WATER AND CHOICE IN CANTERBURY :

Review and Assessment of Research Priorities for Lower Rakaia and Central Plains Irrigation Planning

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with

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PREFACE

With the need for increased production from New Zealand's traditional resource strength, land, the waters of our rivers can be seen to make a significant contribution to this end via irrigation. But such uses of river water can conflict with other existing and potential water uses, notably in the realm of conservation and fisheries. These potential conflicts, and the information needed to help resolve them, is the topic of this report.

The study was undertaken by a multi-disciplinary team of economists, geographers, physicists, biologists, sociologists and public policy and legal experts from a range of institutions in Canterbury. The project was supervised by Dr K.L. Leathers, Senior Research Economist in the A.E.R.U. The publication of this report forms part of an existing A.E.R.U. programme of research in the field of natural resource economics and management.

This report should make a valuable contribution not only to the present decision problem regarding the Rakaia River but also to the future approach to research by various agencies responsible for the development of the country's natural resources. It is important for such agencies to approach these difficult issues with a multi-objective philosophy, if not with a multi-disciplinary team of qualified personnel. This philosophy is important because the resolution of issues such as described in this report calls for logical and integrative thinking by all concerned.

P.D. Chudleigh
Director

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(1) the Ministry of Agriculture and Fisheries' Farm Advisory Service, Research Division and Fisheries Research Laboratory (Christchurch);
(2) the Ministry of Works and Development's Water and Soil Division and Science Centre (Christchurch);
(3) the North Canterbury Catchment and Regional Water Boards' Resource Investigation and Management Sections;
(4) the Canterbury United Council's Planning Department; and
(5) the Lincoln College/University of Canterbury's Agricultural Economics Research Unit, Centre of Resource Management, Agricultural Engineering Department, and the New Zealand Agricultural Engineering Institute.

A number of individuals deserve special recognition for the time they willingly contributed at various stages in the study. The Study Team is grateful to Mike Bowden and staff (Resources Section, North Canterbury Catchment Board), Walter Lewthwaite, Sally Davis, Nicola Shadbolt, Dave Joblin and staff (Ministry of Agriculture and Fisheries' Research Division) for providing a wealth of informative data, including some yet unpublished information. Peter Chudleigh, Bruce Ross, Ken Hughey, Grant McFadden, Herb Morriss, Walter Lewthwaite, John Greer, Garth Cant, and colleagues at the Agricultural Economics Research Unit and Centre for Resource Management provided useful criticisms on content and presentation. The editorial suggestions of an anonymous reviewer, from the Water and Soil Division (M.W.D.), were also greatly appreciated. The final draft benefits greatly by their suggestions. Special mention is due to Herb Morriss and Walter Lewthwaite, the liaison officers for the study, for their able assistance in formulating and guiding the research effort, and for their critical appraisal of the methodology and results.

The funding agency provided considerable flexibility in conducting the study, particularly with regard to the length of time taken to complete it. More effort went into the study than was originally envisaged. This was partly due to individuals' enthusiasm for an exciting area of applied research, but also because it became evident from the importance of the issues that much care was needed in presenting a balanced appraisal. The conclusions reached and recommendations, however, are not necessarily endorsed by the funding agency or by Lincoln College, nor should they be attributed to any organisations or individuals who co-operated in the study. The senior author accepts responsibility for any remaining errors and omissions in the final editing of the report.

SYNOPSIS OF FINDINGS

Regional agencies responsible for the administration, planning, development and management of water resources in Canterbury face some difficult decisions in the near future. Applications for rights to divert water from the Rakaia to supply two major Community Irrigation Schemes may have to be decided in the next 12 months or so. On the basis of present scheme designs, it is possible that the proposed level of abstraction will affect detrimentally present recreation and preservation uses of the river. The magnitude of this possible loss in regional welfare is not well established, while the anticipated regional income and employment benefits of the proposals are more clearly understood. The dilemma that confronts the Regional Water Board is that the water allocation decisions will have to be made with limited knowledge of the consequences, especially when some of those decisions are potentially irreversible.

A considerable amount of research in connection with the proposals has been carried out by the Regional Water Board, M.W.D. and M.A.F. in recent years. In some cases the level of understanding about certain parameters needed for allocation decisions is more than adequate and supported by well documented empirical evidence. However, there are other decision parameters for which present knowledge is inadequate for informed decision making, and still others where virtually no reliable information exists. The purpose of this study has been to establish what these information "needs" are, to carefully review and assess previous and ongoing research directed at fulfilling these needs, and to recommend priority research areas which can fill gaps in knowledge and which take account of near-term and future planning requirements. The work was carried out by a multi-disciplinary group of social and physical scientists with backgrounds in economic project appraisal and social and environmental impacts assessment.

The findings of the Study Team can be summarized under four general research topic headings. These concern: (1) the irrigation proposals themselves, (2) the environmental impacts of abstraction and development, (3) the economic, social and demographic impacts, and (4) the longer-term water resource development options for the region. Other concerns, such as the implications of present water law and government policies, multiple use development options and regional planning, are considered within the context of these general headings. In total, 28 specific studies or research topics were identified by the Study Team. Related investigations currently being carried out by the planning agencies and the degree to which these address the Team's recommendations are summarised in the accompanying table.

While many of the recommended studies appear to be covered by regional investigations now underway, it is necessary to understand that these present efforts are largely descriptive in nature, and include little of the empirical analyses that are suggested in this report. Rigorous analyses which produce reliable planning information for decision makers require time and considerable budget allocations, neither of which are available in the time frame allowed for near-term decisions. Consequently, a method of sorting out higher from lower research priorities is obviously needed.

In order to rank the identified research needs in a meaningful way, the Team applied four criteria: (1) the sense of urgency in obtaining the necessary information, (2) the possible importance the information might have in terms of total regional impact, (3) whether or not a potential decision could lead to irreversibilities, and (4) the cost of obtaining the information needed. Each proposed investigation was scrutinised in light of these, and the resulting priorities indicated by a "high", "moderate" or "low" ranking were obtained. (See accompanying table).

Of the 14 study topics receiving high priority emphasis, five are apparently not being investigated at this time. Only two of the 14 areas can be regarded as being adequately covered by ongoing investigations. However, the dividing line between moderate and high priority research needs is highly subjective and, therefore, the Study Team recommended a re-examination of these results using different weighting schemes which could better reflect individual agency or planning bodies' concerns.

The research needs which stand out as deserving immediate attention are: (1) the economic value of seasonal irrigation water supplies, from

SUMMARY OF RESEARCH TOPICS AND PRIORITIES IN RELATION TO INVESTIGATIONS CURRENTLY UNDERWAY*

Issues and Topics Suggested For Further Study	Research Priority Ranking	Extent of Coverage by Regional Planning Agency Ongoing Investigations[1]	
A. The Irrigation Plans (as proposed):			
Intraseasonal Water Values	High		a
Economic Limits to Groundwater	High	NCCB	c
Opportunity Costs of Groundwater	High	NCCB	b
Optimal Scheme Water Supply	High		a
Cost Sharing and Finance Effects	High		a
Irrigation Land Use	Moderate	NCCB, CUC	b
Conjunctive Use under 'One Plan'	Moderate	NCCB	b
Refinement of Secondary Impacts	Low	CUC	c
B. Social and Demographic Impacts:			
Baseline Data Surveys	High		a
Review of ongoing Irrigation Projects	Low		a
Assessment of 'Local' Resources	Low	CUC	b
Regional Development Leakages	Low	CUC	c
C. Impacts on the Environment:			
Commercial Salmon Ranching	High	CUC	b
Recreation Implications	High	NCCB, CUC	b
Fish and Wildlife 'at Risk'	High	NCCB, CUC	b
Fishery Enhancement Prospects	High	CUC	b
Hydro-Biological-Habitat Modelling	Moderate	NCCB,CUC	b
Instream Values	Moderate		a
Drainage Problems	Moderate	NCCB	b
Human Health Implications	Moderate	NCCB	b
Coastal Erosion	Moderate	NCCB	b
D. Future Water Resource Developments:			
Inter Catchment Transfers	High	NCCB	b
Fishery Enhancement from Storage	High	CUC	b
Revenue Sharing with HEP	High		a
Regional Development Benefits	High	CUC	c
Lake Coleridge Storage	Moderate	NCCB, CUC	b
Benefits of Additional Electricity	Low	CUC	b

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* Summarised from Table 9.1 and Table A5.1.

[1] Abbreviations: North Canterbury Catchment and Regional Water Boards (NCCB) and the Canterbury United Council (CUC). The letters indicate the adequacy that present investigations will satisfy the information needs identified by the study team: a = currently not under study, b = largely descriptive and involving limited analysis, and c = results will probably be sufficient to satisfy the information needs identified by the study team.

alternative sources and in different combinations, to Canterbury farmers; (2) the role of hydro-power development as an adjunct to irrigation, particularly in regard to the apparent regional socio-economic benefits obtainable from multiple use planning of the Rakaia River; and (3) the environmental and economic benefits attributable to the River, emphasising what the regional benefits to Canterbury will be under alternative water use arrangements in the future.

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CHAPTER 1

INTRODUCTION

This report presents the results of a multi-disciplinary research project funded by the Ministry of Works and Development to review and evaluate the economic, social and environmental impacts of developing the water resources of the Rakaia River catchment. It has become clear in recent months that competing, possibly conflicting, uses are being proposed for this resource and that the relevant authority, the North Canterbury Catchment and Regional Water Boards, will soon be faced with allocation decisions. These decisions must be made in a context which allows full, frank and informed discussion on all the options and their implications.

It cannot be emphasised too strongly that the authors of this report do not assume any advocacy role in the merits or otherwise of the irrigation proposals relative to other use options. Rather, the purpose of this study has been to detail objectively the regional economic and social implications of irrigation development as a focal point to the analysis of wider issues in water resource use and management. Furthermore, the report is based on the collation of existing information rather than on primary research. It therefore presents an overview of the types of probable impacts and indicative estimates of their magnitude which will be useful in assessing future research and planning needs.

1.1 Statement of the Problem

The problem focus of this study is the economic and social implications of large-scale Community Irrigation Scheme development in central Canterbury. Two major schemes have been proposed, one south of the Rakaia River known as the Lower Rakaia Scheme and the other north of the river known as the Central Plains Scheme. In total, these two irrigation projects will supply water abstracted from the Rakaia to some 400 farms, bringing under irrigation an additional 80,000 to 100,000 hectares of land creating new income and employment opportunities and a more stable agricultural base to a regional economy now subject to the vagaries of dryland farming. Yet the proposed development is highly controversial. Why?

The Rakaia River is the largest in Canterbury, with a mean annual flow of about 200 cubic metres per second (cumecs). It is a braided "snow" river of a classic type, found in few areas of the world, with periodic flood events sometimes exceeding 3,500 cumecs in the Spring, wiping bare its sparsely vegetated islands and margins over a two kilometre wide shingle bed. Winter flows, with a much lower glacial silt load than in the summer, have been recorded below 80 cumecs at the Rakaia Gorge, where the 2,640 km^2 catchment on the eastern side of the Southern Alps drains on to the Central Canterbury Plains. Apart from small abstractions for stockwater, several small (mostly private) irrigation schemes, and two small hydro-electric plants (only one of which involves the diversion of a tributary), the Rakaia remains virtually undeveloped in its present state. Its current economic and social worth to the region derives primarily from its recreational amenities and "scarcity" value.

The proposed developments pose a spectre of irreversible loss in the utility of the river's present use. The past experience of water abstraction and storage on other river systems in Canterbury, and elsewhere, shows that developmental uses are not always compatible with instream uses such as recreational angling. In fact, many South Island rivers so familiar in New Zealand's rich angling literature are but shadows of their former selves today. The public concern expressed over the proposals therefore has valid historical roots, dating back to a time of single purpose development projects in an era of abundant natural water supplies "wasting to the sea".

The times and the circumstances are now changed; there is no looking back. Natural flowing surface waters are limited in supply and they are being called upon to serve a growing multitude of uses, some of which are inherently competitive. Regional and national planners and policymakers face an increasingly difficult task in deciding water allocations that reflect the genuine needs of society. Because water resource development decisions tend to have long term implications, the needs of future generations must also be anticipated.

In the near future, decisions will be taken on water right allocations for the proposed Community Irrigation Schemes. The implications of <u>not</u> granting the rights to abstract river water for the proposed beneficial use are reasonably well known, but the impacts of the level of abstraction contemplated on current instream (also beneficial) uses are poorly understood. The potentially adverse effects of a reduced low flow regime concern, for example, recreation, amenity and scientific interests associated with the river's trout and salmon fishery and its natural environs for unique and rare animal species. Given these and other beneficial but potentially competing needs, the issue is one of how to determine an efficient and equitable allocation rather than a decision to abstract or not to abstract.

Because of the unique nature of water itself, its use often can result in perplexing consequences that can trouble water planners. Expensive drainage and reclamation of once productive lands situated in low-lying areas and the contamination of groundwater used for domestic purposes are well known side effects that can occur with irrigation. All too often such consequences are unforeseen at an early enough stage in planning to be avoided, resulting in considerable social costs to be borne by the tax paying public at a later time. Both rising water tables and nitrate contamination of groundwater are potential problems in Canterbury. Inflexibilities also can occur in water planning if water projects proceed incrementally without careful reference to future planning needs. A present allocation decision can permanently limit future planning options, particularly when parts of a hydrologic system are developed independently and at different points in time.

In Canterbury, considerable quantities of groundwater exist under both scheme areas which are designated for surface irrigation. Developing the groundwater resource is a possibility that could leave more water in the river to satisfy instream needs, but reliable information on the amount that can be economically abstracted and sustained over time is not yet available. Another potential source of irrigation water is lake storage behind reservoirs in the upper catchment. Detailed investigations of hydro power development in conjunction with irrigation and other water uses and transfers within and between the river catchments in Central Canterbury would be required to fully rationalise water resources planning in the region.

Unfortunately, certain planning decisions must be taken in the very near future which highlight another important characteristic of the problem faced by Regional Water Boards: having to make important choices in the absence of full information about the consequences. There is an urgent need at this time to carefully assess what is known and not known, and to identify the critical information needs that require attention in the near term. Consequently, this means discriminating between near and longer term policy issues in order to focus research and planning efforts in a way that will be most effective to decision makers.

1.2 General Terms of Reference

Gaps in knowledge exist concerning the likely impacts of the proposed irrigation schemes for the Lower Rakaia and Central Plains, particularly with regard to demographic, environmental, economic growth and related concerns. A sound, empirical analysis of these issues was proposed in a two phase research programme. Phase One would review existing knowledge about water use and irrigation development in the region, emphasising the need to establish the relative importance (order of magnitude) of the anticipated socio-economic impacts. The second phase of study would comprise more detailed issue-oriented analyses of aspects identified in Phase One as priority research needs. The present study, which reports on Phase One, had the following general terms of reference:

(i) To identify the possible regional economic impacts, primary and secondary, that would likely result from implementing the proposed Community Irrigation Schemes in central Canterbury;

(ii) to identify the possible social impacts of irrigation development, including effects on regional and community employment, migration and settlement patterns and related social services;

(iii) to identify the possible environmental impacts of water management and development options, including water-based recreation activities, wildlife and habitat preservation and the potential for commercial salmon ranching;

(iv) to identify other possible water resource developments that could occur in the future and their likely interaction with irrigation and environmental uses;

(v) to develop an appropriate analytical framework for analysing the problem and issues including national, regional and community objectives and the implications of trade-offs arising from water development alternatives; and

(vi) to integrate this knowledge as a means of identifying priority information needs to focus the Phase Two research effort.

Within these broad terms of reference more specific research objectives were formulated to guide the review and assessment of available information. These are outlined below in the context of the general problem issues studied.

1.3 The Detailed Study Objectives

A concern of increasing importance to decision makers who must evaluate the comparative merits of alternative investment projects is the extent to which these projects contribute to regional development. The impacts on local employment and household income are generated directly in the form of new jobs and increased production and indirectly through the stimulus provided to local business as a result of increased economic activity and consumer spending. From a regional perspective these indirect or secondary effects can be just as important as the direct effects.

Accordingly, consideration is given to describing and quantifying (where possible) the economic regional development impacts of the proposed Community Irrigation Schemes. Specifically, the study:

(i) reviews previous research on the economic impacts of irrigation development;

(ii) describes community and privately owned irrigation development in the region and options proposed for the foreseeable future;

(iii) assesses the physical impact of irrigation development on the agricultural sector in terms of land use patterns, crop and stock productivity, the potential for horticulture, and farm inputs, labour and income; and

(iv) evaluates the linkages between sub-sectors of the regional economy with particular reference to agriculture, and assesses the secondary impacts which could be generated by developing the Community Irrigation Schemes.

At present there is a paucity of information on the possible social and demographic impacts of irrigation development in Canterbury. In particular, there is a need to establish the likely consequences of large-scale irrigation schemes on regional and community employment, migration and settlement patterns and the provision of economic and social services. Accordingly, specific tasks for this part of the study included:

(i) assessment of the present socio-demographic situation in Central Canterbury;

(ii) a review of existing knowledge about the socio-economic impact of irrigation in Canterbury and North Otago;

(iii) a preliminary assessment of possible irrigation impacts in Central Canterbury; and

(iv) development of a framework for more detailed investigation.

The consequences of an alteration in the physical environment are among the least understood impacts of irrigation development. Recreation, protection of wildlife habitats, commercial freshwater fishery development and other "instream" uses of Rakaia River water are recognised in conjunction with irrigation abstraction, but their relative importance in terms of comparable social benefits have yet to be established. Informed decision making with respect to choices that have the potential for irreversible consequences requires a careful balancing of potential gains and losses. Accordingly, the ability to measure "preservation" and "development" impacts on a comparable basis deserves urgent attention by social scientists.

Hence, specific objectives in this area are:

(i) identify the recreation, preservation and other amenity aspects "at risk" due to irrigation development;

(ii) explore the possibilities of irrigation development "enhancing" recreation opportunity;

(iii) provide a preliminary assessment of the future development of commercial salmon ranching;

(iv) examine available evidence concerning the probable effects of large-scale irrigation on groundwater resources, particularly the potential problems of drainage and water quality; and

(v) establish a priority listing of research needs with respect to the environmental implications of future irrigation development in Canterbury.

The potential development of the Rakaia River for hydro power is an important longer term consideration for the region. The multiple use implications of a major hydro development scheme are at present not widely understood, and for this reason, a considerable effort was made to examine the present irrigation proposals in light of future water resource development options. The specific objectives which guided this examination included:

(i) a detailed review of the hydro power development proposals that have been suggested for the river;

(ii) an assessment of the current irrigation plans - their economic, social and environmental implications - in the absence of hydro power development; and

(iii) an assessment of the possible social and economic consequences, including environmental impacts, of a multipurpose water resource development plan that would include irrigation, power and fishery (both recreational and commercial) enhancement as joint project outputs.

Analytical tools and frameworks for evaluating alternative water development policies, especially when policy choices involve complex tradeoffs between uses whose implications are not fully understood or easily compared, are needed at both the national and regional levels. In this part of the study attention is focused on the existing institutional-legal-planning "framework" within which water resource policies and plans are now framed, and on the channels and processes through which information passes and decisions are made regarding Community Irrigation Scheme development. Within this "social context" an analytical framework which can aid policymakers and planners in identifying and evaluating the economic and social implications of water allocation decisions is described.

Accordingly the specific objectives associated with this aspect of the review were:

(i) to describe (and in some cases to evaluate) present water institutions, laws and policies relating to the planning and implementation of a Community Irrigation Scheme; and

(ii) to develop an analytical framework for use in evaluating regional water allocation policies which confront conflicting interests, multiple social objectives and uncertain consequences.

1.4 Review Framework, Data Sources and Limitations

This study was undertaken by a team of social scientists representing the sub-disciplines of economics, public policy, law, sociology, and geography. Accordingly, extensive reliance on the assistance and judgement of professionals in the physical and biological sciences was necessary in assembling the technical information base upon which the Study Team's conclusions are based.

As the terms of reference suggest, a broad range of interests and topics was scrutinised. The empirical data reviewed and discussed in this report were obtained almost solely from secondary (published) sources. In some cases judgemental information provided by experts working on particular aspects of the problem was necessary where relevent literature was non-existent or was yet to be published for public dissemination. The confidentiality of information of a proprietory nature and comments made to the members of the Team through personal communications has been respected in this report.

Preliminary drafts of the individual chapters were reviewed at several stages in their development first internally and later with the help of collaborators outside the Study Team who provided assistance in gathering much of the data. The overall draft report was then submitted to a more formal review by the local and regional planning agencies and regional offices of national government. The present report has benefited markedly from this interchange of ideas and critique.

The study suffers from the usual limitations imposed by time and financial resources which constrain its breadth of coverage and accuracy of detail. In several instances the authors resorted to "ball-park" guestimates of the magnitude of certain impacts, in particular the recreation and amenity implications that could result from single purpose water developments and the potential benefits accompanying the development of groundwater, and the reader is cautioned to respect the tentative basis upon which these estimates are put forward. It should go without any special emphasis that a study of this nature is oriented to stimulating thought about issues of considerable public importance, whose importance derives, in part, from the uncertainty surrounding their actual magnitudes.

1.5 Organisation of the Report

The results of this investigation are presented in eight chapters which are more or less self-contained in terms of subject matter. In Chapter 2 the recently advanced proposals for two major Community Irrigation Schemes requiring a water right from the Rakaia River are described as a backdrop to the discussion of water allocation policy issues. In this chapter the basic assumptions which underlie the nature of these proposals are documented for reference in subsequent chapters.

Chapter 3 presents an overview of the enabling legislation which brings Community Irrigation Schemes into being, and elucidates certain aspects of present water law and public irrigation development policy and planning procedures that are germane to immediate concerns in regional water allocation and the social and economic assessment of water policy and management options. In addition to providing insights into areas requiring more careful future examination, this discussion provides the essential social context for the discussion presented in Chapter 8 which outlines a conceptual/analytical framework for studying regional water resource allocation and planning alternatives.

The likely primary and secondary economic impacts of the irrigation proposals on the regional economy are reported in Chapter 4. The physical production potentials and suitability of the region are examined in light of the availability of water for irrigation, and the 'flow-on' effects of large-scale irrigation development in terms of expected regional income and employment impacts are discussed.

The social and demographic implications are taken up in Chapter 5. A conceptual framework for assessing such changes is discussed, and the information needs required to make definitive statements about irrigation development-induced changes in rural communities are described. The ability of rural communities to respond to the infrastructure requirements and opportunities presented by major construction and longer-term development activities, which under present circumstances would be beyond their capacity to cope with is emphasised.

Chapter 6 reports the potential environmental impacts of the current proposals to abstract and use Rakaia River water. While the implications are obviously far-reaching, especially to the many interest groups that have expressed concern over the proposals, the Study Team concentrated its efforts on what are believed to be the most critical issues confronting regional planners in the near term, i.e. information that could influence the granting of water rights which are scheduled for a Tribunal hearing in late 1983. Research needs, some of which appear to be of a higher priority than others, are described. The potential loss of wildlife habitat is a primary concern, as is the potential "created by" irrigation and other forms of water flow modification. The possible social and economic implications, both adverse and beneficial, are noted, including the implications for commercial salmon ranching ventures on the River which also have an impending water right claim (to a minimum allowable low flow) and which could prove to be a use highly beneficial to the regional community in the future.

The discussion in Chapter 7 extends the scope of the review to future considerations regarding options for water resource development that present a different outlook on the present irrigation proposals and the attendant environmental concerns. The indicative regional benefits of large-scale hydro power development of the Rakaia River are presented, and the potential benefits of considering electricity generation in association with irrigation are explained. Possibilities that a multi-purpose regional water development approach may enhance recreational benefits are also explored in this chapter.

In Chapter 8 we briefly outline our thinking on an appropriate assessment framework for dealing with the water allocation issues now confronting the Regional Water Board. The suggested analytical approach is premised on conditions that will lead to economically efficient and socially equitable solutions. Suggestions on how to deal with potential irreversibilities and intergenerational concerns, especially with respect to present decisions that must be made without the benefit of full information, are discussed in the context of actual water resource policy and management options that are currently under study by the planning agencies.

Finally, Chapter 9 summarises the recommendations for further study and reports the Team's conclusions as to "priority" research needs. The criteria used to "rank" the various research proposals that might constitute Phase Two investigations are explained, and the designated "high" priority research areas are discussed in relation to some ongoing studies by the Regional Water Board and other responsible regional and national agencies of government.

CHAPTER 2

IRRIGATION FROM THE RAKAIA RIVER: OVERVIEW AND IDENTIFICATION OF PLANNING IMPLICATIONS

2.1 Introduction

The Central Plains Irrigation Scheme (CPIS) and the Lower Rakaia Irrigation Scheme (LRIS) are two proposed community irrigation projects that require the abstraction of significant amounts of water from the Rakaia River.[1] Over the summer period, when crop and pasture irrigation demands are highest, on some days the proposed abstractions could amount to about 40 percent of the river's total flow. It is possible that this level of potential abstraction would have a deleterious effect on the River's sport fishery, recreational use and other attributes. However, irrigation is necessary in Canterbury to overcome the limitations that seasonal drought places on the region's agriculture. Irrigation is also viewed as a major stimulus to the region's growth through more intensive land use and greater productivity.

The purpose of this chapter is to provide background information on the irrigation proposals as a base of reference for the review of issues contained in the chapters which follow. The discussion begins with a description of the proposals to utilise water from the Rakaia River for irrigation. Following this, the implications of water abstraction on the River's summer flow are examined through an analysis of flow duration curves. Since the Rakaia River is not the only source from which the water requirements of the irrigation schemes could be met, a description of the groundwater resources of the Rakaia region is also presented. The next section summarises the overall economics of the irrigation scheme alternatives. In particular, the effect of altering the balance between river abstraction and groundwater development is highlighted. The final section in this chapter draws conclusions from the discussion and identifies areas where further research might be usefully concentrated.

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[1] A third scheme, just recently proposed, would divert water from Lake Heron in the upper Rakaia catchment to irrigate a 5,000 to 10,000 hectare block in the Barrhill area. Since the details of this proposal are not known it was excluded from consideration in the present study.

2.2 The Current Proposals

Figure 2.1 illustrates the spatial extent of the proposed Community Irrigation Schemes between the Ashburton and Waimakariri Rivers in Canterbury.[2] Both the CPIS and LRIS projects would require substantial amounts of water from the Rakaia, given that the combined area of these two schemes will be about 190,000 ha, 125,000 ha in the CPIS and 65,000 ha in the LRIS. While the total potential coverage of these two major irrigation schemes is reasonably well defined, the source and quantity of water supplied to each scheme has not been finalised, although the preferred design alternative will utilise water from both the Rakaia River and groundwater.

Table 2.1 compares six alternative combinations of riverwater and groundwater that were proposed by the Ministry of Works and Developmennt (MWD) in 1980 as options from which the design details of the actual LRIS scheme could be developed. The areas detailed for the CPIS are in draft form only, in that there are hydrological differences between the Central Plains and the Lower Rakaia regions, and that the apparent flexibility in changing from river-dominant Scheme 1 to groundwater-dominant Scheme 6 may not exist in practice. Current studies by the North Canterbury Catchment Board (NCCB) on the grounwater resource of the Central Plains area will enable a better assessment of the role of groundwater in the near future (Bowden, 1982).

Table 2.2 presents the estimated peak irrigation demands associated with each scheme option. The source of water supply is shown for each option and the suffix following the scheme number indicates the roster period (in days) used for scheduling deliveries to individual farms. Total irrigation demand over the range of design options varies between 131-145 cubic metres per second (cumecs). Schemes 1, 2 and 3 obtain the majority of their total requirements from the Rakaia River, while Schemes 4, 5 and 6 rely on groundwater development to supply water to the majority of their scheme areas.

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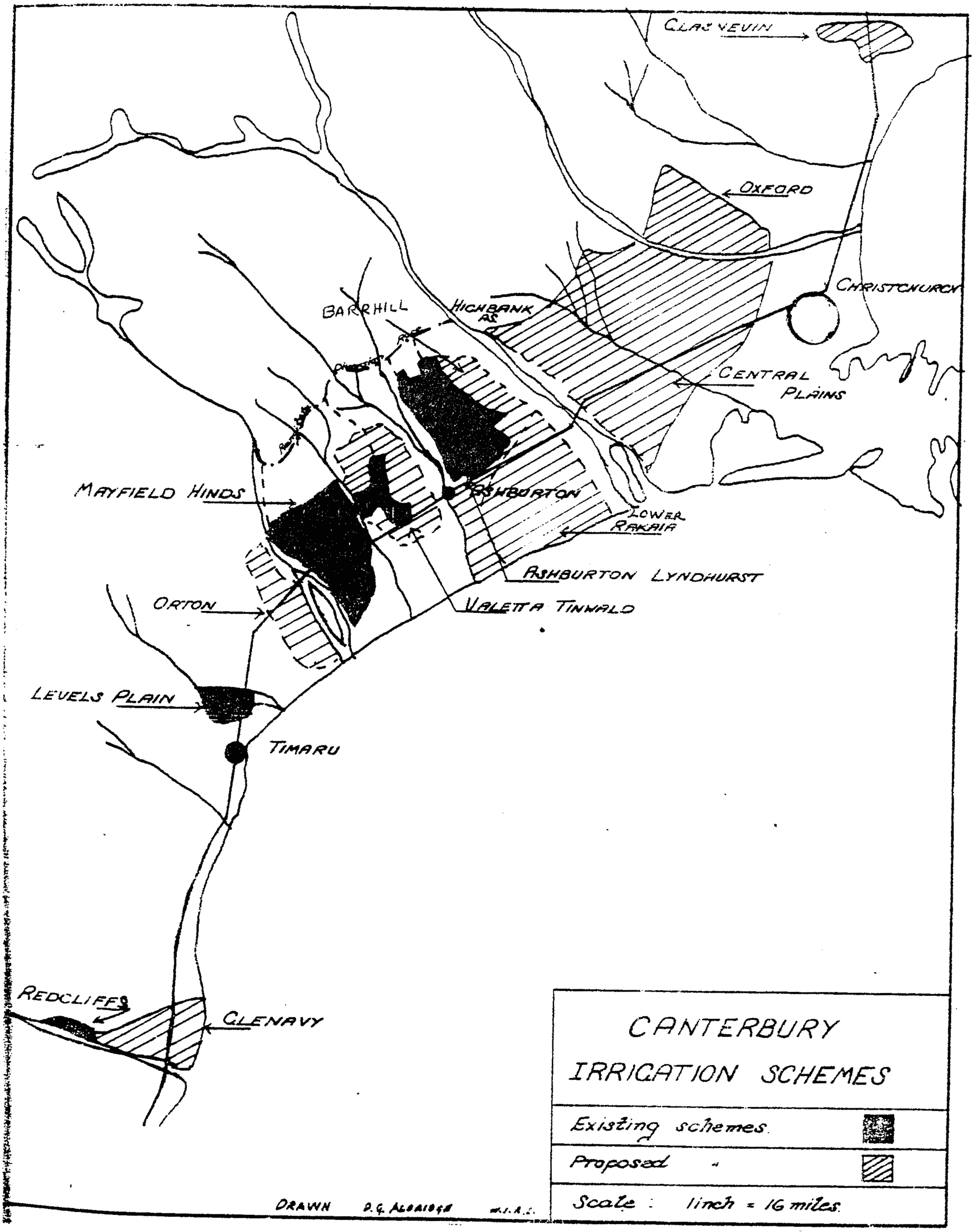
[2] The Barrhill Irrigation Scheme will abstract water from the Rangitata Diversion Race (via a diversion from Lake Heron), so there will be some reduction in the amount of water which is now being transferred from the Rangitata to the Rakaia River.

FIGURE 2.1

Existing and Proposed Irrigation Schemes in Canterbury



Source: Fitzgerald (1970)

TABLE 2.1

Possible Design Options for Areas Serviced by Rakaia River Water and Groundwater

Scheme Design Option	River Supply LRIS[1]	River Supply CPIS[2]	River Supply Total	Groundwater Supply LRIS[1]	Groundwater Supply CPIS[2]	Groundwater Supply Total
		(000 ha)			(000 ha)	
1	56	112	168	8	16	24
2	47	94	141	17	34	51
3	39	78	117	25	50	75
4	29	58	87	35	70	105
5	22	44	66	42	84	126
6	16	32	48	48	96	144

[1] Source: Maidment _et. al_ (1980: 33)

[2] Determined by applying the Lower Rakaia's river-to-groundwater mix to the total Central Plains area (refer to text).

The river-dominant schemes were favoured in early irrigation planning. For example, the Southern Energy Group's (SEG) joint hydro-power and irrigation development plans indicated that a Scheme 2 scale of river-supplied irrigation development was possible (SEG,1975; SEG, 1979). The SEG's 1975 plans proposed that Lake Coleridge be raised by 24 metres, and that the additional storage be utilised by drawing water off the lake into a canal system and taking water to the Central Plains via a series of hydro-electric power stations. In 1979, the SEG's plans were modified. The proposed development of Lake Coleridge was deferred, which meant that water for irrigation and hydro-power development would have to be taken directly out of the Rakaia.[3]

Philpott (1980) subsequently analysed the alternative irrigation proposals and found that 'river-dominant' schemes, such as Scheme 2, could not be supplied, under the North Canterbury Catchment Board's (NCCB) 1974 allocation plan, with their full irrigation water requirements from the Rakaia on 24 percent of the days during an average irrigation

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[3] A more detailed discussion of these proposals is reported in Chapter 7.

TABLE 2.2

Peak Irrigation Demands and Alternative Water Supply Mixes

Scheme Design Option	River Supply			Groundwater Supply			Total
	CPIS	LRIS	Total	CPIS	LRIS	Total	
				Cumecs			
1/28	77	39	116	12	6	18	134
2/23	73	36	109	24	12	36	145
2/28	65	33	98	24	12	36	134
3/23	59	30	89	34	17	51	140
3/28	53	27	80	34	17	51	140
4/23	45	22	67	46	23	69	136
4/28	41	21	62	46	23	69	131
5/23	33	17	50	56	28	84	134
5/28	*	*	*	56	28	84	*
6/28	*	*	*	64	32	96	*

Source: Based on data presented in Maidment _et. al_ (1980:34) for the LRIS with interpolation to the CPIS

* Data not reported.

season. In February, the full abstraction requirement could not be met on for example, 54 percent of the days (a 25 percent deficiency in terms of volume). Such high probabilities of deficiences in water availability have caused planners to reconsider those scheme options which would require a reduced level of abstraction from the Rakaia.

Daniel (1980a and 1980b) reported plans for the LRIS which allow for river water to supply just under 29,000 ha, with a peak irrigation abstraction of 20 cumecs. This level of river water use is consistent with Scheme 4, a groundwater-dominant option. Scheme 4 also implies that 70,000 ha in the Central Plains could be supplied with a peak flow of 45 cumecs from the Rakaia (Tables 2.1 and 2.2), hence total river abstraction for both schemes would be about 65 cumecs with groundwater abstraction at about 69 cumecs. However, applications for water rights totalling 90 cumecs, 20 for the LRIS and 70 for the CPIS, have been submitted by the irrigation associations representing the two proposed schemes.

Two important questions arise from these proposals to abstract water for irrigation; indeed much of the present controversy can be attributed to our lack of knowledge about them. One concerns the potential impacts of river abstraction during periods of low natural flow, and the other concerns the availability of economically abstractable groundwater. The next section reviews the possible influence of abstraction on the seasonal flow of the Rakaia River.

2.3 The Influence of Abstraction on River Water Volume

Estimating the flow of the Rakaia River over the warmest and driest summer months (December, January and February) is critical to the analysis of conflicting demands for the Rakaia's water.[4] This three month summer period encompases peak irrigation demands, a tapering-off of natural flows, and the salmon run passing from the sea up through the Rakaia Gorge. Clearly, if the river's flow over summer is less than that required to satisfy both abstraction and instream needs, then either one or both alternative uses of the water must accept a supply shortfall and, as a consequence, incur the economic or environmental cost associated with it. Of course, irrigation demands and the salmon's environmental requirements are but one example of a number of potential conflicts between abstraction and instream uses that require water to be retained in the river. The instream consequences are discussed in Chapter 6.

Given the apparent importance of the Rakaia's summer flow, the authors carried out an analysis of the daily mean flows for the months of December, January and February over the period covering December 1967 to December 1977.[5] Data for subsequent months (after December 1977) include the influence of the Wilberforce River diversion into Lake Coleridge, and since power releases do not necessarily coincide with natural flows, these data were excluded from the analysis.

The objective of the analysis was to produce duration curves for:

(i) the abstractable flow from the Rakaia River over summer;

(ii) the residual flow of the River; and

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[4] Late summer and autumn may also be important as natural flow drops off dramatically in March and April. However, for the purposes of this study, the flow duration analysis focuses on peak irrigation months.

[5] An earlier study on flow duration, reported in Maidment et al. (1980), does not indicate clearly the consequences of abstraction during this period.

(iii) the number of consecutive days of low-flow conditions.

The analysis was undertaken assuming a peak irrigation demand of 70 cumecs for the CPIS, and 20 cumecs for the LRIS (i.e., a post development scenario), subject to different assumptions regarding the minimum flow standard for the River, currently 42 cumecs (55 cumecs at the Gorge).[6] Given a range in minimum flow options, historical mean river flows are assessed in light of these water management possibilities.

2.3.1 <u>Abstractable Flows</u> Table 2.3 summarises the percentage of days that the maximum abstraction demands from the proposed irrigation schemes could be met, for a number of different minimum flow standards. The results indicate that only without any minimum flow standard could the peak demand for water by the CPIS be met at least 50 percent of the time. If the current minimum flow standard was maintained, peak irrigation requirements could be met around 40 percent of the time in the CPIS. Further, the analysis shows that a minimum flow standard of 100 cumecs accommodates peak irrigation demands from the CPIS about as often as a minimum flow standard of 20 cumecs. This result occurs because of the 'plateau' in the WMP for river flows between 87 and 115 cumecs above the minimum flow (see Appendix 1).

TABLE 2.3

<u>Summary of Summer Flow Analysis for the Period 1967-1977: Abstraction Demand</u>

Minimum Flow Standard	Percentage of days when maximum demand could be met if required	
	CPIS	LRIS
(Cumecs)	%	%
0	57	28
20	48	24
40	43	21
60	37	20
80	33	18
100	45	17
150	26	30

Source: Appendix 1, Table 1.1-1.7, from columns (3) and (6).

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[6] The Water Management Plan (WMP) is currently under review by the North Canterbury Catchment Board. The present WMP is described in Appendix 1.

Since peak irrigation requirements in the CPIS and LRIS are likely to coincide, Table 2.3 suggests that for almost any minimum flow standard, peak irrigation demands in the LRIS would be met less than 30 percent of the time. Only when the minimum flow standard approaches 150 cumecs can peak irrigation demand be met for 30 percent of days during summer. This result occurs because the CPIS's supply of water is restricted severely under higher minimum flow standards, leaving more water in the river for the LRIS to abstract.

2.3.2 Residual Flows Table 2.4 summarises results for a minimum flow standard of 60 cumecs, close to the current standard of 55 cumecs at the Gorge. The results suggest that a residual flow below the CPIS of 70 cumecs can almost always be assured, but after loss to groundwater below State-Highway 1 a residual flow of 60 or even 50 cumecs cannot be guaranteed.[7] Again, it must be stressed that these results assume that abstractable flows equal to the CPIS's and LRIS's peak irrigation demands are actually abstracted.

TABLE 2.4

Summary of Summer Flow Analysis for the Period 1967-1977: Residual Flows for a 60 Cumec Minimum Flow Standard

Residual Flow	Percentage of Days When Residual Flow Equalled or Exceeded		
	Below CPIS Return Outlet	Below State-Highway 1	Below LRIS Return Outlet
(Cumecs)	(%)	(%)	(%)
40	100	96	96
50	100	87	87
60	100	76	76
70	96	66	66
100	66	37	37
120	50	29	29
140	33	23	19
160	26	19	16

Source: Appendix 1, Table 1.4, columns (4), (5) and (7)

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[7] Catchment Board estimates of flow loss to groundwater in the lower reach of the River range from 12 to 30 cumecs (Bowden, 1982).

2.3.3 Duration of Low Flow Events For the purposes of this analysis, a "low flow period" was defined as a sequence of days when irrigation abstraction demands could not be met because of the limitations imposed by the WMP. The results are reported in Table 2.5. For the CPIS, low flow periods of five or more days make up about 60 percent of total low flow days. Ten percent of total low flow days were accounted for by periods lasting at least 25 days. The LRIS, because it is situated below the CPIS, has higher probabilities of longer low-flow periods for minimum flow standards up to 100 cumecs. For minimum flow standards over 100 cumecs, restrictions on abstraction for the CPIS allow the LRIS a more certain water supply.

TABLE 2.5

Summary of Summer Flow Analysis for the Period 1967-1977: Low Flow Periods

Minimum Flow Standard (Cumecs)	Low Flow Period in Sequential Days								
	1	2	3	4	5	10	15	20	25
	Probability of Low Flow Period Being Equalled or Exceeded (%)								
A. The CPIS:									
0	100	85	65	53	42	22	16	16	9
20	100	93	78	64	58	24	12	10	8
40	100	94	90	77	65	33	17	14	14
60	100	91	84	78	71	36	16	13	13
80	100	91	84	77	68	43	20	12	12
100	100	91	81	70	63	33	16	11	9
150	100	91	81	70	63	33	16	11	9
B. The LRIS:									
0	100	88	83	76	68	42	20	12	12
20	100	89	82	75	68	43	25	14	14
40	100	84	75	74	68	40	30	17	14
60	100	96	85	81	77	44	31	20	16
80	100	96	92	82	79	47	34	20	16
100	100	100	96	87	85	54	39	22	20
150	100	89	72	55	41	17	6	6	5

Source: Appendix 1, Table 2.

For mid summer conditions the economic returns to the supply of irrigation water are likely to be at their greatest (Frengley, 1979). The frequency with which low-flow periods of over five days in duration occur suggests that when water is most needed by farmers it is not likely to be available in the required amount, hence rationing between users will be required.

To ensure that significant deficits in meeting abstraction requirements do not occur, seven policy options noted by Maidment et al. (1980) are relevant:

1. plan for maximum use of groundwater;
2. plan to develop only one of the two schemes;
3. develop only a proportion of each of the two proposed schemes;
4. propose adjustments to the Water Allocation Plan;
5. tolerate restrictions in water supply;
6. plan for more minor schemes; and/or
7. plan to use Lake Coleridge storage to augment summer low flows.

At present, policy options 1, 3, 5, and 7 appear acceptable to agencies involved in planning the CPIS projects. Option 7 is already being used to a limited extent.[8] It is important to note, however, that as the two scheme proposals now stand, future development options - including decisions regarding scale, specific location, and the mix of water uses by source of supply - are entirely open at this point in time, and will be influenced by research work currently in progress.

2.4 The Groundwater Resources of the Canterbury Plains

2.4.1 Geology and Groundwater Potential

Wilson (1973) and Scott (1980) describe the geological origins of the Canterbury Plains and the influence their geology has on groundwater availability. Figure 2.2 identifies two major geological divisions of the Canterbury Plains, the first composed of gravels deposited after glacial recession in the Southern Alps, and the second composed of post-glacial outwash. The availability of groundwater varies greatly between these two gravel types. Wilson (1973) explains how wells drilled on the glacial outwash

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[8] With the completion of the Wilberforce diversion in 1977, the Lake Coleridge power station has been able to operate on a more stable generating pattern and summer river flows have been augmented as a result (see Chapter 7).

yield only 10-100 litres per minute, compared to the 400-2,000 litres per minute from those on the alluvium. Thus in general terms, it would appear that those portions of the Community Irrigation Schemes utilising groundwater would have to be situated in close proximity to the major river systems.

Scott (1980) noted that yields from wells drilled at increasing distances away from major rivers and moving inland decline, and tend to be highly variable due to thin aquifers with low transmissivities and storage capacities. One reason given by Scott for the high groundwater yields close to the major rivers is the infiltration of river water into the groundwater system. The evidence presented by Stephen (1972) regarding the loss of river flow in the Rakaia between the Gorge and State Highway 1 supports this hypothesis. Bowden (1979) reported on the variability of pumping yields, contrasting a winter to summer groundwater level fluctuation of 0.25 metres adjacent to rivers and near the coast and a ten metre fluctuation in the glacial outwash gravels. Groundwater levels tend to peak in late spring, with the lowest water levels occurring in early winter, typically May through July.

2.4.2 The Role of Groundwater in Current Irrigation Planning

Current irrigation planning for the LRIS highlights the most favourable areas for groundwater development. Daniel's (1980a, Figure 1) outline of the LRIS, when overlaid on Thorpe's (1979) isobath[9] map for the Lower Rakaia area, indicates that river water will supply the area above the 20 metre isobath, and groundwater, the area below the 20 metre isobath. Since no firm outline of the area to be supplied by river water in the CPIS is available, no conclusions can be made regarding the appropriateness of the total area designated for groundwater supply in the Central Plains. The data presented in Tables 2.1 and 2.2 indicate, however, that a Scheme 4 plan for the CPIS is based on a groundwater supply sufficient for 70,000 ha with a peak irrigation demand of 46 cumecs.

At the present time precise estimates do not exist for the quantities of groundwater available 'over time and space' within the

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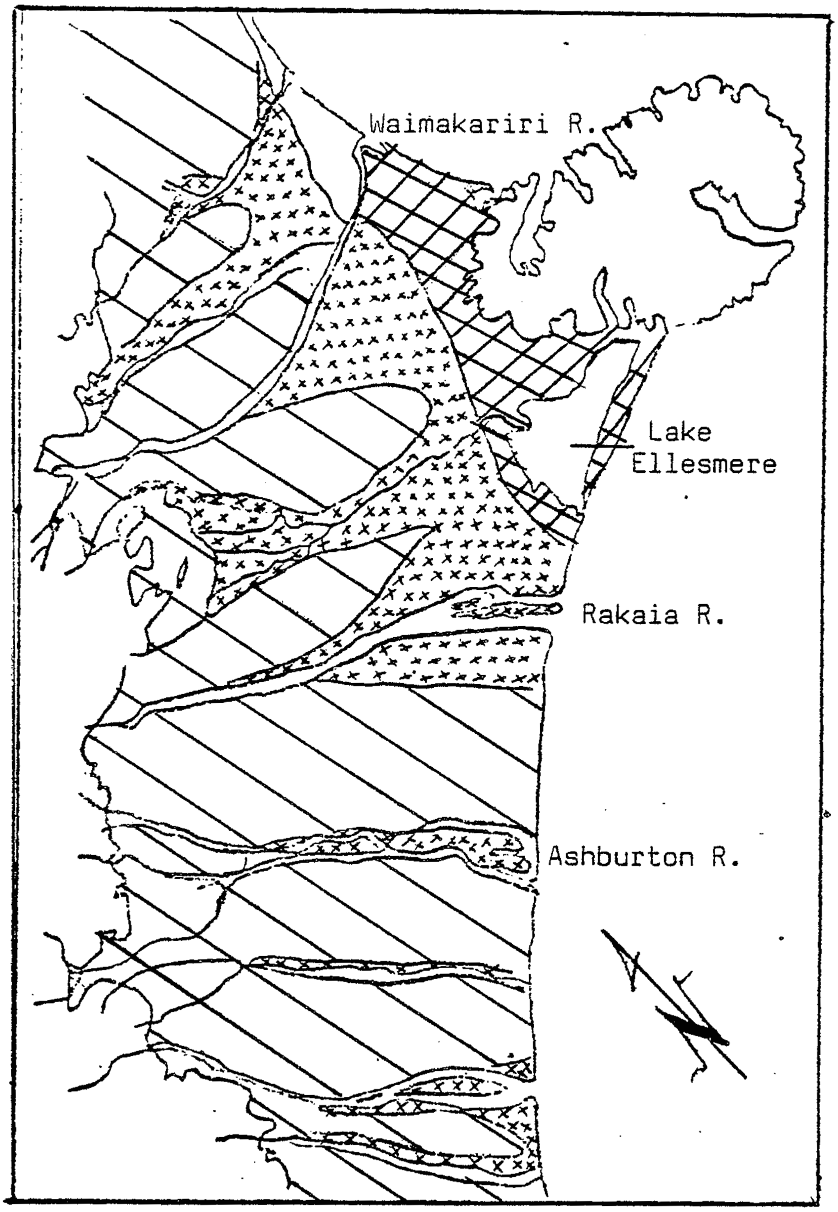
[9] Lines of equal depth to groundwater.

FIGURE 2.2

Geology Related to Aquifer Properties



Source: Wilson (1973).

▧	Periglacial and glacial outwash, permiability improves eastward.
	Post-glacial alluvium, and estuarine and marine deposits.
▩	(a) Artesian area.
×××	(b) Over glacial outwash, permiability increases eastward.

two project areas. Farmers in the proposed LRIS area now abstract some 3.2 cumecs on an annual basis to spray-irrigate approximately 9,300 ha. In the CPIS area, current abstraction of groundwater could be as high as 25 cumecs per year (NCCB, 1982). Although no appreciable draw-down on the aquifers has been noted due to irrigation development thus far, there is not consensus of opinion as to the potential amount, or the safe rate of abstraction, that would sustain the resource over time. The current drought in Canterbury has highlighted the tenuous nature of this resource, as water levels in established wells have dropped measurably since the onset of the dry cycle (Bowden, 1982).

Thorpe (1979) estimates that aquifers under the LRIS are being recharged at an annual rate of 34 cumecs, 44 percent of which is derived from the Rakaia River, 41 percent from precipitation, and the residual by drainage from upland border-dyke irrigation (the Ashburton-Lyndhurst Scheme). Given a Scheme 4 development option, Thorpe's calculations suggest an upper bound estimate of groundwater abstraction at 12 cumecs over the irrigation season, assuming a per hectare crop-water demand of 0.4 litres per second (l/s). Over the year then, if recharge occurs at an average rate of 34 cumecs, and abstraction from groundwater at a rate of 12 cumecs, 22 cumecs will remain unallocated. This of course is a maximum estimate, since the groundwater hydrology of the area is immensely complex and not well understood.

Price (1981), using a different approach, provided what might be regarded as a lower-bound estimate on groundwater abstraction. He estimated an average seasonal drawoff of six cumecs for the LRIS (assuming a Scheme 4 level of development), based on the observed practices of irrigators currently utilising groundwater in that area. If Price's estimates are as reliable as Thorpe's,[10] their work, taken together, suggests that a substantially greater proportion of the LRIS area might be serviced from the groundwater resource than presently contemplated (i.e. under Scheme 4). The estimated groundwater recharge and abstraction levels on an annual or seasonal basis, however, may be very misleading in terms of peak irrigation demands over shorter

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[10] The Study Team does not have the competence to decide on such matters, but the available data warrants consideration, particularly when research results are juxtaposed.

time intervals (McFadden, 1982).[11] But, given that the pattern of available groundwater and crop and pasture requirements are likely to coincide in the late Spring - early Summer period, the problems of peak abstraction from groundwater may not be too severe, especially if groundwater users are "rostered" in a manner similar to border-dyke irrigators.

There are other limits to groundwater exploitation which may be just as important as quantity constraints. Some of these have been raised in connection with earlier irrigation proposals for the area (Mandell, 1974). If aquifers are in contact with seawater and are exploited at a rate greater than their average annual replenishment, seawater intrusion occurs. Intensive use of groundwater near the coast should, therefore, be avoided if there is evidence that saline water pollution poses a serious problem to water users in the future.

Energy requirements for pumping water and the depletion of shallow aquifers are potentially severe constraints to exploiting the groundwater under the Central Plains. In comparison to the Lower Rakaia area, where bores of less than 30 m to 100 m are required, wells of up to 150 m in depth are presently found in the Central Plains. The average pumping depths, however, are much less than the upper bound on these ranges. Unless there is a high-valued use, such as horticulture, pumping depths exceeding about 50 metres may be considered uneconomic for the conventional livestock and cropping farmer (McChesney and Sharp, 1980).

Groundwater pollution, largely related to an increase in nitrates in groundwater resulting from the leaching of fertiliser and livestock wastes, is a recognised health hazard, particularly in urban areas. Where municipal water supplies are obtained from groundwater the accumulation of nitrates could create a demand for alternate sources of fresh water. Water logging is also a potential problem, especially in the Selwyn-Ellesmere drainage where a higher natural water table exists at present.

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[11] Also see Maass and Anderson (1978), Frengley (1979) and Hanks and Hill (1980) for useful discussions on this issue.

2.5 Economic Assessment from the National Viewpoint

2.5.1 Results from Earlier Studies An economic analysis of the present scheme options for the LRIS is reported in Le Page and Ritchie (1980). Le Page (1980b) also reported on the river supplied portion of a Scheme 4-sized Lower Rakaia project. In an earlier study, Hadfield *et al*. (1974a) undertook a cost-benefit analysis of a Scheme 3-sized, river-supplied irrigation scheme for the Lower Rakaia. Apart from a study undertaken in the same year by Hadfield *et al*. (1974b) for a small river-supplied irrigation scheme in the Central Plains, no independent studies on the economics of alternative design options for the CPIS have been conducted.

Furthermore, all previous economic evaluations have been "preliminary in nature". That is, formal cost-benefit analyses from the national point of view, using sound farm management data and encompassing detailed engineering design costings, have not been carried out for either of the two proposed Community Irrigation Schemes. The above-mentioned studies were commissioned to obtain "indicative' results as a guide to future planning and more detailed investigations for project design purposes. Nonetheless irrigation project proposals are considered for funding on the basis of these preliminary findings, and only after they have been "approved in principle" is a formal cost-benefit analysis requested (see Chapter 3, section 3.3). The following reviews the results of previous (preliminary) economic evaluations.

2.5.2 Scheme Options and Economic Efficiency The reported studies reveal that the irrigation proposals do not meet the 15 percent Internal Rate of Return (IRR) guideline suggested by Government.[12] Table 2.6 summarises the most recent IRR's obtained for the LRIS and CPIS. On the basis of Le Page and Ritchie (1980), the groundwater area, considered by itself, achieves a rate of return about four percentage points higher than the river supplied area. The reason for this can be found in the lower capital cost of groundwater development, and the faster rate of on-farm adoption of irrigation, usually spray application. River supplied irrigation requires large off-farm capital costs, since water must be diverted and reticulated from the river to farms by a gravity conveyance system. On-farm capital improvement can also be expensive,

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[12] For a discussion of current Government policy guidelines regarding public investment in community irrigation schemes, see Chapter 3.3.

TABLE 2.6

Comparison of Irrigation Scheme Options on the Basis of the IRR Criterion

Scheme	Option	River Water Area (000 ha)	River Water IRR (%)	Groundwater Area (000 ha)	Groundwater IRR (%)	Total Scheme IRR (%)
LRIS[1]	4	29	7.8	35	12.0	9.4
	5	22	7.6	42	11.6	9.7
	6	16	7.5	48	11.4	9.8
LRIS[2]	4	32	9.7			
LRIS[3]	3	36	9.3			
CPIS[4]	5	46	8.1			

Sources:
1 Le Page and Ritchie (1980)
2 Le Page (1980)
3 Hadfield *et al*. (1974a)
4 Hadfield *et al*. (1974b)

particularly when river water supply is associated with a border-dyke system of surface irrigation which requires land levelling.

The effect of spreading large off-farm capital costs and the slower rate of on-farm development is significant for the scheme's IRR. For example, Hadfield *et al*.(1974a) compared the sensitivity of IRR's for the LRIS to different off-farm capital costs and development rates, the results of which are summarised in Table 2.7. Assuming a 15 year scheme development, they found that the IRR increased by about three percentage points if off-farm capital costs were reduced from \$100 ha^{-1} to \$60 ha^{-1}. Given a \$60 ha^{-1} capital cost, the IRR increased another two percentage points with a development period of seven rather than 15 years. It is not surprising, therefore, that planning for irrigation involving large scale river water abstraction usually requires a large area to reduce the average off-farm capital cost per hectare serviced, and a rapid rate of on-farm development (see Chapter 5.5).

TABLE 2.7

The Influence of Off-farm Capital Costs and Development Rate on a Scheme's IRR

On-Farm Development Rate (Years)	Off-Farm Capital Cost ha^{-1}		
	$60	$80	$100
	IRR (%)		
7	13.1	11.3	10.0
10	12.2	10.5	9.3
15	11.0	9.5	8.4

Source: Hadfield et al. (1974a), p.32

Tables 2.8 and 2.9 compare the off- and on-farm capital costs associated with the LRIS options 4, 5 and 6. These estimates were calculated from data reported in Le Page and Ritchie (1980). In Table 2.8 a further option, a hypothetical "all groundwater" supply, has been calculated by the authors of this report. The estimate of the capital cost of a groundwater-only case (Scheme 7) assumes that sufficient water resources do (hypothetically speaking) exist. The cost calculations, admittedly crude, were based on the additional pumping costs of abstracting the "indicated" resource which underlies the upper portion of the LRIS, i.e., above Thorpe's (1979) 20 metre isobath.

TABLE 2.8

Off-Farm Capital Cost per Hectare for the LRIS Water Supply Alternatives

Scheme Option	Average Capital Cost for River Supply ($ ha^{-1})	Average Capital Cost for Ground-water Supply ($ ha^{-1})	Average Capital Cost for Total Area ($ ha^{-1})
0	428.49	-	428.49
4	491.76	103.59	281.38
5	533.15	112.27	254.64
6	582.43	120.23	239.36
7	-	147.66	147.66

Source: Le Page and Ritchie (1980), except for Option 7, which is a study estimate.

As could be expected from the preceeding discussion, the data show that average off-farm capital costs for diverted water decrease steadily as the area supplied by the river increases. The average capital cost of groundwater supply increases with increasing groundwater development due to greater bore depths and higher energy costs of pumping. However, the average total capital cost of water development declines as the proportion of the scheme served by the relatively cheaper groundwater source increases. Although Scheme 7 appears to be the least costly method of development, this result is based on the existence of groundwater resources which are considered not to be readily available.

In Table 2.9 an examination is made of the sensitivity of on-farm capital cost for development "with" and "without" government assistance.[13] These data show that average on-farm capital costs vary little between the scheme options for the LRIS for the "without" assistance case. However, subsidies on the border-dyking costs have a marked effect, lowering the farmer's share of average on-farm capital cost by nine to 20 per cent (depending on the scheme option). Obviously, the design options with the greatest area serviced by river supply are associated with the greatest on-farm development subsidies. It is also apparent that both off- and on-farm capital cost considerations would tend to encourage the development of the LRIS in such a way that the area serviced by river water is as high as possible, thus spreading the off-farm capital cost and taking advantage of subsidies which favour more expensive on-farm development. Such encouragement of a river supplied, typically border-dyke, irrigation system which is favourable to the individual farmer is contrary to the intent of a national cost-benefit (economic efficiency) analysis of the development options.

It is important to emphasise that the technical assumptions underlying these calculations may not be necessarily correct. For example, it may not be valid to assume that an increased area of surface supply from the river will mean more border-dyking. As McFadden (1982) points out: "One of the common public fallacies at present is that surface supply is associated with borders and underground supply associated with sprinklers. In fact in the first instance the method of application is determined by other factors, particularly farming systems and the available labour and managerial requirements. The

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[13] Financial assistance to farmers under a Community Irrigation Scheme is discussed in Chapter 3.3.

TABLE 2.9

The Influence of Government Development Subsidies on "on-Farm" Capital Cost for the LRIS Water Supply Alternatives

	Average Capital Cost, River Supply Portion ($\$$ ha^{-1})	Reduction in cost with subsidy (%)	Average Capital Cost, Ground-water supply portion ($\$$ ha^{-1})	Reduction in cost with subsidy (%)	Total Average Capital Cost, LRIS ($\$$ ha^{-1})	Total Reduction in Cost with Subsidy (%)
A. Without Subsidies						
4	555		529		536	
5	543		530		535	
6	539		530		532	
7	-		528		528	
B. With Subsidies						
4	376	32	478	10	431	20
5	379	30	477	10	444	17
6	375	30	477	10	451	15
7	-	-	479	9	479	9

Source: Based on Le Page (1980b) and Le Page and Ritchie (1980).

nature and amount of water supply is only one of the factors in the decision and it is usually only in extreme situations that it becomes the dominant factor." At this time an informed guess would be that about 30 percent of the CPIS area would be sprinkler irrigated (Lewthwaite, 1982).

Unfortunately, no published cost-benefit analysis is available on a groundwater-only option for the LRIS. Using data contained in Le Page and Titchie (1980) and Le Page (1980b), a preliminary analysis of such an option was undertaken in the present study. Rough calculations indicate that an IRR of just under 20 percent may not be unrealistic. The reasons for such a high IRR are partially explained by lower off-farm capital costs per hectare, and a faster rate of on-farm development. However, while the methods, assumptions and data provided by Le Page and Ritchie (1980) and Le Page (1980b) were followed as closely as possible, it is also likely that the high IRR is partially attributable to error in extrapolating some of the assumptions and data to the groundwater - only case, option 7. In any event it is apparent that the possible economic importance of conjunctive use of surface water and groundwater justifies further investigation.

2.5.3 <u>Considerations for Further Study</u> It is evident from the preliminary nature of the proposed plans that considerable scope exists for both under- or over-estimating benefits and costs. The economic analyses that have been conducted thus far have demonstrated the sensitivity of IRR's to certain assumptions, for example the rate of on-farm development, but there are other important features of the proposals which, as far as we are aware, have not yet been examined. This section concludes with a brief outline of some aspects of the irrigation schemes that could markedly effect their economic attractiveness.

First, while it has been shown that under the present water allocation plan there will be periods of shortfall in potential deliveries to farms (Section 2.1), the marginal costs of irrigation water rationing in terms of reduced output have not been estimated. Depending upon the time of season that rationing would occur, the losses to farmers could range from nil to very large. Such potential losses must be carefully weighed against the potential benefits of enforcing minimum flow standards for allocating seasonal river flows (see for example Maass and Anderson, 1978).

A second, related concern stems from recognised water supply alternatives that could be used conjunctively. Diverting water from lake storage to meet peak irrigation needs, or to augment river flows, has not been submitted to economic analysis. A sound economic appraisal of a wider set of irrigation water development options could reveal a combination of surface, ground and storage water that would better achieve the stated project objectives, either from greater levels of output, reduced development costs, or perhaps both.

The above argument also applies to scheme area size and the sequence of development. Being scheduled for implementation first, the LRIS development plan could set in train a sequence of decisions with irreversible implications for the design and development of the CPIS. With limited surface water for abstraction, the two schemes are potentially in competition with each other. A useful study would be to examine the schemes as <u>one</u> plan, seeking to optimise the spatial distribution of all water resources as well as land area serviced. Presumably, such a regional rationalisation of water and land resources would also provide a greater degree of flexibility in adjusting to future uses, for example shifts in land use patterns resulting from factors besides the availability of water - better use of micro-climates, transportation and other infrastructure, etc.

More intensive land use and increased productivity - the ultimate aims of the irrigation proposals - in large measure will be the determining factors of their success. Simply reducing the hazard of summer drought is not likely to be a sufficient justification by itself. High-valued uses of irrigation water, like horticulture and intensive cropping, would have a significant effect on scheme economics if the proportion of these enterprises could be increased by it. What are the necessary and sufficient conditions for expansion of high-value land uses in the proposed scheme areas, and to what extent will expansion (if any) be attributed to Community Irrigation schemes? A review of the expected changes in land use and production levels with irrigation is reported in Chapter 4.3.

A final comment relates to the need for a broader view in investigating multiple use. Hydroelectric power generation in conjunction with irrigation (discussed in Chapter 7) is a well-known complementary development prospect. Also, enhanced recreational enjoyment of water-based activities such as swimming and fishing have received limited study in connection with the irrigation proposals (see Maidment et al., (1980). Some of these are very important to the regional community, particularly angling, yet the economics of fishery enchancement through relatively inexpensive modifications in structural designs has not been seriously studied to date. Overseas experience suggests that multiple use water development schemes are almost always preferred to single purpose schemes, particularly when the development is sited near a major population centre.

2.6 Conclusion and Research Needs

2.6.1 Summary and Implications Irrigation planning for the Lower Rakaia and Central Plains is based on the assumption that about half the irrigable area will be served by water from the Rakaia River, and half from groundwater. There is not enough hydrological evidence available to support or reject such an assumption. Indeed, there could be substantially less groundwater than has been assumed available for planning purposes. Analysis of the river's summer flow indicates a high probability that peak irrigation demand from the CPIS and LRIS will partially overlap natural low flows, resulting in shortfalls in irrigation abstraction.

Another implication is the assumed extrapolation of LRIS data to the CPIS. From a geological point of view, this does not seem appropriate since the depth to groundwater is at least double that of the Lower Rakaia region, and aquifer transmissivities are also lower. Accordingly, it is possible that the groundwater resources of the Lower Rakaia may be under-utilised, and those of the Central Plains over-utilised. An alternative, yet to be investigated, would be to fully develop the groundwater of the Lower Rakaia area, and in so doing free up water from the Rakaia River for abstraction by the CPIS, allowing the river-supplied area in this scheme to increase. Consequently, the off-farm capital costs of river abstraction would be spread over a greater area.

The hydrological differences between them need to be explicitly accounted for in planning. While these differences may be found to impose constraints on the total development of the two schemes, they could equally show full development of the schemes to be a compatible and complementary goal. For example, Noel et al. (1980) illustrate such an approach to planning for a Californian county and conclude that planning units for water resource development should be based, not on political or geographical boundaries, but on the degree of hydrological interdependence between different regions.

2.6.2 Research Needs Four areas of research were identified which will improve the information base on which irrigation decisions can be made:

1. The groundwater resources of both the Lower Rakaia and Central Plains require intensive study, so that the contribution groundwater could make to irrigation water demands can be more firmly established.
2. The value of groundwater use for irrigation, in allowing a greater volume of water to remain in the river, is unknown. Utilising available groundwater can lower the cost of abstraction in terms of its possible impact on the recreational and amenity quality of the Rakaia River.
3. Research is also needed on the degree of compatability and complementarity between the CPIS and LRIS, with conjunctive use of surface and groundwater being a key element in future planning. Also, the use of storage associated with hydro-electric power development deserves careful evaluation.
4. Previous cost-benefit analyses have tended to centre on preferred options from the standpoint of engineering considerations and have not explored some potentially worthwhile economic possibilities. Future cost-benefit analyses must pay greater attention to the sensitivity of results with respect to such important assumptions as land use patterns, joint project benefits (for example enhanced wildlife habitat) and scheme size.

CHAPTER 3

THE INSTITUTIONAL FRAMEWORK FOR WATER RESOURCE PLANNING

3.1 Introduction

Planning and implementing a Community Irrigation Scheme is a complex undertaking requiring close co-operation between agencies of central and local government, the farming community, independent research organisations and many special interest groups. Often the appropriate channels for input into planning decisions are unclear, since water institutions are continually "evolving" in response to new knowledge and new challenges in allocating the resource to meet changing social needs. Nonetheless, broad-based involvement in water resource planning is essential (and unavoidable) due to the many ramifications that are associated with the use of this important natural resource.

It became apparent at an early stage in this study that a better understanding of water agency planning objectives, and the rules and regulations which guide regional water development and management, was essential to any worthwhile review of specific proposals. Accordingly, a general frame of reference, or framework, was necessary to ensure that the research areas identified by the Study Team were relevant and timely, and consistent with the needs of the agencies who are entrusted with decision-making responsibilities. The next section of this chapter outlines such a framework. The roles and responsibilities of government agencies and other statutory bodies involved with Rakaia River planning are reviewed with the aid of this general framework, and the planning sequence and nature of public involvement at various stages in the decision-making process are identified. A more detailed discussion of some legal and procedural issues concerning the initiation and implementation phases is reported in Appendix 2. Section 3.4 examines the financing of publicly-sponsored irrigation schemes, and the chapter concludes with a discussion of the implications for future policy - oriented research relevant to the LRIS and CPIS proposals.

3.2 Water Institutions and the Framing of Public Water Policy

3.2.1 A Conceptual Framework A useful starting point for this discussion is a conceptual framework which encompasses the general subject matter of any water resource management problem. Figure 3.1 is an illustration of such a framework. The three major boxes in the diagram represent the basic components of the water planning environment: the physical resource base (which was described in Chapter 2), the social context of needs and priorities which water resource development are meant to serve, and the planning system which interfaces the social and physical systems leading to the identification of required actions and management decisions.

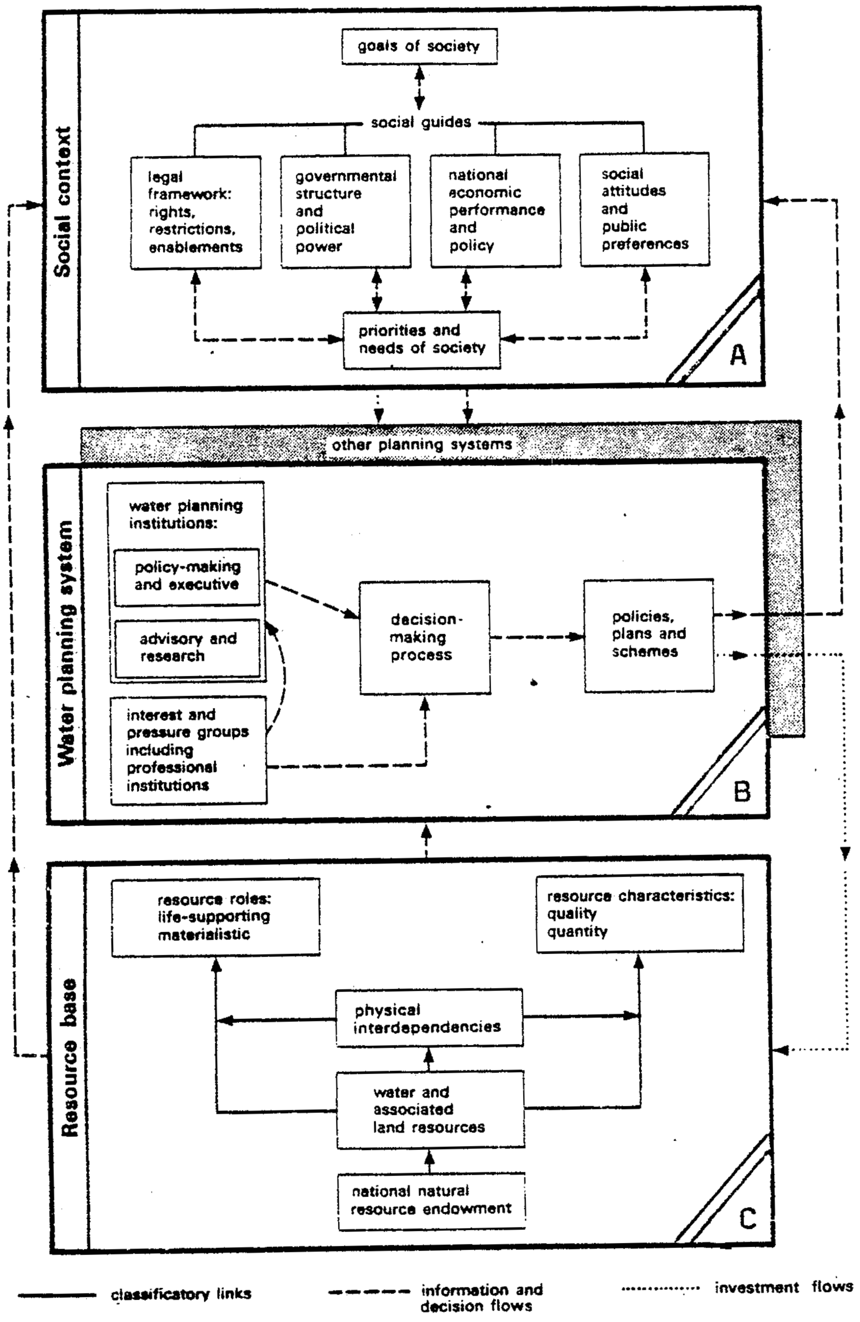
The resource base represents that part of the planning environment which provides society with opportunities and constraints. It is these potentials and limitations that water planning seeks to optimise in the social interest. In addition to the interrelatedness of land and water, interdependencies which are peculiar to water resources and their use must be recognised if they are to be successfully developed for society's benefit. Much of the discussion in Chapter 2, in terms of Figure 3.1, can be viewed as a concern for the linkages represented within the "resource base " component of the planning environment (block C), and, to a lesser extent, the "national economic performance and policy box" in block A.

The social context encompasses the relevant goals and priorities for water planning, as expressed through governmental and interest group organisations and information structures, and the performance criteria and legal obligations under which alternative projects and programmes are evaluated (block A). While water agencies are typically structured in an hierarchy of planning responsibility, as suggested in block B, the "openness" of the planning process in a democratic society is such that individual agency terms of reference often overlap and, in some cases, conflict with each other. The functions and responsibilities of government and statutory bodies concerned with Rakaia River development planning are described in the next section.

3.2.2 The Concerned Public Agencies Many agencies have terms of reference, in one form or another, for protecting, managing and

FIGURE 3.1

The Water Planning Environment:
A Conceptual Framework



Source: Adapted with Minor Modification from Parker and Penning-Rowsell (1981).

planning the use of water resources and/or water-related activities. They include River Catchment Boards, Catchment Commissions, Regional Water Boards, the Ministry of Agriculture and Fisheries, and the National Water and Soil Conservation Authority (MWD) which administers the Water and Soil Conservation Act 1967 and the Soil Conservation and Rivers Control Act 1941. The central policy making body, comprising Rivers Control Council and the Water Resources Council, is the National Water and Soil Conservation Organisation. The Organisation is responsible for formulating general policy guidelines and each of its councils has certain functions delegated to it.

Representation on the Authority and Councils includes counties and municipalities, catchment authorities, regional water boards, drainage and river boards, farming, manufacturing and recreational interests as well as other governmental departments. Acclimatisation Societies also have a function associated with waterway management, and they act in an advisory capacity to government agencies and conduct independent research on policy-related issues.

3.2.3 Jurisdiction The special purpose authorities most relevant to Rakaia River water planning are the Catchment Boards, which in the case of North and South Canterbury, also operate as Regional Water Boards. These Boards have the primary responsibility for the development and allocation of natural water within their regions. Historically, the Catchment Boards were set up to assist farmers in maintaining and increasing productive land by the use of flood control and irrigation schemes. Their functions increased with the enactment of the Water and Soil Act 1967, and now they must also consider fisheries' requirements, wildlife habitats and recreational use of water in relation to agricultural and other usage.

Acclimatisation Societies, although non-governmental bodies, have statutory responsibility for the day to day management of acclimatised fresh water and protected wildlife under the Fisheries Act 1908 and the Wildlife Act 1953. With respect to natural waters (lakes and rivers) the primary concern of the Societies is the protection and management of a suitable habitat for wildlife. The Societies issue sport licences and set bag limits, and have the power and responsibility to prosecute offenders.

The "boundaries" of water authorities, whether they be physical areas or terms of reference, are highly over-lapped. This is especially evident in the case of the Rakaia River. Malvern, Ashburton and Ellesmere are the main counties concerned (refer to Figure 3.2). The northern boundary of Ashburton County is the River, but above the Gorge it is the Mathias branch which acts as the boundary. The North Canterbury Catchment Board's area includes only part of the Rakaia catchment; the boundary between the North and South Canterbury Catchment Boards follows the south bank of the Rakaia from its mouth. The boundary changes in the high country, where Lake Heron and the Cameron River, which flow into the Rakaia via the Lake Stream, are under South Canterbury Catchment Board's jurisdiction.

The Rakaia River is jointly administered by both the North Canterbury and Ashburton Acclimatisation Societies, since the river is the boundary between them. However, this boundary differs from the county boundary. The matter of jurisdiction is further complicated by the vested interests of other national, regional and local bodies, particularly the Canterbury United Council which has broad regional planning responsibilities confined under the 1978 Town and Country Planning Act.

The major regional bodies directly responsible in the development of the Rakaia River are therefore Malvern, Ellesmere and Ashburton County Councils, the Canterbury United Council, the North and South Canterbury Catchment Boards and Regional Water Boards, the North Canterbury and Ashburton Power Supply Boards, the North Canterbury and Ashburton Acclimatisation Societies, and possibly other local authorities such as drainage boards who may enter into the planning process at several different stages.

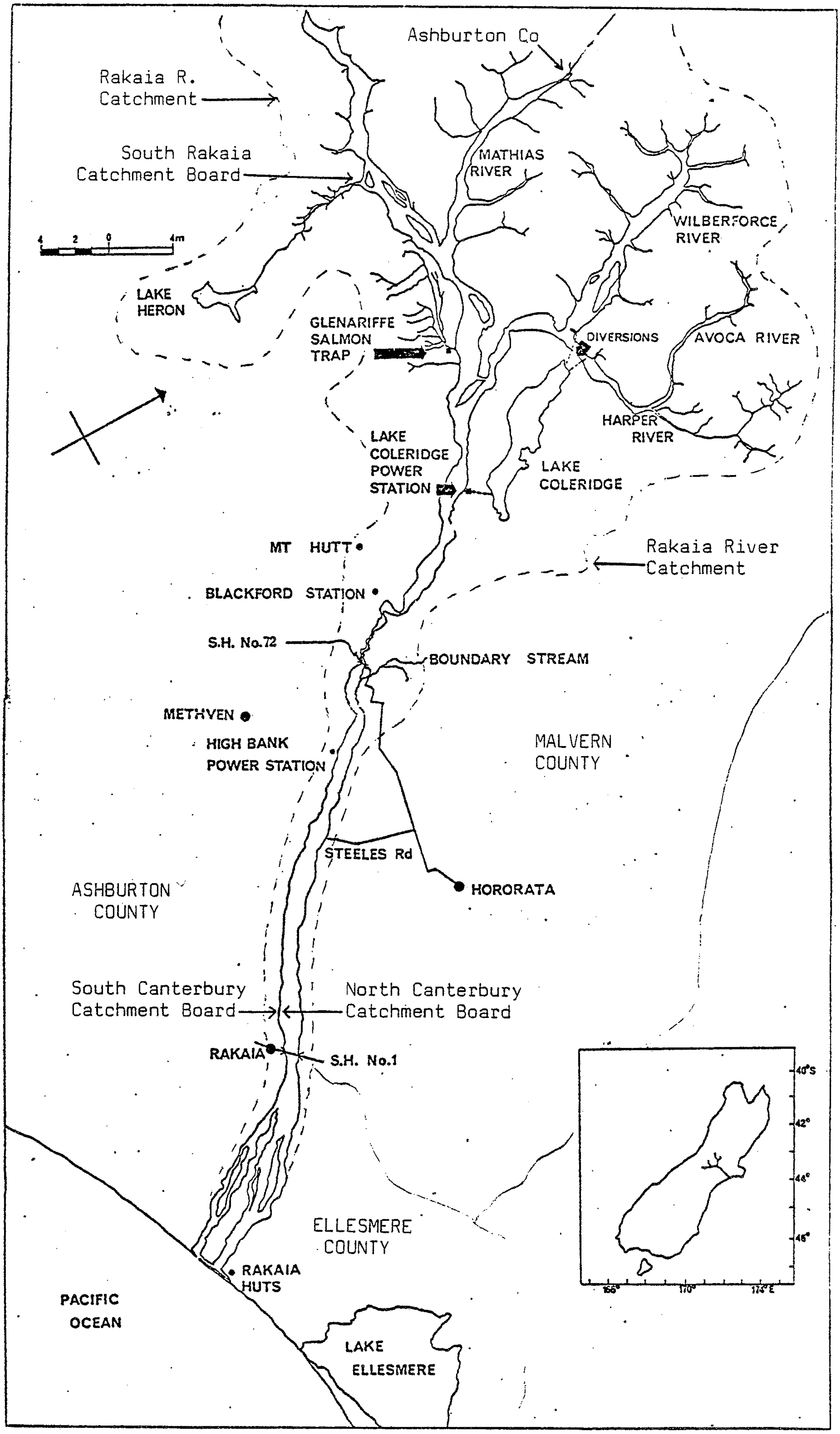
3.3 Community Irrigation Scheme Planning and Procedures

Development of a Community Irrigation Scheme falls into three general procedural phases:

1. initial feasibility and planning studies leading to project identification and the formation of an irrigation district;
2. scheme planning, during which necessary water rights and planning consents must be obtained; and

FIGURE 3.2

Planning Boundaries of Local and Regional Authorities



3. the construction phase, which can only go ahead with the necessary government approval for funding.

A schematic representation of the planning process, which expands on block B of Figure 3.1, is presented in Figure 3.3, and describes in some detail the specific planning agencies' and other bodies' roles at particular stages in the planning sequence. The CPIS and LRIS proposals are presently at stage 2 in the planning sequence. A detailed review of the more important aspects of the steps involved in bringing a Community Irrigation Scheme to fruition is reported in Appendix 2.

3.4 Scheme Funding

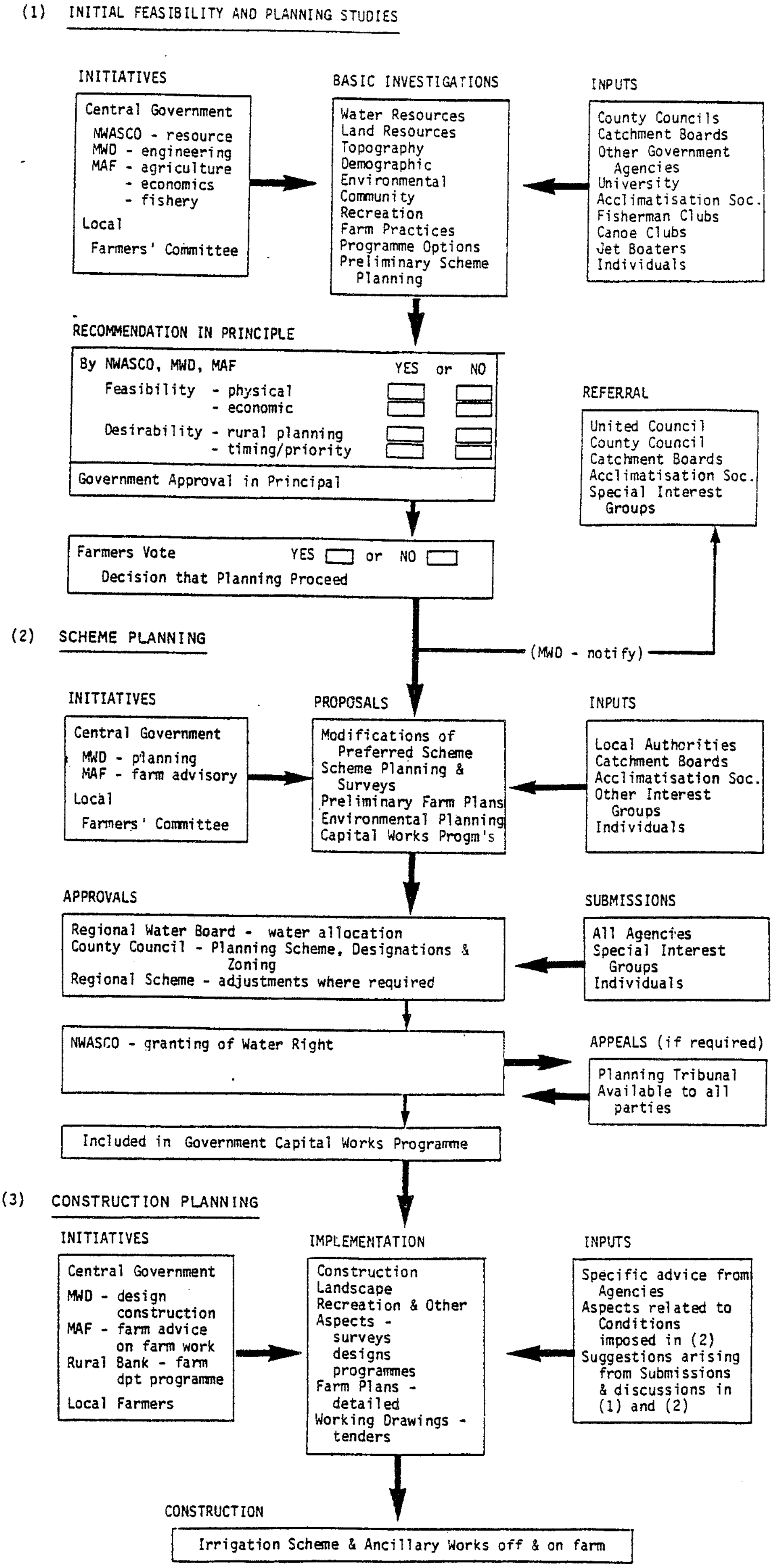
A substantial portion of the funds to finance Community Irrigation Schemes comes from public tax revenues. Accordingly, the financial return expected from public support to irrigation projects is considered in light of alternative investment opportunities elsewhere in the public sector (see block A, Figure 3.1). Until recently, the rule has been that publicly-sponsored irrigation projects must meet a minimum financial return criterion of 15 per cent (based on the IRR) to qualify. This has subsequently been reduced to ten percent. The objective of rationing public tax revenues among competing investment opportunities is to ensure that 'limited' funds are spent wisely. The following discussion reviews cost-sharing arrangements and highlights some related issues which are of current interest to planning bodies in connection with the proposed Rakaia developments.

3.4.1 Public Finance and Cost Sharing

The national financial policy for Community Irrigation Schemes has been developed with two main objectives. Firstly, irrigation schemes are required to be self-supporting over a fixed time period, and secondly, farmers are to be encouraged to bring under irrigation as much of the irrigable land on their properties as is possible in the shortest possible time. Once the scheme is ratified (see Appendix 2), this second objective is encouraged by charging non-irrigators as well as irrigators, in the designated area, an initial water supply fee. For this reason it is obviously important that the anticipated water charges be publicised before farmers are required to vote for or against the establishment of the scheme.

FIGURE 3.3

The Irrigation Scheme Planning Sequence



Source: Douglass et.al. (1979).

Presently, the government meets all of the costs of headworks, and half of the costs of all other off-farm development works. Off-farm development is initially paid for completely by the government, with half of this recoverable over a 40 year period at interest rates stipulated by the Rural Bank.

The government's share of on-farm development takes the form of a suspensory loan through the Rural Bank, written off after ten years so long as the contracting farmer does not sell the property and continues to pursue his development programme. Works eligible for the loan include fixed facilities, electric service lines, surveying and construction supervision costs, and the cost of disruptions to normal farm operations. Rural Bank finance is also available to assist with financing the farmers' half-share of on-farm costs and the cost of portable equipment. A proposal to include pumps, motors and mobile spray applicators in the suspensory loan is presently under review.

The suspensory loan, together with other Rural Bank financing at concessionary interest rates and repayment terms are designed to encourage a steady implementation of the scheme. As was pointed out in Chapter 2, the amount of these 'combined' subsidies can substantially reduce the per hectare costs of irrigation development, particularly border-dyke systems. An important implication is that where the capital costs of developing surface and groundwater supplies are of about the same magnitude, as is the case in the Lower Rakaia area, a concessionary policy toward Community Scheme cost-sharing acts to discourage the private development of groundwater on farms in the "nominated" scheme area.[14]

3.4.2 <u>Irrigation Charges and Water Pricing</u> The farmer's share of scheme costs is recovered through charges made annually over a period specified in the Order-in-Council constitution of the irrigation district, typically 40 years. The charges are of two types: a basic charge which is calculated on the basis of the irrigable area of land of the occupier, and a water availability charge based on the quantity of water taken under a water availability agreement. All

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[14] Rural Bank interest charges are currently 14 percent for private irrigation development as opposed to 7½ percent for loans under a Community Scheme, and no suspensory facility is available to private developers.

occupiers of land within the designated scheme boundaries must pay the basic charges, while occupiers of land subject to water availability agreements must pay the greater of the two. Charges only become payable after a time determined by the Minister (MWD) as the commencement of availability (usually when water is available to a substantial proportion of the scheme area). They are payable to the Crown at the end of each irrigation season, and if not paid within 28 days of demand the occupier will normally be required to pay 10 percent interest on the amount unpaid.

Provision is made for a graduated scale of charges during the initial development (six years under present schemes), but once full charges commence adjustments may be made to reflect actual costs. Any water availability agreement must be in accordance with the allocation of water and conditions of supply as determined by the Authority. For variations in supply, occupiers have no claim to compensation or any right of action against the Crown if the quantities of supply agreed to are not met during any irrigation season. However, in such cases the annual water availability charge (excluding the portion representing the basic charge) can be reduced by an amount the Minister considers reasonable. Using the Waitaki Scheme as an illustration of what these charges might be for the Rakaia, the annual basic charge (after ten years) could range between $5 and 10 per hectare or $1.50 to 3.00 per 100 millimetres of water applied per hectare. While Rakaia water charges are unlikely to be less than these, it is probable that they could be much higher.

An important point to be made about the water servicing agreement is that water itself does not have any marginal cost to users. In other words, the amount of water actually used by farmers over the season, whether more or less than the agreed quantity, has practically no influence on the annual charges paid. Furthermore, water rationing, if necessary in a water-short year, is based on an equity formula that does not take into account the value of water in alternative uses. For example, if a choice arises between supplying an orchard or a pastoral property when water is limited, no rules presently exist for deciding priority users.[15] Accordingly, there is little scope for

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[15] The principle alluded to emphasises economic efficiency as superior to equity in resource allocations. For an excellent discussion of alternative water allocation rules and implications for regional economics, see Maass and Anderson, (1978).

"optimally" allocating water among farms within a scheme, or between two schemes on the same river system. Because water is not priced per unit of quantity delivered to the farm headgate, there is also limited scope for encouraging efficient on-farm water management practices other than through administrative rationing.

3.5 Summary and Conclusions

An overall conceptual framework of New Zealand water law and public management of water resources has been presented. The law, relevant to the implementation of Community Irrigation Schemes, has been outlined. The planning procedure, which is already complicated by the need to make separate applications under the Town and Country Planning Act and the Water and Soil Conservation Act, and further complicated by recent changes in the Water and Soil Conservation Amendment Act, are discussed (Appendix 2). In the discussion, reference was made to the National Development Act only in passing, as it is unlikely to be used in the case of the proposed Rakaia schemes. In any case, plans to develop the Rakaia River for irrigation could provide a test of the efficacy of some new provisions governing the development of water resources.

The roles of non-governmental bodies with an interest in particular aspects of water development, for example the Acclimatisation Societies, remain unclear as to their planning responsibility (or the nature of their effective involvement) in the actual design of the Rakaia irrigation schemes. In particular, opportunities that might lead to enhancement of sporting (or commercial salmon ranching) interests are not considered within the present irrigation design options. While the Act calls for "due regard" in terms of environmental and amenity considerations, the legal basis for protecting "instream" uses, and in seeking compensation for loss, remains unclear. The potential for examining the efficacy of public laws and institutional mandates is, of course, unlimited. Accordingly, several avenues of specific study are suggested that might be regarded as "urgent" in the context of the present irrigation proposals.

First, what criteria are relevant to deciding an appropriate basis for allocative decisions? If an economic welfare criterion is given dominance, i.e. allocative efficiency in dollar terms, then what social welfare losses are at stake (and what benefits to be gained) in changing the present use of a public water resource? Under present legislation natural water is recognised as having "amenity value", but the economic "penalty" of any differing prescribed use does not consider the "social" opportunity cost. Should water be priced on the basis of its opportunity value foregone in alternative uses?

Related to these questions are a whole set of issues involving water use efficiency. Where irrigation abstractions are meant to satisfy on-farm needs, there remains a problem in deciding what these "needs" actually are. Under present policy, water diversions are provided to meet maximum expected needs which may considerably overestimate actual consumptive-use. In addition, the pricing mechanism for diverted water does not effectively encourage efficient on-farm water use. If water supplies are limited on a seasonal basis, how will the responsible agencies allocate river flows between competing needs (as required by law), especially when irrigation uses are suspected of being wasteful?

Another area for useful investigation is the valuation of water in alternative uses, especially the value of water "instream" as opposed to out-of-river. Even though current law recognises the possibility of a "social cost" in diverting natural water from its present use, quantitative estimates of the magnitudes of such losses, which would be admissible in Tribunal hearings, are not available at present.

CHAPTER 4

REGIONAL ECONOMIC IMPACTS OF RIVER-SUPPLIED IRRIGATION DEVELOPMENT IN CANTERBURY

4.1 Introduction

In this chapter a discussion of the regional economic implications of the Rakaia Community Irrigation Schemes is presented. The review is based on a collation of existing information rather than on primary research. Therefore, the discussion which follows presents an overview of the types of probable economic impacts that might be expected in the region from the development of the Rakaia River for irrigation. Further, more detailed research is required to firm up both the present data base and the regional impact estimates reported herein.

The discussion is divided into five sections. In section 2 the underlying concepts used in assessing regional economic impacts of resource development projects are reviewed. In the next section the primary or direct benefits and costs of the irrigation proposals are identified. Section 4 quantifies, to the extent possible, the regional economic impacts that can be expected to occur, and the last section contains a brief summary and concluding comments.

4.2 Regional Economics and Resource Development Programmes

This section briefly reviews the primary and secondary economic impacts of resource development programmes on regional economies, and discusses alternative methods for estimating the relevant parameter values.

4.2.1 Primary and Secondary Economic Impacts[16] Resource development through, for example, investment in Community Irrigation Schemes, is likely to stimulate local economic activity, initially through scheme operating expenditures and later through increased levels of agricultural output. The overall increase in economic activity can be expected to lead to higher levels of output, income and employment than would have occurred had not the investment been

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[16] A more detailed presentation of these concepts, techniques and data requirements is contained in Brown and Hubbard (1980).

made. This total impact on the economy will incorporate both primary and secondary components. Primary impacts are the initial or <u>direct</u> economic stimulus, and the secondary impacts are a function of the multiplier,[17] and will incorporate what can be referred to as indirect and induced impacts (refer to Figure 4.1).

The <u>indirect</u> economic impact results from all sectors in the economy being, to some extent, interdependent. The impact on the economy of an increase in agricultural production, for example, does not stop at the farm gate. As the increased production works its way through from farmer to final consumer, the demand for transport, marketing and processing services will increase. Increased agricultural production can also be expected to increase the demand for fertilisers, seeds and farm machinery. However, these linkages are not confined solely to those industries or sectors of the economy that are directly associated with the farm sector.

As an example, the increase in demand for fertilisers will usually mean that the fertiliser industry will need to increase its output and, as a corollary, its demand for inputs. In turn, the industries supplying these inputs will themselves need to expand output and so on. Similarly, the increased demand for transport services may lead to the purchase by transport firms of extra trucks, tyres and spare parts. The firms producing these goods and services will then need to expand their output, and so on. Together these increases in production constitute the indirect impact of the initial expansion. This indirect impact can be thought of as technical in nature in that, given the infrastructure of the economy, an increase in production in one sector requires, or is associated with, increased production in other sectors.

In addition to the indirect impact generated by the initial expansion, an <u>induced</u> economic impact will also tend to increase production in various sectors of the regional economy. The induce impact is initially a function of personal consumption expenditure and relates to the increase in personal income that is a concomitant

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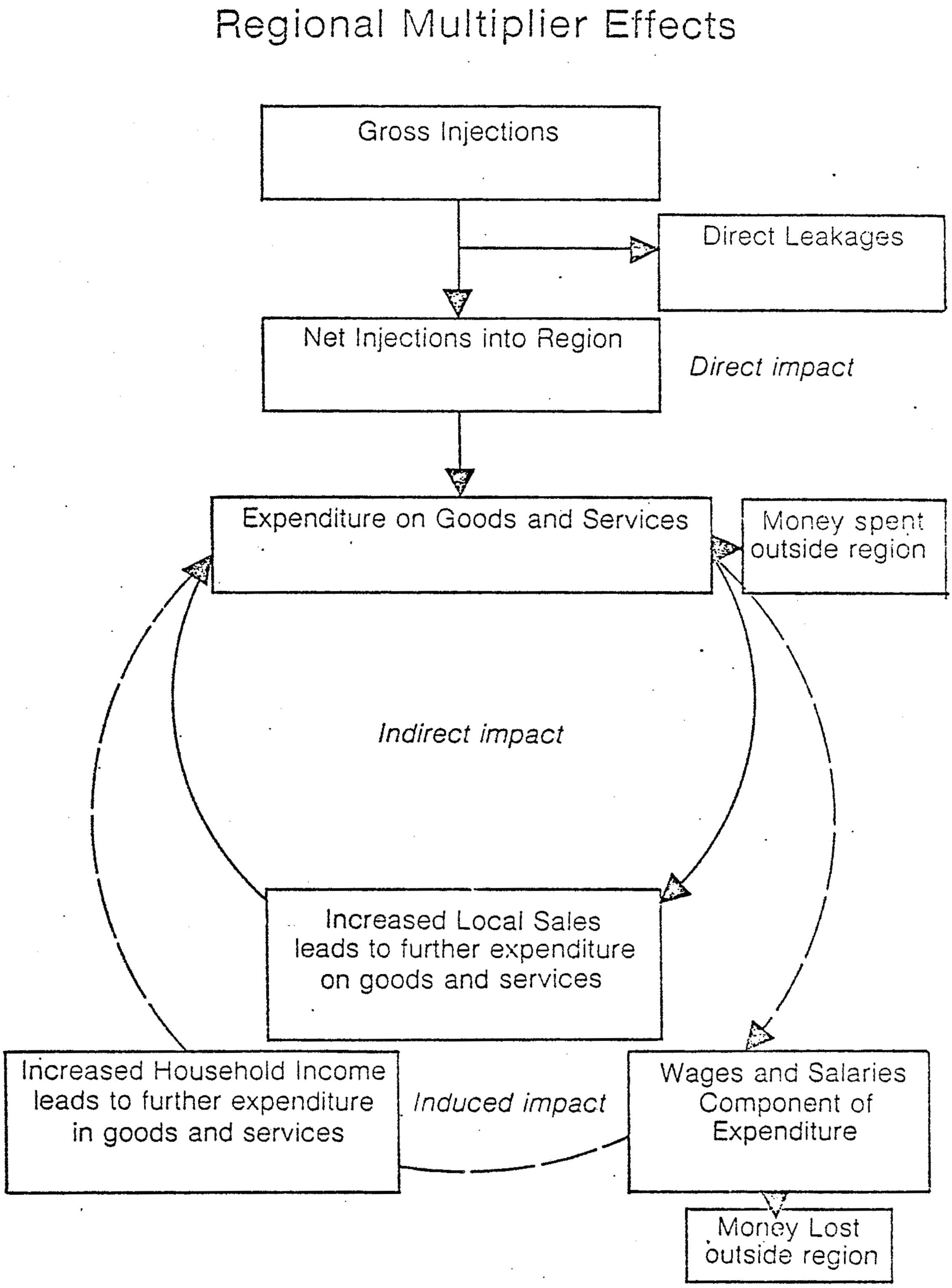
[17] The term "multiple" is used to indicate the number by which the initial investment would be multiplied in order to obtain the total amplified increase.

FIGURE 4.1

Schematic Diagram of Regional Multiplier Effects



Source: Hubbard and Brown (1981)

of increased production in the regional economy. The increase in personal income leads to an increase in the demand for consumer goods and services. In response to this increased demand, the industries supplying consumer goods and services increase their production and, as with the indirect impact, these increases then generate further production in other sectors of the economy.

The extent to which a region may benefit from the indirect and induced impacts will depend on how much of the total increase in production, over and above the initial expansion, is supplied from local industries. The greater the increase in local production the greater the local impacts. Conversely, if the increases in production occur mainly outside the region, then the local impacts of the initial expansion will be negligible. Regional multipliers will be indicative of the extent to which the impacts are felt locally.

From the national viewpoint, it has normally been assumed that these secondary economic impacts do not produce an increase in aggregate output (i.e., national benefit) since gains in the region from the investment will be offset by losses somewhere else.[18] It is now being increasingly accepted, however, that this approach is a drastic over-simplification of the impacts generated by investment. Many resources are presently unemployed, and therefore aggregate output impacts will vary depending on the pattern of investment within the region (Haveman and Krutilla, 1968).

Furthermore, it has generally been assumed that the secondary economic effects arising from alternative resource development programmes will be similar. However, this rarely occurs since investment in one sector will have markedly differing regional impacts than investment in another. For instance, electricity development is capital intensive, and while it may generate a large number of short-term employment opportunities during the construction phase, the long term employment impacts are small. Conversely, investment in the

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[18] The conditions under which 'regional' impacts are valid for inclusion in 'national' impact assessments have been widely debated among policy analysts; see for example Kelso et al. (1973).

agricultural sector may provide continuing employment opportunities both within farming and, through the secondary effects, in other sectors of the economy. It is essential then that the regional economic impacts of any proposed resource development programme be assessed, particularly in the context of multi-objective planning.

4.2.2 Estimation Procedures and Limitations There are three methods commonly in use for estimating regional multipliers and therefore the magnitude of secondary impacts from resource development projects. These are export base multipliers, Keynesian income multipliers, and input-output multipliers. The advantages and shortcomings associated with each approach have been recently reviewed by Hubbard and Brown (1979:36-81). It is becoming increasingly common, where possible, to use multipliers derived from input-output tables.

The Agricultural Economics Research Unit of Lincoln College has recently published a set of regional input-output tables for each Statistical Area in New Zealand (Hubbard and Brown, 1981). Although the multipliers derived apply to the 1971/72 year, they are a useful guide for deriving indicative estimates of the magnitude of secondary impacts.

The next section therefore quantifies the primary impacts of irrigation development in the Lower Rakaia and Central Plains Schemes, and estimates of the magnitude of secondary economic impacts are detailed in Section 4.4.

4.3 The Primary Impacts

Irrigation can both increase and stabilise agricultural output levels compared with production under dryland farming conditions. Higher crop yields and stock carrying capacities achieved under irrigation are more predictable year to year in contrast with the annual fluctuations experienced on farms without irrigation due to varying climatic conditions. In fact, irrigated pastures in Canterbury average twice the annual dry matter production of equivalent rainfed pastures, and experience one-quarter of the production variability between years (refer to Table 4.1).

TABLE 4.1

Differences Between Irrigated and Rainfed Pastures in Canterbury

Comparative Measure	Rainfed	Irrigated
Productive Life	Temporary	Permanent
Species composition	Subterranean Clover	White clover
Mean annual production (kg DM/ha^{-1})	6,000	12,000
Variation in production between years	± 48% of mean	± 12% of mean

Source: Ag Link FPP 79 Ministry of Agriculture and Fisheries, Wellington.

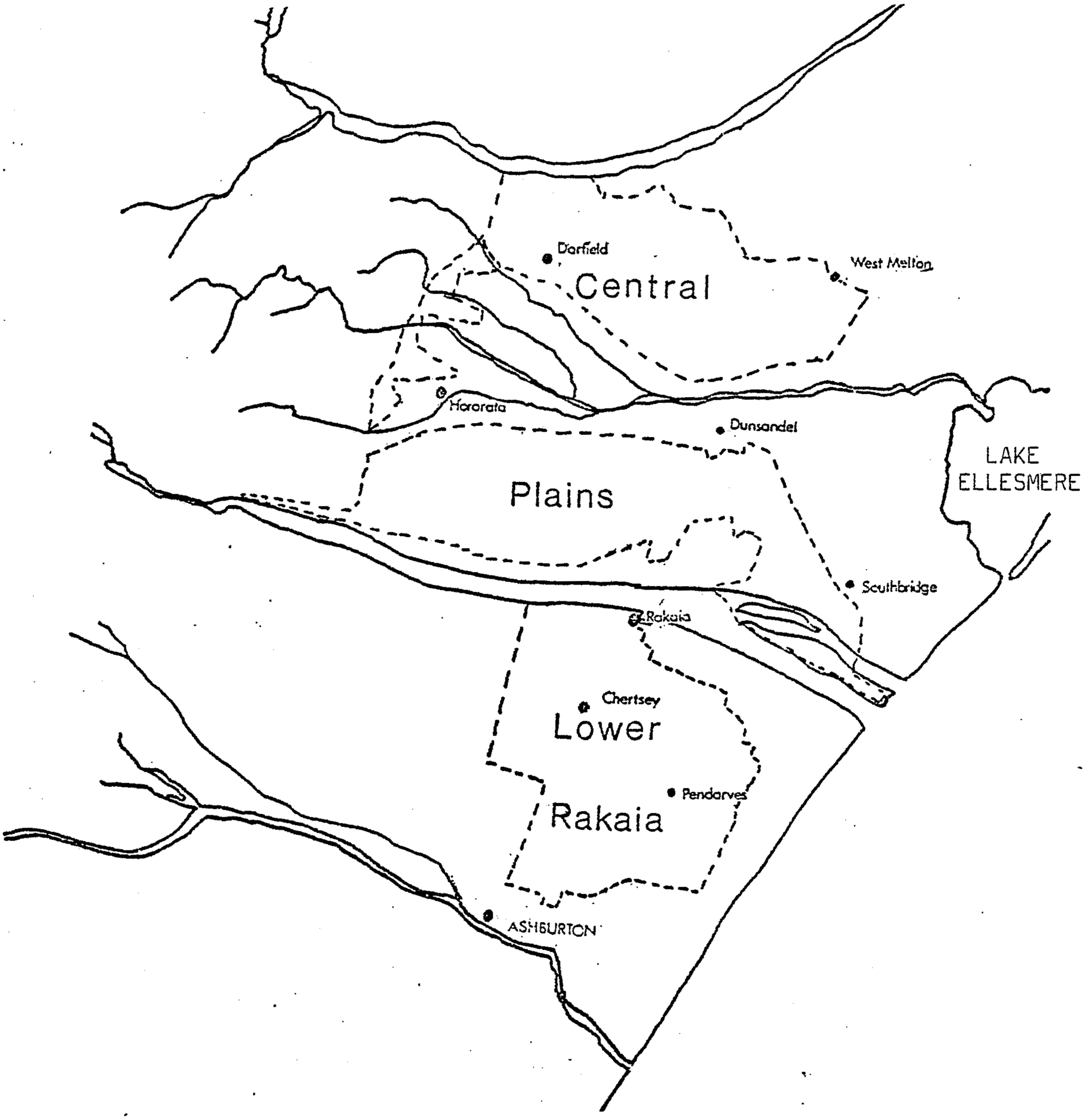
Higher output levels require a concomitant intensification of inputs, with greater use of, for example, fertilisers and labour. The flow of goods and services into and out of an agricultural area which has irrigation is therefore significantly greater than a similar area of dryland agriculture, and the effects of this are felt throughout the local economy.

This section discusses the primary impacts of the two proposed irrigation schemes by first describing projected land use changes, and then quantifying the construction and operating costs involved, and the resultant increases in agricultural output and demand for farm labour. It must be emphasised that the two schemes described are still in the preliminary planning stages, and therefore scheme areas and boundaries are subject to change. The data here, therefore, reflect one possible system scenario to develop a general appreciation of the economic impacts involved.

4.3.1 Scheme Areas The boundaries of the Lower Rakaia and Central Plains Schemes, as currently envisaged to be supplied with water from the Rakaia River, are shown in Figure 4.2 and encompass gross scheme areas of 35,600 ha and 72,000 ha respectively (including roads, creeks, shelter belts, and waste areas). The gross farm area is estimated at 90 percent of the above figures, of which 90 percent is potentially irrigable (i.e. 81 percent overall). The actual potentially irrigable areas within the two schemes are, therefore, 28,850 ha and 58,300 ha respectively, for a total of 87,150 ha (Scheme 4 in Table 2.1).

FIGURE 4.2

Lower Rakaia and Central Plains
Scheme Boundaries (Preliminary)



There are no easily accessible data on the actual number of farms in each of the two areas at the present time. From average farm size data however, indicative estimates are that the LRIS would involve about 140 farms, and the CPIS about 270 farms, a total of 410. As pointed out in Chapter 2, there is already some spray irrigation within the two scheme areas - an estimated 5,000 ha in Lower Rakaia (Le Page 1980b: 3) and 9,500 ha in Central Plains.[19]

4.3.2 Land Use Land use in the two areas is very similar, with production of fat lambs and crops predominating, and it is likely that this general land use pattern will not change significantly with the introduction of irrigation. The main crops grown are wheat, barley, oats, peas, ryegrass and white clover.

There are two basic groupings of soils in the proposed scheme area:

(1) the better Templeton and the deeper Lismore related soil sets on the south bank of the Rakaia River and a large part of the area north of the Selwyn River, and,

(2) the shallower Lismore soils in a large part of the area between the Rakaia and Selwyn Rivers.

Farms in the two areas of deeper and better soils have a history of cash cropping, and development of spray irrigation will enable an intensification of the cropping systems. Those farmers who choose pastoral systems in these two areas will develop border-dyke systems, as will those farmers on the lighter, shallower Lismore soils. A possible trend toward direct drilling over border dykes, however, may convince some farmers to increase the cropped area of their farms.

Specific details of the current and project land use systems for the LRIS area are described in a recent study by Le Page (1980b). Discussions with local officers of the Farm Advisory Service Division of the Ministry of Agriculture and Fisheries suggest that similar

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[19] Based on an analysis of data provided by the North Canterbury Catchment Board. These data detailed all farmers with water permits within the proposed Scheme area.

changes are likely to occur within the CPIS area, with perhaps around two-thirds of farms to the north of the Selwyn River adopting a relatively intensive cropping regime (compared with 10-15 percent now). Extrapolation of these assumptions across the two Scheme areas results in aggregate land use patterns as summarised in Table 4.2.

TABLE 4.2

Aggregate Land Use
Lower Rakaia and Central Plains Schemes (ha)

Land Use	Lower Rakaia[1]		Central Plains[1]	
	Without Scheme	With Scheme	Without Scheme	With Scheme
Pasture	19,475	19,665	34,560	34,245
Lucerne	2,160	2,180	3,835	3,800
Wheat	2,820	2,100	7,665	6,075
Barley	2,100	1,400	5,675	4,045
Peas	1,475	1,735	4,125	5,025
Ryegrass	410	885	1,220	2,555
White Clover	410	885	1,220	2,555
TOTAL	28,850	28,850	58,300	58,300

Source: Le Page (1980b)

[1] Area supplied with water from the Rakaia River only.

There are only small, localised areas of horticulture within the two proposed schemes. In the Lower Rakaia Scheme area there are two orchards and some small market gardens close to Rakaia township, with a total area of less than 20 ha. In the CRIS the area of horticultural crops, excluding potatoes, is estimated at around 250 ha, mainly concentrated in the Darfield, Courtney, and Rolleston districts. Crops grown include blackcurrants, asparagus, garlic, vegetables and grapes. Discussions with MAF Horticultural Advisory Officers suggest that it is unlikely that development of the Community Irrigation Schemes will stimulate rapid expansion of horticultural crops in the area. There is potential for increased areas of export onions south of the Rakaia, and for specialist horticultural crops such as berry fruits, asparagus, garlic, pipfruit and flowers in the Darfield-Rolleston area. However, these locations offer no particular comparative advantage over other areas potentially irrigable from groundwater. Diversification away from the current base will require the establishment of a new industry, but without such an incentive horticulture will only gradually expand and would probably involve less than five percent of the total scheme area.

A similar situation exists with process vegetables. Areas of oil seed rape, linseed, process peas and beans in Canterbury are all contracting because of tightening market conditions, and although the free draining soils of the Central Plains are ideal for such crops if irrigation is available, the constraints to expansion are market related, rather than due to the availability of water.

Another land use which might be influenced by the development of the two schemes is dairying. There is considerable interest in converting sheep and/or cropping units within Mid Canterbury Community Irrigation Schemes to dairying, with four new suppliers to the Temuka Dairy Company having started in 1981.

A recent survey in Canterbury/North Otago by Thornton (1981) forecasts a doubling of seasonal milk production over the next five years, 43 percent from increased production from the 279 existing factory suppliers, and 57 percent from new dairy farms. Again, however, in terms of the total area commanded by the two schemes, the proportion which could be converted to dairying would in all probability be less than five percent.

4.3.3 Production Response with Irrigation Irrigation can be expected to lead to an average increase of 70-95 percent in stock carrying capacity on pasture and lucerne, and average percentage yield increases of 65-85 on wheat, 60-68 on barley, 25 on peas, 77 on ryegrass, and 165-235 on white clover seed compared with a dryland situation in the Lower Rakaia area (Le Page 1980b: 7-8). There is no reason why similar effects can not be expected in the Central Plains area (refer to Chapter 2.5).

In total, it is expected that irrigation will lead to an increase of 580,000 livestock units (LSU) within the two scheme areas, 35 percent of which will be within the LRIS. It must be stressed, however, that this increase would take place over a number of years - on-farm development is scheduled over ten years, and with the LRIS for instance, border-dyking is not expected to be completed until 18 years after the start of scheme operation. Agricultural output from the two areas would be expected to rise by nearly $30 million annually ($December 1981) - refer to Table 4.3).

4.3.4 Labour Requirements The effect of irrigation on the demand for farm labour is difficult to quantify, since there are little data and analyses on this topic. Le Page (1980b:9) estimated that an additional 78 full-time labour units would be required on farms in the LRIS area if the scheme was implemented. If the same assumptions on which these figures were based are applied to the CPIS, the corresponding figure is 157 full-time labour units, or a total of 235 across the two projects. Some MAF field advisory staff estimate that for irrigation development on an average sized unit, the farmer will need to employ one additional full-time labour unit who, in most situations, remains on staff after the development period because of the additional workload associated with higher stock numbers (Shadbolt, 1982). This indicates that the estimate of 235 extra labour units across the 410 farms in the two scheme areas is, if anything, probably conservative.

The other significant impact on labour generated by investment in community irrigation schemes is that associated with the construction and operations workforce. While permanent operations staff for the two schemes will probably be less than 10, the construction workforce will be substantial, and significant numbers would be associated with maintenance. Estimates can be made using data on the workforce associated with the Waiau Irrigation Scheme, where an average daily workforce of around 60 was involved during the construction period, with associated expenditure of $4m annually (Lewthwaite, 1982). The LRIS would probably involve a works programme of twice the magnitude of that associated with the Waiau Scheme, and the CRIS up to four times the scale. Therefore, average daily workforces during the construction period would total around 120 and 240 persons respectively.

TABLE 4.3

Agricultural Output with Irrigation[1]

(December 1981 prices)

Scheme Area	Lower Rakaia River Supply	Central Plains River Supply	Total River Supply	Lower Rakaia[2] Groundwater Supply
Increases in livestock carried (LSU)	202,400	380,500	582,900	168,000
Value of increased stock output - Farm gate	$7.3m	$16.0m	$23.3m	$6.1m
Increased tonnage of crops				
- Wheat	1350	5050	6400	
- Barley	200	1300	1500	
- Peas	1650	5250	6900	
- Ryegrass	500	1350	1850	
- White Clover	200	650	850	
Value of Increased Crop Output - Farm Gate	$1.6m	$4.8m	$6.4m	$1.3m
Total Value of Increased Output - Farm Gate	$8.9m	$20.8m	$29.7m	$7.4m

Source: Estimates by W.A.N. Brown and Associates.

[1] Indicative estimates only, particularly for the Central Plains Scheme area since no detailed farm-level data are available. Excludes any expansion in horticulture or dairying, since these are not expected at a scale to significantly affect results.

[2] Indicative figures for comparative purposes only.

4.3.5 Development Costs Projected scheme costs for both the Lower Rakaia and Central Plains areas are summarised in Table 4.4. Off- and on-farm capital costs are estimated at \$51m and \$112m respectively (December 1981 prices excluding stock costs), or a total of \$163m. Scheme operating costs are expected to be \$3.2m annually, both off- and on-farm.

4.4 The Secondary Impacts

As described in Section 4.2, increased farm output levels due to irrigation development create additional demand for goods and services from firms which both supply inputs to farms and/or process or handle farm output, with associated multiplier effects - the indirect effect. Furthermore, higher turnover levels and additional employment increases aggregate disposable income, which increases consumption expenditures with further concomitant multiplier effects - the induced effect.

It is not possible within the scope of this review to estimate definitively the extent of these multiplier effects. Data from two other studies can be used, however, to indicate the probable order of magnitude involved. These two studies are an analysis of the regional impacts of the Lower Waitaki and Moreven-Glenavy Schemes (Hubbard and Brown, 1979), and detailed sectoral multipliers derived for each Statistical Area in New Zealand (Hubbard and Brown, 1981). The output, employment and income multipliers for Canterbury are reported in Appendix 3.

The Lower Waitaki study estimated an employment multiplier of around 2.0 (Brown and Hubbard, 1980: 16). That is, for every job created in the agricultural or construction sectors, one further off-farm job was supported within the region.[20] The data for Canterbury indicate 1971/72 sectoral employment multipliers of 2.2 for agriculture and 2.9 for the construction sector (Hubbard and Brown, 1981:62).[21]

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[20] Clearly, the job support impact of job creation in the agricultural sector probably continues over a longer term than that created by temporary expansion of activity within the construction sector.

[21] McFadden (1982) of the Ministry of Agriculture and Fisheries noted, when reviewing a draft of this chapter, that the higher sectoral multipliers for agriculture in Canterbury compared with Otago could well be due to the higher proportion of crop activity in the Canterbury district.

TABLE 4.4

Scheme Costs (December 1981 prices)

	Lower Rakaia[1] River Supply	Lower Rakaia[2] Groundwater	Central Plains[3] River Supply
Gross Farm Area	32,040 ha	26,640 ha	64,000 ha
Off-farm Capital Costs:			
(a) Headworks	\$4.5m	-	\$10.5m
(b) Distribution	\$18.3m	-	\$42.0m
(c) Total	\$22.8m	\$4.5m	\$52.5m
Off-farm Operating Costs:			
(a) Headworks	\$75,000 yr^{-1}	-	\$75,000 yr^{-1}
(b) Distribution[4]	\$192,000 yr^{-1}	-	\$390,000 yr^{-1}
(c) Total	\$267,000 yr^{-1}	\$410,000 yr^{-1}	\$465,000 yr^{-1}
On-farm Capital Costs:			
(a) Border-dyking[4]	\$18.4m	\$17.0m	\$25.6m
(b) Spray[5]	\$4.2m	\$3.5m	\$20.5m
On-farm Operating Costs[6]	\$680,000 yr^{-1}	\$615,000 yr^{-1}	\$1,400,000 yr^{-1}
Associated Costs:			
(a) Stock	\$4.7m	\$3.9m	\$8.8m
(b) Additional Labour	78 labour units	65 labour units	156 labour units
(c) Housing[7]	\$1.2m	\$0.9m	\$1.4m
(d) Yards and Sheds[8]	\$152,000	\$126,000	\$285,000
(e) Plant[9]	-	-	\$175,000
(f) Water Supply[10,11]			
Capital	\$4.8m	\$4.0m	\$9.7m
O & M	\$144,000 yr^{-1}	\$120,000 yr^{-1}	\$292,000 yr^{-1}

[1] From Le Page (1980b) updated by the MWD CC Index.

[2] Indicative figures for comparative purposes only.

[3] Estimates from MWD and MAF staff, or prorated from the Rakaia data.

[4] \$6 ha^{-1}

[5] Includes fencing and other non-subsidisable costs, with a weighted average across soil types of \$800 ha^{-1}.

[6] Weighted average of \$1100 ha^{-1} including power reticulation costs.

[7] 3 percent of capital costs.

[8] At one house per two labour units, and taking into account surplus housing capacity estimated at 15 in the Lower Rakaia area and 40 in the Malvern area.

[9] \$750 1000^{-1} LSU (Livestock Units) change.

[10] \$50,000 100^{-1} ha cropping area change.

[11] Capital cost of \$150 ha^{-1}, and O & M at 3 percent.

These latter figures are calculated on average employment:output ratios, and the marginal figures would be expected to be lower - possibly less than 2.0.

If, on average an employment multiplier of 2.0 is assumed appropriate in the absence of more detailed analysis, the total employment impact in Canterbury of the development of the two river-supplied irrigation schemes is estimated at around 570 persons, made up as follows:[22]

On-farm employment	235
MWD operations staff	10
Scheme maintenance	40
Total Direct employment	285
Regional employment multiplier	2.0
Total regional employment impact	570

The build up to this level of job support would match the gradual increase in agricultural output, appreciating the complementary effects afforded by a declining construction workforce and increasing demand for agricultural labour. Job impacts, therefore, peak about 10 years into the construction programme.

The data from Hubbard and Brown (1981:62) can also be used to estimate the order of magnitude of total output and income impacts on the Canterbury region. The output multiplier of 2.1 indicates that total regional output levels would increase by around $60 million annually because of the scheme, and the household income impact could be around $11 million annually. While these figures are subject to revision, after a more detailed assessment of primary

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[22] This employment multiplier of 2.0 is considerably at variance with the multiplier of 5.0 derived by B. Easton (1982 pers. comm. and as reported in the <u>Listener</u>, "Farming it Out"). Easton estimates that for every 100 farm workers there are <u>another</u> 410 off-farm workers - 35 providing farm inputs, 11 providing investment inputs, 137 processing and distributing output, 125 providing total additional consumption goods required, and 102 providing additional Government services. There would, however, appear to be little data to substantiate the use of these figures to estimate multipliers relevant to <u>marginal</u> increments in agricultural output in the Canterbury region.

impacts and appropriate regional multipliers has been undertaken, they do indicate the likely order of magnitude for the parameter values.

4.5 Summary and Conclusions

This Chapter has reviewed the regional economic impacts that could result from development of the Lower Rakaia and Central Plains Irrigation Schemes. While more detailed analysis of land use changes under irrigation and expenditure schedules could firm up the parameter estimates, the data do give indicative levels of the impacts expected.

Primary economic impacts will result from construction expenditure and increased agricultural output. Off-farm and on-farm capital costs are estimated at $163m (excluding stock costs), and the resultant increase in agricultural output is estimated at just under $30 million annually. A further 285 permanent jobs will be created, of which 82 percent will be on-farm.

The total, economy wide, economic impacts for the Canterbury region are estimated to be about double the primary impacts. Annual gross output should increase by around $60 million, household income by around $11 million and the job support impact should total around 570.

As indicated previously, further research could refine these estimates, but they do indicate the likely magnitude of the regional economic impacts associated with the irrigation proposals. Such information should assist decision makers faced with resource allocation decisions in a multi-objective framework.

CHAPTER 5

SOCIAL AND DEMOGRAPHIC IMPACTS OF THE IRRIGATION PROPOSALS

5.1 Introduction

The social and demographic impacts of introducing irrigation into a previously dryland farming system are complex and not very well understood. It is commonly assumed that increases in production will lead to demand for more labour, which in turn will lead to increased population in the area, hence increased regional income. In studies carried out for planning purposes, the approaches used have tended to emphasise the economic dimensions of social change. Other effects, such as changes in land tenure and the age structure of the rural population, are often considered to be unimportant, are not recognised or are avoided due to problems of measurement. A broader view of social impacts is needed, since the manner in which an irrigation scheme develops and its eventual success or failure is hardly ever explained by economics alone.

This Chapter extends the previous discussion of regional economic impacts in several ways. Firstly, while economic impact methodologies are well developed, social impact assessment, because of its more complex subject matter, is not well developed. In the next section social impact assessment methodologies applicable to irrigation schemes are reviewed, and in section 5.3 the results of previous irrigation impact studies in New Zealand are outlined. Secondly, additional social and demographic data on the CPIS and LRIS areas are presented and the information gaps identified (section 5.4). And finally, the expected change in demographic characteristics are presented and discussed in relation to the income and employment changes reported in Chapter 4. Conclusions and recommendations for further study are summarised in section 5.6.

5.2 Social Impact Assessment Methodology

Concern with the social impacts of development projects is a relatively recent phenomenon, growing with the increased acceptance in the late 1960s and early 1970s that development projects were not uniformly or completely "good". The study of social impact in

New Zealand has been promoted by the introduction of Environmental Impact Reporting, although it also set in train a process which revealed in the short term that social scientists were ill-prepared to make a contribution (Fookes 1979:82).

A clear methodology of social impact assessment has not yet emerged, nor has any definitive description of the legitimate field of study. Crothers (1980: 3) accepts the difficulty of defining the 'boundaries' of social impacts, and emphasises that a "concern with types of people and their quality of life" should form the core of social impact studies. The present study is not exempt from these uncertainties, and although it is intended to follow Crother's dictum as far as possible, there is no doubt that both omission and over-inclusion will occur. For the purposes of this review, the impact upon areas outside scheme boundaries will generally be ignored, and comment upon impacts which appear to belong more in the economic and environmental sections of this review will be limited to a minimum.

A spatially and institutionally extensive development such as irrigation suggests an approach to the problem which emphasises the identification of the involved groups, their goals, and the relationships between them which may do much to determine the overall and specific impacts of the innovation. In terms of the institutional framework illustrated in Figure 3.1, an important aspect of social impact assessment is to rationalise the linkage contained in block A. The groups concerned in an assessment of irrigation impacts include farmers, farm workers, agricultural and transport contractors, providers of other farm and rural services, other rural dwellers, County Councils and many local authorities (refer to Chapter 3.2.2).

5.3 Previous New Zealand Experience

In the year ended June 1979 there were 166,402 ha of irrigated land in New Zealand, of which 51 percent was in Canterbury and 33 percent in Otago (New Zealand Government, 1979). Major schemes are the Ashburton/Lyndhurst, Mayfield/Hinds and Valetta Schemes in Mid-Canterbury, using water from the Rangitata Diversion Race, those on the Lower Waitaki in North Otago and South Canterbury, and the recently opened scheme on the Waiau Plains.

Evans and Cant (1981)[23] conducted a post-project study of the Ashburton/Lyndhurst Scheme covering the period 1945 to 1976. One of their major conclusions was that "the successes of the quiet revolution in dryland farming have matched those recorded in the irrigation zone" (Evans and Cant, 1981; 62). During the 1950s and 1960s farmers were reluctant to exploit the potential irrigation for a number of reasons, including:

1. insufficient advisory services to farmers;
2. insufficient incentives for farmers to change from well-known practices to more intensive practices which were yet unproven;
3. economic developments (e.g. the wool boom) which made the change less attractive; and
4. the amount of labour and financial input required to develop and then operate a manual-shift system of irrigation.

In a comment on this paper, Rickard, Hayman and Stoker (1981) of the Winchmore Irrigation Research Station emphasised that farmers in the Ashburton/Lyndhurst Scheme had, in early decades, used irrigation as drought insurance rather than adopting a more comprehensive management system of irrigation farming. They point to the findings of Evan and Cant (1981): "... that almost a quarter of the farms in the 'irrigation' sample had less than 50 percent of their area irrigated", emphasising that the scheme was imposed upon farmers 'from above', and that there was no compulsion on them to take water from the Community Scheme.

In contrast to an average development rate of about one percent per year between 1945 and 1975 for the Ashburton/Lyndhurst scheme, the Morven-Glenavy Scheme on the Lower Waitaki River achieved a rate of ten percent per year between 1974 and 1979 (Maidment et al., 1980: 41). This increase in the rate of on-farm development is due largely to the fact that more recent schemes require that 60 percent of the landowners owning more than four hectares vote for the scheme in a public poll before works are begun (refer to Chapter 3.3). This is reinforced by compulsory water charges, levied on all farmers

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[23] Also see Evans (1977).

within the scheme boundaries, to pay for running and maintenance costs and repayment of half of the off-farm reticulation. Further, incentives have been provided since the Malvern-Glenavy Scheme in the form of preferential and suspensory loans to farmers for on-farm development. With these incentives, the anticipated development rate for the recently-initiated Waiau Scheme in North Canterbury, for example, is 12 percent per year.

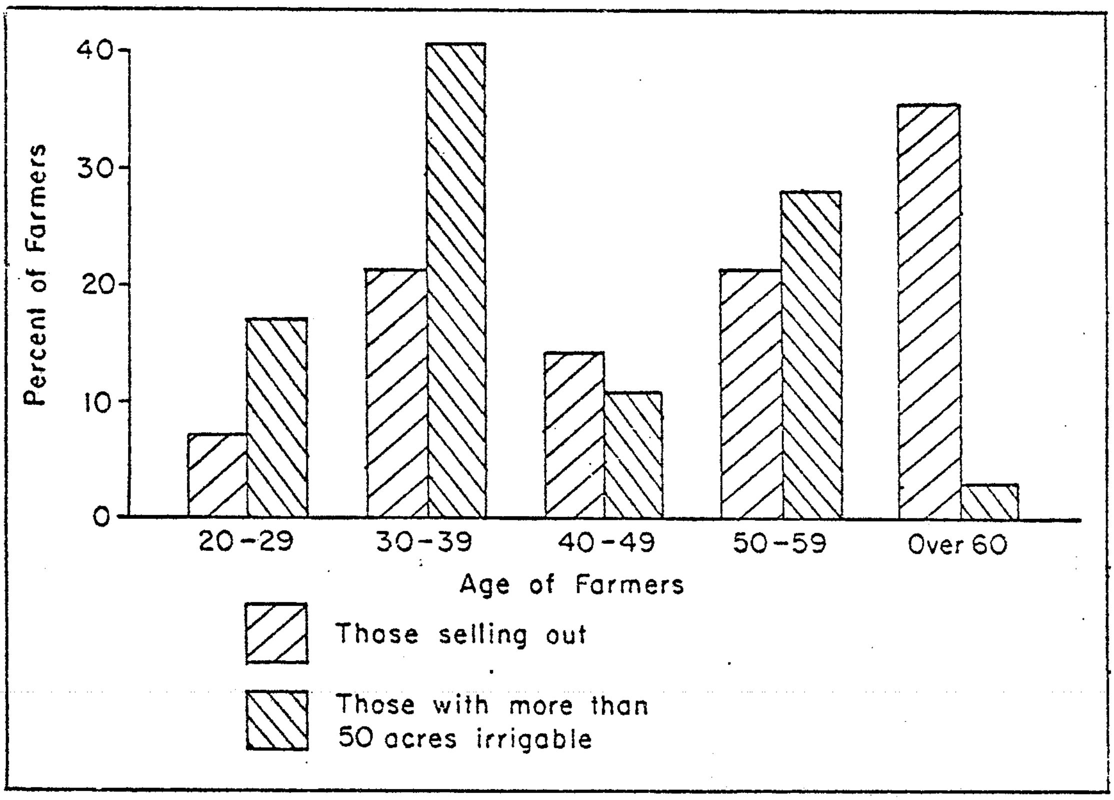
Gillies (1977a, b), in her studies of irrigation schemes on the Lower Waitaki River, compared the social and demographic characteristics of a sample of early adopters of irrigation with those of dryland farmers in an adjacent area. She found that her 'irrigation sample' tended to be younger, had fewer dependants and had absorbed more male school-leavers on to their farms than had dryland farmers. She also reported an increase in population in the irrigation area, whereas the dryland area had experienced continuing decline. These results are in distinct contrast to the observations reported by Evans and Cant (1981), and may reflect a change in farmer attitudes as a result of labour-saving border-dyke technology which occurred in the late 1960's and early 1970's. But more importantly, they may also reflect attitudinal differences relating to different historical features of farm development in Otago and Canterbury.

Mathieson (1976) examined the decision-making characteristics and behaviour of farmers who had been affected by the Lower Waitaki Irrigation schemes. He found that those who decided to irrigate, and those who purchased so that they might irrigate, tended to be younger than those who sold their farms rather than irrigate (see Figure 5.1). Interestingly, Mathieson found that the majority (72 percent) of those who sold out agreed that "Irrigation would be the greatest advantage on my property" (p.40). He also found that the greater the level of education the greater the willingness to adopt irrigation (p.69). Similarly, the greater the experience in farming the less the willingness to adopt irrigation. Both relationships were correlated with age, with older farmers tending to have less formal education and greater length of time farming in that Valley.

FIGURE 5.1

Lower Waitaki Irrigation Scheme

Farmers: Ages of Irrigators and Sellers



Source: Mathieson (1976).

Houghton's (1980) study of the Lower Waitaki communities identifies a historical decline in population which "has been reversed, or at least slowed in the last five years." She found a change in the age structure of the area - "Residents notice an increase in the number of young families in some communities ... there is not, according to residents, an increase in population, but there is a change in balance" (p. 52). She also notes (p. 53) a 'baby boom' in some communities. She suggests (p. 55) that ..."to date, productivity has not increased at the pace expected by some observers. Also, few units have hired extra labour; a greater increase in labour units had been expected", and concludes that irrigation appears not to have affected trends towards amalgamation. Her conclusion that population changes had not, at that stage, been as great as expected receives some support from 1981 Census provisional results. Between 1976 and 1981, the rural areas of both the Waitaki and Waimate Counties declined in population (New Zealand Government, 1981; 46).

More recent data on population changes are not yet available, but it does seem that major increases in permanent population have not occurred as a result of irrigation development in this area.

The effect of Community Irrigation Schemes on population growth remains unclear, but their role in generating change within the population is clearer. All three of the studies covered in this section refer to a considerable turnover in farms since the schemes began. In general, the studies suggest that in the first five years of the schemes about 30 percent of farms changed hands completely, and perhaps a further 20 percent changed hands within families. (Caution is necessary here as changes may well have been in name only rather than effect.)

5.4 Baseline Conditions for the Study Area

The population of the LRIS and CPIS areas affected by the proposals (excluding the Ashburton urban area, 15,265 in 1981) is about 10,000 at present (Table 5.1). The largest concentrations of population are at Darfield (1,151) and Rakaia (750), with several smaller settlements both within and close to the scheme boundaries (New Zealand Government, 1981a). The "Eastern Area" of Ashburton County has boundaries very similar to those of the LRIS. Ellesmere County shows strong growth overall, but this is occurring in the eastern parts of the County and appears to be related to proximity to Christchurch.

In recent years the LRIS area has been declining in population. This loss is indicated by a decline in the number of houses occupied - 13 dwellings - as well as by the average numbers reported per household (New Zealand Government, 1981b: 93). Conversely, the Ashburton urban area experienced a small decline in population between 1976 and 1981, but an increase of just over 400 occupied dwellings. In Malvern County census mesh block boundaries do not fit very well with the proposed CPIS boundaries, which are in any case not yet as definite as those of the LRIS. For Malvern as a whole, a pattern of relative stability in numbers in the rural areas and smaller settlements is apparent, with any growth being concentrated in Darfield.[24]

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[24] A survey carried out by students of the Geography Department, University of Canterbury, showed that nearly 90 percent of those interviewed who were either retired or within ten years of retirement expressed a preference to retire in Darfield.

TABLE 5.1

Population Trends, Central Canterbury 1971-81

	Population 1971	% Difference 1971-1976	Population 1976	% Difference 1976-1981	Population 1981
Eastern Area of Ashburton County	2 678	+ 1.2	2 710	- 5.4	2 563
Ashburton Urban Area	14 386	+ 6.7	15 357	- 0.6	15 265
Malvern County					
- outside Christchurch S.D.*	2 588	+ 1.1	2 617	- 1.8	2 570
- inside Christchurch S.D.	1 380	+ 0.8	1 391	- 1.4	1 372
Darfield	831	+ 21.2	1 007	+ 14.3	1 151
Ellesmere County (rural)	4 808	+ 9.8	5 277	+ 4.7	5 523
New Zealand		+ 9.3		+ 1.2	
South Island		+ 6.1		- 1.0	
Canterbury		+ 7.5		- 1.1	
N.Z. Rural					
- inside S.D.'s				+ 4.7	
- outside S.D.'s				+ 0.9	

* S.D. = Statistical Division

Sources: Department of Statistics (New Zealand Government, 1981b), and Census of Population and Dwellings Provisional Statistics Series, Bulletin 1, pp. 43 and 45 (New Zealand Government, 1981a).

Evidence from the 1976 Census suggests that retirement to urban rather than rural areas also appears to occur in the LRIS area. The area was divided into a "more farm" part, comprising most of the scheme area, and a "less farm" part, comprising the Rakaia township and a more densely populated area close to Ashburton. Youthful dependency ratios,[25] at 549 per thousand for the "more farm" area and 480 per thousand for the "less farm" area, are not greatly different. Aged dependency ratios, however, are 79 per thousand for the "more farm" area and 146 per thousand for the "less farm" area, indicating far more aged people proportionally in the "less farm" area.

The age/sex structure of rural Malvern County and of the LRIS, summarised in Figure 5.2, shows some differences between the two which may affect the response to irrigation introduction. Rural Malvern has a younger population with the notable exception of males in the 15 to 19 age group. On the basis of these limited data, two implications may be worth pursuing:

1. that the greater relative number of young males in the LRIS may reflect employment on farms which have already adopted irrigation via groundwater development, and
2. that the generally older population in the LRIS area may lead to higher rates of farm turnover than might occur in rural Malvern if river-supplied irrigation is provided.

More detailied information will shortly become available via the 1981 Census of Population and Dwellings. This demographic information should be sufficient to provide baselines and to give a more accurate indication of the main demographic processes operating in the scheme areas over the last few years. With this information it will be possible to set up detailed working hypotheses concerning the range of possible demographic impacts that could accompany irrigation development.

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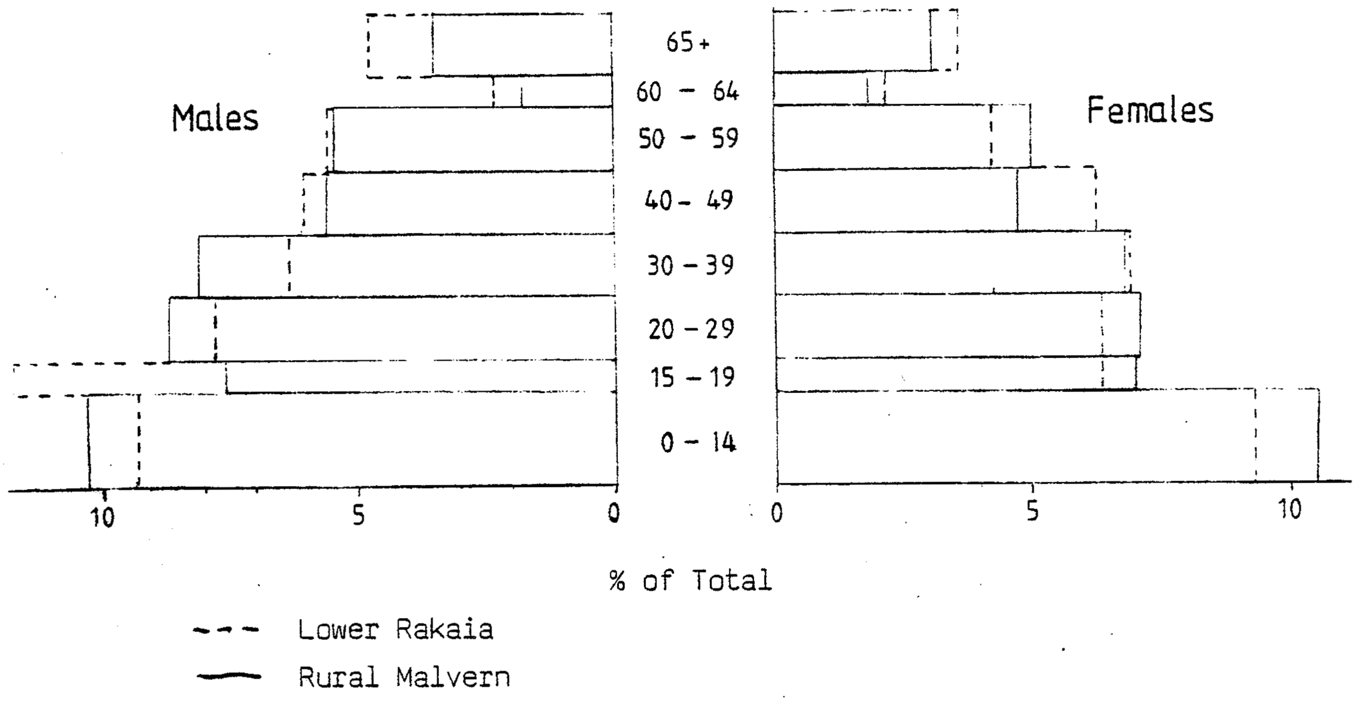
[25] Youthful dependency ratios are derived by dividing the number of inhabitants 0-14 years old by the number of inhabitants 15-64 years old. Aged dependency ratios are calculated by dividing the number of inhabitants 65 years and over by the number of inhabitants 15-64 years. Both ratios are expressed as units per thousand.

FIGURE 5.2

Age-Sex Structure Rural Malvern and Lower Rakaia Scheme Area, 1981



At the present time there is a lack of information available concerning rural social structures, goals or decision-making processes of farm owners, managers and workers. Frengley (1979) interviewed a random sample of farmers in the LRIS area to determine their perception of risk associated with a future change to an irrigated farming system. His results suggested that farmers were definitely risk-averse, and that the actual rate of adoption may turn out to be significantly less than the potential rate assumed by project planners. More recent studies by Greer (1982) and Beck (1982) are expected to shed more light on the role of farmer motivation in explaining technology adoption and observed farm investment behaviour. Considering the importance of this information in appraising scheme impacts, it is desirable that research work in this area is continued.

5.5 Expectations of Irrigation Development Impacts

Working through the assumptions made by Le Page (1980b) with respect to the LRIS,[26] a figure of about 80 extra on-farm jobs emerges as a direct result of irrigation development (refer to Chapter 4.3). Identifical assumptions applied to expectations outlined by Le Page and Ritchie (1980) produce a figure of 90-100 labour units as the extra on-farm requirements in the groundwater area of the scheme, assuming that the whole of this area would be spray irrigated.

These figures are approximately one additional labour unit for every two irrigated farms, and agree with Hubbard and Brown's (1979: 108) estimate of 30 jobs directly created by irrigation on a scheme covering, at the time, just under one quarter of the proposed LRIS area.[27] Quoting from Hubbard and Brown, such estimates ..."assume a linear relationship between employment and output ... it would appear that, in the majority of cases, farmers have not employed extra full-time labour but have, instead, increased their own workload", and they go on to suggest that 30 new jobs is probably an overestimate. They also estimate that a further 77 jobs related to agriculture would have been created following increased production.

The required construction labour force for intake works and other off-farm structures can be estimated with rather more certainty. Work commenced on the Waiau Plains Irrigation scheme in North Canterbury in November 1980. The Water and Soil Division of the MWD (Lewthwaite, 1982) advises that during the peak construction phase some 20 persons will be employed by the MWD on and off-farm. Approximately 60 contractors plus staff are at work on the scheme on any one day. Fifteen of these are local residents. Many of those who do not live in the area permanently have rented houses and cottages.

The above figures are estimates of average numbers, and may not hold for years two through five of the project. They would require doubling for the LRIS and quadrupling for the CPIS if the same proportional rates of development (12 percent per annum) are to be achieved. These estimates are below those for direct construction projected on

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[26] The major assumptions were: one extra labour unit would be required for every 2,500 extra stock units; one labour unit change for every 100 ha change in the amount of crop grown; changes towards cropping on spray and/or better soil areas; changes towards pasture on border-dyke and/or lighter soil areas.

[27] The irrigation scheme used as an example here is the Waitaki Community Irrigation Project.

the basis of Hubbard and Brown's (1979) estimates. The impact of the construction workforce will tend to be localised because the bulk of the work will be taken up with intake structures and main races. In the case of the LRIS much of this work will take place close to the Rakaia township, and in the case of the CPIS to the west of Hororata.

The studies of earlier irrigation schemes reviewed above provide a critical base from which to examine suggestions that irrigation could have a considerable impact upon demographic and social systems in central Canterbury. Douglass et al. (1979: 44) suggest that the LRIS is ... "is not expected [to] lead to any major social change in the form of population size, settlement density and farm size." Other evidence from previous schemes suggests that projections of large increases in on-farm employment should be treated with scepticism. Houghton (1982) comments with respect to the Waitaki experience ... "A preliminary review suggests that the schemes have had little effect on local population density, size and composition." The scale of extra employment which is possible, and the extent to which it may have permanent social and demographic effects upon Central Canterbury are major research questions which will require further study. The pattern of these outcomes will be shaped by the responses of farmers and providers of rural services to the opportunities and the challenges created by the development of the schemes.

Irrigation schemes tend to differ from other development projects in that regional benefits are, potentially at least, as great, if not greater following construction than they are during the construction phase. They also differ in that there is far more overlap between the phases in terms of time, and in terms of the kinds of expertise they require. This suggests that long-term regional development might be promoted by planning for compatability between the scale of the construction and the operating phases of the proposed schemes.

The rate at which the proposed schemes are to be developed obviously has important implications regarding their impact upon the agricultural services sector of Central Canterbury. A fast rate of development appears to be preferable from the narrow viewpoint of 'scheme economics', as suggested in Chapter 2, but the ability of local contractors and others to supply the necessary services in support of the construction phase could be severely tested. As is currently happening in the Waiau Plains, the rate of on-farm development is limited by contractor services and not by the farmers themselves.

If the rate of development of an irrigation scheme could be held to a level which would not overload local service and infrastructure capacities, then it is possible that fewer of the workforce involved might have to be brought in from outside the region. As the construction phase wound down, they might shift from work on the scheme to fill on-farm employment demand created by the scheme itself. Hence, the possibility of promoting long term regional development through carefully planned use of available resources exists and is worthy of consideration. However, this would possibly involve accepting additional national costs in the construction of a scheme, and a slower rate at which productivity benefits come on-stream.

5.6 Conclusions and Recommendations

Irrigation holds the potential to greatly increase the productivity of the Central Canterbury Plains. Increases may come about through reduction of the drought hazard, the intensification of existing farming enterprises, and the adoption of new ones (e.g. dairying, horticulture).

It is known that these developments may induce social and demographic changes, such as increased farm ownership turnover, increased demand for on-farm labour and, consequently, changes in the age/sex structure of an area. The nature of these impacts will, for the most part, be determined by MWD planning, and by the capacity of local and regional communities to supply the necessary support services.

The impacts of on-farm construction and potential production increases will depend very much on how farmers react to the possibilities irrigation provides. There appear to be three different types of response: sell-up, adopt as a risk-minimising strategy, or adopt a new management approach which makes maximum use of the resource. The social, demographic and economic implications would clearly be different for each strategy. The reactions of farmers will, in turn, be determined partly by the extent to which present productive resources are utilised, and partly by the goals of the farm families concerned.

Further research into the potential social and demographic impacts of irrigation development in Central Canterbury is advisable before any firm decisions are made regarding implementation. With respect to specific research needs, three areas of study should prove useful to planning agencies in the near and longer terms:

1. to identify and evaluate ways in which the proposed irrigation developments can be used to achieve a wider set of local, regional and national socio-economic goals, such as employment creation, rural stability and quality of life aspects;
2. to make a careful assessment of the region's human resources and the capacities of local communities to make the most of irrigation development opportunities; and
3. to establish a sound information base from which change can be monitored, more accurately predicted, and used by local and regional planning bodies.

Sources of data for these studies would include the 1981 Census which would enable more precise demographic and social baselines to be derived. Also, a detailed review of existing South Island irrigation schemes would provide useful case study data of a cross-sectional and longitudinal nature that could lead to considerable insights for irrigation development planning in Central Canterbury. Further survey work will also be necessary, particularly of those people living in and around the scheme boundaries, in order to establish relevant and worthwhile targets for gauging performance.

CHAPTER 6

THE ENVIRONMENTAL IMPLICATIONS OF IRRIGATION DEVELOPMENT

6.1 Introduction

This chapter presents an overview of the public concerns that have arisen in recent months relating to the environmental consequences of abstraction, and attempts to provide evidence which may support or lessen their importance. Not all the issues or evidence available are reported as this would be clearly beyond the scope of this review.

This Chapter is organised in four sections. In Section 2 a review of the literature on biological resources of the river is given together with an outline of present knowledge concerning the possible impacts irrigation abstraction will have on the stability and maintenance of wildlife habitats. Section 3 reviews previous work on the recreational importance of the Rakaia. Earlier studies are described and their results compared, and recreation uses and amenity values which have not been studied are highlighted. A preliminary estimate of the economic importance of recreational salmon and trout angling is reported.

The implications of river water abstraction for commercial salmon ranching on the Rakaia are described in Section 4. The environmental requirements of anadromous salmon are reviewed and the critical parameters which could be influenced by irrigation development are discussed. Indicative estimates of the commercial economic worth of salmon ranching on the river are calculated. Section 5 reviews previous studies of the interaction between irrigation and groundwater quality. The experience of nitrate pollution in Canterbury is reviewed, and the relationship between land use and levels of nitrate concentration in shallow aquifers is examined. Implications for irrigation scheme planning and further research are described in Section 6.

6.2 Effects of River Water Abstraction on Biological Resources

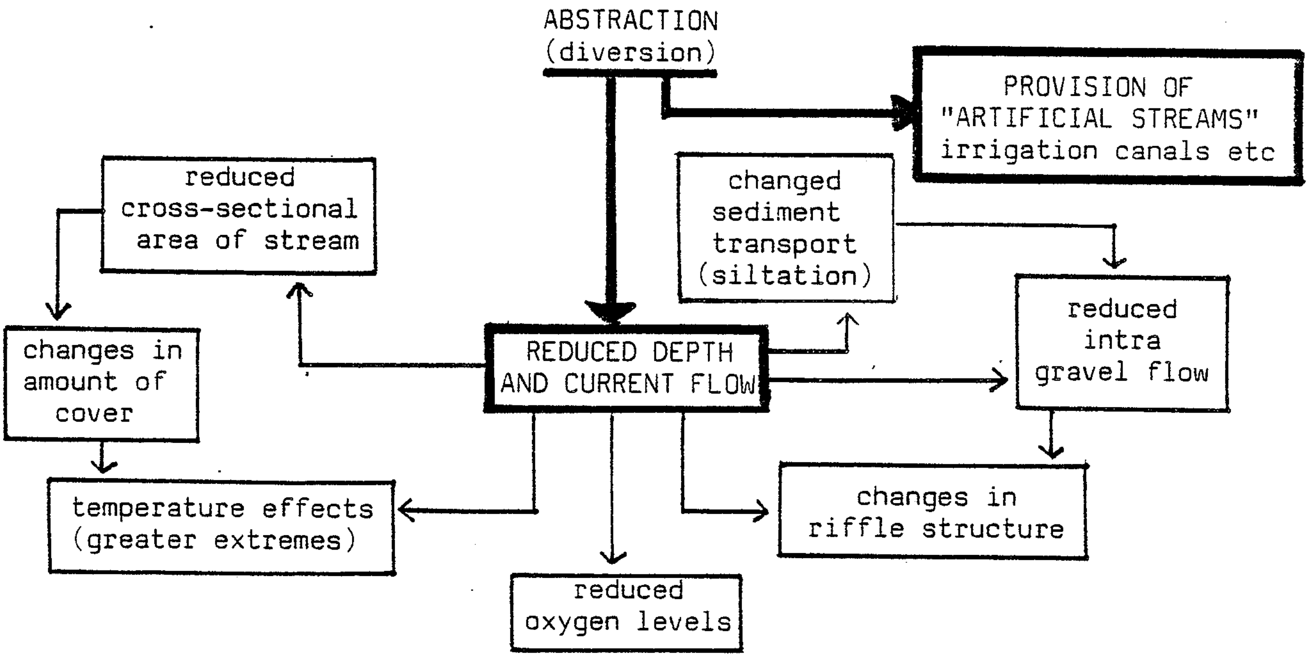
The effects of water abstraction on multi-channel or braided river systems are neither well-understood nor easily predicted. For instance, it is not known how abstraction affects the distribution of water within the braids (i.e., is a constant percentage of water removed from each braid or do the smaller braids dry up?) or how it affects losses of river water to groundwater (Sagar, 1979). The only predictions that can be made with any degree of certainty are (from Maidment et al., 1979):

1. the spatial effects of abstraction will be most severe in lower reaches of the river where the most braiding occurs and losses to groundwater are greatest, and
2. the temporal effects of abstraction will probably be most severe in late summer, when river flow is dropping from its November maximum and irrigation demands are reaching their peak.

Data on the effects of abstraction on hydrological features of single channel rivers (both in New Zealand and overseas) have been summarised by Church et al. (1979) (Figure 6.1). These indicate that the primary effects are reduced depth and reduced current flow. Secondary effects may include reductions in current velocity, wetted perimeter, cross-sectional area, surface area and concentrations of dissolved oxygen, increased sedimentation and algal production, and changes in water temperature (usually higher maxima and lower minima and higher monthly means) and in the amount and/or type of cover.

FIGURE 6.1

The Effects of Water Abstraction on Rivers



Source: Church et.al. (1979).

Abstraction from the Rakaia may also cause the lagoon to increase in depth and the mouth to close (Kirk et al., 1977). Increased coastal erosion may occur, and land adjacent to the lower river margins may be more prone to flooding.

6.2.1 Biological Resources at Risk A review of the literature indicates that fish, aquatic invertebrates and river-nesting birds constitute the dominant wildlife of the Rakaia River bed. In the region surrounding the river, waterfowl, other insectivorous and predatory birds, and mudfish, arthropods and small mammals are found. Frogs, geckos and skinks also inhabit the riverbed and/or surrounding areas, although these are not mentioned in the literature.

Fish Twenty-one species of fish inhabitat the Rakaia River system and more than half migrate at some stage of their life-cycle between fresh water and the sea (Davis, 1979). Seventeen species are native and the remaining four are introduced salmonids. Eight species are of recreational and/or commercial interest, particularly the brown and rainbow trout and the quinnat salmon.

Fisheries biologists are not yet in a position to specify the effect of water abstraction on the fish populations of the Rakaia. At present, little is known about how the proposed irrigation schemes will affect parameters important in the micro-habitat of stream fish, particularly depth and velocity, but also temperature, substrate, and cover. Furthermore, even if physical scientiests could predict changes in such parameters and channel form, aquatic ecology is not yet at the stage where the changes in the numbers of fish associated with any particular flow regime can be quantified (Stalnaker, 1980). A more detailed discussion of these aspects is reported in Appendix 4.

Despite these difficulties an attempt was made to develop some preliminary prediction about the most probable, mainly direct, impacts of low flow on Rakaia fish populations. These are summarised in Table 6.1.

Five general conclusions emerge from this analysis:

TABLE 6.1

Fish of the Rakaia River System

Potentially at Risk from Low Flow Due to Abstraction[1]

Species	Potentially at risk from low flow due to:					Recreational Importance	Commercial Importance
	Loss of habitat in main river	Changes in habitat in lagoon and river mouth	Loss of Migrational passage in main river	Loss of spawning habitat	Loss of invertebrate food in main river		
Inanga		X	X	X		X	X
Kahawai		X				X	
Yellow-eyed mullet		X				X	
Black flounder		X				X	X
Common smelt		X	?	?	?		
Stokell's smelt		X	?	?	?		
Common bully		X	?	?	X		
Lamprey	?		?	?	?		
Long-finned eel	X		X		X	X	X
Short-finned eel	X		X		X	X	X
Koaro			?				
Common river galaxias							
Alpine galaxias							
Long-jawed galaxias							
Rainbow trout							
Brown trout	X		X	?	X	X	
Brook char							
Quinnat salmon	X		X		X	X	X
Torrent fish	X		?	?	X		
Blue-gilled bully	X		?	?	X		
Upland bully	X		X	X			

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[1] Also see Appendix 4.

1. Fish species most likely to be significantly affected by loss of habitat in the main river below the Gorge are juvenile salmon, brown trout, long-finned eels, short-finned eels, torrent fish, blue-gilled bullies, upland bullies and possibly larval lampreys.

2. Fish species whose habitat is most likely to be significantly affected by changes in the lagoon and river mouth are inanga (whitebait), flounders, kahawai, yellow-eyed mullets, common smelt, Stokell's smelt and common bullies.

3. Species whose migrational passage is likely to be significantly affected by low river flows and/or closure of the river mouth in late summer are adult salmon (moving upstream to spawn), and adult eels and inanga (moving downstream to spawn). Koaro hatchlings moving downstream and adult lampreys moving upstream may also be affected.

4. Long-jawed galaxias, alpine galaxias, common river galaxias, brook char and rainbow trout are unlikely to be affected by irrigation proposals as they live in the river predominantly or completely above the highest point of abstraction.

5. Species considered to be at the greatest potential risk because of their overall habitat, feeding, migrational, and/or spawning requirements and their recreational and/or commercial importance, are (in approximate order of risk): salmon, long-finned and short-finned eels, inanga and brown trout. Also at some risk but of little or no recreational or commercial importance (although they are of scientific interest) are: torrent fish, blue-gilled bullies, upland bullies, lampreys and possibly koaro.

Birds The Rakaia River and its environs are home to 43 species of birds during at least part of their life-cycle. Twenty-two of these are native species. A minimum of eight species nest during spring-summer in the riverbed itself, some almost exclusively in this river (Turbott, 1969). These are the black-billed gull, black-fronted tern, South Island pied oystercatcher, wrybilled plover, pied stilt, banded dotterel, black-backed gull and pipit. All of these species are either native or endemic, and all but the black-backed gull are fully protected (Marshall et al., 1972, 1973).

Of these eight river-nesting species, most concern is directed towards the fate of the wrybill (e.g., Douglass et al., 1979).

This species is regarded as an international ornithological oddity; it is unique amongst birds in having a laterally-curved bill (Hay, 1979). Some concern is also directed towards the survival of the black-fronted tern. Although the total population of wrybills is not extremely low (about 6,000 to 7,000 according to Hay, 1979), the restricted habitat preferences of this species make it vulnerable to any further reductions in habitat.

Proposals to modify the natural flows of the Rakaia River, which is the most important breeding ground of the wrybill are therefore of considerable public interest (Hughey, 1982). Since the birds are confined to nesting in open areas of clean shingle, regions of the riverbed that have been invaded by exotic weeds (lupin, gorse and broom) are useless to breeding birds. Periodic freshes and floods keep the shingle bed free from vegetation; however, a reduction in river flow may lead to the encroachment of these plants onto the wrybills' already limited nesting habitat. Such a phenomenon has already occurred in the Lower Waitaki River as a result of controlled flow (Hay, 1979).

Water abstraction may also adversely affect wrybill and other riverbed bird populations by reducing the abundance and availability of the aquatic invertebrates on which they feed, by allowing increased access for mammalian predators and humans to the normally isolated nesting islands and by attracting black-backed gulls (predators of eggs and chicks) to nearby sites of human activity (Douglass et al., 1979).

The remainder of the avirfauna of the region comprises birds of the coast, swamps and inland waters. Coastal lagoons, swamplands and some of the slower-flowing side streams of the Rakaia River are used by waterfowl, some of which are hunted for sport. Drainage of swamps has been responsible for the loss of much of their habitat and some populations have consequently declined.

Water abstraction may reduce the feeding areas and isolation from predators (such as ferrets, rats and stoats) of waterfowl breeding on the slower-flowing side streams of the Rakaia River. Reductions in flow, if they lead to drying of side braids, may also reduce the availability of hatching insects on which insectivorous birds such as fantails feed. However, some fish-eating birds (e.g. shags, herons, gulls) may derive short-term benefit from low flows as fish concentrate in pools and are then more easily caught.

Other Animals Arthropods of scientific interest are found in the subterranean waterways and indigenous grass swards of the Rakaia region (Douglass et al., 1979); however, it is not known if these are likely to be affected by the proposed irrigation schemes. Several species of small mammals, of which rabbits, hares, ferrets and weasels are the most common, support a small-game hunting activity. It is believed that these are not sensitive to changes from irrigation. In fact, reduced water flows could increase the food supply of mustelids, and also rats and cats, by providing easier access to the eggs and chicks of birds nesting in the riverbed.

Vegetation The major sites of botanical significance in the region are found on Great Island and Feeday Island near the mouth of the Rakaia River. The area at the top of these two islands contains a wide variety of native species formerly more widespread throughout the area, and has the status of "a reserve set aside for protective works." The undisturbed soils and rare native vegetation associations make this reserve of high botanical value, and the area is regarded as unique in the Canterbury Plains. However, water abstraction could endanger this area. Northwesterlies drive water through channels in which ferns are found, and botanists from DSIR regard periodic flooding as essential for long-term maintenance of the area (Douglass *et al*., 1979).

6.2.2 Possible Effects on Other River Systems A potentially important environmental concern, although it is has received little attention thus far, is the question of what happens to the diverted water after irrigation. The possibility of intercatchment transfer, for example into the Selwyn River and its tributaries, has been raised as a means of mitigating the periods of no-flow, which currently necessitate trout salvage operations in that river during the summer (Hughey, 1980). While this might work, it would also reduce the quality of the normally clear Selwyn (increasing its silt and nutrient concentrations) and might also have detrimental effects on the ecology of Lake Ellesmere, into which the Selwyn drains. Lake Ellesmere is the region's main wetland ecosystem, and changes in its water level and/or increased discharge of nutrients could worsen its already eutrophic waters.

Irrigation development may also jeopardise the survival of a unique and little-known fish found in the Rakaia region, the Canterbury mudfish. Several factors have already challenged the survival of this species, in particular, drainage of the swamps in which it lives and conversion of these to pasture (Eldon, 1979). It is listed in the International Union for the Conservation of Nature Red Data Book on endangered species of fish (McDowall, 1980). Thus priority should be given during any future farm development (including the construction of irrigation raceways) towards minimising any further reduction in habitat of this unique fish. In particular, diversion of irrigation water into the Hororata River should be viewed with concern, since this is an important habitat of the fish.

6.2.3 Enhancement Possibilities It is possible that irrigation development could in fact enhance the survival of the Canterbury mudfish as it is known to occur in irrigation races. Other possibilities for the enhancement of wildlife as a consequence of irrigation are discussed by Douglass et al. (1979). These include stocking main irrigation races with brown trout, and developing parts of the irrigation system as waterfowl habitat. Brown trout are adaptable to irrigation races (for example the Ashburton-Lyndhurst system), but tend to be smaller and more prone to disease than those in natural waters. Enhancing the region's salmon stock may also be possible with suitable modification to irrigation races and intake structures and very careful water management. Appendix 4 contains a more detailed discussion of the pros and cons associated with such possibilities.

The irrigation system could more readily be adapted to provide waterfowl habitat. Irrigation races per se are inadequate, as waterfowl prefer standing water and nearby shelter for nesting. However, parts of the race system could be modified to provide permanently flowing subsidiary channels or ponds. Douglass et al. (1979: 76) provide details of how settlement ponds might be designed for the benefit of ducks and geese.

6.2.4 Research in Progress Several government departments and research organisations are currently gathering data on features relevant to the wildlife of the Rakaia River. The Environmental Hydrology Group of the Ministry of Works and Development, the North Canterbury Catchment Board, and the Water Abstraction Team from the Fisheries Research Division (FRD) of the Ministry of Agriculture and Fisheries, are all in the process of gathering information on how physical parameters of the river change under natural low flows. These studies will enable the effects of water abstraction on the hydrology and morphology of the river to be made much clearer in the future.

The FRD (MAF) are collecting information about the life histories of the fish of the Rakaia, their distribution, abundance, and movements within the river, and their specific habitat requirements. The distribution and abundance of invertebrates are also under study. The importance of the main river in rearing juvenile fish (especially salmon) on their way to the sea, the importance of recreational salmon, trout and whitebait fisheries in the Rakaia, and of the species composition and abundance of zooplankton and epibenthic invertebrate populations in the Rakaia Lagoon are all part of the FRD's impact evaluation which is scheduled for completion in early 1983 (Glova, 1981).

The Wildlife Service of the Department of Internal Affairs and Hughey (1982) are presently investigating the birdlife of the Rakaia River. The Wildlife Service is preparing a report on the importance of each of the major Canterbury rivers for particular bird species (Moore, 1982), and the hydrologic requirements of the wrybill and the black-fronted tern are being examined by Hughey.

6.3 Recreational Impacts and Opportunities

As with any major change in a natural environment, it is extremely difficult to say beforehand what the consequences will be or whether the costs will outweigh the benefits of the change. Perhaps a better example of this could not be found than in the juxtaposition of irrigation and recreation concerning the Rakaia.

Little research has been done in the past to measure the economic importance of Rakaia-based outdoor recreation. Previous studies have been largely descriptive and often limited to a single activity.

Indepth investigations to ascertain recreationists motivations, particularly why they select the Rakaia over other nearby rivers with many of the same attributes, have not yet been undertaken. Amenity values of the river system to recreators and non-users alike are poorly documented. It is not surprising then that irrigation poses a threat (real or imagined) to the future welfare of many Cantabrians. The linkages between river abstraction and biological processes, and between these and recreational opportunities, are simply not understood well-enough to be able to appraise the risk.

6.3.1 The Rakaia as a Recreational Resource What is currently known about outdoor recreational activities associated with the Rakaia are described in detail elsewhere (Douglass et al., 1979). The more important recreational pursuits are trout and salmon angling, jet boating (usually in association with angling), waterfowl and small game hunting, eeling and whitebaiting, rafting, picnicking, bird watching and sightseeing among others. In addition to the actual users of the resource, others derive satisfaction from the knowledge that the river provides a sanctuary and habitat for unique animals and plant species. Being among the last major braided river systems in New Zealand that remains relatively untouched by man, the Rakaia also derives importance from its "scarcity value".

Few of these user and amenity values have ever been quantified in any objective sense. Previous efforts to appraise their worth to the regional community have concentrated on angling, and in particular the recreational salmon fishery. For this reason, and because of limited empirical data on other uses, the balance of this discussion focused on recreational angling.

Qualitative Assessments The most common approach to establishing the importance of the River's sport fishery has been the annual reporting of licence sales and angling-effort data by the FRD. Annual statistics collected for the Rakaia may be divided into one of three categories: fishing licence sales, fishing effort and success, and fish populations and other assessments of the fishery.

Sales of whole season fishing licences by the North Canterbury Acclimatisation Society (NCAS) rose to 15,541 in 1981, an increase of 87 percent since 1960 (Table 6.2). In per capita terms, annual licence sales, at about five percent in 1980, have been growing at a rate faster than the region's population growth. If licence sales can be thought of as a proxy for the demand for angling, then there is a relatively low level of regional demand but its significance is increasing with time.

TABLE 6.2

Fishing Licence Sales Data for Selected Years Since 1960

Year	NCAS Licence Sales	AAS Licence Sales	Total Licence Sales	Total Per-Capita Licence Sales[1] (%)
1960	8,309		8,309	3.2
1965	10,361		10,361	3.5
1970	12,788		12,768	4.1
1975	13,240	2,394	15,634*	4.7*
1980	15,475	2,768	18,243*	5.2*
1981	15,541		15,541	4.4

Source: Urwin (1981)

[1] Based on population estimate from census data covering the area between the Rangitata and Waimakariri Rivers.

* Includes Ashburton (AAS) and North Canterbury (NCAS) Acclimatisation Society added together.

The results from a national angling diary scheme, undertaken periodically from 1947 to 1968, provide the only comprehensive data concerning fishing effort and success in earlier years. Table 6.3 summarises these data for the North Canterbury (NCAS) Acclimatisation Society district. Graynoth and Skryzynski (1974) note that the diary results are possibly biased, since only the more experienced and successful fishermen tended to complete them. A survey carried out in 1963 to test the degree of bias in the diary results calculated the average number of days fished per season at 17.6, with the number of fish kept per season at only 9.4 (almost half that obtained from the diary data). A more recent survey in 1976 estimated that an average of 6.7 fish were kept by anglers in that season (Octa, 1976). These results support the view that the earlier catch rates were biased upward.

TABLE 6.3

Results of Fishing Effort and Success for Mens' Whole Season Licence Holders (NCAS District)

Measure of Effort or Success	Diary Year			
	1952	1958	1963	1968
Days fished season^{-1}	18.5	21.1	17.8	20.1
Hours fished day^{-1}	3.7	3.6	3.4	3.2
Fish kept season^{-1}	33.9	22.6	17.6	18.4

Source: Graynoth and Skrzynski (1974)

Table 6.4 is based on the results from the 1968 diary year and shows that the Rakaia River is unique among the major fishing rivers in Canterbury in that salmon make up the majority of the total catch. Since the end of the diary scheme in 1968, data regarding fishing effort and success have been published from surveys carried out by the Fisheries Research Division (FRD) in 1974 and 1975, and annually since 1979.

TABLE 6.4

Composition of Catch, 1968 Diary Year

Site	Trout	Salmon	Other	Total
	----------------	in percent	----------------	
Rakaia	35	65	0	100
Selwyn	100	0	0	100
Waimakariri	56	44	0	100
All NCAS District	86	13	1	100

Source: Graynoth (1974)

From a sample of licence holders in the NCAS and AAS districts, estimates of the total number of anglers fishing the Rakaia and their success in terms of the number of trout and salmon caught were calculated. In Table 6.5 the published data for the salmon catch in selected survey years are summarised. The low catch and angler effort estimated for the 1980 fishing season was attributed to poor river conditions for fishing and a lower than average salmon run (see Figure 6.2).

TABLE 6.5

Estimated Number of Anglers and the Salmon Catch in the Rakaia River, Selected Years Since 1974

Year	Number of Anglers	Salmon Catch	Estimated Effort[1] (Angler Days)
1974	4,405	3,218	n.a.
1975	5,332	4,416	n.a.
1979	7,700	14,000	90,000
1980	6,050	7,300	50,000

Source: Unwin (1981)

[1] Assumes each angling trip is equivalent to an angling day. Total effort is the sum of angler days per angler for the fishing season.

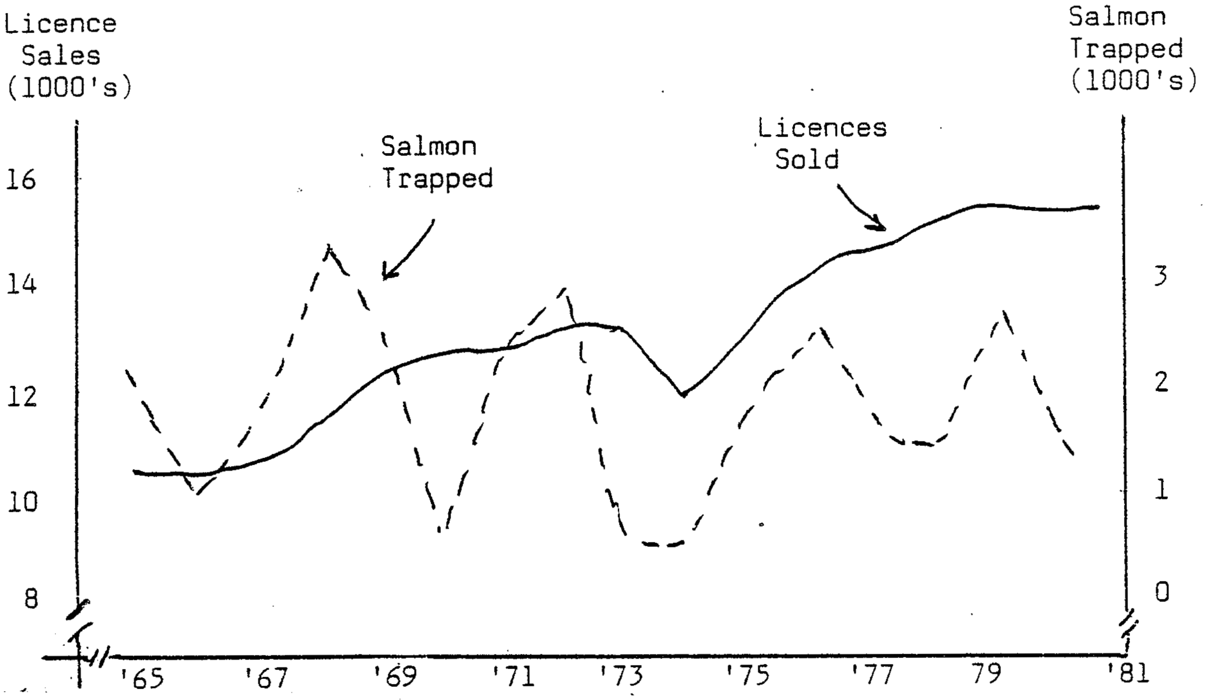
n.a. Not available.

Little data exist as to the total fish population inhabiting the Rakaia River. The only hard data collected relate to the annual numbers of salmon returning to spawn in the Glenariffe Stream, a major spawning tributary in the upper Rakaia catchment. The data are, however, probably a good indication of annual fluctuations in the salmon population. Figure 6.2 graphically displays the wide variation in the number of salmon trapped at the FRD facility on Glenariffe. The two very low return years of 1970 and 1973 have been attributed to floods in 1967 and 1970 respectively, which caused a high rate of juvenile mortality. Figure 6.2 does not indicate any obvious relationship between licence sales and the number of salmon trapped at Glenariffe.

A final observation about fishing licence sales and angler effort data is warranted. Results recently made available by NCAS show that the Rakaia was in a "fishable" condition (i.e., not carrying a high silt load) only for about half of the time during the most recent angling season (North Canterbury Acclimatisation Society, 1982). In comparison with earlier years that is about average, but the percentage variation in "fishable weekends" between years is probably more important in explaining the observed variation in annual licence sales and fishing effort than whether or not there was a good run of fish (Leathers *et al.*, 1982).

FIGURE 6.2

Annual Trends in North Canterbury Licence Sales and Salmon Trapped at Glenariffe Stream, Rakaia River



A National Angler Survey undertaken by the FRD in 1980 sought to find out what features of each particular river made it attractive to anglers (Teirney, 1981). The Rakaia was not rated highly for its scenic beauty, but was attractive in terms of the large fishable area, and the good size of the salmon caught in the river.

Quantitative Assessments In the 1973/74 angling season Gluck (1974) surveyed a random sample of salmon anglers in the first attempt at estimating the monetary value of the Rakaia recreational fishery. Due to a survey design flaw his results did not yield a statistically reliable demand function, based on the travel cost method of estimation. The alternative approaches that were tried - "willingness-to-pay for and/or sell" fishing rights - also were not judged to yield reliable measures due to the likelihood of biased responses. Indicative figures can be obtained, however, using Gluck's survey data and information available from a more recent study (Octa, 1976).

In current (1982) dollars Gluck's survey revealed an average expenditure of about \$35 day^{-1} for a typical Canterbury resident's trip to the Rakaia. This would be equivalent to a 100 km roundtrip costing 35 cents km^{-1}. Assuming that most anglers travel with a friend to and from the River, the average cost of travel might be shared equally, say \$18 angling day^{-1}. In addition, the direct expenditure on gear, licence fees, and related annual costs were estimated by Gluck to be about the same magnitude as the variable travel costs for each angling day. Hence, in current dollars, these data (in the absence of more reliable estimates) would put a monetary value on the Rakaia salmon fishery in the neighbourhood of \$35 angler day^{-1}.

An indicative value of the annual worth of the Rakaia to the angling community in Canterbury can be calculated by multiplying total annual angler days by this average value. Using Unwin's (1981) estimates (from Table 6.5), this sums to about \$1.8 million for 1980 and \$3.2 million for 1979 levels of angling effort. If one allows for between year variations in fishing conditions of the river (and the additional expenditure of operating jet boats, etc., which was not taken into consideration above) a conservative estimate of \$4 million would not be unrealistic as a preliminary indication of the Rakaia's annual sport fishery recreation value. In present value terms, discounting the expenditure stream at eight per cent over an infinite time horizon,[28] the total value of this recreation activity under present conditions of use would be of the order of \$50 million. To state the above result differently, seven thousand anglers each year spend an average of \$570 to pursue a rural outdoor recreational activity they personally value in excess of \$7,000 over their lifetime.

In a random sample of 2,000 NCAS licence holders Octa (1976) used a gross expenditure approach to estimate total angling expenditure for the 1975 season by North Canterbury anglers. Expressing their results in 1982 dollars, the estimate of total expenditure ranged from \$2.5 to 3.2 million. It should be noted that this estimate covered all lakes and rivers in North Canterbury, and that licence holders outside the NCAS district were excluded from the sample. Adjusting the Octa data for Rakaia only anglers (about 40 percent of the total), and adding in Ashburton and South Canterbury licence holders (increasing the angling population to about 20,000), yields a rough indicative estimate for Rakaia angling expenditure at about \$2 million per annum. This amount falls within the range calculated from the use of Gluck's (1974) data.

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[28] The present value criterion provides an estimate of the "capital value" of the resource in its present use, much like the asking price of a home or piece of real estate. A lower discount rate would increase present value and a higher rate would reduce it.

There are two additional measures of value which should also be considered. One is the secondary regional multiplier effect of "user values" and the other is the "preservation value" ascribed to the Rakaia in its present form by the Canterbury public. Using the appropriate multiplier,[29] the indirect and induced effect of an initial (direct) expenditure of $4 million by salmon anglers in the region generates a total of $8.8 million annually in economic activity. The household income effect would be of the order of $2.8 million annually.[30]

Non-user preservation values (the so-called "intangibles") have not been measured before in New Zealand. In a United States study of the South Platte River in Colorado, Greenley et al., (1980) found preservation values to be of approximately the same magnitude as recreation values. If the average Canterbury household (about 150,000 in total) was "willing-to-pay" $20 per year[31] to see the river protected in its present state (or to ensure that any detrimental irrigation impacts were mitigated), the amenity or preservation value in annual dollar terms would amount to $3 million.

Again, it must be stressed that the above estimates are indicative only of what the Rakaia fishery and amenity resources might be worth in economic terms to the region. Unless such measures of value are carefully developed using sound empirical data and appropriate methodologies, they will have little significance to national and regional water resource planning.

6.3.2 Plausible Development Effects A major change in the physical parameters of a natural system from which social satisfaction is derived will, eventually, be reflected in a change in social welfare. It is the direction of that change which matters. In the following an attempt is made to identify the most probable effects the proposed irrigation developments will have on the river recreationist.

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[29] The multiplier used was taken from the wholesale and retail trade sector, line no. 16 in Appendix 3.

[30] Calculated by multiplying $4 million by .69 (line no. 16, Appendix 3).

[31] Average annual preservation value estimates obtained by Greenley et al., (1980) exceeded $20 household^{-1}.

Impacts on Users It is apparent from the numbers of anglers and their annual expenditure that recreational fishing is most likely the major environmental amenity afforded by the Rakaia. Jet boating (unrelated to angling) and other river-based activities are of secondary importance according to previous research. Accordingly, analyses of possible impacts of irrigation should concentrate on implications for the angler first, and on other user groups second.

On the basis of available evidence, the natural condition of the river is such that little angling benefit can be derived for about half of the main angling season in a normal water year, with the majority of use occurring late in the angling season (February to April).[32] In addition, fish stocks - primarily salmon, but trout also - are important in determining angling success and therefore the "demand" for this recreational activity. A careful analysis of available time series data should reveal these to be the two key explanatory variables in estimating the demand for Rakaia angling. Disposable income, leisure time and available substitute angling opportunities could prove of lesser importance.

The relevant questions, then, are how river abstraction (or any other flow modification) will affect:

1. the "fishability" of the river from the angler's viewpoint; and
2. the quantity and quality of salmonid stocks in the long term (i.e. the sustainable population of adult fish available to the recreational angler).

With fish numbers seen as a necessary, but not sufficient, condition the nature of the research problem becomes more meaningful. Answering these questions is a job for both physical and social scientists and work in this area clearly deserves a high priority in the near future.

If the present irrigation proposals were adopted and implemented without any changes in design or measures to protect existing fish

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[32] This is due to the temporal variability in "fishable conditions" (see Leathers *et al*., 1982).

habitat and patterns of juvenile migration, the implications for future recreational angling, in the Study Team's judgment, are not good (see section 6.2.1, also Appendix 4). On the basis of the available evidence, biological conditions during years of low natural flow suggest a gradual reduction in salmonid resources (quality and/or quantity) over time. How the "fishability" of the river below the Gorge will be affected in normal to high runoff years is unclear, but any abstraction during periods of low flow would generally downgrade already difficult angling conditions. The result, over time, would be a shift in recreational use of the Rakaia to other less preferred local rivers and lakes, increasing congestion and resulting in a net loss of regional economic welfare.

Impacts on Non-Users If there is a direct loss in the recreational value of the Rakaia, no resident of Canterbury, whether a current user or not, will be unaffected by it (via the multiplier effect). A loss in economic welfare would also be associated with the loss in intangible, preservation value. The monetary-equivalent of this loss to present and future generations is obviously difficult to measure. An educated guess would be that it is close in magnitude to the direct benefits to recreational users. Therefore the justification of assessing potential impacts to non-users, essentially the amenity value to all Canterbury households, goes hand in hand with the recognised need to firm up estimates of user value.

6.4 The Commercial Salmon Fishery

6.4.1 Salmon Ranching Economics The prospect of commercial salmon ranching on South Island rivers is relatively new. Its future commercial viability is a matter of considerable speculation, since ranching trials in North America and elsewhere have been conducted for many years with mixed success. The most notable exception is Japan (Joyner, 1981). The idea of a commercial Pacific salmon fishery in New Zealand, however, can be traced back to the original introduction of the quinnat in the early 1900's, but this was based on developing a commercial ocean fishery. The 'ranching' concept relies on the salmon's homing instinct and suitable means for 'harvest' of adult fish returning to their natal streams.

This section focuses on the extent to which present knowledge is able to predict the impacts of abstraction on the Rakaia River salmon fishery. Emphasis is given to impacts which might detrimentally affect the economic viability of the recently established salmon ranching venture.

For commercial salmon ranching to be successful, removal of the environmental limitations to the potential size of the stock are obviously necessary. Constraints on the population can occur at any phase of the life cycle.[33] Spawning and nursery habitats appear the most limiting on the Rakaia, and it is precisely these shortcomings that are in fact surmountable from the point of view of the commercial salmon rancher. Because of the ability to control these two important life phases using advanced techniques of artificial propagation and timing the release of smolts, the commercial rancher's primary worries are the capacity of the inshore ocean to sustain larger salmon numbers, the potential predation of the stock by commercial or sport fishermen, and barriers to access of the returning adults to a suitable point of capture.

The economic viability of commercial ranching rests on the costs incurred up to the point of releasing smolts to the sea, and the marketable value of the returning adults. Overseas experience suggests that one percent return of the smolts released is the minimum requirement to recover costs. Under natural conditions the percent survival on average is considerably less than one percent, since only about 0.1 percent is needed to maintain a wild salmon stock at a constant size. A two percent return has already been obtained from timed-release trials at Glenariffe, so the prospects of a commercial ranching venture on the Rakaia are definitely worth pursuing. Under present plans, up to ten million smolts per year could be released by the late 1980's. Assuming a two percent return could be achieved, the size of the annual salmon run would average about 200,000, or ten times the present level.

To put this into perspective Table 6.6 shows the potential annual total revenue that might be generated by commercial salmon

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[33] A discussion of the life phases is presented in Appendix 4.

farming on the Rakaia, based of course on assumptions which must be regarded as highly speculative. The release of 10 million smolts at a two percent rate of return, and assuming that 75 percent of returning adults are marketable at $25 each, would generate a gross revenue of about $3.8 million. Higher prices, or a better return rate, would substantially raise this figure.[34]

TABLE 6.6

Potential Salmon Ranching Gross Revenue
Under Alternative Rates of Return and Market Prices

Smolts Released per year	Number of Returning Adult Salmon as percent of smolt release				Gross Revenue @ 2 percent Rate of Return[1] ($)
	0.5	1.0	2.0	5.0	
in thousands					
500	0.25	5	10	25	188
1,000	0.50	10	20	50	375
2,500	1.25	25	50	125	938
5,000	2.50	50	100	250	1,875
10,000	5.00	100	200	500	3,750
100,000	50.00	1,000	2,000	5,000	37,500

[1] For a conservative estimate an average wholesale value of $25 per fish is used. This price could prove to be a substantial under-estimate of the F.O.B. value of a high quality fresh export product. It is also assumed that 25 percent of the returning fish are retained for propagation and/or are not fit for human consumption.

Whether or not commercial ranching opportunities can be realised, however, depends in part on how the proposed irrigation schemes will influence river conditions. Of major concern to commercial ranching interests is the question of access of returning adult fish to a suitable capture and holding site. As pointed out earlier the recreational angler stands to benefit considerably from a successfully induced commercial run, and from the point of view of economics

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[34] For example, the present export price for fresh (chilled) salmon F.O.B. to Europe is about $10 kg^{-1}. If half of the returning fish were export quality, and they averaged seven kilograms net weight the total annual revenue would be (200,000 x 50 percent x 7 kg x $10) $7 million.

a sport-caught salmon may be worth more to the region than one "in the can" for domestic consumption or foreign export.

6.4.2 Possible Impacts of Flow Modification The South Pacific Salmon Company is located on the tailrace below the Lake Coleridge Power Station. As the points of irrigation abstraction are between the Company's release site and the river mouth, it is possible that low flow conditions could be detrimental to a commercially-induced salmon run. Of primary concern to the Company is the migratory access of returning adults to the point of recovery (the tailrace). While artificial propagation and rearing techniques can substantially reduce the losses that normally occur in "wild" stocks prior to the marine phase of the fish's life cycle, suitable river migration conditions are absolutely essential to success of salmon ranching on the Rakaia. A brief review of the quinnats' life cycle and environmental requirements, and possible impacts of low flow on each of the four life phases, is presented in Appendix 4.

The effects of abstraction on the salmon fishery can only be ascertained by detailed hydrological studies which quantify the distribution of residual flows within the braided river system, and the habitat changes caused by altering these flows. Water flow characteristics of the Rakaia have been under investigation for several years by researchers from the MWD and the FRD. The results of these studies remain inconclusive as far as water depth constraints on migrating adults under simulated low flow conditions (Mosely, 1982), but indicate the possibility of a thermal barrier (excessive temperature) during extended periods of low flow in mid and late summer (Glova, 1982). Unfavourable water depth and temperature would result in increased physical damage and disease, with the condition of the affected migrating adults not suitable for commercial sale.

Another obstacle for returning adult salmon, and one that should not be underestimated, is the recreational angler. Firm estimates of the annual sport catch, as well as the number of salmon that return to the Rakaia each year, are limited. Using angler diaries and survey data, Unwin's (1981) estimates of the recreational catch vary between 3,200 in 1974 to 14,000 in 1979 (Table 6.5). In a Delphi survey of salmon researchers, Leathers and Holms (1981) obtained estimates indicating that in 1979/80 about 5,000 salmon were caught out of a total run of about 16,000 fish, a sport harvest rate of approximately 33 percent. In a good year the run might exceed 20,000, but with one quarter to one third going into the anglers' bag it is conceivable that fishing pressure may be an important limiting factor on the present stock. This is a problematic situation for upstream commercial salmon ranchers, since an induced run of significantly more salmon could be an anglers' bonanza.

6.5 Irrigation and Water Quality

Deterioration of groundwater quality has been recorded in several areas of Canterbury. Concern over increasing nitrate-N levels and their possible effects on human health has received widespread publicity. As drainage from irrigated land influences both the water table and concentrations of nitrate-N in groundwater, this section considers the water quality implications of the proposed border-dyke irrigation schemes in the Central Plains and Lower Rakaia areas.

6.5.1 Aquifers and Nitrate Pollution

Descriptions of the geological structures which form the aquifer systems under the plains of Central Canterbury can be found in a number of publications (Bowden and Ayrey, 1979; Quin and Burden, 1979; Wilson, 1976) (see Figure 2.2). A recent detailed assessment of the Lower Rakaia area by the MWD awaits publication. For the purpose of considering the effects of land-use on groundwater quality, but with admittedly great simplification, aquifers in the region can be divided into two types:

1. Confined aquifer systems found under Christchurch and extending along a coastal strip around the western and northern edge of Lake Ellesmere which are overlain by impermeable material and contain water at greater than atmospheric pressure (Ayrey and Bowden, 1982), and
2. Unconfined aquifers covering the remainder, and majority, of the region where surface water may infiltrate into the system.

Throughout the latter zone infiltration from precipitation increases with distance west of the confined aquifer systems and with distance from the major rivers (Ayrey and Bowden, 1982).

6.5.2 Human Health Concerns Two health risks due to the consumption of water containing excessive levels of nitrate-N have been identified. Under certain circumstances nitrate-N is reduced to nitrate in the human stomach, which then combines haemoglobin to form methhaemoglobin, resulting in an impairment of oxygen transport in the blood. This constitutes a serious and sometimes fatal health hazard for bottle-fed infants.

Recent overseas studies have shown a positive correlation between nitrate-N levels and gastric cancer. No studies assessing the applicability of overseas experience to the New Zealand situation have been conducted, but the Department of Health has adopted the 1971 recommended W.H.O. limit of 10 g m^{-3} of nitrate-N for public water supplies.

6.5.3 Present Groundwater Quality in Central Canterbury Christchurch drinking water pumped from the confined aquifers underlying the city is of exceptional quality and has not varied significantly since testing commenced in the 1920s (Ayrey and Bowden, 1982). The origin and recharge rates of the confined system are, as yet, not completely understood, although Wilson (1976) identifies influent seepage from the Waimakariri River as the main contribution.

Analysis of wells in the unconfined groundwater area in the Central Plains was carried out from 1977-1980 by the North Canterbury Regional Water Board and the Chemistry Division (Christchurch) of the DSIR. Summary results presented by Ayrey and Bowden (1982), show 10 percent of wells sampled had nitrate-N levels greater than 10 g m^{-3}, and 34 percent had mean levels greater than 5 g m^{-3}. The general pattern was for low levels of nitrate-N to occur in wells in the vicinity of the Waimakariri and Rakaia Rivers with values gradually increasing with distance from the rivers towards the Lincoln and Prebbleton area. In some localities little variation in nitrate-N levels were found with increasing depth.

Groundwater quality investigations carried out between the Rakaia and Ashburton Rivers gave nitrate-N levels of 5-20 g m^{-3} and chloride levels of 10-30 g m^{-3} in the Lower Rakaia area. Quin and Burden (1979) explain these findings as arising from drainage of the upstream Ashburton-Lyndhurst surface irrigation scheme and the relatively intensive use of spray irrigation utilising groundwater with a much higher chloride content than river water. In this area nitrate-N content is a function of depth with concentration above 5 g m^{-3} largely confined to the uppermost 30 metres of groundwater.

6.5.4 Land Use and Groundwater Quality The origin of nitrate-N in groundwater of the Canterbury Region has been addressed in a number of studies. Initial research focused on point sources such as piggery wastes, sewage disposal systems and industrial effluent as major contributors. A recent study by Adams (1981) quantified nitrate-N leaching under different land uses in the Paparua County. These results, which are presented in Table 6.7 show the relative contributions from different farm types.

TABLE 6.7

Approximate Total Annual Nitrate-N Leaching Losses in Paparua County by Type of Farm

Farming System	Approximate Area (ha)	Approximate annual nitrate-N leaching loss (kg/ha/yr)	Approximate total annual nitrate-N leaching loss (kg/yr)
Pasture Non-irrigated	20,573	5	102,865
Cash crops (Wheat, oats barley etc.)	2,921	50	146,050
Peas	452	90	40,680
Green root & forage crops	1,147	50	57,350
Small seeds & lucerne	3,679	10	36,790
Pig farms	79	400	31,600
TOTAL			415,335

Nitrate-N leaching from pasture at the Winchmore Irrigation Research Station has received detailed attention from Quin (1979). He focuses on urine as the main contributor. Urea in the urine is converted to nitrate at a much faster rate than the pasture can take it up resulting in considerable quantities of nitrate-N being leached when the water holding capacity of the soil is exceeded through rainfall or irrigation.

In dry areas irrigation increases the potential for nitrate-N leaching by increasing pasture growth and therefore stocking rates, and also by increasing the volume of drainage. Quin (1979) estimates nitrate leaching losses from light soil, non-irrigated pasture to be less than 10 kg $ha^{-1}y^{-1}$, whereas he estimates the comparative figure for similar surface-irrigated land was 100 $kg^{-1}y^{-1}$. Results for cropping show there is little, if any change in nitrate-N leaching losses with irrigation. The rise in nitrate-N concentration in close to surface groundwater at Winchmore from 1.6 g m^{-3} in 1961 to 7.5 g m^{-3} in 1976, can possibly be attributed to the Ashburton-Lyndhurst irrigation scheme (Quin, 1979). The findings of Adams (1981), which relate the intensification of land use moving south east across the Paparua County to the gradual increase in groundwater nitrate-N levels, indicate a relationship which is firmly established under current agricultural practices.

Spray irrigation has the potential to reduce nitrate-N leaching as it allows better control of losses below the root zone. However, no detailed studies comparing leaching losses with the various types of flood and spray irrigation under different management regimes are available. Thus, on-farm water management to control the contributions of increased stocking rates and increased drainage to nitrate-N leaching from irrigated pasture is an important area for future research.

6.5.5 Implications for Development Planning Concern over the adverse impacts of the Rakaia-based surface irrigation schemes on groundwater quality in the unconfined aquifer has been expressed by a number of researchers. Quin (1981) pointed out that the older schemes, such as Ashburton-Lyndhurst, were originally designed for 50 percent irrigation, whereas the proposed Rakaia schemes will provide sufficient water for close to 100 percent irrigation. He anticipates that nitrate-N levels in groundwater may rise to 15 g m^{-3} under the proposed schemes. Given that the present levels for nitrate-N are between 4 and 8 g m^{-3} in most of the Central Plains area and up to 10 g m^{-3} in the Rolleston, Islington and Springston areas, Ayrey and Bowden (1982) and Quin and Burden (1979) recommend that if the W.H.O. standard for drinking water is not to be exceeded within the proposed irrigation scheme area then provision for a reticulated rural water supply from a confined aquifer source must be made.

Nitrogen is also frequently cited as the major nutrient contributing to eutrophication of surface waters. The significance of increases in nitrate-N levels and increased groundwater flows to the ecology of coastal lagoons northeast of the Rakaia River, including Lake Ellesmere, is not understood. Existing eutrophication problems in Lake Ellesmere will almost certainly be aggravated by changes in water levels or increased nutrient supply through drainage of groundwater with high nitrate-N concentrations. Proposals to prevent underground and surface water with high nitrate-N levels from entering Lake Ellesmere include providing a canal to channel return flows directly back to the Rakaia River.

Findings which indicate a substantial increase in nitrate-N pollution in response to increased irrigation pose some hard questions for planners. Foremost is the acceptance of their inevitability or the delaying of planning until the implications for groundwater quality of various agricultural practices in the Canterbury area are assessed. The factors in irrigation scheme design and management which will lead to the minimisation of nitrate-N leaching need to be identified as does their relationship to soil type and aquifer characteristics.

The problem of nitrate-N in household water supplies rests on the definition of what constitutes a health hazard. Questioning of the W.H.O. limit of 10 g m^{-3} for drinking water must, as with all matters of public health, proceed with cautious evaluation of local and overseas experiences.

6.6 Summary and Conclusions

The Rakaia River is the last of the great South Island East Coast rivers to exist in a virtually unmodifed state. If the LRIS and CPIS go ahead as planned, there exists some doubt about the future of the quinnat salmon run, the wrybill plover, and the vegetation reserve on the river islands. Although there are possibilities for providing more wildlife habitat in the irrigation schemes than has been done previously, there are a number of practical reasons which advise a cautious approach to such endeavours. Furthermore, it is unlikely that the suggested enhancement/mitigation measures would fully compensate for the loss of wildlife in the natural river ecosystem. The following questions are suggested topics for future research:

1. Does the river discharge significant amounts of nutrients to the lagoon and the sea, and if so, how important is this in supporting lagoonal and off-shore fisheries?
2. What are the implications of discharging irrigation scheme water into the Selwyn, Waimakariri, Ashburton or other local rivers?
3. What sedimentation changes are likely to result from abstraction, and will this affect coastal morphology and stability?
4. What specific changes could be incorporated into the irrigation system that would allow the stocking of trout or salmon and/or the development of waterfowl habitat?
5. Are the arthropods of scientific interest found in the Rakaia region likely to be affected by the irrigation proposals?

The present recreational uses of the Rakaia account for much of its current economic worth to the local community. Salmon and trout angling alone are estimated to contribute up to nine million dollars annually to the regional economy. Other river-based recreation, and the value of the River to those who wish to see it preserved in its present state (its "preservation value") could up the annual value to an amount in excess of $12 million. The relevant question, however, is the degree to which the River's amenity value will be degraded by abstracting water for irrigation purposes, and the answer is not readily apparent. Presumably, with careful planning the incremental loss in amenity value can be kept to a minimum. The seasonality of recreational use, and rates of water abstraction, will apparently be a key factor in future water allocation planning and decision making.

The prospect of a successful salmon ranching enterprise also has important planning implications. If present targets for artificially-reared smolt releases are met, by about 1990 gross revenues exceeding $3 million, and possibly as high as $7 million, would accrue annually to a successful venture. This potential benefit to the regional economy could be in jeopardy, however, since the effects of large abstractions during the migratory run (mid to late summer) are not yet known. Predation of the commercially-induced run by sport anglers is also a potential problem for water managers in the future. However, as the value of the sport catch, in terms of expenditure per fish caught, apparently exceeds the market value of salmon as an export commodity, on balance the regional economy would benefit by an improved sport fishery.

Rapid fluctuations in flow, which could leave upstream migrating adults stranded, can also be avoided with careful water management. Irrigation return flows, from either surface run-off or groundwater, can contain pesticides, hormones, mineral salts, and nutrients all of which have an adverse effect on water quality. The possibility of a decline in water quality and its effect on salmon in the Rakaia River requires investigation, as does the potential effect of low flow, including the reduced carrying capacity for released juveniles, decreased quality and quantity of returning adults, and delayed or premature release of juveniles.

Even though the quinnat salmon in the Rakaia River have been, and are still,the target of a large fisheries research effort (Davis, 1982) no firm conclusions as to the impact of proposed abstractions have been reached. More research within the timescale of water allocation decisions will of course clarify some of the likely impacts on the life-cycle of quinnat salmon. But given the dynamic nature of the fishery, the associated instability of the Rakaia River and the 3 to 4 year life cycle of the salmon, firm conclusions (rather than speculation), as to the impact of abstraction on the salmon population, lie many years in the future.

The link between irrigation, intensification of land use and an increase in nitrogen-N levels in shallow groundwater is firmly established on the Canterbury Plains. Thus, irrigation planning should include an appraisal of the long term requirements for potable water supplies. In some areas deep wells may have to be drilled to confined aquifers, while other localities may require water piped in from low nitrate-N level wells. Underlying the use of such sources are the questions of the long term implications of drawoff from deep confined aquifers, especially those from which metropolitan supplies are drawn.

CHAPTER 7

HYDRO-ELECTRIC POWER RESOURCE POTENTIAL OF THE RAKAIA

7.1 Introduction

Thus far, the review has only considered irrigation development and its possible consequences for the Canterbury region. But lesser known (less immediate) developments may be just as important (and controversial) in the longer term. In recognising the Rakaia's potential as a major source of irrigation water, planners have also considered the complementarity of irrigation development and the production of hydro-electric power (HEP).

This chapter reviews the complementary nature of irrigation and power planning for the Rakaia River, and identifies implications for current irrigation planning. The historical background to HEP development planning is briefly outlined, and the proposed HEP scheme options and how they might relate to the CPIS are emphasised. Possible regional development impacts of HEP, including income generation and environmental implications for water allocation and management decisions, are discussed.

7.2 Early Hydro Development

The development of HEP on the Rakaia River preceded major irrigation development of the river by at least 30 years. The Lake Coleridge Power Station, utilising the fall between Lake Coleridge and the bed of the Rakaia River, commenced electricity generation before 1920 with an installed generating capacity of 38 megawatts (MW). In 1926, Lake Coleridge was raised by one metre through the partial diversion of the Harper and Acheron Rivers which flow into the lake. The higher inflow enabled the power station to operate closer to its installed capacity for a greater length of time.

It was not until 1945 with the completion of the Rangitata diversion race, that major irrigation development took place on the Canterbury Plains. The Rangitata diversion race also enabled the first complementary development of irrigation and HEP in the region. In the summer, nearly all of the 28.3 cumec flow in the race is abstracted by the Ashburton-Lyndhurst or Mayfield-Hinds

Irrigation Schemes. Residual summer flows in the diversion race, and most of the race's winter flow, are discharged into the Rakaia River through the Highbank power station. Highbank has an installed generating capacity of 25 MW.

The most recent HEP development on the Rakaia was completed in December of 1977, with the diversion of the major tributary of the Rakaia, the Wilberforce River, into Lake Coleridge. Through a system of gravel banks across the Wilberforce and Harper Rivers, with canals dug between the rivers and also between the Harper River and the Lake, up to 30 cumecs can now be diverted from the Wilberforce into Lake Coleridge. During floods the Wilberforce diversion works may be washed out so periodic maintenance of the gravel banks is necessary.

The primary objective of the Wilberforce diversion was to increase the power output from the Lake Coleridge power station. By increasing the rate of inflow, a higher rate of draw-off for HEP generation could be undertaken, increasing the plant factor[35] of the power station from 0.43 to 0.70. This increase in power generation has been achieved without altering the maximum allowable level of Lake Coleridge (509.6 m), or the allowable range in the lake's level (3.95 m). Two alternative proposals were also considered by the New Zealand Electricity Department (NZED): raising the level of the Lake with a permanent dam across the Wilberforce, and increasing the allowable range in the level of the Lake. Both proposals were rejected because of their major anticipated environmental impacts (NZED, 1975).

Even in its present form, the Wilberforce diversion has been criticised because of its possible environmental impacts, especially those resulting from the alteration in the natural flow of the Rakaia below the confluence of the two rivers. Hardy (1975) presented evidence that the Wilberforce might contribute one third or more to Rakaia flow below the confluence, and was concerned for the safe passage of salmon to their spawning ground, especially to the Glenariffe Stream. Concern has also been expressed over the effect

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[35] Plant factor: the ratio of mean output to installed capacity.

of diverting flood waters from the Wilberforce into Lake Coleridge. Suspended sediments in the flood water could significantly discolour the normally clear lake. Such a situation, if it persisted for any length of time and over a large area of the lake, would be detrimental to the recreational fishery. Sediment discharge into Lake Coleridge from the Wilberforce diversion exceeded the maximum allowed by NZED's water right on 20 percent of the days in 1980 (Bowden, 1982).

Maidment et al. (1980) suggest that beneficial environmental effects have also resulted from the Wilberforce diversion, at least to the reach of the river downstream from the power station. The reason is that more continuous generation from the Coleridge power station during the summer months is producing some improvement in low flows in the Rakaia River.

7.3 Proposals for the Future

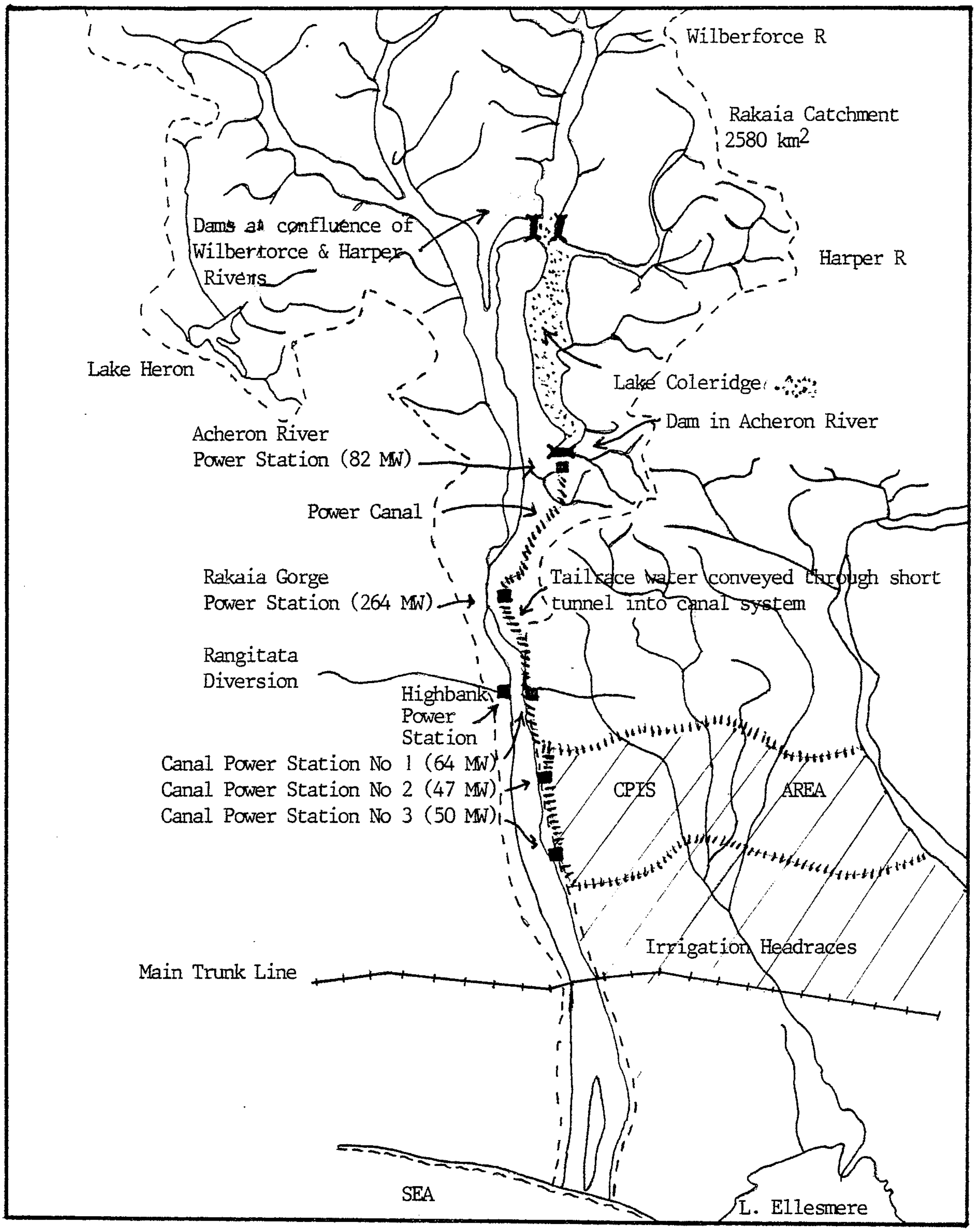
Like the earlier Rangitata diversion scheme, current planning for HEP is based upon its potential complementarity with irrigation. The origins of the most recent HEP proposals are found in the work of the Southern Energy Group (SEG, 1975). The SEG's plans were based on a dam to be built at the confluence of the Wilberforce and Harper Rivers (Figure 7.1). Such a dam would enable almost 50 percent of the catchment's surface drainage to be diverted through Lake Coleridge.

Three potential schemes were formulated to utilise the Lake's storage capacity. Scheme A involved a major rebuilding of the Lake Coleridge power station so it would have an installed capacity of 200 MW. The maximum lake level would remain unchanged, but during the winter the lake would be drawn-down by 18 metres to accommodate spring and early summer peak flow. Scheme B was similar to A except the lake level would be allowed to rise by 12m during the summer, enabling a greater winter draw-down. Scheme C, favoured by the SEG, called for additional dams on both the Wilberforce and Acheron Rivers, thus enabling the level of Lake Coleridge to be raised by 24m.

With Scheme C the present power station siting would be obsolete since the outflow from the lake would occur at the Acheron River

FIGURE 7.1

Illustration of the SEG's Hydro Proposals for The Rakaia River



Source: Southern Energy Group (1975).

end of Lake Coleridge. An 82 MW power station built below the Acheron dam, would be passing water to a canal flowing parallel to the Rakaia River. The capacity of this canal was designed for 170 cumecs, and just below the Rakaia Gorge a 264 MW power station would utilise the drop between the canal and the river. Once through the Gorge power station, the water would either be discharged into the river or passed into another canal for irrigation use and/or further HEP generation. The canal system below the Gorge involved a main canal running along the terraces above the river, and three smaller canals branching off at different contour levels, eventually discharging surplus water into the Waimakariri, Selwyn and other river catchments. Along the main race, three additional power stations would be built, with a combined generating capacity of 161 MW.

The canal scheme was planned so that it could be developed either independently or in conjunction with Scheme C. In fact, the SEG proposals in 1975 anticipated that the canal scheme should be developed as Stage I in an overall plan that left the Lake Coleridge developments until Stage III. In the absence of the diversion of Lake Coleridge water into the canal system, Stage I plans envisaged intakes for the canal at the Rakaia Gorge and at the 230m contour level on the river bed. Of course, without the storage capacity of the Lake and the ability to direct its outflow into the canal system, the potential of the complementarity between irrigation and HEP development would be reduced.

Table 7.1 summarises the maximum annual power output for each of the 1975 proposals. The total development of Scheme C in assocation with the canal scheme would produce 2,852 gigawatt hours (GWh) of electricity, more than ten times the present 226 GWH output. To the SEG, the attractiveness of the additional power generated was accentuated by the proximity of Christchurch, a population centre with a high peak-load demand. Transmitting the additional power to Christchurch not only reduced the cost of erecting transmission lines, but also reduced the unavoidable losses of electricity that occur in power transmissions over long distances. Also, the risk of power failure was lowered compared with transmission from the hydro-schemes further south.

TABLE 7.1

Maximum Annual Power Output From the 1975 HEP Design Alternatives

Proposed Design Alternatives	Power Station Output							
	Lake Coleridge	Acheron	Gorge	Canal No. 1	Canal No. 2	Canal No. 3	Highbank	Total
	In GWh year^{-1}							
Present capacity	137						89	226
Scheme A	942						89	1,031
Scheme B	1,055	421	1,342				89	1,144
Scheme C		421	1,342				89	1,852
Canal Scheme				395	289	316	89	1,089
Scheme C and Canals		421	1,342	395	289	316	89	2,852

Source: Present capacity of Lake Coleridge and Highbank power stations is the average (not maximum) power output over the period 1958-1978, taken from Maidment *et al*. (1980, p. 28). All other data are taken from the scheme estimates calculated by SEG (1975).

In terms of potential gross revenue, an upper bound estimate of 2,852 GWh produced through full development of the Rakaia's potential can be obtained using the price the Christchurch Municipal Electricity Department (MED) pays for electricity purchased from the NZED. The average price paid for the year ended March 1981 was 3.254 cents KWh^{-1}. If it is assumed that this electricity has a ready market at that price, 2,852 GWh would have an annual value of about $93 million. The annual value of the 226 GWh produced without any further development of the Rakaia is currently worth $7.4 million based on the 1981 price.[36]

In 1979, the SEG modified its earlier proposals for the Rakaia River (SEG, 1979). Three major changes in the assumptions upon which the 1975 plans were based necessitated a re-evaluation. Firstly, updated flow data at the Rakaia Gorge revealed a lower mean flow than was previously assumed. Secondly, the irrigation requirements of the proposed LRIS were known with more certainty, resulting in a greater amount of water to be left in the river to meet this demand. Thirdly, and probably most importantly, the assumption of complete control over the Wilberforce River and the associated rise in Lake Coleridge's storage capacity, together with the ability to manipulate the Rakaia River's flow, was found to be not justified to the extent presupposed in 1975.

As mentioned earlier, the NZED rejected the alternatives of raising Lake Coleridge or increasing the range in fluctuation of the lake's level. Instead, the NZED decided to partially divert the Wilberforce into Lake Coleridge using gravel dams and canals. Also, the Lake Coleridge power station was not to become obsolete. Thus, the SEG's 1975 proposals became irrelevant with NZED's decision.

The SEG's modified (1979) proposal was similar to "Stage I" of their 1975 design. Potential intakes for the canals were identified at two sites, the first approximately two kilometres upstream of the Highbank power station. Water would be abstracted from this site along the 238m contour to the top of the North bank terraces. Irrigation water would be diverted across the plains in a canal, and the residual water dropped 30m down the terrace to a 20 MW

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[36] 1 GWh = 1,000,000 KWh

capacity power house. The tailwater would be returned to the river, or if required, taken back along the terrace on the 180m contour to a second irrigation supply race.

A major difficulty encountered with this proposal is inherent in building and maintaining the intake at the 238m contour. At this point the braided river bed is 1.6 km wide, so ensuring the required flow into the intake would be a recurring problem. Also, floods would tend to damage the intake works and create problems due to sediment build-up as now occurs with the Rangitata diversion.

To overcome this potential problem the SEG proposed an alternative site, the Rakaia Gorge. This intake would be built into rock so problems of scour and sediment build-up would be avoided. However, siting the intake at the Gorge would entail longer canal works to carry the abstracted water to the irrigation canals and power station downstream. But the extended canal was recognised as an advantage since an extra power plant (15 MW) could be built upstream of the irrigation canal, and utilise all water abstracted for power generation rather than only the residual water available to the downstream power station.

Given the scaled-down version of the 1975 proposals to which the 1979 plans were restricted, the principle design problem confronting the SEG in 1979 dealt not so much with the siting of the intake works, but with the size of the intake. The bigger the intake (i.e. the amount of water able to be diverted) the larger could be the generating capacity installed in the power plants. Also, bigger intake works would allow for a higher peak irrigation demand, that is, a larger area able to be irrigated by surface water.

The size of the intake works is constrained by the potential allocatable flow, or the difference between the river flow, the minimum flow standard, and the abstraction demand (prior water rights) further downstream. The seasonal minimum flow standards are fixed, as are the majority of downstream abstraction demands. Therefore, the size of the intake and subsequent abstraction for HEP and irrigation development is determined solely by river flow. In the 1975 proposals, the flow of the Rakaia River was to be highly manageable because of the degree of control over water storage in Lake Coleridge. The 1979 proposals were constrained by the absence of such a high degree of control, apart from that afforded by the Wilberforce River diversion.

In identifying the degree of control over the river's flow as the main constraint on both HEP and irrigation development, the complementary nature of the two is reinforced. The SEG, uncertain as to how much control could be exercised over the Rakaia, studied three different-sized intakes (see Table 7.2). Without river control, 100 cumecs could be abstracted, but in the winter when power generation demands are highest, the full 100 cumecs could be abstracted only 22 percent of the time. Fifty cumecs could be abstracted for 80 percent of the time, increasing the plant factor from 70 to 94 percent. Again these figures assume no degree of river control.

TABLE 7.2

Flow Deviation and Plant Factors For Alternative Intake Sizes

Design Alternatives	Size of Intake m^3/S	Percentage of Time Flow Available for Abstraction in Winter percent	Winter Plant Factor percent
1	50	80	94
2	70	50	88
3	100	22	70

Source: SEG (1979). Based on Figure 3 and text of SEG (1979).

So far the discussion has concerned proposals for HEP development above the Gorge and on the north bank of the River. On the south bank, a small scale HEP development is proposed in association with the LRIS (Daniel, 1980a and 1980b). The LRIS, as proposed, will abstract a maximum of 20 cumecs to meet peak irrigation demand. In the winter when irrigation does not take place, water abstraction could continue to generate power for load needs. The distance between the LRIS intake and the return outlet is estimated (Daniel 1980a) at around 3.5 km. Planning for HEP development in association with the LRIS has, however, advanced little beyond this initial recognition of its potential.

7.4 Implications for Regional Water Resource Planning

Proposals to develop the Rakaia's power potential have not received the public attention that the proposed irrigation schemes have, but the implications of HEP development for the region are possibly as important. In the following some of the consequences of HEP development for regional energy policy, the environment and the overall economics of irrigation development are highlighted.

7.4.1 Energy Pricing and Policy The 1979 plan, assuming 70 cumecs were abstracted for two power houses with a combined capacity of 35 MW (the intake design option 2), would generate an additional 242 GWh per annum above that now produced by the Lake Coleridge and Highbank power stations. At 1981 prices, and assuming that a market for this power exists, this extra power is worth $7.9 million annually. In comparison, $85 million worth of additional power could be generated if the original 1975 proposal was implemented.

The SEG estimated the capital cost of the 1979 proposal at about $42 million, or, in terms of a cost per unit, 2.09 cents KWh^{-1} produced. These costs assume that irrigation development would occur and that irrigators would contribute to the capital cost of the intakes and canals. As a single purpose project (i.e. power generation only), the unit cost of the electricity was estimated at 2.26 cents KWh^{-1}. Even so, this is well below the three plus cents KWh^{-1} national incremental cost for providing additional generating capacity (SEG, 1979: 21).

The difference between the price the MED pays for electricity (3.254c KWh^{-1}) and the cost of obtaining further power from the Rakaia (2.09c KWh^{-1}) is 1.164c KWh^{-1}, a significant amount even after inflating the costs to 1981 dollars. If Canterbury could substitute local for national grid electricity at the assumed supply price, the annual savings to households and industry could be of the order of $2 million. The implication is that it might be in the interests of the local power board to undertake the scheme if the NZED did not. The potential savings could actually be larger, especially if the marginal price paid by the MED for winter peak loads was used in the financial analysis.

7.4.2 Environmental and Recreational Considerations As with irrigation development, the environmental and recreational consequences of HEP development are uncertain. Clearly, the most extensive harmful impacts would be associated with the proposed modification to the Wilberforce River and the fluctuating surface levels of Lake Coleridge. Because the proposed development would substantially alter the flow pattern of the Rakaia, if managed appropriately, it is also conceivable that significant enhancement of the sport and commercial fishery could result. On the other hand, a permanent dam on the Wilberforce without a suitable fish pass would eliminate migration up and down that tributary.

The current Wilberforce diversion is not without its environmental draw-backs, particularly the potential for increased sedimentation and water turbidity. Discolouration of the water will have a major impact on food production for the lake's fish, especially in the littoral zone where both food production and vulnerability to silting are the greatest. If the increased flow into Lake Coleridge through the Wilberforce diversion requires a considerable flux in the lake's level, then damage caused to birds nesting on the lake's edge and the littoral zone will have to be balanced against the benefits gained from better control of potentially damaging flood events. Given that the 1979 modified proposals are more likely to be implemented than the earlier plans, the main concerns about environmental impacts will focus on the potential implications of abstraction from a site at or just below the Gorge. Chapter 6.2 and Appendix 4 detail the probable effects of reduced downstream flow on fish and invertebrates.

Unless modifications in the present scheme designs are made with specific regard to the habitat needs of wildlife "at risk", significant abstraction of water for HEP over long sections of the river will likely impose social costs that require "weighing up" against the apparent social benefits. Since HEP development will, in all probability, be associated with irrigation development, and because of its potential for recreational enhancement as well as degradation, planning agencies must also carefully consider the "opportunities forgone" that could result from any given decisions.

Douglass et al. (1979) discuss a number of specific enhancement possibilities. Recreational facilities could be developed in association with water canals and settling ponds, providing fishing, boating, waterfowl habitat and hunting, and picnicking and sightseeing opportunities. An artificial white-water canoe course and similar specialised activities are also possible with controlled water flows. In spite of these recreational enhancements made possible by water developments, it is difficult to see how such proposals could compensate for the loss of fishing and boating opportunities and other amenity benefits that would be associated with a natural "wild and scenic" river resource.

An interesting possibility that has not been seriously studied thus far is the use of the power and irrigation reticulation system as a habitat for salmonid rearing and propagation. The evidence reviewed in Chapter 6 (and Appendix 4) led to the conclusion that "high" as well as low flow conditions were potentially limiting to increased Rakaia salmon stocks. Since water development can exercise some degree of control over natural flows, and in particular the dampening effect of reservoir storage (via large scale HEP development) on flood events, the potential for enhancement of the river fishery could be considerable. Intercatchment transfer of tail water and subsurface return flows could permanently open up the ephemeral (in summer) reaches of rivers such as the Selwyn, thus creating "new" recreational opportunities for sportsmen. New commercial salmon ranching opportunities may also be made possible, especially if canals and settling ponds could be modified to serve a dual role as spawning and rearing habitats.[37]

The visual aspects of the joint HEP and irrigation proposals were also considered by Douglass *et al*. (1979). The intake works, canals, and power stations will have a considerable visual impact on the Rakaia River environs. But with appropriate landscaping, this negative effect might be minimised. A less obvious but important effect is the probable increase in wind-blown silt on and around the riverbed. Such 'dust storms' are already a problem along the river due to the prevalence of strong northwesterly winds over summer, and can only be aggravated during construction of HEP and irrigation works.

7.4.3 Multiple Use Development Economics If irrigation, hydroelectric power and enhanced recreational amenities are joint products in

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[37] See Appendix 4 for a brief discussion of some limitations associated with this possibility.

a water resource development scheme, such a multi-purpose scheme could prove more economically attractive than its single-purpose cousins. The answer lies in the ability to share capital cost. A well-known example is HEP revenue helping to relieve the repayment burden and/or running costs of farm irrigation development. Sharing the expense of costly headworks and structures can make viable certain worthwhile developments that could otherwise not be able to bear the financial burden alone, for example, a major sport fishery or commercial fishery enhancement programme involving both natural and artificial methods.

7.5 Conclusions and Implications

The Rakaia River has been used for the generation of hydro-electric power since before 1920, with the construction of the Lake Coleridge power station. In 1945, the complementary nature of power and irrigation development was demonstrated with the completion of the Rangitata diversion race. Current irrigation proposals for the Central Plains and Lower Rakaia also recognise the potential of power generation. Earlier HEP plans called for a significant degree of control over the storage contained in Lake Coleridge and therefore over the flow in the Rakaia River. Accordingly, the early plans considered a much greater generating capacity and irrigation water supply than the more recent plans which do not require this degree of flow manipulation.

Decisions regarding the scale and design of irrigation for the Central Plains and Lower Rakaia are likely to be made within the next year or two. Decisions regarding power development will likely be postponed to a later date. In the Ministry of Energy's (1980) "Energy Plan", major HEP proposals and their required approval dates are detailed for the period up to 1986, which if approved, would be fully commissioned in 1993. HEP plans for the Rakaia are not included in the 1980 Energy Plan. However, small scale hydro development is an option open to local authorities. On the basis of SEG's findings, this option appears attractive, given the difference between the unit cost of additional power from the Rakaia and the marginal cost of buying peak power requirements from the NZED.

Before firm decisions are made regarding the scale and design of HEP/irrigation developments on the Rakaia, several important areas of research should be completed. In the short term, the on-going research which focuses on gaining a better understanding of the environmental requirements of wildlife whose habitat includes Lake Coleridge should be stepped up. Future studies should concentrate on the environmental implications of storage and flow management that would accompany the various options for joint hydro and irrigation works, emphasising the tradeoffs in recreation and wildlife enhancement and degradation.

An equally important issue deserving immediate study is the potential cost and revenue sharing benefits of multiple use options for Central Plains water development. Of specific interest to planners would be:

1. the potential capital cost savings per hectare irrigated,
2. the incentive of cheaper electricity on the development of groundwater resources in both the CPIS and LRIS area, and
3. the equitable sharing of development costs and project revenues between the irrigation associations and local authorities.

Implicit in these studies would be the optimum timing and spatial considerations of a total water resource development plan for the region.

Obviously, additional research is necessary on the future power requirements of Canterbury. Since South Island HEP developments are likely to continue through the early 1990's, estimates of Christchurch's future power needs are required. If a local authority is to develop the HEP potential of the Rakaia River, it needs to know at the outset how the power will be utilised when it becomes available. This research also needs to consider the increased demand associated with the conversion of coal, wood and oil-fired heaters to electricity, a development which might occur if the apparent reduction in power generation costs were passed on to the consumer, or if the local authority took legal steps to reduce winter air pollution in Christchurch, a major source of which is domestic heating by coal and wood.

CHAPTER 8

AN ANALYTICAL FRAMEWORK FOR REGIONAL WATER POLICY ANALYSIS

8.1 Introduction

Unlike the previous chapters of this report, which reviewed issues and available information on specific aspects or topics in irrigation development, this Chapter describes an analytical approach which attempts to integrate this information into a meaningful form for decision making. It is clear from the broad public interest in Rakaia River planning that a multi-objective analysis framework is needed. Because knowledge of the consequences is not adequate in some important dimensions of the river's use, risk and uncertainty play an integral part in project assessment. The assessment methodology must also be consistent with the institutional framework of laws, regulations, planning procedures and terms of reference (Chapter 3) if it is to aid resource planners and policy makers at the practical level of near and intermediate term decision needs.

In Section 2 an impact assessment framework is outlined and its underlying assumptions are discussed. The assessment framework is applied to the Rakaia planning context in Section 3. The expected impacts developed in previous chapters are summarised, the complementary and competitive nature of river uses are described, and the section is concluded with a brief, preliminary analysis of some alternative water development policy scenarios. The implications to be drawn from the discussion are presented in Section 4.

8.2 Analytical Impact Assessment

The term "analytic" means to employ a method of reasoning, logical and deductive, and "assessment" means valuation in the measurable, comparable sense. Analytical impact assessment is a broad, multi-discliplinary and multi-dimensional approach to the analysis of change, emphasising the quantification and comparability of its consequences. In water resource applications, the approach is necessarily systems oriented in recognition of the complexities that exist in the hydrologic, geologic, biologic, spatial, economic, social, political and other dimensions. This section reviews the basic assumptions and content of an assessment framework for Rakaia River planning.

8.2.1 Time, Resource and Data Limitations Planning never proceeds without the multiple constraints of limited time, funding, expertise and data availability. Accordingly, resource budgets must reflect information and analytical priorities. A useful way to approach the task of identifying priority data and analytical needs is to begin by asking some fundamental questions (after Schramm, 1980)[38]:

1. For whom are we planning?
2. What are the social, economic and environmental concerns at issue?
3. What are the needs of the people to be served?
4. How can these needs be met with or without the proposed developments?
5. What knowledge about the physical, chemical, biological, economic, institutional and other aspects is required to be able to assess the designed function and consequences of the proposed developments?
6. How much detail and accuracy is required for each type of data in order to arrive at acceptable decisions -- what is the range in acceptable error and what are the potential penalties of being wrong?
7. Does the planning framework permit the consideration of a wide range of alternatives to solve observed problems, including those that may fall outside the specific responsibilities of the planning bodies?
8. Will the planning agencies have the expertise needed for multiple objective planning and evaluation procedures, especially in the economic, social and environmental fields?
9. Does the framework facilitate the adaption of plans to changing national, regional and local priorities?
10. Does the framework seek representation of all parties affected by the proposed development?

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[38] Adapted from "Guide to the Planning and Evaluation of Multi-purpose Hydraulic Projects from the Economic, Financial, Environmental and Social Points of View, Organisation for Economic Co-operation and Development, Paris, July, 1978.

11. Does the framework reward initiative and innovation among the members of the technical and management sections of the responsible agencies?

8.2.2 Social Objectives and Beneficial Use Public water resource agencies are required by law in New Zealand to exercise due regard for all beneficial uses in developing natural water. Yet, as discussed in Chapter 3, what constitutes a beneficial use is not made clear by the governing legislation. Rules and regulations promulgated under the 1967 Water and Soil Conservation Act (as amended) are intended to promote "wise use", and the authors interpret this to mean efficient and equitable allocation of the resource in the best interests of society and future generations.[39] Accordingly, predominance is given to considerations of resource use efficiency and distributional aspects in the analytical assessment framework.

Beneficial uses of natural water, and in particular free flowing rivers, take many forms including non-consumptive as well as consumptive (abstractive) uses. Recreation, navigation, and waste disposal are well known examples of instream uses which are beneficial to society, yet because these public goods and services are often not priced in the market place their importance in economic terms is not easily compared with marketed commodities like agricultural produce and municipal services. Instream and abstractive uses are often competitive, and decisions to expand the beneficial use of one results in a trade-off in social welfare. Under the above interpretation of the meaning of "wise use", such allocation decisions require measurement of these trade-offs insofar as that is possible.

8.2.3 A Common Numeraire? Environmental goods, services and amenities are difficult to quantify in dollar terms, and consequently many people are unwilling to accept the idea, even in principle.[40] Too often, economists, in their zeal to find the market value of amenities, end up like Oscar Wilde's cynic, knowing the price of everything and the value of nothing. However, many environmental concerns, if properly evaluated within the framework of societal needs and preferences, are no different than any other set of economic values -- values that fulfill human ends -- which

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[39] Planning Tribunals have so far been reluctant to define beneficial use, especially where "public good" aspects of water use are juxtaposed with development or "commodity goods" (Black, 1978; also see Appendix 2).

[40] As someone said, "We have heard so often than you cannot quantify beauty that we tend to forget that you really cannot quantify beauty".

compete for limited means and available resources. A common measure of value is required, and since development uses, particularly projects which require public tax revenue, are justified on the basis of monetary performance criteria, it follows that quantification of non-market goods in comparable terms would aid decision making.

An Example. The North Canterbury Catchment has at its disposal several means of controlling river water allocations, where users may be in conflict, to promote efficient and equitable use of the resource. In addition to granting and renewing water rights, the primary management tool is the administrative minimum flow standard. Allocative rules based on seasonal minimum flow standards are controversial since the potential gains and losses to society of any set flow rate are not now known. For the Rakaia the essential question is the magnitude of the trade-off between abstraction benefits and instream benefits over the relevant range of proposed withdrawals. One way to better understand the implications of alternative minimum flow standards is to establish the economic value of instream and abstractive uses over this relevant range. An example illustrating the use of economic valuation procedures is reported in Figure 8.1.

The relevant range in river water abstraction is measured along the horizontal axis, and the vertical axis measures marginal (or incremental) social costs and benefits, in dollar terms, associated with any particular abstraction level. The marginal social cost function (MSC) describes the relationship between instream benefits foregone due to incrementally greater levels of abstraction.[41] The marginal social benefit function (MSB) states the relationship between abstractive user values for incrementally greater amounts of water. Provided that instream and abstractive uses are ordered according to priority uses (i.e., the most valued uses first, the next highest valued uses second, etc.) the MSC and MSB functions will be positively and negatively sloped respectively.

Now, suppose that the two different minimum flow standards are under debate, Policies I and II. "Environmentalists" support Policy I because it leaves more water in the river while "developmentalists" support Policy II because it doesn't. Both arguments are valid since the points of intersection of the policy standards with the MSC and MSB curves are "positive" amounts,

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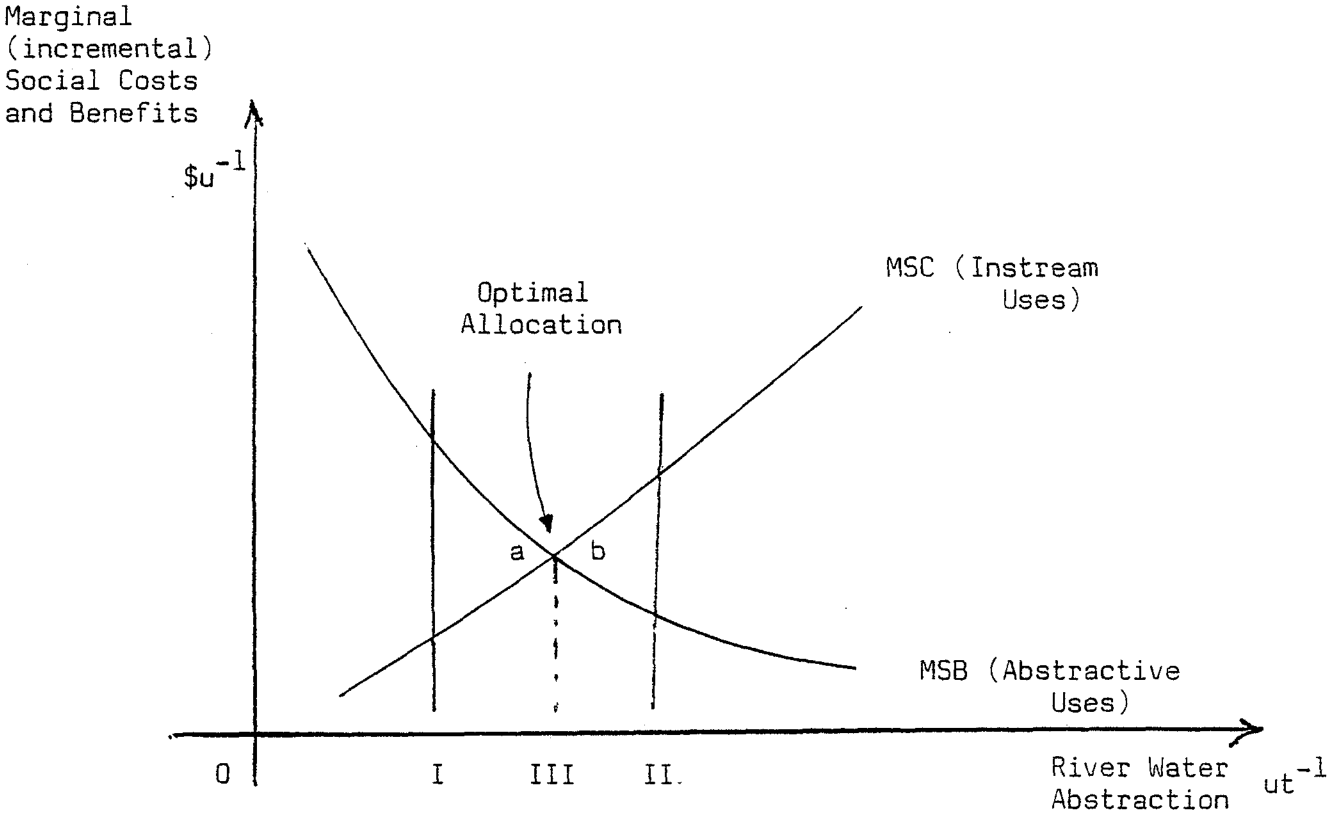
[41] This is also commonly referred to as the environmental damage function.

FIGURE 8.1

Illustration of an Optimal Minimum Flow Standard



Notes: $\$u^{-1}$ is dollars per additional unit of water abstracted
ut^{-1} is units of water abstracted per unit of time, t.
I, II, III = alternative minimum flow standards

indicating that either group stands to gain or lose something depending upon which policy is selected. In the absence of knowledge which enables the estimation of MSC and MSB, it is not possible to assess the social welfare implications of the choice between Policies I and II.

As the example in Figure 8.1 shows, Policy I leads to a net loss in social welfare equivalent to the area labelled "a", where abstractive users are penalised by the standard since the incremental benefits exceeds the incremental cost (MSB > MSC). The reverse effect is shown by area "b" with Policy II, because at that level of abstraction costs exceed the benefits gained by society as a whole. Having this information at their disposal will enable regional water authorities to compare competing uses in common terms, thus it may be possible to identify more efficient and equitable solutions, as suggested by Policy III, to river water allocation problems.

8.2.4 Accounting Stance Many of the differences in decision making settings faced at different governmental levels concern the so-called 'accounting stance' assumed by decision makers; i.e., whose benefits and costs are to be counted when making water development decisions? Some benefits may accrue to persons in the decision maker's own town or county. Others may be spread throughout the region and the nation. Costs may be absorbed partly by the direct project beneficiaries, by the local, regional and national tax payers, or by the parties who are injured by the project without compensation. Irrigation projects, which typically receive a large public subsidy and have generally localised benefits, are likely to be attractive to a local or regional constituency whether or not they make sense from a national viewpoint.

If the project's distributional implications are too inconsistent with the broader national interests, then some changes may be necessary so that the creation of external benefits and costs are rewarded or penalised within the reward structure of the local and/or regional planning framework. Impact assessment procedures require an appropriately broad view concerning the inclusion of benefits and costs over space and time. In addition to distinguishing between local, regional and national effects of water developments as they affect existing population, potential new populations should also be considered to the extent that concerns with future conditions and conditions outside the immediate area are made known to the water planner.

8.2.5 The With - Without Criterion The objective of analysing a prospective project should be to assess the net overall impact or change expected to result if it proceeds. Obviously such an analysis covers more than just the directly measurable economic impacts, and depends upon assumptions made regarding present and future conditions. When confusion occurs in identifying what is to be included as cost or benefit, the with - without guideline is a useful point of reference. This guideline is different from a before and after project analysis, since prior to the project certain trends in yields, prices, population growth, etc., will exist. Irrigation is only one of numerous factors which increase agricultural productivity or shifts rural populations, hence the analyst has a guideline for separating out only those effects attributable to the project. Often in the process of doing this other alternatives (different projects) are identified which might better satisfy some of the intended project objectives.

8.2.6 Assessment Procedures The nature and scope of an impact assessment is largely determined by the complexity of the problem under examination and the need for accuracy. In general, however, there are a number of procedural phases or steps to the assessment exercise. The sequence of steps might be as follows:

1. Develop a profile of existing conditions in the planning area -- assembly and documentation of pertinent statistical and other data, including the definition of the relevant planning area for the assessment of project impacts;

2. Make projections of "without project" conditions -- as the projections should cover the expected life of the project, and because the future is uncertain, a reasonable range in probable effects should be developed;

3. Estimate "with project" impacts and identify the conditions (assumptions) under which they are made -- causative and interactive factors and relationships, and their inter-relatedness with economic, social and environmental objectives should be identified;

4. Identify all significant impacts and quantify to the extent possible -- significant meaning those potential impacts of consequence to the decision-making process, both beneficial and adverse;

5. Evaluate the impacts and conditional assumptions -- in monetary terms as appropriate, quantitatively where possible, and qualitatively in any case;

6. Consider and examine project modifications where adverse impacts are significant -- measures to eliminate or mitigate the impact by reducing its effect to an acceptable level, or by compensating for it with a balancing positive effect;

7. Seek assessment feedback from other sources -- independent of the planning agency(s) directly concerned.

As these steps suggest the process of impact assessment is comprehensive and must be integrated with project planning.[42] The range of economic impacts considered is much broader than a project cost-benefit analysis, and is

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[42] See Appendix 2 for a review and critique of 'environmental' impact assessment procedures in irrigation scheme planning.

focussed on the manner in which these impacts will influence quality of life in the planning region. The process requires many different types of skills and expertise, supplemented with feedback from a variety of sources including direct participation by interest groups and the public. In addition to national economic development (the conventional objective in cost-benefit analysis), regional economic development is of prime importance in impact assessment. Included within the latter (or sometimes dealt with separately) are analyses of population growth and migration patterns, public services and facilities, local authority finance, land use and productivity, and interactions among economic, social and environmental impacts.

8.3 Application to Rakaia River Planning

8.3.1 Summary of Estimated Development Impacts The preliminary estimates of Rakaia River development impacts, reported on individually in Chapter 2 through 7, are summarised in Table 8.1. While indicative magnitudes of regional impacts must always be regarded with scepticism, they are a useful first apportionation of the relative importance of alternative development proposals and the trade-offs that exist between certain present and future uses. These data suggest that present and proposed future uses are both significant to the regional economy, with recreational uses dominating the former and abstractive uses the latter. The irrigation proposals would more than triple (by the late 1990's) the annual direct gross revenue obtained from the river's present uses. The greatest future use in the long term would appear to be the development of the river's considerable potential for hydro-electric power generation. However, this is only a preliminary assessment of possible present and future states; it is not a "with - without" project assessment. What is needed for policy decisions is information about the interrelationships between individual projects and uses, i.e., knowledge of their complementary and competitive nature.

8.3.2 Complementary and Competitive Relationships The discussions in previous chapters of this report highlighted some important potential conflicts (and complementarities) that exist between (and among) the Rakaia use alternatives. An important task for river planning authorities is to identify clearly and weigh up these trade-offs and complementary benefits.

TABLE 8.1

Summary of Indicative Magnitudes of Rakaia River Water Development and Recreation Impacts, Present and Proposed

Current and Future River Water Use	Measures of Regional Economic Impact[1]		
	Gross Revenue ($\$mY^{-1}$)	Income ($\$mY^{-1}$)	Employment (Permanent Jobs)
CURRENT RIVER USES:			
Recreation[2]:			
Direct Impact	4		39
Total Impacts[3]	8.8	2.8	84
Preservation[4]	3	?	?
Lake Coleridge Power[5]:			
Direct Impact	3		14
Total Impact	6.8	1.5	41
Small Irrigation Schemes and Livestock Water[6]:			
Direct Impact	1		9
Total Impacts	2	.3	18
Current Use Totals:			
Direct Impacts	8		62
Indirect Impacts	17.6	4.6	143
PROPOSED FUTURE USES:			
The CPIS and LRIS[7]:			
Direct Impact	30		285
Total Impacts	60	11	570
Commercial Salmon Ranching[8]:			
Direct Impact	3.8		30
Total Impacts	8.4	2.7	100
Electric Power Generation[9]:			
Direct Impact	93		420
Total Impacts	211	46	1,270

[1] Estimates of regional gross revenue (output), household income and employment effects were calculated with the use of sectoral multipliers for the Canterbury region (Appendix Table A3.1)

[2] Refer to Chapter 6.3.1.

[3] "Total" impacts include direct, indirect and induced impacts as defined in Chapter 4.2.1

[4] "Preservation value" is shown separately from recreation (user) value, and does not enter into the estimate of current regional impacts since it is not a direct expenditure.

[5] Refer to Chapter 7.4.1 and row 14, Appendix Table A3.1

[6] Study Team estimate.

[7] Refer to Chapter 4.5.

[8] Refer to Chapter 6.4.1. The secondary impacts were estimated from line 2, Appendix Table A3.1

[9] Refer to Chapter 7.4.1. The figures shown are those for the maximum power generation option.

An initial attempt at identifying some of these interactions and how they might be analysed is outlined below.

Some Important Interactions. The preservation of the Rakaia in its present state for the enjoyment of future generations is obviously at odds (denoted by "–") with almost any form of commercial development. The LRIS, considered in isolation of the other proposals, is not expected to interfere significantly (indicated by "?") with instream uses since the proposed abstraction, 20 cumecs, should not materially alter the natural low flow regime. On the other hand the CPIS, at 70 cumecs, could markedly affect the flow regime, and therefore, by itself or in combination with the LRIS, creates a potentially important trade-off situation with respect to instream uses, including commercial salmon ranching. HEP development is complementary (denoted by "+") to the CPIS since the headworks and main canal system could serve a dual purpose. If a constraint is imposed on the level of water abstraction via the North Canterbury Catchment Board's Water Management Plan (WMP), then it is possible that the LRIS and CPIS will have to compete for available abstractable flows, especially in the latter part of the irrigation season. Finally, recreational angling stands to gain from a successful commercially-induced salmon run, but at the same time the economic viability of salmon ranching is also dependent upon the extent of the recreational harvest.

An Analytical Approach to Assessment. A more detailed analysis of water use trade-off and complementary relationships is clearly warranted. Following on from the interactions shown in Table 8.2, the next step is to consider some alternative approaches that could avoid or reduce the expected negative impacts while at the same time preserve the positive or intended beneficial effects. This idea is conceptually illustrated by the idealised policy analysis/analytical framework shown in Figure 8.2.

Analytical policy analysis is based on an empirically and theoretically sound system of inter-relationships, models of cause and effect. For Rakaia water management planning, this means constructing a set of interrelated physical models of the groundwater and surface water systems, the hydro-biological system, and the appropriate linkages between these and the economic and social system framework required for analysis of policy or development alternatives. With such a planning model, alternative

TABLE 8.2

Complementary and Competitive Interactions Between Present and Proposed Rakaia River Water Uses

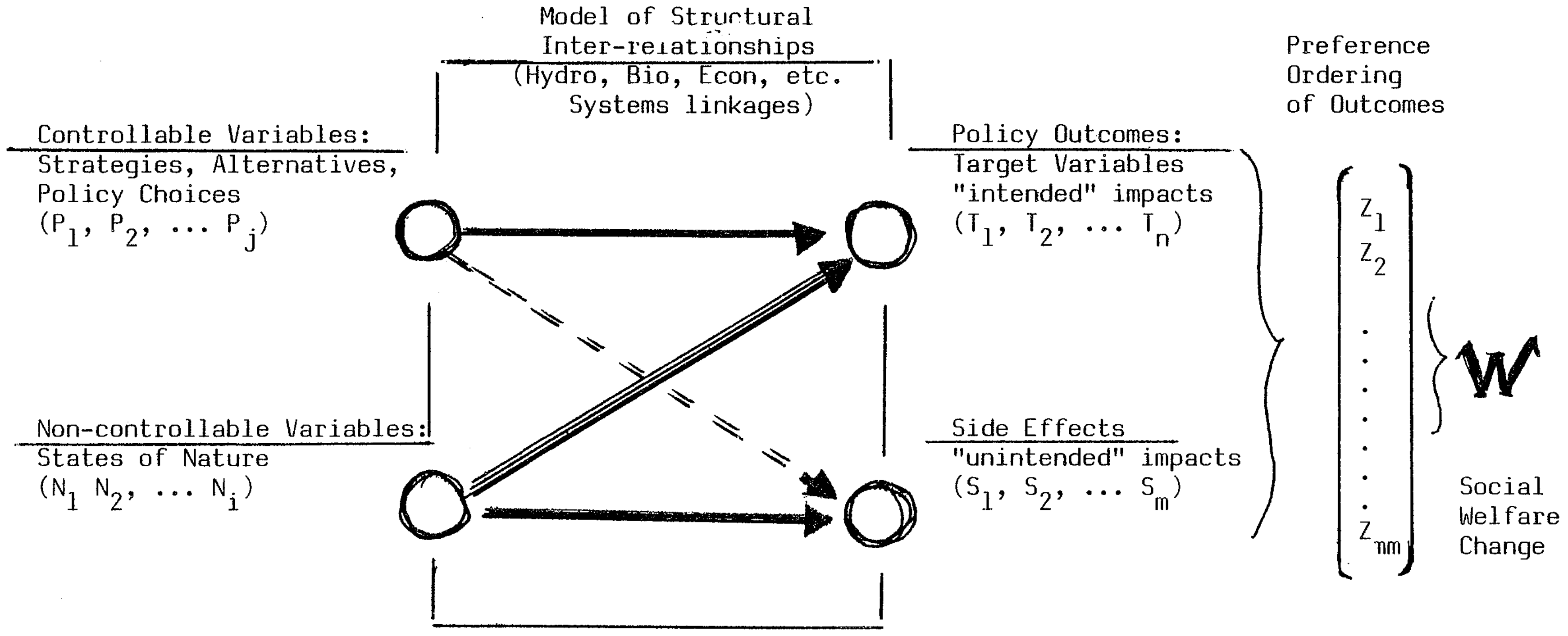
River Use	Proposed Future Uses			
	Salmon Ranching	LRIS	CPIS	HEP
	--- Interactions[1] ---			
Current River Uses:				
Preservation	?	-	-	-
Angling	+/-	?	-	-
Power Boating	0	?	-	-
Streamside Recreation	0	?	-	-
HEP (Coleridge)	0	0	0	?
Irrig/Stock water	0	0	0	0
Proposed Future Uses:				
Salmon Ranching		-	-	-
LRIS			-	-
CPIS				+

[1] Interactions indicate the probable positive and negative impacts that the proposed future uses will have on current and future uses. Complementary (+) indicates mutual benefits, competitive (-) indicates a negative impact, (?) indicates a possible negative impact, and (0) no apparent impact.

management policies or development scenarios (P) can be appraised in light of the intended (T) and unintended (S) consequences that might result from the adoption of a particular policy choice, subject to a common evaluative standard or preference ordering of social goals (Z). The risk associated with uncontrollable factors such as climate and world markets (N) must also be considered if the model is to yield reliable results. The overall objective of the analytical approach to policy formulation and analysis is to provide decision makers with recommended courses of action expected to lead to an improvement in social welfare (W).

FIGURE 8.2

Analytical Structure of Policy Analysis



Although the use of such a framework is beyond the near term planning horizon of regional and national water agencies, research work currently underway will contribute to the development of many of the necessary structural relationships within the next several years. A partial listing of some relevant on-going research is reported in Appendix 5. Some useful overseas studies which report results of practical applications of the approach to river water management include Doubert and Young (1981), Burt (1974), Noel et.al. (1980), Parker and Penning-Rowsell (1981), Buras (1963), Russell (1975) and Schramm (1980).

For the present, however, planners and decision-makers have to consider policy choices in the absence of full knowledge about the consequences. The interactions between present and future use options summarised in Table 8.2 provide a useful basis for considering some alternative management approaches, even though the incremental gains and losses cannot be quantified. By adopting the safety-first principle, it is possible to identify several approaches or management scenarios that reduce the risk of an irreversible negative impact without appreciably altering expected project benefits. For example, if Policies A and B yield about the same level of expected target benefit, and the risk of harmful side-effects is higher for A than B, then Policy B is the preferred choice. Policy A would only be chosen if the reduced risk of a negative impact is unacceptably large in terms of the expected benefit foregone.

8.3.3 Toward An Integrated Assessment of Water Planning Alternatives

Using the potentially competitive relationship thought to exist between instream and abstractive uses as a focal point, a number of different policy scenarios were identified as worthy of closer examination. Consistent with the idealised analytical policy analysis framework (Figure 8.2), the objective is to search for an optimum mix in river water use.

Some Development Scenarios. The following ten scenarios were used to illustrate how the trade-offs and complementarities might be formulated for a more systematic analysis:

1. No development -- a preservation option consistent with the "Wild and Scenic" Amendment to the Water and Soil Conservation Act (refer to Chapter 3.3 and Appendix 2). While preserving the river in its present state, society would bear the opportunity costs of non-development;

2. Proceed with the irrigation scheme as proposed under the Catchment Board's present Water Management Plan (WMP) -- no further consideration given to design alternatives or inter-relationships between the two schemes, or to other future uses of the river;

3. Adopt a programme of optimal irrigation scheduling, on- and off-farm, under 2 above. Improved water management can be expected to increase scheme operating costs but reduce water losses and increase irrigation efficiency, hence achieve higher gross revenues per hectare while requiring less water diverted from the river. Depending on what amounts of water prove optimal to apply over the irrigation season, the scheme areas, as proposed, would either increase or decrease in size;

4. Raise the minimum flow standard under 3 above -- a direct measure to retain more water in the river during periods of natural low flow and high irrigation demands;

5. Develop the LRIS as a groundwater-dominant project under 4 above -- this would reduce the river-supplied portion of the LRIS in favour of the CPIS, possibly achieving a greater total irrigated area with the same or a lesser amount of water abstracted from the Rakaia;

6. Install fish screens on intake structures to limit losses of migrating smolts within the irrigation distribution system -- a policy of mitigation under 5 above;

7. Provide compensation, as appropriate, to restore fish stocks to pre-project levels under 6 above -- this would most likely take the form of a facility to artificially propogate and rear salmonids to balance the decline in wild stocks, if that should occur;

8. Develop a multiple-use scheme with objectives of fishery enhancement and irrigation -- this approach would entail additional structures, major design modifications and more sophisticated water management than envisioned under 7 above. The increased fish stocks, i.e. above pre-project levels, would be available for commercial development or recreational use, or both. Cost- and revenue-sharing considerations in a joint commercial development could prove mutually beneficial to both abstractive and instream users;

9. Develop an expanded multiple-use project including run-of-the-river hydro-electric power with 8 above -- to capitalise on the potential cost-sharing benefits of developing a common river diversion structure. In addition to cost-sharing advantages to both water development schemes (CPIS and HEP), further possibilities are created for salmonoid enhancement; and

10. Develop a comprehensive water development scheme incorporating reservoir storage -- basically a "full-blown" multi-purpose regional development project centred on the Rakaia River Catchment. Lake Coleridge storage affords the opportunity to better utilise flood waters and manage residual river flows. High quality lake water diverted through the irrigation canal system, or in separate channels, would open up new possibilities for creating salmonoid spawning and rearing habitats. Power revenues resulting from the scheme could be used to partially defray irrigation operating and maintenance costs, as would a successful commercial salmon ranching venture developed as part of the overall scheme. However, environmental impacts are likely to be aggravated due to the fluctuation necessary in Lake Coleridge, and because a greater area of land will be potentially irrigable with the additional water made available, exacerbating the problem of rising water tables and attendant drainage and nitrate pollution hazards in areas situated below the project.

These brief scenarios obviously exclude many other possibilities that could be considered. The first, third and fourth are examples of non-structural measures that could reduce the risks of injury to instream river users. The remainder are structural (and potentially more costly) changes or modifications, with the last three (scenarios 8 - 10) looking to opportunities of enhancing the Rakaia salmon fishery as a joint product of water development.

A Preliminary Evaluation. The criteria to be used in examining the scenarios and in comparing outcomes are important also and should be carefully thought out. In fact, the selection of appropriate impact assessment criteria often suggests further options to consider that might otherwise be overlooked by design engineers, regional planners, economists, sociologists, and others involved with the assessment. Drawing upon earlier discussions, in particular Chapter 4, 5 and 6, four broad types of impact are necessary for inclusion in a multi-objective analysis:

1. The effects on irrigation water users, to include the areas likely to be serviced by the schemes, the repayment and annual servicing obligations, and the expected benefits to be gained in terms of increased productivity and net income;

2. The effects on present and future water uses of a commercial nature, including the economic viability (profitability) of salmon ranching and hydro-electric power generation;

3. The effects on recreational and environmental interests, including salmon and trout angling (a significant activity in terms of local retail trade at present), and the potential social costs of losing natural habitats to support native animal and plant species, and abatement of "unintended" drainage problems and human health risks associated with large-scale irrigation; and

4. The effects on rural communities situated near or within the project areas, most importantly the employment opportunities created by the schemes and the possible destablising impacts of a sudden influx in population, during the construction phase, on local services.

Clearly, the above concerns are an over-simplification of the range of impacts that may eventually concern Rakaia water planners. They were chosen as possibly being of immediate interest in current plan formulation, particularly with regard to the granting of water rights and the setting of minimum flow standards. Without knowing more precisely what the quantitative outcomes are likely to (or could) be, some preliminary indications of how the ten different policy scenarios might impact on the Canterbury region are illustrated in Table 8.3.

As an extension on the apparent trade-offs identified in Table 8.2, the purpose of Table 8.3 was to show how regional economic, social and environmental impacts might be arrayed to analyse a range of alternative development and/or water management policies. The illustrated positive and negative signs can be interpreted as the direction of change for each of the impact criteria listed across the top of the table for an incremental change in policy moving down through the sequence of scenarios. At the

TABLE 8.3

An Assessment Matrix to Evaluate Regional Economic, Social and Environmental Impacts of River Development and Management Alternatives

	Irrigation Impacts					Other Development Impacts					Recreation and Environmental			Social Impacts	
	River-Supplied Irrigated Area[1]		Scheme Capital & Operating Costs	Scheme Profitability		Salmon Ranching[2]		HEP Profitability[3]			Salmon Angling Expenditure[4]	Native Wildlife Habitats[5]	Drainage, Nitrate Hazards[5]	Job Creation[6]	Fiscal Autonomy of Local Authorities Construction Phase
	LRIS	CPIS		Gross Revenue	IRR	Capital & Operating Costs	Gross Revenue	Capital & Operating Costs	Gross Revenue	IRR					
1. NO DEVELOPMENT (i.e. PRESERVATION)															
2. Develop CPIS and LRIS as proposed under current WMP							-				-	-	-	+	-
3. (2) with optimal irrigation scheduling	?	?	+	+	+		+				+	+	+	+	
4. (3) with an increased minimum flow standard	-	-		-	-		+				+	+	+		
5. (4) with a LRIS Groundwater-dominant plan	-	+	-	?	+		+				+	+	+	+	
6. (5) with mitigation of "intake" fishery losses			+		-		+				+			+	-
7. (6) with compensation for "downstream" fishery losses			+		-		+				+	+		+	-
8. (7) with major fishery enhancement efforts	-	-	+	-	-	+	+				+			+	-
9. (8) with 'Run of River' HEP/CPIS development			-		+	-	+	-	-	+	+	?		+	-
10. (8) with Lake storage HEP/CPIS development	+	+	-	+	+	-	+	-	-	+	+	-	-	+	-

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[1] Excludes irrigation areas developed from groundwater sources.

[2] The indicated effects apply to salmon ranching in general, and are not meant to imply the expected conditions for an individual firm. In particular, the impacts associated with development/management alternatives No. 8-10 are based on the possibility of a publicly-owned salmon ranching venture as facilitated by this level of water resource development

[3] Assumes that the HEP development scheme is a 'stand close' project which seeks to maximise power output. This project becomes relevant to the irrigation development alternatives under scenarios No.s 9 and 10.

[4] Excludes jet boating, streamside activities and other recreational expenditures apart from salmon and trout angling.

[5] Obviously difficult to identify or measure -- could be completely wrong about these relationships (refer to Chapter 6.2 and Appendix 3).

[6] Sustainable new employment opportunities in the long term.

[7] The likelihood that "boom-town" conditions prevail in the construction phase: a stimulation of local economic activity without the tax revenue base to support the additional demands on social services (health, education, communication, sanitation, amenities, etc.)

present time only indicative +'s and -'s are possible with respect to likely inter-relations between given policy choices and probable outcomes. Overall, this analysis suggests that there is considerable scope for avoiding losses to the recreational fishery (and commercial fishery development interests) with the use of non-structural means, but also due to options in the structural design of the development proposals.

Non-structural options which can have an important mitigating effect on fishery impacts include irrigation scheduling and the setting of higher minimum flow standards. Structural options include a range of possibilities for avoiding detrimental impacts on instream uses, from the installation of fish screens at nominal cost to irrigation scheme development to the construction of fish hatcheries and rearing facilities at considerably greater expense. Structural changes create the possibility of a fishery enhancement policy, to include the commercial development of a salmonoid fishery as an integral part of the irrigation scheme. Because of the improved water quality of reservoir storage releases made possible by the HEP development of Lake Coleridge, fishery enhancement possiblities are considerably improved over the non-storage development options.

Apart from some potentially severe environmental impacts associated with modifications to Lake Coleridge, comprehensive Rakaia River planning would appear to pay substantial long term dividends as opposed to incremental development planning on a project by project basis. Moreover, if the interactions and directions of change depicted in Table 8.3 are generally sound, then a safety-first planning philosophy[43], which purposely avoids irreversible decisions where possible, would seem to be an appropriate policy stance in the near term. It should be stressed that this inference is not based on environmental concerns alone, but also, and perhaps even more importantly, on the economic and social implications of future water development opportunities.

8.4 Summary and Conclusions

The current economic importance of the Rakaia River is attributed to its salmon and trout fishery as a source of angling and related boating recreation, small scale hydro-electric generation and limited abstractions

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[43] Also known as the "mini-max" criterion -- minimising the chance of a maximum future loss (See for example Randall, 1981).

for irrigation and livestock water. The river is also a considerable 'store of value' in terms of its potential use for large scale irrigation/ hydro power development and for commercial salmon ranching. Planned consumptive uses, primarily agricultural, pose a risk to future recreational enjoyment through altered seasonal flows and its possible negative impact on fishery and wildlife habitat, a similar risk to potential salmon ranching activities, and other possible environmental impacts including alteration of the coastal zone sediment balance, raised water tables and ground-water pollution. Abstraction could also be beneficial to one or more of these concerns. The resulting future impacts are poorly understood at the present time.

Integrated planning should account for all potential benefits and costs that may result from proposed actions and non-actions. Environmental consequences are an integral part of this assessment. Consequently, environmental planning, like social and economic planning, must be built into the overall planning framework. Even if environmental issues are set apart from other socio-economic concerns because their consequences are less readily apparent in the early stages of scheme designs, it is essential that preventative measures are addressed before implementation begins. This is especially important with a large project like the CPIS.

Analysing the development proposals within a multi-objective and multi-dimensional assessment framework is a useful guide to rationalising water use in the regional and national interest. As a result of this preliminary assessment the exigencies of the water management problem were brought into a clearer focus, and some useful development and policy alternatives were identified. The assessment framework also facilitated an initial appraisal of some concrete planning scenarios designed to minimise conflicts of interest in water allocations, and to maximise the potential future benefits from development. Overall, the results suggest a prudent path to be followed in near term decision making. Rakaia River water planning is not as simple as finding the courage to decide to trade-off $ X million in recreation benefits for $ Y million in irrigation benefits. With additional research and time it may be possible to "Save the Rakaia", as the car stickers proclaim, for the mutual benefit of all concerned.

CHAPTER 9

ASSESSMENT OF RESEARCH NEEDS AND PRIORITIES

9.1 Introduction

This chapter briefly summarises the identified research needs which are discussed more fully in the conclusion sections to each chapter, and reports on the Study Team's views on their relative importance. Priority research topics were decided on the basis of several different criteria in an effort to present a balanced view of the information needed for improved water allocation and planning decisions. The senior author accepts responsibility for the final ordering.

9.2 The Research Needs Identified

As pointed out in the Introduction (Chapter 1) the authors did not attempt an exhaustive review, but rather a reconnaissance-type examination of the issues (present and emerging) and the gaps in knowledge that must be filled to deal effectively with them. Due to time and resource constraints, no doubt some of the issues and data sources were missed. It is, therefore, important to recognise at the outset that the following listing of research needs is necessarily a partial one.

9.2.1 Relating to Current Irrigation Plans The discussion in Chapters 2 and 3 highlighted a number of areas where additional research would be worthwhile. As they now stand the proposals appear to be only marginally beneficial from the national viewpoint. The overall economic performance of the schemes might be enhanced with completion of the following studies (not in order of priority):

I1 Analysis of the marginal (incremental) value of irrigation water and its optimal allocation (conservation) when water is in short supply: (a) on a seasonal basis and (b) the legal and institutional arrangement to accomplish this;

I2 Analysis of land use potentials and constraints to higher-valued production enterprises in the irrigation scheme areas;

I3 The "economic limits" to groundwater abstraction in the nominated scheme areas;

I4 The "opportunity cost (or value)" of groundwater development in the LRIS vs CPIS at alternative specified minimum flow standards for river water abstraction;

I5 Further analyses of optimal scheme design based on "alternative" water supply delivery systems and project area serviced;

I6 The optimal conjunctive use of surface and groundwater treating the LRIS and CPIS as "one plan";

I7 Sensitivity analysis of cost-sharing and financing arrangements on private irrigation benefits and the rate of on-farm development (from Chapter 3); and

I8 An update and refinement of the regional production, income and employment multipliers for use in appraising secondary impacts (from Chapter 4).

9.2.2 Relating to Social and Demographic Concerns The paucity of sound baseline data upon which to assess and monitor social and demographic changes brought about by irrigation development is a major handicap at the present time. On the basis of the available data reviewed in Chapter 5, several important gaps in knowledge could be filled with the following research activities:

S1 Review of current irrigation projects to gather cross-sectional and time-series data needed for future "pre-project" impact assessments;

S2 Collection of primary data via farmer and local community surveys to establish baseline socio-economic and additional information for monitoring impacts;

S3 Analysis of "local resource capacities" and the ability of rural communities (and the region) to cope with and/or take advantage of large-scale irrigation development and the associated growth opportunities; and

S4 Assessment of implications of local (regional) resources on the rate of irrigation development and the "retention" of benefits in the region, particularly during the construction phase.

The complimentarity of the recommended studies I8 and S3 and S4 is noteworthy since one of the major limitations of input-output (I/O) analysis, namely accurately quantifying the "leakage effects" between regions or between the impacted region and the nation, can be addressed directly in a co-operative research effort involving demographers, sociologists and economists.

9.2.3 Relating to Recreation and Preservation of Amenities These are the least known implications and for this reason considerable research work is urgently needed on several fronts. Again, without listing them in order of priority, the following studies are recommended (Chapter 6) on the environmental issues associated with irrigation:

E1 The implications of flow modification on hydro-biologic change in supporting habitats for river-based life forms (i.e., to augment current research programmes in the physical sciences notably the FRD and Wildlife Service ongoing studies of the Rakaia River);

E2 The economic implications of river flow modification on the viability of commercial salmon ranching;

E3 The recreational impacts (adverse and beneficial) of the irrigation proposals, and for significant changes in the proposals designed to enhance recreation benefits (see E9 below);

E4 The implications of "endangering" animal species at risk due to irrigation development, for example, the Wrybill Plover and the Black-fronted Tern;

E5 An appropriate "instream value charge" (or penalty cost) to be accounted for in terms of the socio-economic benefits foregone due to irrigation (or any other development) "as a means of" rationalising water allocations between competing uses;

E6 The human "health effects" of possible nitrate pollution of groundwater resources resulting from irrigation development;

E7 The economic and environmental implications of drainage implications resulting from sub-surface irrigation return flows, to include: (a) the possible requirement of a permanent opening to Lake Ellesmere and the resultant effects on preserving the lake's character as a "wetland" resource; and (b) the recharge of aquifers for eventual use by pump irrigators situated below the river-supplied areas;

E8 The long-term implications of modifications in water return flow points on erosion of the Canterbury coastline; and

E9 The economic implications of "joint use" of the irrigation development works to enhance the existing salmonoid fishery, i.e., a multiple product (use) development scheme: (a) on a seasonal basis and (b) the legal and management requirements necessary to accomplish this.

9.2.4 Relating to Longer-Term Water Resource Development Options

On the basis of the findings in Chapter 7, it was argued that almost all plans to allocate water from the Rakaia should take future energy development into account. The implications of water storage and the potential of power revenues in the long term are so considerable that near term water resource allocation decisions take on ominous importance. This is because present water resource planning decisions can lead to irreversible consequences for (inflexibilities in) future decisions, and in the case of the Rakaia both preservation and development interests may be "at risk". The following research topics would substantially improve understanding of the potential gains that may be associated with longer-term plans for water resource development in Canterbury:

H1 The environmental implications and "trade-offs" in using Lake Coleridge storage to satisfy instream and irrigation needs downstream;

H2 The potential benefits and costs of intercatchment water transfers, emphasising the addition of Rakaia water to river systems with ephemeral flows;

H3 The fishery enhancement potential (both commercial and recreational) of using reservoir releases to assist in habitat modification and other means to benefit recreational, preservation and developmental water uses: (a) on a seasonal basis, and (b) the legal/institutional/management requirements to accomplish them;

H4 The potential cost savings per hectare of irrigated land (hence scheme profitability) of joint headworks development for irrigation and power production;

H5 The economic benefits to farmers and local (rural) communities of having power revenues to assist with financing irrigation and other productive developments;

H6 The socio-economic and health effects of a relatively less expensive energy resource (electricity) made available for use in urban communities (for example in Christchurch) where air pollution from fossil fuels is a problem; and

H7 The regional industry growth and foreign exchange (national) stimulus of additional electrical power, and the tourism potential created by multiple use water resource development emphasising enhancement of the sport fishery.

9.3 Criteria Used to Set Priorities

Establishing priorities for future research is necessary since the water agencies and funding institutions concerned face time and budget constraints, and because individual studies may differ in their importance for achieving a resolution of the larger problem. Furthermore, a single criterion for ranking research needs may not be appropriate since the nature of the studies required varies from immediate problem-solving policy-type research to more basic research which will realise benefits only over the longer-term. Accordingly, research priorities should reflect a balance of interests and social needs both present and future.

In establishing the relative importance of individual issues and areas of study the Study Team considered the following criteria:

1. Urgency - How important will the answer be to the upcoming Tribunal hearing regarding water rights?
2. Importance - What is the likely impact on the overall (net) benefit to the region if the irrigation proposals were to proceed as planned?
3. Revocability - In the absence of better information, are the consequences of an impending decision potentially irreversible?; and

4. <u>Cost of Information</u> - Over what timeframe and at what costs can the necessary information be obtained?

9.4 Research Priorities for the Future

The results of the Team's assessment are summarised in Table 9.1. To illustrate how these were obtained some examples may be helpful.

<u>Example 1</u>. How will farmers be affected in the event that irrigation water is withheld at certain times during the irrigation season (recommended study I1)? This topic deserves <u>high</u> priority emphasis in future research since:

1. This will be a key argument in the amount of abstractable water required to justify project benefits in the upcoming water right hearing -- it is <u>urgent</u>;

2. The level of water stress that might occur at a critical stage of plant growth could materially reduce crop and livestock output -- it is <u>important</u>;

3. Although water rationing between farms is always possible no matter how severe the cutback, an efficient or optimal allocation policy is yet to be determined -- although such implications on the amount of water abstracted are <u>not irrevocable</u>; and

4. Given the available data and methodologies for examining the problem, an answer should be readily forthcoming without any major expenditure of additional resources and time -- the <u>cost of information</u> should not be too great.

<u>Example 2</u>. Social and demographic baseline data collection (recommended study S2). This research is not <u>urgent</u> in the sense that the results will not affect the outcome of a water right Tribunal hearing, but its potential <u>importance</u> in assessing the future impacts of irrigation development on local communities should be clear since a sound data base does not now exist to do this. Further, the <u>costs</u> of gaining benchmark information are reasonable, but unless the study is implemented in the near future an adequate pre-project "baseline" may not be possible to obtain -- it is an <u>irrevocable</u> decision. On the basis of the above reasoning this study was also rated "high" priority.

TABLE 9.1

Summary of Priority Research Needs in Support of Future Decisions Regarding the Development of Rakaia River Water for Irrigation

Recommended Studies:		Overall Priority Ranking	Considerations in establishing research priorities:				
ID	Topic		Urgency?	Potential Importance?	Revocable?	Cost of Information?	
						Expenditure[1] $	Time
I1	Intraseasonal Water Values	High	Yes	Major	Yes	7,000	3 mo.
I2	Irrigation land use*	Moderate	Some	Major	Yes	15,000	1 yr
I3	Economic limits to groundwater	High	Some	Major	Partially	15,000	1 yr
I4	Opportunity Costs of groundwater	High	Yes	Major	Partially	30,000	1 yr
I5	Optimal scheme water supply	High	Yes	Major	Partially	15,000	1 yr
I6	Conjunctive use under "one plan"	Moderate	Some	Major	Partially	60,000	2 yrs
I7	Cost sharing and finance effects	High	Yes	?	Yes	5,000	3 mo.
I8	Refinement of secondary impacts	Low	Some	Minor	Yes	7,000	4 mo.
S1	Review of ongoing irrig. projects	Low	Some	Minor	Yes	10,000	1 yr
S2	Baseline data surveys (social)	High	Some	Major	No	20,000	1 yr
S3	Assessment of 'local' resources	Low	Some	?	Yes	20,000	9 mo.
S4	Regional development 'leakages'	Low	No	?	Yes	15,000	9 mo.
E1	Hydro-biologic-habitat relations	Moderate	Yes	?	No	?	2+ yrs
E2	Commercial salmon ranching	High	Yes	Major	Partially	10,000	6 mo.
E3	Recreational impacts	High	Yes	Major	Partially	20,000	1 yr
E4	Endangered species	High	Yes	?	No	20,000	1 yr
E5	Instream values	Moderate	Yes	Major	Uncertain	30,000	2 yrs
E6	Drainage problems	Moderate	Some	Major	No	?	3+ yrs
E7	Human Health Implications	Moderate	Some	?	Partially	?	3+ yrs
E8	Coastal erosion	Low	No	?	Uncertain	?	?
E9	Fishery enhancement prospects*	High	Yes	Major	Uncertain	20,000	1 yr
H1	Coleridge storage	Moderate	Some	major	Partially	?	?
H2	Intercatchment transfers*	High	Yes	Major	Partially	20,000	1 yr
H3	Fishery enhancement from storage*	High	Yes	Major	Partially	20,000	1 yr
H4	Cost sharing with HEP	High	Some	Major	Yes	10,000	3 mo.
H5	Revenue sharing with HEP	high	Some	Major	Yes	10,000	3 mo.
H6	Benefits of additional electricity	Low	Some	Major	Yes	20,000	3 mo.
H7	Regional development benefits*	High	Yes	Major	Yes	30,000	18 mo.

* Reconnaissance-level investigations, primarily aimed at "orders of magnitude" rather than precise estimates.

[1] Indicative research budgets. By combining certain study topics into a single investigation the 'cost of information' can be substantially reduced in most cases.

Example 3. A potential externality of irrigation is rising water tables as a result of sub-surface return flows (recommended study E7). The external effects (i.e., the unintended consequences outside the irrigation scheme) can be detrimental if it causes a drainage problem, or beneficial if it results in an additional supply of water to established (and future) irrigators who rely on pumping from aquifers. In the present instance both possible effects are important (or at least potentially so), but not necessarily urgent to resolve before the water right hearing. The resultant impacts are nonetheless potentially irrevocable, as once established major irrigation schemes are not likely to be closed down. The costs of obtaining the needed information to assess all of the possible impacts are likely quite large. For these reasons this area of research is rated a "moderate" priority.

The recommended studies accorded a "high" priority tended to be those considered most urgent and with a shorter timeframe for completion (typically within one year or less). Studies with a perceived major future impact but which could only be accomplished with a considerable research effort (i.e., large budgets and two or more years for completion) tended to receive a "moderate" priority ranking. With few exceptions, "low" priority studies were those considered less urgent and/or having less potential impact on the overall outcome of near-term water planning decisions. However, all of the studies identified by the Review Team are important otherwise they would not have been recommended in the first place.

To accomplish all of the recommended research would likely require a programme budget exceeding half a million dollars over the next three to five years. As they now stand, the identified "high" priority projects would require a funding appropriation of about $250,000. It is abundantly clear that perceived research needs must somehow be ranked in order to compete successfully for limited public funding allocations. The criteria used to rank the "candidates" represent a balance of interests, and therefore should be a useful guide to the agencies of government responsible for water planning and management. A partial listing of ongoing studies by the North Canterbury Catchment Board and the Canterbury United Council, and how these relate to the recommended areas of research above, is reported in Appendix 5.

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APPENDICES

APPENDIX 1

FLOW DURATION ANALYSIS OF THE RAKAIA RIVER OVER SUMMER

The flow of the Rakaia River over the summer months (December, January and February) is critical in the analysis of the conflicting demands for the Rakaia's water. This three month summer period coincides with both peak irrigation demands downstream of the gorge, and the salmon run passing through the Rakaia gorge. Clearly, if the river's flow over summer is less than that required to satisfy both demands, then either one or both alternative uses of the water must accept a supply shortfall and, as a consequence, incur the economic or environmental cost associated with it. The objective of the analysis was to produce duration curves for:

1. the abstractable flow from the Rakaia River over summer,
2. the residual flow from the river, and
3. the number of consecutive days of low-flow conditions.

Assumptions

The analysis assumes a peak irrigation demand of 70 cumecs for the CPIS and 20 cumecs for the LRIS. The abstraction demands are subjected to a number of alternative minimum flow standards under the North Canterbury Catchment Board's (NCCB) Water Management Plan (WMP), which determines the abstractable flow for any particular total river flow.

It was assumed that peak irrigation demands by both the CPIS and LRIS can occur on any day over the three-month period from December to February. Of the total volume of water abstracted by either irrigation scheme 15 per cent was assumed to be returned to the river at the scheme return outlet. A further assumption was that 30 cumecs of the River's flow is lost to groundwater below State Highway 1 (SH1). Recent hydrological investigations have shown that losses to groundwater below SH1 range between 12 and 30 cumecs (Bowden, 1982). The upper bound estimate of 30 cumecs was used in this analysis to ensure that the results obtained for residual flows were conservative (i.e., not over estimated).

The results of the analysis are calculated from daily mean flow data for the months December through February for the Rakaia River over the period December 1967 to December 1977. Before the results are presented, it would be appropriate to define what is meant by abstractable flow, residual flow, low-flow conditions, and also the concept of a duration curve.

Definitions

Abstractable Flow. The abstractable flow is that amount of water able to be diverted out of the Rakaia River on any particular day. The actual amount of water able to be abstracted is determined by the North Canterbury Catchment Board's (NCCB) Water Management Plan (WMP). The WMP has set the minimum river flow at 42 cumecs[1], or 55 cumecs at the gorge to allow for infiltration to groundwater and abstraction for stockwater. For flows above 55 cumecs but below 142 cumecs, a certain percentage of the total flow may be abstracted (but always leaving at least 55 cumecs in the river). This percentage varies according to the month in which the flow occurs, e.g. for December the percentage is 50 per cent, January 40 per cent and February 35 per cent. For convenience, a 40 per cent value was used in analysing the data for all three months.

One hundred per cent of the additional river flow above 142 cumecs, and below 179 cumecs must remain in the river so that over this range 57 cumecs is the maximum abstractable flow (i.e. 40 per cent of 142 cumecs). For river flows over 170 cumecs, 75 per cent of the additional water may be abstracted. Given these WMP allocation rules, the abstractable portion of the daily mean flows in the Rakaia over summer can be calculated.

Minimum Residual Flow. The residual flow is defined as the difference between the daily mean flow of the river and the maximum abstractable flow allowed under the WMP for that daily mean flow. Accordingly, it should be regarded as a "minimum" estimate.

Low Flow. For the purposes of analysis, a "low flow" is defined as any daily mean flow which does not generate an abstractable flow of at least 90 cumecs. Nintey cumecs is assumed to be the peak irrigation requirement of the combined CPIS and LPIS. In defining a low flow in terms of the irrigation requirements, the environmental needs of wildlife and the recreational needs of instream users are ignored. This flow may be environmentally damaging, especially if it persists over long periods during summer. Wildlife and recreational interests prefer to define low flow in terms of residual water flows, not abstractable flows. However, in the absence of information regarding what these flow requirements are, the present definition is adhered to. The results will, however, be valuable for wildlife and recreational interests, since the pattern of residual flows with irrigation development will be known and their compatibility with instream uses open for discussion.

Duration Curves. A duration curve is essentially a graphical presentation of a set of probabilities. For example, if the data relate to abstractable flows, then the duration curve will graph each level of abstractable flow against the probability that the abstractable flow will be equalled or exceeded. Therefore, the duration curve represents a cumulative probability curve. The probabilities are usually expressed in terms of percentages. An important weakness of this approach is that it deals with discrete values of flow and reveals nothing about the sequence of low flows, nor whether they occurred consecutively or were widely scattered in time.

Results

Tables A1.1 and A1.2 summarise the results generated using daily mean flow data for December, January and February over the period December 1967 to December 1977. Table A1.1 presents cumulative probabilities for minimum flows, abstractable flows for the CPIS and LRIS, and residual flows at various points in the River, given six different minimum flow standards. The cumulative

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[1] One cumec = one cubic metre of water per second (m^3/S).

probabilities are presented in terms of the probability of being less than the cumec value in column 1. To calculate the cumulative probabilities in terms of the cumec value in column 1 being equalled or exceeded, the probabilities in Table A1.1 should be subtracted from one (as was done for data presented in Tables 2.3 and 2.4, Chapter 2). Table A1.2 presents the probabilities associated with the length of low-flow periods, i.e. periods of consecutive low flow. These were summarised in Table 2.5, Chapter 2.

TABLE A1.1

Summer Flow Analysis for the Rakaia River (1967-1977)

1.1 Minimum Flow Standard = 0 cumecs

(See key at end of table for column definitions)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.00000	0.00000	0.00000	0.61794	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.68328	0.00000
20	0.00000	0.00000	0.00000	0.00000	0.71761	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.76412	0.00000
40	0.00000	0.13289	0.00000	0.02104	0.79845	0.02104
50	0.00000	0.22813	0.00000	0.05869	0.81949	0.05869
60	0.00221	0.32447	0.00000	0.18162	0.83942	0.18162
70	0.03654	0.43300	0.02104	0.37763	0.86047	0.37763
80	0.09635	0.54153	0.05869	0.49612	0.86822	0.49612
90	0.38760	0.61794	0.18162	0.56811	0.88372	0.56811
100	0.66445	0.68882	0.37763	0.62791	0.89037	0.64784
110	0.79181	0.72204	0.49612	0.67331	0.89701	0.72647
120	0.85382	0.76412	0.56811	0.70764	0.90476	0.76191
130	0.89037	0.80066	0.62791	0.74086	0.91141	0.79181
140	0.90919	0.82060	0.67331	0.76855	0.92137	0.80620
150	0.92913	0.83942	0.70764	0.79402	0.92580	0.82281
160	0.94352	0.86046	0.74086	0.81063	0.93134	0.83610
170	0.94906	0.87043	0.76844	0.82945	0.93577	0.85161
180	0.95460	0.88372	0.79402	0.83942	0.93798	0.86489
190	0.96345	0.89147	0.81063	0.85604	0.94463	0.87154
200	0.97010	0.89922	0.82946	0.86600	0.94684	0.88372

1.2 Minimum Flow Standard = 20 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.00000	0.00000	0.00000	0.66445	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.70764	0.00000
20	0.00000	0.00000	0.00000	0.00000	0.75526	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.79181	0.00000
40	0.00000	0.02326	0.00000	0.04430	0.81285	0.04439
50	0.00000	0.29679	0.00000	0.09192	0.83610	0.09192
60	0.02326	0.39867	0.00000	0.16058	0.85382	0.16058
70	0.06977	0.51938	0.04430	0.27353	0.86600	0.27353
80	0.13289	0.50358	0.09192	0.48726	0.88261	0.48726
90	0.20819	0.66999	0.16958	0.56811	0.89037	0.56811
100	0.49612	0.71096	0.27353	0.62791	0.89590	0.62791
110	0.70764	0.75526	0.48726	0.67331	0.90144	0.69435
120	0.81063	0.79291	0.56811	0.70764	0.90919	0.76190
130	0.86600	0.81395	0.62791	0.74086	0.92027	0.79181
140	0.89590	0.83610	0.67331	0.76855	0.92359	0.80620
150	0.91916	0.85493	0.70764	0.79402	0.92912	0.82281
160	0.93466	0.86600	0.74086	0.81063	0.93466	0.83610
170	0.94574	0.88261	0.76855	0.82946	0.93798	0.85161
180	0.95017	0.89036	0.79402	0.83942	0.94352	0.86489
190	0.95681	0.89590	0.81063	0185604	0.94684	0.87154
200	0.96567	0.90144	0.82946	0.86600	0.94795	0.88372

1.3 Minimum Flow Standard = 40 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.00000	0.00000	0.00000	0.70100	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.74197	0.00000
20	0.00000	0.00000	0.00000	0.00000	0.78516	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.80620	0.00000
40	0.00000	0.02326	0.00000	0.04430	0.83278	0.04430
50	0.00000	0.36766	0.00000	0.12625	0.84496	0.12625
60	0.02326	0.48173	0.00000	0.21595	0.86489	0.21595
70	0.09635	0.57143	0.04430	0.28682	0.87929	0.28682
80	0.19380	0.64784	0.12625	0.36213	0.88594	0.36213
90	0.27353	0.79321	0.21595	0.56811	0.89590	0.56811
100	0.33776	0.74197	0.38682	0.62791	0.90033	0.62791
110	0.57475	0.78738	0.36213	0.67331	0.90698	0.67331
120	0.74640	0.80620	0.56811	0170764	0.91805	0.72647
130	0.83278	0.83278	0.62791	0.74086	0.92359	0.79181
140	0.88040	0.84718	0.67331	0.76855	0.92580	0.80620
150	0.90033	0.86600	0.70764	0.79402	0.93245	0.82281
160	0.92359	0.87929	0.74086	0.81063	0.93798	0.83610
170	0.93798	0.88815	0.76855	0.82946	0.94020	0.85161
180	0.94795	0.89590	0.79402	0.83942	0.94463	0.86489
190	0.95127	0.90033	0.81063	0.85604	0.94795	0.87154
200	0.95903	0.90698	0.83946	0.86600	0.94906	0.88372

1.4 Minimum Flow Standard = 60 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.00000	0.00000	0.00000	0.72647	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.76855	0.00000
20	0.00000	0.00000	0.00000	0.00000	0.80066	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.82281	0.00000
40	0.00000	0.02326	0.00000	0.04430	0.83942	0.04430
50	0.00000	0.16058	0.00000	0.12625	0.86047	0.12625
60	0.02326	0.54817	0.00000	0.23699	0.87154	0.23699
70	0.09635	0.63234	0.04430	0.33666	0.88372	0.33666
80	0.21595	0.68882	0.12625	0.41085	0.89147	0.41085
90	0.32447	0.72647	0.23699	0.49612	0189922	0149612
100	0.39867	0.77187	0.33666	0.62791	0.90587	0.62791
110	0,48726	0.80177	0.41085	0.67331	0.91251	0.67331
120	0.64673	0.82281	0.49612	0.70764	0.92248	0.70764
130	0.78516	0.83942	0.62791	0.74086	0.92580	0.76301
140	0.84496	0.86157	0.67331	0.76855	0.93134	0.80620
150	0.88594	0.87154	0.70764	0.79402	0.93577	0.82281
160	0.90698	0.88372	0.74086	0.81063	0.93909	0.83610
170	0.92580	0.89369	0.76855	0.82946	0.94463	0.85161
180	0.94020	0.89922	0.79402	0.83942	0.94795	0.86489
190	0.94906	0.90587	0.81063	0.85604	0.94906	0.87154
200	0.95349	0.91251	0182946	0.86600	0.94906	0.88372

1.5 Minimum Flow Standard = 80 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.00000	0.00000	0.00000	0.75858	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.79291	0.00000
20	0.00000	0.02104	0.00000	0.00000	0.81506	0.00000
30	0.00000	0.05869	0.00000	0.00000	0.83610	0.00000
40	0.00000	0.10853	0.00000	0.00000	0.85493	0.00000
50	0.00000	0.18162	0.00000	0.00000	0.86711	0.00000
60	0.02326	0.34219	0.00000	0.23699	0.88372	0.23699
70	0.09635	0.67331	0.00000	0135216	0.89037	0.35216
80	0.21595	0.71429	0.00000	0.47176	0.89701	0.47176
90	0.33776	0.76190	0.23699	0.54817	0.90144	0.54871
100	0.47176	0.79402	9.35216	0.60797	0.90919	0.60797
110	0.54817	0.81506	0.47176	0.67331	0.92137	0.67331
120	0.60797	0.83610	0.54817	0.70764	0.92359	0.70764
130	0.69435	0.85604	0.60797	0.74086	0.92912	0.74086
140	0.80620	0.86711	0.67331	0.76855	0.93577	0.79291
150	0.86379	0.88372	0.70764	0.79402	0.93798	0.82281
160	0.89480	0.89036	0.74086	0.81063	0.94352	0.83610
170	0.91584	0.89701	0.76855	0.82946	0.94684	0.85161
180	0.93245	0.90144	0.79402	0.83942	0.94795	0.86489
190	0.94463	0.90919	0.81063	0.85604	0.94906	0.87154
200	0.94906	0.92137	0.82946	0.86600	0.95017	0.88273

1.6 Minimum Flow Standard = 100 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.02104	0.00000	0.00000	0.69989	0.00000
10	0.00000	0.05869	0.00000	0.00000	0.80952	0.00000
20	0.00000	0.10853	0.00000	0.00000	0.83278	0.00000
30	0.00000	0.18162	0.00000	0.00000	0.84718	0.00000
40	0.00000	0.26135	0.00000	0.00000	0.86600	0.00000
50	0.00000	0.33666	0.00000	0.00000	0.88040	0.00000
60	0.00221	0.41085	0.00000	0.00000	0.88815	0.00000
70	0.07530	0.54817	0.00000	0.04097	0.89590	0.09192
80	0.19491	0.74862	0.00000	0.48173	0.90033	0.48173
90	0.31672	0.78848	0.00000	0.56811	0.90698	0.56811
100	0.48173	0.80952	0.04097	0.62791	0.91916	0.62791
110	0.59136	0.83389	0.48173	0.67331	0.92369	0.67331
120	0.64784	0.84828	0.56811	0.70764	0.92691	0.70764
130	0.69214	0.86600	0.62791	0.74086	0.93466	0.74086
140	0.73200	0.88261	0.67331	0.76855	0.93798	0.76855
150	0.82614	0.88926	0.70764	0.79402	0.94131	0.81063
160	0.87375	0.89590	0.74086	0.81063	0.94574	0.83610
170	0.89922	0.90033	0.76855	0.82946	0.94795	0.85161
180	0.92359	0.90808	0.79402	0.83942	0.94906	0.86489
190	0.93688	0.91916	0.81063	0.85604	0.95017	0.87154
200	0.94795	0.92359	0.82946	0.86600	0.95127	0.88372

1.7 Minimum Flow Standard = 150 cumecs

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	0.00000	0.33666	0.00000	0.00000	0.56700	0.00000
10	0.00000	0.41085	0.00000	0.00000	0.65006	0.00000
20	0.00000	0.49612	0.00000	0.00000	0.70321	0.00000
30	0.00000	0.56811	0.00000	0.00000	0.87375	0.00000
40	0.00000	0.62791	0.00000	0.00000	0.88372	0.00000
50	0.00000	0.67331	0.00000	0.00000	0.89369	0.00000
60	0.00000	0.70764	0.00000	0.00000	0.90033	0.00000
70	0.00000	0.74086	0.00000	0.02104	0.90587	0.02104
80	0.00000	0.76855	0.00000	0.05869	0.91473	0.05869
90	0.00111	0.79181	0100000	0.14839	0.92359	0.14839
100	0.16611	0.84385	0.02104	0.28128	0.92580	0.28128
110	0.31340	0.86379	0.95869	0.40642	0.93245	0.59801
120	0.44961	0.87375	0.14839	0.55150	0.93798	0.70764
130	0.57697	0.88483	0.28128	0.74086	0.94020	0.74086
140	0.70986	0.89480	0.40642	0.76855	0.94463	0.78295
150	0.80399	0.90033	0.55150	0.79402	0.94795	0.80399
160	0.81949	0.90698	0.74086	0.81063	0.94906	0.81949
170	0.83832	0.91584	0.76855	0.82946	0.94906	0.83610
180	0.88372	0.92359	0.79402	0.83942	0.95127	0.86489
190	0.90255	0.92580	0.81063	0.85604	0.95349	0.87154

Key to Table A1.1:

Column	Definition
(1)	Volume of water (cumecs)
(2)	Cumulative probability of having a minimum flow (determined by the WMP) less than the flow in (1)
(3)	Cumulative probability of an abstractable flow for the CPIS less than the flow in (1)
(4)	Cumulative probability of a residual river flow downstream of the CPIS return outlet less than the flow in (1)
(5)	Cumulative probability of a residual river flow downstream of S.H. 1 less than the flow in (1). (Note: assumed 30 cumecs lost to groundwater at S.H. 1).
(6)	Cumulative probability of an abstractable flow for the LRIS less than the flow in (1)
(7)	Cumulative probability of a residual river flow downstream of the LRIS return outlet less than the flow in (1).

TABLE A1.2

Periods of Low Flow at Alternative Minimum Flow Standards

2.1 Probabilities of Low Flow Periods - CPIS

Low Flow Period (Days)	Minimum Flow Standard						
	0	20	40	60	80	100	150
	Probability of Low Flow Period Being Equalled or Exceeded (%)						
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	85.4	93.2	94.2	90.9	91.1	90.7	90.7
3	65.4	77.9	90.4	83.6	84.0	81.4	81.4
4	52.7	6.43	76.9	78.1	76.9	70.3	70.3
5	41.8	57.5	65.4	70.8	68.0	62.9	62.9
6	30.9	43.9	59.6	63.5	66.2	53.6	53.6
7	29.1	37.1	46.1	56.2	60.8	44.3	44.3
8	27.3	32.0	42.3	48.9	57.2	42.4	42.4
9	21.8	25.2	34.6	38.0	48.3	33.1	33.1
10	21.8	23.5	32.7	36.2	42.9	33.1	33.1
11	21.8	20.1	28.9	28.9	37.5	27.5	27.5
12	21.8	16.7	23.1	25.3	28.6	21.9	21.9
13	21.8	15.0	21.2	19.8	25.0	20.0	20.0
14	16.3	11.6	17.4	19.8	21.4	16.3	16.3
15	16.3	11.6	17.4	16.2	19.6	16.3	16.2
16	16.3	11.6	15.5	16.2	19.6	14.4	14.4
17	16.3	11.6	15.5	14.4	14.2	12.5	12.5
18	16.3	9.9	15.5	14.4	14.2	12.5	12.5
19	16.3	9.9	15.5	14.4	14.2	12.5	12.5
20	16.3	9.9	13.6	12.6	12.4	10.6	10.6
21	10.8	9.9	13.6	12.6	12.4	10.6	10.6
22	10.8	9.9	13.6	12.6	12.4	10.6	10.6
23	10.8	9.9	13.6	12.6	12.4	10.6	10.6
24	9.0	8.2	13.6	12.6	12.4	8.7	8.7
25	9.0	8.2	13.6	12.6	12.4	8.7	8.7
26	9.0	6.5	9.8	9.0	12.4	6.8	6.8

TABLE A1.2 contd.

2.1 contd.

Low Flow Period (Days)	Minimum Flow Standard						
	0	20	40	60	80	100	150
27	9.0	6.5	9.8	9.0	10.6	6.8	6.8
28	9.0	6.5	9.8	9.0	8.8	6.8	6.8
29	7.2	4.8	7.9	9.0	8.8	4.9	4.9
30	5.4	4.8	7.9	7.2	7.0	4.9	4.9
35	5.4	1.7	4.1	5.4	5.2	1.9	1.9
40	5.4	1.7	4.1	5.4	5.2	1.9	1.9
45	5.4	1.7	2.2	1.8	1.8	1.9	1.9
50	5.4	1.7	2.2	1.8	1.8	1.9	1.9

2.2 Probabilities of Low Flow Periods - LRIS

Low Flow Period (Days)	Minimum Flow Standard						
	0	20	40	60	80	100	150
	Probability of Low Flow Period Being Equalled or Exceeded (%)						
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	88.1	89.3	84.2	96.2	96.1	100.0	88.8
3	83.0	82.2	7.54	84.7	92.2	95.7	71.5
4	76.2	75.1	73.6	80.9	82.4	87.0	55.2
5	67.7	68.0	68.3	77.1	78.5	84.8	40.9
6	62.6	60.9	57.8	67.5	70.7	78.3	35.8
7	57.5	59.1	57.8	65.6	66.8	74.0	30.7
8	55.8	55.5	54.3	57.9	60.9	71.8	27.6
9	47.3	48.4	49.0	52.1	55.0	63.0	21.5
10	42.2	43.0	40.2	44.4	47.2	54.3	17.4
11	37.1	43.0	40.2	44.4	47.2	52.1	13.3
12	32.0	34.1	38.4	42.5	47.2	52.1	11.3
13	26.9	3.23	34.9	36.7	39.4	45.6	7.2
14	25.2	28.7	33.1	34.8	37.4	41.3	6.2
15	20.1	25.1	29.6	31.0	33.5	39.1	6.2

TABLE A1.2 contd.

2.2 contd.

Low Flow Period (Days)	Minimum Flow Standard						
	0	20	40	60	80	100	150
16	18.4	21.5	22.6	23.3	25.7	32.6	6.2
17	15.0	17.9	19.1	23.3	23.7	26.1	6.2
18	11.6	16.1	17.3	19.5	19.8	21.8	6.2
19	11.6	16.1	17.3	19.5	19.8	21.8	6.2
20	11.6	14.3	17.3	19.5	19.8	21.8	6.2
21	11.6	14.3	15.5	17.6	17.8	21.8	5.2
22	11.6	14.3	15.5	17.6	17.8	21.8	5.2
23	11.6	14.3	15.5	17.6	17.8	21.8	5.2
24	11.6	14.3	13.7	15.7	15.8	19.6	5.2
25	11.6	14.3	13.7	15.7	15.8	19.8	5.2
26	11.6	12.5	13.7	15.7	15.8	19.6	4.2
27	9.9	12.5	11.9	13.8	13.8	17.4	4.2
28	8.2	10.7	11.9	13.8	13.8	17.4	4.2
29	8.2	10.7	11.9	13.8	13.8	17.4	4.2
30	8.2	8.9	11.9	13.8	13.8	17.4	4.2
35	4.8	7.1	8.4	11.9	11.8	17.4	1.2
40	1.4	5.3	6.6	10.0	9.8	13.1	1.2
45	1.4	3.5	4.8	6.2	5.8	6.5	0
50	1.4	1.7	1.2	2.4	1.9	2.2	0

APPENDIX 2

COMMUNITY IRRIGATION SCHEME PLANNING

A Review of Enabling Legislation and Implications
For Multi-Purpose Water Planning Procedures

The following discussion expands on the planning steps outlined in Chapter 3 (Section 3), emphasising the legal and procedural requirements germane to considerations of managing public water resources when the proposed uses are in potential conflict. As pointed out in Chapter 3, the government agencies with major roles in irrigation planning at the national level are:

1. the Water and Soil Division of the Ministry of Works and Development, responsible for the investigation, design and construction of irrigation schemes;
2. the Ministry of Agriculture and Fisheries, responsible for the overall economic appraisal of any proposal, for assisting with on-farm irrigation design and construction programmes, and for advising farmers on necessary changes in farming practices; and
3. the National Water and Soil Conservation Organisation[1], which has general responsibility for the use, allocation and management aspects of natural water resources.

The legal basis of the government's power to promote and construct irrigation schemes derives from Part XIX of the Public Works Act 1981. The Act sets out the current procedural requirements and the financial policy. The procedures recognise the need for consultation, discussion and understanding before approval is given. The power to undertake irrigation development is given to the Minister (Ministry of Works and Development), but he may appoint any territorial authority or catchment board as his agent. The Minister (or his agent) must give public notice that an irrigation scheme is being investigated and renew the notice annually until the investigation is either completed or abandoned.

Initial Feasibility Studies

Planning Approvals The result of any investigation must be submitted to the National Water and Soil Conservation Authority ("the Authority") which,

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[1] The Organisation consists of the National Water and Soil Conservation authority, at the head of the hierarchy, with the overall responsibility for administering the Water and Soil Conservation Act 1967 and the Soil Conservation and Rivers Control Act 1941 and advising the Government on matters of national policy affecting water and soil. Responsibility for water quality and allocation of water is delegated to the Water Resources Council, with Regional Water Boards responsible at a local level for implementing policy through the issues of water rights (Crown water rights excepted). Matters of water and soil conservation and rivers control are delegated to the Soil Conservation and Rivers Control Council, with implementation and management at the local level being the responsibility of Catchment Commissions or Boards.

after due consideration, is required to report to the Minister (Ministry of Works and Development) whether in its opinion the proposed scheme is practicable and economic and would result in increased productivity of the land (s.201). In reaching its opinion the Authority must act according to its duties under the Water and Soil Conservation Act, including the duty introduced by the 1981 amendment which is to take into account the needs of all forms of water-based recreation, fisheries and wild-life habitats, and the preservation and protection of wild, scenic and other natural characteristics of rivers.

If the Minister approves the recommendation of the Authority, firm proposals will be publicly notified for consideration by farmers within the proposed district. The notice will specify the area to be included, the nature and extent of the proposed works and the estimated capability of the scheme, the charges and conditions of supply, the intended order of construction, and the degree of acceptability of the scheme required to make it viable (to be not less than 60 per cent of ratepayers). An irrigation district cannot be validly constituted unless the stipulated percentage of ratepayers vote in favour of the scheme, or all ratepayers in the area have consented in writing to the proposed scheme and charges (s.208).[2] If the terms and conditions are favourably received, the Governor-General may constitute the area an irrigation district by Order-in-Council.

Environmental Impact Procedures During the initial feasibility planning phase, studies on the environmental impact of the proposed project are also undertaken. Although such studies are not required by law (except in the case of development under the National Development Act), it is government policy that all projects carried out by its departments or funded in part from public revenues should include environmental assessments. The prime objective is to ensure that the full consequences of development are examined from the outset, when choices are still open.

If the initial environmental impact assessment (EIA) discloses that the project may have a significant harmful effect on the human, physical or biological environment, an environmental impact report (EIR) is required. However, it is up to the Government department concerned to determine whether an EIR is actually necessary, although the Minister of the Environment has the authority to direct the preparation of such a report.[3] Although the report is prepared by the department promoting the project, it is intended to be multi-disciplinary, with expert advice being sought from those appropriately qualified both within and outside Government departments, to provide an objective evaluation.

Once an EIR is prepared it will be published and opportunity given for public submissions (unless Cabinet deems its publication to be against the public interest). The Commission for the Environment prepares an audit

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[2] The procedural requirements for polls are set out in sections 204 to 207 of the Act. Any subsequent alterations to an irrigation district require the consent of the stipulated percentage of ratepayers.

[3] A matter which may influence the need for a report is whether the proposal has already been fully considered under the Town and Country Planning Act 1977 or Water and Soil Conservation Act 1967. This situation should not arise often because the procedure is intended to apply at an early stage of planning. Furthermore the legal proceedings are directed at defined legal criteria and provide only restricted opportunity for public participation.

of the report, taking into account the public submissions which are also published. The aim of the audit is to provide an independent evaluation of the proposal and the EIR, but it does not bind the department to any of its findings. It is simply an aid for the decision maker. Although the environmental impact reporting procedure is not binding, its value in providing an opportunity for public participation in an important phase of the planning process should not be overlooked.

Scheme Planning

Development of an irrigation scheme cannot proceed before water rights have been obtained by the proposed users. However, there is nothing to prevent the Ministry of Works and Development from lodging an application for a water right before an irrigation district has been formally constituted.[4] Indeed, it may be desirable to set the process in motion at the earliest possible time since the water right hearings may be lengthy on account of appeals by competing interests.

Application for Water Rights The need to specify the quantity of water required places a practical limitation on the stage at which application may be made. Applications for Crown water rights are governed by s.23 of the Water and Soil Conservation Act.[5] This differs from the procedure for non-Crown applications, principally in providing for decisions to be made by the Authority rather than regional water boards and in imposing tighter and more restricted rights of hearing.

An application is initially referred to the Regional Water Board for consideration, and for a report and recommendation back to the Authority. At present, it is the policy of the Authority to advertise the application and allow any interested members of the public to make submissions within 28 days to the Regional Water Board, which may hold an informal hearing. It should be emphasised that there is no statutory right to make submissions to the Board (or Authority), and persons doing so do not thereby acquire a right of appeal. The Authority is bound to consider the report and recommendations of the Regional Water Board, but it need not follow them and it is not restricted solely to the consideration of the matters in the report.[6]

It is worth noting here that the chairman of the Authority is the Minister (Ministry of Works and Development), who in irrigation cases is also the Minister applying for the water right. Given that the Authority, the members of which are appointed on the advice of the Minister, is responsible for evaluating proposed irrigation schemes, this overlap of functions does not ensure complete impartiality. It is difficult, however, to challenge a decision on grounds of bias, since evidence is needed that the matter for decision

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[4] The Crown cannot, it appears, be stopped from commencing ancilliary work before water rights have been obtained. See McGregor v. Attorney General (1979) 7 NZTPA 355.

[5] Applications for water rights for irrigation from the Rakaia have already been lodged by the Lower Rakaia and Central Plains Irrigation Associations. If these rights are granted before the MWD is ready to apply, and if they are for a suitable quantity of water, they may be transferred to the Crown under section 24 A(1) of the Water and Soil Conservation Act.

[6] EDS v NWSCA (1980) 7 NZTPA 385 (SC).

has been approached with a closed mind (a formidable task, especially when the legislative mandate explicitly contemplates a degree of conflict of interest). For this reason appeal rights are important, but here the Act falls short of a desirable statutory check.

Rights of Appeal Any Board, public authority or person claiming to be detrimentally affected by the decision of the Authority has a right of appeal within 28 days of public notification of the decision. To be "detrimentally affected" the appellant must be able to show loss, damage, or prejudice to a degree greater than that to the public at large.[7] This excludes what may be termed "public interest" appellants. Thus, the Environmental Defence Society, whose objectives include the preservation and protection of natural amenity resources, has consistently been held to have no standing to appeal under section 23.[8] That is not be say that all persons or groups representing wider aspects of the public interest will be excluded. Acclimatisation Societies, the Conservator of Wildlife, MAF, the Nature Conservation Council and regional and local authorities have all been held to have interests greater than the 'public at large' on account of their statutory duties. Those with commercial or property interests affected by the grant of a right or by failure to grant it, clearly fall within the terms of section 23. Individual recreational users would also have standing, and it seems likely on the basis of past decisions that local branches of recreational organisations would too.

Public interest groups who find themselves barred by the rules as to standing may perhaps overcome this difficulty by supporting an organisation which does have standing, because it is clear that once appeal status is achieved the appellant is not confined to giving evidence relating solely to his own detriment.[9] While the rules as to standing may not prove a fully effective barrier to the introduction of public interest evidence, they nevertheless produce a distorting effect. Through the failure to allow such groups a right of appeal, the Planning Tribunal is less able to gauge the strength of public feeling for or against a development proposal. Furthermore, underfinanced statutory authorities cannot always be relied on to represent public interest issues, and very often such bodies have conflicting functions. Finally, there seems to be no valid reason why appeal rights should be more restricted simply because the Crown is applying for the water right. Indeed, the public will often have a greater interest in the outcome of Crown water rights than ordinary water rights.

Adjudication of Rights Appeals are made to the Planning Tribunal whose decision is final (subject to rights of appeal to the High Court on grounds of which the discretion to grant or refuse a water right is to be exercised). Looking to the provisions of the Act as a whole, and in particular the sections which set out the functions and powers of the Authority and describe the duties of the Regional Water Boards, it is clear that the Tribunal must take into account recreational needs, the need to safeguard scenic or natural features, the needs of local water supplies and of primary and secondary industries, among many other needs now, and in the future.[10] Therefore an

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[7] Mahuta v NWSCA (1973) 5 NZTPTA 73.

[8] e.g. EDS v NWSCA (1976) 6 NZTPA 49. The Royal Society is in a similar situation (Annas v NWSCA and Ministry of Energy (1981) 7 NZTPA 417. The position of a group such as the Rakaia River Association is not clear.

[9] Mahuta v MWSCA (1973) 5 NZTPA 73.

[10] See in particular, sections 14 (3) & (4), 20 (5) & (6), 21 (3A), 22 (1) and 3.3 of the 1981 Amendment.

attempt must be made to balance competing demands in the best public interest. That is not an easy task, and the Act provides no guidelines as to how demands between the various competing interests should be met (except to recognise a multi-use approach), or whether some interests should be considered more important than others.

The multi-use approach, however, provides little assistance to the decision-maker where a specific demand for water, such as a major abstraction, is essentially irreconcilable with the demands of those who wish to see a river preserved largely in its natural state. A value judgement must therefore be made as to which use will ultimately best serve the public interest. In the absence of any clear guidelines from the legislature, the Tribunal has so far declined to recognise any hierarchy of interests and will judge each application on the evidence before it.

On the basis of past decisions, it would be prudent to say that environmental and recreational interests are at a disadvantage. There are several reasons for this. The environmental consequences of granting a water right will often be difficult to predict precisely, and will usually be more difficult to quantify or place a value on than, for example, the expected economic gains from an irrigation development. Previous evidence suggests that the Tribunal, no doubt unconsciously, has tended to impose a heavier evidential burden on those opposing the grant of a water right on environmental or recreational grounds. Whether rightly or wrongly, such interests have sometimes been associated with elitism.[11] Nonetheless, perhaps the greatest difficulty faced by those seeking to protect environmental and recreational interests is the restricted view the Tribunal has taken of its function, which it sees as one of determining whether to permit withdrawal of a specific quantity of water for a specific purpose. It has chosen to not concern itself with the precise way in which the water will be used or whether there are better ways of achieving the desired objective, given that the method chosen is at least reasonable.

In an application to withdraw water for the Waiau Irrigation Scheme the Tribunal would not decide on the merits of border-dyking versus spray irrigation, and would not have regard to evidence that the soil in the area was not as suitable for irrigation as had originally been supposed. It said that if it was felt the method of distribution was wasteful it would simply reduce the allocation, and it would be up to the withdrawer to decide how to best use the reduced supply.[12] Recently, the Tribunal stated quite clearly that although it only has power to grant or refuse the right applied for, that does not mean evidence of alternatives is irrelevant. If such evidence is available it should be weighed as part of the general process of evaluating the whole proposal in accordance with the relevant matters to be taken into account under the Act.[13] Here the Tribunal was referring to evidence of well-researched alternatives and not merely to hypothetical possibilities. It is unclear at this stage what effect the recent High Court decision on water rights for the Clutha may have on the Tribunal's powers or terms of reference in hearing evidence.

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[11] See, for example, Royal Forest and Bird v Bay of Plenty Water Board (1978) 6 NZTPA when the Tribunal upheld the grant of a water right for construction of a dam in the absence of absolute evidence that the wildlife would leave the area and the fishing be destroyed forever. It accepted, with no supporting evidence offered, that additional hydro-electricity generating capacity was needed and felt the public interest in electricity outweighed the interests of the select few who used the river. It also indicated that it would award costs against appellants where the appeal principally involves a value judgement.

It is apparent from the Waiau decision that Tribunal adjudication under the Act is less than ideal in examining the wider economic and social issues of a proposed water resource service development. Besides claimants for non-exclusive uses like recreation, existing water right holders have no guarantee of priority for the quantity of water specific in their prior grants.[14] Normally the Tribunal will strive to grant a new water right in such form that provision is reserved for the reasonable needs of those already lawfully entitled to take water from points lower downstream, but the interests of existing water-right holders may be outweighed by the greater public benefit of granting the later application. From the point of view of national economic efficiency this would be an appropriate policy, except that the Act provides no right of compensation for those adversely affected. It is important to note that the Crown can by-pass rights of appeal by invoking section 23(7). This means that the Governor-General has the power to declare any water to be of national importance. It is not clear, however, under what circumstances this power would be used, but it is clear that those affected by such an application will have no legal right to be heard.

The "Wild and Scenic" Amendment The 1981 Amendment to the Water and Soil Conservation Act, which came into effect on 1 April 1982, provides for the granting of national or local conservation orders to protect rivers in their natural state. At the present time the Rakaia is a possible candidate for such a conservation order. It has been listed in a draft inventory of wild and scenic rivers for use by applicants seeking protection for rivers under the Amendment. Once a river is protected by a national conservation order, a new water right can only be granted if the combined effect of it and any existing rights is such that the terms of the conservation order can remain without change. In the case of a local conservation notice, however, the Authority would simply be required to take into account the provisions of the order.

An order or notice may provide for the quantity, rate of flow or level of the water concerned to be retained in its natural state, or may specify maximum and minimum depths or rates and ranges of flow. The form an order may take will be constrained by the effect of section 20 D (7), which provides that nothing in any order shall affect or restrict any prior granted right. There appears to be nothing in the Act to prevent the Authority from granting water rights whilst a conservation order application is under consideration.

Because of the very nature of the conservation order application, it is expected that the Tribunal would take a much broader approach to environmental issues in making its recommendations than it has felt able to in the case of water rights. Ultimately, one may perhaps doubt whether an unbiased decision will be possible when both irrigation schemes and national conservation orders are decided by the Governor-General in Council on the advice of the Minister (Ministry of Works and Development). An outline of the conservation order procedure is set out in Figure A2.1.

Town Planning Requirements Section 116(1) of the Town and Country Planning Act prohibits the Crown from constructing or undertaking any public

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[12] EDS v NWSCA (1976) 6 NZTPA 49. In this decision the Tribunal also indicated that it would not accept an Environmental Impact Report or Audit as evidence.

[13] Annan v NWSCA and Ministry of Energy 7 NZTPA 417. Application for water rights for Clutha High Dam.

[14] Stanley v South Canterbury Catchment Board (1971) 4 NZTPA.

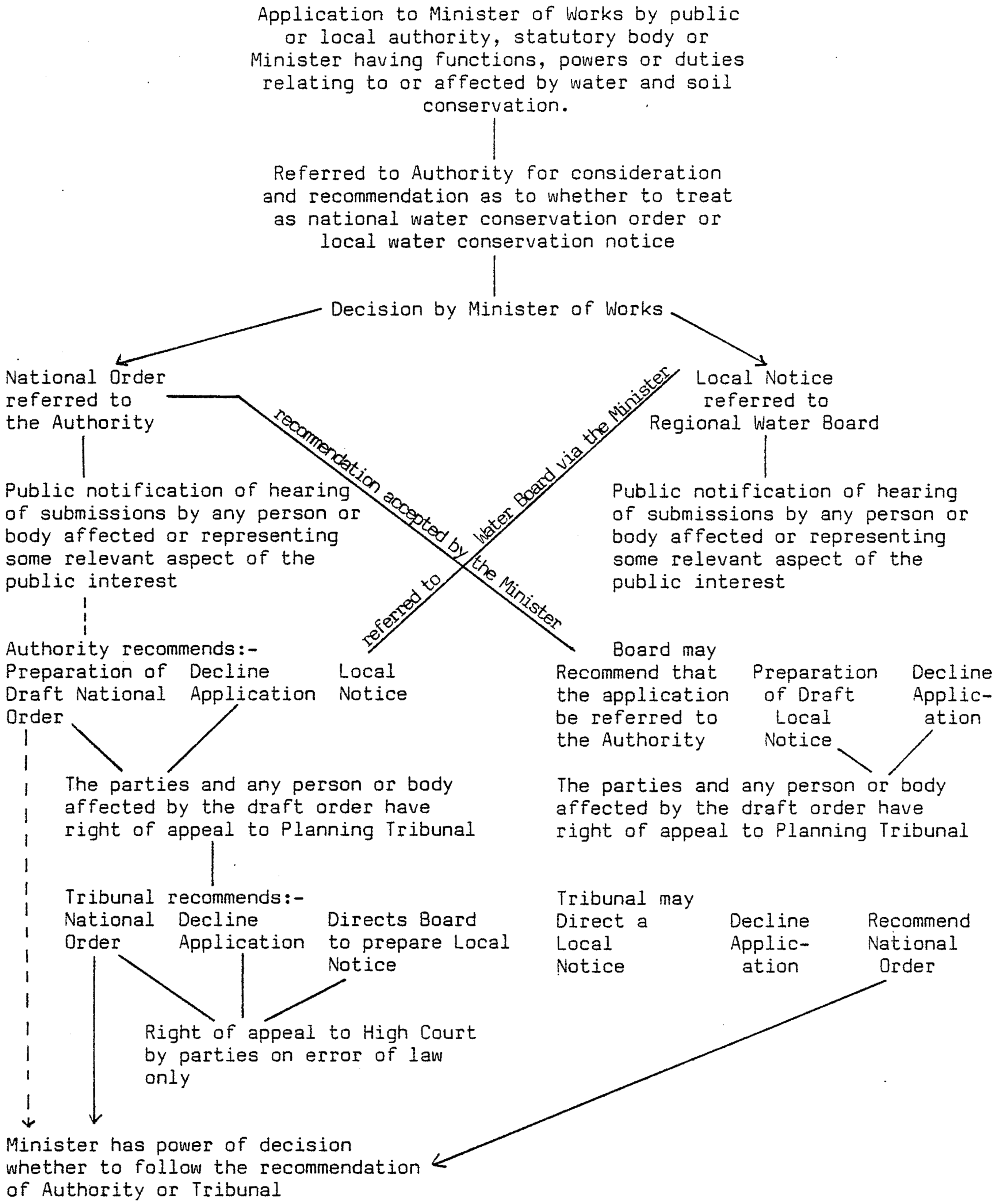

FIGURE A2.1

Outline of Conservation Order Procedure

Under the 'Wild and Scenic' Amendment

work where there is an operative district scheme (other than uses permitted as of right or as conditional uses in the scheme) until either the public work has been designated "as part of" the district scheme, or planning consent has been applied for.[15] The Minister of Works has full discretion as to which procedure he will follow. Irrigation races, drains, channels and necessary incidental equipment are deemed to be permitted "as of right" throughout every district by virtue of s.64(1)(c), although 21 days' notice of their proposed location must be given to the council before any work is undertaken.[16] It is not clear whether any impoundment ponds which may be necessary for an irrigation scheme fall within this definition. Certainly any hydro-electric development planned in conjunction with the proposed irrigation schemes would fall outside this section of the Act.

In practice, designation will normally be sought, regardless of whether the use is permitted or not, to ensure that the land is not put to a use which is incompatible with the proposed development. Section 120 provides that once a requirement has been made, and until such time as it is withdrawn or revoked, no person shall carry out any work or subdivision or make any change in the use of the land contrary to the requirement without the consent of the person(s) making that requirement. The designation procedure is set out in s.118.[17] The council must publicly notify the requirement and any body or person affected or representing some relevant aspect of the public interest has a right of appeal.

After considering any objections and submissions and the Minister's reasons for the requirement, the council makes a recommendation but it does not bind the Minister who retains the power of decision. There is a right of appeal to the Tribunal from the Minister's decision, but if no appeal is lodged within the time specified the council must amend the district scheme to include the requirement.[18] The regional plan must also be amended if as a result of the requirement it is at variance with the district scheme.

Under the Act, the Tribunal is (expressly) required to have regard to the economic, social and environmental effects of the proposal, whether the proposed work is reasonably necessary for achieving the objectives of the Minister, whether the site is suitable, and the extent to which adequate consideration has been given to alternative sites, routes, or methods of

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[15] Where consents have been granted under the National Development Act this section will not apply.

[16] The council may appeal to the Tribunal against the proposed location within 14 days of notification. No right of appeal is given to any other body or person affected. (s.64(2)).

[17] Where there is a proposed district scheme s.43 applies rather than s.118.. They are broadly the same in effect, the former simply being incorporated into normal appeal procedures for proposed schemes.

[18] At this stage it is not sufficient to claim to represent some relevant aspects of the public interest. An appellant must already have put in an objection on this basis, or must be able to show that he is affected by the decision. It is worth noting here that Regulation 69 of the Town and Country Planning Regulations 1978 authorises the Tribunal to hear together appeals relating to the same matter under both the Town and Country Planning Act and the Water and Soil Conservation Act.

achieving the objectives (s.118(8)). The Tribunal does not consider these to constitute an exhaustive list of the matters to which it may have regard.[19] It takes the view that the economic effects it is directed to have regard to (s.s.8) are those related to land use; thus, it will not consider the cost of an irrigation proposal as such.[20] Nor will it question the objectives of the designating authority or decide on the "best" site for the proposed works. But where a proposed designation conflicts with matters declared to be of national importance (by s.3), the authority will be expected to prove a necessity for the public work in the particular area and show why other sites are not suitable.[21] Matters of national importance include:

1. the conservation, protection and enhancement of the biological, cultural and social environment;

2. the preservation of the natural character of the margins of rivers and their protection from unnecessary development;

3. the wise use and management of the country's resources.

In general, previous decisions of the Tribunal have made it clear that the reference to conservation or preservation is not intended to prevent change; controlled change being a prime objective of the Act. Similarly that reference to wise use of resources is aimed at ensuring, in a planning sense, that opportunity is afforded for making full use of resources. But it will not decide on issues concerning the economics of the end product or consider their impacts on social welfare![22] In addition, there is no right of appeal against the recommendations of the Tribunal or the decision of the Minister. Also, the Minister appears to have an unfettered discretion as to whether he will invoke section 119 (overturn the Tribunal) and thus retain full power of decision.[23]

One final section of the Town and Country Planning Act which may have relevance for irrigation development should be mentioned. Section 56 empowers the Minister (Ministry of Works and Development) to request that any provision of an operative district scheme be changed (except during a period of review of an operative district scheme). The Council must publicly notify the request and follow the procedure for changes to operative district schemes. If the request is disallowed by the Council the Minister can appeal to the Planning Tribunal. This power may be very useful in a situation such as currently prevails in the Malvern County District Scheme, which allows subdivion of

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[19] Pukekohe Borough v Minister of Works and Development (1981) 7 NZTPA 184.

[20] Adamson Taipa v Manganui County D. No. A134/80 C2062

[21] Barron v MWD D. No. A161/80 C1997, Hutt County and Hutt Valley Drainage Board D New 56 180 C1379.

[22] Smith v Waimate West County Council 1981 7 NZTPA 241.

[23] S.125 requires that outline plans of works to be constructed on designated land must be submitted to the council for consideration before construction commences, unless they have been otherwise approved. The council may request changes and, if the request is refused, may appeal to the Tribunal. S.s.2 excludes the need to submit plans for irrigation races, drains, channels and incidental equipment (or for hydro-electric installation or dams), but the section would apply to settling ponds (supposing they do not fall within s.64 (1) (c)) and to recreational facilities provided in association with the proposed irrigation schemes if plans for these were not submitted when the requirement was made.

smaller areas of land once the land is irrigated. From the point of view of irrigation development, it is clearly desirable that subdivision should occur before irrigation is put in rather than after. The Minister may, therefore, wish to request a change in the district scheme to take this into account.

APPENDIX 3

SECTORAL OUTPUT, INCOME AND EMPLOYMENT MULTIPLIERS FOR THE CANTERBURY REGION

TABLE A3.1

Sectoral Multipliers - Canterbury Statistical Area [1]

	Output Multipliers		Income Multipliers			Employment Multipliers (x10^{-3})		
	Simple	Total	Direct	Direct + Indirect	Direct + Indirect + Induced	Direct	Direct + Indirect	Direct + Indirect + Induced
			Income paid/$ of output 1971-72 prices			No's employed/$ of output, 1971-72 prices		
1 Agriculture	1.641	2.109	.107	.260	.393	.083	.140	.182
2 Fishing & Hunting	1.477	2.337	.336	.478	.722	.139	.182	.260
3 Forestry & Logging	1.301	1.819	.196	.288	.435	.052	.078	.125
4 Mining & Quarrying	1.501	2.198	.230	.388	.586	.073	.118	.181
5 Mnf. of Food, Beverages & Tobacco	1.925	2.599	.189	.375	.567	.056	.135	.196
6 Textiles, Apparel & Leather Prod.	1.581	2.398	.291	.454	.686	.125	.185	.258
7 Wood and Wool Products	1.550	2.358	.287	.450	.679	.082	.130	.202
8 Paper, Printing & Publishing	1.351	2.107	.308	.420	.635	.098	.130	.198
9 Chemicals and Chemical Products	1.341	1.939	.231	.333	.502	.074	.103	.157
10 Non-Metallic Mineral Products	1.412	2.158	.288	.415	.627	.087	.124	.191
11 Basic Metal Industries	1.320	1.979	.272	.366	.553	.119	.148	.208
12 Fabricated Metal Products	1.444	2.171	.270	.404	.610	.087	.128	.193
13 Other Manufacturing	1.367	2.092	.291	.403	.609	.113	.146	.211
14 Electricity, Gas & Water	1.681	2.268	.179	.327	.493	.045	.084	.137
15 Construction	1.795	2.672	.254	.488	.737	.080	.149	.228
16 W. & R. Trade	1.410	2.231	.334	.457	.690	.098	.136	.210
17 Transport & Storage	1.509	2.514	.401	.559	.844	.097	.144	.235
18 Communication	1.135	2.430	.675	.720	1.088	.173	.186	.302
19 Business Services	1.305	1.992	.281	.382	.577	.176	.105	.167
20 Owner-Occupier Real Estate	1.453	1.689		.131	.198		.039	.060
21 Public Administration	1.344	2.720	.650	.765	1.156	.127	.160	.284
22 Education Services	1.203	2.788	.819	.882	1.332	.168	.187	.329
23 Health Services	1.275	2.405	.540	.628	.949	.160	.187	.389
24 Other Community Services	1.434	2.713	.554	.712	1.075	.180	.225	.340
25 Personal & Domestic Services	1.520	2.419	.328	.500	.755	.160	.213	.294

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[1] Adapted from Hubbard and Brown (1981).

APPENDIX 4

FISHERIES' IMPLICATIONS OF RAKAIA WATER DEVELOPMENT

A Background Supplement

The following data and discussions provide additional background information on the Rakaia fisheries, and explore in more detail some of the issues raised in Chapter 6. These materials are presented in four sections:

1. Fish species and possible changes in the river eco-system due to irrigation,
2. Enhancement possibilities and limitations with irrigation,
3. The current status of quinnat salmon in east coast South Island rivers, and
4. The possible impacts of irrigation development on the life-cycle phases of the Rakaia quinnat.

A4.1 Rakaia Fisheries and Ecological Change

The diversity of fish species in the Rakaia River ecosystem (see Figure A4.1) is dependent on a variety of habitats being available. Of special importance is the existence of pools and riffles. Riffles help to reoxygenate the water, support invertebrate populations, provide cover and living area for juvenile fish, and are places where salmonids can spawn. Pools provide cover, nursery areas for young fish, and can stabilise water temperatures, especially when overhead vegetation is present. Such vegetation provides cover, food (in the form of falling terrestrial insects) and also enhances bank stability because of its root systems.

The main food source for fish in the Rakaia is aquatic invertebrates. Riffle zones of side (minor) channels are the most important for aquatic invertebrate production. However, these areas are likely to be the first to disappear if flow is reduced (Davis, 1979).

The maintenance of the river ecosystem is also dependent on temporal variability. Fluctuating water levels are integral to river ecosystems, and the fish and invertebrates found there are adapted to changing flows (Stalnaker, 1980). This notion of the variability in ecological systems, including major disruptions such as floods, being extremely important in contributing to ecosystem resilience or persistence is of major importance in applied ecology (Holling, 1978). One of its consequences is that attempts to reduce variability in space or time, even in an effort to improve "environmental quality",should always be questioned.

FIGURE A4.1

Fish Species Inhabiting the Rakaia River

A. LAGOON INHABITANTS[1]

*	*Galaxias maculatus*	Inanga (R, C)
	Arripis trutta	Kahawai (R)
	Aldrichetta forsteri	Yellow-eyed mullet (R)
*	*Rhombosolea retiaria*	Black flounder (R, C).

B. LOWER RIVER RESIDENTS

*	*Retropinna retropinna*	Common smelt
*	*Stokellia anisodon*	Stockell's smelt
*	*Gobiomorphus cotidianus*	Common bully

C. OTHERS

*	*Neochanna burrowsius*	Canterbury Mudfish
*	*Geotria australis*	Lamprey
*	*Anguilla dieffenbachii*	Longfinned eel (R, C)
*	*Anguilla australis*	Shortfinned eel (R, C)
*	*Galaxias brevipinnis*	Koaro
	Galaxias vulgaris	Common river galaxias
	Galaxias paucispondylus	Alpine galaxias
	Galaxias prognathus	Longjawed galaxias
+	*Salmo gairdnerii*	Rainbow trout
*+	*Salmo trutta*	Brown trout (R)
+	*Salvelinus fontinalis*	Brook char
*+	*Oncorhynchus tshawytscha*	Quinnat salmon (R, C)
*	*Cheimarrichthys fosteri*	Torrent fish
*	*Gobiomorphus hubbsi*	Bluegilled bully
	Gobiomorphus breviceps	Upland bully

Source: Basedon Davis (1979)

Notation: * indicates migratory species, + indicates introduced species,
R = of recreational important, C = of commercial importance

[1] A further two species, the perch *Perca fluviatilus* and the gian bully *Gobiomorphus gobioides*, are occasional inhabitants of the lagoon (Eldon, 1981).

Conversely, the importance of periodically high and/or low flows to the integrity of the river ecosystem should not be taken as evidence that the ecosystem is capable of withstanding such maxima or minima indefinitely. Although the fish stocks of the Rakaia once survived a low flow of 79 cumecs for a short period of time, it does not follow that they could do so over longer periods, or successively summer after summer. In fact, recovery from such drought conditions probably occurs over several years (Stalnaker, 1980).

Not surprisingly, therefore, it is not yet possible for fisheries biologists to specify the effect of water abstraction on individual fish populations of the Rakaia River. This uncertainty is complicated by the previously mentioned absence of knowledge on how the proposed schemes will affect physical parameters important in fish microhabitat. Furthermore, even if such changes could be predicted, the changes in numbers of each fish species associated with any particular flow regime can not yet be quantified (Stalnaker, 1980).

As far as the latter point is concerned, an attempt has recently been made to summarise the available information on the habitat requirements of New Zealand fish (Church et.al., 1979). However, because many habitat factors interact in a complex manner, it is not possible to simply add the responses of fish to each factor in isolation, to quantify their overall response. Furthermore, the complexity of biological interactions means that even if one species is not directly affected by changes in physical parameters such as water temperature, it may still be indirectly affected if another species on which it feeds or with which it competes is affected. An example of such an indirect effect would be if low water flows made upstream migrating salmon more vulnerable to predators (which include anglers).

The irrigation intakes themselves are likely to have direct but localised impacts on fish populations. They may render the immediate reaches of the river unsuitable for fish habitat by altering stream morphology and reducing the amount of cover. Damming of part of the river may also trap adult salmon migrating upstream to spawn, as has occurred in the Level Plains Irrigation Scheme on the Opihi River (Hardy, 1972). However, placing fish screens over intakes or constructing by-passes to divert fish back to the river can reduce the loss of fish into intakes (Field-Dodgson, 1979), but for economic reasons these have not been included on most previous irrigation schemes (Wing, 1981).

A4.2 Enhancement Possibilities and Limitations with Irrigation

It is possible that irrigation development could enhance the survival of the Canterbury mudfush, as it is known to occur in irrigation races (McDowall, 1980). Elsewhere, it has been suggested that the irrigation races could be developed as trout habitat (Douglass et.al., 1979) or as salmon-rearing habitat (Lewthwaite, 1982). However, it is doubtful that such a resource would be of any significance for several reasons.

Biological The characteristics of present irrigation systems make them unsuitable as salmonid habitat. Although trout are sometimes found in irrigation races (e.g., in the Ashburton-Lyndhurst Scheme), they tend to be small and disease-prone. Some of the limitations of present irrigation races are:

1. depth, temperature, velocity and oxygen content unlikely to be suitable,
2. the invertebrate insects on which salmonids feed are found on gravel bottoms, not mud bottoms as many races have,
3. a sequence of pool/run/riffle is necessary to provide habitat for a range of ages; this would require a meander in the races or a purposeful engineering design,
4. there is insufficient overhanging cover to provide shade and terrestrial food items,
5. the irrigation races are drained in winter and fish would have to be salvaged and returned to the main river,
6. the behavioural responses of salmonids (in particular, the territorial requirements of trout) are inadequately known and may limit their tolerance of conditions in irrigation races,
7. run-off of fertilisers, pesticides and other chemicals from the surrounding fields may impair survival of fish, and
8. the very real danger of disease and the expense of controlling it.

<u>Social, Institutional and Legal</u> Who are the fish to be provided for? If they are for recreational fishermen, then the following problems arise:

1. trout fishing in irrigation races is unlikely to hold much appeal to anglers,
2. the fish present are unlikely to be in good enough condition to attract fishermen,
3. farmers would almost certainly be unwilling to allow fishermen access to their races, and
4. they are also unlikely to want terrestrial vegetation around the races.

If they are for a commercial operation, then the question of ownership arises when the fish return to the river from the sea.

<u>Economic</u> The area taken up by fisheries requirements would reduce the economic viability of the irrigation schemes, since:

1. modifications to the races might alter the efficiency of irrigation,
2. if sufficient food was not naturally available, the cost of supplying fish food would be expensive, and
3. the costs of salvage operations could prove expensive as well.

These problems place constraints on the significance of any fish production that could be achieved in irrigation raceways. The possibility of providing waterfowl habitat is probably a more feasible idea, although increased duck and geese numbers might not be favoured by farmers. However, such habitat would probably be limited in extent to areas around the sediment ponds. Again, as with fish production, the questions of who the resource is being provided for and whether a demand for it exists need to be examined.

A4.3 Current Status of the Quinnat Salmon Fishery in New Zealand[1]

Introduction Three species of salmon have been successfully introduced to New Zealand: Quinnat salmon (Oncorhynchus tshawytscha), Sockeye salmon (Oncorhynchus nerka) and Atlantic salmon (Salmo salar sebago). Salmon are found only in the South Island, with the most abundant species, the Quinnat, occurring as sea-run and lake limited stocks. Neither Sockeye nor Atlantic salmon have established sea-run populations in New Zealand, and, because of their relatively small size they are seldom fished for by the freshwater angler. The quinnat however is greatly sought after as a recreational fish.

Distribution At present the northern-most distribution of quinnat is the Waiau River, North Canterbury (Flain, 1972); although isolated spawning is known to occur in the Wairau and Clarence Rivers. The greatest fisheries, however, occur in the rivers draining the Southern Alps, and flowing into the sea off Canterbury and North Otago. Hence, to the south of the Waitaki, the Clutha is the only river in which a sea-run quinnat fishery occurs. On the West Coast of the South Island prolonged liberations of quinnat fry have resulted in the development of some small runs (Flain, 1972).

There seems little doubt that the successful acclimatisation and present distribution of quinnat is largely due to ocean currents, temperature, and salinity being similar to those off the mouth of the Sacramento River, California (Eggleston, 1972; Parrott, 1971), which is where the New Zealand quinnat originated. It seems improbable, therefore, that the present range of distribution will be extended to other areas. The present distribution of sea run quinnat salmon in the South Island is shown in Figure A4.2.

The Status of Salmon Rivers A summary of those East Coast Rivers where yearly runs of salmon are recorded is provided in Table A4.1. Table A4.2 reports the estimated salmon populations for the 1979/80 season.

1. Waiau River:

The salmon run in the Waiau varies considerably in size but is normally of the order of a few hundred fish. Angling pressure is low because of the small run and because of the distance from Christchurch. The Waiau Plains Irrigation Scheme is the principal water abstraction on the river, with future schemes now being planned. During the 1980/81 season the river mouth closed, apparently for the first time (Hughey, 1982).

2. Hurunui River:

Variable sized runs occur in this river. Because of the distance from Christchurch it has low to moderate fishing pressure. Low flows during the summer spawning migration are known to lead to physiological stress in the salmon (Docherty et.al., 1978). This situation may be exacerbated

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[1] Excerpts from The Salmon Angler, Vol. 8, No. 1, October 1981, pp. - 10-21.

TABLE A4.1

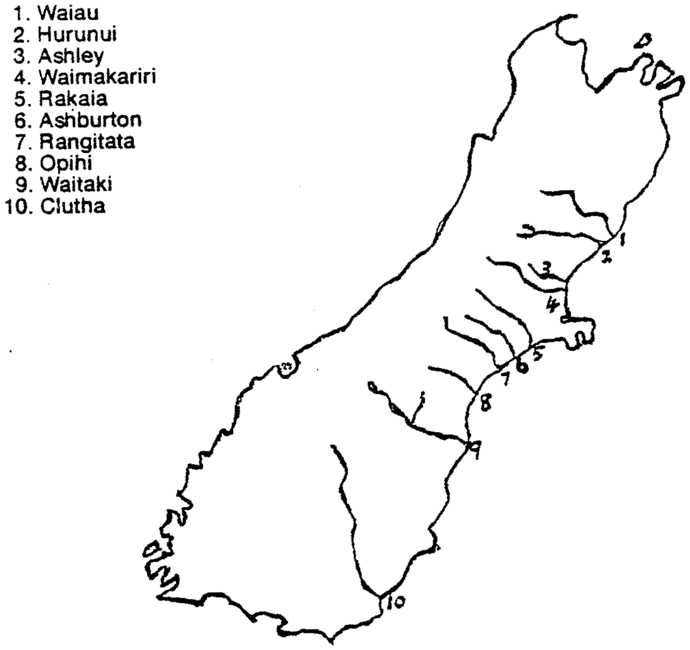
Status of Salmon Rivers and their Subjective Ranking[1]

River	Water Resource Development Status				Salmon Productivity (Relative Ranking)	Status of Salmon Fishery	Likely Future Status (New Development)	Recreational Ranking (All user Groups)	Scientific Research Ranking[2]	Scenic Value Ranking	Angler Satisfaction with River and Salmon Fishery
	Existing Schemes	Under Construction	Impact Ranking[3]	Planned[4]							
Waiau	Irrigation		2		10	Variable	Same	10	-	2	All right at times
Hurunui	Irrigation	Irrigation	2	HEP/Irrigation	5	Significant	Decline	6	3	1	Acceptable
Ashley	On farm water/ irrigation		1		8	Variable	Same	7	2	5	Good at times
Waimakariri	Pollution in lower reaches		3	Irrigation/HEP	4	Major	Decline	1	4	4	Good to excellent
Rakaia	Small amount of irrigation		3	Irrigation/HEP	1	Major	Decline	2	1	3	Extremely satisfying
Ashburton	Irrigation		1		6	Significant	Decline	8	-	7	Generally unhappy
Rangitata	Irrigation		2		2	Major	Decline	4	-	6	Pleasing
Opihi	Irrigation		1		7	Significant	Same	9	-	10	Generally unhappy
Lower Waitaki	Irrigation/HEP		1	Channel alignment/ irrigation/HEP	3	Major	Decline	3	5	9	Good-should be better
Lower Clutha	HEP		1	HEP	9	Variable	Same	5	-	8	Allright at times

1. Much of this table is a subjective evaluation of the salmon fisheries and is based on personal knowledge and discussions with those having personal experience of conditions in the rivers concerned.
2. The Rakaia is given top ranking because of the Fisheries Research occurring on the river and because of the important habitat provided for the Wrybilled Plover and Black-fronted Tern populations.
3. Key:
    1. Major effect on salmon fishery, i.e. closure of river mouths, prevention of access to spawning grounds.
    2. Significant effect, i.e. reduction in suitable rearing habitat, occurrence of stress situations.
    3. Minor effect, i.e. as yet undefinable.
4. Assuming planned development proceeds.

FIGURE A4.2

The Distribution of Quinnat Salmon Rivers on the East Coast of the South Island



by the development of the Balmoral Irrigation Scheme due to the unnatural flow conditions which will then occur in the river. A proposed local hydro dam on the North branch may lead to detrimental effects. These impacts have been summarised (Bryant, 1979) as being associated with: increases in water temperature and reductions in dissolved oxygen levels; reduction in rearing habitat; diversion of fish into irrigation races; salinity increase; and barriers to migration.

3. Ashley River:

There is a variable run of salmon in this river which is generally dependent on the flow conditions prevailing during the season in question. Water abstractions have resulted in the annual drying of large sections of the river-bed. This stops salmon migration to stable spawning grounds and forces adult fish to spawn in the flood prone gravels thus resulting in greatly increased juvenile mortality. Fishing pressure is generally low to moderate.

4. Waimakariri River:

This river is extensively fished by Christchurch residents, particularly in the middle to low reaches. It has a major salmon run and is also intensively

TABLE A4.2

Estimates of the Number of Sea-Run Salmon Returning to Spawn in South Island East Coast Rivers During the 1979/80 Season

River System	Expert Opinion on Probable Salmon Numbers		
	Highest	Most Probable	Lowest
	....	in thousands	....
Waimakariri	25.0	9.0	3.0
Rakaia	30.0	16.0	7.0
Rangitata	20.0	8.0	3.0
Waitaki	20.0	12.0	3.0
Clutha	3.0	1.0	0.5
Ashburton	4.0	2.0	1.0
Opihi	2.0	1.0	0.5
Hurunui	7.0	3.0	2.0
Ashley	0.5	0.2	0.1
Waiau	3.0	1.0	0.2
River Totals	114.5	53.2	20.3

Source: Leathers and Holmes (1981)

used by trout fishermen, jetboaters, canoeists and other recreationalists. There are no major water abstractions from the river at present, but pollution is a potentially serious problem in the lower reaches. During summer natural river flows can drop to a very low level. Hydro-electric and irrigation development have been proposed for the River, with the latter seeming the most probable in the forseeable future.

5. Rakaia River:

The Rakaia is the most important recreational salmon river remaining in New Zealand, being heavily fished by anglers from Christchurch, Ashburton and Timaru, from the North Island, and from overseas. For the 1978/79 period Unwin (1980) calculated that about 8,000 anglers used the river. This figure is certain to underestimate the actual total because of the limited size of the population sampled. Thus, it is estimated that the total number of anglers using the river is over 10,000 per annum. Historically, fishing pressure has been greatest at the mouth. Now it is spread more evenly over the entire river to a point 40km above the Gorge bridge.

The river is unpolluted and at present there are only minor abstractions for irrigation purposes. However, due to the diversion of the Wilberforce

River into Lake Coleridge (aimed at raising generating capacity), access to spawning grounds associated with the river has been greatly impeded.

6. Ashburton River:

The Ashburton was once an excellent salmon river (Hughey, 1982). Now, because of irrigation abstractions, its salmon stock has been significantly reduced. During the 1980/81 season the river mouth was closed for a period of 10 weeks. Angling pressure is almost exclusively concentrated at the mouth.

7. Rangitata River:

Although the Rangitata is considered a good salmon river, it was formerly regarded as being excellent. This degradation in status is directly attributable to major water abstractions, particularly the Rangitata Diversion Race. There is moderate to heavy fishing pressure from the mouth to the Gorge. Further irrigation plus a hydro dam in the Gorge area are possible in the future.

8. Opihi River:

Like the Ashburton this was once an excellent salmon river, but it too has been greatly degraded by water abstraction for irrigation. The river closes virtually all summer and is opened by manpower to let some salmon into the river each year. Fishing pressure is moderate. The middle reaches of the river are characterised by extreme low flow problems.

9. Waitaki River:

Prior to development this was New Zealand's greatest salmon river. However, the construction of the Waitaki dam prevented access for migrating adult salmon to key up-river spawning areas. Pre-development runs have been estimated to exceed 100,000 fish. Now they are reduced to less than 10,000. Fishing pressure is relatively heavy from the mouth to Kurow. The major hydro scheme now planned for the lower reaches of the Waitaki could result in the demise of the salmon fishery in this river if appropriate mitigating measures are not taken.

10. Clutha River:

The construction of the Clutha dam has virtually eliminated this historically important salmon river. Access is prevented to practically all important spawning grounds.

Discussion The relative status and angling importance of salmon rivers in New Zealand has changed markedly due to water developments in the past. Every salmon river has been affected to some extent. These impacts have led to major reductions in the productivity of fisheries such as the Clutha, Waitaki, Opihi, Ashburton and Ashley Rivers. Other rivers like the Rangitata, Hurunui and Waiau have, until now, been only moderately affected. This leaves only the Rakaia and Waimakariri Rivers as substantially unmodified.

It is also important to note that development is planned for those four rivers having "major" salmon runs. For the Waitaki this might mean that future anglers will fish in an artificial "recreational channel". In the Rangitata recent modifications to the intake of the major diversion race have resulted in the fortnightly desilting of the settling ponds. As this occurs on a Thursday, it is a dirty river every second weekend. Irrigation of large areas north of the Waimakariri are planned for the future. This river already suffers from low flows. The Rakaia is seldom characterised by natural low flow problems, but this would become more likely with major abstraction for irrigation.

A4.4 Possible Impacts of River Abstraction on the Rakaia Salmon's Life Phases

The life-cycle of the salmon can be divided into four semi-discrete phases, each with different environmental requirements. They are:

1. spawning, development, and early life in river gravels,
2. growth in freshwater and migration downstream to the sea,
3. distribution, growth and maturing in the sea, and
4. homing to fresh water and migration upstream.

To sustain or enhance the salmon fishery requires the successful completion of each phase. The following reviews the potential effects of irrigation development on each phase of the life-cycle.

Spawning Salmon spawn in moderately swiftly flowing coarse gravelly streams (McDowall, 1978), with the peak period on the Glenariffe tributary being usually in April with significant numbers also in May. Spawning in the main river below the Gorge is thought to be uncommon (Jellyman, 1982) and due to frequent flooding would be of only small but variable input to the fishery. As irrigation abstraction occurs below the Gorge it is unlikely to have significant effects on spawning conditions and early development in gravels after hatching.

Downstream Migration Depending on water temperature the fry emerge from the gravel two to four months after egg deposition. Observations at the Glenariffe Research Station have shown that between 91 and 98 per cent of the juveniles leave the spawning stream during August/October, shortly after they are capable of swimming (Unwin, 1981). The remainder migrate from November onwards as fingerlings, with a very small proportion of yearlings remaining to the following spring.

By analysing the rings on fish scales it is possible to determine how much of an adult salmon's first year of life was spent in freshwater. Unwin's (1981) analysis shows three main types of salmon returning to the Rakaia River in the following proportions:

1. Ocean: little or no freshwater residence, 1 per cent;
2. Intermediate: part of first year spent in fresh water, 80 per cent;
3. Stream: over one year spent in fresh water, 20 per cent.

Unwin (1981) postulates that the difference in survival rates can be taken as indicating the relative importance of the rearing habitat in different reaches of the river.

The Rakaia River is subject to frequent flooding during spring, and fingerling and smolt mortality due to floods varies from year to year. Direct correlation between major spring flood events and the return of adult fish has been attempted for the Glenariffe Salmon trap (Eggleston, 1972). These data suggest that in years of severe flooding the main contribution to the adult return probably comes from juveniles that rear for at least three months in the tributary streams before entering the main river (Hopkins, 1981). Clearly, though it is established that the main river is a rearing area for juveniles, its significance and variable contribution to returning adult stocks is not well understood. A major FRD study is currenlty underway which seeks to answer this question (Davis, 1982).

While flooding is recognised as perhaps the major limiting factor, reduced river flows may also affect salmon rearing habitat during summer and autumn. Apart from a predominant diet of mayfly larvae (Davis, 1979), little knowledge of the micro-habitat requirements of juveniles in the Rakaia River is available. For example, reduced flows may increase predation (Scott and Crossman, 1973). European studies (Kallenberg, 1958) have shown that, within limits, the salmonid carrying capacity of a stream is determined primarily by velocity. Whether this is true for the Rakaia can only be assessed by determining the juvenile micro-habitat and relating changes in it to water abstraction.

Other effects of low flow include the accumulation of silt which can cause a loss of invertebrate habitat, and increased algal growth. An increase in water temperature of smaller braids may occur at low flow periods, depending on the interaction of river and underground flows. Of special importance is the relationship between increased temperature, increased oxygen requirements of fish and invertebrates, and the reduction in dissolved oxygen. Temperatures above 16°C subject fingerlings to stress with adverse consequences for growth and susceptibility to disease (Bryant, 1979). Limited records showing spot temperatures in the main braid of 6-19°C, and up to 22°C in side braids in February, suggest that abstractions over summer and autumn could have a significant impact on juvenile quinnat survival (Davis, 1979).

Knowledge of the environmental and physiological changes which trigger the urge to migrate to the sea is limited. The importance of the Rakaia lagoon in preparing smolts for the stress of entry to seawater is not understood, although large numbers of juvenile quinnat have been observed there in spring and summer (Church et.al., 1979). Raymond (1969) found that the downstream migration rate of young quinnat salmon in north-western USA rivers was generally directly related to stream flow. Suggestions that reduced flows might be advantageous in delaying migration, and thereby allowing more time for the physiological development necessary for survival in salt water, are worthy of investigation (Church, et.al., 1979).

The Marine Phase New Zealand quinnat salmon usually spend up to their third or fourth year in the sea. No evidence exists to suggest that the salt water phase of the quinnat salmon's existence limits their population in the Rakaia River (Eggleston, 1972).

Homing and Upstream Migration Salmon are famous for their ability to home on their river and stream of origin. Observations in New Zealand, however, indicate that up to 10 per cent stray (Eggleston, 1972). The start of the run at the Rakaia Mouth usually commences in November with the peak varying between January and April. This period coincides with irrigation abstraction. Various irrigation options indicate minimum river flows could occur up to 60 per cent of the days in February. (See Chapter 2, also Appendix 1).

Knowledge of homing and what triggers commencement of upstream migration in New Zealand quinnat is very limited, but Eggleston (1972) has stated that more fish appear to enter the river at spring tides than at neap tides. Once entry has been gained salmon cease to feed, the digestive tract degenerates and reproductive organs mature (Netboy, 1974). Detailed knowledge of migration time up river is not available, but circumstantial evidence gained from fishermen indicates that the passage from the mouth to the gorge probably takes less than a month (Davis, 1979). Observations of large numbers of salmon in deep holes in the Rakaia River above the Gorge suggest that the fish complete the maturation process (an additional month or more) before moving into the spawning stream.

Flow reductions might result in unsatisfactory river channel geometry, in the Lower Rakaia River, for upstream migrating salmon. Riffle areas of less than body depth (15-20 cm) can be major obstacles and increase stress (Docherty, 1979). Again, increased temperatures would also be detrimental. At the Glenariffe fish trap temperatures exceeding 16°C in February have been associated with a high incidence of Saprolegnia infestation (Docherty, 1979). The combination of high water temperatures, low dissolved oxygen and increased incidence of disease could result in seriously impaired spawning.

APPENDIX 5

FIGURE A5.1

Summary of Ongoing Rakaia-Related Research By Regional Planning Agencies

Organisation and Research Topic	... In relation to Review Team Recommendations*	
	Study I.D.	Priority
North Canterbury Catchment/Regional Water Baords (Completion date February 1983):		
Hydrology of Surface Water (Bowden/Duffield, with MWD and FRD).	I6, H2	Mod, High
Coastal Sediment Budgeting and Mouth Closure (Kirk, University of Canterbury)	E8	Low
Groundwater Effects on Agriculture Around Lake Ellesmere (McFadden, MAF)	E7	Moderate
Economic Depth of Pumping Groundwater (McFadden, MAF)	I3	High
Storage Potential of HEP and Irrigation (Bowden/Glennie, with MWD-PDD)	H1	Moderate
Ecological Effects of Lake Coleridge Storage (Stout, University of Canterbury)	H1	Moderate
Ecological Effects of Water Quality in Lake Ellesmere (McGraild, University of Canterbury)	E7	Moderate
Irrigation-Groundwater Computer Modelling (Hunt, University of Canterbury with Bowden)	I4	High
Extent and Quality of Irrigating Soils (Mason, with Webb, DSIR)	I2	Moderate
Landscape Evaluation (Miskell, Boffa Jackman Association)	E3	High

* Refer to Table 9.1, Chapter 9.

Organisation and Research Topic	Study I.D.	Priority
Recreation (Saville-Smith, Poole)	E3	High
Land and Water Rsources Evaluation: - Rakaia Catchment .- Central Canterbury		
Canterbury United Council (Completion date December 1982):		
Natural Resource Inventory and Appraisal (Smail, with Wilson, Clayton, Roper-Lindsay, MWD-EDS)		
Recreation Potentials and Assessment (Smail, with Wilson, Clayton, Roper-Lindsay, MWD-EDS)	E3	High
Ecologically Sensitive Areas and Issues (Smail, with Wilson, Clayton, Roper-Lindsay, MWD-EDS)	E1, 4, I6, H1	Mod., High
Land Resources and Land use Strategies (Williams and White)	I2	Moderate
Water Resources Study Synthesis (with NCCB)		
Community Facilities and Resources (Ogilvie and White)	S3	Low
Farming Potential (Tilling)	I2	Moderate
Forestry Potential (Tilling)		
Mining Potential and Impacts (Anderson and Barker)		
Fishing - Fresh and Saltwater Resources (Tilling)	E2, 9, H3	High
Tourism and Regional Development (Barber)	E3, H7	High
Secondary Industry (Barber)	H6, 7, I8, S4	Mostly low
Public and Private Sector Services (Barber)	H7, S3	
Employment Issues and Scenarios (Cronin and Barber)	I8, S4, H7	Low to High
Infrastructure and Communications		
Synthesis Report of Regional Resource and Development Policies	H7	High

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