other areas associated with Woolston Loop;
- over time mitigate flood damage caused by the development and redevelopment of the middle of the catchment;
- significantly reduce the effects on flood damage from development in the upper part of the catchment (including the Cashmere Stream sub catchment); and
- reduce potential damage caused by the flooding of high risk/high damage development in the Waimakariri River overflow channels within the upper part of the catchment.

Also, it is important that consideration be given to the form of protection required to maintain the future option of the development of the Curletts Retention Basin. Further, the strategic benefit of removing or redesigning structures that currently restrict the flow of water across the Heathcote River floodplain in flood conditions should be recognised.

The next chapter will examine the implementation of the strategy, including agency responsibility, mechanisms, timing and financing matters.

Table 15 Chosen bundle of floodplain management measures

Management Measure	Description	Anticipated Flood Damage Benefits	Secondary Benefits	Issues addressed
Retain existing retention, ponding and conveyance system	Includes Woolston Cut, Wigram East Retention Basin, and Cashmere/Worsleys, Hendersons and Hoon Hay Basins. The method protecting the existing system may include regulation, land purchase, or other mechanisms to obtain an interest in the land	No additional flood damage and some continued mitigation for future flood damage	Maintains present amenity, heritage, ecological, recreation, cultural and landscape values and provides opportunity for enhancement of these	All
Maintain effective emergency plans and procedures	Emergency response procedures and civil defence	Provides response to flood events and opportunities to reduce flood damage	-	All
Maintain flood warning systems	Meteorological warnings, and telemetered rain gauge and water level recorders	Provides warning of flood event and opportunity to reduce flood damage	-	All
Liaison with affected property owners and the wider community	Education, information and advocacy	Community awareness and ownership of the flood damage issues leading to reduction in damage as a result of actions taken by individuals	-	All
Impose financial contributions to the cost of additional floodplain management measures	Requirement of a developer to contribute money, land works, services, or a combination of these	Exacerbater pays	Provides for community affordability	Future – all
Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Control of the use of pervious and semi pervious surfaces	Reduces stormwater volumes reaching retention, soakage, and treatment devices, and river system	Provides water quality benefits through natural soakage. Reduces stormwater reticulation costs	Future – all

Management Measure	Description	Anticipated Flood Damage Benefits	Secondary Benefits	Issues addressed
Retain setbacks from waterways and strengthen controls (particularly in relation to filling)	From the estuary upstream to the Heathcote River/Cashmere Stream confluence the minimum setback is 30 metres, while for the upper Heathcote River and Cashmere Stream it is 20 metres in the rural zones and 15 metres in the urban zones	Retention of the present floodplain conveyance and storage in the immediate vicinity of the floodway and the avoidance of development within areas subject to higher water depths and velocities	Provides for riverscape amenity, heritage, ecological, recreation, cultural and landscape values to be maintained and enhanced. Retains access options	Future - all
Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Manages development in the identified overflow paths by avoiding high risk/high damage development in these locations. Includes incorporating overflow channels within green corridors where practicable, allowing residential development at appropriate floor levels based on an assessment of risk, and developing secondary flow paths where necessary.	Reduces potential flood damage, and avoid the risks posed to the community and environment by the flooding of high risk development in the upper part of the catchment by managing development in the Waimakariri River overflow channels.	Overflow channels could be developed as 'green corridors'	Future - upper floodplain
Control development in the tidal floodplain	Avoids high value development on the tidal floodplain by appropriate controls	Avoidance of future flood damage	Provides amenity, heritage, ecological, recreation, cultural and landscape values to be maintained and enhanced	Future - lower floodplain
Set minimum floor levels	Minimum floor levels for buildings be set to ensure there is no flood waters above floor level.	Reduction in flood damage by the progressive raising of existing buildings that are presently flooded upon redevelopment and the avoidance of future flood damage caused by inappropriate floor levels	-	Future - middle and lower floodplain

Management Measure	Description	Anticipated Flood Damage Benefits	Secondary Benefits	Issues addressed
Enhance storage in Cashmere/Worsleys Basin	Restrict the outlet of the Cashmere/Worsleys Basin to slow the release of ponded water into the Cashmere Stream and Heathcote River	Reduction in flood damage in the middle catchment caused by the present development in the middle of the catchment and ongoing redevelopment of the middle of the catchment.	-	Present and future - middle floodplain
Develop community soakage basins for development in upper catchment (pervious)	Develop soakage basins to direct runoff into the underlying gravels	Neutral effect on flood damage within the catchment due to the development of the areas of the upper catchment with relatively pervious soils.	Provides amenity, heritage, ecological, recreation, cultural and landscape values to be enhanced and potential ground water quality and quantity benefits	Future - middle floodplain
Roof water and all runoff into soakage from new development	Direct all roof water through private or community system into the underlying gravels	Reduces the size of the stormwater reticulation system required	Provides surface and ground water quality and quantity benefits.	Future - middle floodplain
Use swales to carry stormwater in upper Heathcote River catchment for new development	Use of constructed surface 'natural channels' to convey stormwater to soakage and retention basins	Provides significant storage, soakage and flood routing opportunities enabling smaller soakage and retention basins	Provides opportunities to enhance amenity, heritage, ecological, recreation, cultural and landscape values. Often requires lower maintenance and replacement costs than traditional pipe system. Provides water quality benefits	Future - middle floodplain
Develop a waterway corridor retention system to manage stormwater for development in the upper catchment (Cashmere Stream sub catchment) prior to it entering Hendersons Road Basin	Enhance the existing surface drainage system into a water way corridor to slow the release of storm water into the Henderson Road Basin and finally into the Heathcote River until after the critical storm event has passed.	Reduces effect on flood damage within the catchment due to the development of the areas of the upper catchment with relatively impervious soils (i.e. Cashmere Stream sub catchment)	Provides surface water quality benefits and the opportunity to enhance amenity, heritage, ecological, recreation, cultural and landscape values.	Future - middle catchment

Management Measure	Description	Anticipated Flood Damage Benefits	Secondary Benefits	Issues addressed
Localised stopbanks around industrial and other development within Woolston Loop area	Development of bunding to protect the existing development in a flood event from inundation by flood water	Protects existing industrial and other development from flood damage	-	Present and future lower floodplain

HEATHCOTE RIVER FLOODPLAIN
EXISTING & RECOMMENDED MANAGEMENT MEASURES

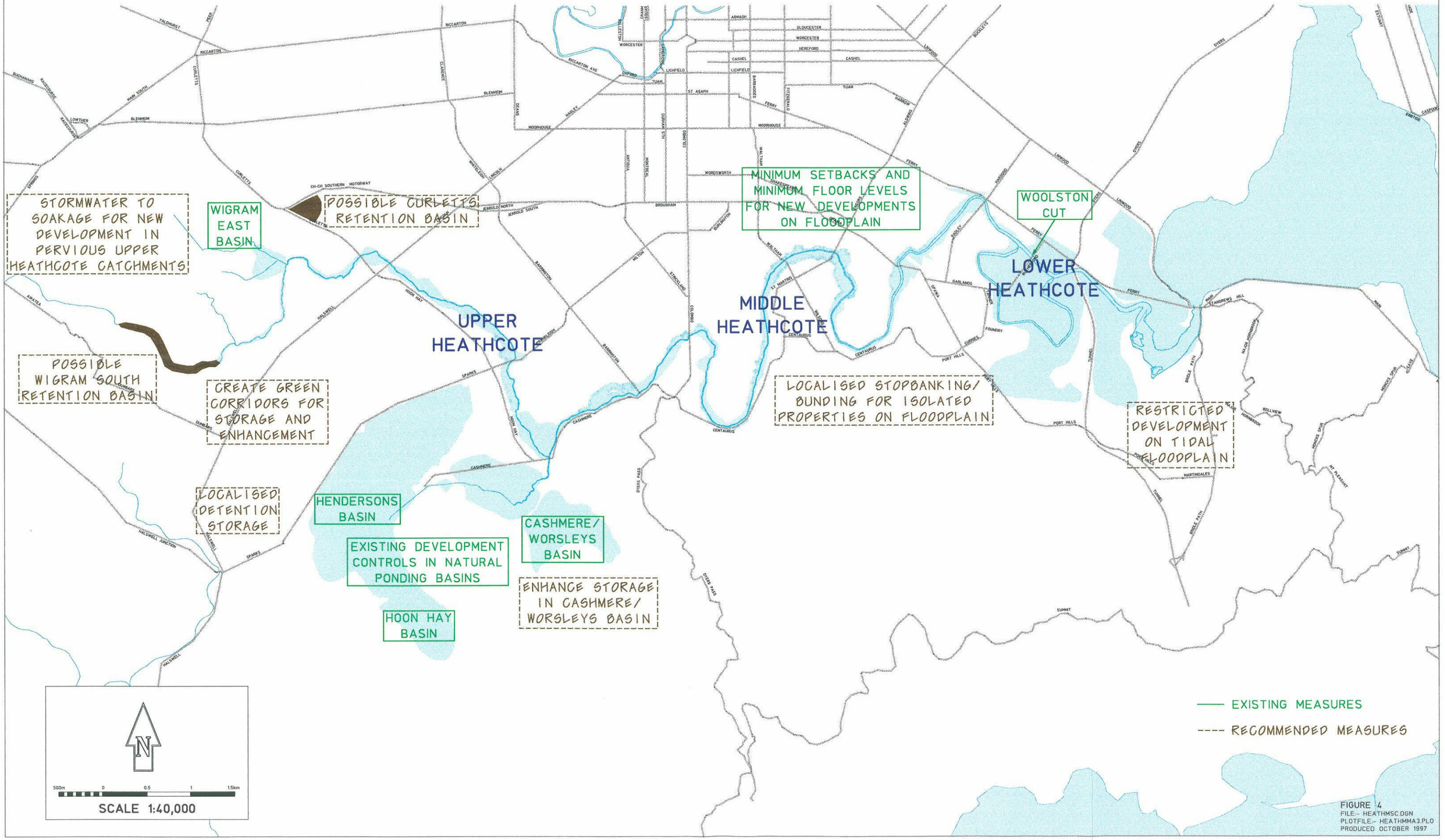

FIGURE 4
FILE:- HEATHMSC.DGN
PLOTFILE:- HEATHMMA3.PLO
PRODUCED OCTOBER 1997

7. Implementation and Operation

7.1 Introduction

In the previous chapter the strategy to manage flood damage within the Heathcote River catchment was determined. The floodplain management measures that form the strategy range in type, location and the extent of their effectiveness. Notwithstanding this, each mitigation measure forms part of the 'bundle' that must be viewed as an integrated whole.

For ease, in this chapter the floodplain management measures will be discussed based on the characterisation in Appendix 1. The relevant classes of floodplain management measures are:

- **land modification** – physical measures relating to ponding, soakage and retention that generally will require capital expenditure on behalf of the community and include the use of swales;
- **river control** – the physical measure of stopbanking and bunding;
- **land use management** – measures that control the location and type of development, including setbacks, minimum floor levels and development control on the tidal floodplain; and
- **community preparedness** – measures that provide for community response to the risk of flood damage, including emergency plans, flood warning systems and liaison with property owners and the community.

The various measures will need to be implemented as:

- capital works (e.g. land modification, purchase and river control measures) incorporated in the Christchurch City Council's Financial Plan and Budget;
- statutory resource management responsibilities of Christchurch City Council (e.g. City of Christchurch City Plan). This may require variations or changes to the City Plan;
- yearly activities (e.g. community preparedness measures) incorporated in the Christchurch City and Canterbury Regional Councils financial plans and budgets.

This chapter will provide an implementation programme for the strategy, including sequence and events, identifying areas of responsibility, timing and other matters.

7.2 Implementation of Measures

7.2.1 Background

The land modification and river control measures associated with the strategy will need to be in accord with the Resource Management Act 1991. This includes the Regional Policy Statement and regional plans and the City Plan.

The design, operation and maintenance of these particular measures also requires an approach that satisfies the Christchurch City Council's Asset Management Strategy for Waterways and Wetlands. This strategy takes a holistic approach whereby management is concerned with all the values associated with waterways and wetlands; landscape, ecology, recreation, culture, heritage, and drainage.

7.2.2 Land modification

7.2.2.1 Enhance storage in Cashmere/Worsleys Basin

The intention of this measure is to avoid the effects of increased rainfall runoff from more intensive development within existing urban areas, mainly in the middle part of the catchment.

In its original natural form, the basin would have contained Raupo swamp. This would have benefited wildlife and water quality in the Heathcote River through reducing sediment load. This measure therefore also provides the opportunity to recreate this original character.

Implementation of this measure is very much dependant on successful negotiations with the owners of the land within the basin. This will be undertaken by the Christchurch City Council who will also be responsible for:

- design of the basin environment and outlet controls within the context of a landscape plan that takes account the existing and potential values of the site and its locality;
- successful application to the Canterbury Regional Council for a resource consent for the control of natural water;
- the establishment of a development levy to meet all, or part, of the costs associated with achieving enhanced storage; and
- City Council approval as to timing of budget provision.

7.2.2.2 Stormwater to soakage

This measure is intended to apply mainly to urban growth areas located on relatively permeable soils within the aquifer recharge area, west of urban Christchurch.

The soakage system will have two separate components:

- roof stormwater to discharge through a sealed system to an approved soakage chamber; and
- surface runoff from garden and paved areas collected separately from roof stormwater and disposed of via swale systems through soil absorption basins.

This measure provides an opportunity for innovative urban design whereby the space required for stormwater collection, treatment and disposal can become an integral part of green space and corridors required for pedestrian access, recreation and landscape values.

Implementation will be by the Christchurch City Council and requires:

- resource consents from the Canterbury Regional Council;
- design, operation and maintenance standards;
- financial contributions from developers;
- special provisions in the City Plan as appropriate, in conjunction with variations and/or submissions relating to urban growth; and
- subdivision consent requirements.

7.2.2.3 Retention Storage in Cashmere Stream catchment

This measure is required for new urban growth on the relatively impervious soils in the Halswell area within the Cashmere Stream catchment.

Retention volumes required will be relatively small (especially during major storms) given the existing catchment dynamics. Key components of these dynamics include; the location of the Henderson Road ponding area, the nature of the impervious soils, high groundwater levels and low rainfall absorption.

It is envisaged that these volumes could be managed by the enhancement of the existing utility waterways into environmental asset waterways as part of urban development. Also, with innovative urban design, efficient water quality and quantity control could be achieved by roadside swales alongside distribution roads.

Implementation would be by the Christchurch City Council and will involve:

- appropriate measures in the City Plan in conjunction with variations and/or submissions relating to urban growth;
- financial contributions from developers;
- subdivision consent requirements;
- design, operation and maintenance guidelines; and
- resource consents for quality and quantity changes to natural water.

7.2.3 River control - local stopbanking and bunding of selected properties

This measure is intended for properties not benefiting from other floodplain management measures. It would involve the sensitive design and construction of low profile earth embankments or walls around the periphery of privately owned land.

The process will need to include:

- discussions with property owners at all stages;
- the granting of the necessary resource consents; and
- recognition and protection of the works on plans and legal documents.

Christchurch City Council staff and property owners will initiate implementation. A policy on cost apportionment will need to be developed.

7.2.4 Land use management

7.2.4.1 Retain existing retention, ponding and conveyance system

No special or additional measures are necessary to protect existing features such as the natural ponding in the Cashmere Stream catchment, Wigram Basin and Woolston Cut. It is anticipated that natural ponding in rural areas will come under increasing pressure for filling as the peri-urban area develops. A review of the effectiveness of current City Plan rules is likely to be needed in the medium term. As part of this review the effectiveness of other methods, including obtaining an interest in the land, will need to be examined.

7.2.4.2 Avoid high risk/high damage development in the Waimakariri River overflow channels

The implementation of this measure is dependent on the outcome of the ongoing discussions between the Canterbury Regional Council and Christchurch City Council following the withdrawal of the Proposed Waimakariri River Floodplain Management Regional Plan. It could include incorporating overflow channels within green corridors where practicable, allowing residential development at appropriate floor levels based on an assessment of risk, and developing secondary flow paths where necessary.

7.2.4.3 Retain set backs from waterways and strengthen control

Waterway setback rules currently exist within the Proposed City Plan and apply throughout the Christchurch City. The rules set limits on building and earthworks for the protection of riparian environments and floodplain storage capacity.

It is possible to apply for resource consent for building and earthworks within the prescribed setback distances. As part of the Proposed City Plan submission and hearings process, setbacks are being reviewed. It is anticipated that the special importance of protecting the storage capacity of the Heathcote River floodplain will be stated in a future variation to the City Plan.

7.2.4.4 Restricted Development on Tidal Floodplain

The New Zealand Coastal Policy Statement, and the Proposed City Plan, require caution to be taken when contemplating development in areas subject to tidal inundation. This includes a requirement to take account of rising sea levels.

Application of the above policies together with information derived from the floodplain management strategy and current predictions of sea level rise, will provide the basis for implementing this measure. It will be applied mainly when responding to proposals for changes to the City Plan that would allow greater development than currently provided for (e.g. rezoning from rural to urban land use or to a higher density of development in urban zones).

7.2.4.5 Set minimum floor levels

Currently floor levels are set at the 2% AEP (50 year) storm event (recognising future catchment development) under the provisions of the Building Act.

Given that setting levels at or above less frequent storm events provide both economy in flood damage terms and 'peace of mind', the setting of minimum floor levels is being reviewed, including considering imposing minimum floor levels for new non residential development (e.g. industrial and commercial). A joint Christchurch City Council/Canterbury Regional Council Working Party on development levels has been reconvened for this purpose. It is anticipated that appropriate minimum floor levels will be addressed through a variation to the Proposed City Plan by mid 1999.

7.2.5 Community preparedness

7.2.5.1 Maintain effective emergency plans and procedures

The relevant information from the Heathcote River floodplain studies will be incorporated into the operation manuals of flood management structures and the Land Drainage/Minor Emergency Response Procedures of the Christchurch City Council. This data, together with actual hydrometric monitoring data will aid emergency managers in their decision making and will remain available should a Civil Defence emergency arise during an extreme storm event.

7.2.5.2 Maintain flood warning system

This is implemented through the procedures described in 7.2.5.1.

7.2.5.3 Liaison with affected property owners and the wider community

This is a pro-active measure intended to both reduce flood damage by empowering individuals to make informed decisions, and to enhance the benefit of flood warnings by having property owners aware of how they might be affected by flooding and what they can do to limit the impact. It will be achieved by ongoing consultation with interested parties. It will be important to ensure that residential and business property owners are aware of how they will be affected by flooding and that they have enough information to make decisions about how the impacts can be limited.

Information booklets will be distributed to property owners, and public meetings held to discuss the issues. These measures will need to be repeated at appropriate intervals to ensure that the information within the community continues to be current and new owners are also informed.

It is anticipated that annual funding will be provided by the Christchurch City Council and the Canterbury Regional Council.

7.3 Implementation Sequence

Land modification measures (7.2.2) should ideally be implemented before development proceeds in order to achieve maximum cost recovery from development levies. Target dates for all types of measures are set out in Table 16.

Table 16 : Target times for the implementation of measures

Measure Type	Reference	Target Time
Land modification	7.2.2.1 (Cashmere/Worsleys)	As soon as practicable.
	7.2.2.2 (Soakage) and 7.2.2.3 (Retention)	As soon as possible after decisions on City Plan urban growth submissions
River Control	7.2.3	Could commence with discussions with property owners at any time with proposal referred to the Council for financial allocation and priority.
Land Use Management	7.2.4	Relates to the proposed City Plan and in most cases implementation is part of the current process of hearing of submissions. The exception is the possibility of achieving floor levels above extreme flood levels. Since existing practice is satisfactory, target review date is December 1998.
'Community Preparedness'	7.2.5	Requires specific budget allocation with respect to publication and ongoing staff time costs and should commence in the 1998/99 financial year.

The other components relating to procedures and warnings have been implemented.

7.4 Summary

This chapter has detailed the implementation responsibilities, sequence and timing of the floodplain management measures that form part of the strategy described in chapter 6. These measures are an integrated whole, which collectively reduce flood damage within the Heathcote River floodplain.

The implementation of the land use management techniques generally requires a statutory response principally by the Christchurch City Council under the Resource Management Act 1991. This may lead to variations to the Proposed City Plan or changes to the City Plan once it is operative. These ideally should be implemented before development or redevelopment proceeds.

The river control measure requires negotiations between and landowners and the Christchurch City Council before it can be implemented. The City Council will need to develop a policy on cost apportionment.

The land use management measures principally rely on implementation through the City Plan. Therefore, the Christchurch City Council retains the major implementation responsibility. Further work involving both the Christchurch City Council and Canterbury Regional Council is required to develop the detail necessary to implement the Waimakariri River overflow, and minimum floor level, controls.

The community preparedness measures are less complex to implement, but no less important. They will generally require funding through the annual plan processes of the Christchurch City Council and the Canterbury Regional Council.

Appendix 1: Classification of Floodplain Management Measures[11]

Purpose	Class		Type	
Modify Flood Event	1	Weather Modification	i	cloud seeding
	2	Land modification	i	afforestation
			ii	conservation planting
			iii	onsite ponding
			iv	natural storage
	3	River control	i	dams
			ii	retention basins
			iii	channel improvements
			iv	diversions
			v	stopbanks
			vi	local drainage
Modify Flood-loss Susceptibility	1	Land use management	i	district and regional plans
			ii	encroachment lines
			iii	subdivision requirements
			iv	building code
			v	land/building acquisition
			vi	urban renewal policies and plans
			vii	floodplain development policies and plans
			viii	removing/rebuilding structures
	2	Floodproofing	i	banks, walls
			ii	elevation of structures
			iii	waterproofing of structures
	3	Community Preparedness	i	education and public information
			ii	flood warning/forecasting
			iii	evacuation plans
			iv	rescheduling of activities
			v	elevation/protection of buildings
	4	Emergency actions	i	flood-fighting
Modifying Flood-loss Burden	1	Insurance		
	2	Tax deductions		
	3	Loans		
	4	Relief Funding		
	5	Feeding and sheltering victims		
	6	Rehabilitation of services		

[11] Based on Ericksen (1986)

Appendix 2: Assessment Factors for Floodplain Management Measures[12]

Category	Main Factors Considered
Physical	• damage reduction performance • maintenance level • implementation problems • timing of effect • limitations and conditions • future flexibility
Economic	• cost level • benefit to cost ratio • user pays
Social	• disruption • recreation opportunities • cultural and political matters • land acquisition • heath and safety • diversion of hazard • public information/opinion
Environmental	• ecology (plant and animal communities and habitat, including mahinga kai species) • visual or aesthetic amenity • water quality
Legal	• ability to implement (including funding) • Regional Policy Statement • proposed Christchurch City Plan • resource consents • Part II of Resource Management Act 1991 • New Zealand Coastal Policy Statement • Building Act 1991

[12] Based on Griffiths (1991) with modification

Appendix 3: Range of Floodplain Management Measures Available

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
Modify Flood Events	Weather Modification	1	Cloud seeding	Alters the timing and intensity of rainfall		Existing/ New
	Land Treatment (Soakage)	2	Stormwater discharge of roof runoff to soakage from new development	Reduces stormwater runoff into Heathcote River, and in areas of permeable soils. Maintains present groundwater recharge system. Identified as particularly relevant for new development on the western plains to control increased flood damage between Lincoln Road and Radley Street	Royds (1996), Oliver (1997), CRC & CCC (1993)[14], B&T (1993) [15]	New
		3	Stormwater discharge of roof runoff to soakage from existing development	Reduces stormwater runoff into Heathcote River.	Royds (1996), CRC & CCC (1993)	Existing
		4	Stormwater discharge of yard runoff to soakage from new development	Reduces storm runoff reaching River system and approximates present groundwater recharge system - particularly relevant for new development on the western plains	Royds (1996), Oliver (1997), CRC & CCC (1993), TB (1993)	New

[13] In this context 'benefit' is taken to mean:
a) For 'Existing' - reducing the flood damage burden to the existing development and development areas
b) For 'New' - assumes that any new development area cannot be established without fully mitigating the potential adverse effects on the existing development and development areas. Therefore, the benefit accruing to the new areas is the ability to establish

[14] Canterbury Regional Council and Christchurch City Council (1993)

[15] Taylor Baines and Associates (1993)

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[15]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Retention)	5	Stormwater discharge of yard runoff to soakage from existing development	Reduces the storm runoff reaching the catchment river system	Royds (1996)	Existing
		6	Stormwater discharge of sub catchment runoff to soakage from existing development	Principally addresses the periodic inundation of houses, garages, sections and roads, particularly in the middle reaches of the floodplain between Lincoln Road and Radley Street by avoiding bank overflows and floodplain inundation	CRC & CCC (1993), Royds (1996)	New
		7	Stormwater discharge of paved areas runoff to soakage from new development	Reduces storm runoff reaching catchment river system and approximates present groundwater recharge system	Royds (1996), Oliver (1997), TB (1993)	New
		8	Create retention storage in large retention basins	Slows the release of storm runoff to the Heathcote River system through the use of community based measures. New development of the upper Heathcote flood plain is anticipated to increase flood damage between Lincoln Road and Radley Street.	Royds (1996), Oliver (1997), CRC & CCC (1993)	New
		9	Develop Curletts Retention Basin	Slows release of storm runoff in upper catchment to the Heathcote River. It is anticipated that the measure would reduce flood damage in the middle of the catchment	CDB (1995)[16]	New

[16] Christchurch Drainage Board (1985)

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
		10	Develop Wigram South Retention Basin	Slows release of storm runoff in upper catchment to the Heathcote River. It is anticipated that the measure would reduce flood damage in the middle of the catchment	CDB (1995)	New
		11	Create retention storage within waterway corridor	Slows the release of storm runoff to the Heathcote River system through the use of community based measures	Oliver (1997) Royds (1996), CRC & CCC (1993)	New
		12	Control outlets of Cashmere/Worsleys Basin	Enhances natural storage slowing the release of storm runoff to the Cashmere Stream and hence the Heathcote River	Oliver (1997), TB (1993)	Existing/ New
		13	Enhance the natural storage in the Hoon Hay Basin	Increases amount of water detained and therefore slows the timing of the release of water into the river system.	Oliver (1997), TB (1993)	Existing/ New
		14	Enhancement of Hendersons Basin	Slows the release of storm runoff to the Heathcote River system	Oliver (1997, TB (1993))	Existing/ New
		15	Enhance Wigram East Basin	Slows the release of storm runoff to the Heathcote River system	Oliver (1997), TB (1993)	Existing/ New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Vegetation)	16	Retrofit storage facilities where space and other opportunities allow	Backwater effects caused by sustained high water levels during large floods in the Heathcote River, particularly within the tributary drainage catchments between Glenpark Street and Gould Crescent, and in the event of urban consolidation within the flat tributary catchments east of Hoon Hay Road between Barrington and Radley Streets.	CRC & Christchurch City Council (1993)	Existing
		17	Control runoff with local retention and green corridors within developments from new development on plains	Slows the release of storm runoff to the Heathcote River system.	Royds (1996)	New
		18	Control runoff with local retention within developments from new development on hills	Manages the release of storm runoff to the Heathcote River system	Royds (1996)	New
		19	Moderating or controlling runoff at various locations via an assortment of tree and shrub planting schemes	Slows the release of storm runoff to the Heathcote River system	TB (1993)	Existing/ New
		20	Valley re-afforestation of Port Hills	Reduces sedimentation of the channels of the rivers and natural ponding areas, thereby maintaining conveyance capacity	CRC & CCC (1993), Royds (1996)	Existing/ New
		21	Hillside re-afforestation of Port Hills	Reduces sedimentation of the channels of the rivers and natural ponding areas, thereby maintaining conveyance capacity	CRC & CCC (1993), Royds (1996)	Existing/ New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	River Control (Channel)	22	Promote re-vegetation on erosion prone slopes and adjacent to waterways	Minimises sedimentation in the Heathcote River and ponding areas, thereby retaining capacity.	CRC & CCC (1993)	Existing/ New
		23	Construct a more efficient channel	Increase in conveyance capacity in the tidal reaches below Opawa Road	CRC & CCC (1993)	Existing/ New
		24	Widen/deepen channel	Removes local hydraulic restrictions thereby increasing channel carrying capacity. Benefits the middle reaches of the floodplain, and Cashmere Valley tributaries and upstream of Hanson Park (if urban consolidation occurs between Tempelton Road and Radley Street). Could exacerbate flooding down stream	CRC & CCC (1993), Royds (1996), TB (1993)	Existing/ New
		25	Increase Heathcote River Channel capacity from Lincoln Road to Woolston Cut	Addresses the periodic inundation of houses, garages, sections and roads in the middle reaches of the floodplain between Lincoln Road and Radley Street by avoiding bank overflows and floodplain inundation	CRC & CCC (1993)	Existing
		26	Remove local constrictions in downstream River Channel (i.e. Colombo Street Bridge)	Maximises channel conveyance by removing localised constrictions, reducing bank overflow and floodplain inundation along the middle reaches of the Heathcote River.	Royds (1996), CRC & CCC (1993)	Existing/ New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	Sedimentation	27	Retain channel maintenance programme	Maintains present channel conveyance capacity in light of continuing sedimentation - Hicks (1993) suggests that this could include some 'over dredging'.	Royds (1996)	Existing
		28	Increase channel maintenance activity	Increases channel conveyance by maintaining the existing conveyance capacity where then sedimentation rate exceeds the removal rate - Hicks (1993) suggests that this could result in additional sedimentation	CRC & CCC (1993), TB (1993)	Existing/ New
		29	Increase remedial bank support programme	Reduces sedimentation and constrictions of the channel thereby maintaining conveyance capacity	CRC & CCC (1993), TB (1993)	Existing/ New
		30	Reduce sediment discharge from Port Hills, including from land-uses and subdivisions	Maintains present channel conveyance capacity in light of continuing sedimentation - Hicks (1993) identified this as a significant source of sediment	Royds (1996), CRC & CCC (1993), TB (1993)	Existing/ New
		31	Reduce vegetation on banks and berms	Increases conveyance on floodplain by removing constrictions	Royds (1996)	Existing/ New
		32	Encourage rapid flooding of river floodplain	Provides for staged release of water into channel thereby optimising the use of the existing conveyance capacity	Royds (1996)	New
	(Stopbanks)	33	Construct continuous stopbanks	Maximises channel conveyance by constraining water movement onto other parts of the floodplain	Royds (1996)	Existing/ New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Diversions)	34	Construct localised stopbanks/bunding	Provide protection from flood damage in targeted areas by constraining water flow outside the stopbanks - particularly relevant in the Cashmere Stream tributaries	CRC & CCC (1993), Royds (1996), Oliver (1997)	Existing/ New
		35	Divert part of upper Heathcote catchment into Halswell catchment, possible through retention basins	Removes part of headwater from Heathcote River system into Halswell catchment - particularly relevant to control flood damage resulting from urban development on the western plains.	CRC & CCC (1993), Royds (1996), TB (1993)	New
		36	Divert part of upper Heathcote catchment into Avon catchment, possible through retention basins	Removes part of the headwaters from Heathcote River system into Avon River	CRC & CCC (1993), Royds (1996)	New
	(Backflow)	37	Maintain tidal gates at Woolston Cut	Ensures salt water does not propagate upstream through Woolston cut.	Royds (1996),	Existing
		38	Retain Woolston Loop tidegates after the Woolston Tidal barrage is operational	Provides protection against extreme high tides in the Estuary resulting in inundation of industrial premises around Woolston Loop.	CRC & CCC (1993)	Existing
		39	Install new tidal-gates at some point on the Heathcote River	Minimise tidal flooding by forming a barrier to up stream tidally based flows	Royds (1996)	Existing
		40	Control tidal backflow	Reduces the influence of tidal conditions on flood levels and hence flood damage	TB (1993)	Existing

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Local Drainage)	41	Improve downstream tributary drains	Maximise channel conveyance in tributaries by removing localised constrictions	Royds (1996)	Existing
		42	Install non-return mechanisms on stormwater drains	Reduces flood damage in tidal floodplains by controlling reverse flow caused by tidal influences	Royds (1996), TB (1993)	Existing
		43	Install special manholes or outfall valves on all drainage outfalls to prevent back flow	Minimises backflow during spring tide conditions that results in street flooding - particularly between Tunnel and Opawa Roads	CRC & CCC (1993), TB (1993)	Existing
		44	Create/upgrade drainage system with short time of concentration while increasing storage and stormwater soakage elsewhere in the catchment	Addresses storm runoff from urban development of Eastern Hills resulting in flooding from new development in Bowenvale Valley and Radley Street, and from urban consolidation within the flat tributary drainage catchments east of Hoon Hay Road which results in increased flood damage between Barrington and Radley Streets	CRC & CCC (1993)	New
		45	Improve internal drainage system within tributary catchments	Addresses backwater effects caused by sustained high water levels during large floods in the Heathcote River, particularly within tributary drainage between Greenpark Street and Gould Crescent	CRC & CCC (1993)	Existing

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
		46	Construct silt ponds and improve farm drainage to reduce sedimentation of natural ponding areas	Maintains capacity of natural ponding areas resulting in reduced back overflows, and capacity in the Cashmere Stream tributaries	CRC & CCC (1993), TB (1993)	Existing
		47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Reduces stormwater volumes reaching retention, soakage, and treatment devices, and river system	Oliver (1997)	New
		48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system	Reduces stormwater volumes and sediments reaching retention, soakage and treatment devices, and river system. Provides extra storage in the collection system. Will be most effective in areas of permeable soils	Oliver (1997), CRC & CCC (1993)	New
Modify Flood-Loss Susceptibility	Land Use Management (Approach)	49	Adopt a catchment wide approach to planning	Promots integrated management	Royds (1996), TB (1993)	Existing/ New
		50	Define floodway zone	Identifies land suitable to act as a floodway and ensures inappropriate development does not occur within it - particularly relevant for the middle reaches of the Heathcote River	CRC & CCC (1993)	New
	(Location)	51	Control/prohibit development on river flood plain	Reduces flood damage by ensuring inappropriate development does not occur	Royds (1996), CRC & CCC (1993), TB (1993)	New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
		52	Control development in natural ponding areas, including agricultural development	Protects function of these ponding areas and reduces flood damage incurred within these areas	Royds (1996), Oliver (1997), CRC & CCC (1993)	Existing
		53	Control development in potential large retention basins	Identifies land as suitable for retention basins and maintains that option for the future	Royds (1996)	New
		54	Control development in waterway corridors (e.g. setback distances)	Reduces flood damage by ensuring inappropriate development does not occur	Royds (1996)	Existing/ New
		55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Reduces flood damage by ensuring inappropriate development does not occur	Oliver (1997)	New
		56	Investigate alternatives to major development in upper catchment	Avoids urban development and hence conflict	Oliver (1997)	New
		57	Encourage development in naturally high runoff areas (avoid highly pervious soils)	Maintains the existing characteristics of the catchment as far as possible, and hence existing catchment responses to storm run off	Royds (1996), Oliver (1997)	New
		58	Encourage large scale development on the Port Hills	Acts as sedimentation control	CRC & CCC (1993)	New
		59	Direct development into Wigram East sub-catchment to optimise benefits of retention basin	Manages additional storm runoff by maximising retention function of Wigram East basin thereby avoiding an increase in flood damage between Lincoln Road and Radley Street	Oliver (1997), CRC & CCC (1993)	New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
		60	Direct industrial development into Wigram East sub catchment	Enables contaminated stormwater from new industry to be disposed off by using existing retention system		New
		61	Direct stormwater into the Wigram East sub-catchment	Manages additional storm runoff by maximising retention function of Wigram East basin thereby avoiding an increase in flood damage between Lincoln Road and Radley Street		New
	(Relocation)	62	Prevent new industrial activities from establishing in Woolston Loop	Prevents exposure to additional flood damage caused by extreme high tides	CRC & CCC (1993)	New
		63	Control hazardous substances associated with industrial activities in Woolston Loop	Removes risk of contamination resulting from inundation	CRC & CCC (1993)	Existing
		64	Control development on tidal floodplain	Reduces flood damage by ensuring inappropriate development does not occur	Royds (1996), CRC & CCC (1993)	New
		65	Relocate all existing development from the floodplain	Reduces flood damage by removing all development from locations within the floodplain	Royds (1996), TB (1993)	Existing
		66	Relocate selective local development from the existing floodplain	Addresses the periodic inundation of houses, garages, sections and roads sited on the floodplain, particularly in the middle reaches of the floodplain between Lincoln Road and Radley Street	CRC & CCC (1993), Royds (1996), TB (1993)	Existing

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Type)	67	Relocate industrial operations from Woolston Loop and eliminate the Industrial Zoning	Reduces flood damage by removing development caused by extreme high tides	CRC & CCC (1993)	Existing
		68	Control types of industrial activities in Woolston Loop	Prevents exposure to additional flood damage reducing the risks associated with existing development, particularly contamination	CRC & CCC (1993), TB (1993)	Existing/ New
		69	Site audit by Trade Waste personnel	Addresses inundation of industrial premises within Woolston Loop leading to risk of contamination	CRC & CCC (1993), TB (1993)	Existing
		70	'Fail safe' chemical storage facilities	Addresses inundation of industrial premises within Woolston Loop leading to risk of contamination	CRC & CCC (1993)	Existing
		71	Promote/require vegetated roofs	Reduces storm runoff (by up to 50%)	Oliver (1997)	Existing/ New
	(Set Back)	72	Require increased set back for new industrial activities in Woolston Loop	Reduces flood damage caused by extreme high tides	CRC & CCC (1993)	New
		73	Designate buffer zones between waterways and development	Reduces flood damage by preventing development within areas of potential high water velocity	Royds (1996), Oliver (1997)	New
		74	Adopt large set backs from ponding areas for any development	Provides buffer from the ponding areas in the event of overflow caused by sedimentation	CRC & CCC (1993)	New

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	(Water Reuse)	75	Promotion of water reuse (e.g. on site roof runoff storage)	Slows and/or limits the release of storm runoff to the Heathcote River system	Oliver (1997)	New
	Beautification	76	Create wetlands in existing natural ponding areas	Multi- purpose facility	Royds (1996), TB (1993)	Flood damage?
		77	Create new wetland areas	Multi- purpose facility	Royds (1996), TB (1993)	Flood damage?
		78	Adopt a River Bank Scheme	Provides for community empowerment and ownership	TB (1993)	Existing
	(Tenure)	79	Public purchase all ponding land and manage for flood retention purposes	Allows absolute control of land use activities and therefore security of functioning of system. Could also allow for multi-use.	CRC & CCC (1993), TB (1993)	Existing/ New
		80	Protect ponding areas through voluntary covenants, designations and similar	Provides certainty of future land use	TB (1993)	Existing/ New
		81	Public purchase land in flood prone areas	Reduces private flood damage	TB (1993)	Existing
	Floodproofing	82	Raise/flood proof existing flood-prone buildings	Reduces flood damage caused by either existing flood levels or increased flood level due to new development	Royds (1996), Oliver (1997), CRC & CCC (1993), TB (1993)	Existing/ New
		83	Flood proof industrial buildings	Reduces flood damage within existing and new industrial buildings	TB (1993)	Existing

Classification of Floodplain Management Measures		Potential Mitigation			Source	Benefit[13]
Category	Type	No.	Description			
			Measure	Purpose/Comment		
	Community Preparedness	84	Set floor levels for new development above flood levels	Reduces flood damage caused by either existing flood levels or increased flood level due to new development	Oliver (1997), CRC & CCC (1993)	Existing/ New
		85	Raise level of riverside roads	Reduces flood damage caused by inundation	TB (1993)	Existing
		86	Manage an effective public education programme	Promotes understanding of flood damage risk encourage community response	Royds (1996), Oliver (1997)	Existing/ New
		87	Maintain emergency plans and procedures	Ensures appropriate response to flood damage risk	Royds (1996)	Existing/ New
	Emergency Action	88	Maintain flood warning systems	Enables flood damage to be reduced by anticipatory actions	CRC & CCC (1993), Oliver (1997), TB (1993)	Existing/ New
		89	Establish responsibilities for the City, developers, individual residents and businesses	Ensures clear line of responsibility	Royds (1996)	Existing/ New
Modify Flood-Loss Burden		90	Impose financial contributions to offset the cost of additional floodplain management measures	Promotes the principle of execrator pays	Royds (1996), TB (1993)	New
		91	Flood Insurance	Protects against flood losses	Oliver (1997)	Existing/ New

Appendix 4: Evaluation of Range of Management Measures Available

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
1	Cloud seeding	Induce floating - other locations Success rate?	Expensive	Creates an artificial weather environment	Chemical contamination	Discharge consent required?	Reject
2	Stormwater discharge of roof runoff to soakage from new development	Requires individual maintenance - community system desirable Need suitable ground conditions and soil type (won't work in clay or high groundwater) Effective in small flood events only	User pays High maintenance Land area required dependent on treatment standard	Potential on site surface water ponding required Educational People take more responsibility for their own stormwater	Groundwater quality issues No regular maintenance guaranteed Need to be via an enclosed system Opportunity for contamination from corrugated iron Increase groundwater recharge	Implement through Resource Management Act 1991 or Building Act 1991 Resource consent needed where an existing stormwater system available?	Explore further

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
3	Stormwater discharge of roof runoff to soakage from existing development	Requires individual maintenance Need suitable ground conditions and soil type (won't work in clay or high groundwater) Retrofitting could be difficult Effective in small flood events only	User pays High maintenance More expensive to retrofit Duplication of existing infrastructure Land purchase may be required	Potential on site surface water ponding Educational People take more responsibility for their own stormwater Changes character of neighbourhood	Groundwater quality issues No regular maintenance guaranteed Need to be via an enclosed system Opportunity for contamination from corrugated iron Increase groundwater recharge	Ability to require retrofitting not clear Resource consent needed where existing stormwater system available	Reject
4	Stormwater discharge of yard runoff to soakage from new development	Requires individual maintenance - community system desirable Hard surfacing i.e. High intensity Need suitable ground conditions and soil type (won't work in clay or high groundwater) Effective in small flood events only	User pays Potential treatment costs	Potential on site surface water ponding Personal responsibility for stormwater disposal Maybe not so acceptable	Groundwater quality issues Discharge quality dependent on what people stored Possible contamination from oil spills, etc Pre-treatment e.g. swales desirable	Implement through Resource Management Act 1991 or Building Act 1991 Resource consent needed? Difficult to determine source of pollutants	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
5	Stormwater discharge of yard runoff to soakage from existing development	Requires individual maintenance - community system desirable Hard surfacing i.e. high intensity Need suitable ground conditions and soil type (won't work in clay or high groundwater) Retrofitting could be difficult Effective in small flood events only	User pays High maintenance More expensive to retrofit Duplication of existing infrastructure Land purchase may be required	Potential on site surface water ponding Personal responsibility for stormwater disposal Changes character of neighbourhood	Requires individual maintenance Groundwater quality issues Discharge quality dependent on what people stored Possible contamination from oil spills, etc Pre-treatment e.g. swales desirable Potential for enhancement areas Potential environmental effect	Ability to require retrofitting not clear Resource consent needed? Difficult to determine source of pollutants Responsibilities for joint systems	Reject
6	Stormwater discharge of sub catchment runoff to soakage from existing development	May have limited effect on soils of high permeability Require large soakage areas Retrofitting difficult	Community based funding likely to be required Require purchase of land Expensive	Community land ownership/control required Receive Benefits Possible new/enhanced wetlands Incorporate discharge areas into local parks?	Groundwater quality issues Environmental asset Enhancement potential Treatment needed to avoid contamination	Resource consents needed Maintenance arrangements RC's Land purchase required	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
7	Stormwater discharge of paved areas runoff to soakage from new development	Addresses extra stormwater flow in Heathcote River Require large soakage area	Financial contributions and/or community funding Requires purchase of land	Community land ownership/control required Possible benefits e.g. wetlands Incorporate discharge areas into local parks?	Groundwater quality issues Environmental Asset Potential for areas suitable for enhancement Treatment to avoid contamination	Resource consents needed Difficulty in Definition Maintenance arrangements	Explore further
8	Create retention storage in large retention basins	Damage reduction design dependant Sedimentation minimal - Wigram Alter existing landforms? Location dependent Retrofitting Useful for settling sediment Reduce flood peaks	Require purchase of land Ensuing maintenance Relatively expensive (land area required)	Community land ownership/control required Recreation asset Potential for multiple use - model boats, fishing practice etc	May settle out some sediment Potential for areas suitable for enhancement Treatment to avoid contamination Potential for habitat enhancement Rubbish collection site New/enhanced wetland	Resource consents needed? Maintenance arrangements Safety issues Land purchase	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
9	Develop Curletts Retention Basin	Damage reduction design dependant Alter existing landforms Reduce flood peaks	Require purchase of land Ensuing maintenance Relatively expensive (land area required)	Community land ownership/control required Recreation asset Potential for multiple use - model boats, fishing practice etc	May settle out some sediment Potential for areas suitable for enhancement Treatment to avoid contamination Potential for habitat enhancement Rubbish collection site New/enhanced wetland	Resource consents needed? Maintenance arrangements Safety issues Land purchase	Explore further
10	Create Wigram South Retention Basin	Damage reduction design dependant Alter existing landform Reduce flood peaks Located in natural local valley	Require purchase of land Ensuing maintenance Relatively inexpensive	Community land ownership/control required Recreation asset Potential for multiple use - model boats, fishing practice etc	May settle out some sediment Potential for areas suitable for enhancement Treatment to avoid contamination Potential for habitat enhancement Rubbish collection site New/enhanced wetland	Resource consents needed? Maintenance arrangements Safety issues Land purchase	Explore further

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
11	Create retention storage within water way corridor	Alter existing landform Less effective in large floods	No land to be purchased Expensive?	Tangata Whenua Community land ownership/control required - may be possible with existing riparian areas Safety issues Potential for multiple/recreational uses	May settle out some sediment May be seen as a benefit Affects on stream ecology during installation and long term	Resource consents needed Land status/tenure implications,	Reject
12	Control outlets of Cashmere/ Worsleys Basin	Either decreases water levels in Heathcote River, or allows for additional development in upper catchment More effective than building new basin Effect of failure - flash floods	Land purchase Compensation cost Physical work costs low	Reduce flood potential Encourages building Unavailability of flooded farmland	Environmental gains May settle out some sediment Off set amenity Inundation of large areas - change in vegetative patterns? Wetland possible Limited effects	Area recognised in Proposed City Plan Compensation for flooded areas Land ownership Resource consents?	Explore further
13	Enhance the natural storage in the Hoon Hay Basin	Sediment reduction Modelling shows limited benefit	Low mechanism in place Relatively expensive Compensation cost	Benefits recreation etc Changes in land use needed?	Add to existing asset May settle out some sediment Vegetation changes - habitat enhancement possible	Area recognised in Proposed City Plan Compensation for restricted land use required? Land ownership	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
14	Enhancement of Hendersons Basin	Limited affect Difficult to achieve Approx. 12 outlets	Low mechanism in place Relatively expensive	Benefits recreation etc Changes in land use needed? Affect number of land owners (30)	Add to existing assets May settle out some sediment Vegetation changes - habitat enhancement possible	Area recognised in Proposed City Plan Compensation for restricted land use? 30 landowners	Reject
15	Enhance Wigram East Basin	Only of benefit to sub catchment Designed so that embankment raised by 0.5m (40mm gain) Modelling shows limited benefit	Low-mechanism in place Relatively inexpensive	Benefits recreation etc Changes in land use needed	Add to existing asset May settle out some sediment	Area recognised in Proposed City Plan Existing resource consent provides for this? Compensation for restricted land use?	Reject
16	Retrofit storage facilities where space and other opportunities allow	May be limited opportunities Only effective on large scale Restrictions on incorporating most effective measures if spare unavailable	Initial $ outlay Possible land purchase required Relatively expensive Lasting infrastructure	Changing character of existing land Restricts opportunities for other uses of available open space	May provide additional green areas Conflict with park space Contamination potential - depending on design		Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
17	Control runoff with local retention and green corridors within developments from new development on floodplain	Creates multiply areas requiring maintenance Manages effects of development as and when it happens Design critical Ability for integrated design Modelling shows only effective if with other methods	User pays Maintenance costs?	Produce localised assets i.e. Wetland features etc Minimal disruption Developers starting to accept Develops ownership of the problem	May provide additional green areas Potential amenity issue Safety issues Potential for environmental/ ecological enhancement Use of swales possible - treatment of runoff Sediment reduction	Implementation through District Plan required Joint responsibilities - maintenance arrangements	Explore further
18	Control runoff with local retention within developments from new development on hills	Of limited benefit for flood damage reduction where soils are impervious Ability for integrated design Sediment loads more difficult to control?	User pays	Produce localised assets i.e. Wetlands features etc Develops ownership of the problem	May act as sedimentation trap Potential for environmental/ecolog ical enhancement Use of swales possible - treatment of runoff Failure impact	Implementation through district Plan required Joint responsibilities maintenance arrangements	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
19	Moderating or controlling runoff at various locations via an assortment of tree and shrub planting schemes	Ineffective More low/moderate flooding over larger area	Inexpensive	Environmental enhancement Safer communities issues - potential to have adverse effects e.g. provision of hiding places	Gains Enhances green corridor network	District Plan?	Reject
20	Valley re-afforestation of Port Hills	Flood damage benefit questionable Only of benefit in low level event	Relatively expensive but get long-term rewards	Changes landscape Provision of jobs	Pines - monoculture Indigenous - increased biodiversity Sediment resolution Positive water quality outcome	Regional Council requirements	Reject
21	Hillside re-afforestation of Port Hills	Flood damage benefit questionable Positive water quality effects, plus land stabilisation	Relatively expensive but get long-term rewards	Changes landscape Provision of jobs	Species dependent Pines - monoculture Indigenous - increased biodiversity Sediment resolution Positive water quality outcome	Regional Council requirements?	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
22	Promote re-vegetation on erosion prone slope and adjacent to waterways	Flood damage benefit questionable	Relatively inexpensive	Reduction disaster potential landslides etc Changes landscape Safer community issues	Reduction of disaster potential landslides Decrease in sediment loads Green corridors enhanced Positive water quality benefits	Consistent with City Plan objectives	Reject
23	Construct a more efficient channel	Alters channel bed Possible more downstream flooding Partly effective	Moderately high	Tangata Whenua implications Unlikely to be accepted by the Community	Effects on stream habitat/ecology	Resource consent required	Reject
24	Widen/deepen channel	Alter channel flows etc More downstream flooding Partly effective	Moderately high	Tangata Whenua implications Unlikely to be accepted by the Community	Some habitat effects Effects on stream habitat/ecology	Resource consents required	Reject
25	Increase Heathcote River Channel capacity from Lincoln Road to Woolston Cut	Some changes to local landscape depends on degree Improved capacity for floodwaters in lower catchment	Moderate costs	Tangata Whenua implications Unlikely to be accepted by the Community Changes to river banks/amenity values Alters landscape	Negative effects Increased artificial waterways	Resource consents required	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
26	Remove local constrictions in downstream river channel (i.e. Colombo Street Bridge)	Improved capacity for floodwaters in lower catchment Few significant constrictions Colombo St Bridge	Infrastructure cost likely to be high marginally low?)	May effect local community Depends on degree Disrupt traffic patterns and people movements	Habitat implications Fish habitat reduced	May need resource consents	Explore further
27	Retain channel maintenance programme	Flood damage benefit questionable Drainage capacity maintained	Relatively inexpensive but on-going	Reassurance that something is being done	Short term discoloration results Periodic disturbance to stream ecology/habitat	Resource Consents required?	Explore further
28	Increase channel maintenance activity	Flood damage benefit questionable	Increased costs		Short term discoloration results Bank stability? Increased disturbance	Resource Consents needed	Reject
29	Increase remedial bank support programme	Affect on landscapes Flood damage benefit questionable Hard engineering designs versus plantings	Initial costs	Amenity value	Benefits sedimentation If plantings used enhanced fish habitat - more insects and places to hide		Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
30	Reduce sediment discharge from Port Hills, including from land-uses and subdivisions Timing/extent cut earthworks/ re-vegetation	Flood damage benefit questionable Not significant in terms of flood levels Improved water quality Not effective	Cost	Improved visual amenity with respect to waterways	Water quality advantage Improved water quality Less silt Water quality improvement		Reject
31	Reduce vegetation on banks and berms	Flood damage benefit questionable Improves channel efficiency Decreased bank stability	Relatively inexpensive	Major effects on amenity etc Not likely to be acceptable to the community	Environmental enhancement Reduced fish/insect habitat		Reject
32	Encourage rapid flooding of river floodplain		High costs Large costs due to property damage	Increases awareness of flooding risk Community resistance may be experienced Unacceptable to downstream dwellers	Continued low level damage	Against philosophy reduce/mitigate event Compensation	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
33	Construct continuous stopbanks	Effective Big problem if development increases and they fail	High cost	May be community resistance May create wrong community perception Landscape/amenity issues (false) security/access	Alter landscape Changes visual character of area Disturbance of riparian margins	Resource consent required	Reject
34	Construct localised stopbanks/ bunding	Targeted Possibly worthwhile Can cause increased problems in other areas	Incurs costs Cost/benefit may not justify Increased maintenance costs	May create wrong community perception Landscape/amenity issues (false)	Alter landscape Changes visual character of area Disturbance of riparian margins	Resource consents required	Explore further
35	Divert part of upper Heathcote Catchment into Halswell Catchment, possible through retention basins	May need a lot of physical works Adverse effects on Lower Halswell catchment - increased flooding Effectiveness unclear	Expensive	Could produce recreational asset Tangata Whenua considerations Negative community perception	Increase potential contamination Lake Ellesmere sensitive receiving environment Increased silt and flooding in Halswell maybe detrimental to habitats etc Mixing of waters (Tangata Whenua concern)	Resource Consents required	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
36	Divert part of upper Heathcote Catchment into Avon Catchment, possible through retention basins	May increase flooding damage in Avon catchment May need a lot of physical works	Expensive	Could enhance recreational asset Tangata Whenua considerations Negative community reception	Increase potential contamination Detrimental effects in Avon due to increased flooding Mixing of waters (Tangata Whenua concern)	Compensation to those flooded in lower Avon Resource consent required	Reject
37	Maintain tidal gates at Woolston Cut	Little flood damage benefit		Security from flooding	Affects saline/fresh water interface - spawning trigger		Reject
38	Retain Woolston Loop tide gates	No physical benefit for flood damage negotiation			Controls salinity levels Affects saline/fresh water interface - spawning trigger		Reject
39	Install new tidal-gates at some point on the Heathcote River	Possible future option Not required at this time Effective for sea level rise	Expensive	Affects amenity	Affects saline/fresh water interface - spawning trigger Change in salinity balance may affect riparian vegetation Change river character	Resource consent required	Reject
40	Control tidal back flow	Unclear how to achieve		Affect amenity	Change in salinity balance may affect riparian vegetation	Resource consent required	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
41	Improve downstream tributary drains	Negatively affect flood damage and only affected in lower end		Amenity value improved Safety features required	Improved habitat opportunities	Resource consents required	Reject
42	Install non-return mechanisms on stormwater drains	Reduced back flow especially at high tides Increased inundation downstream	Relatively inexpensive	Improved community conditions Fewer flooding concerns in localised area	Effect on saline/fresh water interface Lower areas wet for longer		Reject
43	Install special manholes or outfall valves on all drainage outfalls to prevent back flow	Reduced back flow especially at high tides Increased inundation downstream	Relatively inexpensive	Improved community conditions Fewer flooding concerns in localised areas	Effect on saline/fresh water interface Lower areas wet for longer		Reject
44	Create/upgrade drainage system with short time of concentration while increasing storage and stormwater soakage elsewhere in the catchment	Effective in lower part of catchment Already exists to some extent		Opportunities to use stored water as a recreational/amenity resource Security of less flooding Less ownership of floodwater by those in area from which it originates	Opportunities to use stored water to environmental advantage, e.g. ponds	Compensation for increase in downstream flooding	Reject
45	Improve internal drainage system within tributary catchments	Effective in lower catchment Quicker removal of floodwater upstream increase flooding downstream		Greater security against flooding for those living in tributary areas, but less security in lower catchment	Less prolonged inundation in tributary catchments - changes in suitability in some vegetation	Compensation for downstream dwellers	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
46	Construct silt ponds and improve farm drainage to reduce sedimentation of natural ponding areas	Flooding damage benefits unclear Requires more land area Improved water quality	Reduces maintenance costs in ponding areas Relatively expensive	Cleaner looking rivers, increased visual amenity	Less silt in waterways - improved habitat Improved water quality. Ponds - incorporate into green corridors	Implementation mechanism not clear	Reject
47	Minimise the use of hard surfaces in urban areas (e.g. the area of roads, carparks and driveways etc.)	Shown as being effective overseas Needs to co-ordinate Increased Groundwater recharge Requires suitable soil type and groundwater conditions to work well	Relatively expensive	Changes in visual appearance of neighbourhood Ownership of problem through increased awareness	Potential for contamination of groundwater Treatment systems needed e.g. swales,	Implement through City Plan	Explore further

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
48	Use swales to carry stormwater for soakage or to slow down rate of runoff into river system	Delay pollution treatment Delaying effect Increased groundwater recharge	More costly	Opportunity for improved visual amenity Maintenance important to avoid wasteland appearance	Public education Groundwater quality issues Some treatment Improved water quality. Opportunity for groundwater recharge Allows for some treatment to improve water quality	Implement through City Plan	Explore further
49	Adopt a catchment wide approach to planning	Principal objective		More likely to involve all affected parties	Integrated management	RMA	Reject – process
50	Define floodway zone	Existing development on floodway Understanding of terrain required	Relatively expensive	Community may resist Awareness and avoidance of flood prone areas	Opportunities for environmental enhancement Water quality concerns	Implement through City Plan Litigation if wrong area defined	Reject
51	Control/prohibit development on river flood plain	Reduced damage in event of a major flood	Cost imposed on individual	People have to live somewhere else, lose association with river	Opportunities for environment enhancement	Implement through City Plan Transferable development rights	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
52	Control development in natural ponding areas, including agricultural development	Ensures existing system maintained	May be high costs if land is required to be purchased	Creation of recreational assets Disadvantages existing land owners	Gains - using natural storage areas	Implement through city plan - already some controls	Explore further
53	Control development in potential large retention basins	Dependent on land availability Require identification Proactive	May be high if land purchase likely to be required	Creates recreational assets Existing development on floodway	Creation of environmental asset	Implement through City Plan and/or designation and/or negotiation	Reject
54	Control development in waterway corridors (e.g. setback distances)	Effects very dependant on what controls Existing development	Impose costs on individuals	Disadvantages existing properties	Create environmental asset in conjunction with planting programmes	Implement through City Plan	Explore further
55	Avoid high risk/high damage development (e.g. industry and hospitals) in the Waimakariri River overflow channels	Existing development present Avoids future inappropriate development	High potential damage if overflow occurs Imposes costs on individuals	Disadvantage existing property owners	Effect existing ecosystems/habitat	Implement through City Plan?	Explore further
56	Investigate alternatives to major development in upper catchment	Effective if other options chosen	Costs - feasibility studies etc	Increased pressure from infill housing etc		Part of city plan process Transferable development rights?	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
57	Encourage development in naturally high runoff areas (avoid highly pervious soils)	Reduce flood potential				Part of City Plan process	Reject
58	Encourage large scale development on the Port Hills	Only affective on high runoff areas		Jeopardise recreational/other values of Port Hills	Increased urbanisation environmentally significant area Effect natural value Port Hills have high landscape values	Part of City Plan process	Reject
59	Direct development into Wigram East catchment to optimise benefits of retention basin	Enough capacity within system Marginal benefit flood damage benefit – only timing	Imposes location cost on developer	Loss of potential flexibility Is it an area where there is increased demand for housing? Development capacity may be insufficient Wigram Aerodrome	Creation of environmental asset	City Plan	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
60	Direct industrial development into Wigram East sub-catchment	Enough capacity within the system	Imposes location cost on developer	Loss of potential flexibility Is it an area where there is increased demand for housing? Development capacity may be insufficient Wigram Aerodrome	Ensure some treatment for contaminated stormwater runoff	City Plan	Reject
61	Direct stormwater into Wigram East sub-catchment	Enough capacity within the system Gravity fall may not be possible	Requires reticulation and possible pumping			City Plan	Reject
62	Prevent new industrial activities from establishing in Woolston Loop	Reduces additional flood damage	Imposes cost on individuals	Effects employment opportunities Existing established industrial area	Reduce risk of contamination	Prohibited activity - may be difficult to justify in City Plan	Reject
63	Control hazardous substances associated with industrial activities in Woolston Loop	Reduces risk of contamination as a result of flood	Low - monitoring enforcement	Benefits reduction of risk of contamination Established industrial area	Reduce risk of contamination	Difficult to determine origin of contaminant	Reject
64	Control Development on tidal floodplain	Effectiveness dependent on level of control	Increased building costs i.e. minimum floor levels	Affects development rights		Implement through City Plan	Explore further
65	Relocate all existing development from the floodplain			Advise community reaction	Place pressure elsewhere	Ability to implement not clear	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
66	Relocate selective local development from the existing floodplain	Reduce flooding potential Targeted damage reduction	High costs	Disruptive to communities Dislocates existing occupiers	Create additional recreational assets	Compensation would be required Does the legal power to implement exist?	Reject
67	Relocate industrial operations from Woolston Loop and eliminate the Industrial Zoning	Reduce level of flood damage	High costs	Employment implications Established industrial area	Reduce risk of Contamination	Existing rights apply	Reject
68	Control types of industrial activities in Woolston Loop	May not be effective	Impose costs on individuals	Established industrial area	Effect level of contamination	Justified for this area - existing use rights Implement through City Plan	Reject
69	Site audit by Trade Waste personnel		Resource intensive	Be better informed	Gain base info on level of contamination		Explore further
70	'Fail safe' chemical storage facilities	Cannot be fail safe in all events	Moderate costs	Provide a degree of assurance	Reduce risk	Rule within Plan	Explore further
71	Promote/require vegetated roofs Education	Reduces roof runoff - effectiveness unclear May not be practical	Moderate costs	Not accepted practice in New Zealand May not be appealing	Promote certain design types	Can this be implemented?	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
72	Require increased set back for new industrial activities in Woolston Loop	Established activities - effectiveness questionable	Cost falls on individual Some costs land not used for industrial purposes	Individual land owners disadvantaged	Gains natural open space	Implement through City Plan Existing use rights	Reject
73	Designate buffer zones between waterways and development	Keep development from floodway Effectiveness dependent on specific control on level of existing development	Cost falls on individuals	Individual land owners disadvantaged Could provide for public access Difficulty in purchasing land	May create 'under utilised' areas Alternately, opportunity for community amenity improvements Increase areas of open space environmental assets	Implement through city plan - already some controls	Reject – duplication
74	Adopt set backs from ponding areas for any development	Reduce damage potential Provides future options	Cost falls on individuals	Individual land owners disadvantaged Recreational assets integrated walkway	May create 'under utilised' areas	Implement through City Plan	Reject
75	Promotion of water reuse (e.g. on site roof runoff storage)	Flood damage risk advantages not clear	Cost falls on individuals	Not accepted practice in New Zealand	Limited/nil impact	Voluntary compliance only Hard to legislate	Reject
76	Create wetlands in existing natural ponding areas	Flood damage benefit questionable	Community cost	Recreational assets	Improved community amenity values	Requires tenure or landowner agreement	Reject
77	Create new wetland areas	Flood damage benefit questionable	Community cost	Recreational assets	Improved community amenity values	Requires tenure or landowner agreement	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
78	Adopt a River Bank Scheme	Flood damage benefit questionable Improvement of local environments	Moderate Costs	Develops community ownership of issues	Local environmental benefits		Reject
79	Public purchase all ponding land and manage for flood retention purposes	Provides ultimate control allowing for improved capabilities	Large cost Initial purchase costs	Displaces individuals Create local/regional recreational assets	Allows for co-use by the community	May need to use Public Works Act or designation	Explore further
80	Protect ponding areas through voluntary covenants, designations and similar	Maintains present flood damage reduction capabilities	Compensation may be required to be paid	Issue of private property rights Local support	Private benefits	Mixture of advocacy and City Plan measures required	Explore further
81	Public purchase land in flood prone areas	Reduce flood damage	Large cost	Displaces individuals Difficult to purchase	Creates opportunity for improved community amenity	Land may not be available for purchase Difficulty in gaining agreements	Reject
82	Raise/flood proof existing flood-prone buildings	Targeted flood damage mitigation Encourage further development - level of assurance Majority of raising now completed	Community incentives likely to be required High initial costs for small numbers Progressively more expensive due to house type remaining	Disruption to individuals Less potential home assets to be ruined	Negligible	Voluntary actions only	Reject

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
83	Flood proof industrial buildings	Targeted flood damage mitigation Encourage further development - level of assurance	Community incentives likely to be required Develop high initial costs		Reduces possibility of contamination	Voluntary actions only	Reject
84	Set floor levels for new development above flood levels	Targeted flood damage mitigation Encourage further development - level of assurance Issue of 'what level'	User pays Increase development costs	People aware of added costs	Negligible	If above 2% AEP implement through city plan Building Act only covers residential development	Explore further
85	Raise level of riverside roads	Reduces surface flooding of road Alter local landscape	Large capital cost for minor flood damage reduction	Avoids community and visual disruption	Provides new roads and opportunity for improved amenity values		Explore further
86	Manage an effective public education programme	Can, in the long term, reduce damage by affecting individuals behaviour	Undefined benefits	Creates knowledge and ownership of the issues	Long term environmental benefits	No legal implication	Explore further
87	Maintain emergency plans and procedures	Ensures optimum response to flood risk event Reduce level of risk	Little	Reduce level of damage Better warning		Part of Civil Defence requirements	Explore further
88	Maintain flood warning systems	Provides opportunity for flood mitigation Reduce level of risk Limited effectiveness due to catchment	Little	Reduce level of damage Better warning		No legal implication	Explore further

No	Measure	Physical	Economic	Social	Environmental	Legal	Decision
89	Establish responsibilities for the City, developers, individual residents and businesses	Essential for integrated management	Little - moderate costs	Clear lines of responsibility		Assigns liability Must be in accordance with statute RMA responsibilities	Reject – process
90	Impose financial contributions to offset the cost of additional floodplain management measures	Lead to a range of mitigation measures	User pays Reduces Community input	Imposes mitigation responsibility on the developer		Must implement through City Plan Bound by the legal principles in the Resource Management Act 1991	Explore further
91	Flood Insurance	Offset damages	User pays Wide spread costs	Provides redevelopment finances Presently structured not to reflect specific flood risk Encourage development	Neutral	Can't control	Explore further

Appendix 5: Effectiveness of Floodplain Management Measures[17]

Development and Mitigation Scenarios	Annual Damage ($million)	NPV[18] of Damage ($million)	Implementation Costs ($million, NPV)		Benefit of Measure ($million, NPV)	
			Excluding Land Costs	Including Land Costs	Excluding Land Costs	Including Land Costs
Present with no development	0.09	0.9				
Present with development over 50 years	0.09	1.0				
Future	0.12	1.2				
Runoff to soakage: high estimate of cost	0.11	1.1	0.0	2.3	0.1	-2.2
Runoff to soakage: low estimate of cost	0.11	1.1	-1.1	1.0	1.2	-0.9
Enhanced storage Cashmere/Worsleys Basin	0.11	1.1	0.1	1.1	0.0	-1.0
Runoff to soakage with enhanced storage Cashmere/Worsleys Basin	0.11	1.1	0.1	3.4	0.1	-3.2
Runoff to soakage with enhanced Curletts Storage	0.11	1.1	0.1	2.6	0.0	-2.5
Runoff to soakage with enhanced Curletts and Wigram South Storage	0.10	1.0	0.6	3.2	-0.3	-3.0
Runoff to soakage with enhanced Cashmere/Worsleys, Curletts and Wigram South Storage	0.09	0.9	0.7	4.3	-0.4	-4.0
Enhanced Cashmere/Worsleys, Curletts and Wigram South Storage without runoff to soakage	0.09	0.9	0.7	2.0	-0.4	-1.7
Bunding to 50 year level (2%AEP)	0.11	1.1	0.2	0.2	-0.1	-0.1
Stopbanking and bunding to 200 year level	0.07	0.7	0.7	0.7	-0.1	-0.1
Stopbanking and bunding to Extreme Event level	0.01	0.1	2.1	2.1	-0.9	-0.9

[17] Based on Brown Copeland (1997)
[18] Net Present Value

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