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A MULTIPLE OBJECTIVE PLANNING FRAMEWORK FOR THE ANALYSIS OF WATER AND SOIL RESOURCE CONFLICT IN NEW ZEALAND

A Thesis
Submitted in fulfilment
of the requirements for the degree
of
Doctor of Philosophy
in the
University of Canterbury

by
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1986

Decision making is a dynamic process: complex, redundant with feedback and sideways, full of search, detours, information gathering and information ignoring, fueled by fluctuating uncertainty, fuzziness and conflict; it is an organic unity of both pre-decision and post- decision stages of the overlapping regions of partial decisions, Starr and Zeleny (1977).

Abstract of a thesis submitted in fulfilment of the requirements for the Degree of Ph. D.

A Muliple Objective Planning Framework
for the Analysis of Water
and Soil Resource Conflict in New Zealand

by
M. J. McGregor

New Zealand water and soil planning is currently facing the challenge of developing a framework which will allow management of the resources to the satisfaction of the wider goals and objectives of the New Zealand community. This implies a shift from the single objective approach, adopted at present, to the multiple objective approach described in this document.

It is shown that there are adequate means available to quantify the effects of water and soil management proposals within a multiple objective framework. The major drawback at present is that experience with these techniques, especially environmental quality and social impact, is limited in New Zealand.

The study stresses that there is a need for the planning process to find local means to attain predetermined national goals and objectives. This is achieved by integrating the public into the decision making framework.

Multiple objective programming techniques are shown to have a place in formalising the analytical structure within which decisions about resource management are to take place. An example of one such technique, goal programming, shows that these techniques have a useful part to play in a multiple objective planning framework.

Analysis of the water and soil decision making process shows that there is a general failure by funding, promoting and implementing agencies to gather and use feedback information from ex-post and monitoring analyses to refine

and develop the ex-ante technique. The results presented illustrate that decision makers should not accept the accuracy of ex-ante analyses without question but need information supplied from an established monitoring and evaluation programme.

KEYWORDS: water and soil planning; multiple objective planning; public participation; multiple objective programming; goal programming; ex-post analysis; monitoring and evaluation.

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CHAPTER I

BACKGROUND AND STATEMENT OF THE PROBLEM

New Zealand water and soil planning has come through three distinct periods of influence and is now entering a fourth. The first phase was a period of unrestricted development of land with only minor restrictions imposed by the Common Law of England. This era was followed by one in which increasing concern was expressed at the effects that land development, especially agricultural development, was having. The problems of note in the early part of the 20th century were increases in erosion and an increase in the incidence of flooding. This concern culminated in the passing of the Soil Conservation and Rivers Control Act in 1941. A consequence of this Act was provision for the establishment of regional water boards (or Catchment Boards) which meant more local interest in the problems of water and soil management.

New Zealand water and soil planning has since come through a period of controlled development of the resource base. Land development and water use have come under increasingly more scrutiny but the a major factor in decision-making in the late 60's and early 70's has been the lack of development funds available in the public sector. The funds that were available had to be rationed and not all projects seeking funding gained approval. The dominant decision criteria over this period has been one of national economic efficiency and the rationing criterion used has been the net present value of the project at a 10% discount rate, Treasury (1971). The use of the economic efficiency objective over this period was a logical step as this period coincided with the push by successive governments for expansion in the New Zealand economy.

One of the consequences of this third period of development has been the increasing competition for land and water resources and an awareness by the public that

development did not have to always occur to the detriment of environmental, recreational and social considerations. Competition for the use of the resources has come mainly from groups wanting to use them for agriculture, forestry, recreation, preservation and urban expansion. It is only recently that planners and decision-makers have been faced with the question of balancing and planning resource use. This has come about as a result of increasing public awareness of the environment and the advent of well organised opposition to economic planning from environmental and sector pressure groups. The increase in awareness has led to conflict over the allocation of the resources which is highlighted by the recent controversies surrounding the allocation of water from the Rakaia and Motu Rivers, Whangamarino Swamp preservation and the Waitangi Tribunal hearings on Manakau Harbour and the sewage outfall for New Plymouth.

The challenges facing the fourth phase of development are:

(1) Water and soil planning has changed from a minor ad hoc activity to one in which it plays a mainline and continuous role in the economic and social development of the New Zealand economy.

(2) The planning of water and soil development, to date, has generally involved a small group of professionals (mainly engineers) but in the future there will be an increasing need to involve many different disciplines and the public at large.

(3) The planning process needs to incorporate the variety of political considerations from the promotion of development in particular regions or the accommodation of the needs of particular social groups.

There is clearly a need for the development of a suitable planning framework within which the management of the water and soil resources can occur to the satisfaction of the wider goals and objectives of the New Zealand

community. This fact was highlighted recently by Howard (1985), Director of the Water and Soil Directorate, in a paper to the New Zealand Institute Agricultural Science Convention;

> "How do you tell a Rakaia farmer that New Zealand is more plentifully supplied with water than almost any country in the world? When do you point out to an environmentalist that the pendulum can swing too far the other way? Neither question is embarrassing, provided that New Zealand has the technical and financial means to allocate its plentiful water resources according to its needs, and has the political means to ensure that allocations have wide social acceptance."

Such a planning framework will require a shift from single objective planning (national economic efficiency) to a multiple objective approach. This need has been ~~is~~ alluded eluded to in the conclusions to Howard's paper in which he listed six future goals for water resources management in New Zealand. These were:

(1) An intensification of anticipatory planning instead of relying on water rights alone to allocate water.

(2) Increased involvement of the market place in water resource uses.

(3) A better balance of resource use objectives to reflect development, conservation and preservation aims, and ethnic value.

(4) Better integration of land and water resource controls.

(5) Improved linking of technological information and skills with planning and development.

(6) More effective harnessing of water resources.

The incorporation of these goals into the analysis framework will mean that decision-makers are fully informed of the consequences of their decisions. As the goals presented contain a range of economic and socio-economic characteristics a consequence of their inclusion in the

decision-making framework should lead to a more balanced management of the resources. This thesis is ~~an attempt~~ to provides suggestions ~~which can lead to the development of a~~ suitable planning framework ~~and tools~~ which will allow the inclusion of the stated goals in water and soil planning.

The study is presented as follows:

Chapter II - A brief history of the legislation, levels of government involvement and the planning framework in which water and soil management decisions have been made.

Chapter III - A brief history of the planning framework in which water resources decision-making has developed in the United States of America. This chapter highlights a water resources planning framework which is at an advanced stage of development.

Chapter IV - A critical review of the literature relevant to planning and evaluation of water and soil resource development.

Chapter V - A critical review of the literature relevant to the measurement of four objectives - national economic development, environmental quality, regional economic development and other social effects.

Chapter VI - Discussion of mathematical programming techniques which can be used to aid resource use conflict.

Chapter VII - An example of the use of a mathematical programming technique, goal programming. The example used is the Rakaia River water allocation debate.

Chapter VIII - The need for improved data bases generated from project monitoring and ex-post evaluation and the part this

plays in a multiple objective planning framework.

Chapter IX - Suggestions for a possible planning framework within which water and soil decision-making can occur within New Zealand.

CHAPTER II

A BRIEF HISTORY OF WATER AND SOIL PLANNING IN NEW ZEALAND

2.1 HISTORICAL LEGISLATIVE FRAMEWORK

First it is important to look at the history of water resources planning in this country. Appendix A gives a summary of some of the statutes, policies, and bodies dealing with water and soil management in New Zealand, and their main mode of operation in management. The major feature of the legislative framework has been the three distinct phases of development that have occurred. The first period up to the early 1930's is characterised by Acts which have allowed the Government to carry out large scale land development. The Hauraki Plains Act in 1926 allowed for flood protection and drainage of 50,000 hectares of the Hauraki Plains by the Government. It is clear that over this period central planning was encouraged.

The late 1930's saw an increase in concern at the effects of this unchecked development. Three factors; the increasing capitalisation of farm land, unchecked erosion and the inability of the Drainage and River Boards (set up in the 1908 Acts) to control flooding, led to the passing of the Soil Conservation and Rivers Control Act in 1941. This Act provided for the setting up of Catchment Boards which overcame some of the previous problems experienced in that whole catchment areas were now administered by one body. It also removed the total planning role away from central Government to the regions.

The period up to the mid 1970's saw the passing of a number of Acts which in effect aimed at managing the resource base. The past ten years has seen the evolution of a strong environmental lobby with, in some cases, aggressive anti-development attitudes. As a consequence of changing

public attitudes this period has seen some major planning legislation, Town and Country Planning Act (1977), Water and Soil Conservation Amendment Act (1981), being enacted. The period also saw the passing of the National Development Act, often referred to as the 'fast track' act, which gave the Government sweeping powers where projects were deemed in the national interest. The early eighties has also seen a heightening of adversary resolution of resource conflict e.g. the Motu River and Rakaia River debates.

2.2 LEVELS AND FORMS OF INTERVENTION

The Soil Conservation and Rivers Control Act 1941 (section 30) gives the National Water and Soil Conservation Authority the power to make grants or loans to local authorities. The aim of these grants or loans is to preserve the national interest. "Soil conservation and water management works are considered essential in the national interest to obtain and maintain maximum production on a sustained yield basis", NWASCO (1985). As the soil conservation and water management works provide benefits to both the nation and the individual, the individual is required to contribute to the costs of the works by way of repayment of the loan component of the total cost. This principle, of contribution according to benefit, is contained in Section 25 of the Soil Conservation and Rivers Control Act 1941.

Over a period of time a system of grants has evolved which are aimed at providing inducement to Local Authorities and private individuals to undertake community schemes that are deemed in the national interest. This mechanism has been used to balance the perceived national and private returns associated with development as well as to ration the available funds. These grant rates have varied over time, for instance irrigation headworks costs have gone from a 100% grant rate in 1975 to 35% in 1985. Recovery of the loan portion of the total cost is generally by way of one of the following:

(1) rates in the case of Regional Water Board works, or

(2) through the payment of charges e.g. water availability and basic charges for irrigation schemes.

The level of government intervention in the 1977-78 to 1983- 84 period is shown in Table 2.1. Over this period the total amount spent has increased 27% in real terms. However, the above figures need to be kept in perspective. The $60.708 million allocated in the 1983-84 year is small when compared with the $75.5 million spent by the Ministry of Agriculture and Fisheries in the productivity growth area in the same year.

2.3 THE EXISTING PLANNING FRAMEWORK

The final responsibility for approval of projects and changes in policy rests with Cabinet. Statutory changes are the domain of Parliament. This does not mean that Cabinet and Parliament do all the work. There is delegated authority for the approval of work (Table 2.2) and an organisational structure (Figure 2.1) which advises Government.

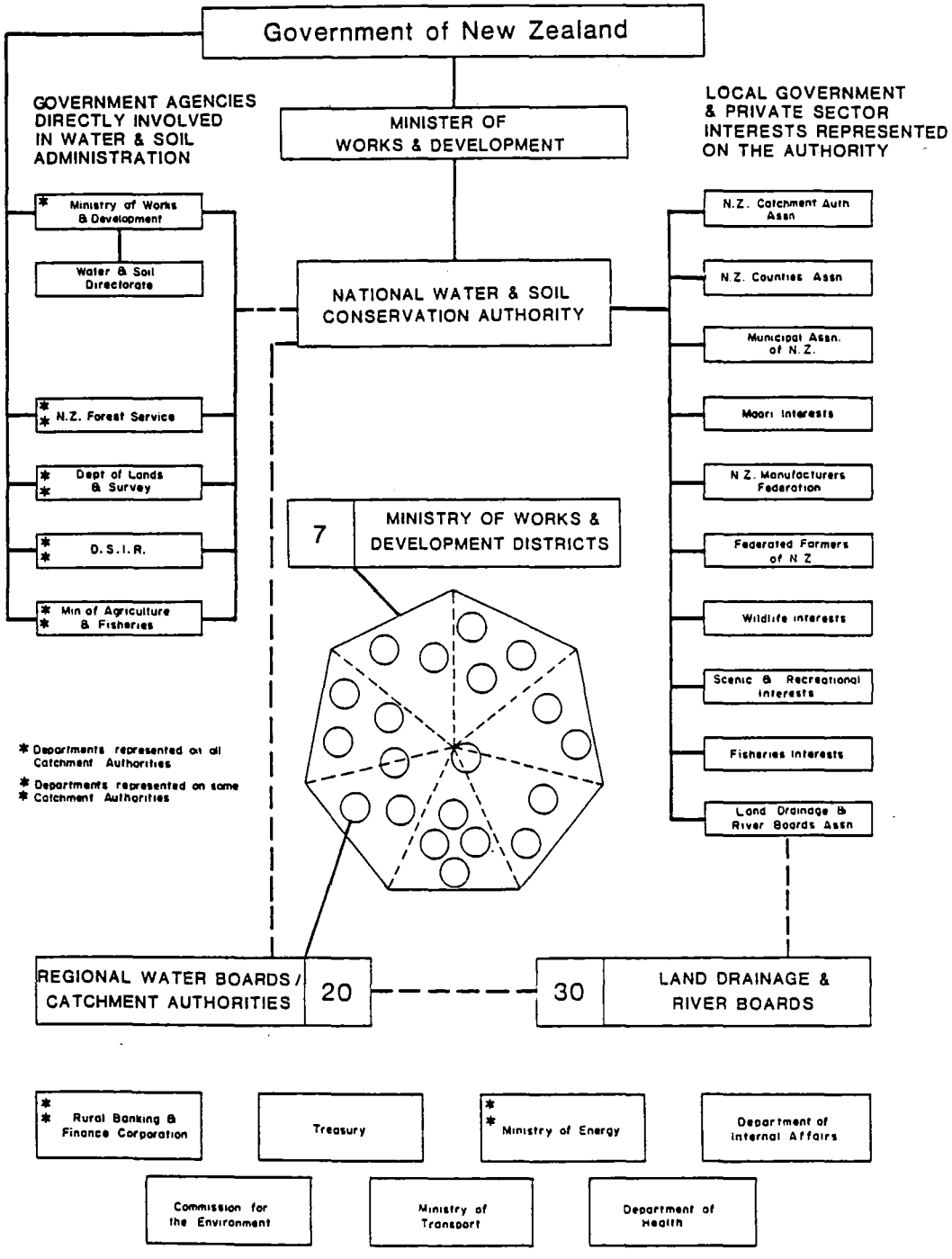
Goals for water and soil conservation agencies, based on the water and soil legislation, were established formally in 1975, NWASCO (1975). The three goals stated were:

(1) Economic: To provide a general basis for development, and to contribute directly to balanced regional development particularly in those areas where water and soil conservation issues are of major concern to the regional economy.

(2) Social: To ensure safety against flood disaster, to promote good community attitudes to the use of water and soil, to maintain agriculture and forestry, and to contribute to recreational opportunities in relation to water, fishing, wildlife etc.

FIGURE 2.1

Water And Soil Conservation Administration In New Zealand



SOURCE: SOIL & WATER (1984)

(3) Environmental: As a principal task, to assure proper management of water resources (quality and quantity). As complementary tasks, to give due consideration to recreation needs, to enhance landscape aesthetics through control of water quality, erosion etc, and to play an advisory role in the production of environmental impact assessments of public works and catchment control proposals.

Table 2.1

National Water And Soil Conservation Works Programme Growth Patterns (Source : NWASCA (1983))

Scheme Type	Year 77-78	79-80	81-82	83-84	Change In Real Terms 1977-84
Irrigation					
Expenditure ($)	2,879	5,467	18,452	22,993	+229%
% Total Programme	15	19	38	38	
Rural Water Supply					
Expenditure ($)	2,358	2,158	3,497	3,872	-32%
% Total Programme	12	8	7	6	
River Control					
Expenditure ($)	8,236	10,314	12,01[illegible]	15,567	-22%
% Total Programme	42	36	25	26	
Catchment Control					
Expenditure ($)	3,603	6,407	9,945	12,867	+47%
% Total Programme	18	23	21	21	
Soil Conservation					
Expenditure ($)	2,080	3,106	4,371	5,408	+7%
% Total Programme	11	11	9	9	
TOTAL	19,645	28,318	48,276	60,708	+27%

Table 2.2

Showing Levels Of Financial Authority For New Works In An Approved Works Programme

Delegated Authority	Level of Delegation New Works in an Approved Works Programme	Level of Delegation New Works Within Policy not in Approved Works
Cabinet	$6,000,000+	$500,000+
Ministers of Works & Development and Finance Jointly		
$6,000,000	$500,000	
Minister of Works & Development	$3,000,000	$300,000
National Water & Soil conservation Authority	$500,000	$115,000
Deputy Chairman of NWASCA	$150,000	$45,000

Source: NWASCO (1985) p. 3.1.

In 1976, the then Director of Water and Soil Conservation highlighted the following in a statement on the regulation of water in New Zealand, (Howard, 1985):

(1) Competing uses must be accommodated,

(2) the resource must be maintained in a satisfactory state for man's continued use, and

(3) the natural order existing in the resource must not be destroyed but may be modified by the use of the resource.

This statement reflected the attitudes prevailing at that time. These were of multiple use of resources, man's domination over nature and the use of natural resources for man's benefit, (Howard, 1985).

The present Director's objectives reflect the current social climate as they account for man's harmony with nature and recognise the intrinsic and cultural values of natural resources. His view of the objectives suitable in this social setting are:

(1) Competing uses are to be accommodated within the national and regional resources available through a judicious blend of development, conservation and preservation.

(2) The water and soil resources must be maintained in a satisfactory condition and may, if appropriate, be augmented to sustain the various uses.

(3) The intrinsic and cultural value of the natural order existing in the water resource is to be recognised as an important factor in the planning and regulation of resource use. Howard (1985)

2.3.1 National Level

The general outline of the national planning approach has been outlined as follows, NWASCO (1975):

(1) Planning Objectives. These are to promote the following activities while at the same time having regard for regional development, maintenance and enhancement of the environment and the economic and physical well-being of people.

a. The most efficient and beneficial use of water
b. Soil conservation and mitigation of erosion
c. The maintenance or improvement of the quality of all natural water
d. The prevention and mitigation of flooding
e. Land drainage

(2) Policy. The policy which encompassed these planning objectives incorporated the following measures and reporting procedures:

a. system of land use zoning,
b. system of rights for the taking of water,
c. system of rights for the discharge of wastes,

d. classification of waters,
e. subsidies for river control works, irrigation, water supply, pollution control,
f. environmental impact reporting,
g. land use capability assessment, and
h. technical standards and services for works.

(3) Implementation. The policy is implemented through:
a. dissemination of technical standards,
b. administrative guidance,
c. promotion and undertaking of research,
d. collection of basic national data,
e. development of techniques for management of resources, and
f. provision of technical services.

by the National Water and Soil Conservation Authority and its technical group; the Water and Soil Directorate of the Ministry of Works and Development.

2.3.2 Regional Level

Planning at the regional level is by way of a Water and Soil Resource Management Plan (WASRMP). This involves a four stage process with the aim of providing a framework for the management of water and soil within a region. The planning objective is "... to conserve and manage resources to facilitate best use consistent with national and regional objectives", NWASCO (1985).

The typical form of the regional planning approach is:

(1) a study of the regions resource base and a statement of the objectives to be used in drawing up the WASRMP,
(2) definition of functional areas i.e. areas where there are critical issues or areas where change is likely to occur or ~~by~~ policy should be encouraged,
(3) development of a management programme for each functional area, and
(4) regular review of the plan to determine whether it is meeting current needs.

FIGURE 2.2

Catchment Works Approval Procedures - April 1984
(Source: Baumgart and Kneebone (1984))

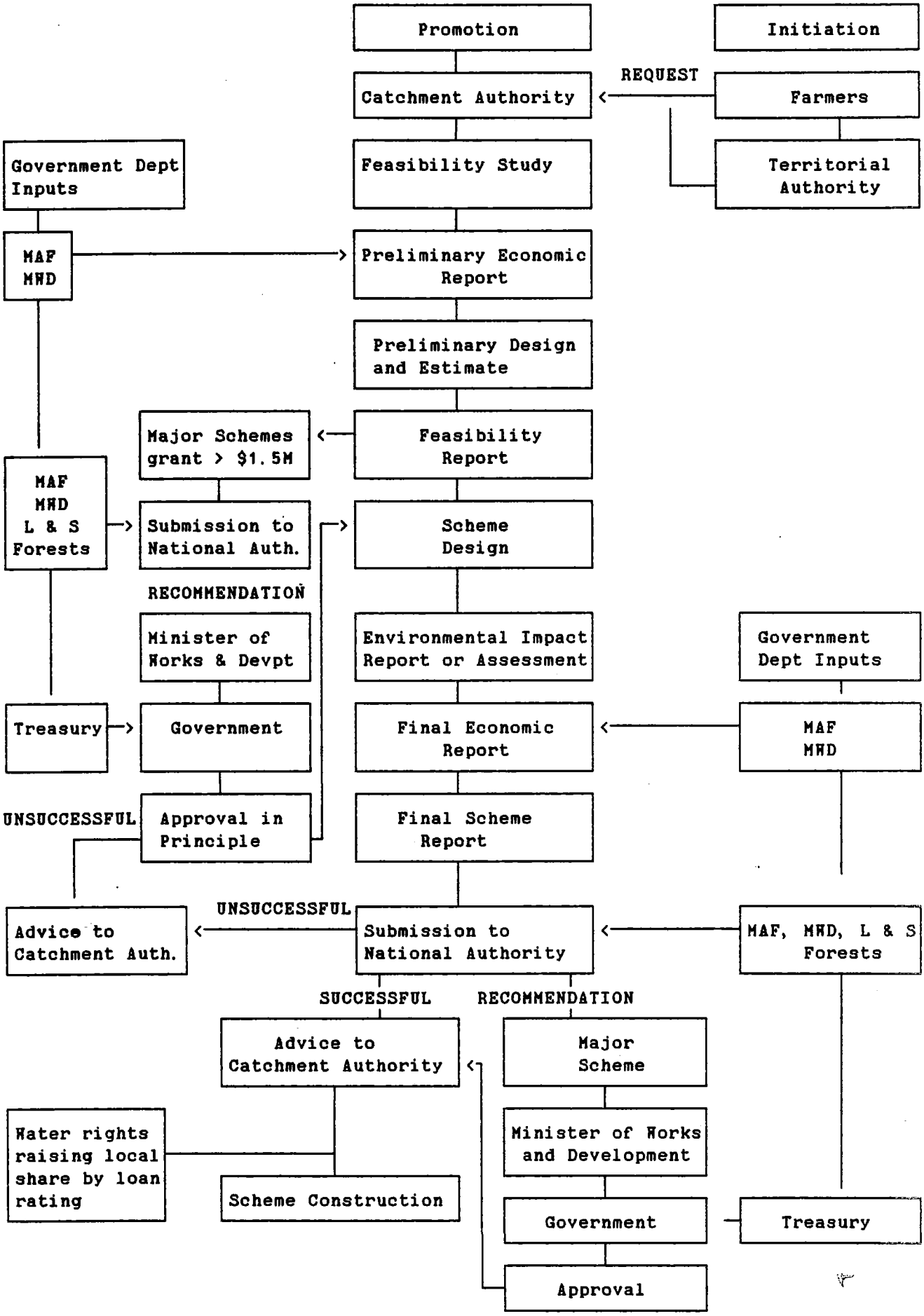
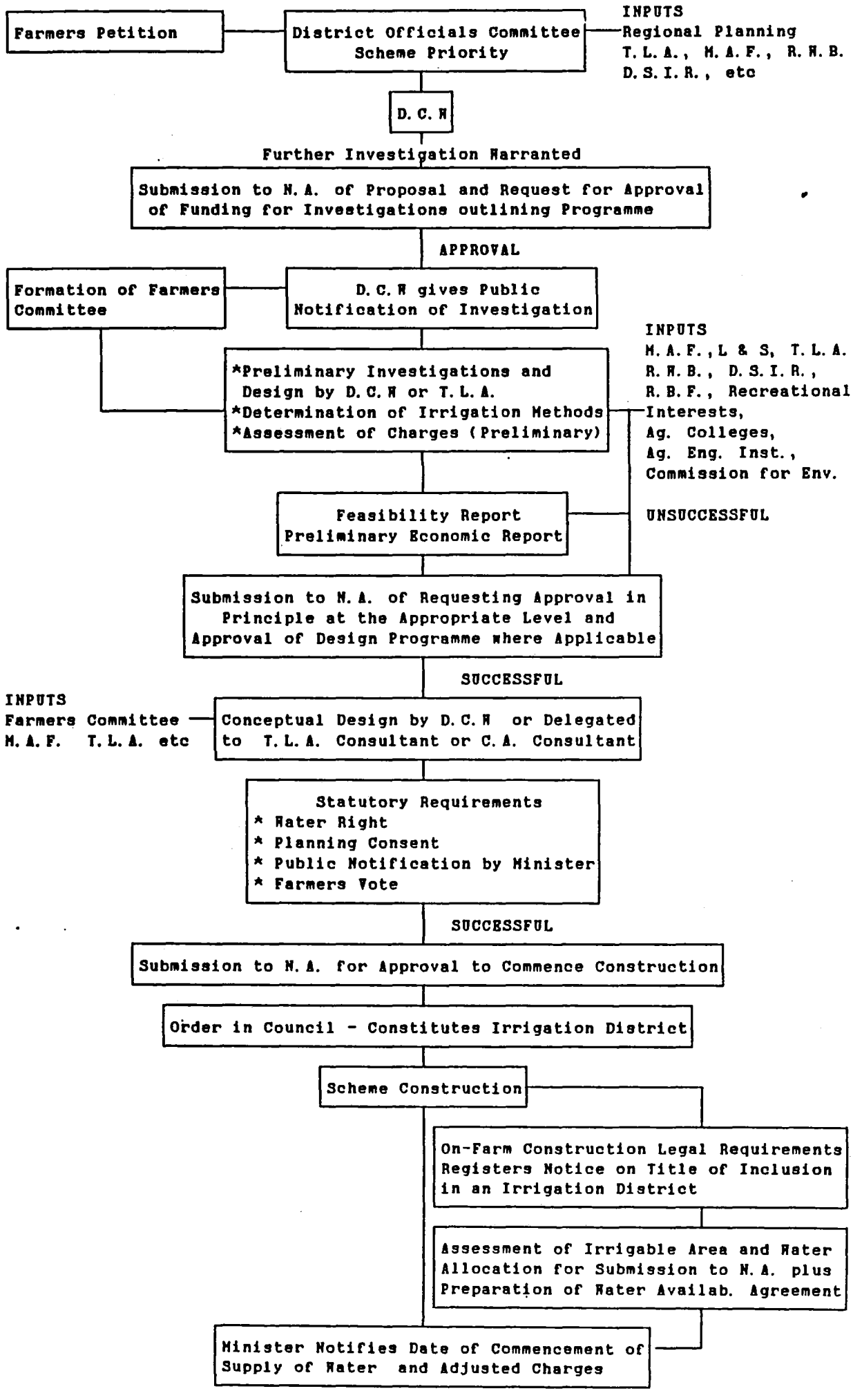


FIGURE 2.3

Irrigation Approval Procedure - April 1984
(Source: Baumgart and Kneebone (1984))



The major limitation of the WASRMP's and water allocation plans (another regional planning tool) drawn up by local authorities is that they have no statutory force. Instead they act as guides for regular catchment authority activities, such as reports, management plans, works proposals and scheme programming.

2.3.3 Scheme Level

Baumgart and Kneebone (1984) in their review of the Water and Soil Directorate (Ministry of Works and Development) described the complex process through which catchment and irrigation works proceeded before scheme completion. The procedures are summarised in Figures 2.2 and 2.3. The early stages of scheme formulation culminate in the submission of the proposed works programme for approval in principle. Approval in principle is necessary for all works in excess of the delegated authority of the Minister Of Works and Development (currently $3,000,000) before they can be included in the approved works programme.

To gain approval in principle a preliminary assessment of cost, timing of costs, design and the economics of the proposed work are required. Multiple use opportunities, regional economic impacts, social effects and environmental considerations must be investigated for irrigation schemes if these factors have a significant bearing on the choice of the scheme option or scheme implementation, NWASCO (1985). The objectives of the approval in principle stage are to ensure that options have been examined and to avoid the cost of preparing detailed proposals for schemes that are clearly not viable.

Once approval in principle has been obtained work continues to complete the details of the works and present a final report. Final reporting includes the detailed technical and cost information, a statement of objectives, details of alternatives analysed, the reason/s for the selection of the proposed scheme and a final economic report. Two further requirements are that statutory (e.g.

water rights, environmental impact assessment, and planning) requirements must be met as well as a statement of local support and provision of the local share and cash flows.

2.4 PROPOSED PLANNING FRAMEWORK

In June 1985 the Ministry of Works and Development circulated a departmental draft of a proposed new Act; the Water and Soil Bill. The aim of the Bill is to consolidate and amend the law relating to water and soil conservation in New Zealand. This new Bill has yet to become law but is expected to do so in 1986.

The proposed Bill takes a two level approach to arrive at policies and decide management systems for the water and soil resources. The two levels are Water and Soil Policy Statements and Water and Soil Management Plans.

2.4.1 Water and Soil Policy Statements

These are statements identifying the issues concerning the management of water and soil resources in a region while having regard to the national objectives stated in the Water and Soil Bill (see Appendix B for details of the Bills' objectives). Apart from identifying the issues, the statement identifies and discusses ways of implementing policies suitable to accommodate the issues. The preparation of a Water and Soil Policy Statement would be mandatory for all regional water authorities and the policies generated would become part of the regional planning scheme. The policies would therefore have statutory force under the Town and Country Planning Act, 1977. Provision is made for public participation in the preparation and drafting of the statement.

The introduction of Policy statements into regional planning means that an adequate framework is provided within which water and soil conservation matters can be administered at a regional level. The inclusion of the

policies in regional planning schemes gives water and soil conservation statutory force at a regional level.

2.4.2 Water and Soil Management Plans

These plans for a specified area which specify:

(1) the uses and values for which water is to be managed,

(2) standards for water quality, levels and flows, and allocation of the resource,

(3) measures to be taken to avoid flood damage and protect water quality, and

(4) land areas and uses which are subject to, or likely to cause subsidence, sedimentation or affect water quality.

Preparation of management plans by regional water boards is optional except where they have been directed to do so by the National Water and Soil Authority. Unlike the Policy Statements, Water and Soil Management Plans are only binding on the regional water boards and do not directly interfere with the rights and obligations of other people. The Plans detail how the regional water board will manage the resources and decisions on water right applications will have to comply with any approved plan. The public are encouraged to participate in the preparation of the plans.

2.5 HISTORICAL ANALYTICAL FRAMEWORK

From as early as 1955 land betterment schemes have required economic reports. The first economic report on an irrigation scheme was carried out in 1955 on the Ida Valley Irrigation Scheme, (Stuart and Mouat (1955)) and in 1960 economic reports on all irrigation schemes were made mandatory. These early economic reports used rules-of-thumb to determine whether a scheme should proceed or not. For instance the 1961 economic report on the Maniototo Irrigation Scheme added the scheme capital costs to the farmer's development costs and compared this with the 'accepted' level of on-farm investment per stock unit. The

values were $158 added by the scheme and an acceptable level of $30.40 per stock unit which meant the scheme could not be recommended. A revised report on the same scheme in 1962 estimated the annual costs associated with the scheme (including interest and a maintenance and renewal fund) and calculated the residual income available to meet these annual fixed costs on a stock unit basis. The report found that the scheme would need a total of 152,000 stock units in the area commanded by the scheme but the area could at the most only support an additional 38,000 stock units.

It was not until the early 1960's that any interest was shown by project analysts in discounted cash flow techniques (see Ward (1961), Ward (1964a & b), Ward (1965), Ward and Parkes (1966)). When the Maniototo Irrigation Scheme was reassessed in 1966, using discounted cash flow techniques, the result obtained was that the scheme was still uneconomic with highly negative net present values and benefit-cost ratios of the order of 0.18 - 0.25. (Ironically the 1962 report found a similar answer without the sophisticated techniques i.e. 38,000 stock units were 25% of 152,000 stock units).

Early soil conservation and rivers control schemes required economic reports which contained the calculation of an annual return on capital expenditure and justification of subsidy rates (Nevins, (1968) and Acheson, (1968)). Nevins also noted that it was not uncommon for drainage schemes in the late 1950's and early 1960's to show estimated returns of 10-50% or more on the subsidised costs, Nevins states "... and such estimates (were) confirmed by economic reappraisals, when full development (had) occurred", ~~Nevins (1968)~~. Normally the preparation of scheme reports was carried out by the classifiers employed by the Catchment Boards and Catchment Boards were expected to check the results of their work against original estimates (Acheson (1968)).

Early reports on rural water supply schemes assessed the increased carrying capacity resulting from the scheme and related the value in dollar terms of this increase to the

annual cost of financing the scheme, Johnson (1967). Annual costs were calculated using a sinking fund calculation. Examples of these reports are the Dunback and Goodwood reports carried out in 1964. The first use of discounted cash flow techniques on rural water supply schemes came in 1964, Donovan and Plunket (1964). In subsequent years a number of reports were presented using the DCF technique, Donovan and Plunkett (1964) and (1965), Plunkett (1965) and Tocker (1966). These reports showed break-even discount rates of between 10% and 15%.

Norton (1963), analysed a drainage scheme by calculating the costs the scheme could support with respect to the likely benefits the scheme would generate. Again the answer obtained was very similar to that which would be obtained using discounted cash flow analysis, Johnson (1967). In latter reports Norton used discounting to account for the timing of the benefits, Norton (1966a) and (1966b).

The 1970's saw increasing acceptance of the cost-benefit technique but the early years "... were preoccupied with formally correct application of this relatively new technique", Frengley (1972). Standardisation of the techniques used in analysing agricultural schemes came through publications produced by Donovan (1968), Johnson and Forbes (1977) and MAF (1984). The first of these publications, Donovan (1968) was produced to give an introduction to the practical aspects of project evaluation for graduates who had a limited knowledge of agriculture. It was not a cost-benefit analysis procedural document as such but a review of the literature pertaining to the likely benefits of irrigation, drainage, flood control and water supply schemes. However, brief reference was made in each section as to the procedures required and conventions used in economic reports. The conventions listed were:

(1) The report was to only include the marginal effects of the project. This was the difference between the with and without scheme cash flows.

(2) Schemes were to be assessed on a normative basis.

(3) Only direct effects of the scheme were to be accounted for and care was needed to include direct effects which occurred outside the scheme boundary.

(4) The decision criteria given prominence was the benefit- cost ratio and the net present value and internal rate of return calculations were optional.

(5) Results were to be presented showing the sensitivity to the discount rate chosen as well as sensitivity to price and benefit assumptions.

In 1977 the Ministry of Agriculture and Fisheries Economics Division produced the first of its two procedural documents, Johnson and Forbes (1977). This document concerned itself with the practical application, rather than the underlying theoretical basis, of cost-benefit analysis. In the eleven year period since Donovan's publication a number of changes had occurred in the theory and practice of cost-benefit analysis in New Zealand. This document reflected those changes. The major points of the second procedural document, MAF (1984), are presented in section 2.6.

The choice of discount rate has varied over time. In the earliest studies a discount rates between 4% and 6% were used. In 1971 a 10% benchmark rate of return was established by Cabinet for use in evaluating new capital investment in the government sector. This discount rate has remained in force since then apart for a period of approximately 18 months in 1979/80 where a 15% discount rate was enforced for irrigation and rural water supply schemes.

In 1971, Cabinet decided that a 10% weighting on foreign exchange be applied to all national cost-benefit analyses of public sector investment proposals. The weighting was intended to account for the perceived scarcity of foreign exchange and meant that export earnings and imported goods were valued higher. The shadow price of 10% was a reflection of the amount by which the exchange rate was over-valued or the amount by which the nominal exchange rate would fall by if exchange controls were removed. The use of

a shadow priced exchange rate ceased in 1985 with the floating of the New Zealand Dollar.

2.6 EXISTING ANALYTICAL FRAMEWORK

The current role of economic reporting in the decision making process has been discussed in section 2.3.3. Four different types of economic report can be carried out on water and soil development projects depending on the stage of scheme development.

(1) Preliminary economic reports are carried out at an early stage of scheme definition. The aim of these reports is to assess the likely magnitude of scheme benefits and indicate any economic constraints on scheme options.

(2) Economic feasibility reports evaluate scheme options and design standards using rough order of costs. These reports are used to assist in decisions on whether detailed scheme investigation and design work should proceed.

(3) Final economic reports are carried out using the final scheme design and cost estimates. These reports accompany the engineering and other necessary reports e.g. environmental impact reports where they are required, for final approval for funding.

(4) Ex-post economic reports evaluate projects at some time after the implementation. They measure actual benefit and cost flows generated by schemes and provide useful insights into project performance which can be used in the planning of future schemes.

Details of the conventions used in the economic analysis of water and soil development schemes in New Zealand are contained in a procedural document produced by the Ministry of Agriculture and Fisheries, MAF (1984). The main conventions can be summarised as follows:

(1) Assume a partial equilibrium analysis i.e. projects are too small in relation to the total economy to have a significant effect on prices. Projects are deemed not to be large enough to have a structural impact on the New Zealand economy.

(2) Projects are analysed from a positive not normative point of view. This means that the project is analysed using the anticipated response of the project recipients to the effects of the development expenditure. Normative studies assess what ought to happen i.e. what the recipients could or should potentially do.

(3) The analysis calculates the marginal effects of the development work from the point of view of the nation and uses the discounted cash flow method to account for the timing of cash flows.

(4) Project life is assumed to be equivalent to the technical life of the major investment item of the project. If the economic life of the major investment item is shorter than the technical life because of obsolescence then the economic life is used.

(5) Current costs and prices are assumed to represent real costs over the life of the project. The implicit assumption is that inflation will effect costs and prices similarly over time.

(6) Product prices reflect medium term projections at the assumed base date. Traded products i.e. those that are traded over the New Zealand border, are valued at border prices and reflect the medium term expectations from international trade. They are average rather than marginal prices.

(7) Non-traded products are valued using domestic product prices.

(8) Transfer payments e.g. taxes, interest on internal borrowing, depreciation and subsidy payments, are

excluded from the analysis as the because they have no call on resources.

(9) Labour is valued at full market cost with the exception of the farmer's own labour which is assumed to have a zero cost.

(10) Foreign exchange is not shadow priced.

(11) A single objective, national economic efficiency, is assumed.

(12) A 10% discount rate is applied to marginal cash flows. This is assumed to reflect the marginal opportunity cost of capital once budgets have been allocated within the public sector, MAF (1984). Both the net present value, at 10%, and internal rate of return are calculated.

2.7 SHORTCOMINGS OF THE EXISTING PLANNING AND ANALYTICAL FRAMEWORKS

2.7.1 Planning Framework

The planning process individual schemes go through are long and tedious. Baumgart and Kneebone (1984) noted that there were long periods of time when the proposing body had no knowledge of the status of their proposal. They made suggestions on ways in which the planning period could be shortened but failed to address whether the planning process itself was satisfactory.

A major problem with the planning framework has been the inadequacy of the water and soil legal framework, in particular the Water and Soil Conservation Act 1967, to provide clear planning objectives give clear guidance in situations where competing uses for water exist. Typical of the questions that need to be answered are:

- what is the best use?
- who should decide?
- what weights should be applied to instream values such as fisheries, recreation,

aesthetics, etc. when conflict occurs in development proposals.

Although in 1976 there was a statement of the goals of water and soil conservation agencies, (see section 2.3) in the succeeding ten years there has been no noticeable move to alter the analysis techniques used to assess schemes. The agencies charged with evaluating schemes have continued to take a single objective approach to a multiple objective problem. Further there has at no stage been a clear statement of objectives at a national or regional level which could act as a guide to analysts, the public and decision-makers in resolving water and soil planning matters. This has led to a situation where water and soil resources are difficult to manage because the policies upon which decisions are made are not explicit and thus cannot be tested.

The 1981 amendment to the Water and Soil Conservation Act recognised instream values by allowing instream users the right to apply for water conservation orders which specified the quantity, flow, or level of natural water that was to be retained in the waterway. The Rakaia River debate has shown this process to be a long and tedious way of resolving resource allocation questions. Further it does not meet the need for a planning and management process which enables the nation and local communities to establish policies for the management of water resources. The amendment also provided no formal processes which would enable policy issues and allocation of the resource to be determined.

Burton (1985) and Anderson, et al. (1984) have questioned the adversary style of conflict resolution used by the 1981 amendment to the Water and Soil Conservation Act. They thought it was not a suitable method for solving resource allocation conflict and Burton cited the situation in Australia where both the Federal and State Governments have abandoned it. Reasons for feeling that it is an

inappropriate method for allocating resources and in effect resolving conflict were because it makes proceedings:

(1) more expensive and time consuming,

(2) less effective, and

(3) lawyers do not have the required technical expertise in hydrology, engineering, agricultural science, resource economics, political science, etc. to make appropriate resource management decisions.

These points highlight the need in New Zealand for a coordinated approach to the resolution of conflict and the recognition of the multiple objective nature of the allocation problem. Quote Frangley

The major limitation of the planning framework being proposed in the draft Water and Soil Bill, MWD (1985), is that the approach adopted is a regional one and there is no clear national planning strategy. Further the plans are directed at the management of the resources and appear to have no provision for presentation of plans for future water resources development, Burton (1985).

2.7.2 Analytical Framework

In an effort to determine some of the shortcomings of the present analytical component of the planning framework a survey of forty people involved in the analysis of water and soil based projects in New Zealand was carried out by the present author in 1985. This survey highlighted the following areas of concern with the currently used analysis methods (details can be found in Appendix C):

(1) Inadequate information for decision making. An information system that provides accurate information on the likely benefits and costs of water and soil schemes is needed.

(2) Concern was expressed at the large number of schemes gaining approval without adequate identification, and analysis of alternatives early in the design phase.

(3) Failure to include objectives other than economic efficiency in the analysis of schemes.

(4) The inability of the current analysis procedures to account for the transfer of benefits between generations and at the same time give appropriate signals to the decision-makers. This is highlighted by the choice of a real public discount rate of ten percent.

The first three points are discussed directly in succeeding chapters of this study and the fourth is an underlying consideration in the discussion of the multiple objective approach to decision-making in Chapter IV.

What about the 30% pricing of 'saved' labour?

50 P.

CHAPTER III

A BRIEF HISTORY OF WATER RESOURCES PLANNING IN THE UNITED STATES OF AMERICA

The major force in water resources planning methodology and legislation in New Zealand (and the rest of the world) has been developments in the United States of America (U.S.). This section will document the changes that have occurred in the U.S.

U.S. Federal guidelines for water resource planning began with the Flood Control Act of 1936. In this Act Congress directed that flood control projects should proceed only if "... the benefits to whomever they may accrue are in excess of the estimated costs, and if the social security of people are otherwise adversely affected." This general guideline was gradually made binding on all water resources projects undertaken by the U.S. Corps of Engineers, Bureau of Reclamation and Soil Conservation Service.

3.1 THE "GREEN BOOK"

The Act also produced a challenge for the development of analytical procedures to evaluate the costs and benefits of proposed projects. This challenge was met and resulted in procedures published as the " Proposed Practices for Economic Analysis of River Basin Projects" in May 1950. This report, also referred to as the "Green Book", was revised and reissued after slight additions and modifications in May 1958.

The main aim of the "Green Book" was explained as follows :

> "The ultimate aim of river basin projects and programs, in common with all other productive activity, is to satisfy human needs and desires. The objective of economic analysis in planning

river basin and watershed programs is to provide a guide for effective use of the required economic resources, such as land, labour, and materials, in producing goods and services to satisfy human wants by determining whether economic resources would be used more effectively than would be the case without the project.

Although it is recognised that public policy may be influenced by other than economic considerations, this is concerned with the economics of project development and justification."

(Subcommittee on Benefits and Costs, Federal Inter-Agency River Basin Committee, 1950).

It is clear therefore that national economic efficiency was the paramount objective. This is not to say that other objectives were to be ignored. The criteria and principles presented were intended for application within the framework of existing agency policies and as such, other objectives were accounted for. An example of this was the 160 acre rule of Reclamation Law which stated that Federally developed water could not be supplied to lands in excess of 160 acres for any landholder. The objective of this rule was to encourage the development and retention of family farms.

There was no formal adoption of the "Green Book" by the Federal Inter-Agency River Basin Committee (or its successor committees) for water resources projects. However, the basic criteria and principles of the "Green Book" were embodied in the Bureau of Budget Circular No. A-47 which was issued in December 1952. This document required agencies to carry out their evaluations of projects in terms of prescribed standards and procedures and to indicate if any legal or institutional constraint was at variance with this approach. This later point implied that changes would occur to any laws which were inconsistent with the official approach and that institutional constraints would only be accepted in exceptional circumstances. To gain funding approval projects had to have a benefit-cost ratio (from the national point of

view) of greater than one at the official discount rate. The advent of Budget Circular No. A-47 meant that other objectives of water resources projects were not to be considered, which was a reversal of the 1936 Flood Control Act.

These draconian measures remained in force through the 1950's but did not go unchallenged by Congress and Federal water agencies. In the mid to late 1950's pressure was exerted by Congress and the Federal water agencies to liberalise the evaluation procedures. The specific changes called for were; an extension to the planning period from 50 to 100 years, recognition of secondary and regional benefits, and acceptance that the enhancement of recreational opportunities and fish and wildlife habitats was one of the major aims of water resources projects. O'Brien, et al. (1977) noted that over this period Congress was able to authorise a number of projects forwarded by the Federal planning agencies regardless of whether the projects had the approval of the Bureau of Budget, or its successor, the Office of Management and Budget.

Another feature of the mid 1950's was the initiation of the Harvard Water Program, (O'Brien, et. al. (1977)) This was a major engineering, economic and governmental study which led to significant advances in water resources systems design in the next decade, (Maass, et.al. (1962)) From the planning point of view one of its major contributions was its emphasis on a shift from single to a systematic multiple objective approach to planning.

3.2 THE MOVE TO MULTIPLE OBJECTIVE PLANNING

In October 1961 the President requested the secretaries of Interior, Agriculture, Army, Health, Education and Welfare to review the existing evaluation standards and to recommend improvements. The resulting report, "Policies, Standards, and Procedures in the Formulation, Evaluation,

and Review of Plans for Use and Development of Water and Related Land Resources", was approved by the President in May 1962 and published as Senate Document No. 97. This document replaced Budget Circular No. A-47.

The national objectives of water planning were now stated as follows:

> "The basic objectives in the formulation of plans is to provide the best use, or combination of uses, of water and related land resources to meet all foreseeable short and long-term needs. In pursuit of this basic conservation objective, full consideration shall be given to each of the following objectives (development, preservation and well-being of people) and reasoned choices made between them when they conflict."

The elements to be considered under each of the objectives were detailed as:

(1) Development - land and water based development was essential for economic development and growth for all the multiple purposes including recreation and fish and wildlife enhancement. Development was to include both national and regional development options.

(2) Preservation - the preservation of the "Nation's natural bounty" and in particular open space, green space, wild areas of rivers, lakes, beaches, mountains, and areas of unique natural beauty, historical and scientific interest. The emphasis was on preservation and rehabilitation for best future use when needed.

(3) Well-being of people - the well-being of all the nation's people was to be the overriding factor in considering the best use of water and related land resources. This objective was to look at the distribution of benefit and also include such things as the saving of life. In addition institutional constraints which met social

objectives were to be observed, e.g. the 160 acre rule of Reclamation Law.

Other features of Senate Document 97 were that; planning was to include structural and non-structural means either singly or as part of a package; the optimal economic efficiency plan was to act as the base-line against which other alternatives were to be measured and there was no requirement for the project to have a benefit-cost ratio greater than one to gain approval. However this later point was not binding on the Office of Management and Budget and it adopted a requirement that projects meet a benefit- cost ratio of at least one.

The advent of Senate Document No. 97 did not lead to many changes in planning and evaluation. The biggest influence was felt in the evaluation of irrigation schemes where two benefit- cost ratios were calculated to justify schemes on other than national economic efficiency grounds. The two ratios calculated were one for the national economic efficiency objective and one for the regional objective. This practice was common in situations where the national benefits did not meet unity. It eventually led to the situation where it became a stated policy that all projects should meet a benefit-cost ratio of one before submission for legislative action, ECAFE (1973).

The change in emphasis away from single objective planning to multiple objective planning was symptomatic of the changes occurring in the U.S.A. in the 1960's. The mid-1960's saw a stable national economy which precipitated a move to resolve other problems such as racial inequalities, air and water pollution and land-use conflict. A consequence of this was a strong environmental lobby developed with aggressive anti- developmental attitudes. As a consequence of changing public attitudes a large amount of planning legislation came into being. The American legislation included the following:

Federal Water Project Recreation Act of 1965,
Water Resources Planning Act of 1965,
Public Works and Economic Development Act of 1965,
Water Quality Act of 1965,
Wild and Scenic Rivers Act of 1968,
Estuary Protection Act of 1968,
National Environmental Protection Act of 1969, and
Flood Control Act of 1970.

Similar changes were occurring in New Zealand in the late 1970's and are still going on today (see Appendix A).

In July 1968 the basis for calculation of the discount rate was altered from that laid down in Senate Document 97. To that date the discount rate used had been calculated on the coupon rate of Federal bonds. The change was to an annual calculation on the basis of the yield rate on outstanding Federal bonds. This had the effect of raising the discount rate 1.375 percentage points to 4.625 percent. This subsequently led to pressures from Congress for change as it was now harder to justify schemes. As a result of these pressures the Water Resources Council set up a task force, in 1969, with the objective of replacing Senate Document 97 completely.

3.3 THE "PRIINCIPLES AND STANDARDS" AND "PRINCIPLES AND GUIDELINES" DOCUMENTS

The task force produced a discussion document "Procedures for Evaluation of Water and Related Land Resource Projects" in June 1969. This publication became known as the "Blue Book". One of its main recommendations was to formalise the inclusion of objectives other than economic efficiency into the decision- making process. The objectives recommended for inclusion were national economic efficiency, regional development, environmental quality and social well-being."In addition the report attempted to identify all benefits of water use or development and

provide procedures for complete measurement of benefits and costs and for consideration of all so-called intangible effects", O'Brien, 1977.

The task force recommendations were then put to the test on nineteen projects by agency, university and consultancy groups. The results of these tests were published as "A Summary Analysis of Nineteen Tests of Proposed Evaluation Procedures on Selected Water and Land Resource Projects" in 1970. The tests showed that a multiple objective approach was practical but there were a number of operational problems with implementing them. The major problems were in the formulation of alternatives and the measurement of effects, especially those associated with the environmental quality and social well-being objectives. The recommendations of the task force were never adopted. Instead the Water Resources Council issued its own document, "Proposed Principles and Standards for Planning Water and Related Land Resources", in December 1971 for public hearing and review.

The Water Resources Council proposal differed from that of their Task Force in the following areas:

(1) The social well-being objective was dropped as a major objective and was not to be considered in plan formulation but its effects were to be measured in a system of accounts.

(2) The regional development objective was only to be considered in plan formulation with prior approval or when directed, otherwise the effects were to be considered in a system of accounts.

(3) Plan formulation was to include two plans - one maximising the national economic development (NED) objective and one accounting for the environmental quality (EQ) objective. Trade-offs were to be made between these two objectives.

(4) The basis for determining the discount rate was altered from the rate of social time preference to the opportunity cost of all federally investment

activities including water resources projects. This cost was thought to be representative of the real rate of return on non-federal investments. The rate calculated under these rules was estimated to be 10% but because of political difficulties in using this a 7% rate was adopted. The lower rate, which implied a subsidy, represented the political importance of regional development and other social effects in water resources projects, O'Brien, et al (1977).

The revised Principles and Standards for Planning and Related Land Resources were forwarded to the President for approval in July 1973. They were subsequently published in the Federal Register on the 10 September 1973 and became binding on all federally, federally assisted, and federally licensed water and land programs in the United States on the 25 October 1973.

The major changes from the 1971 Proposals were that only two objectives, national economic development (N.E.D.) and environmental quality (E.Q.), should be considered in development proposals. These two objectives were to be considered in the planning cycle from conception to decision-making. This meant that alternative designs were to be formulated recognising the two objectives, N.E.D. and E.Q. separately. Regional development had been dropped further in status to an account only. Therefore in theory planning agencies could not specifically develop plans considering RD and OSE at the project formulation stage.

The second major change was that the basis for calculating the discount rate was altered to be the average cost of federal borrowing, calculated as the average yield on all interest bearing marketable securities ranging from 13 weeks to 40 years. This had the effect of lowering the public sector discount rate to 6.875%. This was further lowered to 5.625% the yield rate on marketable securities with at least 15 years to run, by Congress in 1974 in the Water Resources Development Act.

The full potential of the "Principles and Standards" legislation was never realised in the 1970's due mainly to lack of practical and acceptable procedures for making tradeoffs between objectives, Eisel, et al (1982). This led to a Presidential directive in 1978 (Carter, 1980a) to improve the "Principles and Standards" especially in the areas of uniformity of evaluation, removal of benefit double counting, consideration of non-structural alternatives and water conservation. The directive meant a change in planning philosophy rather than a change in evaluation techniques. It was clear that any procedures adopted had to be operational in nature and workable in the field if they were to gain acceptance by evaluators and decision makers alike. This meant that even while effort was being made to develop procedures that complied with established theory, the procedures were often impractical because of lack of data and inadequacies in computational capability, resources and legislation, Eisel, et al. (1982).

Cost efficient and environmentally attractive options for achieving water resources goals were; non-structural alternatives included floodplain management, pricing policies (especially for water supply and electricity) and groundwater recharge. In addition, water conservation, in the form of increased efficiency in use rather than structures to impound water, would also achieve the same result.

The U.S. Water Resources Council carried out work on the Presidents directive in three phases. These phases included;

(1) Phase I - Initiated in August 1978 this phase involved the development of the Procedures for Evaluation of Economic Development (NED) Benefits and Costs in Water Resources Planning (Level C). These were subsequently published as a final rule in December 1979, U.S. Water Resources Council (1979). Also as part of Phase I the "Principles and Standards" were revised to include water conservation considerations and evaluation of a

non- structural option as one of the project alternatives, U.S. Water Resources Council (1979).

(2) Phase II - This phase, started in August 1979, undertook to develop procedures for environmental quality evaluation. The results of this work were published as "Environmental Quality Evaluation Procedures for Level C Water Resources Planning; Final Rule", U.S. Water Resources Council (1980b). In addition this phase included the rewriting of the "Principles and Standards" to provide a clear and concise document (U.S. Water Resources Council, 1980a), integration of Urban and Community Impact Analysis into the "Principles and Standards", and development of two further sub-parts to the NED and OSE evaluation procedures (U.S. Water Resources Council, 1980c).

(3) Phase III - Phase III was ~~scheduled~~ started in 1980 but was stopped by President Reagan's decision to terminate funding in September 1981. This phase was to focus on the following for publication as final rules:

a. Principles, Standards, and Procedures for Water and Related Land Resources Planning - Level B,
b. Procedures for Level C Water Resources Planning,
c. Regional Economic Development Evaluation Procedures for Level C Water Resources Planning,
d. Other Social Effects Evaluation Procedures for Level C Water Resources Planning.

The only other changes to the "Principles and Standards" was a rewriting to make them clearer and more concise. In addition they were adopted as formal rules which meant they could be enforced by a third party through a court of law.

Another consequence of the Carter directive was the development of a planning manual by the Water Resources Council to ensure consistency of evaluation. This manual was

designed to supplement and implement the "Principles and Standards" and other economic evaluation requirements, Carter (1980b). The major sections of the manual were to be procedures for the evaluation of beneficial and adverse effects on; national economic development, regional development, regional economic development and other social effects. In addition, procedures for plan formulation and cost allocation were to be drawn up.

The first two sections were completed, U.S. Water resources Council , 1979a, 1980d, and 1980c, but further development was stopped by President Reagan's decision to terminate funding in September 1981. In 1983 the Principles and Standards were replaced by the "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies", U.S. Water Resources Council (1983). This was done to reduce the burden on agencies in complying with detailed and legally binding technical rules. The major change from the earlier Principles and Standards documents was that the NED account was now the only required account while other information would be included in the EQ, RED, and OSE accounts, or "in some other appropriate format", U.S. Water Resources Council (1983). The Principles and Guidelines provided extensive guidelines for the NED and EQ accounts but provided much less information on the RED and OSE accounts. In the intervening period water resources development has all but ceased in the U.S. and research effort has been directed into other areas. Table 3.1 summarises the development of water resources planning procedures in the U.S. since Senate Document 97 in May 1962.

TABLE 3.1

Summary Of The Development Of Water Resources Planning Procedures In The U.S. 1960-80

Item	Senate Document 97 (May 1962)	Task Force recommendation (July 1970)	WRC Proposal (Dec. 1971)	Principles & Standards (Sept. 1973)	Principles & Standards (Sept. 1980)
Objectives	National efficiency with adjustments for preservation, well-being or regional development	Multiple objectives NED, EQ, social well-being, RD considered equal	Multiple objectives NED & EQ; RD only when directed	NED and EQ	NED and EQ
Plan Formulation	Rigorous national economic efficiency Adjust for preservation, well-being or regional development	Formulate for all objectives Trade-offs among alternative plans	Formulate alternative plans for NED and EQ objectives RD only when directed No formulation for social effects	Formulate alternative plans for NED and EQ, objectives No formulation for RD or social effects	Formulate alternative plans for NED & EQ objectives as well as primarily non-structural plan. Trade-offs among alternative plans. OSE where directed
Measurement of effects	Measure only monetary effects	System of accounts Measure and record all effects towards NED, EQ, social well-being, RD	Same as Task Force recommendation	Same as Task Force recommendation	System of accounts Measure & record all effects towards NED, EQ, RED and OSE
National economic development effects	Primary and possibly secondary benefits valued by actual or simulated market prices, increased income, alternative costs	Output valued by willingness to pay, increased income, alternative costs Use of unemployed or underemployed resources, external economies	Output valued by : willingness to pay, increased income, alternative costs, external economies	Same as WRC proposal	Output valued by willingness to pay Increases in the economic value of the national output of goods & services, external economies, alternative costs, use of unemployed & underemployed resources

Table 3.1 continued

Environmental quality effects	Preservation of open space, wild areas and areas of unique beauty and cultural interest	Enhance quality of environment by management, preservation & restoration of cultural resources & ecological systems	Same as Task Force recommendation	Same as Task Force recommendation	Effects on ecological, cultural and aesthetic attributes of significant natural and cultural resources
Other social effects	Well-being of all people the overall determinant but criteria not defined	Income distribution Population distribution Economic stability Life, health & safety Educational & recreational opportunities, national security	Income distribution Life, health & safety Emergency preparedness Other	Income distribution Life, health & safety Emergency preparedness Other	Urban and community impacts and effects on life, health and safety; displacement; long-term productivity; energy requirements & energy conservation
Regional economic development	Adjust national efficiency for regional development Include regional secondary benefits Compute separate B/C ratios for primary & total benefits	Regional incidence of NED effects, regional employment, regional economic stability, regional environment and social well-being	Regional incidence of NED effects, use of unemployed or underemployed resources, regional employment, population distribution, economic stability, educational cultural & recreational opportunities, and regional EQ Induced activities	Regional incidence of NED effects, regional employment, population distribution, economic stability, regional EQ, induced activities	Regional incidence of NED effects, income transfers and employment effects

Table 3.1 continued

Cost sharing	No provision	Review cost sharing for multi-objectives; 50:50 on water quality storage for environmental quality	Same as Task Force recommendation	Review cost sharing for multi-objectives	SCRB, apportion financial costs among purposes served by a plan. Allocated among Federal & Non-Federal, public & private interests
Discount rate calculation	Coupon rate of Federal Bonds (3-1/4 percent)		The opportunity cost of all federal investment activities including water resources projects (approx. 10% but lowered to 7% to reflect importance of RD and OSE)	Average yield on all interest bearing marketable securities ranging from 13 weeks to 40 years, i.e. average cost federal borrowing. (6-7/8% later ammended to 5-5/8%)	
Coverage	River basin planning Corps of Engineers, Bureau of Reclamation Soil Conservation Service watershed projects	Comprehensive regional or river basin plans, all federal, federally assisted, & federally licensed water & land programs	Same as Task Force recommendation	Same as Task Force recommendation	Comprehensive regional or river basin plans, all Federal, Federally assisted, & Federally licensed water and land programs

Abbreviations :

WRC	Water Resources Council
NED	National Economic Development
EQ	Environmental Quality
RED	Regional Economic Development
OSE	Other Social Effects
SCRB	Separable Cost-Remaining Benefits

CHAPTER IV

DEVELOPMENT OF AN IMPROVED PLANNING FRAMEWORK

Burton, (1985) in a critique of water resources planning in New Zealand stated that modern thinking in water resources planning highlights the following five areas:

(1) A systems approach to planning which recognises inter- relationships between components and the effects of the project,

(2) A total catchment approach to resource development,

(3) Planning for multiple use of resources,

(4) Planning for multiple objectives, and

(5) Community involvement in planning and decision-making.

The first two areas of concern are presently covered adequately in New Zealand but it is in the last two areas, and to a lesser extent the multiple use of resources, that significant progress can still be made. This chapter highlights suitable planning frameworks, discusses public participation in the planning process and the development of planning for multiple objectives.

4.1 PLANNING FRAMEWORK

Public sector intervention in water and soil resource planning occurs because of the desire to:

(1) Overcome market failures and maldistribution of benefits and costs of water and soil resource use,

(2) Ensure that community preferences are satisfied, and

(3) Achieve long-term community goals.

In achieving these objectives the government also wants to obtain the most efficient return on its capital outlay and to manage the water and soil resources in the best interests of the community. This implies the most cost effective use

of scarce tax gained funds (efficiency) and the need for public participation (community interests).

Planning for the redistribution of tax gained funds and the management of the resources, in New Zealand, falls into the sphere of the public agencies (Water & Soil Directorate, Treasury, Ministry of Agriculture and Fisheries, etc.). The planning processes adopted by the public agencies are varied but will involve one or a number of the following approaches:

(1) Inactive - This is the case where no action is taken and the market forces are left to determine satisfactory levels of production, prices, resource use and distribution of benefits.

(2) Reactive - This approach is the response to problems after they have occurred. It involves no elements of planning for the future and often the planners resist the changes associated with progress and return to past practices.

(3) Preactive - More commonly known as management by objectives. This form of planning aims at achieving a set of organisational objectives. The objectives are set after analysing current trends and projecting these forward to achieve the desired result.

(4) Interactive - The contribution of a wide range of ideas to the decision-making process is implicit in this approach. The initial step is to decide on the goals and associated objectives that are desired and then set up structures that allow this to occur. The whole system is dynamic and objectives are continually being reformulated and refined; appropriate monitoring is therefore implied.

The inactive approach to planning will only be a viable alternative in situations where a perfectly free market is allowed to operate and socially optimal distribution of resources occurs. The reactive approach is clearly not acceptable at this time as it would ignore economic,

environmental and social consequences of development at a time when there is pressure from the community to have these factors included in the planning process.

A preactive approach, or management by objectives, is in widespread use in both the private and public sectors. It has limitations in that the setting of objectives is made either at an individual or organisational level, leading to a situation where objectives are too broad or too specific. This limitation is clearly shown in both the New Zealand and American approaches to water and soil planning. New Zealand water and soil planning has adopted a preactive approach to planning but there has been no clear statement of objectives other than in legislation. The Americans also have their objectives embodied in legislation but have developed an analytical framework, multiple objective planning, to incorporate the objectives into the planning process. The American planning process was developed to meet the needs of the analytical framework rather than the needs of society and as such failed to consider effectively society's objectives. Limitations to the approach adopted by the Americans are:

(a) the specification of the objectives is done in the "Principles and Standards" document,

(b) there is no recognition of the public's role in the decision making process, and

(c) the need for monitoring and evaluation of projects to ensure that objectives are being met is ignored.

Interactive planning overcomes the limitations of the above approaches. In addition, it lends itself to decision making in the public sector because in order for the government to maintain or improve all aspects of the communities' quality of life it must know the preferences of the people that it serves. The inclusion of the public in the interactive planning process means that the publics' preferences can be implicitly incorporated into decision making. In order to be effective, and to account for the dynamic nature of planning and decision making, this

planning approach requires a substantial data base to monitor whether objectives are being met. The interactive approach to planning has been adopted by the New South Wales State Government for use in its water resources planning, N.S.W. Water Resources Commission (1984), and is undoubtedly the most suitable for water and soil resource decision making in New Zealand.

For interactive planning to be effective it is essential that the goals, objectives and criteria to be monitored are clearly laid out at the start. Goals, therefore, provide the framework for planning decisions. They need to be consistent with the overall aims of government and define a specified state. An example of an economic goal is:[1]

> "To foster economic diversification, both industrial and geographical, to provide the economy with some insulation from the effects of variations in climate, domestic and world markets and technology."
>
> (N.S.W. Water Resources Commission, 1984)

Objectives are designed to achieve the goals and at the same time act as a guide to elements in the planning process and aid in policy formulation. They are the operational aims of the organisation and provide the steps which are necessary to attain defined goals. Establishment of objectives makes monitoring worthwhile and provides the basis to permit effective monitoring to take place. Therefore, it is necessary that the objectives are clearly presented and specific. This will then allow effective and efficient monitoring, ease of understanding, and ease of refinement should this be necessary. It is essential that objectives do not overlap within or between goals as this will lead to double counting. As there will be some conflict between objectives there is a need for a mechanism to reach a compromise between conflicting objectives. This mechanism must also be flexible enough to allow changes in public (social) opinion and at the same time acknowledge the uneven distribution of lobbying power and wealth within the

1. Further examples can be found in the N.S.W. Water Plan appended as Appendix D.

community. An example of an economic objective is;[1]

> "To publicly fund the provision of water and water services where these generate net public benefits for which individual beneficiaries cannot be identified and/or charged."
>
> (N.S.W. Water Resources Commission, 1984)

Criteria are the factors that will be monitored to measure whether, and to what extent, objectives have been met. Ideally there will be one criteria for each objective but this is seldom so in practice because of the complex nature of the processes e.g. economic, environmental and social. The measurement units can be either quantitative or qualitative in nature. Examples of some criteria adopted by the N.S.W. Water Resources Commission are shown in Appendix D.

For interactive planning to be effective planners need to recognise that:

(1) Planning is about the future and not the present or past, Sewell (1985). They therefore need to anticipate technological and social changes that are likely to occur in the future.

(2) Secondly planners need to change their role as experts. Michael (1977) showed that the changes required will be even more demanding on the planning expert (Table 4.1).

One problem associated with adopting interactive planning in New Zealand is that decision making occurs at a number of different levels; Government, regional and local levels. Water and soil schemes which are approved at governmental level affect areas of local concern, involve regional and local governments to varying degrees, and include a strong emphasis on planning. It is therefore necessary that all levels of the decision making process have interlocking planning goals. Bolton, et. al. (1983), in a study of the perceived planning goals of groups interested in the planning process (in the U.S.), showed that this is not always the case. The study found that the four most

1. Further examples can be found in the N.S.W. Water Plan appended as Appendix D.

commonly perceived planning goals were:

(1) Responsiveness to local problems and concerns,

(2) Responsiveness to national goals and objectives,

(3) A balance among competing preferences about how water resources should be used and protected (conflict resolution), and

(4) Public understanding of the potential consequences of policies and alternatives.

The relative weightings given to each of these goals by five interest groups is shown in Table 4.2. The conflict between planning goals is shown by the relative weights assigned to the four goals by the different interest groups. Federal agencies placed more emphasis on the achievement of national goals than did the public and non-federal groups. These later groups placed weights of 0.44 or above on achievement of local goals. It is unlikely that the situation would be much different in New Zealand.

The underlying factor in the Bolton, et.al. (1983) study was that there is conflict in the goal and objective setting for planning purposes. However, there was a general consensus that development was occurring in response to local problems and concerns. If this is the case it is important that local groups should be involved in goal and objective setting. National goals should act as guidelines for these local groups but should not act as a major constraint in the achievement of local goals. This is complicated further by the fact that central government is involved via grants and subsidies for projects that solve local problems. Central government then feels that it should play a greater part in the local goal setting.

4.2 CONFLICT IN PUBLIC PLANNING

Lord (1979) described three types of conflict in water resources planning. These were:

(1) Cognitive - Cognitive conflict arises because of different understandings of the conflict situation

Table 4.1

Old and New Experts in Planning

Old Expert	New Expert
SOLUTION-ORIENTED (defines a problem in terms of a solution)	PROBLEM-ORIENTED (explores a situation to define the problem).
Bounded	Unbounded
Emphasis on primary effects	Secondary & tertiary effects
Simplifying	
Assumption accepting	Assumption challenging
QUESTION ANSWERING	QUESTION ASKING
EXPERTISE	EXPERTISE
Professional	Extra-professional
Error-denying	Error-embracing
Surprise-free	Surprise-embracing
SYSTEM CLOSING	SYSTEM OPENING
Elitist	Democratic
Technocratic	Public
Comforting	Threatening
Conflict-masking	Conflict-exposing
Product-oriented	Process-oriented
ORGANISATION CAPTIVE	BOUNDARY SPANNING
Protected	Exposed
'Hired gun'	Free-floating
Institutional	Personal
Client-oriented	Issue-opportunistic
POLITICALLY EXPLICIT	POLITICALLY AMBIGUOUS
Late in political process	Early in political process
Choice related	Issue-formulating
Well-defined expectations	Uncertain expectations

Source: Michael (1977)

TABLE 4.2

Relative Weightings Given to Planning Objectives

by Interest Groups

	LOCAL PROBLEMS	PUBLIC UNDERSTANDING	CONFLICT RESOLUTION	NATIONAL GOALS
Federal Lead Agencies	0.39	0.19	0.20	0.21
Federal Non-Lead Agencies	0.33	0.27	0.18	0.23
Non-Federal Agencies	0.45	0.19	0.31	0.06
Local Elected Representatives	0.48	0.25	0.15	0.12
Public	0.44	0.27	0.21	0.07
Total	0.45	0.25	0.25	0.07

Source: Bolton et al (1983)

and is normally associated with technical of the 'if A, then B' variety. This type of conflict can be resolved by using techniques that narrow the range of conflict. Such measures include research, appeal to higher authority, interpersonal communication, and collection of new empirical information.

(2) Value Conflict - This grouping of conflict is ideological in nature for example the debate between economic efficiency and environmental quality objectives. The groups involved in the Rakaia River debate may agree on the affects of water abstraction (removing cognitive conflict), yet they may be at odds on the desirability of the results. Such conflict can be resolved by interpersonal communication to achieve compromises between different positions. Resolution is facilitated by introspective and/or analytical re-examination of personal values or unilateral (authoritarian) or collective (democratic) choice, in which one view prevails over the other/s.

(3) Interest Conflict - This arises because the parties perceive prospective impacts on their own well being which may be desirable or undesirable for others. Interest conflict occurs where the beneficiaries of a project may be different from those who bear the costs and results from differences in the incidence and magnitude of the socio-economic impacts of the project. Conflict of this type can be resolved by inter-personal and/or inter-group bargaining.

It is normal for public policy conflict to involve at least two of the above types of conflict groups. Cognitive conflict is present in nearly all cases because of our lack of knowledge and understanding of the biological and socio-economic systems. Value conflict again is common because of differing social values and because of the need

to rationalise our immediate interests by creating and adopting a value structure which supports and legitimises those interests, Lord (1979). Finally, interest conflict nearly always occurs because no public policy decision is never Pareto-optimal.

Conflict resolution is the process which focuses upon achieving agreement between conflicting interest groups. Lord, et al. (1981) identified the following three requirements of the planning process if conflict resolution is to occur:

(1) Iteration of the planning process. The reiteration of planning allows refinement to occur as conflicts of interest arise.

(2) A large number of agencies are involved in the planning process. This allows a wider range of technical expertise to be available.

(3) The planning framework include adequate provision for mediation and consensus building.

The planning process that Lord, et al. (1981) proposed to accommodate conflict resolution is shown in Figure 4.1. This shows the bodies that should ideally be involved in each step of the planning process for three representative models. The models presented highlight the differences in the groups involved in the planning process according to the focus of the planning model. If a national perspective is taken then Government and Government agencies take a significant role in the planning process. However, local or a conflict resolution focus shifts the emphasis away from Government and Government agency and highlights local and public involvement in the planning process. The participation of the public in all aspects of the planning process is the most common means of resolving conflict in public sector planning.

FIGURE 4.1

Planning Process Characteristics of Three Representative Models

Functional Planning Step	Representative Planning Model: I National Goals Focus	II Local Problems Focus	III Conflict Resolution Focus
First Iteration			
* Initiation of Planning	Government mandate	Single local interest	Conflicting local interest
* Problem Definition	Government agency	Non-government agency	Non-government agency
* Objective Setting	Governent mandate	Single local interest	Conflicting local interest
* Option Identification	Government agency	Non-government agency	Non-government agency
* Option Evaluation	Government agency	Non-government agency	Non-government agency
Subsequent Iteration			
* Problem Definition	Government agency other agencies	Non-government agency other agencies	Non-government agency other agencies
* Objective Setting	Government mandates multiple local interests	Multiple local interests government mandates	Multiple local interests government mandates
* Option Identification	Government lead agency other agencies	Non-government agency other agencies	Non-government agency other agencies
* Option Evaluation	Government lead agency other agencies	Non-government agency other agencies	Non-government agency government agencies
* Option Selection	Instrumental Rationality supplemented by consensus seeking on secondary aspects	Instrumental Rationality supplemented by consensus seeking on secondary aspects	Consensus Seeking supplemented by instrumental rationality to enforce national constraints

N.B. Underlined entries indicate which variables are primary in subsequent iterations of planning.

4.3 PUBLIC PARTICIPATION IN PLANNING

In the U.S. one of the reactions to increasing public pressure on environmental and social concerns in water resources development has been increased public participation in the planning and decision making process, Goodman (1984). Recognition of the importance of public participation in water resources planning in the U.S. can be found in the "Principles and Guidelines" document, U.S. Water Resources Council (1983). This states that the onus is on the planning agencies to try and include interest groups in all aspects of the planning process and efforts to secure this participation should be pursued through appropriate means. These were listed as public hearings, public meetings, workshops, information programmes and citizen committees.

Delays or abandonment of resource development projects through prolonged conflict between interested parties has led to the realisation that public participation in the planning process can in fact be justified as good management practice because it presents opportunities to, Goodman (1984):

(1) Identify legal requirements, funding limitations, or other constraints and ensure that the plan is compatible with them.

(2) Take advantage of technical expertise that may be available in the various publics involved.

(3) Develop plans that more adequately reflect the needs and preferences of the public.

(4) Clarify positions of different groups and individuals affected by the plan.

(5) Identify sensitive issues and ways of preventing or reducing adverse impacts.

(6) Overcome conflicts and reach a consensus when there are different points of view with respect to plan components, particularly when multiple objectives are involved.

(7) Gain support for the project or project implementation.

One important aspect of public participation in planning is that the publics' input is not seen as an optional activity or a public relations exercise, Dysart (1978). Instead public participation should be viewed as an integral and continuous part of the planning process. Public participation serves as an essential information exchange, processing and evaluating information that drives the planning process, Bishop (1975).

4.3.1 Levels of Public Participation

Dysart (1978) identified the following five levels of public participation:

(1) Non-participation.

(2) Information participation. In this case the aim of the programme is to inform the public but there is rarely any meaningful interface with the them.

(3) Consulting participation. Committees and boards of review are asked to comment upon development proposal and other activities. This means that the public is interfaced with the planning process but there is no implied obligation to actually consider or incorporate the input or to necessarily provide a meaningful feedback mechanism.

(4) Iterative participation. This type of participation allows a significant level of involvement by a an advisory group which would ideally include representatives of a number of interested public groups. One important aspect of this approach is that the engineers, planners, and public officials are obligated, up to some a point, to revise the plan in line with the recommendations from the group.

(5) Authorisation participation. The consultative group has legislated or delegated powers to override the

engineers, planners, or government officials on decisions concerning the project or alternative.

The first three levels of participation are common, the fourth less common and the last extremely rare in public planning, and water and soil planning in particular, in New Zealand. The Southland Catchment Board for instance used a blend of consulative and information participation for the Oreti Catchment Control Scheme. The public were informed, via a newsletter, of the alternatives being analysed and the progress of the proposal. In addition local consultative committees were established to interact with the Board.

The regional water board concept used in New Zealand can be looked on as a form of authorisation participation. These boards have wide ranging representation, both publicly elected and appointed, but do not provide a representative public group when it comes to discussing the needs and preferences of groups affected by specific proposals. At this level it is desirable that iterative participation occurs and the regional water boards can act as the quasi-public group which can have final responsibility for referral of specific proposals to national bodies to obtain subsidy, etc.

4.3.2 Factors Necessary to Ensure Effective Public Participation

Goodman (1984), Potter and Norville (1979), Dysart, (1978), Water Resources Research Institute (1978), and Bishop (1975) have identified the following as necessary factors to ensure an effective public contribution to planning:

(1) Preplanning: this involves the definition of the problem and identification of the issues that will be of concern to the public. Of interest also is the community itself. Such things as the characteristics of the community, the acceptance of similar projects in the past, the political decision making framework and identification of the

local groups or individuals who are interested or affected by the proposal should all be addressed early in the planning phase. Using this information and information about the scheme itself i.e. its complexity, scale, etc. the planner can then determine the scale of the public involvement needed.

(2) Clear and well defined objectives of the participation programme need to be specified. The following two basic objectives are relevant in an effective participation programme, Bishop (1975):

(a) information, education and liaison, and

(b) reaction and feedback on proposals.

These two objectives can be further broken down to include:

(i) identification of problems, needs, issues and concerns,

(ii) idea generation and problem solving,

(iii) review and comment on plan data and analysis,

(iv) provide values and preferences for decisions, and

(v) conflict resolution and consensus.

(3) Agency policy: the development agency must have a clear policy of when public involvement will occur, who will be invited to participate, channels of communication and the degree to which the public is involved in the decision making process. It is important that these factors are clearly stated so there is an air of confidence built up between the planning agency and the public it seeks participation from. The decision making process must be seen to be fair and equitable and not just a front to short circuit confrontation.

(4) Resources: The development agency must allocate sufficient resources to enable an effective programme to be put in place. Controversy reins over the benefits of a public participation. Fusco

(1980) found that a controversial project may require as much as 15 to 30% of the total budget. Montanari (1978) found that the costs associated with public involvement (delays and monetary costs) were more than compensated for by rapid progress in the design and construction phase.

(5) Effective identification of the participants. There are four basic groups; public agencies, organisations with a pecuniary interest in the project, public interest groups that have points of view that they want to bring to bear on the project, and groups which stand to neither gain nor loose as a result of the project but who have an interest in the project.

(6) Effective communication: The proposal(s) under review needs to be presented clearly and effectively to the public if effective discussion of the proposal between the proposer and the public is to occur. In addition, there is a need for honesty by all parties in the process.

(7) Responsiveness: At all points the public must feel it is involved. This can occur through media or personal contact with the people involved. Responsiveness should include discussion of the public's views, significant comments and suggestions, and how the input was used, and if not used why not.

4.3.3 Public Participation Techniques

It is assumed by many agencies and groups that public participation is a narrow phenomenon and treat it as a means by which an agency seeks or exchanges information, or tries to obtain consensus on its programme or a specific project plan. To meet these ends agencies commonly use public hearings, newsletters, attitude surveys and nominal group consensus. However, the broader perspective of public participation encompasses both a wider range of procedures

and a more extensive role for citizens in the decision-making process. Glasser et al. (1975) classified 24 public participation and education techniques which can be classified under the following headings:

(1) Large group meetings e.g. public hearings and meetings,

(2) Small group meetings e.g. presentation to community groups, site visits, citizen advisory bodies and task forces, role playing, values clarification exercises, workshops, and delphi exercises,

(3) Organisational approaches e.g. regional and local offices; citizen representation on policy bodies; Ombudsman and community interest advocate; and public interest centre.

(4) Media e.g. information pamphlets, brochures, and reports; slides and film presentation; tape-recorded information network; radio and talk show; and press release, special feature articles, and newsletters.

(5) Community interaction e.g. response to public inquiries, and formal attitude survey.

(6) Legal mechanisms e.g. citizen suits, and environmental impact statement.

Table 4.3 briefly describes these techniques along with discussion on their advantages and disadvantages.

As a result of lessons learnt from the major resource developments in Taranaki and Northland, public input into project design and implementation has been incorporated into social impact assessment, Ministry of Works and Development (undated). The basis of the approach (see Figure 4.2 for details) is that communication channels, between affected groups and the developer, are established early in the planning phase and information transfer is through simplified channels of communication.

TABLE 4.3

Public Participation and Education Techniques

Technique	Description	Advantages	Disadvantages
		Large Group Meetings	
Public Hearing	Definition: Formal public meeting usually required by law. Purposes: To certify proposed plans and discuss other related issues.	Provides an opportunity for the public to ask questions and voice opinions. It is a traditional technique familiar to many citizens.	Does not usually allow for two-way communication or continuity of interactions.
Public Meeting	Definition: Informal public proceeding. Purposes: To discuss issues.	Same as above.	Same as above.
		Small Group Meetings	
Presentation to Community Groups	Definitions: Lecture and discussion with specialists. Purposes: To identify community concerns and to inform citizens of the plans, issues, pollution control techniques, water quality agencies, etc.	Opportunity for informing the public and exchanging information.	Is not a decision-making meeting. Lack of good two-way communications may lead to citizen apathy.
Site Visit	Definition: Field trip to sites of existing or potential impacts.	Provides opportunity to more clearly understand the many dimensions of a problem.	Time consuming and expensive, especially where sites are distant or inaccessible.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Site visit (ctd)	Purposes: To sensitize planners and citizens to project impacts.		
Citizen advisory body	Definition: Formally appointed representative citizen group	Provides opportunity for continuous two-way communications with a representative body and reduces the need for community meetings. Assists in gaining community support for a plan.	Role of body often mistakenly seen by the public as a decision-making body and by agencies as often reluctant to cooperate and use the body for superficial activities.
Citizen task force	Definition: Formally appointed citizens knowledgeable about a specific problem.	Provides in-depth information on issues. Often can cut across agency jurisdictional boundaries to seek solutions to problems.	Task force has no power to implement findings. It is usually disbanded after its work is completed, thus limiting its continued involvement with the problem.
Role Playing	Definition: An educational and decision-making technique where real-world problems are simulated by individuals who act the part (play the roles) of decision-makers or citizens.	Provides an opportunity for citizens to experience a decision-making problems and become sensitive to the complexities of economic, social, and environmental decision-making.	Requires skilled group leader to be most effective.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Role Playing (ctd)	Purpose: To sensitize citizens and decision makers to the economic, political, social, and environmental aspects of resource decision-making.		
Values Clarification exercises	Definition: Carefully designed activities for people to examine conflicts between their behaviours (life-styles) and their stated beliefs (values). Purpose: To clarify people's values and align their behaviours to these values.	Provides an opportunity for the public and agency persons to re-examine the basis for their opinions and decisions on water resource issues and potentially, to change their behaviours.	Requires careful preparation and well-trained leaders to be effective.
Workshops	Definition: Working sessions in which interested affected public and government representatives discuss specific issues. Purpose: To identify and recommend solutions to problems.	Provides an opportunity for two-way communication and a good learning experience for both the public and government representatives.	Same as above.
Delphi exercises	Definition: An educational and decision-making tool in which citizens and	Facilitates the processing of a large amount of information in a systematic	Requires skilled group leader and participants who are committed to the

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Delphi exercises (continued)	decision-makers can choose alternatives via pairwise comparisons. Purpose: To reach concensus on the solutions to problems by jointly considering the opinions of a diverse group of expert witnesses.	manner. Immediate feedback and ranking by Delphi is a low-cost method of assimilating expert opinion.	objective of reaching a concensus.
		Organizational Approaches	
Regional and local offices	Definition: Public agency offices located close to projected areas to administer programs. Purpose: To provide better contact between agency and local citizenry.	Opportunity for agency personnel to become more sensitive to local issues. Increased services at the local level.	May be expensive to house. There may be some loss of central control.
Citizen representation on policy bodies	Definition: Lay citizen participation in the decision-making process Purpose: To provide community interest groups with greater involvement in decision making.	Permits citizens to participate in decision making. Encourages committment to support project implementation.	Appointed representative may not, in fact, represent their constituency. To be effective, representative must be forceful and articulate.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Ombudsman and community interest advocate	Definition: An agency appointee to serve as a liason with the community Purpose: To investigate and resolve community complaints and make policy recommendations to decision-makers.	Provides a mechanism for two-way communication between public and agency. Cut through bureaucratic roadblocks.	Agency can abuse this mechanism by not giving the ombudsman access to vital information or by not considering citizen concerns.
Public interest center	Definition: An office which disseminates information and provides speakers for community meetings. Purpose: To serve the community as a source of information on environmental issues, citizen rights, and technical information.	Provides a new institit-ution devoted to assisting the citizen in improving two-way communication with government.	May easily be ignored by government which may see the center as a treat to their authority or merely as a public relations office.
		<u>Media</u>	
Information, pamphlets, and summary reports	Definition: Brief written materials on environmental issues. Purpose: To provide the public with general information and easily understood documents.	Can reach a large number of people at a low cost to the agency. Simplify complex information for easy consumption.	One-way communication with little feedback. Brevity may omit key information from being transmitted.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Slides and film presentation	Definition: Brief pictorial presentation showing water quality issues and solutions. Purpose: To create awareness of water quality problems, and methods of dealing with them (e.g. land use practices).	Can be expensive to develop. When used with local issues and opinion leaders it can be an effective change tool.	Distribution of films and projectors can be expensive.
Tape-recorded information network	Definition: Tape cassettes sent to citizen groups with discussion topics. Citizen responses are recorded and returned. Purpose: To inform citizens and obtain their opinions on issues quickly.	Allows information to be distributed to a wide audience. Promotes two-way communication.	Technique is expensive and requires time to prepare.
Radio and talk show	Definition: Program that provides experts a forum to respond to telephoned questions from citizens. Purpose: To provide a forum where many citizens can listen to a question and answer session with leaders or experts.	Citizens can have direct two-way communication with decision makers and a wide audience can be reached.	Agency administrators may be unwilling to commit the time to such a program. They may also not like the public scrutiny.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
Press release, special feature articles, and newsletters	Definition: Easily understood articles that reach a wide audience. Purpose: To inform people of issues rapidly. To announce meeting dates, changes in technology, and changes in the law.	Provides a forum for local issues and continuous communication.	Editorial subjectivity can distort issues and destroy credibility. Maintaining updated mailing lists may be expensive.
		Community Interaction	
Response to public inquiries	Definition: Official response through letter, telephone, or other. Purpose: To maintain good communication with the public and to respond to questions.	Can provide honest and precise responses to concerns of citizens.	Requires open and knowledgeable persons in agencies to respond competently.
Formal Attitude Survey	Definition: A systematic assessment of a representative sample of a community. Purpose: To determine the values and positions of the public on specific issues.	Provides an objective view of popular values and preferences that are representative of the community.	Is expensive and requires experts to conduct accurately. Questions must be carefully worded so as to be interpreted correctly by respondents and analysts.

Table 4.3 (continued)

Technique	Description	Advantages	Disadvantages
		Legal Mechanisms	
Citizen Suits	Definition: Opportunities in the law for citizens to sue agencies and individuals for not enforcing water-related laws. Purpose: To ensure that the laws are enforced, that consideration is given to the impacts of projects, and that public information is available.	Provides direct line of citizen access to the policy process, and ensures equitable discharge of agency responsibility as defined by the judicial system. The threat of suit also acts as a restrains on agency action and is not expensive.	Is often expensive. Few citizens have the skills to use this technique effectively. It is often used to block agency actions, stopping them from fulfilling their public responsibilities.
Environmental impact statement	Definition: Legal document that must be filed by any agency spending federal funds on a project with potentially large impacts. Purpose: To provide the public and other agencies with technical data needed to understand the nature of the potential impacts from a project.	Is a source of information for proponents and opponents of the projects to support their viewpoints. Often, the statements are prepared by researchers not employed by the developer. This outside viewpoint can help the developer improve a project.	Is usually highly technical and difficult to read and understand. They are prepared late in the planning process so that many decisions are already irreversible. They often cause delays in the project planning, causing unnecessary expenses to the developer.

Source: Glasser et al. (1975)

Table

FIGURE 4.2

Process for Assessing the Social Impacts of Major Developments

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Step 1. The regional or united council sets up a regional steering group.

2. A seconded worker (or team) to the regional or united council sets up technical advisory group(s) on the regional steering groups behalf.

3. Specialist technical advisory group(s) provide information to the regional steering group from all levels of the community.

4. A community development worker is employed to ensure full public community participation.

5. The regional steering group negotiates with central, regional and local government, and the developer to ensure that if the project proceeds, costs to the region are minimised and maximum benefits are gained.
(steps 3 to 5 are ongoing)

6. The developer prepares a social/environmental impact report.

7. The Commission for the Environment prepares an audit of the impact report.

8. Planning permission is given or refused.

A PROJECT PROCEEDS

9. Payment of the development levy is made by the developer.

10. Monitoring is established in areas of potential impacts.

CONSTRUCTION ENDS

11. The completion of the construction phase of a large industrial project is likely to bring social impacts with it which, while different in nature from the construction stage, will be equally as important. Monitoring and action should continue with all of the central government and regional coordination approaches still in operation.

OPERATIONAL PHASE BEGINS

12. The regional steering group, technical advisory group(s), seconded worker and monitoring functions are reassessed.

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Source: Ministry of Works and Development (undated)

4.3.4 Problems With Public Participation

The major problem associated with public participation is to get representative participation. Some groups in the community have the ability to articulate their preferences but in many cases participation of those most affected by the proposed development is limited by their lack of opportunity and ability to articulate their preferences. For this reason it is important that the results of the participation programme should not be interpreted as the public will by the planner but should be used as a basis for showing competing views of the public will.

The second major problem area is that public participation can be viewed from two often conflicting points of view, Potter and Norville (1979). The first is that of the public agency which is endeavouring to reduce the uncertainty, and the social and economic costs of decisions. In addition it is aiming to avoid or minimise delays between decisions and their implementation. The second viewpoint is that of the citizens who are trying to have an effect on decisions that often have significant effects on their lives.

Warner (1971) found that citizens groups who might be expected to be active in resource planning decisions cited their role as:

interested observer	44%
independent reviewer	28%
participant in recommendation formulation	28%

Their desired roles placed emphasis on more and earlier involvement by participating in objectives formulation and as task force members.

On the other hand Wilson (1973), found that the planners themselves thought that the public did not have the competence and ability to aid plans. They saw the public role as one of expediting final acceptance of the planners ideas, in other words the public was co-opted.

It is clear from these research findings that reconciling these viewpoints is imperative to the success of

a public participation programme. This can occur through the design of a clear decision making process with timely citizen participation built into the total planning effort.

Two further problems identified by the Water Resources Research Institute (1978) are firstly that there is no one way of involving the public in the water and soil planning process. What works in one situation will not necessarily work in the next situation. This means that care needs to be taken in designing the participation programme for a development project to ensure that it is suitable for the community within which it is to be used and also suitable to the overall planning process being used. Secondly, public participation is not a panacea and will in some cases will generate more conflict, mean new time schedules and require commitment of resources.

The problems mentioned above are not insurmountable and there are techniques available which allow effective input into the water and soil planning and decision-making processes from interested groups and individuals. The over-riding consideration is that public participation programmes contribute positively to the decision-making process and allow decisions to be made from a better set of base data.

4.4 EVOLUTION OF ANALYSIS METHODS USED IN WATER AND SOIL PLANNING

4.4.1 Traditional Versus New Cost-Benefit Analysis Methods

All government expenditure is made with the objective of improved welfare in mind. Welfare is made up of socio-economic, environmental, cultural and other aspects of national, regional and personal conditions, Hafkamp (1984). The multi- dimensional nature of welfare means that there is no direct measure of welfare and evaluators, of alternative proposals, have problems of giving guidance to decision-makers on how to allocate a limited budget. This

problem is further compounded by the fact that decision-makers

(1) Do not view their expenditures as producing increments of welfare but generating a number of values i.e. flood control, education, power generation, etc. This means that there are a large number of often competing objectives to reconcile, and

(2) Because of the constraints imposed on them (normally limits to funding) it is not always possible to have for example more flood control and more education. The decision is often "either/or".

To date evaluators have attempted to attach dollar values to the principal benefits and costs of government expenditure and then use the efficiency criteria (IRR, NPV, B/C, etc.) to act as a basis for the decision-making process. However it is now clear that the efficiency criteria are unable to capture the multi- dimensional nature of welfare. Using the efficiency criteria (traditional cost-benefit analysis) means that the analysis often does not include the many effects of projects upon which it is difficult to impose a dollar value e.g. income distribution, environmental quality, pollution, etc. A further problem is that the traditional techniques assume only a single objective, economic efficiency, but as was stated above the objective of government is to improve welfare. Welfare is multi-dimensional and as such no one objective is able to characterise it. Any analysis tool must therefore recognise the multiple objective nature of the problem and there must be some means of assigning priorities to the various objectives.

Since the early 1970's traditional (or conventional) cost- benefit analysis has given way to a new group of thinking referred to as the new methodologies. The new methodologies fall into two categories, Miester (1985):

(1) The proponents of Little-Mirrlees-Squire-van der Tak (LMST) approach, and

(2) The multiple objective analysis approach based on no major methodology.

4.4.2 The LMST Method

The LMST approach recognises that from the standpoint of welfare economics, there are two basic elements, economic efficiency, and equity in the distribution of income. All other so-called objectives other than efficiency and equity can be evaluated in terms of these basic objectives. Falkson (1976) stated that environmental quality is not a separate objective but can be evaluated under the efficiency criterion in terms of the value society places on it. The multiple-objective problem becomes therefore a valuation problem and exists because of limitations in techniques for assigning values, Freeman (1977). If all costs and benefits of a project could be valued on some logical basis e.g. dollars, the problem of multiple objectives would disappear. The important aspects of the LMST approach are:

(1) Productive efficiency for all traded goods is taken as determined independently of domestic consumption patterns;

(2) Interpersonal utility comparisons are firmly re-established via the principle of social valuation of consumption benefits to different groups;

(3) The new methods express macro-planning variables in terms of micro level selection criteria (NPV, IRR and B/C). This means that the methods can be used in a central role in the overall planning process (Irvin, 1978).

The major features of the approach are that world prices are used to overcome market imperfections and income disparities; distributional weights are used to account for distributional effects and cost-benefit analysis becomes part of the planning process as a tool rather than an a thought organising technique as it was under the traditional approach, Miester (1985).

4.4.3 Multiple Objective Analysis

This second school of thought arose out of concern about the narrowness of conventional analysis and problems of monetarising so called intangibles. Chaemsaithong, et. al., (1974) noted a number of fallacies associated with traditional cost-benefit analysis. These are:

(1) Sole criterion: a single criterion is selected as a basis for evaluation, Eckstein (1956), Haveman (1965), Krutilla and Eckstien (1958), Marglin (1962).

(2) Use of ratios: the alternative with the best ratio e.g. benefit-cost ratio or IRR, is selected. Ratios, it should be noted, hide the magnitudes of the benefits and costs.

(3) Quantification: various aspects of a public project are hard to transform into the same dimension (particularly money) and in many cases get ignored because of this, Howe (1971), Layard (1972), Nijkamp and Vos (1977).

(4) Interrelationships: it is assumed that a single super criterion can be used to evaluate projects and that this will account for interrelationships between objectives. The attempt to convert all project effects into monetary units is an example of this fallacy.

(5) The neglect of spillovers: no system is completely isolated and to ignore the effects a system has on other systems is incorrect.

(6) Concepts of optimum systems: the term 'optimum', when applied to a system on the basis of evaluation of two or more criteria (or subsystem characteristics), becomes attached to the total system evaluation with the result that the criteria which make up the system are disregarded.

Advances in the multiple objective analysis area have concentrated on evaluation methods which account for the multi- dimensionality of the decision problem. Nijkamp and

Vos (1977) distinguish between two types of evaluation method; multicriteria and multiple objective methods. The feature of the multicriteria methods is that project effects are not necessarily transformed into monetary values but a series of weights are developed which reflect the relative importance of each decision criteria. Examples are the goals achievement method, the permutation method and the concordance or ELECTRE methods.

Multiple objective methods are based on mathematical programming algorithms e.g. goal programming. They seek to present a feasible set of solutions containing efficient (nondominated or Pareto optimal) solutions rather than locate the single optimum solution, Romero and Rehman (1984b).

The advantages of the multiple objective approach over the LMST approach are:

(1) The multi-dimensional nature of welfare is accounted for,

(2) That non-monetarised effects of projects can be accounted for in the analytical process,

(3) A range of solutions is provided rather than a single 'best' solution,

(4) Trade-offs between objectives can be analysed in the decision making process, and

(5) The LMST approach can be incorporated into this approach.

4.5 MULTIPLE OBJECTIVE ANALYSIS METHODS

The literature offers three basic approaches to the multiple objective problem. These are:

(1) The first approach is to provide the decision-maker with a schedule showing the results of an economic efficiency analysis plus a description of the other benefits and costs for each alternative design. It is then left to the decision-maker to assess subjectively society's preferences. Comparisons

between the results of the chosen design and the other alternatives will provide some guide as to the relative weightings of valued and unvalued benefits held by the decision-maker.

Problems with this approach are:

(a) It is unlikely that decision-makers have the ability to determine society's valuation for unvalued benefits (and costs) and apply this consistently over time.

(b) The decision-maker is not asked to provide an explicit relative value but use judgment after viewing the alternatives.

(c) The relative price or trade-off ratio between valued and unvalued benefits cannot be consistently applied over a range of projects and over time.

(2) This approach, described by Marglin (1967) and Major (1969), sets a minimum level of one benefit and maximises the other benefit/s subject to this constraint.

Problems with this approach are:

(a) There are no established rules to decide which variables should be constrained and which maximised.

(b) The choice of an alternative implies a certain relative valuation or trade-off ratio between valued and unvalued benefits and costs. In other words choice determines value. The question then remains, should choice be allowed to determine value or should value be determined independent of a particular project and used to make the choice?

(3) The use of weighted welfare functions. Eckstein (1961), has argued that economists could make an important contribution to policy making if they would interpret the desires of the policy people and express them in a form such as an objective

function. This would then allow the development of analytical decision models which would explicitly reveal what actions will maximise the achievement of specified objectives. He felt that if the preferences of policy people could be expressed as weights or values of one form of benefit in terms of the other, then the consequences of this particular set of weights on the design and selection of projects could be seen. If the consequences were thought to be desirable, then the same weights, or objective function, could be used to achieve a consistent set of decisions for all proposed projects.

The advantages of such a system are:

(a) It overcomes the implicit valuations made by the decision-maker.

(b) An explicit objective function is formulated which means the valuations are obvious and the implications of different weights for project design and selection can be calculated.

(c) As valuations are made explicitly and are subject to political review, decisions are more likely to reflect the general preferences of society, and less likely to be influenced by the pressures from special interest groups. The valuations are also more likely to be more consistent over a wide range of choices and a longer period of time.

Problems with this approach are:

(a) Some economists and political scientists see positive value in failing to define clearly the objectives of programmes. This point of view, which might be called the political value of ambiguity, emphasises decision making as a political exercise rather than an analytical exercise.

(b) The determination of suitable weights. Freeman (1977) stated that if weighting functions are to be used they must be based on consideration of legislative intent, guidelines established in law and precedent, and ultimately subjective evaluations by politically responsive decision-makers.

With a multiple-objective planning framework in place there should be less pressure on and between government departments to widen the benefit base and/or alter the discount rate used in the analysis of schemes. In addition other objectives e.g. regional planning, social and environmental, will not be overshadowed by the push for national economic efficiency. These objectives should be accounted for within the multiple-objective frame-work.

4.6 CONCLUSIONS

Public sector planning needs to be of an interactive type with clearly defined goals and objectives. Such a planning framework needs to be responsive to local problems and concerns but have regard for national goals and objectives. To achieve local aims the planning framework should include local people in the setting of local goals and objectives which will be used to analyse future development. These interested groups and individuals should be well informed as to the consequences of policies and alternatives and information should be supplied by planning agencies in a form that is easy to assimilate.

The need to be responsive to national goals and objectives means that there is a clear need for the planning process to find local means to attain predetermined national goals and objectives. The national goals and objectives should be viewed as national constraints upon the selection of alternatives to solve local, and regional problems and should not act as plan formulation objectives. Local goals and objectives should fill this role as they are developed

in response to the local need. The degree to which the local planning process focuses on these national concerns will undoubtedly vary between regions and between projects. It may also lead to conflict between the national and local interests.

Any planning framework needs to recognise that conflict and conflict resolution are an integral part of the planning process. The planning process should therefore reflect a balance among competing preferences on how the water and soil resources should be used and protected and the incidence and magnitude of the socio- economic impacts of the policy or alternative. Public and multiple agency participation in all phases of the planning process will lead to a better understanding of the issues, and the perceptions of these issues, by the groups and individuals involved in the planning process.

Finally because of the multiple objective nature of the problem, the selection of alternatives should be by way of a multiple objective analysis framework. Such an approach allows the multitude of objectives to be analysed and traded off in a meaningful way. In addition, within such a framework, valuations of objectives are made explicitly and are subject to political review. This will mean decisions are more likely to reflect the general preferences of society, and less likely to be influenced by pressures from special interest groups. Chapter V analyses some of the techniques available to measure the most common objectives of water and soil development projects.

CHAPTER V

ANALYTICAL PROCEDURES I - SPECIFICATION AND MEASUREMENT OF OBJECTIVES

5.1 SPECIFICATION OF OBJECTIVES

The objectives that may be valid in the implementation of a particular scheme are many and varied but could include, for example, all or some of the following:

- Improving national economic efficiency
- Improving foreign exchange balances
- Improving living conditions by:
  (a) increasing employment
  (b) increasing personal income
  (c) improving social conditions
- Improving distribution of population
- Protecting and enhancing the natural environment

This study will examine in detail four objectives - national economic efficiency, environmental quality, regional economic development and other social effects.

5.2 NATIONAL ECONOMIC EFFICIENCY

The national economic efficiency objective measures the net increase in goods and services contributed by the project to the national economy. Projects may achieve this by utilising additional resources and/or making more efficient use of existing resources. The main method of assessing this effect has been by the use of cost-benefit analysis. Many writers have covered the theory of cost-benefit analysis; Mishan (1975), Pearce (1983), Pearce and Nash (1981), Dasgupta and Pearce (1972), Sugden and Williams (1978). It is a technique developed out of

neo-classical economic theory which allows the comparison of discrete sets of alternative plans.

This section will concentrate on the traditional methodology of cost-benefit analysis as defined in section 4.4.1. As such it will focus on economic efficiency aspects of project analysis and no account will be taken of the distribution of project benefits and costs. The distributional aspects will be discussed in succeeding sections under the headings of regional economic development (section 5.4) and other social effects (section 5.5).

To determine the economic efficiency of a proposal the marginal effects (costs and benefits) related to the proposal need to determined. There are techniques available for measuring the majority of direct scheme effects and generally expertise in this area is high. The techniques in use at present are not infallible: questions are still unresolved in the measurement of indirect effects e.g. technological externalities. The marginal project cash flows are discounted using the applicable public sector discount rate to give the net present value at the start of the expenditure period. In general, benefits are valued on the basis of willingness to pay by the users of the project's output of goods and services. Other methods have been discussed in Section 4.4.1.

The U.S. Water Resources Council's has published a detailed procedural document to be used in the evaluation of national economic effects for water resources planning, U.S. Water Resources Council (1979). The aim of this document and the others that proceeded it is to produce procedures which were unambiguous, workable, and technically sound. Further the procedures needed to be carried out utilising available data and be applied easily by field staff, Eisel, et. al. (1982). The procedures covered the following range of benefit and cost determination categories:

agricultural flooding, erosion, and sedimentation,
agricultural drainage,
agricultural irrigation,

external economics,
recreation,
urban flood damage,
commercial fishing,
unemployed or underemployed labour resources,
hydro-electric power,
municipal and industrial water supply, and
inland and deep raft navigation of waterways.

Clearly not all these elements are relevant for the New Zealand situation. The MAF cost benefit procedural document, MAF (1984) only includes procedures for the determination of agricultural effects of water and soil schemes, e.g. drainage, irrigation, flooding, erosion and sedimentation, rural water supply and recreation. Brief mention is also made of external economics and the valuation of labour resources. The analysis of hydro-electric power development schemes is carried out by Treasury and no procedural documentation is available. Urban flood damage assessment is another area in which procedural documentation is lacking but analysis of urban flood control schemes has occurred as part of an overall catchment control schemes, McGregor (1980a and 1980b), McGregor and Spiers (1981), McGregor and Dent (1986), and as a solely urban scheme, Vrens (1980a and b). There has been a reluctance on the part of the Ministry of Agriculture and Fisheries to include urban flood effects in their economic reports, Hadfield (1981).

The following discussion highlights where the U.S. procedural methods differ significantly to those in use in New Zealand.

5.2.1 Agricultural Benefit Evaluation Procedures

Agricultural benefits are generated by the following water and soil schemes; irrigation, flood control, catchment control, rural water supply and drainage schemes. The benefits derived from these types of scheme are assessed as the marginal increase in value of agricultural output to the nation or the reduced costs associated with maintaining a

certain level of production. Benefits derived from these schemes are:

(1) Increased production associated with the proposed management or control measure,

(2) Reduced costs of maintaining a level of output,

(3) Reductions in production and other associated costs,

(4) Reduced damage from floods, erosion, sedimentation, inadequate drainage, or inadequate water supply, and

(5) Gains from the economic efficiency of increasing agricultural production in the affected area.

The determination of marginal benefits and costs of projects is stressed in both New Zealand and the United States. This means that projections of future production, land use and product prices and costs with and without the scheme need to be assessed.

The U.S. water resources regulations, U.S. Water Resources Council (1979) and U.S. Water Resources Council (1983) drew a distinction between basic field crops (cereals, pulses, pasture and hay) and specialty crops. The reasons cited for the split into the two crop types are that basic field crops have total national production levels so high that an increase in area devoted to them or an increase in yield as a result of a scheme will have a negligible effect on the crop price. In addition, basic crops are seldom restricted by factors other than availability of suitable land. The benefits derived from basic field crops (ten in all) are assessed as the marginal reduction in production costs and/or the intensification of production resulting from the scheme.

Speciality crops are all other crops excluding those classified as existing and basic crops. These crops are not limited by the resources controlled by the project but by factors such as market demand, availability and cost of risk capital, shortages of specialty labour and management, government programmes, and other institutional restraints.

The benefits of specialty crops are assessed as the increase in efficiency achieved by producing these crops in the project area rather than at an alternative site.

In New Zealand the without scheme situation is assessed as the returns produced by existing agriculture within the scheme boundaries subject to the assumed modification and improvements in farming practices that would occur without the scheme. The with scheme situation is assessed as the increased returns from properties within the scheme boundary based on future land use patterns judged to be reasonable and made possible by the project and its supporting infrastructure. There is no requirement to justify that the benefits are generated as a result of the water and soil project as is the case with the U.S. procedures. This may be leading to over-estimation of benefits, especially in some horticultural and new livestock enterprises e.g. goats and deer, where factors such as availability and cost of risk capital are contributing factors.

A further problem with the New Zealand practise of assessing agricultural benefits is the valuation of changes in agricultural product volumes. Currently the Ministry of Agriculture and Fisheries produces medium term price forecasts for use in all water and soil development analyses. These measure average returns to the nation whereas it is the marginal returns which are relevant. The little research done to date suggests that the difference is substantial, Ellis, pers. com..

5.2.2 External Effects

External effects, referred to as externalities, are indirect benefits and costs of a project that are not reflected in the financial accounts. The effects can be either external economies (benefits) which refer to the favourable consequences which consumption or production by an individual or group has on others or external diseconomies which refer to the harmful consequences which occur in the same way.

Externalities can be split into two broad categories; technological and pecuniary. Technological externalities result from the physical interaction between the activities of two or more individuals or groups. Examples are: soil conservation work in the upper catchment of a river aimed at preventing on-site erosion can produce downstream benefits by reducing the amount of detritus carried by the river, especially in times of high flow, McGregor (1980c); a dam constructed for the purpose of generating hydro-electric power also produces downstream benefits in the form of mitigation of flood and low flows; channel modifications as part of a flood control scheme may cause downstream floods or the scale of the project may mean that private firms may be forced to decrease output or face higher input costs.

The market does not allocate resources efficiently in the presence of technological externalities because no market transaction takes place. The individual/firm causing the externality will not consider the external effects because they are not reimbursed or penalised for causing the externality. Clearly technological externalities associated with projects should be identified and incorporated into the economic efficiency account.

Pecuniary externalities result in a change in output or utility of a third party as a result of changes in the level of demand or supply. They refer to the financial effects of the project on others and are reflected in price changes for outputs or inputs. Generally these effects will accrue to supply or processing industries and represent a transfer between economic sectors as a result of the project. Examples of pecuniary externalities are the economic and labour multiplier effects experienced as a result of a development project.

Only technological externalities are relevant in cost benefit analyses as they provide a measure of change in national economic efficiency. Pecuniary externalities are excluded because it is argued that in an economy where all resources of labour and capital are fully used, the

secondary effects do not create increased economic activity. An increase in labour or capital in one region is associated with a similar decrease in another region. If there are under-utilised resources in the community e.g. unemployment, it may be justifiable to include some secondary benefits in the economic efficiency accounts. The measurement and inclusion of pecuniary externalities in the regional development account is discussed in Section 5.4.

5.2.3 Recreation

Recreation is often referred to as a non-market good. This does not mean that it has a zero valuation but that it is not formally traded except in the case of amusement parks etc. The basis for valuing non-market goods like recreation is willingness to pay but as no clear market exists for recreation, an artificial market must be simulated in order to derive the willingness to pay for the experience. The artificial markets rely on the principal that individuals within society can assign implicit valuations to the recreational experience.

A number of approaches to the valuation problem have been discussed in the literature (see Herfindahl and Kneese (1974), Hufschmidt, et al (1983), Sinden and Worrell (1979)), but it is the cost side measurements, in particular the travel-cost method; and the survey techniques, in particular the contingent valuation method; that have received the most attention.

U.S. water resources planners have concentrated their efforts on three approaches; travel cost method, contingent valuation method and the unit day value method. The travel cost method assumes that demand can be indirectly estimated by relating the changing level of participation in recreation to the out-of-pocket and time costs experienced in travelling from the place of origin to the site. A demand curve is generated by assuming that the current user would react to the levying of an admission fee in the same way as they would to increased travel costs. The progressive

addition of admission fees, and the consequent decreases in site visitation, leads to a total demand curve being defined. The area under the demand curve defines the total consumers' surplus enjoyed by the present users of the site. The consumers' surplus is a proxy for the willingness to pay for the recreational experience as no fee is actually charged.

Problems with this technique are:

(1) A single purpose trip is assumed. This means that no change in utility occurs from visits on the way to the site or from the trip itself. This becomes more of a problem as the distance travelled increases.

(2) The costs of travel are assumed to be equivalent to entrance fees in their ability to limit use. This assumption is acceptable where distances travelled are short but over longer distances it is probably not the case.

(3) The basic model assumes an equal standard of wealth in each zone. The standard of living of users can be accounted for in the more complex stratified travel cost models, Pearse (1968) and Norton (1970).

(4) A value for a particular recreation site is generated but it is normally site specific and not useful for analysing project design alternatives.

The contingent valuation method derives estimates of recreational value by using survey techniques to determine the recreators willingness to pay. Iterative and non-iterative bidding games are used to determine what the user is prepared to pay for the experience or pay for changing quantities of recreation. This technique is particularly suitable where the project area is one of several visited in a single trip or the project results in small changes in the quality of the site, Goodman (1984).

Critics of this approach state that it:

(1) Is difficult to obtain rational and consistent expressions of willingness to pay in answer to questions that, although direct, are hypothetical.

(2) Is easy for the user to introduce bias to the result depending on what he perceives to be the aim of the study.

(3) Includes only those people using the site at the time of the study and has no regard for future users.

The third method described by the U.S. Principles and Standards document, U.S. Water Resources Council (1979), is the unit day value method. This approach relies on expert or informed opinion and judgment to provide approximate values for the users willingness to pay for recreational developments. This approach is used when it is not feasible or justified to use either of the other approaches discussed above. There are two classes of recreational day; general and specialist. A general recreational day is defined as one that is attractive to a majority of outdoor recreationists and requires the development and maintenance of convenient access and adequate facilities, e.g. picnicing, camping, fishing, hunting, etc. In 1982 the range of values used was between US$1.60 - 4.80. The final value used depends on the value of the recreation experience, availability of opportunity, carrying capacity, accessibility and environmental quality, Goodman (1984).

Specialist recreation days occur where opportunities are limited, intensity of use is low, and a high degree of skill, knowledge and appreciation of the activity by the user may be involved. Big game hunting, white water rafting and canoeing, and fishing in the remote high country would use values at the high end of the range while activities like high country duck shooting and specialist nature photography would be at the low end. The range of values used in 1982 was between US$ 6.50 - 19.00.

The values used are based on expenditure and usually contain an element of value judgment and represent a consensus of opinion of experienced people. They cannot be considered objective valuations of the recreational experience and as such will not provide an accurate value of the site. The major advantage of this approach is that it leads to uniformity of treatment in planning but they are not an economically correct treatment. The major problem is that this technique took no account of the level of use, attractiveness, and degree of substitution of the area in question and biased evaluation toward development at the expense of preservation.

An evaluation of recreational benefits and use estimating models for water resources planning by Waters and Moustakis (1981) found that the stratified travel cost method provided the most accurate results. The most significant factor though is the high costs of carrying out the studies and the high data requirements of all the methods except the unit day value method (Table 5.1).

TABLE 5.1

An Evaluation Of Recreational Benefits And Use Estimating Models For Water Resources Planning (Source: Waters and Moustakis, (1981)).

Method	Cost	Data Requirements	Accuracy of Results
Travel Cost Method	Very High	Very High	Good
Stratified Travel Cost Method	Very High	Very High	Excellent
Contingent Valuation Method	High	High	Questionable
Unit Day Value	Moderate	Moderate	Good

The 1979 U.S. Procedures emphasised the travel cost (Clawson and Knetsch, 1966) and the contingent valuation (Davis, 1963) methods. In addition they gave guidelines as to the selection of the appropriate method, limited the use of the user day method to certain classes of project and pointed out the desirability of using regional recreation models. Research work in this latter area was to be on-going.

Unlike the United States, New Zealand analysts have given little attention to the effects of water and soil development projects on recreational opportunities. The earliest study in New Zealand was the use of the travel cost method to evaluate recreational aspects of the Kaiamai ranges, Orsman (1968). This study was carried as part of the economic analysis of the Waihou Valley Scheme. An opportunity cost approach has been used by Forbes (1981) and Orsman and Forbes (1973) to analyse the effects of proposed schemes on wildlife and recreation, and the Lake Taupo trout fishery respectively. The contingent valuation method was used by the Waikato Valley Authority to determine the willingness to pay for water quality improvement in the Waikato River, Harris (1983), and by Gluck (1974) with limited success to value fishing in the Rakaia River. The travel cost method has been used successfully to derive the recreation benefit from soil conservation measures in the Lake Tutira Catchment, Harris and Meister (1981).

However there is no clear policy as to which procedure should be used and the present practice in New Zealand is often to exclude explicit consideration of effects of projects on recreation which means decision makers are being provided with erroneous results on which to base their decisions. One reason for this is that data collection makes the detailed assessment of recreational values prohibitive but where the size of the scheme, or the external effects generated by the scheme are large, every effort should be made to internalise these effects.

5.2.4 Urban Flooding

Urban flood damage schemes provide inundation reduction, production intensification and location benefits, Goodman (1984). The "Principles and Guidelines" document, U.S. Water Resources Council (1983), has suggested the 10 step evaluation process shown in Figure 5.1.

There are two major differences between this approach and that currently adopted in New Zealand. The first is the estimation of other flood related costs. This step in the U.S. procedures looks at the other costs of using the flood plain including flood-proofing costs, national flood insurance costs and opportunity costs when structures are used less efficiently with a project, Goodman (1984). The second is the use of land market values to derive location benefits which occur as a result of the scheme. To date no report, on a urban flood control scheme, in New Zealand has acknowledged this benefit of schemes.

5.2.5 Unemployed or Unemployed Labour Resources

The need to shadow price labour arises because distortions occur in the labour market. The shadow price assigned to labour should reflect the net cost to the nation of the input of labour into the project. The net cost is made up of;

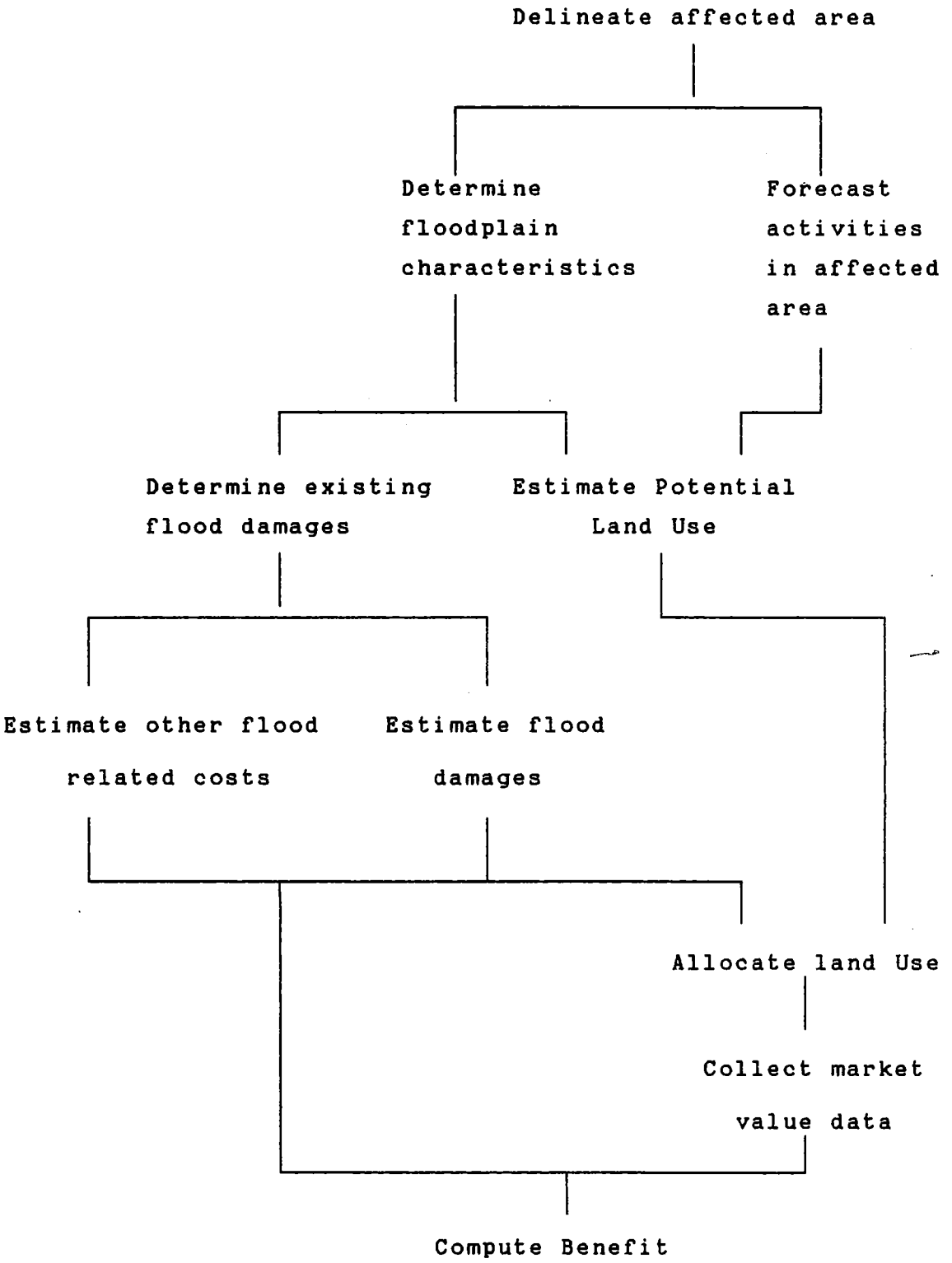
(1) The opportunity cost of moving labour from its alternative use to the project. For unemployed workers this will be zero because there is no corresponding decrease in production in another sector as a result of the project. For underemployed workers the opportunity cost will be something less than the market wage.

(2) The marginal increase in consumption and other demands on output attributable to employment in the project. This can be calculated by comparing the consumption levels of unemployed and under-employed workers with those of fully employed labour.

FIGURE 5.1

Flowchart Of Urban Flood Damage Evaluation Procedures

(Source: U.S. Water Resources Council (1983))



There are two problems associated with the labour shadow pricing question. The first is defining under-employment and unemployment. This was noted in a New Zealand Treasury document on unemployment and public sector projects, Treasury (1983). The second is the necessity to determine whether the under-employment and unemployment is short term or structural?

The shadow pricing of labour resources is not normally carried out in New Zealand and labour is valued at its full market price, MAF (1984). It is therefore assumed that no under- employment or unemployment exists. This is clearly inaccurate with the percentage of the work force registered as unemployment or on special works programmes being 8.6% in February 1984. In the U.S. the opportunity cost is included as a project benefit rather than a decrease in project costs. This benefit can only be claimed for the construction and implementation phases of the project. The reasons for this restriction are because of the identification and measurement problems associated with unemployment and because unemployment is seen as a temporary phenomenon, U.S. Water Resources Council (1983).

The basic assumption used in shadow pricing labour is that the opportunity cost of employing unemployed labour is zero. The opportunity cost of underemployed labour is assessed as the without project earnings which is less than the current market value.

5.3 ENVIRONMENTAL QUALITY (EQ) OBJECTIVE

The environmental quality (EQ) objective measures the net effect of the proposed project on the environment. The environmental attributes that the U.S. Water Resources Council identified as being necessary to sustain and enrich human life were; the ecological, cultural, and aesthetic properties of natural and cultural resources, U.S. Water Resources Council (1983).

(1) The ecological attributes were defined as the "... components of the environment and the interactions among all its living (including people) and nonliving components that directly or indirectly sustain dynamic diverse, viable ecosystems", U.S. Water Resources Council (1983). There are two aspects of the ecological attributes. These are:

(a) Functional aspects, which are the production, nutrient cycling, succession, assimilative capacity, erosion and other dynamic interactive processes and systems, e.g. the potential for wetlands areas to act as sinks for nutrients and pollutants, high producing farm land and clean clear water systems.

(b) structural aspects: plant and animal species, habitats, and the chemical and physical properties of air, soil, water and other geological features, e.g. water quality factors that support fisheries, soil characteristics that support plants, endangered species, and rock strata with scientific and educational significance.

(2) Cultural attributes include all evidence of past and present habitation which would be necessary to reconstruct or preserve human lifeways e.g. Maori pa sites, historic buildings and engineering structures.

(3) Aesthetic attributes were described as those factors which provide a diverse and pleasant environment for human enjoyment and appreciation.

The scope of the environmental quality objective in the U.S. Water Resources Councils 1983 ruling (U.S. Water Resources Council (1983)) was:

(1) The environmental quality objective was one of the four evaluation accounts in which the effects of the various options were to be evaluated and displayed. This was a significant change from

previous documents, U.S. Water Resources Council (1973, 1979b, and 1980c), where the EQ objective was a national objective and held equal status with the national economic development objective.

(2) The evaluation of the environmental quality objective was limited to considering the effects on the ecological, cultural, and aesthetic attributes of significant natural and cultural resources.

(3) Any effects that could be monetized were to be included in the national and regional economic development accounts and also in the other social effects account if appropriate.

(4) The environmental quality evaluation was to assess the effects of the project on the human environment.

Environmental quality can be described by quantity and quality indicators. Quantity indicators describe the amount of a resource attribute present in terms of size, magnitude, or dimension. Quality indicators describe how good or bad an attribute is.

5.3.1 Procedures For Evaluating Environmental Quality Effects

In the 1980 Rules and Regulations document, U.S. Water Resources Council (1980b), a set of procedures was described which provided a conceptual framework within which EQ effects could be evaluated. The procedures are summarised in Figure 5.2.

(1) Phase 1 - Define resources. There are two activities in this phase. These are:

(a) Identify the significant resources that from an institutional, public or technical point of view are likely to be affected by one or more of the alternative plans. This stage also involves determining the attributes that need to be studied recognising that some

resources may have more than one attribute. For example a river may have both ecological and aesthetic attributes while at the same time having attributes beyond the EQ account. These later attributes may be recreational and are recognised in the NED account. As this is a preliminary stage, conclusive evidence of resource significance and the likelihood of effect are not required. The involvement of the public in the identification of resources is desirable.

(b) Development of an evaluation framework. This activity involves determining how resources and attributes are to be measured and what indicators will be used to describe them. At least one measurement unit is required for each indicator. In addition it is necessary to establish a guideline (or base level) for each resource-attribute combination so that adverse and beneficial effects can be determined. Examples of guidelines are; habitat suitability can be expressed as a range between two levels e.g. ph of 6.5-8.0 for fish, or as a threshold level e.g. minimum water depth of 0.26 metres. Measurement techniques were listed, see Table 5.2, but were by no means mandatory. Instead it was left up to the analyst to decide which method/s best suited the project under consideration.

(2) Phase 2 - Inventory resources. The second phase of the evaluation process is the collection of the relevant information to be used in the adopted technique for comparing alternative plans. This involves three activities.

(a) Collecting information on existing conditions and historical trends. The information is

presented using the already defined indicators.

(b and c) The aim of these activities is to attempt to describe the most probable condition of the resource with and without the alternative plan under consideration. The following forecasting techniques were suggested for use:

(i) adoption of available forecasts,

(ii) scenario writing,

(iii) expert judgment techniques e.g. Delphi surveys,

(iv) extrapolation of historic trend information,

(v) use of comparable information in a similar environment.

(3) Phase 3 - Assess effects. This phase is the identification and description of the effects of the alternative plans on environmental quality resource attributes. There are three steps involved;

(a) identification of the differences between the with and without plan forecasts. This information allows the dropping from further consideration of any attribute which is not affected by any of the alternatives under consideration.

(b) description of the effects of each alternative in terms of duration, location and magnitude of the effect.

(c) identification of the effects which are institutionally, publicly or technically recognised as important by people and therefore should be taken into account in decision making. If none of the effects, on the studied attribute, is significant it can be dropped from the evaluation.

(4) Phase 4 - Appraise effects. This phase determines the desirability of the individual effects of each alternative plan. It involves the following two activities;

(a) determine the adverse and beneficial effects of each alternative plan on each significant EQ resource attribute. The effects are measured against the previously set guidelines. A beneficial effect is one which improves net environmental quality. The following factors should be considered when determining the desirability of an effect on an EQ attribute;

(i) duration, location and magnitude of the effect,

(ii) quantity and quality change,

(iii) institutional recognition,

(iv) public response, and

(v) whether the effects would be critical based on scientific or technical knowledge or judgment.

(b) subjective judgment of the marginal environmental quality effects. This final activity states the net overall EQ effect of each alternative plan. The effects are described as either;

(i) net beneficial EQ effect i.e. the combined beneficial effects outweigh adverse effects, or

(ii) net adverse EQ effect, or

(iii) no net EQ effect.

The final judgment, a narrative statement, identifies the type of "net EQ effect expected", and where possible the report is expected to give an indication of how the judgment was made.

FIGURE 5.2

Evaluation Process; Phases and Activities

(Source: U.S. Water Resources Council (1980b) p.64420)

PHASES	ACTIVITIES
PHASE 1 Define Resources	a. Identify Resources
	b. Develop Evaluation Framework
PHASE 2 Inventory Resources	a. Survey Existing Conditions
	b. Forecast Without-Plan Condition
	c. Forecast With-Plan Condition
PHASE 3 Inventory Resources	a. Identify Effects
	b. Describe Effects
	c. Determine Significant Effects
PHASE 4 Appraise Effect	a. Appraise Significant Effects
	b. Judge Net EQ Effects

TABLE 5.2

Summary of the example techniques listed in the "Environmental Quality Evaluation Procedures for Level C Water Resources Planning; Final Rule", (U.S. Water Resources Council (1980b), p. 64427 & 28).

Technique	Indicator Measured	Current Uses
Habitat Evaluation Procedures (HEP)	Carrying capacity	Nationwide. Major Corps, WPRS, & SCS projects. Also applicable to BLM & USFS projects.
Habitat Evaluation System (HES)	Habitat quality	Information/ analysis base fully developed only for the lower Mississippi Valley.
Instream Flow Incremental Methodology (IFIM)	Minimum, sustained augmented & maximum flows	Nationwide Major Corps, WPRS & SCS projects. Also applicable to BLM & USFS projects.
Visual Resource Contrast Rating	Visual contrast	
Upland Visual Resource Inventory and Evaluation	Scenic quality	
Procedure To Establish Priorities in Landscape Architecture	Landscape resource quality	Developed for nationwide use. Primarily used for SCS studies.
Visual Management System	Scenic variety classes and sensitivity levels	Primarily used for Forest Service studies.

5.3.2 Environmental Quality Evaluation Techniques

A number of different environmental quality evaluation techniques have been suggested but few have reached the stage of practical application. The methods that have been used to describe environmental quality effects have been classified as:

(a) alternative cost valuation methods e.g. replacement cost and shadow project methods.

(b) creation of hypothetical markets for the environmental goods and measuring the effects in monetary units e.g. travel cost method,

(c) intuitive methods which place human values on physical and biological impacts,

(d) survey based methods e.g. contingent valuation method, and

(e) defining and developing a non-monetary value index for environmental quality.

All monetized benefits and costs of projects should be included in the national economic efficiency account where this is feasible. The market and survey methods are suitable for monetising effects. Where it is not possible to use these methods, the non-monetary value index methods provide a workable method for determining the effects of projects and project alternatives on environmental attributes. The following discussion briefly describes some non-monetary value index methods that have been proposed and used to measure changes in environmental quality.

(1) U.S. Water Resources Council's 1973 Proposal, U.S. Water Resources Council (1973). This proposal involved classifying the potential effects into a number of classes. These classes were:

(a) areas of natural beauty and human enjoyment,

(b) archaeological, historical and cultural elements,

(c) biological, geological and ecological elements,

(d) quality considerations e.g. water, air, land, sound and visual,

(e) irreversible considerations, and

(f) unique resources.

In addition to categorising the environmental effects a series of evaluation factors were suggested to aid in the assignment of values to scheme effects. For each category except irreversibility and uniqueness, three types of evaluation factor - quantity, quality and human influence - were rated. Quantity factors use physical units e.g. kilometers, litres, hectares etc., whereas quality and human influence factors are assigned a value between 1 (worst known) and 10 (best known). The rating was used to compare the conditions at the target site with those at other sites.

The evaluation factors used for the categories of irreversibility and uniqueness are magnitude and importance. In the category of irreversibility, a list is made of resource elements that would be lost or their use pre-empted through irreversible action. The magnitude of the irreversible action on resources was again rated on a 1 (under 20%) to 10 (best known) scale. The values represented the proportion of the resource lost or pre-empted in the planning setting. A further scale of 1 (of no importance) to 10 (of the highest significance) was used to distinguish relative importance of the resource and whether the development proposal had an irreversible effect on the resource use.

The evaluation system required that all environmental resources unique to the affected area were to be listed and evaluated in terms of the magnitude of the effects of the project and the importance of these effects. The rating for magnitude of project effect indicates the proportion of the resource affected in the planning setting on the basis of a scale of 0 (no effect) to 10 (over 90%). Importance, within the uniqueness category, was expressed as the degree of uniqueness on a 0 (unique in the planning setting but occurs in the abundance elsewhere in the nation) to 10 (the only one of its kind or only population of a species occurring in

the planning setting). To aid field evaluation a number of worksheets were produced.

The aim of the procedure was to provide an array of value indicators which would assist the decision maker in determining the likely effects of the alternatives under consideration. This it did but the system is subject to the following limitations.

(a) The classification did not take into account the interactions of plants and animals, on food webs and life processes.

(b) The categories took a totally human perspective of the environment.

(c) The values generated by such an analysis could not be aggregated to give a total as this value would be meaningless.

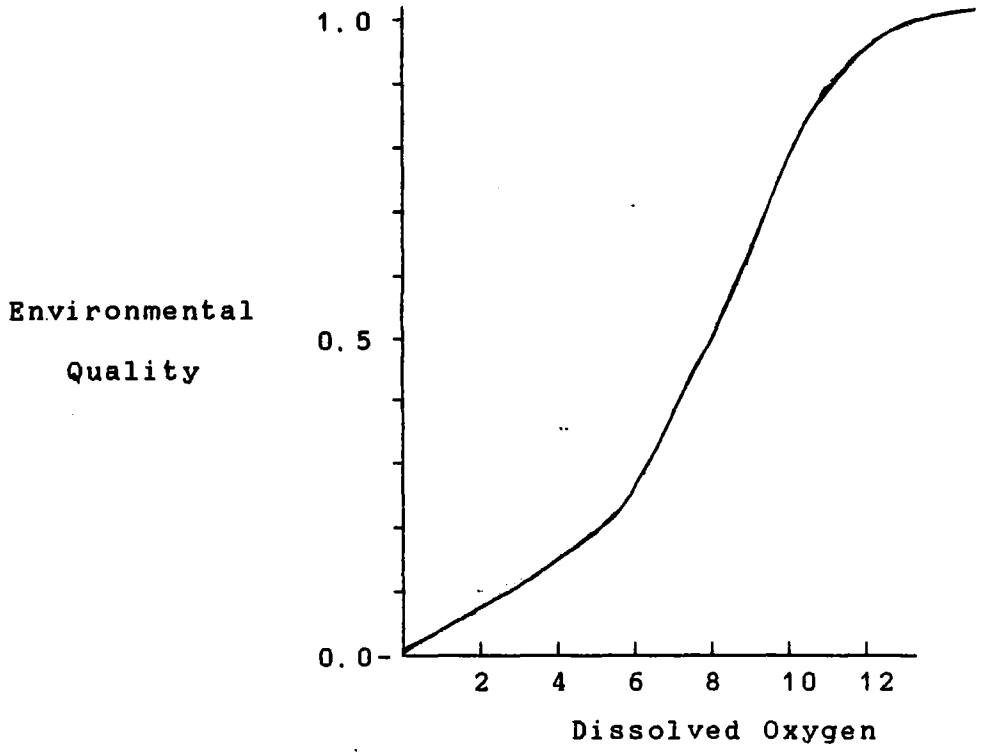
(d) Generally more than one alternative design is analysed resulting in more than one value for each category. The large amount of data produced could become confusing for the decision-maker.

(2) Environmental Evaluation System (EES), Dee, et. al. (1974). This technique attempts to transform all parameters into measurable units based on a hierarchy of quality indicators. The major areas of environmental concern are classified into four categories - ecological, environmental pollution, aesthetics and human interest - and these categories were further subdivided into 18 components and finally 78 parameters.

Each parameter is a physical entity which could be quantified utilising historical data and represented an aspect of environmental significance worthy of separate consideration. The parameter estimates related environmental quality to a value function on a scale of 0 (bad quality) to 1 (good quality), see Figure 5.3.

FIGURE 5.3

Relationship Between Environmental Quality and Dissolved Oxygen Levels



Each parameter is then assigned a weight to signify its relative importance. The weights indicate the degree of disturbance or enhancement of the environment caused by the project under consideration. The weights were subjectively assigned by the analysts.

One advantage of this system is that the results could be combined to give a single indicator of environmental quality (environmental impact units) and a marginal effect could be calculated by comparing the with and without project values. The technique has two major limitations. These are:

(a) the subjective assignment of weights by the analyst, and

(b) consensus is required as to the shape of the value functions.

(3) Quantified Evaluation for Decisions (QED), Gum, et.al. (1982). This method was developed to show

trade-offs between environmental quality and economic objectives and has been used successfully on real world problems, Gum, et. al. (1978), Gum and Martin (1979) and Arthur (1981). The steps involved in this method are that environmental quality is first disaggregated into a series of quality components until a point is reached where human perceptions of physical changes are possible. At this level the perceived environmental quality attributes are linked to technical indicators so measurement can take place. Once measurement has taken place the process reverses until final aggregation takes place to give a measure of environmental quality.

The basis of the system is that by breaking the system into components and further breaking these components into perceivable attributes, the analyst is able to measure the effects the alternatives will have on environmental quality. Figure 5.4 presents a component/attribute tree for water. Survey techniques can be used to put values on debris, algae, soil or mud, and odour for each alternative plan analysed. Weighting factors can then be used to aggregate these values into an overall water appearance measure taking the general form;

$$\text{EQ attribute/component index} = \prod_{i=1,n} X_i w_i$$

where,

X_i is the measure of a policy's effect on component/attribute i,

w_i is its preference weight, and

n components/attributes are to be aggregated into a measure of impact on the next highest component/attribute in the hierarchy.

or more specifically for example:

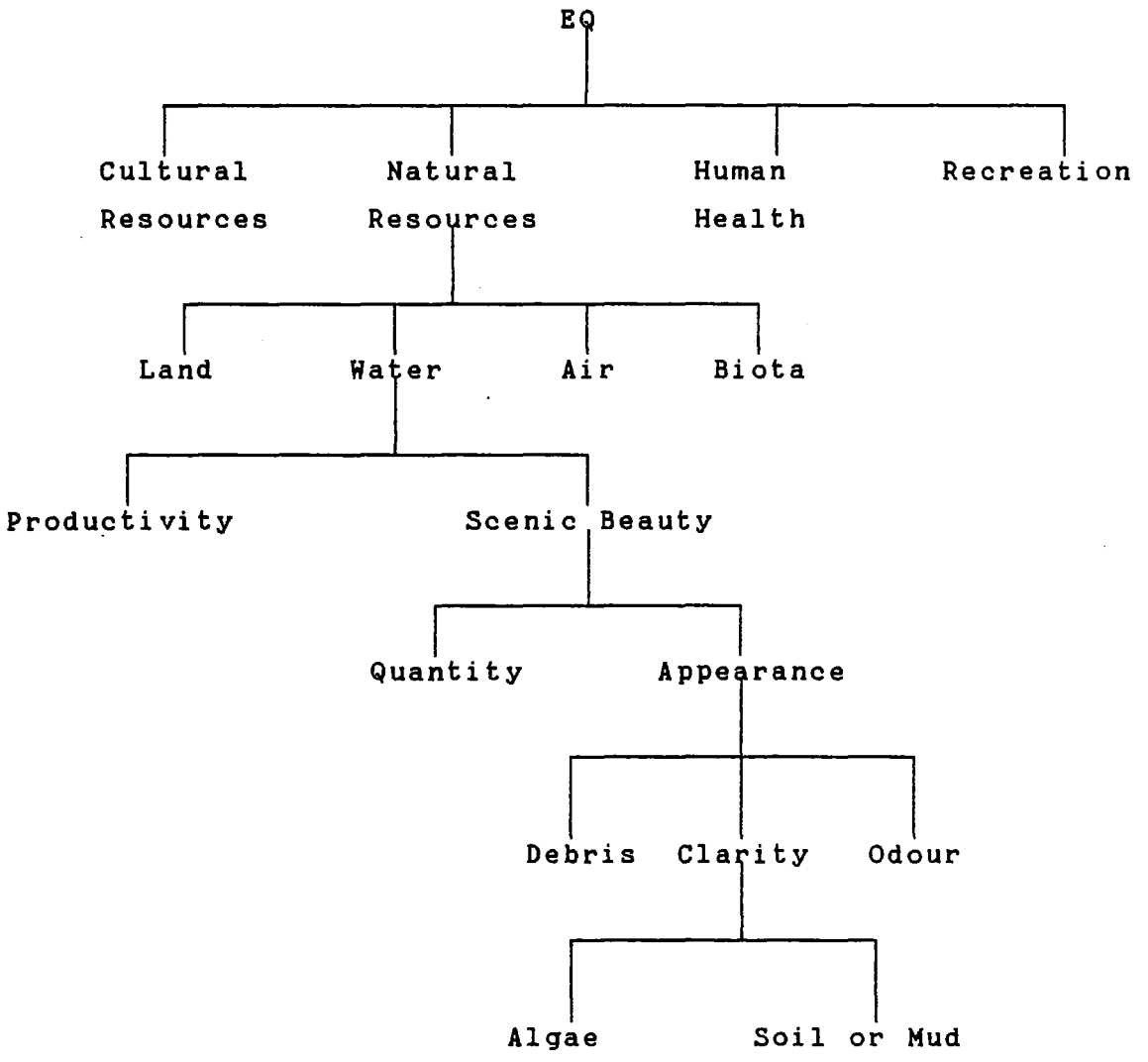
$$\text{water appearance} = \text{clarity}^{.38} * \text{odour}^{.37} * \text{debris}^{.25}$$

Gum, et. al. (1982) suggested two ways to generate the preference weights. These were by way of a public opinion survey or use the opinions of the policy makers. The procedure described above can then be used to combine the environmental quality component measures into the total environmental quality measure.

The major advantages of this approach are that it can be used to distinguish between alternative plans and policies, and it provides a single measure of environmental quality. Its limitations are that subjective assessments are required to derive the weights and the values assigned to the components.

FIGURE 5.4

The Component/Attribute Tree For Water



5.3.3 Summary

In summary, a large number of disciplines are required to quantify the effects of alternative development options on environmental quality. In addition, the diversity in attributes means that quantification of environmental quality changes is clearly beyond the scope of one discipline and therefore requires a multidisciplinary approach. It is also essential that there is early and continuing interaction between the environmental quality evaluation team and other groups in the planning process.

The monetarisation of environmental effects is at best difficult and at worst impossible. As a result the environmental quality effects of water and soil development will in all likelihood continue to be measured in non-monetary terms. The attributes that are used to describe these effects should include ecological, cultural and aesthetic aspects. The indicators used to describe the attributes are numerous and decisions on which to use and the method used to describe environmental quality changes, for each alternative scheme, should desirably remain in the hands of the analyst(s.) The measure chosen should reflect the end use,, for example if multiple objective programming methods are to be used then numerical measures are required so trade-offs can be shown.

Where it is possible to measure environmental quality effects in monetary terms the values obtained should be included in the economic efficiency accounts. However, care should be taken to ensure double counting of effects does not occur. Monitoring of key environmental effects of existing projects will provide analysts with a better basis to predict the effects of similar projects in the future.

5.4 OTHER SOCIAL EFFECTS (OSE) OBJECTIVE

Water resources projects are more than physical structures, they are also an intervention into the social system, Goodman (1984). The effect on the social environment

is wide ranging with benefits (and costs) spread over geographical and social class boundaries. The main concentration of effect is normally in the vicinity of the project. This often means that the local community feel that it is being forced to bear too large a share of the cost of the project and will oppose it. This is especially so in areas where the benefits of the development are derived away from the affected area. The local people are also in a better position to form pressure groups to oppose the scheme than the more widely spread beneficiaries. The use of social assessment in the planning process can alleviate some of these problems and be helpful in suggesting appropriate trade-offs between costs and benefits. The basis of any social assessment is values, or in particular the way people perceive how things ought to be. Because of this it is essential that social impact assessment should involve people, Goodman (1984).

As was the case with environmental quality the assessment of the social effects of projects may be contradictory, Fitzsimmons, et.al. (1975). For example, an irrigation scheme drawing water from a river may increase the agricultural production in an area. This would generally be well received by the local agricultural population. The urban population may be concerned that the scheme will also detract from the recreational activities associated with the river. The overall effect may be good or bad depending on your point of view. Therefore, a sound social assessment must take these contradictory effects into account.

In New Zealand social impacts of development projects are covered in environmental impact reports. The importance of the social consequences of development have only recently been recognised and recent reports on the Upper Clutha hydro development, the synthetic fuel plant at Motonui and the aluminium smelter at Aramoana have included detailed sections on social-community impacts, Taylor and Sharp (1983).

Social impact analysis is still in its infancy in New Zealand and resource development debates have concentrated on the physical and economic matters leading to a situation where there is no mechanism for incorporating social aspects into planning, Maturin (1983). It has also been suggested that social impact assessment in New Zealand should not just form an important part of the environmental impact reporting but should be incorporated into the overall planning process along with engineering, physical, environmental, and economic issues, (Ministry of Works and Development (undated) and Maturin (1983).)

Taylor and Sharp (1983) noted that research to date in New Zealand has concentrated on profiling the existing situation and only limited work has been done involving the projection and assessment of likely project effects. They called for an issues orientated approach which would give full recognition to the local or community issues that emerged in projects, especially those that proceed largely for the benefit of groups external to the area affected. Such an approach was used by the Joint Centre for Environmental Sciences in a study of the effects of lignite mining in Otago and Southland, Joint Centre for Environmental Studies (1982).

5.4.1 Social Impacts Of Development

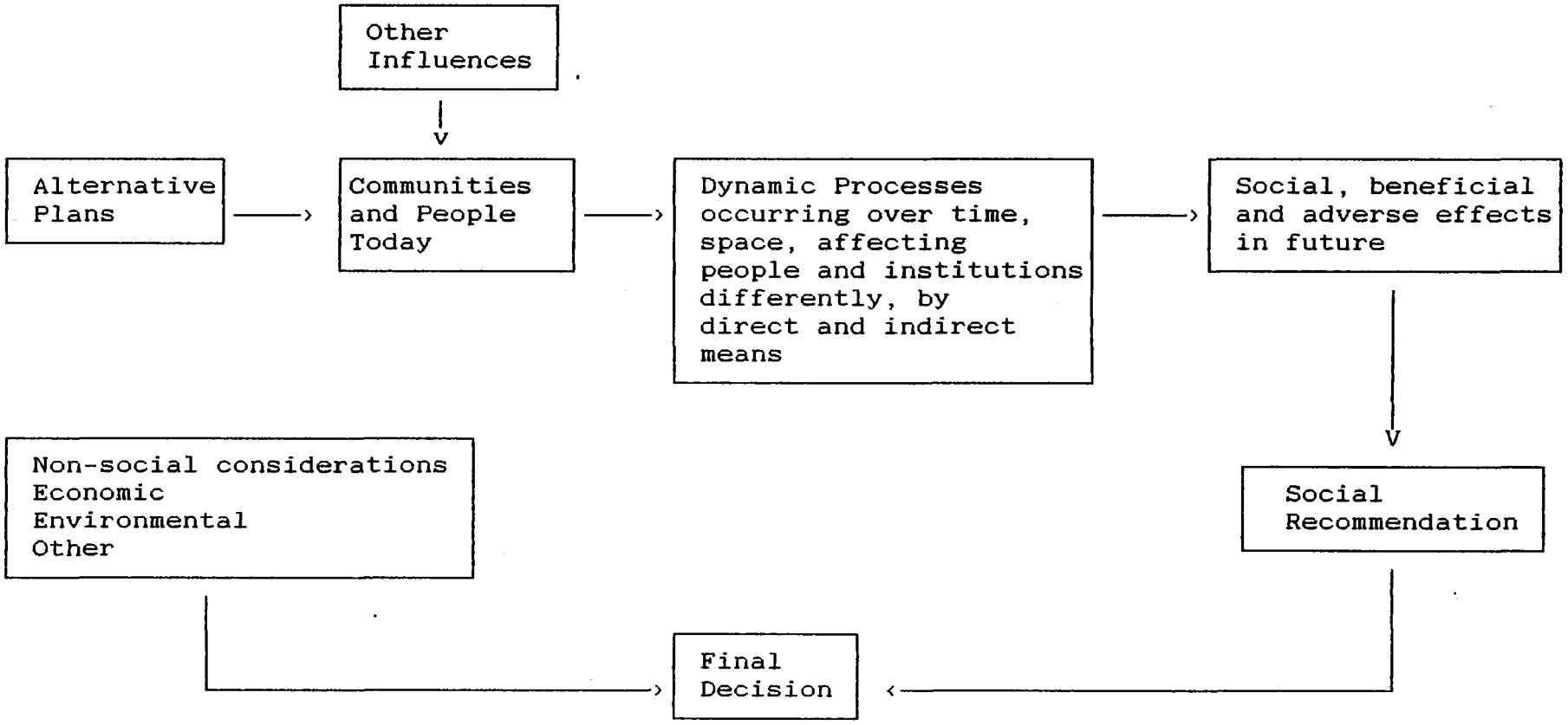
Social assessment must take account of the fact that in response to a stimulus, such as water resource development, the community will respond and the character of the community may undergo significant change as a result. Social assessment is therefore dealing with the dynamics of the change. A representation of this dynamic system is shown in Figure 5.5.

There are four broad categories of social impact resulting from water resources projects, (U.S. Army Corps of Engineers (1977)). These are:

(1) Distributional impacts: These are the impacts generally classified into:

FIGURE 5.5

Diagram of the Dynamic Systems Model of a Communities Response to Development
(Source: Fitzsimmons, et al. (1975))



(a) demographic effects characterised by shifting residential patterns, population mobility, relocation impacts and effect on local housing,

(b) real income distribution effects, and

(c) distribution of the costs and benefits of a project action.

(2) Opportunity impacts: These involve a clear change in the ability to enjoy a variety of opportunities and are highlighted by changes in educational, cultural and recreational opportunities. This grouping also includes the general effects on the local level of economic opportunity.

(3) Local service delivery impacts: A range of impacts is often considered ranging from economic and health e.g. safety from floods and improved health care, to what is generally the primary focus, changes on local government e.g. changes in the tax base, expenditure, structure, services and effectiveness.

(4) Community cohesion impacts: These involve the perceptions of change and reactions to that change. They can be caused by conflict over the project but also involve peoples awareness of the project's existence and the accuracy of that awareness. This aspect has been the factor examined in 76% of the ex-ante studies carried out in the U.S. to 1976, U.S. Army Corps of Engineers (1977).

The principal variables listed by the U.S. Water Resources Council as baseline variables used in major water resources studies in the 1970's are listed in Appendix Table E.2. The list is by no means comprehensive but it gives the major components and their associated variables that should be considered in social impact analysis. The U.S. Water Resources Council has not recommended any methodology for use in proposals prepared for it which is a reflection of the lack of experience in this area of analysis.

5.4.2 The Assessment Framework

Finsterbusch (1980) notes that there is now an acceptable methodology for the assessment of social impacts of development projects. This framework (shown in Figure 5.6) has gained widespread acceptance apart from minor variations used by different agencies.

FIGURE 5.6

Steps In Social Impact Assessment

1. Scoping

   Set level(s) of assessment and dimension of impact categories, formulate terms of reference and develop the study design.

2. Problem Identification

   Explicate policy goals and planning objectives, identify publics and concerns, perform a needs assessment and determine evaluative criteria.

3. Formulation of Alternatives

   Define a set of "reasonable" alternatives, characterise and describe the technical system(s), analyse for social components and correlatives and profile change agents and instruments.

4. Profiling

   Characterise potentially impacted system(s), select impact categories, assign impact indicators, perform indicator measurements and compile a profile of the system.

5. Projection

   Explicate "state of society" assumptions, perform a trend impact analysis, construct dynamic system models and estimate impact indicator values for alternatives ("with and without" implementation).

6. Assessment

   Perform a sensitivity analysis for alternative outcomes of alternative plans, a cross-impact analysis and a cumulative impact analysis and describe and display "significant" impacts.

7. Evaluation

   Rank and weight preferences for alternatives, perform a trade-off analysis and identify the preferred alternative.

8. Mitigation

   Review unavoidable adverse impacts, identify possible mitigation measures, perform a sensitivity analysis of possible measures and specify terms and conditions for the application of measures.

9. Monitoring

   Devise a monitoring plan, measure actual versus predicted impacts and feed back measurements to policy makers and publics.

10. Management

    Devise a management plan and adjust planning objectives, operating procedures, and design specifications.

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Source: Cited in Taylor and Sharp (1983), adapted from an anonymous handout at SIA conference, Richmond B.C. 1982, see also Krawetz (1981).

Problems with this framework were highlighted by Taylor and Sharp (1983). These were that there is at present no clear means of linking the a priori assessments with the monitoring and management phases and the value stances taken by researchers. They felt that social impact assessment work "... is couched in the value system of the institutions that are promoting a development and funding social impact assessment can become part of a mutually reinforcing system of decision-making and research".

An important feature of social impact analysis is the involvement of the public in the decision-making process. This aspect has been covered in some detail in Section 4.3 and the place of conflict and conflict resolution in the planning process has been discussed in Section 4.2.

5.4.3 Analytical Techniques For Assessing the Social Impacts Of Projects

Because social impact assessment is a new field of social activity it lacks proven analytical tools but experience is increasing with time. Some examples of tools used to date include:

- social profiling
- content analysis
- community impact assessment
- institutional analysis
- small group processes techniques
- human cost accounting
- policy profiling
- population projections
- ethnographic field analysis
- questionnaire and non-parametric statistical analysis
- value mapping
- trend and cross impact analysis

Delli Priscoli, (1981) discussed the uses of these techniques in water resources planning. He found two techniques, small-group processes and values analysis, have had the widest use to date. A third technique, community impact analysis has been used in New Zealand to carry out preliminary investigations into the Southland lignite mining proposals, Joint Centre for Environmental Studies (1982), and on-going studies are under way with two further energy projects; Marsden Point and Taranaki, MWD (1983).

The applicability of a number of techniques to various steps in the planning process is shown in Table 5.3. No one technique is useful in all phases of the planning process

TABLE 5.3

Application of Social Science Tools to Water Resources Planning

Techniques	Steps In Planning Process: Specify Problems	Inventory Conditions	Formulate Alternatives	Evaluate: Assess	Evaluate: Appraise	Compare Plans	Selection
Social profiling	X	X					
Content analysis	X	X		X			
Community impact assessment		X		X	X		
Institutional analysis		X			X	X	X
Small-group processes	X		X	X	X	X	
Human cost accounting	X	X		X			
Policy profiling			X			X	X
Population projections		X					
Field analysis		X		X			
Questionnaire and nonparametric	X	X			X		
Values analysis			X	X	X	X	X
Trend and cross-impact				X		X	

Source: Delli Priscoli (1981)

but combinations of processes will allow social effects to be handled comprehensively in the planning process.

5.4.4 Development Of A Social Well-Being Profile

Fitzsimmons, et al. (1975) discussed the following five step process for developing a social well-being profile. The five steps involved are:

(1) Causal agent: A description of the historic water and soil resource needs and problems experienced by the area. This gives the basis for understanding the reasons why social impacts are expected and how they will differ between alternatives (including do nothing).

(2) Context and present day life: Describe the historical context, social profile, and general characteristics of life in the area. Comparisons can then be made with regional and national profiles to ascertain whether the study area is above average, average or below average. This provides the planning setting.

(3) The alternatives are then examined separately to determine their likely social impacts. Data are collected first and then an assessment is made whether the impact is beneficial or adverse. The future social impacts are a measure of the changes in state variables, conditions or systems. The net impacts attributable to each alternative are then determined according to the nature of the impacts. The categories suggested are:

   (a) whether the impact is direct or indirect i.e is the impact caused directly by the project or as a result of a direct impact,

   (b) whether the effects are short term or long term,

   (c) the geographic location of the impact, and

   (d) the various groups impacted e.g. income group,

individuals, communities, entire regions or the whole country.

(4) Social well-being components. Comparisons can now be made between plans in terms of the impacts of different plans. Trade-offs among plans are identified and a decision made using the following logic:

Condition	Decision
Plans' social benefits are greater and costs lower than with no plan.	A plan should be implemented
Plans' social benefits are lower and costs higher than with no plan.	Reject plans
Plans' social benefits are higher, but plans' costs are also higher than with no plan.	Trade-offs require a decision based on whether higher costs offset by higher benefits or vice versa. Decision could go either way.

(5) Recommendations. The best plan from the perspective of the beneficial and adverse social effects is selected and a recommendation can be made in the context of the overall project report. The decision logic applied is as follows when comparing two plans, Plan A and Plan B:

Condition	Decision
Plan A has higher social benefits and lower social costs than B.	Implement A
Converse of above	Implement B

Plan A has higher social benefits but also higher social costs than Plan B

Implement A or B depending upon which in the final analysis, is most acceptable - losing the benefits sought or accepting the costs.

Plan A has social benefits and costs which are neither higher nor lower in the same desirable and/or intolerable) benefits and both have social costs, but they are not comparable.

Implement A or B, depending on which benefits are most desirable and/or which costs are more tolerable (or they both have social ways than Plan B. That is, are more tolerable (or they both have intolerable) benefits and both have social costs, but they are not comparable.

5.4.5 Summary

The present system of reporting, through environmental impact reports, means that projects are assessed at a point where development is most likely to proceed albeit with small changes in some cases. One approach to the amelioration of adverse social effects of water and soil development is better public input into project design and implementation. This has the effect of incorporating social impact assessment into the planning process. Such an approach was proposed for use in New Zealand by the Town and Country Planning Directorate of the Ministry of Works and Development as a result of lessons learnt from the major resource developments in Taranaki and Northland, Ministry of Works and Development, (undated). Details of this method are included in Appendix E.

5.5 REGIONAL ECONOMIC DEVELOPMENT (RED) OBJECTIVE

Regional development may be best defined as the net change in the distribution of regional economic activity that results from a resource development proposal. The importance of regional planning in New Zealand was increasing in the years till 1984 and central government was taking a more active role by promoting regional employment

generation and income distribution objectives through the Minister of Regional Development, Butcher (1986) and MAF (1984). As a result of this, planners were being asked to report on the regional development aspects of schemes when submitting them for approval at the central government level. At present there is no formal requirement for presentation of regional effects. The present convention adopted by the MAF for water and soil projects is that secondary effects and in particular regional development effects should not be quantified but should be dealt with in a qualitative way if it is thought they are significant, MAF (1984).

The reasons for this stance are that from the national point of view, secondary effects, including regional development, cannot produce a net increase in economic activity if full employment of resources, and no changes in efficiencies are assumed (as has been the case in New Zealand). This is because national aggregate output is not increased but is merely redistributed between regions. In other words, the increase in economic activity in one region will lead to a corresponding decrease in economic activity in another. This might not always be the case as shown by irrigation development in Canterbury where development has occurred in stages ensuring a continuity of work for an experienced work force and construction equipment.

If on the other hand there is national under employment of resources there will be a net gain in national and regional income associated with the development. However, in New Zealand when there is a situation of under employment of resources, it has been assumed that the secondary effects of public works investment will be similar. Hubbard and Brown (1979), found that this only rarely occurs and investment in one sector can have a markedly different effect on the regional economy compared with investment in another sector. They used electricity and agricultural development as examples. Electricity development is capital and job intensive for the construction phase but provided only small

long term employment opportunities. On the other hand, agricultural development is not as capital and labour intensive and provides long term employment opportunities.

5.5.1 U.S. Procedures

The United States Water Resources Council's procedures document, U.S. Water Resources Council (1983), suggests two factors should be used to measure the effects of proposals on regional economies; regional income and regional employment. Regional income effects were defined as the positive and negative effects of a proposal on the regions net income. Regional net income accrues from the sum of the national economic development benefits and costs that the region receives plus transfers of income into and out of the region. Apart from the direct effects mentioned above indirect effects such as expansion in the production of inputs to industries supplying increased final products and regional exports, and the induced effects resulting from changes in consumption expenditure generated by increases in personal income, were to be included in the regional development account, U.S. Water Resources Council (1983).

The procedures require that the positive and negative regional employment effects of a project should be stated along with each of the associated regional income categories used to show regional income effects. Reporting on schemes was also to contain estimates of the composition of increased employment according to relevant service, trade and industrial sector with a separate estimate for agriculture. The level of skill required ~~was~~ must also be described.

It is clear that the U.S. water resources planners see the regional effects of their schemes in a different light to similar planners in New Zealand. The 1979 and 1983 "Principles and Standards" documents, U.S. Water Resources Council (1979b) and (1983) both included regional economic development as a separate objective but only assigned the lower status of an "account" to the objective and stipulated

that regional development effects were only to be included in the analysis where directed. Controversy has surrounded the inclusion of regional development effects as an objective for two reasons. The first is that many people thought that regional development effects should be included under the "other social effects" (OSE) objective and the second was that it should not be included as an objective at all.

5.5.2 The Rationale for Excluding Regional Economic Development Effects

Freeman and Haveman (1970) set out the following line of argument for the exclusion of regional economic development effects from the analysis of water resources development schemes:

(1) The regional development objective is only relevant where one region is deemed more deserving than another. If this is not the case and all regions are given equal weighting, then the total regional income effect is the sum of all regions which in turn is the national income effect. Deservingness must be based on a concept of equity in income distribution and the way in which this is expressed will have a significant effect on the analysis undertaken. For instance if the objective of the project is to stimulate a region of low per capita income these regions would need to be identified and some weighting applied to income generated in this area as a result of projects so that capital expenditure is attracted to the region. This would mean that a region like the West Coast might have a weight of 2.0, whereas a region like Auckland might have a weighting of 0.5. If such a system were to work it would be necessary for these weights to be made explicit before any project analysis is undertaken. Such a system would obviously have widespread political ramifications. If on the other

hand the objective is one of equity between individual income levels then policy would concentrate on projects which aided lower income groups irrespective of where they lived. The need for a regional objective is then lost.

(2) Static relationships are hard enough to determine so the assessment of dynamic relationships associated with regional linkages will be harder especially with the lack of quality information. This has also been noted in New Zealand by Hubbard and Brown (1979) and Butcher (1986).

(3) To carry out a meaningful regional analysis it is necessary to be able to determine the impacts of projects on other regions as well as the region in which the project is intended. This will allow consequential decreases in economic activity in the other regions to be measured.

(4) Any regional development objective must involve some equity judgment. Trying to establish equity on the basis of aggregate regional income provides no useful information and the use of regional per capita income is too crude a measure. The dynamics of income distribution within and outside the region need to be understood for equity considerations to be become an effective part of the planning process. In a critique of U.S. water resources policy, Gaffney (1969) stated that in actual fact the benefits of water resources development become capitalised into land values and as such provide a subsidy to the rich and very rich. Similar results have been noted in New Zealand (Dent, 1985) where it would appear that the market has capitalised irrigation availability into land values at about 15% (T.I. Marks pers. comm.) for the more established community irrigation schemes.

(5) The introduction of a regional development objective into national planning may lead to sub-optimal public expenditure decisions being made. It is more effective for regional authorities to develop regional development policies as they can often see more effective means (other than water and soil development) of stimulating regional development.

5.5.3 Summary

In summary, there is some debate over the role of the regional development objective in water and soil planning. The inclusion of regional development effects is valid in situations where resources are under- or un-employed but there are theoretical problems in defining when, and to what extent, these situations occur. Further, it is clear from decisions that have been made in New Zealand that decision-makers place some implicit weight on the regional effects of projects in the decision making process e.g. the decisions to proceed with the Maniototo irrigation scheme, rail coal from the West Coast, and special drainage subsidies for the West Coast. It can only be assumed that because regional development is used by decision-makers, either explicitly or implicitly, in the decision-making process that it retained its "account" status in the U.S. water resources planning procedures. It is for these reasons that the analysis of regional effects of water and soil development should at least be included in scheme reporting. However, where there is full employment of resources the effects should be given little weighting.

A number of assessment techniques are available for quantifying the regional effects of development. These have been summarised in Appendix F. The use of input-output tables provides the most thorough approach to multiplier calculation, Hubbard and Brown (1979). These tables reflect the structure of the economy in question at a particular point in time and the coefficients reflect the average

relationships that exist between the sectors using the technology available at the time, Butcher (1986). The GRIT method has been used successfully applied in New Zealand as a semi-survey technique, Butcher (1986), and a non-survey technique, Hubbard and Brown (1979). A semi-survey approach should be used in preference to non-survey techniques because the accuracy of the later is in doubt.

CHAPTER VI

ANALYTICAL METHODS - MATHEMATICAL PROGRAMMING

6.1 MATHEMATICAL PROGRAMMING TECHNIQUES

The previous chapters have shown that goals and objectives are often in conflict and that decision-makers also have additional constraints to work within when making decisions on resource development proposals. Herein lies the basic difficulty of decision analysis; how can multiple, conflicting goals and objectives be reconciled, subject to technical constraints. In order to satisfy conflicting objectives as much as possible, decision-makers must assign priorities to them. These priorities may be set in consultation with interested public groups and individuals or by the decision-maker's perception of what the public's priorities are. Comprehensive planning for water and soil development requires that each objective and constraint is considered. In this chapter some possible approaches using mathematical programming are assessed. In Chapter 7 the application of one method, lexicographic goal programming, to a real world situation (the allocation of water in the lower reaches of the Rakaia Catchment) is described in order to illustrate the process.

The change from a single- to multiple-objective water resources planning, in the United States of America, lead to a resurgence in interest in the vector optimisation techniques developed earlier by Kuhn and Tucker (1951) and Koopmans (1951). These techniques were suitable for solving problems with more than a single objective function. Multiple-objective programming techniques seek the feasible set containing the efficient (nondominated or Pareto optimal) solutions rather than locating a single optimum solution. In other words the feasible set contains solutions that have the same, or a higher, level of performance for all objectives, and strictly better for at least one

objective. Contributors to recent development have shared one aim; that of ensuring that the methods developed are theoretically operational and avoid large computational effort, Cohon and Marks (1975).

6.2 CHOICE OF MODELING TECHNIQUE

The use of symbolic models has become widespread but the operations research literature gives little guide as to the choice of the most appropriate model for any given situation. The choice of technique has been generally left to the interests and skills of the analyst or researcher. Rogers (1978) questioned the advisability of constructing large-scale and complex models for resource planning without first considering whether the approach being used is suitable and/or cost effective. He described the attributes of an simple and a realistic model. These are shown in Table 6.1.

TABLE 6.1

Attributes Of Simple And Realistic Models

(Source: Rogers, 1978)

Simple Model	Realistic Model
not too many data	dynamic
easy to compute	continuous time
easy to understand	stochastic
easy to explain	many interest groups
few results	interregional
only key variables	intertemporal
prescriptive	nonlinear
many variables	
many constraints	
descriptive	
prescriptive	

Loucks (1975), and Cohon and Marks (1975) have both discussed the characteristics needed by a model if it is to capture the decision-making process (Table 6.2). These criteria aim at determining the extent to which the technique is consistent with multiple-objective cost-benefit analysis.

TABLE 6.2

Characteristics Of Models If They Are To Capture The Decision-Making Process. (Source: Loucks, 1975; Cohon and Marks, 1975)

Loucks (1975)	Cohon & Marks (1975)
simulate the decision-making process	computationally feasible and relatively efficient
recognise the degree of uncertainty in trade-offs and preferences	explicit quantification of trade-offs among objectives
predict the outcome of the decision-making process	sufficient information that an informed decision can be made

It is the search for realism and robustness that has caused planners and researchers, alike to violate the attributes of simplicity. As there are no guidelines, or rules of thumb, for setting boundaries of modeling studies, it is normally the intuition of the modeller/s or the budget that sets these restraints.

Thomas (1967) looked at two sources of error in systems models; parameter and outcome variation. His study examined the consequences for project selection of design errors induced by uncertainty in the parameters of a model. Rogers

(1978) used these two error groupings and introduced a third grouping, that of model choice, to Thomas' analysis. Using a simple irrigation model as an example Rogers compared a conventional linear programming approach to a non-linear programming approach. His conclusions were that there was no strong evidence that the less complex models were a more appropriate choice than complex models. However the model choice errors (from selecting a simple model) were within the range of errors that might be expected from parameter estimation in the more complex model.

The choice of modeling technique should ideally depend on the cost of achieving a result, the availability of data and the likely value of the result obtained. These decisions need to be made at an early stage of the planning process and adhered to unless one of the factors alters considerably.

A large number of modeling approaches have been used to analyse water and soil planning problems but few have been used extensively in the applied situation. The following discussion will review those techniques that have potential to handle a wide range of water and soil planning problems practically and realistically. The classification adopted to structure the discussion was reported in Cohon and Marks, (1975).

6.3 GENERATING TECHNIQUES

These techniques do not incorporate the decision-makers preferences into the solution process. Instead, the decision-maker is provided with a range of choice, represented by the non-dominated set, and asked to choose from that range. This type of technique is represented by the following methods:

6.3.1 Weighting Method

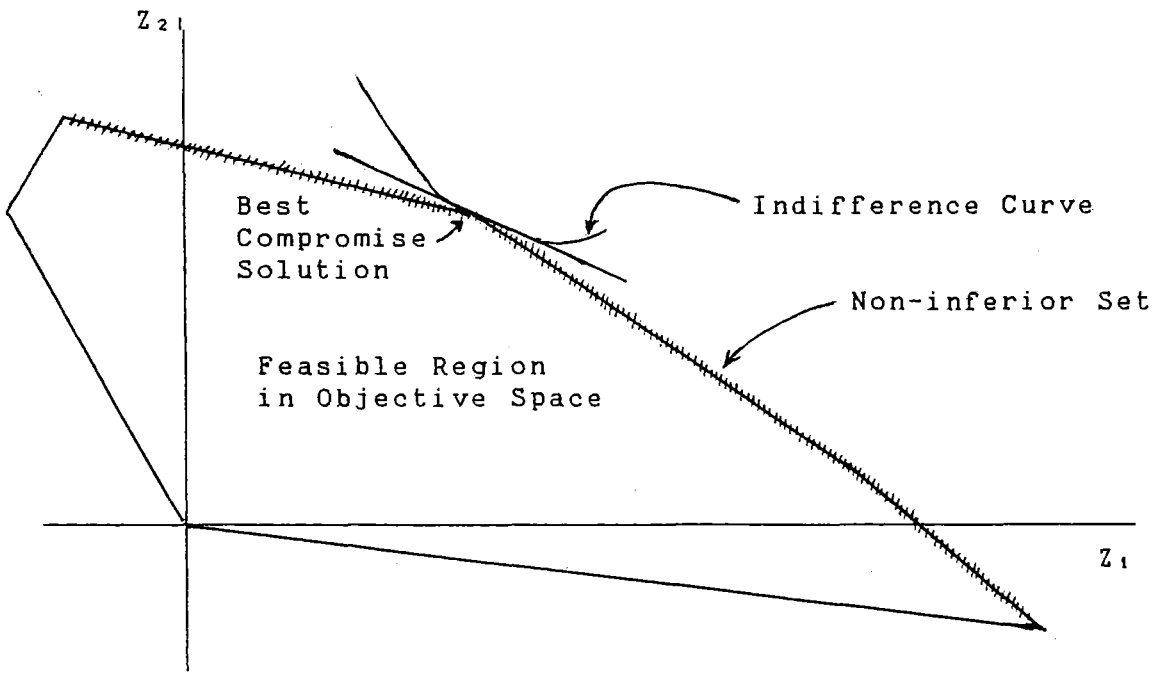
Marglin (1962) and Major (1969) discussed the use of weighted objective functions in public investment problems

(see section 4.5 for further discussion). The weighting method, involves combining the multiple objectives into one overall objective function. Each of the independent objective functions is assigned a weight, 'w', before it is combined into the aggregated objective function. Given a single objective and a series of constraints, a solution can be obtained by using well known techniques such as the simplex method. The solution obtained would be the best compromise solution for a decision- maker with a weighting preference of 'w'. The set of non-inferior solutions is then obtained parametising the weights and solving a single objective mathematical model. In other words the extreme points of the feasible region are generated (Figure 6.1). If the weights represent the decision-makers preferences, then a single objective linear program can be used to generate a single "best" compromise solution. The mathematical representation of the weighting method is shown in Appendix G.1.

FIGURE 6.1

Feasible Region in Objective Space, the Non-Inferior Set and the Best Compromise Solution

(After: Cohon and Marks (1975))



The results are then presented graphically or in a tabular form for the decision-maker who, based on this information, selects a best compromise solution.

6.3.2 Constraint Method

This method involves the optimisation of one objective while all the other objectives are constrained to some value. Parametisation of these constraints generates the efficient set or the non-dominated solutions. Marglin (1962) appears to be the first person to have suggested such an approach to multiple objective problems. The constraint method can be used to generate a number of alternatives which can then be considered by the decision-maker. Cohon and Marks (1973) applied this method to river basin planning on the Rio Colorado in Argentina and Louie, et al. (1982) to consider water supply allocation, water quality control and prevention of undesirable overdraft in a groundwater basin.

6.3.3 Advantages of Generating Techniques

(1) They allow the analytical goal to be one of generation and evaluation of alternatives, and not one of political analysis or prediction. This is achieved by including the decision maker near the end of the development process when decisions between alternatives are required.

(2) A relatively small burden is placed on the decision-maker/s in terms of the supply of information.

(3) The number of decision-makers, their accessibility, and their identifiability will not detract from the usefulness of the techniques.

(4) The generation of alternatives may aid conflict resolution because decision-makers who understand the alternatives and trade-offs are more likely to compromise.

6.3.4 Disadvantages of the Generating Techniques

(1) The analysis may occur without complete identification of or access to the decision-maker/s.

(2) Where there are multiple conflicting decision-makers, the techniques may only solve part of the problem. The problem occurs when the best compromise solutions chosen are not the same for each decision-maker and conflict arises.

(3) The major weakness is that with more than three objectives, computational burden and the complexity of the result displays makes their use prohibitive.

(4) The techniques are not true multiple objective techniques but are single objective techniques with associated constraints.

6.4 TECHNIQUES THAT RELY ON PRIOR ARTICULATION OF PREFERENCES

These techniques rely on the explicit statement of preferences by the decision-maker (or his/her proxy) prior to the solution of the multiple objective problem. The best compromise solution is then generated without generating the non-inferior set, or parts of it. Examples of these techniques are:

6.4.1 Goal Programming

The aim of goal programming is to minimise the weighted deviations of multiple objectives from desired goals. This is achieved by transforming the objective functions into constrained equations, setting the equations equal to a desired goal level and allowing for under- and over attainment of the desired goal level. The form of the problem is an objective function (minimising the deviation from desired goals) with constraints which can be solved using the simplex method (Figure 6.2). The solution is not the optimum but that which best satisfies the stated policy

levels set for goal attainment. The technique makes it necessary for the decision maker or evaluator to assign values for the goal levels and the relative weightings. The general goal programming formulation is shown diagrammatically in Figure 6.2 and mathematically in Appendix G.2.

A goal cannot be both under and over-achieved. Thus at least one of the deviation variables must have a value of zero. When both take on a value of zero the goal matches the aspiration level exactly. There are three basic situations:

(a) The level of the goal has to be greater than or equal to its target. In this situation the under-achievement is minimised.

(b) If the goal is to be less than or equal to its target then over-achievement is minimised, and

(c) where the goal is to be exactly achieved then both under- and over-achievement are minimised.

Where preemptive weights (weights that are elicited from the decision maker prior to running the model) are included in the minimisation process the technique is termed lexicographic goal programming (LGP) and when non-pre-emptive weights are used on goals the technique is referred to as weighted goal programming (WGP). Lexicographic goal programming (LGP) assumes that the decision-maker can define all the goals relevant to the decision and give pre-emptive priorities to the goals. The LGP algorithm then satisfies the highest priority goals first then considers lower priority goals subsequently.

A vector or achievement function is substituted for the objective function used in a linear programme. The function is the minimisation of the deviation variables (+ve and -ve) and ranks the goals in order of priority. Romero and Rehman (1984) described the achievement function as follows:

FIGURE 6.2

Goal Programming Formulation (Source: Bartlett, et al. (1978))

MANAGEMENT SCHEMES	PRODUCTS (USERS)	DEVIATIONAL VARIABLES		
Production Rate For Goal Constraints Of Variable Resources	Use Rates For Goal Constraints Of Variable Resources	"Link" Matrix Between Deviational Variables And Goal Constraints	$\leq$ $\geq$ $=$	Goal Levels
"Link" Matrix Between Production Of "Factors" On Fixed Resources And Management Schemes	Null Submatrix	Null Submatrix	$\leq$	Fixed Resources (Land, Supplement)
Production Rates Of Variable Resources	Use Rates Of Variable Resources	Null Submatrix	$\geq$	Lower Limit Of Variable Resources
Null Submatrix	"Link" Matrix Between Users And Requirements	Null Submatrix	$\geq$	Quality Of User Requirement
		Objective Function Of Weights And Priority Factors For The Minimisation Of The Deviation From Each Goal		

Minimise $\underline{a}$ = [h1($\underline{n}$, $\underline{p}$) , h2($\underline{n}$, $\underline{p}$) , . . . , hl($\underline{n}$, $\underline{p}$)]

or alternatively,

Minimise $\underline{a}$ = [a1, a2, . . . , al]

where, al = hl($\underline{n}$, $\underline{p}$) is a function of the deviational variables.

The aim of this approach is to find the lexicographic minimum of $\underline{a}$ in the order stated. It first determines the smallest value of the first component a1, then the smallest value of the second component a2 compatible with the value of a1 and so on.

In developing the achievement function the decision-maker may if necessary, attach weights to the goals within a determined priority. Thus for any priority level it is possible to say that goal 1 has twice the weighting of goal 2.

e. g. (2$\underline{n}$1 + $\underline{p}$2) .

A large number of planning priorities can be explored, by carrying out sensitivity analysis on priorities and target levels.

Weighted goal programming (WGP) is similar to the weighted method (see 6. 1. 2) in that it includes all the goals in a single objective function. This objective function minimises the sum of all the deviations among the goals and their aspiration levels. Weights are attached to the deviations according to the relative importance of each goal to the decision-maker. The variables in the objective function are expressed as percentage deviations from targets to overcome the problem of incommensurable units used to measure different goals. Mathematically the problem becomes the same as a conventional linear programme and can be solved using the simplex method.

Advantages of goal programming are:

(1) It is a computationally efficient technique in comparison to the generating techniques.

(2) It can account for non-commensurable items e. g. dollars can be traded-off with water quality rankings.

(3) The technique is conceptually easy for the decision- maker to assimilate and trade-offs can be made in a logical manner. In addition, a vast amount of information is available to the decision-maker in the final tableau; including trade-offs, sensitivity to changes, etc.

(4) The technique can be used with some confidence because it has had wide-spread application, and gained a degree of acceptance as a useful planning tool in U.S. water resources planning on both hypothetical problems, Neeley, et. al. (1976), Panagiotakopolous, (1975), Bishop, et al. (1977), North, et al. (1977) and real world problems; Rossmiller, et al. (1979), Bartlett, et al. (1978).

(5) It provides a logical, easily understood process of analysis which allows the analyst to proceed from goal definition to goal achievement in an orderly manner. Work is needed to prepare the model but in doing so the analyst is forced to understand the problem completely. This understanding leads to better definition of the interactions taking place which in turn produces more reliable results.

(6) It can provide explicit quantification of trade-offs among objectives when used in the way described by Willis and Perlack (1980). This method, described in Appendix G, turns the goal programming approach into the equivalent of the weighting method.

Disadvantages of goal programming are:

(1) There are situations in which goal programming will give unexpected or inappropriate results. The first of these is the possibility of identical solutions being generated by conventional linear programming and goal programming models for a given problem. This leads to the analyst concluding that the technique is redundant or of limited usefulness, Flinn, et al., (1980) and Barnett, et al., (1982).

Romero and Rehman (1984) observed that the equivalence of solutions was more to do with the formulation of the problem than the technique.

(2) Naive prioritisation can occur because the algorithms designed to solve LGP problems assume that the first problem of the sequence has alternative optimal solutions. When there are no alternative solutions, goals in lower priorities are ignored. When the number of priorities is low (3-5) this should not be a problem and goals in the lowest priorities can still play an active role in the solution process. However, when the number of priorities is large, goals in the lowest priorities can become redundant. It is important that the goals reflect the desires of the decision-maker/s and are not added for 'decoration'. Romero and Rehman (1985) noted that naive prioritisation can be a serious weakness when the size of the problem is small in relation to the number of priorities.

(3) Goal programming assumes infinite trade-offs between goals situated in different priorities. The inherent assumption of linear goal programming is that although trade-offs between goals can take place within a given priority they cannot be traded off across the boundaries of different priorities. This is a particular problem with linear goal programming where this cannot occur but can be overcome by sensitivity analyses of the final solution.

(4) There is a tendency for goal programming to produce non-efficient optimal solutions where the target levels have been set at very pessimistic levels (Zeleny and Cochrane (1973) and Cohon (1978)). This is more likely to occur where the optimal solution includes a large number of deviational variables. A possible remedy is to carry out a parametric analysis of the aspiration levels used

in the model. This would show whether or not it is possible to increase the satisfaction of some goals without reducing the achievement of others.

(5) The public sector is characterised by a complex decision-making process in which no single entity sets targets for objectives, (Cohon and Marks (1975).) This means that the goal attainment levels and penalty weights for non-attainment need to be established by a number of decision makers and/or evaluators.

(6) The value judgments elicited are explicit and possibly incorrect because they are requested from the decision-maker without prior knowledge of the likely trade-offs. Such criticisms were countered by Ignizio (1978) in the following way:

(a) the effort required to develop the model forces the analyst to understand better and appreciate the real problem,

(b) trade-offs may be made in a logical manner, and

(c) a vast amount of information is available to the decision-maker in the final tableau (including trade-offs, sensitivity to changes, etc.)

(7) Maximisation of the achievement function is not the same as optimising the utility function of a decision-maker.

6.4.2 ELECTRE Method

The ELECTRE method was developed by Benayoun, et al., (1966). There are two versions of this method; ELECTRE I and II. The successful use of the ELECTRE method has been reported by a number of authors, Roy (1971 and 1972), Chaemsaithong, et al. (1974), David and Duckstein (1976), and Gershon, et al. (1982). One of the major reasons for choosing the method has been its simplicity and the ability of the techniques to handle both ordinal and cardinal values

in the analysis. This means that multiple objective planning problems can be solved without recourse to a cardinal scale.

The aim of ELECTRE I is to choose those systems that are preferred for most of the criteria and do not cause an unacceptable level of preference loss (discontent) for any one criterion, (Gershon and Duckstein (1983)) The basis of the technique is that relevant alternatives are narrowed down into three groups; those that can be accepted, those that can eliminated, or those that require more information. The accepted alternatives are then partially ordered.

The method relies on the concepts of concordance, discordance and threshold values. An index of concordance is calculated by making pair-wise comparisons between two alternatives, i and j, and calculating the weighted frequency with which i is preferred to j, or i equals j, for each of the objectives. Weights can be assigned to show levels of preference. The mathematical representation of the concordance condition is shown in Appendix G.3.

Discordance relies on the use of a predefined common interval scale. This scale is used to compare the level of discomfort caused between the best and worst of each criterion. Examples of scales that can be used are; 0-150 or a-e, where 150 or 'e' would be the highest value and 0 and 'a' would be the lowest value. Each criterion can be assigned a different range.

Njikamp and Vos (1977) describe a variation of the concordance analysis which is based on the satisfying of project outcomes. The differences between their approach and that described above are that they introduced the concept of a norm vector p^{o} and associated weights (w^{+} and w^{-}) which are used to evaluate positive and negative deviations from the norm. The pairwise comparisons are made as before but in this case two weighting systems are used depending on whether the outcome shows positive or negative deviation from the norm.

The traditional discordance index is described as the maximum difference between the weighted project outcomes of

criteria belonging to the discordance set. A problem with this approach is that the outcomes often have different dimensions, so a priori scaling has to be carried out. Njikamp and Vos (1977) overcame this problem by relating the outcomes to a norm vector, p^0, so that the relative discrepancies (as dimensionless outcomes) could be considered in the analysis.

Threshold levels state the values of p (concordance) and q (discordance) the decision-makers are willing to tolerate. These are referred to as the threshold values. A threshold level of p=1 means the decision-maker requires full concordance between i and j for all criteria. If discordance is set at zero (q=0) then the decision-maker is unwilling to accept any discordance and the full concordance condition is met. Usually the decision-maker will select a value above and below 0.5 for concordance and discordance threshold values.

The final result of ELECTRE I is a preference graph which gives a partial ordering of the alternative systems.

The derivation of weights for use in ELECTRE is discussed by Nijkamp and Vos (1977). They used weights generated by responsible decision-makers and interest groups to represent an interval scale their priorities with respect to the decision criteria. In cases where there is conflict in the weights obtained it was necessary to carry out sensitivity analyses using each set of weights obtained. They go on to state that it is sufficient to know the order of magnitude of the successive weights and the sensitivity analyses will allow a better insight into the possible compromise solutions.

ELECTRE I is suitable for the elimination of alternatives at the feasibility stage thus leaving the decision-maker with a limited number of alternatives on which to decide but it does not provide a single best choice.

Gershon, et al (1982) developed a second stage in the ELECTRE analysis which allows a single best choice to be

achieved. ELECTRE II relies on two preference graphs generated from ELECTRE I. The two are a strong and a weak preference graph which reflect the upper and lower bounds of system performance the decision-maker is prepared to accept. The strong preference graph (G_F) is generated by using stringent threshold values (high p and low q values) and is defined by (Y_F, V_F). The weak preference graph (G_f), uses relaxed threshold values and is defined by (Y_f, V_f).

where Y = the set of nodes representing the alternatives, and

V = the set of direct arcs showing preferences among alternatives.

and an arc is placed between nodes i and j if i P j

The algorithm for ordering the systems from these preference graphs is presented in Gershon, et al (1982).

Cohon and Marks (1975) dismissed the ELECTRE I method on the grounds that it failed to provide opportunity cost information and failed to measure alternatives by comparative value. They also noted that the technique is more suited to comparisons of discrete alternatives rather than design alternatives and highlighted the problem of getting a large number of value judgments from decision-makers and getting the decision-makers to agree on these.

6.4.3 Compromise Programming

Compromise programming helps choose the optimal solution from the set of efficient solutions. It starts by first establishing the ideal point by solving a number of single objective linear programmes in which each objective is optimised separately subject to the constraints laid down. This point is usually infeasible and has coordinates which are given by the optimal values of the various objectives given by the decision- maker. The compromise solution is

that which is closest to the ideal point. If the ideal point is feasible then there is no conflict between objectives, Gershon and Duckstien (1983).

If a MINSUM approach is used the aim is to minimise the weighted sum of the fractional deviations from the ideal point. This means that it is similar to goal programming but in this case the goals are the ideal values of the objectives, McDougall (1984). The deviations are expressed in fractional terms rather than absolute terms to allow for noncommensurability between objectives. Another approach discussed by Dallenbach, et al (1983) overcomes this problem by using percentage deviations as the measure of deviation. An advantage of this approach is that decision-makers would find it easier to express preferences in percentage terms.

The algorithm for solving a compromise programming problem is described in Appendix G.4.

6.4.4 Surrogate Worth Trade Off Method

The surrogate worth trade-off method is a mathematical programming methodology similar to goal programming. It has the ability to deal with noncommensurable objective functions and is based on the concepts of Pareto optimality. This approach assesses the relative trade-offs between objectives by way of trade-off functions;

$$T_{ij} = df_i(x)/df_j(x)$$

where T_{ij} is the trade-off function between objective functions i and j.

A major advantage of this technique is that both of the objectives, 'i' and 'j', can be measured in noncommensurable units. For instance $f_i(x)$ may be measured in \$ and $f_j(x)$ may be measured in hectares. The resultant trade-off function would have the units of \$/ha.

These noncommensurable units are transferred into commensurable units by way of surrogate worth functions.

Surrogate worth functions are a function of the trade-offs which estimate the desirability of one objective over another. Hence, they measure whether the marginal change in one objective function is worth more or less than one unit change in the other. Haimes and Hall (1974) used a -10 to +10 scale to indicate the value of the marginal units, e.g. -10 units of $f_i(x)$ are worth a lot less than +10 units of $f_j(x)$ and zero signifies an even trade.

Once the trade-off functions have been developed the set of feasible solutions is reduced by considering only non-inferior solutions. This means that if the improvement of one objective function is not possible even at the degradation of another, then, it is inferior. However, if there is an improvement in the value of one objective function with a corresponding degradation in the other it is termed a non-inferior solution. An optimal solution is any non-inferior solution that belongs to the indifference frontier and the point at which all trade-offs are selected to make all surrogate functions equal to zero.

Advantages of the surrogate worth trade off method are:

(1) It provides explicit trade-offs between objectives to the decision-maker and the decision-maker is able to interact with the model by subjectively assigning preferences to the trade-off functions and noting the results of changes in these preferences.

(2) Noncommensurable objective functions can be handled quantitatively.

(3) The decision-maker interacts with the model at a general and moderate level. The decision makers subjective input is not related to setting priority levels and weightings (the decision space) but involves decisions on the relative trade-offs (the functional space). This is important as the size of the functional space is smaller than the decision space.

The limitations of this technique are:

(1) That there is a need to assign surrogates. These are based on subjective assessments and as such could pose problems when used in the public sector. The determination of surrogates for trade-offs appears to be a more difficult procedure than the specification of policy levels for an objective required in goal programming, Taylor, et. al. (1975).

(2) The technique is complex and the mathematical framework is lengthy and complex.

Lawson (1977) explained the theory and procedures involved in applying this technique to planning problems in the Waitaki River Basin. His study stopped short of applying the technique but concluded that it had potential for solving multiple-use and multiple objective problems in New Zealand.

6.4.5 Disadvantages of the A Priori Specification Methods

(1) The decision-maker is required to state his/her preferences in an informal void, Cohon and Marks (1975). When these decisions are made the decision-maker does not have the complete range of feasible solutions available upon which to base the decision.

(2) Assume that the decision-makers preference for an objective are consistent, regardless of the level of attainment of that, or any other objective. The surrogate worth trade-off method overcomes this but requires a large amount of computational effort.

6.5 TECHNIQUES WHICH RELY ON PROGRESSIVE ARTICULATION OF PREFERENCES

These techniques are characterised by an approach which relies on the decision-maker reacting to non-inferior solutions and the analyst modifying the problem until a satisfactory solution or termination condition is reached. The approaches recognises that weights, orderings, and constraints cannot always be elicited at the start of a study even though they play an implicit role in the decision-making. The following are examples of this approach:

6.5.1 Step Method (STEM)

Cohon and Marks (1975) considered this method, proposed by Benayoun et al. (1971), as representative of this class of techniques. The method has also been discussed by Haith and Loucks (1976) and Loucks (1978). The initial step in this approach is the construction of a 'payoff table' (Table 6.3). Algorithm used to construct the payoff matrix used in the STEM method is described in Appendix G.5.

TABLE 6.3

Payoff Table For The Step Method

(Source: Cohon and Marks (1975))

Solution That Optimises kth Objective	Value of kth Objective					
	Z_1	Z_2	. . .	Z_k	. . .	Z_p
x_1	M_1			Z_k^1		
x^2		M_2		$Z_k 2$		
.			.	.		
.			.	.		
.			.	.		
x^k	Z_1^k	Z_2^k	. . .	M_k	. . .	Z_p^k
.				.	.	
.				.	.	
.				.	.	.
x^p				Z_k^p		M_p

Row k of this table gives the maximum value for the kth objective, M_k. The associated values of the other objectives in the feasible decision space are shown by $Z_j k$.

The ideal solution (represented by the diagonal cells M_k, $k = 1, 2, \ldots, p$) is assumed to be infeasible and not to exist as if it did there would be no conflict between the objectives. Step 1 consists of finding a non inferior solution which is the 'nearest', in the minimax sense, to the ideal solution. The aim of this step is to minimise the weighted deviation of an objective from the ideal solution. Step 2 consists of asking the decision maker to indicate which objectives in the solution can be relaxed in order to improve on the unsatisfactory levels of other objectives. The minimax solution is repeated, and the decision makers are again approached. This process continues until the decision makers are satisfied with the results.

If the decision maker decides at any point that none of the objectives is satisfactory, then the iterations stop with the conclusion that no compromise solution exists. The maximum possible number of iterations that can be performed is 'p', the number of objectives. Cohon and Marks (1975) found this rule most curious. They stated that it showed that the decision maker is unwilling to forego any of the satisfactory objectives to improve the unsatisfactory ones. If this situation occurs no decision is possible which is quite unrealistic. The Step method and the other interactive methods do not explicitly capture the trade-offs between objectives because the weights do not reflect a value judgement of the decision maker. Instead the weights and the ideal solution are artificial quantities generated by the analyst and tend to "... obscure rather than capture the normative nature of the multiobjective problem", Cohon and Marks (1975).

6.5.2 Trade-off Development Methods

Two methods have been described as follows:

(1) TRADE - Goicoechea, et al. (1976) described a modified version of the Stem method called Trade which incorporates a surrogate objective function

to overcome the problem of weight specification. In addition a vector of goal achievement percentages is generated to aid the decision maker in the trade- off development process. The use of a surrogate objective function in the Trade method enables the decision maker to generate an initial solution vector without having to generate weighting coefficients for the individual objectives, as would be the case for the Stem method; once this initial solution is generated, it is expressed in terms of goal percentages achieved to assist in the decision making process.

(2) PROTRADE - Goicoechea, et al. (1979) developed a method called Protrade (PRObalilistic TRADEoff development method) which accounts for both the multiple objective and the uncertainty aspects of decision making. The approach was developed in an effort to enable the incorporation of risk in the development of objective trade-offs but with enough flexibility to handle the preferences of the decision maker in a progressive manner.

6.6 SIMULATION

Simulation of the water resources system allows stochastic studies to be carried out on the system under analysis as well as allowing the effects of numerous options to be analysed quickly and efficiently. Gilliland, et al. (1985) have used a simulation model approach successfully on a water resources problem and Haimes, et al. (1979), Louie, et al. (1982) and Helweg and Labadie (1976) have successfully linked simulation models and mathematical optimising models to solve water resources problems. The example presented in the following chapter achieves a similar linkage.

A simulation model developed by Gilliland, et.al. (1985) of the Platte River Basin in Nebraska included hydrological,

ecological and economic components (see Table 6.4). The modeling process used to develop this model is known as Adaptive Environmental Assessment (AEA) which was initially developed for conflict resolution by Holling (1978). The aims of the process and computer model were to analyse the consequences of various water management and water development alternatives, and develop a common understanding among the decision makers and interest groups of the behaviour of the modeling system. The AEA process relies on workshops which involve the decision makers and the groups with an interest at stake in the final decision. Discussion and disagreement centres on the construction of a computer simulation model of the system under study.

The development of the final model took place in three phases. The first was a one week workshop of the decision makers and interest groups which had the aim of developing the initial model. The participants collectively made the decisions on the structure of the model e.g. time step, state variables to be simulated, the structure of the algorithms, etc. A core team of scientists and engineers provided technical guidance and programming skills. It was found that by being forced to focus on the model building the participants were forced to identify their preconceptions and disaggregate vested interests. Once these preconceptions and judgments were reduced to the technical detail required by a computer model they often became transparent. At the end of the workshop a general model had been developed.

The next stage involved the core team refining the model data and algorithms. Any changes made were made in consultation with the workshop participants as well as other technical people. The third phase was a second shorter workshop which was held to examine the simulation results for several alternative water management strategies.

TABLE 6.4

A Sample Of The Variables In The Platte River Model

(Source: Gilliland, et. al. 1985).

Submodel	Variables
Hydrology - Surface Water	- Instream flow at 10 gauging stations (reach boundaries). - Water available for meeting water rights.
Hydrology - Ground Water	- Groundwater levels. - Nitrate concentrations. - Well yields.
Agriculture	- Areas of 5 crop types. - Area of irrigated crop type. - Crop yields. - Water use efficiency.
Municipal and Industrial	- Municipal well field water quality. - Population. - Electric power production.
Wildlife and Recreation	- Areas of 4 riparian habitat types. - Relative amount of crane habitat. - Recreation user days for hunting, fishing, boating, etc.
Economics	- Net returns to agriculture, recreation, and electric power production. - Employment and income by economic sector.

The advantages of such a system are that the decision maker and interest groups participate in the development of the model and the model can be used to provide explicit trade-offs between the objectives of the interest groups. Being interactive the model can be used to analyse what if? questions. The major advantage of this technique is that it can produce solutions that are much superior to the other techniques discussed above.

Limitations are that the cost and effort to achieve such an end result is large and would only be suitable where a large project is under consideration. A further limitation is the complexity of the systems under study. In a large number of areas there is a lack of information on the technical coefficients.

6.7 CONCLUSIONS

Each of the techniques described in this chapter will produce acceptable solutions if the decision maker can cope with its requirements and if the formulation fits the problem at hand. The question though is which of the techniques is most likely to be correctly and easily assimilated and manipulated by the decision-maker. In most cases the question of algorithmic efficiency is secondary as all of the techniques, with the exception of simulation (unless optimising routines are used), use the same or similar mathematical programming algorithms as subroutines.

Prior weighting of objectives is effective where the number of objectives is small, less than 10, and where the objectives themselves are well specified. The generating techniques have the additional advantage that they reduce the problem to a single objective allowing the problem to be solved using standard mathematical programming techniques.

The use of techniques which rely on the progressive articulation of preferences is particularly attractive because they do not assume that the decision maker is capable of specifying an overall objective function.

Instead, the decision maker is required to make decisions about the nature of the preference function in the locality of a specific solution. These techniques are not without problems, as shown by the Step method which may not terminate if the decision makers judgement is not completely consistent.

Goal programming on the other hand requires that the decision maker treat the problem as one of separate objective functions with the requirement of assigning the desired levels of these objective functions. The programme then attempts to find a solution that does not deviate "too much" from the specified goals. This approach corresponds well to the established methods commonly used by managers, Price (1976). Additional advantages are that it is suited to situations where the decision maker is unable or unwilling to specify a single objective function, a large number of objective functions can be handled and it is computationally efficient.

In summary, goal programming has the advantage of corresponding well to the usual conceptions of the manager of the decision making process: those of goal setting and goal ranking. It has the additional advantage that it can handle large problems and can be adapted easily to handle a wide range of problems. Its major drawback is that it is not an interactive technique but it can be given interactive capabilities. This is achieved by interaction between the decision maker and the computer through the assignment and changing of weights until a satisfactory result is achieved.

It is this writers feeling that the generating techniques, although they have the advantage of providing explicit information on trade-offs between objectives, are not feasible in a practical sense because of the computational inefficiency associated with them. Because of the nature of the water resources systems that we are dealing with there will normally be more than four objectives that be dealt with in any situation. In addition the fact that the objectives being traded off are

noncommensuable means that goal programming and some of the other techniques show more promise from a practical sense. The ideal situation is one in which goal programming could be used as a generating technique. Such an approach has been described by Willis and Perlack (1980) and the mathematical details of their approach are shown in Appendix G.

CHAPTER VII

AN ILLUSTRATION OF A MATHEMATICAL PROGRAMMING APPROACH TO A RESOURCE ALLOCATION PROBLEM

7.1 BACKGROUND TO THE RAKAIA RIVER DEBATE

7.1.1 Location

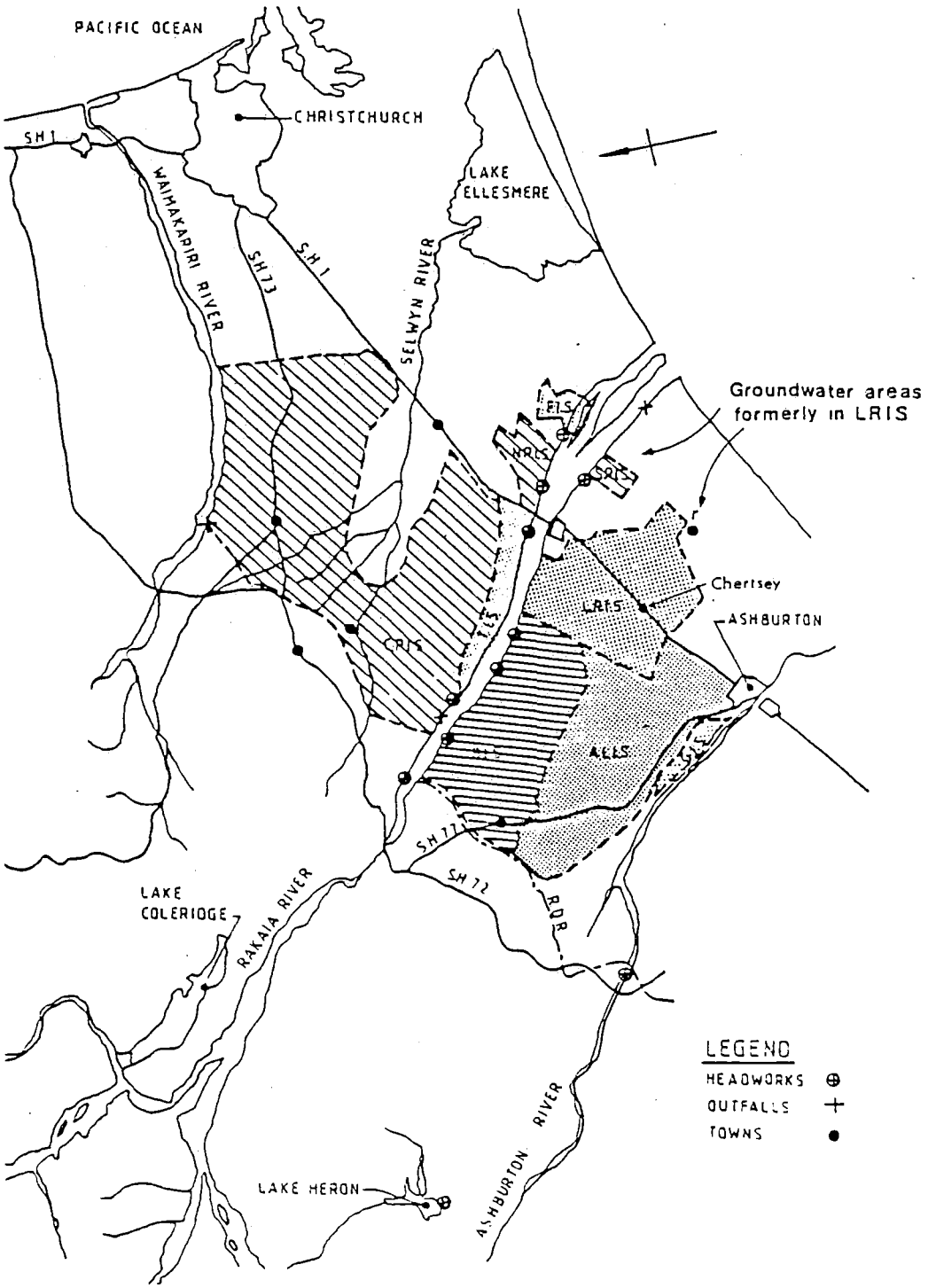
The Rakaia River rises in the Main Divide and flows 140 km to the sea on the east coast of the South Island of New Zealand. The upper catchment consists of 2640 square kilometres. The river is fed by the Wilberforce, Mathais, Avoca and Harper Rivers and the catchment contains a number of lakes, the largest of which is Lake Coleridge (see Figure 7.1). The large storage capacity of Lake Coleridge is utilised to generate electricity. The river is a wide braided channel over its length except where it is confined in a gorge, which extends 6 km above the Gorge bridge. The 39 km of river below the Gorge bridge to the State Highway 1. bridge has a wide braided channel of 1.5 - 2.0 km width and is bounded by high terraces. In the 22 km from the State Highway 1. bridge to the sea the channel increases in width to approximately 5 km and is contained by low natural banks.

Rainfall in the catchment ranges from 7600 mm in the Main Divide area, to 1000-1200 mm at the Gorge and 600 mm at the mouth. Wind is a dominant feature in the catchment, especially the North west wind which contributes to high evapotranspiration rates on the Canterbury Plains in the spring and summer. The same wind brings rain in the upper catchment and contributes to the spring snow melt. Low annual rainfall and high summer evapotranspiration make recurring summer drought the major limiting factor for agriculture in the lower catchment area.

There are two large population centres, Christchurch (60-90 km away) and Ashburton (40-60 km away), in close proximity to the catchment. The Christchurch population of approximately 300,000 provides 60% of the recreation users

FIGURE 7.1

The Rakaia River Catchment And Irrigation Schemes Adjacent To The Rakaia River.



LRIS Lower Rakaia Irrigation Scheme

BIS Barrhill Irrigation Scheme

CPIS Central Plains Irrigation Scheme

TIS TePirita Irrigation Scheme

ALIS Ashburton Lyndhurst Irrigation Scheme

FIS Fereday Island Irrigation Scheme

NRIS North Rakaia Irrigation Scheme

SRIS South Rakaia Irrigation Scheme

(Source Lewthwaite 1983)

of the river and Ashburton with a population of approximately 15,000, makes up 24% of the river's recreational users, Bowden (1983d). The remaining river users come from the smaller communities in the surrounding districts or from further afield. The major recreational uses of the river are fishing, particularly salmon fishing (80% of use) and jet boating (10% of use).

7.1.2 Conflict over the Use of the Water Resources of the Rakaia River

In June 1983 an application was lodged for a National Conservation Order (NCO) for the Rakaia River. National Conservation Orders were introduced in an amendment to the Water and Soil Conservation Act in 1981 and were intended to protect rivers and lakes with outstanding wild, scenic, recreational, or other natural values. The granting of a NCO could protect a water resource from development and in the case of the Rakaia preclude irrigation development. In December of that year a seven day hearing was held before a committee of the National Water and Soil Conservation Authority (NWASCA). The decision of this committee, announced in March 1984, recommended a draft NCO for the Rakaia River, NWASCA (1984b).

The draft NCO included allocation criteria which committed the first and largest allocation of water to instream uses (wildlife and recreation). This was done to ensure that instream values were not compromised as a result of irrigation abstraction. The draft NCO also set a maximum abstraction rate at 70 cumecs to stop any large changes in sediment load occurring. Abstraction rates were less than required to satisfy irrigation requirements which meant that there would be a need for some form of water restrictions on irrigators, scheme redesign or some form of resource supplementation. Possibilities for resource supplementation were identified as a dam near the Rakaia Gorge or out of river storage at Lake Coleridge.

The acclimatisation societies and other interested parties felt that the terms of the draft NCO were inadequate to protect the outstanding features of the river. As a result they lodged an appeal with the Planning Tribunal. The subsequent 28 day inquiry was held in Christchurch in late 1984 before the Tribunal made up of Judge P.R. Skelton and three others. The Tribunal reported back in May 1985 with the following recommendations:

(1) Full protection status was given to the upper parts of the Rakaia River above the confluence of the Wilberforce River. This status also applied to Lake Heron.

(2) Partial protection status to all other water resources in the catchment including Lake Coleridge.

(3) The two levels of protection recognised the outstanding natural characteristics of the braided river and the outstanding wildlife habitat, fishery and recreational features of the river.

(4) Water quality and flows of the fully protected areas are to remain in their natural state. In the partially protected areas the water quality and flow levels are only to be modified if current water rights exist or the activities affecting these characteristics are not prohibited.

(5) The following minimum mean daily flow rates were set for the Gorge:

Month	Flow (m^3/s)
January	123.9
February	107.9
March	105.3
April	96.7
May	94.6
June	95.7
July	91.4
August	91.9
September	90.3
October	106.4
November	128.9
December	138.7

(6) If the above flow rates are exceeded, the excess is to be allocated to irrigation on a 1:1 basis to a maximum of 70 cumecs.

(7) The construction of dams was prohibited in the protected areas. The only exceptions to this ruling are that dams can be constructed in the partially protected waters provided the flow and quality restrictions could be met.

(8) The restrictions on water rights included the prohibiting of grazing on the river-bed, breaching of a specified range of water quality criteria, and requirements for the provision of fish screens where these were deemed necessary.

(9) Water rights could be issued for the following reasons:

(a) research into, and enhancement of, fisheries and wildlife habitats,

(b) the maintenance or protection of roads, bridges, pylons, and other necessary public utilities,

(c) soil conservation and related matters undertaken pursuant to the Soil Conservation and Rivers Control Act 1941, and

(d) to enable the Ellesmere County Council to continue to provide for its rural water supply.

In July 1985 Federated Farmers appealed to the High Court against the whole of the determination of the Planning Tribunal. This is yet to be heard.

7.1.3 Use of the Rakaia River Water Resource for Irrigation

Irrigation has been a recurrent theme in the history of land development in Canterbury. In the 1970's and early 1980's the promotion of irrigation has received widespread support in Canterbury. This has occurred because the dryland potential of the soils on the Plains has reached its

potential under existing farming practices and the ability of farms to withstand the economic effects of drought has diminished. Irrigation is not seen as the panacea for drought but as a means of facilitating the intensification and diversification of land uses in Canterbury. The water resources of the rivers in the region, in particular the Rakaia River and to a lesser extent the Waimakariri River, offer considerable potential for irrigation development on the Canterbury Plains.

A total of 100,000 hectares is already irrigated in Canterbury. Approximately half (64,550 ha.) of this is served by river supplied community irrigation schemes (see Table 7.1 for details) and the remainder is supplied from private groundwater development. The groundwater development is concentrated closer to the coast where groundwater is more readily available at economic pumping depths. An additional 500,000 hectares has been identified as potentially irrigatable in Canterbury, Douglas, et al. (1984) and investigations by Ministry of Works and Development have identified seven potential community irrigation schemes which would draw water solely or partially from the Rakaia River Catchment (Table 7.2). Planning for some of these schemes is well advanced e.g. water rights have been obtained for the Te Pirita Scheme, while others are only long term possibilities and may be considerably modified before implementation. Table 7.3 summarises the benefits and costs of irrigation development. A number of these effects are not quantifiable at present but those that can be quantified are included in the goal programming model described in the later sections of this chapter.

TABLE 7.1

Existing Community Irrigation Schemes In Central Canterbury
(Source: Williman, pers com.)

Scheme	Type of Irrigation	Water Supply Source	Dominant Land Use	Irrigatable Area (ha)
Existing:				
North Rakaia	Border strip	Rakaia River	Pastoral	2,360
Fereday	Border strip	Rakaia River	Pastoral	1,000
South Rakaia	Border strip	Rakaia River	Pastoral, crops	1,052
Ashburton-Lyndhurst	Border strip	Rangitata Diversion Race	Pastoral, crops	26,000
Greenstreet	Border strip, sprinkler	Ashburton River	Mixed farming, dairying	2,700
Valetta Farm Settlement	Border strip	Rangitata Diversion Race	Pastoral, crops	7,000
Mayfield-Hinds	Border strip, sprinkler	Rangitata Diversion Race	Pastoral, crops	24,440
			Total Area	64,552

TABLE 7.2

Conceptualised Community Irrigation Schemes In Central Canterbury

(Source: Williman, pers com.)

Scheme	Type of Irrigation	Water Supply Source	Dominant Land Use	Irrigatable Area (ha)
Proposed:				
Northern Central Plains Pumped Extension	Spray	Rakaia and Waimakariri Rivers	Crop, pastoral, horticulture	5,500
Northern Central Plains	Spray	Rakaia and Waimakariri Rivers	Crop, pastoral horticulture	23,000
Southern Central Plains	Border strip	Rakaia River	Pastoral, crop	20,000
Southern Central Plains Pumped Extension	Spray	Rakaia River	Pastoral, crop	5,500
Te Pirita	Border strip	Rakaia River	Pastoral, crop	2,500
Highbank	Spray	Rangitata Diversion Race	Crop, horticulture	8,000
Lower Barrhill	Spray	Rakaia River	Crop, horticulture	10,000
Lower Rakaia	Border strip, spray	Rakaia River	Crop, pastoral	20,000
			Total Area	94,500

TABLE 7.3

The Major Effects Of Irrigation Development

Primary benefits:	Primary costs:
1. increased agricultural production and flexibility of management	1. capital cost of the development
2. complementarity between dryland and irrigated areas on the same property	2. increased costs e.g. cost of increased fertiliser and electricity
3. reduces seasonal variations in production.	
4. cost savings e.g. pasture replacement costs	
Secondary benefits:	**Secondary costs:**
1. improvements in social structure and community spirit	1. provision of additional roading, electricity supplies and social services
2. multiplier effects within the economy	2. opportunity costs associated with the water and capital use removed from use by recreation, industrial or service sector development
3. groundwater recharge in the lower plains leading to decreased pumping costs for some irrigators	3. groundwater recharge may lead to flooding problems outside the scheme area
	4. increases in concentration of nitrates in unconfined aquifers
	5. increased stock pressure may result in a decrease in the bacteriological quality of shallow groundwater
Social benefits:	**Social costs:**
1. increased farmer confidence as seasonal variation removed. This encourages farmers to invest, plan ahead	1. increased financial strain on farmers because of reduced equity levels.
2. reverse to some extent rural depopulation	2. displacement of farmers who don't have the management ability for irrigation or do not want to adopt the new technology.
3. create additional jobs especially if there is a move to more intensive systems e.g. horticulture and dairying.	

Table 7.3 (continued)

Social benefits:	Social costs:
4. changes in ownership could mean younger people are attracted to the area. This will lead to an increased demand for some social services and may also mean some services are able to be maintained which would otherwise have been lost.	
Landscape benefits:	**Landscape costs:**
1. increased plantings of shelter belts 2. headraces and borders would be visually distinctive but acceptable features and increased subdivision when combined with shelterbelt planting will mean a more enclosed landscape.	1. reduced seasonal tonal and textural changes in pasture but this will be countered by the increased area of crop.

7.1.4 Recreation in the Rakaia Catchment

An estimated 75,000 visits are made annually to the Rakaia Catchment with the majority being for fishing over the summer months, Bowden (1983d). The majority of visitors to the Rakaia Catchment come from Canterbury (85%) followed by Otago and Southland (6.7%), Bowden (1983d). Angling for salmon and trout accounts for over 80% of the recreational activity undertaken in the Catchment with salmon angling being the predominant attraction. Jet boating, the next most popular recreational activity, accounts for approximately 10% of the total recreational use. Although picnicking and tramping were not identified as major recreational pursuits by surveys of river users, these activities are thought to be important as secondary activities and add to the quality of experience gained from the major pursuit. Details of the levels of surveyed recreational use of the Catchment can be found in Appendix H and Bowden, (1983d).

The section of river between the Gorge and State Highway 1 road bridge attracts the largest number of anglers. The National Angling Survey highlights the importance of the Rakaia as an nationally important angling river. Among South Island rivers, the Rakaia is exceeded in usage only by the Waimakariri River and that river derives much of its value from its proximity to a large population centre, while the Rakaia is valued for the quality of its salmon. In addition to salmon and trout, the river supports recreational fisheries for whitebait, kahawai, flounders and mullet, and commercial fisheries for eel, salmon, kahawai and (potentially) smelt.

7.1.5 The Wildlife Resources of the Rakaia Catchment

The Rakaia system has been described as an outstanding fully integrated ecosystem from the point of view of wildlife, O'Donnell (1983). He identified Lake Heron as an area of vital importance to migratory birds which also provided an example of an unmodified habitat type not represented elsewhere in the country. A total of 166 bird species (54% of the 305 bird species for the New Zealand region) have been recorded in the Rakaia ecosystem (which includes Lake Ellesmere). The migratory charadriiform wader, gull and tern species use the braided rivers when river flows are high and are most viable in spring because of snow melt in the headwaters. This corresponds with an increase in the availability of the invertebrate foods on which these birds feed. At this time there is an increase in the invertebrate numbers in the river drift. Numbers decline again in the autumn when mean flows decline and migratory birds disappear during periods of lowest flow during the winter.

The environmental impact report on the Lower Rakaia Irrigation Scheme highlighted that the aquatic vertebrate fauna (mostly insect larvae) in the Lower Rakaia is important as food for the significant bird and fish species, Douglas et al. (1984). The invertebrate populations are

periodically decimated by floods and freshes and rapid reductions in flow (whether natural or man-induced) cause a temporary reduction in invertebrate densities.

Six species of birds which occur on the South Island braided rivers; the Black Stilt, Black-fronted Tern, Black-billed Gull, Wrybill, Banded Dotterel, and South Island Pied Oystercatcher, are endemic breeders confined to New Zealand, Hughey (1983a). Except for the Black Stilt, all species have large populations in the Rakaia Catchment. Appendix I sets out some criteria for assessing the relative importance of the various birds nesting in the Rakaia riverbed. New Zealand is the only place in the world where bird species have specifically adapted to living on braided rivers and one of these, the Wrybill Plover, is the main reason for the Rakaia being classified as an outstanding wildlife habitat. The Wrybill Plover's beak is curved sideways so it can probe around stones. It is thought to be the only species in the world with an asymmetrical beak. This species is only found in New Zealand and numbers are estimated to be between 5,000 and 7,000 birds.

It is the plight of the Wrybill Plover that has gained the most attention (from the wildlife point of view) in the conflict over the use of the Rakaia's water resources. Surveys have shown that 53.3% of the total surveyed New Zealand Wrybill population use the upper reaches, and 18.9% the lower reaches, of the Rakaia Catchment during the peak breeding season, O'Donnell (1983). The Wrybill migrate to and from the braided rivers of the east coast of the South Island annually and are present in the braided rivers from August to March, with peak numbers occurring from September to January.

7.1.6 Impacts Of Water Abstraction For Irrigation On Recreational Opportunities And Wildlife

The following are the impacts of water abstraction on recreational opportunities and wildlife highlighted in the Rakaia River National Conservation Order hearings:

(1) Inadequate depth for the passage of large salmon. At very low flows the passage of some large adult salmon can be restricted due to insufficient water depth. The depth of water in the main channel required to allow passage of large salmon has been estimated at 0.25 metres, Glova (1983). This minimum depth requirement for salmon is based on their body depth and it is assumed that flows providing such water depths would be adequate for fish passage. However, such a measure does not take into account fish behaviour (it assumes fish follow the main channel), nor the availability and flow characteristics of holding pools at critically low flows.

(2) Changes in the "fishability" of the river. The concept of fishability of a river is poorly understood. There are no quantitative data available on the effects of low flows on angling effort and catch, for salmon and trout, in the Rakaia River. The minimum flow needed to provide high quality salmon fishing is higher than that needed for fish passage, maintenance of the river mouth and rearing of juvenile salmon, Glova (1983). Preliminary results of a study carried out by the North Canterbury Catchment Board suggest that flows between 81 and 160 cumecs are the most fishable and the River was considered fishable 95% of the time at these flows, Bowden (1983d).

Glova, (1985) found that 83.4% of salmon caught by a sample of experienced anglers in the January to March period were caught at the tail-end of freshes (>300 cumecs) when mean daily Gorge flows ranged from 106 to 204 cumecs. Optimal fishing conditions were found to occur at flows of between 135 and 180 cumecs after freshes in the river of greater than 300 cumecs. In such conditions the river system has been flushed and water conditions

i.e. colour, temperature and amount of algae growth, are ideal for fishing.

(3) Damage of fish rearing and feeding areas.

(a) The reduction in mean flows (as distinct from fluctuations in flow) caused by abstractions will significantly reduce invertebrate populations at high levels of abstraction and consequently lead to reduced fish feed supplies.

(b) The most important fish species for recreational angling and increasingly for commercial harvesting is quinnat salmon. Abstraction is most likely to effect the rearing and feeding areas of this species.

(c) Silt flushing and abstraction of water would have some effect on the quantity and quality of rearing habitat for juvenile salmon. At present available habitat is not fully utilised but increasing releases from commercial salmon farms and abstractions of water from the river may lead to a situation where river rearing habitat is the limiting factor for further expansion of the fishery.

(4) Possible closure of the mouth. Evidence was presented at the National Water Conservation Order Application Hearing which emphasised that the mouth of the Rakaia should be kept open at all times, Glova (1983). Short term closures of a few days over a 5- 10-year period were thought to have little biological impact but could effect the River's reputation as a nationally important salmon fishery. Glova (1983) concluded that a flow of 45 to 50 cumecs at the lagoon outlet would be sufficient to maintain the river mouth open. Assuming that the losses to groundwater and underflow (approximately 10-26 cumecs) re-emerge in the lagoon area, these mouth flows translate to a

Gorge flow of approximately 55-65 cumecs, Bowden (1983b).

(5) Loss of fish into the irrigation reticulation system.

(6) Reduction in resident native fish stocks.

(7) Reduction in the water available for salmon angling.

(8) Damage to fishing areas and loss of scenic quality.

(9) Irrigation has been identified as a management practice that would be most likely to have a significant impact on wildlife in a braided river system, (Hughey (1983a)) To date most irrigation has occurred on rivers which have had low to moderate wildlife values and that no comparative studies have been carried out to determine the effects the abstraction of water for irrigation has had on wildlife in these systems.

Only the first half of the irrigation season is relevant to the riverbed nesting birds as most leave the river by early January, (Douglas, et al. (1984)) Irrigation would have only a limited effect on the large floods needed to keep the riverbed vegetation free. Any reduction in flooding would favour the Banded Dotterels which nest very close to the waters edge. Abstraction during low flows would have some effect on the invertebrate populations and would make the nests of ground nesting species vulnerable to predation. The Wrybill Plover and Black-fronted Tern can be regarded as indicator species meaning that if the needs of these two species are met then the other species will thrive, Hughey (1983b). Further to this Hughey (1984) has stated that variability of flow is less likely to affect wrybill than the fish species in the river. It can therefore be concluded that the minimum flows necessary to meet fish needs

will also meet the needs of the wrybill on the Rakaia.

(10) Reduce braiding and flood flows in the river. The known feeding preference of Wrybills, along the edges of minor braids, and the highly territorial nature of its breeding behaviour indicates that substantial reductions in the braiding index associated with the loss preferred minor braids may well affect the population status of this species. The invasion of riverbeds by lupin, broom and gorse restricts the availability of potential breeding sites. There is therefore a need to maintain flood flows to enable the establishment of nesting sites which are clear of significant vegetation growth. It should also be noted that these same floods, which occur in the spring and summer in the Rakaia River, can significantly effect breeding success by destroying nesting sites.

7.2 THE GOAL PROGRAMMING MODEL

The multiple use of resources has developed from planning techniques that seek a compromise between competing uses. Such planning techniques rely on the fact that the sharing will take into account all the critical factors for all the users and allocate the resource according to critical needs. The Rakaia is a particularly complicated example of this problem because of the large and diverse nature of users for which critical factors must be determined. The user groupings include; river birds, swamp birds, invertebrates, native and introduced fish, anglers, farmers, jet boaters, tourists and scientists all of whom want to carry out a range of activities within the confines of the Rakaia Catchment area. Each of these user groups has a peculiar set of requirements for the resources available within the catchment and these have no common unit of measure other than the level of importance to the user. The

less tolerant have many critical factors e.g. the feeding and breeding of salmon and the Wrybill Plover, while other users have a wider range of tolerance, and are therefore more tolerant to changes e.g. the human users. The goal programming approach, to the Rakaia River debate, adopted in the following discussion, takes into account the critical factors for a number of the user groups and accounts for their degree of tolerance where this is known.

The goal programming model developed in this chapter will be used to illustrate that the application of mathematical programming methods is possible and feasible in the resolution of resource allocation problems in New Zealand. The goal program is used to analyse the trade-offs between instream and agricultural demands for water from the Rakaia River System. The model is by no means comprehensive and covers the area from the Gorge Bridge to the sea. The data used in the model have been derived from information sources available prior to the Planning Tribunal's' decision in May 1985. Two water use options are analysed: the use of water for irrigating farmland adjacent to the Rakaia River and the maintenance of instream values e.g. fish, wildlife and recreational uses. The possibilities associated with hydro- electric power have not been addressed in this model because planning in this area is not as well advanced as that for irrigation. However, the model is constructed in such a way that hydro-electricty generation options could be explored at a later date.

The goal programming algorithm used in this study, GOAL, was developed by the Range Science Department, Colorado State University, Bartlett, et al. (1978). The program is a lexicographic weighted goal programming formulation (see section 6.1.3 for details). Details of the steps involved in developing the following model are described in Appendix J. A summary of the model structure is shown in Figure 7.2. This can be used by the reader to focus on sections of the model that may be of particular interest.

FIGURE 7.2: Overview of the Goal Programming Model

Activities / Constraints	Initial Supply	Relation-ship	Water Supply	Incremental Water Depths	Water Allocation Inst.	Water Allocation Agric.	Agric. to Inst. Water Transfers	Total Instream Flow	Agricultural Activities Dry.	Agricultural Activities Irrig.	Water Depth	Instream Income	Employ-ment	Total On-farm	Capital Off-farm	Area Irrig	Totals Dry	Produce Sales	Total Income Farmer	Total Income Nat	Total Income Region
Monthly Flow	0	=	Supply Coef		+1	+1															
River/Highbank Constraints	1	=	+1																		
Maximum Flows	Supply	≥		+1																	
Water Depth Reconciliation	0	≥		Supply Coef							+1										
Allocation Rule	0	=			+1	-1															
Agricultural Allocation	0	≥				-1	+1			Demand Coef											
Instream Allocation	0	≥		+1			-1														
Instream Reconciliation	0	≥		-1				+1													
Instream Income	0	≥						Supply Coef				+1									
Employment	0	≥						Supply Coef		Supply Coef			+1								
National Income	0	≥							Demand Coef			-1						Supply Coef		+1	
Farmer Income	0	≥							Demand Coef									Supply Coef	+1		
Regional Income	0	≥																		-2.7	+1
Land Area Ties	Supply	=							+1	+1.25											
Irrigation Drylands	0	≥							-1	-1.25						+1	+1				
Capital Ties	0	≥								Supply Coef				+1	+1						
Crop/Pasture Production	0	≥							Supply Coef									+1			
GOALS																					
Flow	Minimum plus overachieve							+1													
Water Depth	Minimum plus overachieve										+1										
Income	Maximum plus underachieve																		+1	+1	+1
Capital	Minimum plus overachieve													+1	+1						

7.3 GOALS

7.3.1 Irrigation Goals

The major effects of irrigation are shown in Table 7.3. Although it would be desirable to develop a model that would include all of these factors, in practice it is impossible because of lack of data. The impacts that have been included in the goal structure for the current model are summarised in Table 7.4. and are discussed below. They are:

(1) Maximisation of national, regional and farmer income. Maximisation of these goals is achieved by setting the goal levels, for each goal, at an artificially high level of $200 million and allowing under-achievement of the goal. The initial high level of goal attainment is necessary to maximise the income level. Under-achievement of the goal allows a lesser value to be achieved.

(2) Minimisation of on- and off-farm capital expenditure. The aim of the Government and the farmers as the irrigation developers and financiers is to keep the capital costs of irrigation at as low a level as possible. To reflect this the goal levels are set at zero and over-achievement of the goal is allowed.

7.3.2 Instream User Goals

(1) River flow. The river flow goal has initially been set at 65 cumecs, at the Gorge, with only over-attainment being allowed. This goal can be used to reflect the minimum flow required to maintain a viable river mouth and can be varied to reflect aspects such as "fishability" of the river.

(2) Water depth. This goal is related to the river flow goal discussed above. The initial level set in the model is 0.25 metres. This depth is used to reflect the depth of water in the main channel required to allow passage of large salmon up the river for spawning. The instream users that would require

such a goal level include not only fisheries interests e.g. fishermen and commercial salmon farming operations, but also jet boaters.

7.3.3 Social Goals

No social impact analysis has been carried out on the conceptualised irrigation development planned for Central Canterbury. The only social indicator that can be quantified at present is the creation of additional employment as a result of planned development. Job creation is not only related to irrigation development. Salmon farming and recreation ventures also provide additional jobs as a result of resource development or exploitation. This model includes the jobs created by salmon farming only. No information was available of the employment multipliers associated with recreation development on the Rakaia. These however, are likely to be small as the potential for recreation development is not employment intensive. Two employment goals are set in the model. The direct job goal includes all the primary employment created by development while the total job goal includes primary and secondary employment created by development. The job goal levels set in the model have been set artificially high at 1,000 jobs for both goals to reflect maximisation of employment. Under-achievement of the goals is allowed.

7.3.4 Goal Priority Levels

The goal priority levels used in runs of the model are shown in Table 7.5. The goal priorities can be altered to reflect the resource user interest groups. Farmers for instance, would want to maximise farmer income while minimising both off- and on- farm capital costs. On the other hand instream users would want to maximise the river flow available and the water depth available for instream pursuits. By varying the priorities and the goal levels set it is possible to determine the trade-offs between these two interest groups.

TABLE 7.4

Summary Of Goals And Goal Attributes

Goal Description	Type Of Equality	Deviation Allowed	Goal Or RHS Value
National Income	Maximum	Under	$200 million
Regional Income	Maximum	Under	$200 million
Farmer Income	Maximum	Under	$200 million
Off-Farm Capital	Minimum	Over	$0
On-Farm Capital	Minimum	Over	$0
River Flow	Minimum	Over	65 cumecs
Water Depth	Minimum	Over	0.25 metres
Direct Jobs	Maximum	Under	1,000 jobs
Total Jobs	Maximum	Under	1,000 jobs

7.4 WATER SUPPLY ACTIVITIES

The two water supply activities used in the model are:

(1) Flow at the Gorge modified by Lake Coleridge,

(2) Flows from the Highbank Power Station.

Details of the flow values used are shown in Appendix L. Flow constraint ties equate the monthly water supply, over the irrigation season, from the Rakaia and the Highbank Power Station with the instream and agricultural demands for water. There are eight flow constraint rows representing monthly periods from September to April (the irrigation season). Units used in these constraint rows are cubic metres per second (cumecs) of water and are mean flows for each month. Three seasons of river flow data have been used in this analysis. They are:

(1) 1961-62 season which reflects a typically average river flow year,

(2) 1970-71 season which was the season of lowest flow in the river. The flows in this season has a return period of 1:30 years, and

(3) 1963-64 season which was the season with the lowest rainfall.

TABLE 7.5

Goal Priority Levels And Goal Attainment Levels Used In The Model Runs

Goal Description	Run					
	A	B	C	D	E	F
National Income	1 (20)	3 (20)	3 (20)	1 (1)	3 (20)	2 (1)
Off-Farm Capital	1 (1)	3 (1)	3 (1)	5 (1)	3 (1)	5 (1)
River Flow	2 (1)	1 (1)	5 (1)	2 (1)	2 (1)	1 (1)
Water Depth	3 (1)	2 (1)	6 (1)	-	1 (1)	-
Farmer Income	5 (20)	5 (20)	1 (20)	3 (1)	5 (20)	3 (1)
On-Farm Capital	5 (1)	5 (1)	1 (1)	5 (1)	5 (1)	5 (1)
Employment	4 (1)	4 (1)	2 (1)	4 (1)	4 (1)	4 (1)
Regional Income	6 (1)	6 (1)	4 (1)	-	6 (1)	-

Note: Values in brackets are the relative weightings given the goal within the same goal level.

In addition to the Gorge flow of the river there is further activity representing the flow of water through the Highbank Power Station over the irrigation season. The flows from Highbank are currently used to generate electricity. The Highbank flow originates from the Rangitata Diversion Race and only water excess to irrigation demands (in the area served by this channel) is spilled into the Rakaia system. Consequently Highbank flows are small over the irrigation season and in some months no flow occurs at all.

The River and Highbank supply activities are set equal to one with by the river and Highbank constraint equalities. These ensure that the total flow from these sources is utilised in each run of the model. The detached coefficient matrix showing the forms of these constraints is shown as Figure 7.3.

FIGURE 7.3

Water Supply Sub-matrix

CONSTRAINT	SUPPLY	SIGN	GORGE FLOW	HIGHBANK FLOW
Water Supply				
Sep.	0	=	-185	-19.24
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Apr.	0	=	-201	-10.24
River Equality	1	=	+1	
Highbank Equality	1	=	-185	+1

7.5 INSTREAM USE ACTIVITIES

A series of 48 activities represent the instream use of water for maintenance of instream values e.g. fish and wildlife habitat, and recreational activities, in the Rakaia River. These activities have been referred to as incremental flow activities and are split into six groupings to allow for the non-linearity exhibited by the flow to

water depth relationship. The curvilinear relationship exhibited by the water depth to flow data has been apportioned by linear segmentation (see Appendix M for details). The groupings used in the model are:

- less than 20 cumecs,
- 21 to 70 cumecs,
- 71 to 100 cumecs,
- 101 to 160 cumecs,
- 161 to 240 cumecs, and
- greater than 240 cumecs.

Each grouping has eight separate activities representing monthly periods over the irrigation season (September to April). A series of maximum flow constraints ensure that the non-linearity exhibited by the water depth to flow relationship is maintained. Details of these activities and constraints are summarised in Figure 7.4 and discussion of the water depth to flow relationships can be found in Appendix M.

Other instream values e.g. commercial salmon farming and recreational activities, are accounted for in the series of activities and constraints shown in Figure 7.5. All water allocated to the incremental instream activities is aggregated into a seasonal instream flow activity. This activity supplies commercial salmon and recreation income activities by way of a series of reconciliations. In addition this activity accounts for the employment created by the commercial salmon farming ventures using the Rakaia resource. The levels set are the currently assessed levels and a linear relationship is assumed for each of the uses. This assumption may prove to be invalid in the future but at present, no quantitative information is available which relates flow levels to these activities. Discussion of the coefficients used in this part of the model can be found in Appendix M and this has been summarised in Figure 7.5.

7.6 WATER ALLOCATION AND TRANSFER ACTIVITIES

Two groups of eight activities, instream and agricultural allocation, allocate the water supply amongst the competing uses. The allocation rule constraints set the ratio in which water is allocated to instream and irrigation uses. Figure 7.6 shows the base run coefficients set at 1:1 which means that for every cumec of water allocated to irrigation above the minimum flow requirement, one cumec will also be allocated to instream users. This ratio can be varied to explore the effects different allocation rules have on the flows allocated to the two competing interests; instream and irrigation. In the NCO hearings a number of allocation ratios were explored. The use of the flow allocated to agricultural will be discussed in Section 7.7.

The water demand by the incremental flow activities (except the minimum flow of 20 cumecs) is met by the water allocated for instream use from the monthly instream allocation activities. The total amount of water used by instream users is reconciled by the eight monthly instream reconciliation rows. The minimum flow of 20 cumecs is drawn directly from the flow constraints. The minimum flow level has been set at 20 cumecs for all runs of the model. Twenty cumecs represents a flow below which the river would cease to exist in the reach below the State Highway 1 bridge.

Eight instream to agricultural water transfer activities transfer any water allocated to agricultural use and not used by the irrigation activities back to instream users (see Figure 7.6).

7.7 AGRICULTURAL ACTIVITIES

Investigations into the feasibility of irrigation development in Central Canterbury have identified seven community irrigation schemes which could draw all or part of their water supply from the Rakaia River. The schemes analysed in the current model include all schemes which currently draw water from the Rakaia River system and all proposed schemes which will draw water directly from the Rakaia River (see Table 7.6 for details).

FIGURE 7.4
Detached Coefficient Matrix Showing Water Depth To Flow Relationships

CONSTRAINT	SUPPLY	SIGN	20 CUMECS Sep.-Apr.	70 CUMECS Sep.-Apr.	100 CUMECS Sep.-Apr.	160 CUMECS Sep.-Apr.	240 CUMECS Sep.-Apr.	240 + CUMECS Sep.-Apr.	WATER DEPTH Sep.-Apr.
Minimum 20 cumecs Supply									
Sep.	20	=	+1						
\			\						
Apr.	20	=	+1						
Maximum 70 cumecs									
Sep.	50	>=		+1					
\				\					
Apr.	50	>=		+1					
Maximum 100 cumecs									
Sep.	30	>=			+1				
\					\				
Apr.	30	>=			+1				
Maximum 160 cumecs									
Sep.	60	>=				+1			
\						\			
Apr.	60	>=				+1			
Maximum 240 cumecs									
Sep.	80	>=					+1		
\							\		
Apr.	80	>=					+1		
Water Depth Recon.									
Sep.	0	>=	-.0085	-.0021	-.0005	-.0004	-.0003	-.0002	+1
\			\	\	\	\	\	\	\
Apr.	0	>=	.0085	-.0021	-0.0005	-.0004	-.0003	-.0002	+1

FIGURE 7.5

Detached Coefficient Matrix Showing Commercial Salmon And Recreational Income And Jobs

CONSTRAINT	SUPPLY	SIGN	20 CUMECS Sep.-Apr.	70 CUMECS Sep.-Apr.	100 CUMECS Sep.-Apr.	160 CUMECS Sep.-Apr.	240 CUMECS Sep.-Apr.	240 + CUMECS Sep.-Apr.	SEASON TOTAL	DIRECT COMMERCIAL SALMON INCOME	TOTAL COMMERCIAL SALMON INCOME	TOTAL RECREATION INCOME	DIRECT COMMERCIAL SALMON JOBS	INDIRECT COMMERCIAL SALMON JOBS
Season Recon.	0	>=	-1	-1	-1	-1	-1	-1	+1					
Direct Salmon Income	0	>=							-3182.58	+1				
Indirect Salmon Income	0	>=							-4913.46		+1			
Recreational Income	0	>=							-2825.24			+1		
Direct Salmon Jobs	0	>=							-.01675				+1	
Indirect Salmon Jobs	0	>=							-.03908					+1
Season Maximum Constraint	1791	>=							+1					
National Income	0	>=								-1		-1		
Regional Income	0	>=									-1			
Direct Job Recon.	0	>=											-1	
Indirect Job Recon.	0	>=												-1

FIGURE 7.6
Detached Coefficient Matrix Showing Water Allocation And Transfers Between Instream And Agricultural Use

CONSTRAINT	SUPPLY	SIGN	20 CUMECS Sep.-Apr.	70 CUMECS Sep.-Apr.	100 CUMECS Sep.-Apr.	160 CUMECS Sep.-Apr.	240 CUMECS Sep.-Apr.	240 + CUMECS Sep.-Apr.	INSTREAM ALLOCATION Sep.-Apr.	AGRICULTURAL ALLOCATION Sep.-Apr.	WATER USE TRANSFERS Sep.-Apr.	TOTAL INSTREAM USE Sep.-Apr.	TOTAL AGRICULTURAL USE Sep.-Apr.
Allocation Rule													
Sep.	0	=							+1	-1			
⋮	⋮	⋮							\	\			
Apr.	0	=							+1	-1			
Agric. Allocation Recon.													
Sep.	0	=								-1	+1		+.00002
⋮	⋮	⋮								\	\		\
Apr.	0	=								-1	+1		+.00004
Instream Allocation Tie													
Sep.	0	>=		+1	+1	+1	+1	+1	-1		-1		
⋮	⋮	⋮		\	\	\	\	\	\		\		
Apr.	0	>=		+1	+1	+1	+1	+1	-1		-1		
Instream Flow Recon.													
Sep.	0	>=	-1	-1	-1	-1	-1	-1				+1	
⋮	⋮	⋮	\	\	\	\	\	\				\	
Apr.	0	>=	-1	-1	-1	-1	-1	-1				+1	

The goal programming model described here uses crop yield and water demand information generated by a simulation model developed by the New Zealand Agricultural Institute (NZAEI). Further details of the NZAEI model and its output are discussed in Appendix N. The NZAEI model uses four soil type classifications which are based on soil moisture holding capacity. The soil type classifications are further split into a total of 40 sub-classifications to account for land-use, climatic influences and whether the area is irrigated or dryland. The model developed in the current study uses 24 soil classification ties to ensure that model developed in the current study uses 24 soil classification ties to ensure that the area in each soil classification type are not exceeded. An example of the ties used in the Lower Rakaia Irrigation Scheme sub-matrix are shown in Figure 7.7.

Each scheme has separate activities representing the land- use and soil classification groupings relevant to that scheme. These are further broken up into dryland and irrigated activities to enable differences in production and water demand to be accounted for. The assumed areas of crop and pasture, and the number of dryland and irrigated activities representing each scheme are shown in Table 7.6 .

The total dryland and irrigated area for each scheme is reconciled by a dryland and irrigated reconciliation row (see Figure 7.7). Similar reconciliations are used to total the dryland and irrigated areas for all schemes. It has been assumed that 80% of the gross area is irrigated. This allows for the area lost to distribution works, head-races, roads and other non- irrigated areas.

Five crops; wheat, barley, peas, white clover seed and ryegrass seed are assumed to be grown on the crop areas. The crop rotation includes a pasture phase and a greenfeed crop. As outlined above, the production for each agricultural activity was determined using the NZAEI simulation model. Details of the actual values used for each activity are shown in Appendices P and Q, for dryland and irrigated

conditions respectively. Five crop ties are used to reconcile the amount of produce produced and sold from each activity (see Figure 7.8).

TABLE 7.6

Summary Of The Land-Use And Numbers Of Activities Representing Each Irrigation Scheme

Scheme	Crop Pasture Area (ha)	Total Area (ha)	Area (ha)	Landuse/Soil Classifications Dryland	Irrigated
Central Plains	15,377	52,123	67,500	15	15
Barrhill	7,187	5,313	12,500	7	10
Lower Rakaia	13,235	11,765	25,000	4	6
South Rakaia	-	1,001	1,001	-	1
North Rakaia	-	2,000	2,000	-	1
Te Pirita	-	3,126	3,126	1	1
Fereday	-	3,283	3,283	-	1
Total	38,830	81,930	114,410	27	35

Note: The crop area includes pasture in the rotation.

The feed produced from pasture and greenfeed oats by each of the cropping activities and each pasture activities is supplied to either a dryland or irrigated pasture activity for each of the following scheme groupings:

- Lower and South Rakaia Schemes
- Central Plains Scheme,
- Barrhill Scheme, and,
- Te Pirita, North Rakaia and Fereday Schemes.

Each of these activities produces lamb, mutton and wool which is then sold. The amount produced and sold is equated by way of animal product reconciliations (see Figure 7.8). Table 7.7 summarises the net returns for each produce selling activity and the replacement and maintenance costs

FIGURE 7.7

Detached Coefficient Matrix Showing Lower Rakaia Irrigation Scheme Area And Capital Ties

CONSTRAINT	SUPPLY	SIGN	LOWER RAKAIA IRRIGATION SCHEME						TOTAL FOR ALL SCHEMES			
			DRYLAND 1PW - 2CW	IRRIGATED 1PW - 2CW	ON-FARM CAPITAL	OFF-FARM CAPITAL	TOTAL DRYLAND	TOTAL IRRIGATED	AREA DRYLAND	AREA IRRIGATED	ON-FARM CAPITAL	OFF-FARM CAPITAL
Agricultural Water Demand												
Sep.	0	=		.00001 - .00004								
⋮	⋮			⋮								
Apr.	0	=		.00007 - .00005								
Soil Classification Ties												
11	2941	=	+1	+1.25								
⋮	⋮		\	\								
22	8823	=	+1	+1.25								
Lower Rakaia Recon.												
Dryland Area	0	=	-1 -1				+1					
Irrigated Area	0	=		-1.25 -1.25				+1				
On-Farm Capital	0	=		-1100 -1400	+1							
Off-Farm Capital	0	=				+1		-1300				
Total Reconciliations												
Dryland Area	0	=	-1 -1						+1			
Irrigated Area	0	=		-1.25 -1.25						+1		
On-Farm Capital	0	=			-1						+1	
Off-Farm Capital	0	=				-1						+1

of pasture for each of the agricultural activities. Details of the calculations can be found in Appendix S.

The per hectare water demands for each irrigated activity have been calculated for the seasons 1959/60 to 1982/83. Details of the demands for water by each soil type-landuse activity are shown in Appendix O and Figure 7.7 shows the per hectare values used in the Lower Rakaia activities.

Two reconciliations for are used to total the per hectare on-and off-farm capital costs of each scheme. The scheme capital activities are then totaled to give the total on-farm and off- farm capital costs for total area irrigated (see Figure 7.7). The capital costs for each scheme are shown in Table 7.8.

TABLE 7.7

Net Returns For Produce Selling Activities And Pasture Replacement And Maintenance Costs

	Farmer ($)	National ($)
Net Returns		
Wheat	107.15/tonne	110.15/tonne
Barley	59.16/tonne	128.66/tonne
Peas	106.21/tonne	156.21/tonne
White clover	1.84/kg	1.07/kg
Ryegrass	0.34/kg	0.46/kg
Lamb	10.27/lamb	18.93/lamb
Mutton	7.70/ewe	6.53/ewe
Wool	3.07/kg	3.24/kg
Pasture Costs		
Dryland (grazing)	99.76 per hectare	
Dryland (cropping)	14.06 per hectare	
Irrigated (grazing)	114.65 per hectare	
Irrigated (cropping)	21.46 per hectare	

FIGURE 7.8

Detached Coefficient Matrix Showing Production, Income And Employment Ties

CONSTRAINT	SUPPLY	SIGN	LOWER RAKAIA SCHEME				PRODUCE SALES					TOTAL INCOME			EMPLOYMENT	
			DRYLAND		IRRIGATED		DRYLAND	IRRIGATED	WHEAT	BARLEY	EWES	WOOL	NATIONAL INCOME	FARMER INCOME	REGIONAL INCOME	DIRECT JOBS	TOTAL JOBS
			1PW	2CW	1PW	2CW	PASTURE	PASTURE									
Lower Rakaia Recon.																	
Dryland Pasture	0	>=	-6.8	-.97			+1										
Irrigated Pasture	0	>=			-11.91	-1.675		+1									
Production Recon.																	
Wheat	0	>=		-.62		-1.14			+1								
Barley	0	>=		-.60		-1.17				+1							
Peas	0	>=		-.54		-.806											
White Clover	0	>=		-45.8		-73.4											
Ryegrass	0	>=		-127		-198											
Lambs	0	>=					-1.09	-1.44									
Ewes	0	>=					-0.39	-0.27			+1						
Wool	0	>=					-8.36	-8.89				+1					
Total Recon.																	
National Income	0	=	+99	+14	+114.65	+21.45			-272	-237	-39.00	-4.18	+1				
Farmer Income	0	=	+99	+14	+114.65	+21.45			-127	-94	-7.70	-3.07		+1			
Regional Income	0	=												-2.1	+1		
Direct Employment	0	>=			-.00328	-.00328										+1	
Total Employment	0	>=			-.00656	-.00656											+1

Each irrigated activity supplies employment to the total direct and the total job reconciliation. The direct employment generated by each irrigated hectare has been assessed as 0.0033 jobs per hectare by Brown, (1983). The total employment generated is assessed as 0.066 jobs per hectare. Details of the structure of the ties used in the model can be found in Figure 7.8 and details of the calculation of the above estimates are found in Appendix R.

7.8 REGIONAL INCOME

The secondary or regional income generated by recreational users, commercial salmon farming and agriculture are totalled to provide a measure of the total regional income generated by the optimal solution. A regional income multiplier of 2.7 has been assumed for the increased agricultural production generated by irrigation development (Source: Brown (1983)). The structure of the regional income effects portion of the model is shown in Figure 7.5 and 7.8.

TABLE 7.8

Scheme Capital Costs
(Source: E.B. Williman pers. com.)

	On-Farm ($/ha)	Off-Farm ($/ha)	Total On-Farm ($m)	Total Off-Farm ($m)
Central Plains Southern	1300	1250	40.3	38.8
Southern Pumped Extension	1300	4500	7.9	27.3
Northern	1300	1350	35.8	35.8
Northern Pumped Extension	1200	2500	8.2	17.2
Te Pirita	1400	1150	4.4	3.6
Barrhill	1300	2000	16.3	25.0
Lower Rakaia Spray	1400	1300	18.5	17.2
Border dyke	1100	1300	12.9	15.3

7.9 RESULTS

The GOAL program used in this analysis provides a significant amount of information, not all of it useful in the decision making process. The following discussion highlights information which would be useful for decision-makers analysing the Rakaia River debate. Appendix T provides the reader a sample of the full printout generated by this program and subsequent appendices summarise the 90 runs made in this study. The reader is directed to these appendices for further information where necessary.

7.9.1 The Effects Of Changing Goal Priority

The first experimentation with the model involved changing the priority assigned to each of the six goals (or objectives) under consideration. The goal achievement levels and weightings used for these runs are shown in Tables 7.4 and 7.5. The results, summarised in Table 7.9, show that changes to the priority levels assigned to each goal had only a minor effect on the area irrigated. This is illustrated by:

(1) No change in area the irrigated when the national income goal and the two instream goals, river flow and water depth are interchanged, Runs A and B.

(2) When the national economic efficiency goal was dropped to a priority of three and the river flow and water depth goals were dropped to five and six respectively (Run C), the area irrigated increased slightly.

(3) A larger increase in area irrigated was obtained by reducing both the on- and off-farm capital expenditure goals to the lowest goal level and assigning highest priority to national economic efficiency criteria. This had the effect of increasing the area irrigated in all seasons. In two seasons, average and low rainfall, all of the potentially irrigatable area was watered. It would

TABLE 7.9
The Effects of Varying Goal Priority Levels On Area Irrigated

	Area Irrigated (ha)	Area Dryland (ha)
Average Flow Season (1960-61)		
Run A	104,603	9,807
Run B	104,603	9,807
Run C	105,469	8,941
Run D	114,410	-
Low Rainfall Season (1963-64)		
Run A	106,822	7,588
Run B	106,822	7,588
Run C	107,244	7,166
Run D	110,750	3,660
Low Rainfall Season (1963-64)		
Run A	110,750	3,660
Run B	110,750	3,660
Run C	110,750	3,660
Run D	114,410	-

Note: The following orders of priority were assumed for the named runs.

Run A = National income (plus off-farm capital), river flow, water depth, farmer income (plus on-farm capital), employment generated and regional income.

Run B = River flow, water depth, national income (plus off-farm capital), employment generated, farmer income (plus on-farm capital) and regional income.

Run C = Farmer income (plus on-farm capital), employment generated, national income (plus off-farm capital), regional income, river flow and water depth.

Run D = National income, river flow, farmer income, employment generated, and off- and on-farm capital costs.

appear that the capital goal was the contributing factor in excluding the areas not irrigated in other runs.

7.9.2 The Effect Of Changing Goal Levels

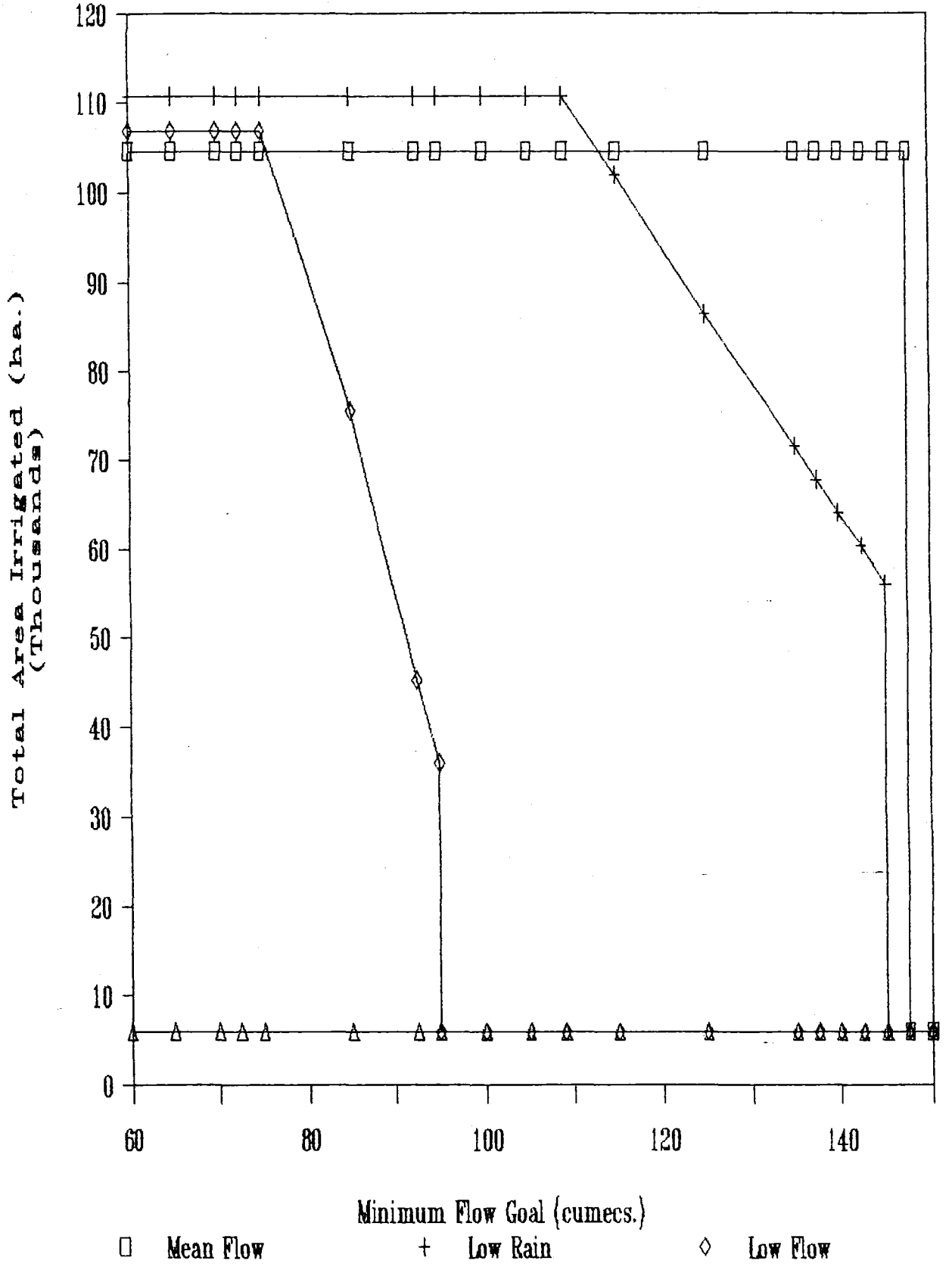
(1) The effect of varying the minimum flow goal on the area irrigated is shown in Figure 7.9. The results presented relate to the goal and priority levels assumed for Run A (see Table 7.5 for details). Changes in the minimum flow left in the river for instream values has the most significant effect on the area irrigated. This is highlighted by:

(a) In a low flow season (1970-71) the area irrigated started to decrease as the minimum flow for each month of the irrigation season was increased above 77.5 cumecs. At monthly minimum flows greater than 95 cumecs the model became infeasible. This occurred because at least one month of the irrigation season could not meet the required minimum flow of 95 cumecs. Subsequent runs of the model allowing both the under- and over-achievement of the flow goal showed that February was the most constraining month flow followed by April and January. Appendix U summarises the under-achievement of the flow goal for runs of the model which set the minimum flow goal between 100 and 200 cumecs.

(b) In the low rainfall season (1962-63) the area irrigated decreases below the initial maximum at approximately 110 cumecs and the problem became infeasible at minimum flows greater than 145 cumecs. Again the most limiting month was found to be February followed by April and December.

FIGURE 7.9

Effect Of Varying Minimum Flow Goal On The Total Area Irrigated.



(c) when the average flow season (1962-63) data were used the area irrigated remained at 104,603 hectares until the problem became infeasible at minimum flows greater than 145 cumecs. The most limiting months for these runs of the model were January and April.

(2) If the minimum flow goal was set to 135 cumecs to represent optimum "fishability" in the river (see section 7.1.6) then the area irrigated would be 104,603 hectares and 71,571 hectares respectively, when data for an average and a low rainfall season is used. An infeasible result was obtained when data for the low flow season was used because the flow available in the river was below the 135 cumec minimum in one or more months over the irrigation season.

(3) The effects of varying minimum flow levels on the annual national income generated are shown in Figure 7.10. The trends shown in irrigated area are reflected in the national, farmer and regional income values obtained in the runs of the model. These results can be used to derive the marginal value product (MVP), per cumec of minimum flow, over specific flow ranges for the irrigation season. Table 7.10 shows that the MVP per cumec of minimum flow over the ranges specified are between $0.926 million and $2.198 million for national income. These values mean that the value of the resources being protected by the minimum flow requirements would need to generate at least these levels of worth annually per additional cumec of minimum flow imposed. At flows less than 79.0 and 112.5 cumecs, for the low flow and low rainfall seasons respectively, the MVP per cumec of minimum flow is zero. This means that the income modelled would not alter should the minimum flow increase (or decrease) by one unit.

FIGURE 7.10

Effect Of Varying Minimum Flow Goal On Gross Annual National Income.

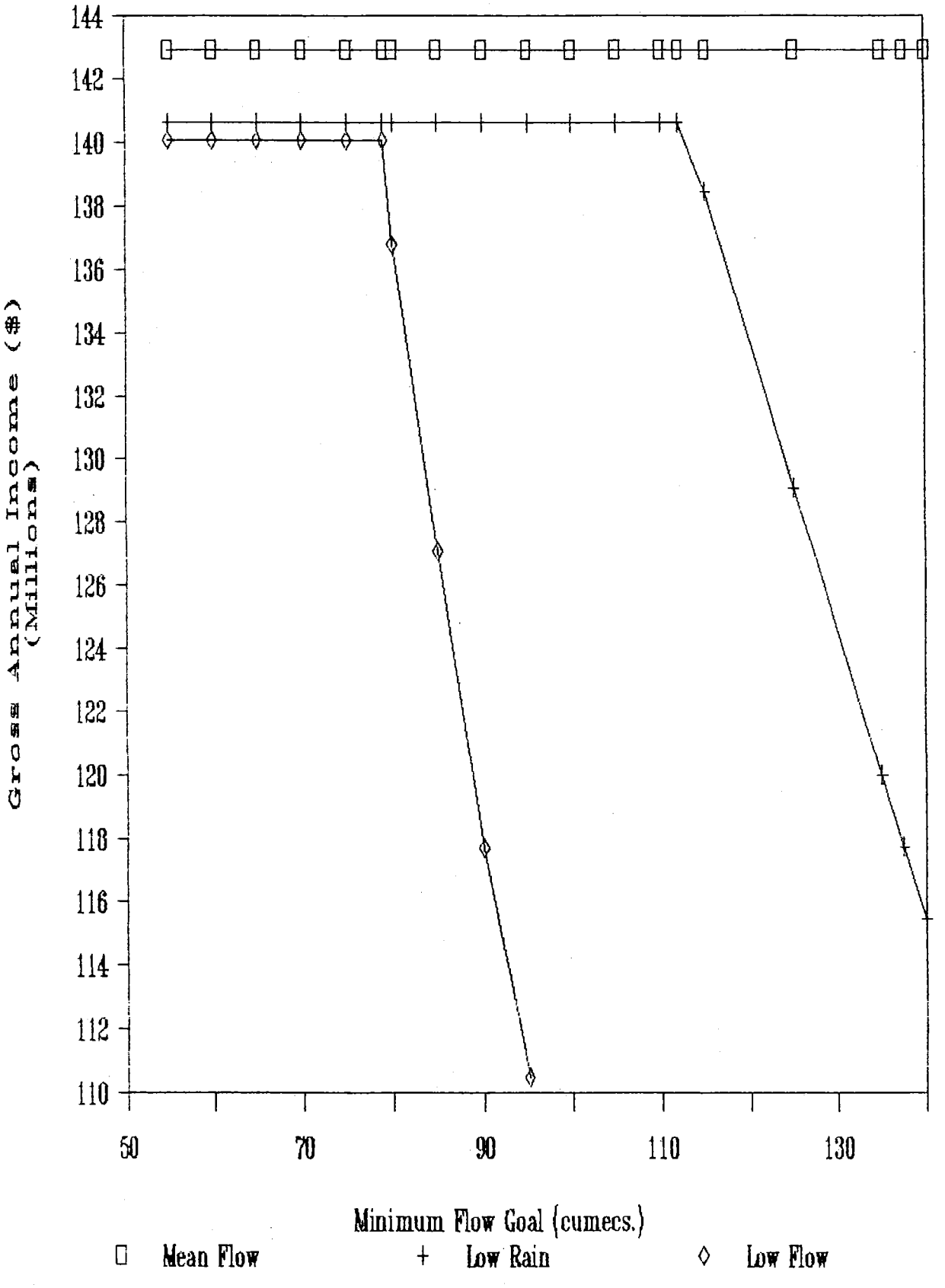


TABLE 7.10

Marginal Value Products Per Cumec Of Minimum Flow

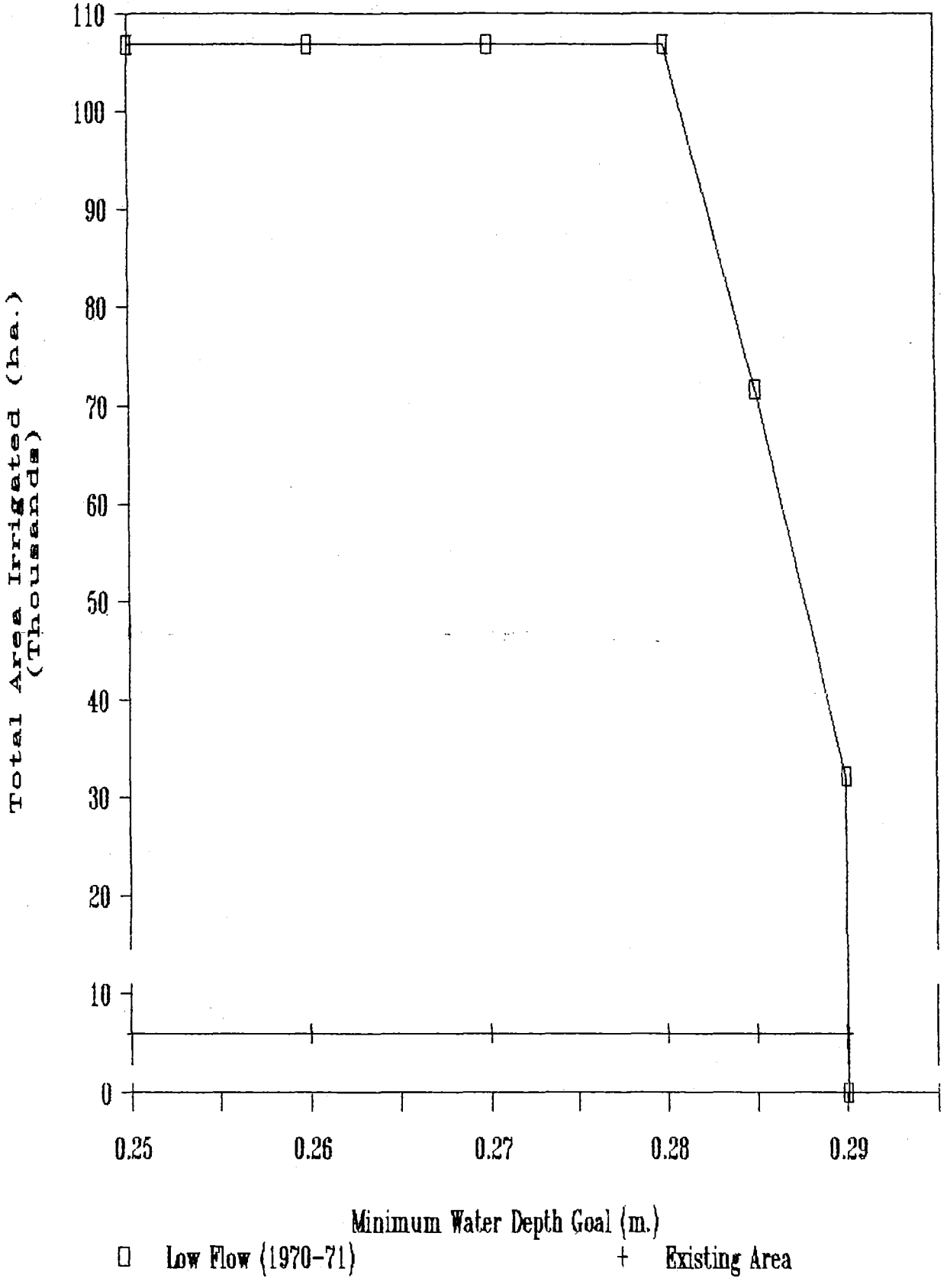
	Marginal Value Product ($/cumec)	Range Valid (cumecs)
Low Flow Season		
National	$2.198 mil.	79.0 - 92.5
Farmer	$1.384 mil.	79.0 - 92.5
Regional	$2.907 mil.	79.0 - 92.5
Low Rainfall Season		
National	$0.926 mil.	112.5 - 145.0
Farmer	$0.579 mil.	112.5 - 145.0
Regional	$1.215 mil.	112.5 - 145.0

Note: The following orders of priority were used to generate the above data; national income (including off-farm capital), river flow, water depth, farmer income (including on-farm capital), employment generated and regional income.

(4) The effects of varying the minimum water depth goal on the area irrigated is shown in Figure 7.11. Runs were made of the low flow season model to explore the effects of varying the minimum water depth goal. The goal priorities associated with these runs were in decreasing order of priority; water depth, river flow, national income (including capital expenditure), employment generated, farmer income (including capital expenditure) and regional income. The results of varying the minimum water depth from 0.25 metres to 0.30 metres is shown in Figure 7.11. The results show that varying the water depth goal had less effect on the area irrigated than varying the flow goal. This suggests that the water depth ties in the model are redundant and that a decision criteria based on

FIGURE 7.11

Effect Of Varying Water Depth Goal On
The Total Area Irrigated (1970-71)



water depth would be ineffectual even if it were practical. The maximum water depth that could be sustained for the whole irrigation season would be of the order of 0.29 metres in the main channel.

7.9.3 Seasonal Effects

The variation in the maximum area irrigated in each of the seasons tested varied according to the input data used. The area irrigated in an average season when national income is given the highest priority is 104,603 hectares and this increased to 110,750 hectares when data for a low rainfall season was used.

7.9.4 Scheme Development

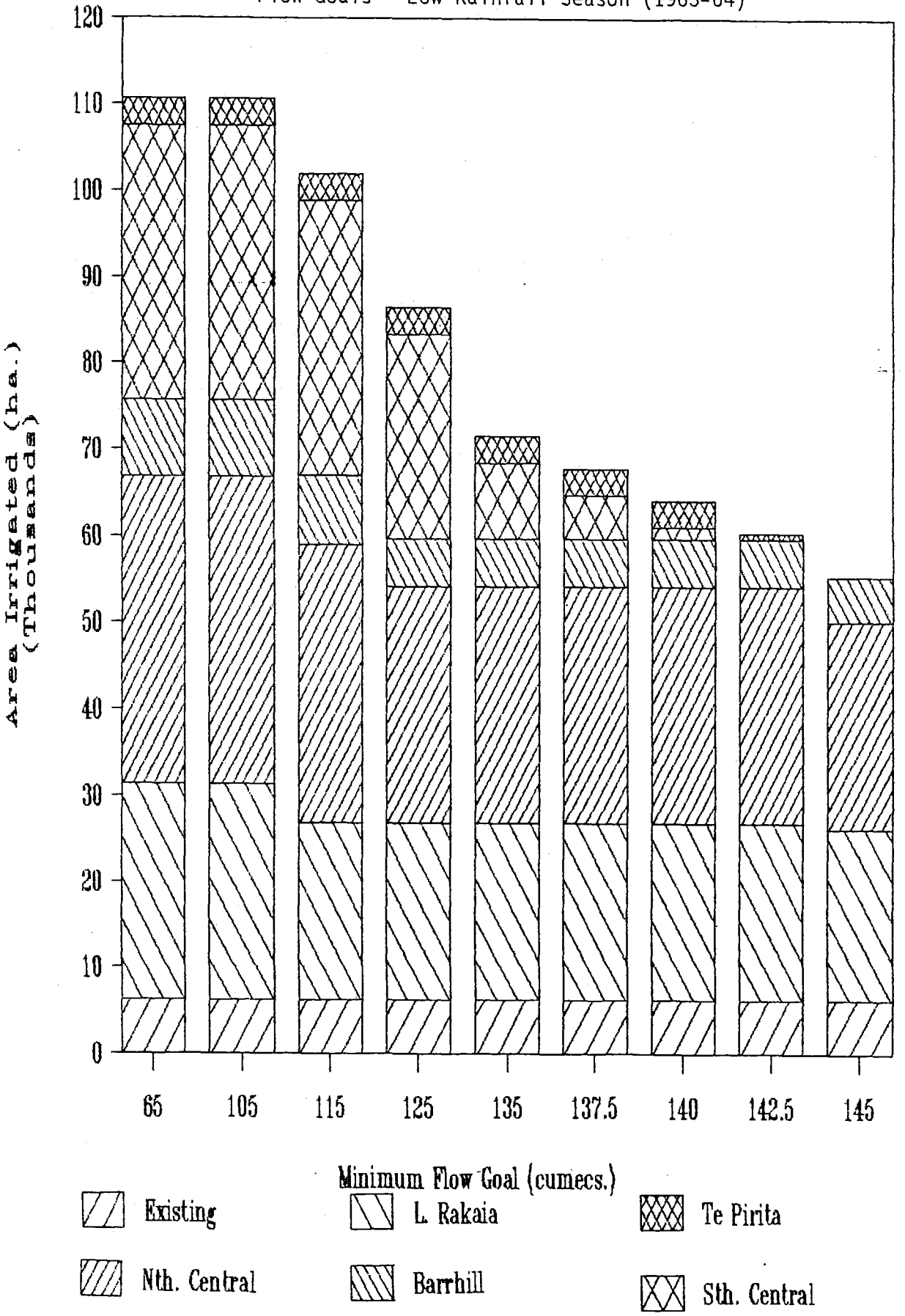
Of local interest is the choice of which, and at what level each of the irrigation scheme options should be pursued. The overriding conclusion in this respect is that the Barrhill, Northern Central Plains and Lower Rakaia Schemes are the most stable developments and the Southern Central Plains and Te Pirita developments the least stable. Data for the low rainfall season (goal priorities are as for Run A) is shown in Figure 7.12 and details for the other seasons can be found in Appendix U.

7.9.5 Discussion Of The Results

The most significant effect highlighted by the runs of the model was the effects that varying the minimum flow goal had on the area irrigated and how this interacted with the seasonal conditions. In average seasons the area that can be irrigated was constant over all minimum flow levels up to 145 cumecs for the whole season. However, at minimum flows less than 77.5 cumecs, the area irrigated in the low flow season (1970-71) was higher than that in the average season.

FIGURE 7.12

Irrigation Scheme Development In Relation To Minimum Flow Goals - Low Rainfall Season (1963-64)



Any decisions made regarding the use of the water resources need to account for the seasonality of demand and supply of water in the catchment and as such should be flexible. The model could be used to explore the effects various sharing and allocation rules would have on the area irrigated.

The major benefit derived from the results is that trade- offs are seen to be available in the decision making on the use of the Rakaia's water resource. These have been presented in such a way that a decision maker could readily explore possible options and also be able to make informed decisions on the effects of different policy decisions. This is best illustrated by the marginal value product information shown in Table 7.10 where the decision maker can see that increasing the minimum flow by one more cumec will mean a drop of national income of between $0.926 million and $2.198 million depending on the season analysed. The decision is then one of subjectively judging whether the likely gains from this one cumec increase in minimum flow are worth this amount.

7.10 PROBLEMS WITH, AND EFFECTIVENESS OF, THE MODELLING APPROACH

The real world application presented all the real world problems that normally show up in the planning process:

(1) Lack of data in some areas. This is particularly so in the effects of flow restrictions on the instream uses of the river. Research effort needs to be concentrated in this area and more particularly on the effects various flow regimes have on salmon numbers and survival.

(2) Too many data in some areas. This could be said of the volume of data available in the agricultural sector. It should be noted, however, that these data have only become available because of a well structured research and monitoring effort over a

number of years. Simulation modelling studies similar to those developed for irrigation would be useful for some of the instream uses of the river e.g. the effects of varying flow regimes on salmon populations. Such studies would allow research priorities to be established and aid in the decision making process.

(3) The need for intermediate decisions along the way. This is highlighted by the assumptions made concerning the flow to water depth relationships, and those about the effects of flow on recreational and income from commercial salmon farming ventures. Areas where further assumptions could be made having the effect of enhancing information generated by the model are:

(a) inclusion of discounted cash flow values for capital and income items,

(b) inclusion of possible power generation alternatives for the river, and,

(c) options which would provide supplementary flows in periods of shortage e.g. the increase in storage in Lake Coleridge or the possibility of damming the Gorge.

(4) Conflicts between the various interest groups. This has been discussed in section 7.1.2. The use of this model in conflict resolution has not been tested as part of this study. It is the feeling of the writer that the involvement of the interested parties in the development and analysis of such a model would provide valuable insights into the significant areas of conflict, the reasons for this conflict and finally the resolution of the conflict by analysing the trade-offs between competing uses.

(5) Shortage of appropriate output data from the model. The model algorithm as used would require modification to include a more detailed analysis of results. Factors that would aid in the analysis of

the results are; inclusion of marginal value product and opportunity cost information as well as details on the stability of the optimum plan to changes in parameters. These points could be overcome by the use of another package or another technique e.g. constrained optimisation techniques.

Despite the above problems the model has been found to be effective in determining how resources should be utilised to meet specified goals and in determining the impacts and trade-offs that would occur if certain decisions were made. The effectiveness of the model was shown by:

(1) The output explicitly lists the resources used and the impacts and trade-offs that occur when certain policy decisions are made e.g. the effect of setting minimum flow levels, and

(2) The development of the model allowed the analyst to gain insights into the inter-relationships that exist and the nature of the trade-offs that have to take place. This meant that a much more realistic model of the problem was constructed.

The model of the Rakaia River developed in this study is by no means complete; it represents a good start toward a model that decision-makers can use to provide the information base upon which decisions can be made for the future utilisation of the Rakaia River. The model provides a static look at the Rakaia River allocation problem. However, if the model was run as an iterative process, analysing conditions at several points in time for various alternative futures it would give information on:

(a) The future impacts and trade-offs that occur if certain decisions are made now.

(b) What sources of water would be utilised and at what point in time they would be needed.

Such a process could be used to screen out those policies and programmes that most nearly attain the desired goals and also screen out those particular sources of water that are most effective in achieving these goals.

A further refinement could include the introduction of uncertainty into the model framework. Such an approach, using MOTAD techniques (see Dent, et. al. (1986) for details) would mean that the effects of decision in a uncertain environment could be explored. Sections of the model which would lend themselves to such an approach would include river flow, water demand by agricultural crops, agricultural yield and product prices, capital costs of development and the uncertainty surrounding the value of instream uses of the resource.

CHAPTER VIII

ANALYTICAL PROCEDURES - MONITORING AND EVALUATION OF PROJECTS

8.1 BACKGROUND TO THE PROBLEM

Emphasis in cost-benefit analysis in New Zealand has centered on the ex-ante analysis of projects. This is logical as cost-benefit analysis has been used to justify new public expenditure. The need for ex-post evaluation of agricultural development projects was highlighted in 1964 by Ward (1964a) and later by Jensen (1967), Johnson (1967), Plunkett (1967) and Stewart (1967). The earliest known ex-post reports were carried out in the late 1960's by Plunkett (1967) and Norton (1967a and b) on drainage schemes, and Gow (1967) on hill country development. Recently there has been a revival of interest in analysing the performance of water and soil development schemes, McGregor and Pittaway (1985), Greer (1984), McGregor (1980), Bailey and McGregor (1980), Hadfield (1976), Kirkland (1980). These reports have found that the ex-ante reports have considerably underestimated the actual benefits derived from the schemes.

Decision-makers should not accept the accuracy of ex-ante analyses without question but should have a consistent and reliable data-base to call upon to help them in the decision- making process. The data-base should consist of information derived from a planned monitoring scheme of selected projects as well as a series of ex-post analyses carried out on a wide range of schemes. There will be no real improvements in water and soil decision-making unless information on the costs and benefits of schemes, already approved, are incorporated into the decision process. Haveman (1972) stated " ... because the behaviour of decision-makers in the public sector is influenced by lack of incentives to achieve efficient programs, it is not

unreasonable to presume that performance in this sector will not improve until the people themselves are informed of the results of ex-post analysis." At present the evaluators, designers and decision-makers have little or no feedback on their work which could then be used in the planning process.

8.2 HISTORY OF EX-POST ANALYSIS IN NEW ZEALAND

Since the late 1960's cost-benefit analysis has been used to justify all major land betterment expenditure in New Zealand with major emphasis centered on the ex-ante analysis of projects. This is logical as cost-benefit analysis has been used to justify new public expenditure. Recently there has been some interest in analysing the economic performance of land betterment schemes; McGregor and Pittaway (1985), Brown, Copeland & Co. Ltd. (1985), Copinga and Harris (1984), Greer (1984), Le Page (1981a and b), McGregor (1980a), Bailey and McGregor (1980), Hadfield (1981 and 1976), Kirkland (1980), Arthur-Worsop (1980), and Greer (1975). The studies done to date provide two things. Firstly, they allow an assessment of the contribution of a particular scheme to the national economic efficiency objective and/or secondly they provide comparisons between the original estimates and those which have actually occurred. This later information can be used as a basis for future ex-ante reports. It can also provide feedback to the design, planning and evaluation agencies on deficiencies in methodologies or policies. There is little evidence to suggest that this feedback has occurred to date.

There have been approximately 13 ex-post reports carried out since 1975 on schemes which have been funded or partially funded from the Government's allocation to water and soil conservation. The results of these studies are shown in Table 8.1 and the details of the Makarewa River flood control scheme report are shown as Appendix V. The ex-post reports quoted in Table 8.1 can be categorised into those which give descriptive accounts of schemes and calculate the contribution of the scheme to national

TABLE 8.1

Summary Of Recent Ex-Post Studies Carried Out In New Zealand

Scheme	IRR ex-ante (%)	IRR ex-post (%)	% change	NPV(10%) ex-ante ($m)	NPV(10%) ex-post ($m)	% change
Catchment Works:						
1. Makarewa River (McGregor & Pittaway, 1985)	6.2	4.6	-26	-9.14	-3.60	+154
2. Torepatutahi Catchment (Copinga & Harris, 1984)	6.7	16.0	+234	-0.99	1.22	+239
3. Whareama Catchment (Brown, Copeland & Co. Ltd, 1985)	-	32.0	descriptive	-	74.20	descriptive
4. Waipaoa Flood Control (Arthur-Worsop, 1980)	-	12.0	descriptive	-	30.20	descriptive
5. Muddy Creek Drainage (McGregor, 1980)	27.0	28.0	+4	0.75	2.74	+265
6. Wither Hills Erosion (Hadfield, 1981)	-	8.2	descriptive	-	0.08	descriptive
7. LII River Improvement (Norton, 1967a)	-	12.0	descriptive	-	not given	descriptive

TABLE 8.1 (continued)

Scheme	IRR ex-ante (%)	IRR ex-post (%)	% change	NPV(10%) ex-ante ($m)	NPV(10%) ex-post ($m)	% change
Rural Water Supply Schemes:						
8. Waimate West (Bailey & McGregor, 1980)	8.9	6.2	-30	-	0.58	no comparison
9. Waipara (Hadfield, 1976)	14.9	15.0	0	0.46	0.72	+15
10. Goodwood (Greer, 1975)	-	14.4	poor ex-ante	-	0.19	poor ex-ante
Irrigation Schemes:						
11. Amuri Plains (Greer, 1984)	-	9.8	no comparison	-	-0.41	no comparison
12. Lower Waitaki (Le Page, 1981a)	7.7	9.7	+26	-2.38	-0.45	+45
13. Hawea Flats (Kirkland, 1980)	6.7	8.5	+27	-0.08	-0.07	+18

Note: NPV values are not in equivalent annual dollar values for each scheme i.e. they are presented in the dollar values used in the ex-post report.

economic efficiency and those which also compare the results with the ex-ante report carried out on the scheme.

From the economic efficiency point of view over half of the schemes show internal rates of return higher than the accepted Treasury 10% guideline and two are very close to meeting that cut off. The remainder of the schemes (4) show returns considerably lower than the 10% guideline and did so at the time of approval. It can only be assumed that these schemes gained approval because of other factors not accounted for in the economic analyses carried out.

A comparison of the ex-ante reports with the ex-post reports show two things;

(1) In all but two cases the internal rate of return calculated in the ex-post report was higher than that in the ex- ante report. The range was 30% lower to 234% higher.

(2) In all cases the NPV (10%) is higher than that calculated in the ex-ante situation. The range is 15% higher to 265% higher with an average of 123% higher. The reasons for such increases in NPV are that this measure of economic worth has shown the scale effect of the schemes.

The main reasons for differences between ex-post and ex-ante analyses are that the promoting agency has underestimated the scheme costs and the ex-ante analyst has underestimated the benefits attributable to the scheme. Table 8.2 shows the ranges of over- and under-estimation of these items.

Cost underestimation at the design stage can have significant effects on the economic results achieved by a scheme. This is because the major scheme costs occur early in the life of the project and discounting, especially at high discount rates, places a higher weighting on cash flows occurring early in a schemes life. Although Table 8.2 shows that the average cost underestimation by design agencies is 14% it masks the fact that three schemes (8, 12 and 13) had cost overruns of greater than 28%.

TABLE 8.2

A Summary Of The Under- and Over-Estimation of Scheme Capital Costs and Benefits Highlighted by Ex-Post Studies

	Lowest Estimate	Highest Estimate	Mean Change	Schemes
Scheme Capital Cost	-46%	+86%	+14%	1,5,8,9,12,13
On-Farm Capital Cost	-40%	+11%	-8%	1,9,12,13
Benefits	+9.4%	+493%	+139%	1,2,9,10,12,13

Notes: For meaning of scheme numbers see Table 8.1.
Negatives mean the value in ex-post analysis is lower than the ex-ante value.
Positives mean the value in the ex-post analysis is higher than the ex-ante.

It is the assessment of benefits that appears to cause the greatest problems for analysts. Table 8.2 shows benefit underestimation to be exceptionally large and this is significant when it is considered that benefit generation is the reason that schemes are promoted. The other startling fact bought out by these reports is the fact that all schemes had lower benefits attributed to them than occurred in practice and five of the six schemes went ahead with estimates that were at least 40% under the benefits achieved.

8.3 PROJECT CONTROL

Clayton (1979) identified three functions of project management:

- project control,
- project monitoring, and
- impact evaluation.

Project control is concerned with maintaining project operation and technical performance. It includes the implementation of recurring work schedules and response to day to day variations from technical performance criteria. This role falls to project management which is concerned with adjustments to project operation to meet changing circumstances, particularly those exogenous to the project. Project management has four main aspects; technological, business, administrative, and public relations.

Agricultural investment projects typically require a large number of components (interdependent activities) that require fitting together and adjusted to each other for the project to achieve its objectives. There are two philosophies that represent alternative ways of accomplishing control in a system which has a large number of interdependent activities, El- Sherbini (1979). These are:

(1) Control by plan - In this case a plan is agreed to by each activity and adhered to for the duration of the project. This approach is useful where the project is stable and predictable.

(2) Control by feedback - Control is accomplished by measurement of selected project criteria and the transfer of this information to project management to allow modification of plans and/or objectives. Success of such a system depends on the efficiency of communications within the management structure.

A typical project feedback structure is shown in Figure 8.1. It shows how an ideal project control system should work. There is the need for clear definition of the criteria, allowable deviations from plan and the data needed to monitor the project. The next step is data collection itself. Data may be either collected in the field or derived from the information system itself. If the monitoring process shows that the project has moved outside acceptable limits there is a need to diagnose the causes of the deviation and subsequent changes can be made to the plan.

For a feedback system to be effective there is a need for an efficient information system. This should meet among others the following five specifications, Becker (1962):

1. Deliver information when it is needed,
2. Provide for total horizontal distribution of information. Each of the interdependent management units should have all the information that it requires to function effectively and efficiently
3. Filter vertical distribution of information. Situations that require decisions should be directed to the lowest level at which decisions can be made. Upper management should only be informed if management at the lower level cannot cope or there are problems with getting action at a lower level.
4. Information should be readily available for assembly into special reports of an unpredictable nature.
5. Execute through its internal logic as many controls as are feasible. Management should govern by controlling exceptions rather than every incident.

8.4 PROJECT MONITORING

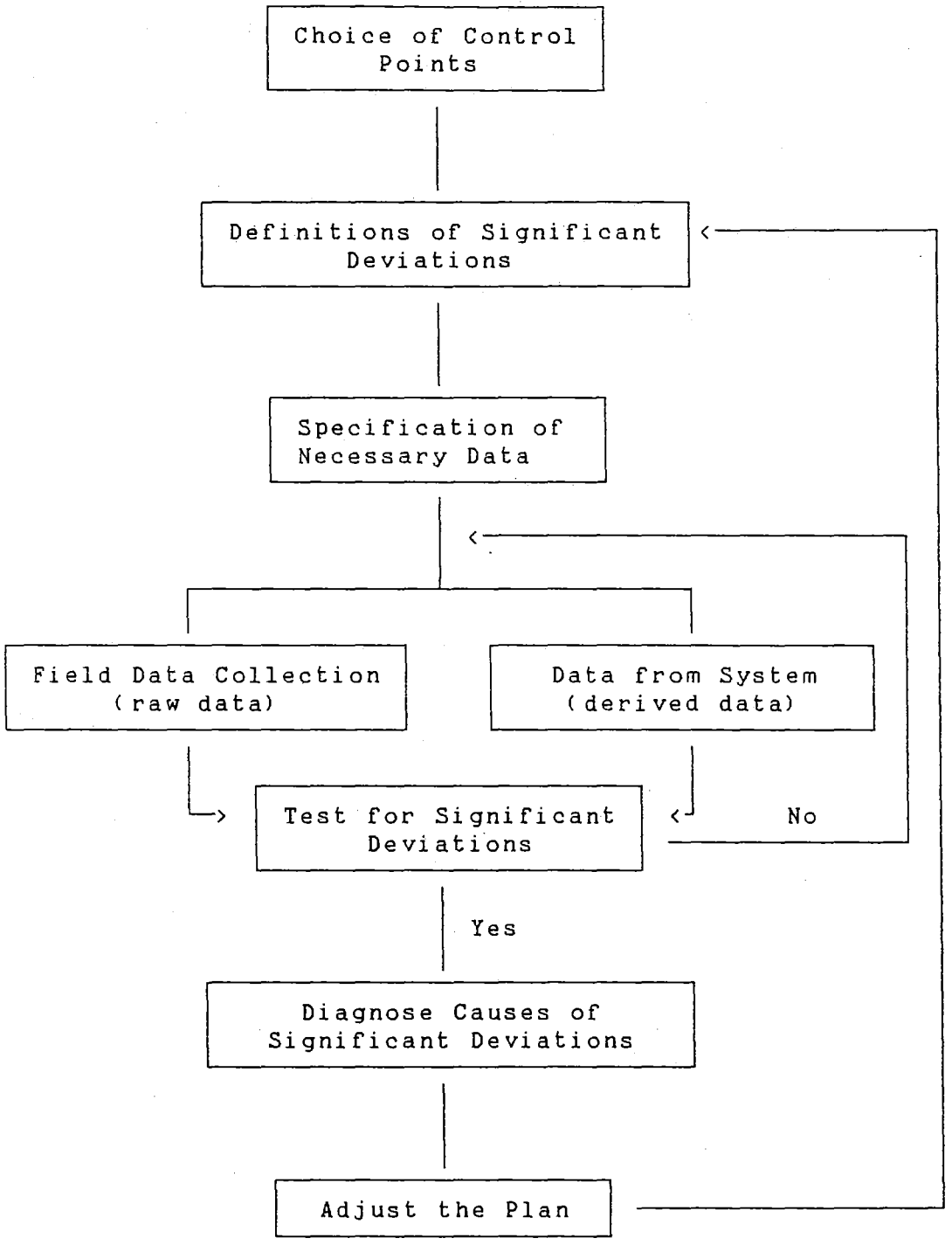
Project monitoring is the process of measuring and recording the on-going project operation and performance. The purpose of a monitoring system is to provide a database for project management and control, and for ex-post evaluation. The idea of monitoring or checking on performance of capital expenditure is not a new one. Monitoring systems contribute to a permanent improvement of knowledge and provide valuable data for decision making.

Agricultural development differs from other capital development in that there is generally a lag period between the expenditure and full production but one of the major determining factors in the success (or failure) of an agricultural scheme is the performance of a group of independent decision-makers, generally farmers, who are external to the project. This is unlike the performance of a

FIGURE 8.1

An Example of a Project Management Feedback System

(El-Sherbini, 1979)



hydro-electric power project, for instance, where the entire operation is in the hands of professionals.

One of the more obvious aims of project monitoring is to determine how the project is performing in relation to its stated objectives and in particular those objectives which were established as decision criteria. Information obtained from scheme monitoring can be used to improve the forecasting techniques used to calculate project benefits (and costs). This is necessary as there is little point in using sophisticated evaluation techniques unless the basic data are correct.

Monitoring must involve more than simply producing a comparison between actual and expected performance. To be of use in the management cycle, the evaluation should endeavour where possible to investigate the reasons for deviations from planned performance levels. Initially, managers and planners need to identify the key elements, both technical and non-technical, that make the project function. These could be drawn together under the following headings; physical resources, capital and human resources. Physical resources are those elements like land and water that are the basis of an irrigation scheme. The engineers impose their technology on these resources and can be expected to be interested in actual performance. This area is in fact one that is rarely neglected, e.g. performance of pumping plant is monitored continuously.

The monitoring of capital expenditure is generally intensive and well documented. The capital flows are monitored closely during the development phase by the funding agency and/or the project management. Any deviations from budget are detected and acted upon once predetermined critical levels have been reached. In addition, the reasons for straying from budget are investigated and control measures introduced to stop future problems. This leads to a complete feedback to management and provides guidelines for future planning studies. The monitoring of operations and maintenance expenditure has received less attention.

Estimates of this expenditure are made at the planning stage and may not represent the true situation as a result of changes that occur during project construction. Rydzewski (1978) has suggested that monitoring of operations and maintenance be done in material rather than financial terms so that sound experience is gained on what goods and services are required for successful operation. The allocation of dollar values can occur at a latter date. For the management feedback loop to be effective, however, financial information should be recorded as this will often determine the level of charging for scheme outputs e.g. irrigation water, stock water supply, etc.

Monitoring in the human resources area generally receives only scant attention. This grouping can be further subdivided into the following sub-headings;

(a) the management organisation itself,

(b) the beneficiaries of the scheme e.g. the farmers or small-holders who own or rent land within the scheme boundaries, and

(c) casual labour and specialist services.

All areas are important but as was stated above the beneficiaries of land betterment schemes, generally farmers, play an important part in the success or otherwise of the scheme. For this reason it is important to monitor the effects the scheme has on them through the use of sample budgets on a regular basis. The monitoring procedure should also endeavour to determine what the situation would have been had the scheme not proceeded. The information gathered should be used to adjust plans in the same way that the information collected in the physical and capital areas is utilised.

In order to introduce a monitoring system it is first necessary to determine what should be recorded, how frequent it should be recorded, the staffing requirements, and the recording and communications procedures. Detailed monitoring systems are costly in time and personnel and it is extremely difficult to measure the benefits against its

costs. This leads to acceptance in principal but rejection in practice by the agencies and decision-makers involved.

There is further group who have an unstated opposition to monitoring because they perceive the ultimate purpose of monitoring is to expose weakness in performance and management. Monitoring and evaluation are dealing with decisions people have made and as such are sensitive matters to be dealt with. When setting up such procedures it should be made quite clear that the objective of the monitoring and evaluation is to learn from experience and to form judgments on management structures, policies and procedures, Olivares (1979). The evaluator should take the approach of; what policies, procedures or management structures made it possible that a persons poor judgment or questionable decisions were not detected and corrected immediately.

The following are the basic elements of a monitoring and control system;

(1) Clearly defined project objectives. The control of a project can have no direction unless it has explicit objectives.

(2) Public participation. The beneficiaries (as well as other affected groups and individuals) of the project should be encouraged to participate in the formulation of objectives. This may help in the achievement of the objectives and will ensure that they are realistic.

(3) The system must be comprehensive and not just concentrate on budget allocation and expenditure control.

(4) The data collection, processing and interpretation steps should be as simple as possible.

8.5 IMPACT EVALUATION OF PROJECTS

8.5.1 Impact Evaluation Methods

This is the last activity in the project cycle and is the point at which it is time to take stock and review the project critically. The analysis ideally uses information collected through monitoring, supplemented by other information collected by survey where necessary, to analyse the actual impact of the project post-implementation. It is clear that monitoring and impact evaluation are two distinct functions and monitoring cannot be a substitute for evaluation. The evaluation can be on-going (ex-nunc) or a post mortem (ex-post). Ex-nunc studies can be carried out at some predetermined point in the project implementation e.g. when half the funds are committed (U.N.D.P.) or when one or more of the critical variables diverges outside accepted limits. The objectives of this type of analysis are:

(1) To assess the current or on-going operation and performance of a project with the aim of comparing the performance of the project with preset technical and operational standards. Significant deviations from these standards signify that project management should take some action.

(2) To provide periodic feedback to the project management. The criteria used are a comparison of initial objectives and predicted performance with actual achievement of objectives and performance. This type of analysis uses indicators like overall productivity, area devoted to cropping, yields and other similar technical indicators.

Ex-post, also known as post-audit or retrospective analyses, are carried out after the project is complete. The main objective of ex-post analyses is to use information that is still recent and valid to provide feedback to the planning process for the next project. Feedback comes in the form of lessons learnt and comparisons of achievements with goals and the relationship with current policy. The analysis should provide information on:

(1) The functioning of the promoting and implementing agencies. The adequacy of decisions taken, their operational policies and procedures, rules, organisation and operation.

(2) The financing of projects.

(3) The way the project itself performed and whether it achieved its stated objectives, and

(4) The validity of the underlying agricultural development.

McGregor and Pittaway (1985), Clayton (1979), and Olivares (1979) expressed doubts about the value of ex-post evaluations carried out some time after the completion of the project. There were two reasons for this reservation. The first was that there are so many variables which contribute to project outputs (and inputs) that after a period of time it is very difficult to determine which could be attributed, or in part attributed, to the scheme. The second is that little can be learned today in regard to organisation, project design, analysis and marketing projections which were made in some cases up to 30 years ago with the methods and technology available at that time.

8.5.2 Analysis Of Project Management And Decision-Making

There is as yet no established ex-post methodology that examines the process of management in detail. This is the point which most conventional ex-post analyses stop. It is also common for economists to confuse management with its results. This leads to the analysis focusing on the decision-making process itself rather than on the processes that led to and resulted in the 'optimal' choices. For this reason it is important that project management and performance should be assessed in comparison with specified scheme objectives. As decisions made lower down in the management structure will determine whether higher level objectives are met it is important that all levels should know what these objectives are. There is also a need, early in the implementation stage of the project, to setup

appropriate project criteria and sequential goals to be met by management.

Clayton (1979) saw a number of difficulties in analysing management in this way. These were:

(1) The identification of the appropriate areas to investigate.

(2) The need for objective measurement, not necessarily numerical, for each of the criteria to be investigated.

(3) How would the results of such a study be interpreted and what characterises good or bad performance?

(4) Once results are given meaning is there the need for aggregation to obtain an overall impression of management and project performance. Aggregation may necessitate the application of weights to different results and the consequential problems that weights entail.

8.5.3 Summary

In summary, ex-post evaluations of water and soil projects should be carried out with the following factors in mind:

(1) The results of the evaluation need to be used in a feedback mechanism to ensure that the evaluation has the maximum effect.

(2) Ex-post analyses are expensive because of the costs of continuous monitoring, surveys and the acquisition of data from external sources. Therefore, they should be restricted to large schemes, schemes that are pioneering new products and technologies, e.g. Glenmark irrigation scheme which was a pioneer in water harvesting technology, and a representative sample of all water and soil schemes.

(3) The analysis can be carried out by either an in-house team or by an outside agency but it is

desirable that the analysis of management and decision-making be carried out by an outside organisation in conjunction with the proposing and implementing organisations.

(4) The time between project completion and the evaluation should be long enough to allow full production to be reached e.g. the end of the first full production cycle, but this will depend on the nature of the scheme.

(5) The project management and decision-making process should be included as part of the analysis.

8.6 OBSTACLES TO EX-POST ANALYSES

There are five major problem areas in achieving consistent ex-post analyses of water and soil projects. These are :

(1) Evolution of evaluation practices. Over time the ex-ante analysis techniques are changed and improved upon in the light of new information. As a result, there is not much to be gained out of saying that the techniques in use 10-20 years ago had severe limitations, especially when there have been a number of changes in the interim. To overcome this problem it is necessary to:

(a) conduct an ex-ante analysis using current evaluation methods but using the data from the original analysis,

(b) calculate the performance of the project, and

(c) compare the realised performance with the re-evaluated ex-ante result.

The problems with such an approach is that the data requirements for the latest evaluation procedures may be different from those used in the original approach. This was a problem found in the ex-post analysis of the Makarewa River Scheme (McGregor and Pittaway, 1985). The original scheme

economic report presented accounts analyses in the "before" and "after" scheme situations. The analysis procedures in use at that time (1960) required that an accounting rate of return be calculated. As the discounted cash flow technique was not used, information on the expected timing of benefits and costs was not presented.

(2) The determination of a suitable control group to assess changes that have occurred without the project and to then obtain reliable time series information on this group. This can only be achieved by monitoring or surveying an identifiable control group.

(3) The stochastic nature of some benefits. This is a common problem in water and soil schemes, especially flood control schemes where a flood event may not have occurred in the period between scheme completion and the ex-post study. In such cases the analysis needs to recognised that the scheme provides protection against the probable occurrence of a flood i.e. insurance. However, the hydrology information on which the scheme design was based should also be analysed to determine the quality of the ex-ante hydrology study.

(4) The time pattern of benefits. There is a need for a suitable elapse time between construction and evaluation to allow the full effects of the scheme to be felt. History has shown that the time taken to achieve full benefits of irrigation schemes is considerably longer than was assumed in the ex-ante analyses and in some cases the full benefits may never be achieved. Waiting for all or a large proportion of the benefits to occur can also cause problems. If the elapse time is too long collection of reliable data can be difficult especially if there is no monitoring system in place (McGregor and Pittaway, 1985). However, these problems can be

overcome by regular monitoring of the project or by carrying out ex-nunc analyses at shorter intervals, McGregor (1980a).

(5) Including non-market external effects. If the projects impacts do not pass through an organised market, or are not registered close to the project site, or are immeasurable then the analyst has the problem of distinguishing between the real and the pecuniary impacts of the project and may have problems accounting for the former. The estimation of non-efficiency impacts of water and soil projects e.g. income redistribution, demographic change, regional development, etc., would require enormous research effort. There is no doubt that projects influence these things but the effects can be confounded by a large number of variables which may or may not be project related. Current knowledge and statistical information are inadequate to allow this filtering to occur.

In conducting an ex-post study care must be taken to evaluate the project in terms of the goals and objectives that prevailed when the project was planned.

8.7 CONCLUSIONS

In general there has been a failure by funding, promoting and implementing agencies to gather and use feedback information from ex-post and monitoring analyses to refine and develop the ex-ante technique. In the water and soil field ex-ante evaluation is at a relatively advanced stage but very little has been done to utilise feedback information. It has been policy of the Water and Soil Directorate to carry out ex-post analyses of selected schemes for a number of years but in that time only a small number of reports have been prepared and there has been no obvious attempt to incorporate the information obtained into a feedback mechanism.

The results presented in section 8.2 show that decision-makers should not accept the accuracy of ex-ante analyses without question. The major reasons for the poor estimation of benefits and costs shown in Table 8.1 are:

(1) Mistakes by the analyst and improvement in benefit valuation techniques in the time between the ex-ante and ex-post reports.

(2) Technological changes that have occurred in the intervening years.

(3) The beneficiaries perceived a higher level of protection from the scheme and developed the benefit area to a level higher than was anticipated, and

(4) The analyst, unlike the design engineer, lacked a comparative data base on which to base the subjective assessments of benefits.

The benefit calculations made by the analyst use the best information available at the time of analysis. Therefore technological changes and improved techniques used in valuing benefits cannot be predicted at the time of scheme analysis. However, the beneficiaries perception of benefit from schemes and the lack of a comparative data base can both be overcome by the implementation of a detailed monitoring and evaluation programme.

The monitoring and evaluation programme should look at the performance of the project and also address itself to project management, the financing of the project and the validity of the development. Such a system needs to be incorporated into the current monitoring and control procedures used in the implementation of projects. It is essential that the monitoring and evaluation of projects is rigorous so not all projects should come under intense scrutiny.

The data-base derived from the monitoring and evaluation programme should consist of information derived from a planned monitoring scheme of selected projects, as well as a series of ex-post analyses carried out on a wide range of

schemes. The benefits of a planned monitoring and evaluation system will be better decision-making and a more equitable distribution of the limited capital resource available. The results presented in section 8.2 would question the 15% increase in expenditure on irrigation and rural water supply schemes, at the expense of catchment works that has occurred over the past 10 years. To achieve this result it would be necessary to set up a specialist monitoring and evaluation unit with the express purpose of carrying out this work. Only when such an integrated management system is in place can decision-makers be sure that they are getting value for the taxpayers money that they spend and will we get flexibility in the management of such schemes.

The burden of monitoring and evaluation of water and soil projects should not fall on the funding agency alone. Those agencies that lobby for and implement schemes have as large a role to play as the Water and Soil Directorate. In fact they have a vested interest in showing that their proposals are successful as well as using the information obtained in the preparation of similar schemes for approval.

Finally, there will be no real improvements in water and soil decision-making unless information on the costs and benefits of schemes, already approved, are incorporated into the decision- making process. Haveman (1972) summed up the situation (in the U.S.) well when he stated "... because the behaviour of decision-makers in the public sector is influenced by lack of incentives to achieve efficient programmes, it is not unreasonable to presume that performance in this sector will not improve until people themselves are informed of the results of ex-post analyses." In New Zealand at present the evaluators, designers and decision-makers have little or no feedback on their work which could then be used in the planning and decision making process.

CHAPTER IX

SYNTHESIS - OUTLINE OF A SUITABLE PLANNING FRAMEWORK

New Zealand water and soil planning is currently facing the challenge of developing a framework which will allow management of the resources to the satisfaction of the wider goals and objectives of the New Zealand community. Such a planning framework is required to incorporate a wide range of goals and objectives, while at the same time be effective in reducing or overcoming the conflict between development, conservation, and preservation. Implicit in these changes is a shift from the single objective approach, adopted at present, to the multiple objective approach described in this document. The formal incorporation of multiple goals into the planning framework will mean that decision makers are fully informed of the consequences of their decisions.

This thesis has shown that a formal multiple objective planning framework would allow the incorporation of a wide range of goals and objectives into resource management decision making. To be effective in incorporating the goals and objectives of the wider community, planning needs to be interactive and based on clearly defined goals and objectives, and backed by a clear statement of the attributes to be measured. The planning process should recognise that water and soil resource planning needs to be responsive to local problems and concerns. This can be achieved by involving local people in the establishment of the local goals and objectives that will be used to analyse policies and development options. This cannot occur without some recourse to national goals and objectives. There is a clear need for the planning process to find local means to attain predetermined national goals and objectives. The degree to which the local planning process focuses on these national concerns will undoubtedly vary between regions and

between projects. From a national viewpoint there is a need to integrate water and soil planning totally into the national economic and social planning process.

Conflict and conflict resolution are an integral part of the planning process. The aim of the planning process should be to reflect a balance between competing preferences on how the water and soil resources should be used/protected, and the incidence of the socio-economic impacts of the policy or alternative. In the past it has been left to the planners and politicians to gauge what the public wanted and how it would respond to the services provided by national and regional government. There is now a need to integrate the public into the decision making framework so they can be involved in the shaping of options and in the decision making process.

Interest groups and individuals should be kept well informed as to the consequences of the policies and alternatives under consideration. The information supplied by the planning agencies should be in a form that is easy to assimilate. A further requirement is that the public must feel that it is involved at all points in the process. Responsiveness should include discussion of the public's view and indicate why this was or was not used in making the final decision. Advantages of involving the public in the decision making process are that interest groups will quite often gain a better understanding of the others needs with the consequence that there is a better understanding of the various viewpoints. In addition, the protagonists are forced to act responsibly in the decision between competing uses. This often leads to higher quality qualitative information, reduced delays caused by expensive planning hearings, and a wider range of options being made available to the analysts investigating the policies/alternatives.

An essential ingredient in effective planning is that the process is comprehensive. A comprehensive approach recognises the following features of planning:

(1) That there are several uses for the resource and each use has an effect on the others. Optimal use can only occur if all potential uses are considered simultaneously. Water and soil policy therefore needs to acknowledge that there are several ways of providing a service or meeting a problem. For instance, flooding problems can be minimised or overcome by a wide range of structural and/or non-structural alternatives. To date managers have only considered a small number of the options and as such sub-optimal choices may have been made.

(2) The complete range of possibilities is not restricted to single purpose alternatives. Multi-purpose projects can often enhance the use of the resources because several proposals can be pursued simultaneously resulting in a larger net gain in objectives.

(3) The inter-relationship of the alternatives under consideration with other resource developments need to be considered when setting the goals, objectives and attributes to be measured in the analytical phase of planning.

(4) That water and soil management requires inputs from a wide range of disciplines in addition to engineering e.g. economics, law, geography, sociology, biology and even psychology. The number and types of disciplines involved in each resource use conflict will reflect the specified goals and objectives of the scheme/policy under consideration and the nature of the problem.

(5) The need for a catchment approach to planning which recognises the total catchment as an integrated biological and physical entity for planning purposes. Such an approach will lead to integrated development and management of the resources of the defined area rather than haphazard development. The catchment approach to water and soil planning has

been policy for some time in New Zealand and regional and national recognition of this approach is high.

The national goal classifications which are suitable to analyse water and soil policy and alternative resource uses can be summarised as; national economic efficiency, environmental quality, other social effects, and regional economic development. However, from a theoretical point of view regional economic development should not be included in the analysis of national effects of policy/development. In New Zealand it should only be included if the national decision makers e.g. Government, feel it is important. It is the role of the decision making entities at both the national and regional (or local) levels to determine what goals and objectives are to be pursued, and the form these should take. It is essential that a two tier goal and objective structure be established. The first tier is the national interest and should be defined by Government. The second tier is the regional tier which should be defined by Regional Water Boards in conjunction with wide public participation from local groups and individuals that have an interest in water and soil policy and development.

The following discussion presents possible national goal definitions for initial discussion. These are based on the experience of the New South Wales State Water Plan and are a reiteration of, or an adaption of their goals.

(1) National Economic Efficiency: Maximise the net increase in goods and services, contributed to the national economy, arising from economically efficient water and soil resource allocation. This goal can be achieved by utilising additional resources and/or making more efficient use of existing resources.

(2) Environmental Quality: To ensure that water and soil management maintains the highest quality of life for all through the proper management, development, conservation, restoration and

improvement of natural resources and ecological systems, and of human built systems.

(3) Other Social Impacts: To provide for the people of New Zealand a quality of life characteristed to the highest degree by:

(a) freedom of thought and participation in decision making,

(b) diversity of lifestyles and employment opportunities,

(c) equality of economic and social opportunity,

(d) provision of society's help to disadvantaged members, and

(e) making available social services such as public safety, law and order, health and education.

(4) Regional Economic Development: Maximise the distribution of regional economic activity that results from water and soil policy and/or development. This goal should also emphasis growth for economically efficient industries in the region and foster economic diversity to insulate the economy from the effects of variations in climate, domestic and world markets and technology.

Discussion in Chapter 5 has shown that there is are adequate means available to quantify the effects of water and soil management proposals on the four goals specified above. The major draw-back at present is that experience with these techniques, especially environmental quality and social impact, is limited in New Zealand. Priority should be given to developing experience in the use of suitable measurement techniques if a multiple objective planning framework is to be developed in New Zealand. This should only occur under the umbrella of clearly defined goals and objectives at both national and regional levels. In addition, the development of expertise should be planned and thought given to the techniques which appear best suited to

conditions prevailing in New Zealand. The testing of techniques should be co-ordinated and well documented.

Chapters 6 and 7 have shown that multiple objective programming techniques have a place in formalising the analytical structure within which decisions about resource management are to take place. The objective of the analytical component of the decision making process is to provide adequate, intelligible information to the decision maker, in a form which is useful in the decision making process. Care should be taken to ensure that the decision maker is not swamped with a lot of superfluous information which confuses rather than clarifies the issue at hand. The example of the multiple objective programming technique, goal programming, presented in Chapter 7 has shown such techniques to be useful in this respect. They do not provide a panacea to the planning process but order debate and can be used to elicit trade-offs between competing/conflicting objectives.

The major advantages of these techniques is that they can be used to generate the trade-offs between quantitative and qualitative effects of schemes. The decision maker can then see the effects that marginal changes in policy have on the overall result. The example presented in Chapter 7 provided the marginal value product of incremental increases in minimum flow requirements in the Rakaia River. A further advantage of using a formalised analytical framework in the decision making process is that the experience gained in developing and running the model means that the analyst obtains a better understanding of the interactions and constraints placed on the resource. The modelling process also highlights areas that require further research effort. These may be so important that research needs to be focused on these areas before a decision can be made.

Finally, there will not be any real improvements in water and soil decision making unless information on the costs and benefits of schemes, already approved, are incorporated into the decision making process. At present

there has been a general failure by funding, promoting and implementing agencies to gather and use feedback information from ex-post and monitoring analyses to refine and develop the ex-ante technique. The results presented in section 8.2 show that decision makers should not accept the accuracy of ex-ante analyses without question but need information supplied from an established monitoring and evaluation programme. Such a programme should not only look at the effects of a project/policy but should also address itself to the management of the project/policy. Only when such an integrated management system is in place can decision makers be sure they are getting value for the taxpayers money that they spend in managing the water and soil resources of New Zealand.

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APPENDIX A

SUMMARY OF THE STATUTES, POLICIES, AND BODIES DEALING WITH WATER AND SOIL MANAGEMENT, AND THEIR MODE OF OPERATION IN MANAGEMENT

Statute/Policy/Body	Mode of Operation
1884 River Boards Act	Laid down a constitution for the existing River & Drainage Boards and River Trusts set up from the 1860's.
1893 Land Drainage Act	Ensured that the functions of river control & drainage were interchangeable.
1908 Fisheries Act	
1908 Land Drainage Act	Constituted 36 land drainage boards.
1908 Rivers Boards Act	Constituted 38 river boards.
1910 Waihou & Ohinemuri Improvement Act 1915 Swamp Drainage Act 1926 Hauraki Plains Act	A series of acts which allowed the Government to develop large & difficult areas of flood-plains and swamps. The Hauraki Plains Act allowed the flood protection and drainage of 50,000 hectares.
1926 Town Planning Act	Required that all cities and boroughs with more than 1000 inhabitants prepare a town planning scheme before 1 January 1930.
1941 Soil Conservation & Rivers Control Act	Formed Soil Conservation and Rivers Control Council. Primary functions were the promotion of soil conservation, prevention and mitigation of soil erosion. Provided for the setting up of Catchment Boards
1953 The Wildlife Act	Law relating to the protection control of wild animals and birds. Provided for wildlife sanctuaries which included water as well as land.

Statute/Policy/Body	Mode of Operation
1953 Water Pollution Act	Prevention of (but not reversal of) pollution of natural waters and setting up of the Pollution Advisory Council.
1953 Town and Country Planning Act	Territorial Local Government was charged with the responsibility of preparing district schemes. Land use planning became a mandatory function. An independent Appeal Board was established to adjudicate on disputes arising from the preparation and operation of district schemes.
1954 Pollution Advisory	Education, persuasion, good-will, co-operation with dischargers.
1963 Water Pollution Regulations	Water quality standards for desired water uses in appropriate classified water bodies.
1963 Town & Country Planning Appeal Board established	
1966 Water and Soil Division formed	Administration, research, surveys and classifications.
1966 Town & Country Planning Act Amendment	Widened scope of 2nd Schedule to include such matters as control of development and the land likely to be affected by geothermal activity, flooding, erosion, landslip and subsidence.
1967 Water and Soil Conservation Act	Water right classifications national & regional management structure. Penalty provision.
1967 National Water & Soil Conservation Authority formed	Responsible for overall national policies on soil conservation and water management.
1967 Regional Water Boards formed	Water rights, regional control and management.

Statute/Policy/Body	Mode of Operation
1969 Second Town & Country Planning Appeal Board established	
1970 Economics Division of Dept. Agriculture formed.	Separate body for economic analysis
1971 Water and Soil Conservation Act Amendment No. 2	Consolidation of national water classification standards
1971 Mining Act	Provides for the mining of all Crown owned minerals, but does not apply to coal, petroleum or geothermal energy
1972 Water Resources Council Formed	Responsible for irrigation and rural water supply schemes, allocation of natural water and maintenance of natural water quality
1977 Town & Country Planning Act	Major review and consolidation of the planning legislation. Sec. 3. covered matters of national importance.
1977 Reserves Act	Made provision for the acquisition, control, management, preservation (including the protection of the natural environment), development, and use of public reserves
1979 National Development Act	Provides for the prompt consideration of works of national importance by the direct referral of the proposals to the Planning Tribunal
1980 Town & Country Amendment	Provision for joint hearings under Town & Country Planning and Water & Soil Conservation Acts.

Statute/Policy/Body	Mode of Operation
1981 Water and Soil Conservation Amendment Act	Provides for the preservation protection of wild, scenic, and other natural character- istics of rivers, streams and lakes by means of national water conservation orders or local water conservation notices.
1981 Public Works Act	Provides legislative authority for irrigation schemes and for rural water supply schemes
1983 Water and Soil Amendment Act	Abolished the Soil Conser- vation and Rivers Control Council & the Water Resources Council. Provisions for the reconstituted National Author- ity to be heard at Planning Tribunal hearings arising from draft water conservation orders, increases in penalties for offences relating to water, the functions, powers, etc., of regional water boards, rights in respect of natural water, costs of admin- istering water rights, and providing for clean-up costs for unlawful discharges to be passed onto the offending party.
1985 Draft Water and Soil Bill	The general objectives of the proposed bill are "...to main- tain, manage, and improve the water and soil resources of New Zealand in such a way as it will best provide for the well-being of its people"

APPENDIX B

OBJECTIVES OF THE DRAFT WATER AND SOIL BILL

The following are the objectives of the draft Water and Soil Bill (MWD, 1985), which has been drafted to consolidate and amend the law relating to water and soil conservation in New Zealand.

(1) The general objective of this Act shall be to maintain, manage, and improve the water and soil resources of New Zealand in such a way as will best provide for the wellbeing of its people.

(2) Without limiting the generality of subsection (1) of this section, the objectives of this Act shall include:

(a) the promotion of:

(i) National, regional and local policies for achieving the general objective of this Act as specified in subsection (1) of this section;

(ii) A co-ordinated administration and management of water and soil resources by all bodies and persons which or who have statutory functions, rights, powers, or duties relating to sustaining, managing, and improving those resources;

(iii) The recognition and implementation of the objectives of this Act in the policies and plans of Government departments and public authorities;

(iv) The use of land and water so as to further the objectives of this Act; and

(v) Provisions in regional, district and maritime planning schemes under the Town and Country Planning Act 1977 which implement the objectives of this Act.

(b) the planned maintenance and improvement of water supplies, water quality, water levels, and water flows to meet all current and foreseeable needs;

(c) the recognition, protection and preservation of the amenity, and cultural and recreational values afforded by waters and their surrounds;

(d) the prevention, mitigation, and avoidance of flooding, erosion, subsidence, and sedimentation;

(e) the identification of land subject to, or likely to be subject to flooding, erosion, subsidence or sedimentation and the avoidance of the use of such land in a manner that is likely to lead to, or increase the risk of danger to life or damage to property or the amenities of an area;

(f) the control of water and erosion that may cause risk of danger to life or damage to property or the amenities of an area and the avoidance of land uses that are, or are likely

to lead to, or increase the risk of such danger or damage; and

(g) the control of discharges, water abstractions and dammings, land drainage, and the extraction of soil, peat, sand, and gravel so as to achieve the general objective of this Act as specified in subsection (1) of this section.

(3) In giving effect to the objectives specified in subsections (1) and (2) of this section and generally in the administration of this Act, the matters to be taken into account shall include the following:

(a) the present and future needs of primary and secondary industry and of the community, including the water supplies of local authorities, in respect of water and soil resources;

(b) all forms of water based recreation, fisheries and wildlife habitats and the wild, scenic and other natural characteristics associated with water in its surrounds;

(c) the role of water in maintaining and improving the natural qualities and conditions in an area that contribute to the pleasantness, harmony, and coherence of the environment and to its better enjoyment;

(d) the cultural beliefs of people, including the relationship, as determined by customary usages and practices, between the culture and traditions of the Maori people, and any land and bodies of water;

(e) the provisions of any relevant regional, district, or maritime planning schemes under the Town and Country Planning Act 1977.

APPENDIX C

RESULTS OF A SURVEY INTO THE SHORTCOMINGS OF THE ANALYSIS OF WATER AND SOIL PROJECTS IN NEW ZEALAND

Early in 1985 survey forms were sent to 40 people involved with the analysis of water and soil based projects. Those surveyed ranged from evaluation field staff, e.g. MAF Economics Division, Water and Soil Directorate and private consultants, to the advisers to the decision-makers, e.g. Water and Soil Directorate and Treasury.

The response rate of 53% was high considering the high proportion (18%) who no longer had an active interest in this area or were overseas at the time of being surveyed.

Each person surveyed was asked the question:

> In your opinion what areas require research within the broad topic area "the economic and financial analysis of water and soil development projects from the national and individual farmer point of views".

The response to this question are summarised below in no particular order of priority.

(1) Financing of Schemes and the Need for Intervention:
- (a) A critical examination of the economic conditions under which the Government should intervene to assist in the promotion of water and soil projects.
- (b) The range of intervention policies (pricing, taxes, planning, regulation, common law remedy, subsidies, etc.) open to Government and the relative cost- benefit efficiency of these in equating individual with social cost.
- (c) Should the Government or the community subsidise water and soil schemes at all, particularly in the light of the high returns achieved by some river control, rural water supply and horticultural irrigation schemes.
- (d) Should the responsibility for water and soil schemes devolve completely to the regions and not be the concern of central government at all.
- (e) The need to determine the level of subsidy that various types of project need to be economic from the farmer and national viewpoint.

(2) Accounting for Risk and Uncertainty in Project Appraisal:
- (a) Scheme design in relation to farmers risk preferences.
- (b) How to incorporate the risk of an individual project within the total portfolio of projects.

(c) Most cost-benefit analyses give little recognition to the unreliability of the information on which they are based. MAF Economic Division is starting to do risk analyses, but this is only the first step. The need is for more information on risk and the means to make better use of that information. The areas of inadequacy are:

(i) the nature of the probability distribution appropriate to each variable. The usual assumption of a normal distribution will not always be desirable. A model which admitted other types of distribution would enable such things as floods to be dealt with directly as a statistical event.

(ii) the variance applicable to each factor. Where risk or uncertainty analysis is carried out now, the variation tested is often largely arbitrary, from a lack of information.

(iii) the interrelationships between variation in different variables need to be accounted for. Independence is usually assumed in the absence of information to the contrary.

Dealing with the above in a fully general way is possible only with Monte Carlo simulation. The question remains, can water and soil projects be adequately expressed in a manner simple enough to permit more direct methods?

(d) Development of risk analysis techniques that take account of the dynamic nature of water and soil conservation schemes rather than concentrating on product prices.

(e) The conventional analysis does not take into account the effect of irrigation on a farmer's ability to avoid risk of drought. The use of long term averages conceals one of the advantages of a reliable water supply compared with the variability of dryland farming.

(3) The Place of Cost-Benefit Analysis in Scheme Design:

(a) Use for the optimising scheme design alternatives.

(b) Under present procedures the economic analysis of a water and soil scheme does not usually commence until the design of the project is largely completed. Even where some overlap does occur, there is little apparent feedback from assessment to the design team. As a result design decisions are made on technical criteria, or from personal preference or tradition, rather than based on improvement resulting from an economic appraisal of alternatives. There is a need to integrate

economic assessment into the design and approval process.

(4) The Identification of Benefits and Costs Including the Monitoring and Ex-Post Analyses of Schemes:

(a) Consideration of existing reviews of past schemes and incorporating this into the current planning process.

(b) There is a need to question the accuracy of current ex-ante analyses e.g. the impact of irrigation schemes on increasing the production possibilities into horticultural crops is currently under- estimated.

(c) What is the best way to monitor schemes and is there a need for a defined policy in respect of this?

(d) The benefits associated with technology changes are not known and hence not included at the time of scheme analysis. Whilst it is not possible to forecast these changes at the time of analysis it would be useful to know what changes have taken place within schemes in the years after implementation.

(5) Valuation of So Called Intangibles:

(a) There are currently problems associated with incorporating recreational and environmental losses and gains into a cost-benefit analysis framework. Such effects are involved with nearly all water and soil projects, but are usually ignored. The problem seems to be as much in assessing the effects as in valuing them.

(b) When should non-market valuations be attempted and will the results be acceptable to agencies and decision-makers?

(6) Public Versus Private Returns:

(a) It is a major shortcoming in present practice that the farmers returns from a scheme are ignored. However, this is probably better than the assessment of first order effects alone. There is a need to examine second order effects since they may be significant in some schemes. This means assessing the income redistribution occurring as a result of individual schemes and policy measures. Determining the ultimate beneficiaries of projects, and especially heavily subsidised ones, is far from easy but would be most illuminating if it could be successfully achieved.

(b) Formulation of an evaluation and decision-making system for funding schemes in accordance with the national and individual returns generated by the scheme.

(7) What is the Appropriate Discount Rate to use in Water and Soil Projects?:
   (a) What is a suitable discount rate to use on projects which have their benefit streams a long way into the future?
   (b) What is the internal rate of return cut off point that is needed to make water and soil projects comparable with private sector and other public sector projects?

(8) Regional Effects and the Appropriate Scheme Boundary:
   (a) Distributional issues of who pays for and benefits from projects. Thoughts so far suggest that the economic boundary should be extended from the farm gate to the border while retaining the partial equilibrium assumptions of the evaluation. A practical methodology needs to be thought through, tested and then lobbied for.
   (b) A more careful analysis of the downstream effects of production from irrigation e.g. effects on economic activity, employment, etc.
   (c) Is the current scheme boundary applicable from the point of view of recreational benefits? Partial analysis suggests that demand for recreation within the scheme area is unsatisfied, i.e. recreational activity will not be transferred from outside, to within the scheme area. If this does occur, then the benefit to the nation is nil, yet under partial analysis it is likely to be counted as a benefit.

(9) Marginal Versus Average Pricing of Inputs and Outputs:
   (a) The present practice is to value changes in agricultural production using medium term price forecasts. However, these measure average returns whereas it is the marginal returns that are relevant. The little research published so far suggests that the difference between the two is substantial.
   (b) The implications of evaluations at the margin, especially with respect to price parameters i.e. the use of marginal revenues rather than average returns.

(10) Multiple Objective Planning and the Decision-Making Process:
   (a) Determine the factors taken into consideration by decision-makers when considering water and soil projects.
   (b) The wider perspective of project selection, i.e. a multiple objective planning framework.
   (c) The issues of multiple objective functions and economic criteria for cost-benefit analyses. Included here is regional benefits.
   (d) Prepare a consistent format for economic reporting that presents findings in terms of

social worth rather than just economic returns.

(11) General:

(a) Place more emphasis on the practice rather than on the theory of cost-benefit analysis. It appears that the practice is the area where improvements would be of greatest significance.

(b) Look at the total expenditure within the water and soil field with a view to optimising the annual returns.

(c) The use and limitations to the use of mathematical modelling techniques in water and soil planning.

(d) The relative emphasis placed on cost-benefit analysis for water and soil projects compared with expenditures in other sectors e.g. roading, housing, forestry, land development, etc.

(e) An examination should be made of the economics of large river maintenance schemes where huge amounts of money are spent every ten years on the basis that if it is not spent previous work will deteriorate. An answer to this would be adequate maintenance provisions built into schemes.

(f) Development of a consistent and easily used method for modelling aspects of soil conservation projects.

APPENDIX D

NEW SOUTH WALES STATE WATER PLANS GOALS AND WATER MANAGEMENT GOALS

D.1 ECONOMIC

(1) State Economic Goals:

(a) To maximise the economy's total output of goods and services demanded by the community, by ensuring economically efficient resource allocation.

(b) To foster continued expansion of the State and regional economies via growth and development of economically efficient industries.

(c) To foster economic diversification, both industrial and geographical, to provide the economy with some insulation from the effects of variations in climate, domestic and world markets and technology.

(2) State Water Management Goal:
To maximise the contribution of water, and water industry funds, to the achievement of the State's economic goals.

(3) Economic Objectives:
The water management goal can be broken down into the following objectives or operational aims:

(a) To provide water and water services which generate private benefits in accordance with the community's demands for those services and for the goods and services produced with their use.

(b) To improve the efficiency with which water and water services are delivered and used.
This objective has two components and may be considered in two parts:

(i) to make cost effective improvements in the efficiency with which water services are delivered

(ii) to promote efficiency in the use of water and water services, where 'efficiency' embodies appropriate adjustments to changes in technology and, where water is a productive input, to changes in market conditions for goods produced

(c) To publicly fund the provision of water and water services where these generate net public benefits for which individual beneficiaries cannot be identified and/or charged.

D.2 ENVIRONMENTAL

(1) State Environmental Goal:
To maintain the highest quality of life for all through the proper management, development, conservation, creation, restoration and improvement

of natural resources and ecological systems and of the human-built environment.

(2) State Water Management Goal:
To ensure that water industry management is consistent with the achievement of the State's environmental goals.

(3) Water Management Objectives:
(a) To ensure that a supply of water can be provided at an appropriate reliability for all water uses and other water services.
(b) To ensure appropriate standards for all water uses and other water services.
(c) To preserve a full representation of environments associated with water which have scientific, cultural and aesthetic value or interest.

D.3 SOCIAL

(1) State Social Goal:
To provide for the people of New South Wales a quality of life characterised to the highest degree by:
- freedom of thought and participation in decision-making
- diversity of lifestyles and employment opportunities
- equality of economic and social opportunity
- provision of society's help to its disadvantaged members
- availability of social services such as public safety, law and order, health and education.

(2) State Water Management Goal:
To manage the provision and use of the State's water services so as to facilitate, as far as possible, the achievement of the State's social goal.

(3) Water Management Objectives:
(a) To improve non-material aspects of the quality of life through the provision of water services where these generate public benefits such as health, safety, diversity of lifestyles and employment opportunities.
(b) To set prices and charges for water industry services so that there is an equitable distribution of net benefits.

D.4 RATING SCALES AND CRITERIA FOR ECONOMIC OBJECTIVE 1

Rating Scale	Criterion
Beneficial high: (6)	A project with outstanding private benefit potential, as measured by N.P.V./unit investment.
Beneficial: (5)	A project with attractive private benefit potential.
Beneficial low: (4)	A project with acceptable private benefit potential.
Neutral: (3)	A project which breaks even i.e. where benefits equal costs.
Adverse low: (2)	A project with low private benefits.
Adverse: (1)	A project with very low private benefits.
Adverse high: (0)	A project with no private benefits.

D.5 RATING SCALES AND CRITERIA FOR ENVIRONMENTAL OBJECTIVE 1.

Rating Scale	Criterion
Beneficial high: (6)	An option which causes an <u>improvement</u> in the conditions within or affecting a <u>high value</u> ecosystem which may result in a <u>substantial increase</u> in the extent, diversity and/or effectiveness of its habitats.
Beneficial medium (5)	An option which causes an <u>improvement</u> in the conditions within or affecting a <u>medium value</u> ecosystem which may result in a <u>substantial increase</u> in the extent, diversity and/or effectiveness of its habitats. <u>OR</u> An option which causes an <u>improvement</u> in the conditions within or affecting a <u>high value</u> ecosystem which may result in a <u>minor increase</u> in the extent, diversity and/or effectiveness of its habitats.

Rating Scale	Criterion
Beneficial low: (4)	An option which causes an improvement in the conditions within or affecting a low value ecosystem which may result in a substantial increase in the extent, diversity and/or effectiveness of its habitats. OR An option which causes an improvement in the conditions within or affecting a medium value ecosystem which may result in a minor increase in the extent, diversity and/or effectiveness of its habitats.
Neutral: (3)	No change in the conditions within or affecting any natural ecosystem.
Adverse low: (2)	An option which causes a deterioration in the conditions within or affecting a low value ecosystem which may result in a substantial reduction in the extent, diversity and/or effectiveness of its habitats. OR An option which causes a deterioration in the conditions within or affecting a medium value ecosystem which may result in a minor reduction in the extent, diversity and/or effectiveness of its habitats.
Adverse medium: (1)	An option which causes a deterioration in the conditions within or affecting a medium value ecosystem which may result in a substantial reduction in the extent, diversity and/or effectiveness of its habitats. OR An option which causes a deterioration in the conditions within or affecting a high value ecosystem which may result in a minor reduction in the extent, diversity and/or effectiveness of its habitats.
Adverse high: (0)	An option which causes a deterioration in the conditions within or affecting a high value ecosystem which may result in a substantial reduction in the extent, diversity and/or effectiveness of its habitats.

D.6 RATING SCALES AND CRITERIA FOR SOCIAL OBJECTIVE 2

Rating Scale	Criterion
Beneficial high: (6)	An option which generates a substantial permanent income increase in a disadvantaged area.
Beneficial medium: (5)	An option which generates a moderate permanent income increase in a disadvantaged area or a substantial increase in any other.
Beneficial low: (4)	An option which generates a temporary substantial or a substantial or moderate permanent income increase in other areas or minor increases in disadvantaged areas.
Neutral: (3)	An option which has an insignificant effect.
Adverse low: (2)	An option which causes a moderate permanent or substantial temporary income reduction in other areas, or a minor decrease in disadvantaged areas.
Adverse medium: (1)	An option which causes a minor income increase in other areas; or a moderate permanent or substantial temporary decrease in disadvantaged areas.
Adverse high: (0)	An option which causes a substantial income decrease in a disadvantaged area.

APPENDIX E

AN APPROACH INCORPORATING SOCIAL IMPACT ASSESSMENT INTO THE PLANNING PROCESS

One approach to better planning, and public input into project design and implementation, is the incorporation of social impact assessment into the planning process. Such an approach has been proposed for use in New Zealand by the Town and Country Planning Directorate of the Ministry of Works and Development, Ministry of Works and Development (undated). Their recommendations are based on lessons learnt from the major resource developments in Taranaki and Northland.

The objectives of this approach are "... to promote and maximise cooperation, coordination and communication between participants who represent all levels of the affected community, including the developer". The aims of the approach are to form an early and continuing flow of information between all participants in the development which will:

(1) Ensure that information is collected and available,
(2) Simplify channels of communication,
(3) Minimise duplication by keeping participants in touch,
(4) Alert the developer and others to the implications of the development, so that planning strategies can be adopted by all participants to gain maximum benefits and minimise costs,
(5) Clarify the objectives of all groups in the region in relation to the development,
(6) Encourage public participation and involvement by using existing community groups, or helping them to form where none exist. These groups can:
    (a) obtain information to assess the range of impacts likely to occur, and if necessary comment on the planning and use of resources;
    (b) obtain a commitment from local people to act on what they believe is relevant to them and their region, in planning and management of the development.

The process used to achieve this objective and aims is shown in Figure E.1.

FIGURE E.1

Process for Assessing the Social Impacts of Major Developments

Step 1. The regional or united council sets up a regional steering group.

2. A seconded worker (or team) to the regional or united council sets up technical advisory group(s) on the regional steering groups behalf.

3. Specialist technical advisory group(s) provide information to the regional steering group from all levels of the community.

4. A community development worker is employed to ensure full public community participation.

5. The regional steering group negotiates with central, regional and local government, and the developer to ensure that if the project proceeds, costs to the region are minimised and maximum benefits are gained. (steps 3 to 5 are ongoing)

6. The developer prepares a social/environmental impact report.

7. The Commission for the Environment prepares an audit of the impact report.

8. Planning permission is given or refused.

A PROJECT PROCEEDS

9. Payment of the development levy is made by the developer.

10. Monitoring is established in areas of potential impacts.

CONSTRUCTION ENDS

11. The completion of the construction phase of a large industrial project is likely to bring social impacts with it which, while different in nature from the construction stage, will be equally as important. Monitoring and action should continue with all of the central government and regional coordination approaches still in operation.

OPERATIONAL PHASE BEGINS

12. The regional steering group, technical advisory group(s), seconded worker and monitoring functions are reassessed.

Source: Ministry of Works and Development (undated)

TABLE E.2
Relations of Social Science Variables, used in Reports, and OSE Components

OSE Components	Baseline Variables
A. Urban and Community Impacts 1. Income Distribution a. General b. Low-income households 2. Employment Distribution a. General b. Minorities 3. Population a. Distribution b. Composition 4. Fiscal condition of government a. State b. Local 5. Quality of community life a. General community quality elements; these may include a broad perspective of elements such as: attitudes, infrastructure, disorganisation, facilities	A. Socioeconomic and Social Differentation 1. Income a. General income b. Income levels c. Income distribution 2. Employment a. Employed b. Unemployed c. Minority employment d. Employment availability B. Population 1. General 2. Number 3. Change 4. Characteristics 5. Mobility & migration 6. Housing 7. Occupation 8. Projections C. Government Fiscal Conditions 1. Taxes 2. Community finances D. Quality of Life or Lifestyle 1. General community quality elements a. Subjective aspects (i) Attitudes toward community: satisfaction, feelings etc. (ii) Perceptions of effects of the project on the community b. Community viability and cohesion 2. General lifestyle patterns 3. Community disorganisation, crime, displacement, poverty breakdown of informal systems 4. Mass communication 5. Transportation facilities

Table E.2 (continued)

OSE Components	Baseline Variables
	6. General individual quality elements a. Subjective aspects (i) Perceptions of the effects of the project on the individual
	E. Community Institutional Infrastructure 1. Health care 2. Safety services 3. Sanitation services 4. Public utilities 5. Schools 6. Government 7. Welfare and social services 8. Religious institutions 9. Recreation opportunities 10. Cultural opportunities 11. General and others
	F. Other Subjective Components 1. Attitudes towardthe project 2. Perceptionsofthe environment 3. Aesthetic elements 4. Other attitudes 5. Level of knowledge about the project
	G. Background & Historical Factors that affect Planning
	H. Land Use Patterns: rural-urban, etc
	I. Special Groups Affecting Planning 1. Ethnic groups 2. Interest groups
	J. Economic Resources of the Area That Affect the Community & Planning: e.g. lumber, mining, agriculture (Also related to safety services of police and fire protection and health and sanitation services.)
B. Life, Health and Safety 1. Risk of flood 2. Risk of drought 3. Other disaster C. Displacement 1. People 2. Business 3. Farms	(Related to attitudes and perceptions toward the project, and community disorganisation components)

Source: U.S. Water Resources Council (1981)

APPENDIX F

METHODS OF CALCULATING REGIONAL DEVELOPMENT EFFECTS

F.1 REGIONAL MULTIPLIERS AND THE BOUNDARY DEFINITION

Multipliers are used to measure the net impact of capital expenditure on an economy, in this case the regional economy. The size of the multiplier is determined by a number of factors. These are; the size of the initial expenditure, the degree of resource under employment in the region, and the degree of leakage from an economy in the form of savings, taxes and imports. Figure F.1 provides a diagramatic representation of regional multiplier effects. At the regional level the multiplier effect is significantly affected by the level of imports into the regional economy. The regional economy is more reliant on imports because in addition to importing from another country, the region must import from other regions.

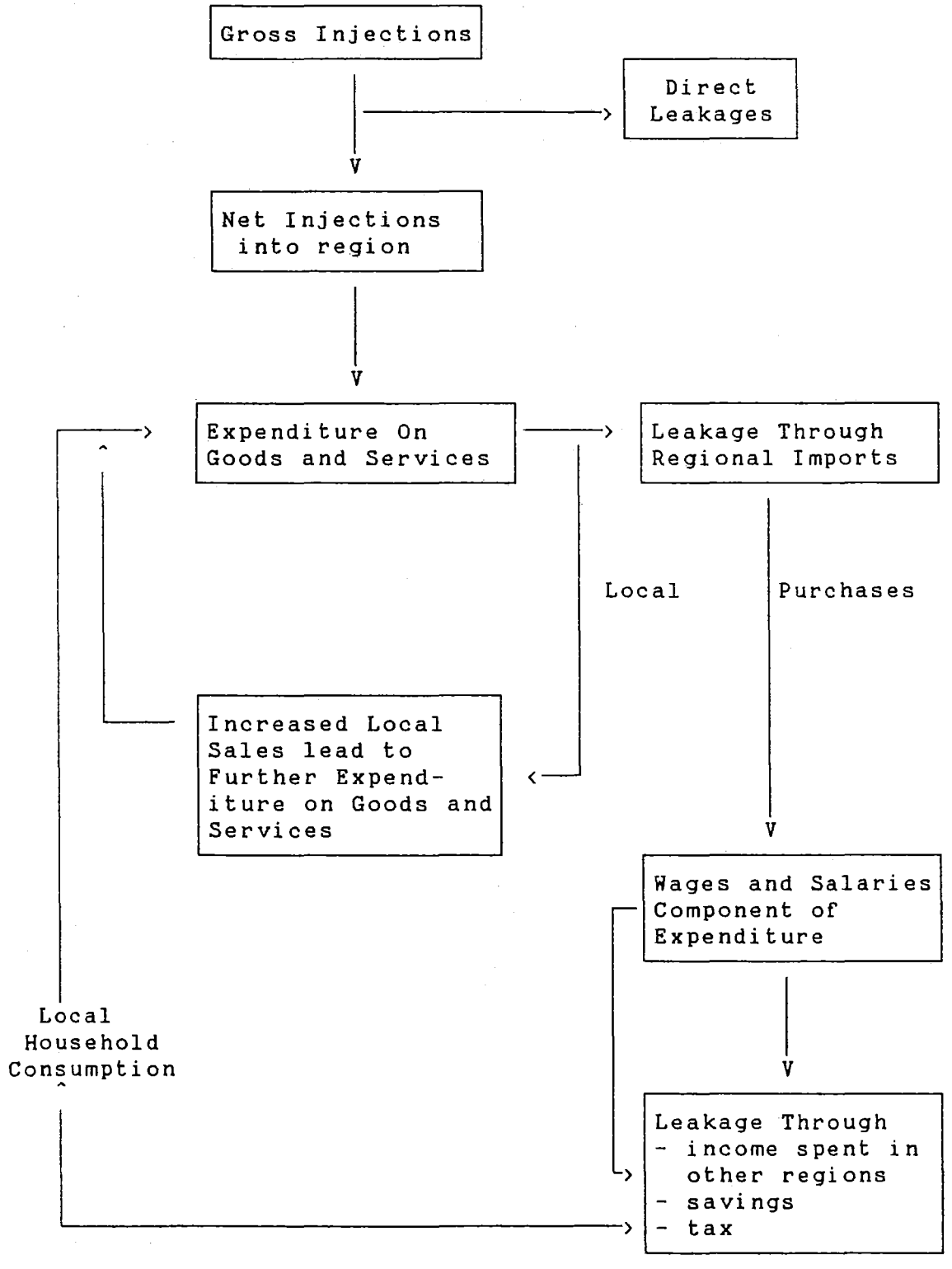
The first requirement of a regional development study is to define the region. This is difficult as economic regions are unlikely to coincide with Local Body, statistical or planning boundaries. This means that data for use in regional studies is aggregated in a format that makes it difficult to disaggregate, or is non-existent. In many cases it is necessary to broaden or contract the economic boundary to obtain useful information, Hubbard and Brown (1979). The cost of collection of new regional data for anything but significant projects is normally prohibitive.

Once the regional boundary is defined the next step is to determine the injections of project capital into the region. This will act as the initial stimulus for the multiplier effects. Capital injections in land betterment projects are typified by expenditure on; scheme and on-farm capital, operations and maintenance expenditure, and income from increased agricultural production.

A number of methods are available for calculating the regional multiplier effects of projects. These have been discussed by Butcher (1986), Hubbard and Brown (1979 and 1981), and Shaffer (1979). The following sections will discuss two of the most commonly used methods, the export base and input-output approaches, for determining regional impacts of development.

FIGURE F.1

Diagramatic Representation Of Regional Multiplier Effects (Source: Hubbard and Brown, 1979)



F.2 EXPORT BASE MODELS

Export base models assume that all economic activity can be categorised as either basic or non-basic, Hubbard and Brown (1979). Further the basic activities are those which derive income from exports and non-basic activities earn income from within the region. The most simple version of the model is:

$$Y = C + X \qquad (1)$$

where: Y = regional income
C = non-basic or domestic income, and
X = basic or export income (includes exports to other regions and other countries)

The value for C is a function of the regional income and X is determined outside the region, so (1) can be rewritten as:

$$Y = cY + X \qquad (2)$$

In words the equation means that a change in export income leads to a change in regional income. This additional regional is spent within the region leading to a change in domestic income, and so on. Therefore the change in regional income is a multiple of the change in regional export income. The multiple or multiplier can be denoted by k.

$$Y = (1/1-c)\ X$$

and,

$$k = dY/dX = 1/1-c = Y/X \quad (3)$$

The multiplier can therefore be calculated by estimating either 1/1-c or Y/X.

A requirement of the export base approach is that all economic activity can be split into basic and non-basic components. This can be done by using survey methods or an indirect approach like the location quotient approach.

(1) Survey methods: The major problem with survey methods is that the costs associated with surveys normally makes their use prohibitive. In addition, the accuracy of surveys is very dependent on the accuracy of the respondents answers but the survey methods, if done correctly, should yield the most accurate estimate of the export base and the multiplier, Shaffer (1979).

(2) Location quotient method: This method works on the assumption that the relative distribution of the economic sectors in the local economy should approach that of the national economy. Further, if the local economy has proportionally more income or employment in specific section of the local economy then that sector is producing for export. Estimates of the basic employment or income for each sector are summed across all sectors to give the total basic employment or income for the community.

The advantages of the location quotient method are:

(a) in its simplest form it is very inexpensive,
(b) data requirements are not extensive,
(c) calculations can be done by hand, and
(d) it is easily understood by the layman.

Problems with the location quotient method are:

(a) There is an implicit assumption that local demand and productivity conditions are identical to national averages. This may not necessarily be so.

(b) This approach has been found to underestimate the export base and therefore produced inflated multipliers. Davis (1975) found that export based multipliers generated using location quotients were 6.19, using survey methods were 2.39 and using input-output tables were 1.64. Similar results were found by Hubbard and Brown (1979). They found export based output multipliers for the combined Waitaki and Waimate Counties of 3.09 compared with those derived using input-output tables for the Otago statistical district of 2.30.

Another problem noted with export based models, Shaffer (1979), is that they yield an average multiplier for all businesses in the export sector and therefore do not differentiate between the different components of the export base initiating the change within the region. This can be overcome by disaggregating the data but the data available in New Zealand is not sufficient to allow this to occur to any great extent, Hubbard and Brown (1979). In their study of the regional impacts of irrigation development in the Lower Waitaki, found that disaagregation of data led to lower multipliers.

F.3 THE USE OF INPUT-OUTPUT TABLES

Input-output analysis is used in regional analysis to provide a framework for showing the direct input requirements and sales of local industries; the interrelationships between local industries, and links to the outside. The approach is based on a system of accounts that represent transactions between sectors within an economy and the interrelationships with economic activity outside the assigned boundary. These show how the value of outputs from each producing sector is distributed among other sectors within the study area and outside the area.

Input-output tables, refered to as transactions tables, are developed by assigning each industry a row and column. Next inter-industry transactions are inserted in the appropriate cells. Any part of an industries output not used as an input by another industry is placed in final demand. This means it is consumed or exported. The same principle applies to inputs that are not outputs of another industry e.g. imports, labour, etc. These are treated as primary inputs. There is one final sub- matrix which is devoted to the transactions between final demand and primary inputs. To

find sources of industry inputs, read down columns and the destinations of industry outputs can be found by reading across rows. The general form of the input-output table is shown in Figure F.2.

FIGURE F.2

Representation Of An Input-Output Table
(Source: Hubbard and Brown, 1979)

	Industry Sector (Purchasing) 1 2 3 ..... n	Consumption, Exports, etc.	Totals
Industry Sector (Producing)	Transaction Matrix	Final Demand	
Labour, Imports, etc.	Primary Inputs		
Totals	Totals		

The tables developed use the accounting principle that the sum of all outputs sold to other sectors and industries must equal the sum of all inputs purchased from the other sectors and industries. This then makes it possible to trace the interdependence between sectors within the economy and the flow of goods needed in the input-output process. The input-output approach allows the analyst to distinguish direct impacts, indirect impacts and if the model is closed, induced impacts.

Multiplier effects are then derived from the input-output tables. Multipliers account for the fact that the total impact of changes in the economy will vary according to which sectors experience the expenditure change, Richardson (1972). Three types of multiplier can be calculated. These are:

(1) Output multipliers. These estimate the direct, indirect, and induced economic activity that is generated by a study area's economic system given an increase of one dollar in final demand in any given sector, Jordan, et al. (1985). They can also be used to compare the contributions to total economic activity from the sales of each processing sector. They therefore indicate the degree of structural interdependence between each sector and

the rest of the economy i.e. the higher the multiplier the greater the interdependence.

(2) Income multipliers. These measure the direct, indirect, and induced effects on household income due to an increase in expenditures for labour in a given sector. They take into account the repercussive effects of secondary rounds of consumer spending in addition to the direct and indirect effects.

(3) Employment multipliers. These show the direct, indirect and induced effects of increasing (or decreasing) final demand on an economy's employment.

The output, income, and employment multipliers that can be derived from a transactions matrix and provide a comprehensive set of data that can be used to assess the impacts of changes in the regional economy.

As with the export based methods the input-output approach has a number of underlying assumptions. These have been described by Goldman (1975) as follows:

(1) Each sector has a linear production function,

(2) Each sector is homogenous in economic character i.e. each business within an industry grouping will look and operate much the same,

(3) Any changes in sales outside the community do not effect economic flows in the community i.e. can isolate the economic traits of a community,

(4) The analysis is static and therefore it is assumed that there will be major changes in the structure and size of the local economy, nor changes in technology over the period of time between revisions.

The major problems identified with the technique are:

(1) The models require detailed data especially when disaggregated to a provincial basis. This often means that the analysis is carried out irregularly and thus studies become out of date. In addition, the costs of carrying out surveys and the high probability of errors in these means that other methods have been developed which achieve input-output matrices without a vast data requirement. This has led to the development of semi-survey and non-survey methods. One such approach, the technique for Generating a Regional Input-output Table (GRIT), was described by Jensen, et al (1977), and applied in New Zealand as a non-survey technique by Hubbard and Brown (1979 and 1981), and as a semi- survey technique by Butcher (1985 and 1986). This method develops regional models from national tables using readily available secondary data. The accuracy of the semi-survey methods is high but the accuracy of the non-survey methods has been questioned by Shaffer (1979) and Morrison and Smith (1974). These methods do, however, provide a relatively quick, easy and

inexpensive method of assessing the effects of development on a region.

(2) The models developed are not normally based on primary data at the disaggregated level i.e. provincial level, and use some form of share approach e.g. location quotients, based on a national model. It therefore assumes that the production functions of firms at the regional level are the same as firms at the national level.

(3) The number and complexity of calculations requiring access to computers but this is becoming less of a problem with programs, such as that developed by The University of Georgia, Jordan, et al. (1985), now being developed for micro-computer systems.

F.4 THE GRIT METHOD OF DERIVING MULTIPLIERS

The GRIT method is a non-survey technique for Generating a Regional Input-output Table (GRIT). This approach is a low cost alternative and is based on national input-output tables and readily available secondary data. This means that the results from such studies are less accurate but they embody the main characteristics of the local economy. It is assumed that a region is more dependent than the nation on imports meaning that the regional multiplier effects are lower than those for the nation. This is expressed in smaller inter-industry coefficients. The aim of the GRIT method is to reduce the national inter-industry coefficients to a level where they more closely represent the transactions at the regional level. The reductions are based on the relative intensities of regional employment.

The GRIT approach involves 15 steps, Jensen, et al. (1977). Table F.1 gives the methodological sequence for the GRIT method. The steps are concerned with altering values in the transactions and primary inputs quadrants of the national input-output table. For each industry it is assumed that the nation and region have the same input mix and the inter-industry coeffeicients in the regional A matrix will differ from those in the national table only as a result of the regions greater propensity to import.

The procedure concentrates on a means of splitting each inter-industry coefficient into two parts; that which represents regional production, and that which has to be imported. The regional production component remains in the A matrix and the imported component is transferred to the imports row of the primary inputs quadrant. Hubbard and Brown, (1979) and Butcher (1985) both used a location quotient approach to adjust the national values. Other methods were described by Schaffer and Chu (1969).

The location quotient approach is based on employment data. If employment data show that a particular industry does not exist in the region then that industry's row coefficients are transferred in full to the imports row.

Where the location quotient (LQ) is less than 1 it is assummed that those industries will be required to supplement their inter-industry sales. The national inter-industry coefficients therefore need to be scaled down to account for these inter-industry sales. The scaling down is done by multiplying the row coefficients of each industry by that industry's LQ. The residuals are transferred to the imports row of the primary inputs quadrant.

In the case where the LQ is greater than one, the row coefficients in the A matrix are left unaltered since regional production is assummed to be sufficient to meet local inter- industry sales.

TABLE F.1

The GRIT Methodological Sequence
(Source: Jensen, et al. (1977))

Step Number	
	Phase 1 - Adjustment to National Table
1	Start with national input-output table.
2	Adjust national table for price levels and updating.
3	Adjust for international trade.
	Phase II - Adjust for Regional Imports
(Steps 4-15 apply to each region)	
4	Calculate non-competitive imports.
5	Calculate competitive imports.
	Phase III - Definition of Regional Sectors
6	Insert disaggregate superior data.
7	Aggregate sectors.
8	Insert aggregated superior data.
	Phase IV - Derivation of Prototype Transactions Tables
9	Derive initial transactions tables.
10	Manually or iteratively adjust initial tables to derive prototype tables.
11	Aggregate to uniform tables if required.
12	Derive inverses and multipliers for prototype tables.
	Phase V - Derivation of Final Transactions Tables
13	Insert final superior data and make any other adjustments.
14	Derive final transactions tables.
15	Derive inverses and multipliers for final tables.

In summary, each coefficient of the regional A matrix will lie somewhere between its value in the national A matrix and zero, depending on the LQ's of those sectors supplying the inputs. A special feature of the GRIT method is that superior data can be used where appropriate. Once the coefficients for the regional A matrix and primary inputs quadrant are determined, they need to be reconverted to dollar values and estimates made of the final demand quadrant.

To obtain the dollar values the column coefficients are multiplied by the total value of output for each sector i.e. the reverse of the procedure to derive the inter-industry coefficients. The final demand values are calculated as the residual remaining after inter-industry sales are subtracted from total output. The main problem with this is the disaggregation of the final demand. GRIT uses three demand categories; household consumption, exports and other (i.e. government, stock change, capital formation, etc.).

The modified table can now be used to derive sectoral output, income and employment multipliers for the region.

APPENDIX G

MATHEMATICAL REPRESENTATION OF THE MULTIPLE OBJECTIVE PROGRAMMING TECHNIQUES DESCRIBED IN CHAPTER 6

G.1 WEIGHTING METHOD

The mathmatical representation of the weighting method is:

$$\text{Max} \sum_{i=1}^{k} w_i Z_i(x),$$

subject to

$$x \in X,$$
$$x \Rightarrow 0,$$

where

the weights, $w_i \Rightarrow 0$ for all i and strictly positive for at least one.

G.2 GOAL PROGRAMMING

The goal programming problem is formulated as follows :

$$\text{minimise } Z = \sum_{i=1}^{k} (w_i\, y_i^+ + v_i y_i^-)$$

subject to :

$$f_i(x) - y_i^+ + y_i^- = g_i \quad (i = 1, 2, \ldots, k)$$

where,

$f(x)$ = an objective function,
y_i^+ = a deviational variable measuring the amount of over-attainment of the goal,
y_i^- = a deviational variable measuring the amount of under-attainment of the goal,
g_i = the goal attainment desired for the objective functon i,
w_i = the relative weight or penalty cost for over-attainment, and
v_i = the relative weight or penalty cost for under-attainment.

G.3 ELECTRE METHOD

The mathematical representation of the concordance condition is:

$$C(i,j) = \sum_{k \in A(i,j)} w(k) \left[\sum_{k} w(k) \right]$$

j has elements j=1
$K_{ii'}$

where w_k = weight on criterion to criterion k
$A(i,j)$ = the set of all criteria for which i is preferred to or equal to j,
and weights supplied by the decision-maker reflect the preference structure

$$0 \leq C(i,j) \leq 1$$

the concordance index ($C(i,j)$) lies between 0 and 1 and is treated as a percentage.

The discordance condition can be represented mathematically as follows:

$$D(i,j) = \frac{\text{maximum interval in which } j > i}{\text{largest range of scale}}$$

or

$$D(i,j) = \frac{\max_{k \in 1,k} (Z(j,k) - Z(i,k))}{R^*}$$

where $Z(j,k)$ is the evaluation of the alternative j with respect to criterion k
R^* is the largest of the K criterion series i.e. 150 or e
$0 \leq D(i,j) \leq 1$

G.4 COMPROMISE PROGRAMMING

The algorithm for solving a compromise programming problem has been described by Daellenbach, et al (1983) as:
Let
T_k denote the objective function value found by optimising the kth objective function over X.
where
T_k represents the ideal value, or best possible level of achievement of the kth objective function.
in the expression

$$Z_k + S_k = T_k \qquad (1)$$

S_k = the difference between the actual level of the kth objective function (Z_k) and T_k.
because of the incommensurability between different

objective functions, the fractional deviations, Vk must be considered, where

$$V_k = S_k / T_k \qquad (2)$$

therefore (1) can be rewritten

$$Z_k + T_k V_k = T_k$$

The general form of the objective function in compromise programming is

$$\text{Max} \left[\sum_{k=1}^{q} (W_k V_k)^p \right]^{1/p}$$

But only for p = 1 (MINSUM programming) and p = infinity (MINMAX programming) is the objective function linear.

MINSUM programming is of the general form:

$$\text{Min} \sum_{k=1}^{q} W_k V_k$$

subject to

$$\bar{x} \in X$$

$$Z_k \bar{x} + T_k V_k = T_k, \quad k = 1 \ldots q$$

In MINMAX programming there is only a single deviation variable v, which measures the largest fractional deviation of any objective value from its ideal value T_k:

$$\text{Min } v$$

subject to

$$Z_k \bar{x} + (T_k / W_k) v > T_k, \quad k=1 \ldots q$$

$$\bar{x} \in X$$

G.5 THE STEM METHOD

Algorithm used to construct the payoff matrix used in the STEM method.

$$\max Z_k(x) = \sum_{i=1} c_j^k x_i$$

subject to

$$x \in X$$

for k = 1, 2, ..., p.

G.6 MATHEMATICAL PROOF THAT GOAL PROGRAMMING CAN BE USED AS A GENERATING TECHNIQUE

The following proof, described by Willis and Perlack (1980), shows that goal programming is equivalent to the weighting method.

The mathmatical representation of the weighting method is shown as:

$$\max \sum_{i=1}^{k} w_i z_i(x), \qquad (1)$$

subject to

$$x \in X \qquad (2)$$

$$x \geq 0, \qquad (3)$$

where

$w_i \geq 0$ for all i and strictly positive for at least one

The mathmatical representation of the goal programming method is :

$$\min \sum_{i=1}^{k} w_i(d_i+e_i), \qquad (4)$$

subject to

$$x \in X, \qquad (5)$$

$$x \geq 0, \qquad (6)$$

$$z_i - d_i + e_i = T_i, \quad i=1,\ldots,k, \text{ and} \qquad (7)$$

$$d_i, e_i \geq 0, \qquad (8)$$

where

d_i and e_i = the +ve and -ve differences of the ith objective from its target

w_i = the weight or priority attached to the ith goal

w_i can be split into two components - one for +ve differences (d_i) and one for -ve differences (e_i).

To show that goal programming is equivalent to the weighting method, rewrite (7) as

$$-d_i + e_i = T_i - z_i(x), \qquad (9)$$

and substitute (9) into (4), producing

$$\min \sum_{i=1}^{k} w_i[T_i - z_i(x)], \text{ or} \qquad (10)$$

$$\min \left[\sum_{i=1}^{k} w_i T_i - \sum_{i=1}^{k} w_i z_i x) \right] \qquad (10')$$

Because $\sum_{i=1}^{k} w_i T_i$ is a constant, minimisation of (10') equivalent to minimisation of $\sum_{i=1}^{k} w_i[-z_i(x)]$. Thus, the goal program problem can be expressed as

$$\max \sum_{i=1}^{k} w_i[z_i(x)], \qquad (11)$$

subject to (5) to (8), which is precisely the weighting method model (1) to (3) with the constraints (7) and (8) added.

APPENDIX H

RECREATION IN THE RAKAIA CATCHMENT

An estimated 75,000 visits are made to the Rakaia Catchment each year with most being for fishing in the summer on fine weekends, Bowden (1983d). Estimates of the number of fisherman using the river on a good fishable weekend range from 300-450, Shelby (1983) to 600-900 fisherman per day, Bowden, (1983d). In poor weather the number of people using the entire catchment can be as low as 16, Douglas, et al. (1984). The majority of visitors to the Rakaia River come from Canterbury (85%) followed by Otago and Southland (6.65%), Bowden, (1983d). Table H.1 shows that salmon angling, followed by jet boating account for the major recreational uses of the river. Although picnicking and tramping were not identified as the major recreational pursuits by respondents these activities are thought to be important as secondary activities and add to the quality of experience gained from the major pursuit.

TABLE H.1

Activities Identified by Respondents as their Recreational Pursuits at the Rakaia (Source: Bowden (1983d))

Activity	Respondents N	Respondents %
Salmon Angling	260	77.1
Jet Boating	33	9.7
Trout Angling	12	3.5
Duck Shooting	10	3.0
Canoeing	7	2.1
Picnicking	5	1.5
Tramping	4	1.2
Whitebaiting	2	0.6
Other Fishing	1	0.3
Swimming	1	0.3
Birdwatching	1	0.3
Deer Hunting	1	0.3
Total	337	100.0
Missing Cases	49	

Angling for salmon and trout is the most popular recreational activity undertaken in the Rakaia Catchment with salmon angling being the predominant attraction. Table *.2 shows the number of salmon and trout caught in the River and the angling effort needed to catch these fish. The section of river between the Gorge and the State Highway 1. road bridge attracts the largest number of anglers. The Rakaia River has been identified by the National River

Angling Survey as a nationally important recreational fisheries river. Among South Island rivers, the Rakaia is exceeded in useage only by the Waimakariri River. However, the Waimakariri derives much of its value from its value from its proximity to a large population centre, while the Rakaia is valued for the quality of its salmon. In addition to salmon and trout, the river supports recreational fisheries for whitebait, kahawai, flounders and mullet and commercial fisheries for eel, salmon, kahawai and (potentially) smelt.

TABLE H.2

Summary of the Results of Fisheries Research Division's Postal Surveys of North Canterbury and Ashburton Acclimatisation Society Whole Season Licence Holders For The 1973/74, 1974/75, and 1978/79-1980/81 Seasons (Source: Davis (1983))

Fishing Season	No. Anglers Who Fished Rakaia R.	Rakaia Salmon Catch	Rakaia Trout Catch	No. Angler-Days Spent Fishing Rakaia R.
1973/74	4,300	3,500	not estimated	
1974/75	4,900	5,000	not estimated	
1978/79	8,900	15,000	13,000	107,000
1979/80	6,300	8,000	5,000	54,000
1980/81	7,200	7,000	7,000	68,000

APPENDIX I

THE WILDLIFE RESOURCES OF THE RAKAIA CATCHMENT

Table I.1 sets out some criteria for assessing the relative importance of the various birds nesting in the Rakaia riverbed.

TABLE I.1

Criteria for Assessing the Relative Importance of some Birds Nesting in the Rakaia Riverbed (Adapted from Douglas, et al. (1984) p. 163)

	Distribution (see Note 1)	Breeding Reliance (see Note 2)	Feeding Reliance (see Note 3)
Wrybill Plover	Restricted	8	8
Black-fronted Tern	Restricted	8	6
Black-billed Gull	Restricted	7	4
South Island Pied Oyster Catcher	Endemic	6	6
Pied Stilt	Endemic	5	6
Banded Dotterel	Endemic	5	8
Black-fronted Dotterel	Self Introduced	8	8
Paradise Shelduck	Endemic	3	4
White-fronted Tern	Endemic	1	6
Caspian Tern	Native	2	8
Spur-winged Plover	Self Introduced	1	4
Black-backed Gull	Native	6	2

Notes:

1. Distribution
   - Restricted - Restricted (breeding almost exclusively on Canterbury and Otago riverbeds)
   - Endemic - Native and restricted to New Zealand
   - Native - Native to New Zealand
   - Self Introduced - Self introduced in recent years
2. Breeding Reliance on Riverbeds
   - 8 - Breed only on riverbed
   - 4 - Breed in a variety of localities including riverbeds
   - 1 - Breed only occasionally on riverbeds
3. Feeding Reliance on Riverbeds (assuming breeding on riverbeds)
   - 8 - Feed only on riverbeds
   - 6 - Most feeding on riverbeds
   - 4 - Feed on a variety of habitats
   - 2 - Occasionally feed on riverbeds

APPENDIX J

STEPS INVOLVED IN DEVELOPING THE GOAL PROGRAMMING MODEL

The following steps were followed in developing the goal programming model of the Rakaia River conflict:

(1) Definition of the problem and the scope of the problem. The objectives and specified goals that contribute to the achievement of the objectives were also identified.

(2) The availability and capability of resources to meet the identified problems and needs, as well as the constraints on the utilisation of the resources were identified and evaluated.

(3) Conversion of each of the constraints, goals and resources to equations.

(4) The allowable deviation (or deviations) for each of the equations is placed into a commensurate, ordinal priority level. All deviations within a given priority level are commensurable.

(5) Assign weights to the deviations within a given priority level. The weights reflect the importance associated with the minimisation of a deviation variable assigned to a given goal or constraint. The weights can be value judgements or can reflect the inherent features of the problem.

(6) Solve the problem.

(7) Goals, limits on constraints, priority rankings and weights were varied to determine the effects these changes had on the original solution.

APPENDIX K

ACTIVITIES INCLUDED IN MODEL

Activity Number	Description
1	Gorge flow of the Rakaia River (Sep. to Apr.)
2 - 9	Water flow from Highbank Power Station (Sep. to Apr.)
10 - 17	Optional water augmentation from a raised Lake Coleridge (Sep. to Apr.)
17 - 24	20 cumec flow (Sep. to Apr.)
25 - 32	21 - 50 cumec flow (Sep. to Apr.)
33 - 40	51 - 70 cumec flow (Sep. to Apr.)
41 - 48	71 - 100 cumec flow (Sep. to Apr.)
49 - 57	101 - 160 cumec flow (Sep. to Apr.)
58 - 65	161 - 240 cumec flow (Sep. to Apr.)
66 - 73	Greater than 241 cumec flow (Sep. to Apr.)
74 - 81	Water depth counter (Sep. to Apr.)
82 - 89	Instream allocation rule (Sep. to Apr.)
90 - 97	Agricultural allocation rule (Sep. to Apr.)
98 - 105	Transfer of flow from agriculture to instream users (Sep. to Apr.)
106 - 113	Total instream use (Sep. to Apr.)
114 - 121	Northern Central Plains Scheme (dryland)
122 - 129	Northern Central Plains Scheme (irrigated)
130 - 131	Northern Central Plains Scheme dryland and irrigated count
132 - 133	Northern Central Plains Scheme on-farm and off-farm capital
134	Southern Central Plains Scheme (dryland)
135	Southern Central Plains Scheme (irrigated)
136 - 137	Southern Central Plains Scheme dryland and irrigated count
138 - 139	Southern Central Plains Scheme on-farm and off-farm capital
140 - 141	Southern Central Plains Scheme Extension (dryland)
142 - 143	Southern Central Plains Scheme Extension (irrigated)
144 - 145	Southern Central Plains Scheme Extension dryland and irrigated count
146 - 147	Southern Central Plains Scheme Extension on-farm and off-farm capital
148 - 151	Northern Central Plains Scheme Extension (dryland)
152 - 155	Northern Central Plains Scheme Extension (irrigated)
156 - 157	Northern Central Plains Scheme Extension dryland & irrigated count
158 - 159	Northern Central Plains Scheme Extension on-farm and off-farm capital
160 - 161	Central Plains Scheme total dryland and irrigated area

Activity Number	Description
162 - 165	Lower Rakaia Scheme (dryland)
166 - 171	Lower Rakaia Scheme (irrigated)
172 - 173	Lower Rakaia Scheme dryland and irrigated counts
174 - 175	Lower Rakaia Scheme on-farm and off-farm capital
176	South Rakaia Scheme (dryland)
177	South Rakaia Scheme (irrigated)
178 - 179	South Rakaia Scheme dryland and irrigated counts
180	North Rakaia Scheme (dryland)
181	North Rakaia Scheme (irrigated)
182 - 183	North Rakaia Scheme dryland and irrigated counts
184	Te Pirita Scheme (dryland)
185	Te Pirita Scheme (irrigated)
186 - 187	Te Pirita Scheme dryland and irrigated counts
188 - 189	Te Pirita Scheme on-farm and off-farm capital
190	Fereday Scheme (dryland)
191	Fereday Scheme (irrigated)
192 - 193	Fereday Scheme dryland and irrigated counts
194 - 200	Barrhill Scheme (dryland)
201 - 210	Barrhill Scheme (irrigated)
211 - 212	Barrhill Scheme dryland and irrigated counts
213 - 214	Barrhill Scheme on-farm and off-farm capital
215	Total area of dryland
216	Total area irrigated
217	Total on-farm capital expenditure
218	Total off-farm capital expenditure
219	Total dryland pasture in the Lower and South Rakaia Schemes
220	Total irrigated pasture in the Lower and South Rakaia Schemes
221	Total dryland pasture in the Central Plains Scheme
222	Total irrigated pasture in the Central Plains Scheme
223	Total dryland pasture in the Barrhill Scheme
224	Total irrigated pasture in the Barrhill Scheme
225	Total dryland pasture in the Te Pirita, North Rakaia and Fereday Schemes
226	Total irrigated pasture in the Te Pirita, North, Rakaia and Fereday Schemes
227	Sell wheat
228	Sell barley
229	Sell peas
230	Sell white clover seed

Activity Number	Description
231	Sell ryegrass seed
232	Sell lambs
233	Sell mutton
234	Sell wool
235	Total direct employment created by commercial salmon farming
236	Total employment created by commercial salmon farming
237	Total direct employment created by all industries
238	Total employment created by all industries
239	Total direct income created by commercial salmon farming
240	Total income created by commercial salmon farming
241	Total income created by recreational users
242	Total national income
243	Total regional income
244	Total farmer income

APPENDIX L.1

MEAN MONTHLY DISCHARGE 1959 TO 1981
RAKAIA RIVER AT GORGE AND FIGHTING HILL
(Source: North Canterbury Catchment Board (1983b))

YEAR	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
1959/60	176	166	299	341	274	254	222	127
1960/61	212	208	200	175	165	232	279	245
1961/62	101	205	266	166	368	146	134	118
1962/63	176	281	323	205	172	240	191	145
1963/64	225	161	229	176	349	173	260	152
1964/65	145	166	165	330	357	235	141	123
1965/66	118	157	369	320	354	274	150	270
1966/67	109	120	233	256	293	231	356	414
1967/68	127	218	406	355	248	250	251	193
1968/69	135	318	251	206	183	145	205	189
1969/70	388	145	131	292	242	125	213	205
1970/71	532	189	246	232	148	125	101	93
1971/72	150	341	189	221	212	127	246	167
1972/73	226	374	406	253	161	122	123	222
1973/74	158	251	399	194	180	202	184	343
1974/75	120	219	253	160	156	218	247	357
1975/76	194	239	263	228	265	180	172	109
1976/77	105	142	157	338	374	217	194	139
1977/78	82	109	233	223	245	150	213	247
1978/79	246	247	253	205	190	234	214	211
1979/80	166	333	342	562	344	208	188	165
1980/81	253	222	249	240	195	220	308	192
1981/82	110	351	235	376				
MEAN	185	224	265	263	249	196	209	201

APPENDIX L.2

MEAN MONTHLY DISCHARGE 1959 TO 1981
HIGHBANK POWER STATION
(Source: Bowden (1983b))

YEAR	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
1959/60	15.59	9.80	0.00	0.00	0.00	0.00	0.00	1.45
1960/61	23.02	22.07	16.93	16.79	7.35	6.74	0.42	16.03
1961/62	23.69	13.42	6.63	7.05	7.28	6.19	5.90	8.50
1962/63	23.36	13.50	6.42	5.56	4.63	3.00	2.23	6.99
1963/64	23.19	13.15	4.71	6.25	2.01	0.00	0.00	0.00
1964/65	20.72	5.52	7.97	4.76	5.20	7.75	3.20	19.57
1965/66	22.30	9.68	17.41	7.31	2.52	2.46	11.64	17.75
1966/67	21.40	15.01	10.27	7.37	2.43	0.82	0.00	8.16
1967/68	20.04	13.46	16.64	9.49	2.72	0.14	9.36	16.79
1968/69	12.15	16.72	6.04	6.09	4.25	0.00	0.00	0.40
1969/70	18.12	1.53	0.60	9.24	11.52	1.95	10.82	13.20
1970/71	16.79	0.00	0.00	0.00	0.00	0.00	0.79	9.63
1971/72	17.01	13.77	10.88	2.75	2.29	1.61	4.13	15.66
1972/73	14.21	14.15	7.03	9.22	2.29	1.44	0.00	0.00
1973/74	18.66	7.91	5.53	3.31	2.78	9.03	17.33	17.20
1974/75	18.65	17.75	11.82	1.95	3.57	4.33	18.17	17.43
1975/76	17.76	15.36	13.26	1.04	3.12	1.72	0.38	8.16
1976/77	15.74	9.15	0.00	0.00	0.00	0.00	0.00	2.35
1977/78	21.10	14.85	0.94	0.00	0.00	0.00	0.93	14.94
1978/79	24.55	23.13	14.90	12.53	5.69	0.03	10.08	23.37
1979/80	22.56	20.95	13.15	7.72	11.59	0.10	0.00	0.00
1980/81	12.83	3.76	13.36	10.35	1.41	0.00	3.97	7.71
1981/82	19.06	14.67	8.07	0.00				
MEAN	19.24	12.58	8.37	5.60	3.76	2.15	4.52	10.24

APPENDIX M

INSTREAM VALUES

M.1 WATER DEPTH RELATIONSHIPS

The minimum water depth to Gorge discharge relationships developed by Mosley, Mosley (1982 and 1983), have been critically examined by Anderson, et al. (1984). They concluded that there is at present inadequate data available from which river discharge and minimum passage depth relationships can be developed with confidence. Their recommendation was that the highest value of a range of predicted flows should be used in the abscence of adequate data. This study takes this approach and uses the following equations, developed by Mosley, to derive the predicted Gorge flows required to obtain minimum depths:

$$D_{min} = 0.14\ Q_t^{0.16}$$

$$D_{min} = 0.053\ Q_t^{0.39}$$

where: D_{min} represents the minimum passage depth of the mainriver channel, and
Q_t represents the total discharge at the Gorge

The depth-discharge values used in the model are shown in Figures M.1 and M.2. Each of the incremental flow activities increases the water depth.

FIGURE M.1

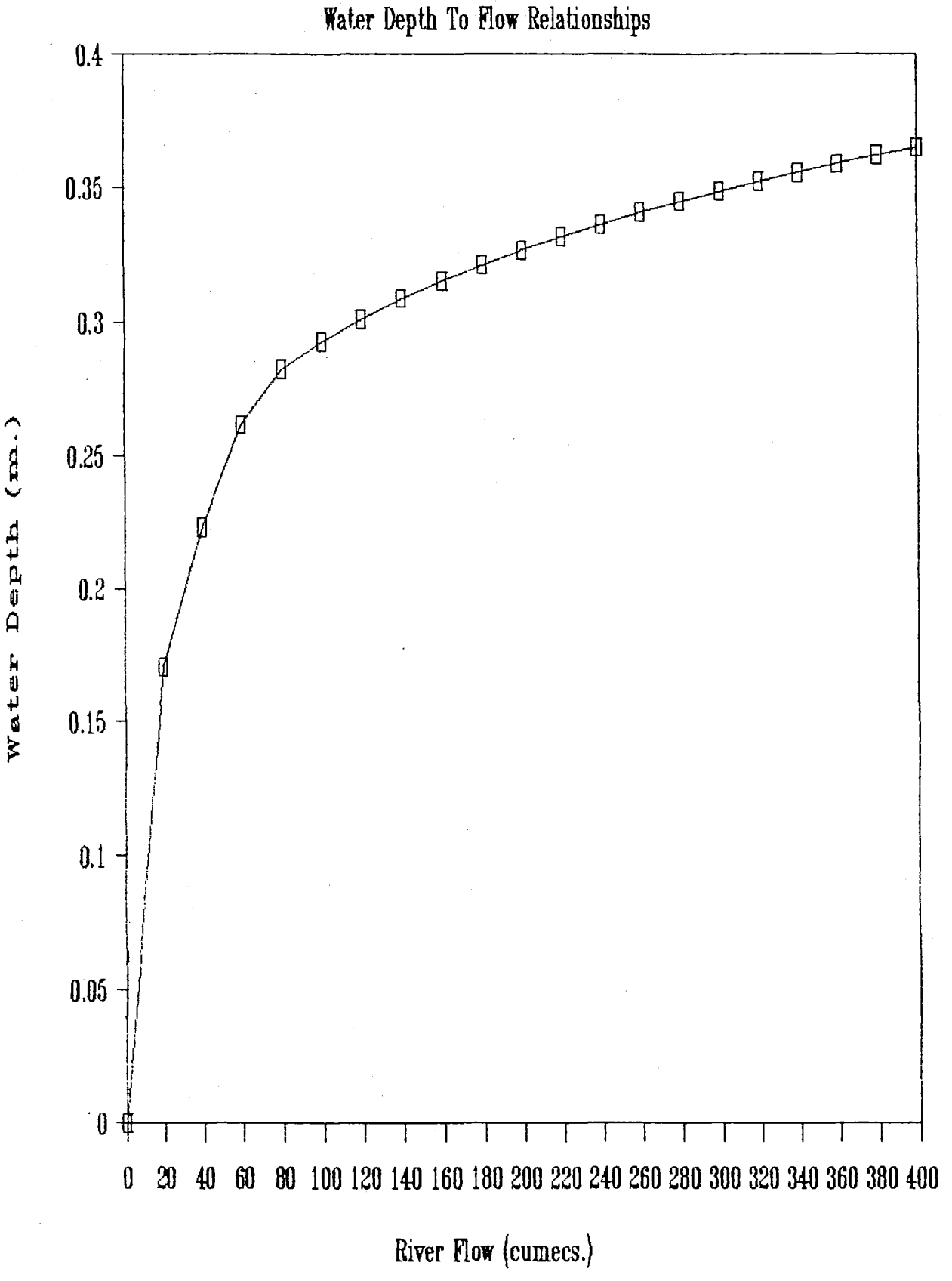
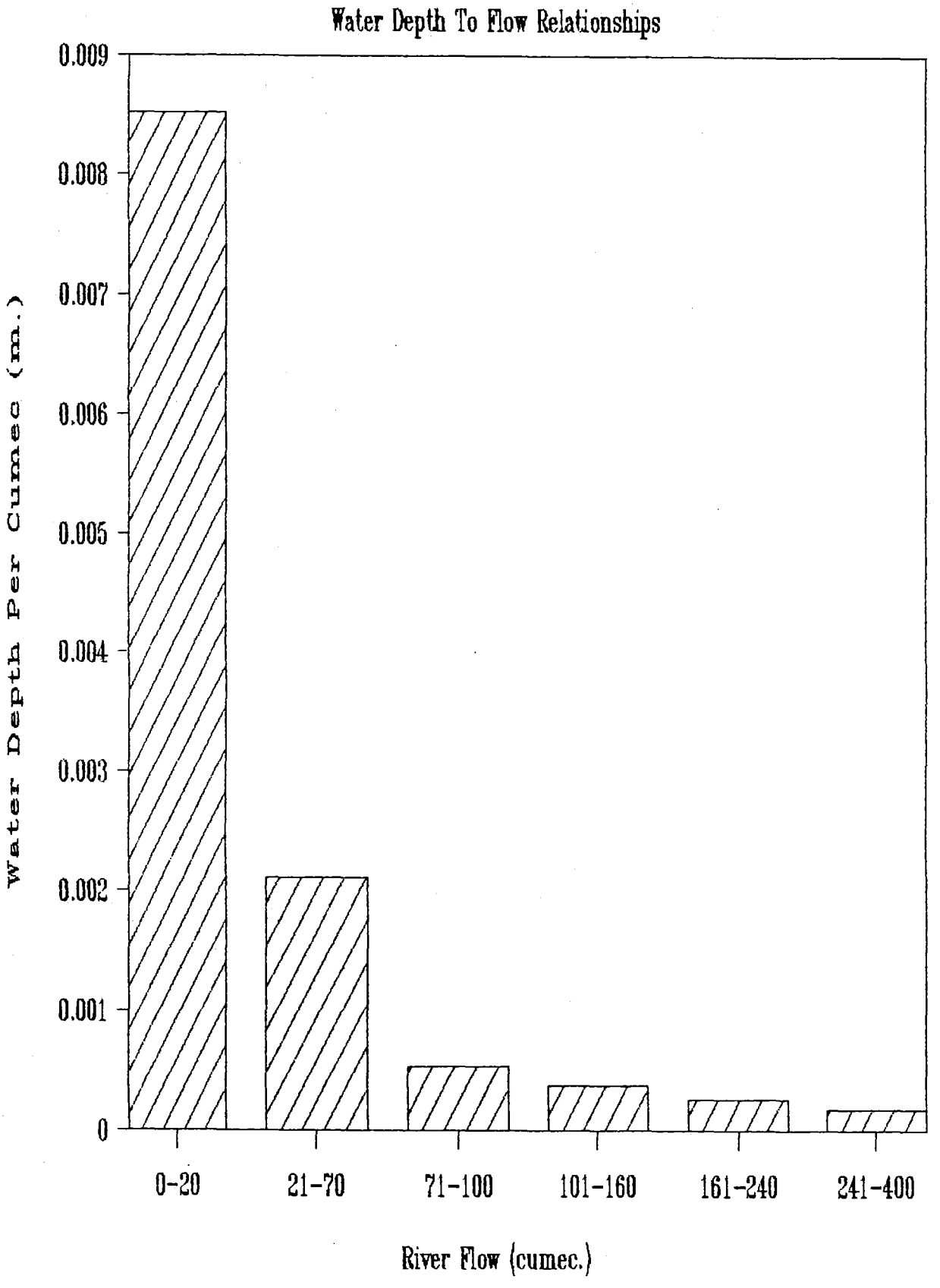

Water Depth To Flow Relationships
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Water Depth (m.)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
River Flow (cumecs.)

FIGURE M.2


Water Depth To Flow Relationships
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Water Depth Per Cumec (m.)
0-20
21-70
71-100
101-160
161-240
241-400
River Flow (cumec.)

M.2 DIRECT AND TOTAL INCOME AND EMPLOYMENT FROM COMMERCIAL SALMON FARMING

A successful commercial salmon farming industry based on the Rakaia would result in:

(1) Increased export earnings. These have been asssesed as providing a direct impact of $5.7 million and a total impact (including secondary effects) of $14.5 million, Leathers, et al. (1983). This has been assessed at $3182.58 per cumec and $4913.46 per cumec for the direct and total income impacts, based on a seasonal flow of 1791 cumecs. The relationship is assumed to be linear over the range of flows used in the model.

(2) Increased employment opportunities. The development of commercial salmon ranching based on the Rakaia River has the potential to produce 30 jobs and a total of 100 jobs when secondary effects are accounted for, Leathers, et al. (1983). This has been assessed at 0.01675 per cumec and 0.03908 per cumec for the direct and total employment impacts, based on a seasonal flow of 1791 cumecs. The relationship is assumed to be linear over the range of flows used in the model.

(3) Reduced dependence on imported salmon products.

(4) Enhancement of the recreational fishery. Todd (1983) estimated that during the 1982/83 fishing season the total angler catch of hatchery-reared salmon was estimated at 605 from the Rakaia River. In addition, some of the returning hatchery fish strayed into, and contributed to, the angler catch in adjacent rivers. An estimated 258 in the Rangitata and 91 in the Waimakariri Rivers.

M.3 INCOME FROM INSTREAM RECREATIONAL USERS

Leathers, et al. (1983) estimated that the direct value of recreation in the Rakaia Catchment was in the order of $5.06 million ($1985). This has been assessed at $2825.24 per cumec based on a seasonal flow of 1791 cumecs. The relationship is assumed to be linear over the range of flows used in the model.

APPENDIX N

DESCRIPTION OF THE RAKAIA IRRIGATION MODEL DEVELOPED BY NZAEI

A simulation model of the irrigation schemes proposed for Central Canterbury was used to determine the irrigation water demands, and the irrigated and dryland crop and pasture yields used in the current study. The model was a significantly modified version of the models used to analyse the Glenmark and Hakataramea irrigation proposals by the New Zealand Agricultural Engineering Institute. The Rakaia model includes all the schemes likely to be served by the Rakaia River system but excludes all anticipated groundwater development.

The soils present in the area likely to be effected by irrigation in Central Canterbury have been classified into four groups according to their water holding capacity. Only soil types 1 and 2 are cropped and the landuse pattern for types 3 and 4 is pasture. Table N.1 shows the assumed percentages of each soil type in crop and pasture and the total areas of each soil type assumed in the model. The large area devoted to pasture means that the likely water demands for diversification options like deer, dairying and horticulture could be met if needed. The total scheme area under consideration is 120,759 hectares of which 80% is assumed irrigable. The remainder (20%) is assumed to be taken up in distribution systems, roading and shelter plantings.

TABLE N.1

Assumptions Relating To Soil Type Used In NZAEI Model

Soil Type	Water Holding Capacity (mm.)	Percentage Crop (%)	Percentage Crop (%)	Total Area (ha)
1	140	60	40	28,282
2	85	50	50	44,722
3	60	-	100	42,472
4	50	-	100	5,283

Soil moisture balances are calculated for each area for a 24 years period, 1959/60 to 1982/83. Potential evapo-transpiration levels are calculated using the Penman equation and data from the Lincoln Meteorological Station. This is then modified according to crop type, stage of growth and soil moisture status to produce an estimate of actual evapo-transpiration. A weighted rainfall estimate is calculated for each soil type classification according to its proximity to the Hororata, Darfield, Lincoln, or Winchmore rainfall stations.

CALCULATION OF ON-FARM WATER DEMANDS

The calculated water demands are related to the critical growth periods of crops shown in Figure N.1. The critical growth periods are periods where it was assumed that the plants tolerance to water stress was lower than usual. At the critical growth stages shown below irrigation was trigerred at 50% soil moisture depletion and filled to field capacity. At non-critical periods of growth irrigation is triggered so soil moisture levels remain between 25% and 75% of field capacity. Pasture is regarded as non-critical in all seasons.

Two irrigation types; border-dyke and sprinkler, have been assumed in the NZAEI model. All crops are irrigated with sprinkler systems with an estimated on-farm application efficiency of 65%. sprinkler irrigated. The same efficiency was assumed for border-dyke but an additional 50 mm. was applied. This had the effect of making light soil types less efficient under border-dyking compared with heavy soils e.g. a soil with a 50 mm total available water holding capacity would have maximum water use efficiency of 43% if filled from 75% depletion to field capacity and a 140 mm soil would have 68% efficiency.

SIMULATING FARMER REACTION TO WATER SHORTAGE AND/OR UNCERTAINTY OF SUPPLY

The model is formulated as either a crop or pasture farm for each sub-area of a scheme. A pasture farm is divided into a number of paddocks according to soil type classification
e.g.

50mm	-	12
60mm	-	14
85mm	-	14
140mm	-	23

Each paddock takes a day to irrigate therefore the number of paddocks determines the roster length.

Cropping farms are divided into five paddocks (one for each crop) and a number of sub-paddocks. The number of sub-paddocks is the same as that for pasture. Five sub-paddocks can be irrigated per day and these can come from one paddock or be spread among any paddock depending on the deficit existing at the time. This allocation of water means that a crop can be rapidly irrigated at its critical period if there are no other demands for water.

Irrigation is triggered on border-dyked areas if the soil moisture is likely to reach the trigger level at one third the roster length ahead. This simulates the situation where a farmer irrigates when the water is available rather than waiting until soil moisture levels reach the trigger level. Paddocks and sub- paddocks are always irrigated in the same order. When water is restricted each paddock or sub-paddock is irrigated to the proportion of the supply available e.g. if supply is only 50% then each area receives 50% of its demand.

FIGURE N.1

Critical Growth Stages of Crops Used in Model
(Source: Harrington and Dewar, (undated))

Crop	Sowing Or Closing Date	Critical Period 1 Name	Critical Period 1 Date	Critical Period 2 Name	Critical Period 2 Date	Critical Period 3 Name	Critical Period 3 Date
Winter wheat	June 1	Ear emergence	Nov. 15	Grain fill	Dec. 3		
Barley	Sep. 1	Tillering	Oct. 12	Ear emergence	Dec. 4	Grain Fill	Dec. 17
Garden peas	Sep. 1	Vegetative	Nov. 13	1st flowering	Dec. 1	Pod fill	Dec. 19
White clover seed	Oct. 1						
Ryegrass seed	Oct. 1						

Note: The critical growth period is the date specified plus or minus 3 to 5 days, depending on the crop and growth stage.

The water demand values generated by the model were validated against Ashburton-Lyndhurst Scheme demands. The water demand values used in the current model for each of the soil-area classifications are shown in Appendix *.

OPERATIONAL LOSS ASSUMPTIONS

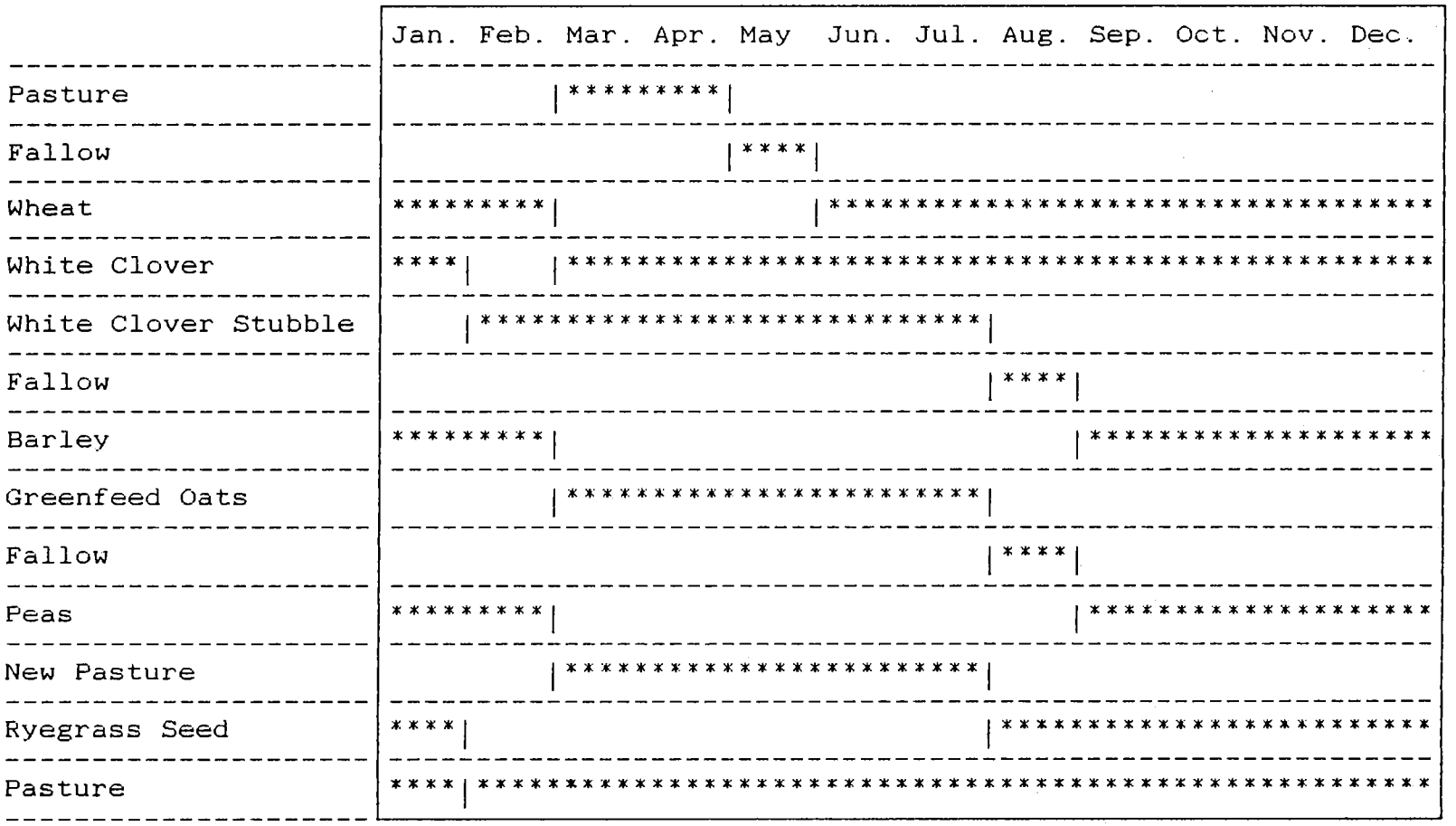
It is assumed that a 0.2 litres/s/ha "operational loss" or "base flow" is maintained in all main channels during the irrigation season to allow for ease of management and flexibility of operation. The "base flow" is lost from the Rakaia System although in reality some will be returned via by-washes to the river. However, some may be by-passed to other river systems e.g. the Selwyn from the Central Plains Scheme. The "operational loss" reduces linearly to 0.07 litres/s/ha as the irrigation demand increases to full capacity. When water is restricted then the operational loss is reduced to 0.07 litres/s/ha before an irrigation deficit is indicated. The lowest level of operational loss (0.07 litres/s/ha) accounts for seepage from races and a minimum by-pass allowance and if the available river flows are less than this then no irrigation takes place.

AGRICULTURAL PRODUCTION

The model uses a daily water balance approach to simulate the growth of crops and pasture through each season using 24 years of historical climate and river flow information (1959/60 - 1082/83). The model calculates the plateau yields, that could be obtained under a practical irrigation regime, for each crop and pasture activity. Details of the yield functions used in the model can be found in Heiler (1981). The plateau yields are less than maximum potential yield. Dryland yields are calculated using rainfall data. Restricted irrigation supplies will produce yields between these two extremes.

FIGURE N.2

Crop Rotation Assumed In NZAEI Simulation Model
(Source: Harrington and Dewar, (undated))



APPENDIX O

AGRICULTURAL WATER DEMANDS

APPENDIX O.1 : MONTHLY WATER DEMANDS FOR 1CD (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.000096	0.00006	0.00024	0.00024	0.00052	0.00035	0.00014	0.00000
1960/61	0.000000	0.00004	0.00004	0.00003	0.00034	0.00000	0.00000	0.00000
1961/62	0.000000	0.00015	0.00060	0.00053	0.00025	0.00034	0.00003	0.00000
1962/63	0.000000	0.00011	0.00010	0.00051	0.00021	0.00021	0.00004	0.00001
1963/64	0.000000	0.00009	0.00017	0.00044	0.00031	0.00052	0.00010	0.00001
1964/65	0.000019	0.00018	0.00029	0.00043	0.00049	0.00000	0.00000	0.00000
1965/66	0.000000	0.00010	0.00004	0.00016	0.00015	0.00016	0.00000	0.00004
1966/67	0.000000	0.00004	0.00010	0.00026	0.00028	0.00036	0.00010	0.00003
1967/68	0.000000	0.00007	0.00006	0.00036	0.00034	0.00001	0.00012	0.00002
1968/69	0.000112	0.00007	0.00030	0.00033	0.00037	0.00020	0.00027	0.00018
1969/70	0.000255	0.00014	0.00045	0.00016	0.00010	0.00014	0.00015	0.00000
1970/71	0.000000	0.00000	0.00025	0.00060	0.00042	0.00039	0.00022	0.00005
1971/72	0.000000	0.00006	0.00004	0.00042	0.00035	0.00013	0.00022	0.00006
1972/73	0.000035	0.00003	0.00024	0.00017	0.00036	0.00044	0.00021	0.00006
1973/74	0.000000	0.00017	0.00022	0.00047	0.00031	0.00020	0.00000	0.00000
1974/75	0.000000	0.00000	0.00006	0.00044	0.00035	0.00002	0.00000	0.00000
1975/76	0.000000	0.00003	0.00005	0.00036	0.00025	0.00008	0.00018	0.00008
1976/77	0.000000	0.00000	0.00013	0.00012	0.00000	0.00016	0.00020	0.00014
1977/78	0.000000	0.00003	0.00036	0.00035	0.00019	0.00039	0.00024	0.00007
1978/79	0.000000	0.00002	0.00006	0.00022	0.00034	0.00049	0.00000	0.00000
1979/80	0.000000	0.00000	0.00002	0.00040	0.00013	0.00017	0.00000	0.00000
1980/81	0.000062	0.00020	0.00017	0.00017	0.00049	0.00045	0.00015	0.00000
1981/82	0.000000	0.00003	0.00009	0.00046	0.00055	0.00057	0.00030	0.00002
1982/83	0.000077	0.00004	0.00020	0.00020	0.00036	0.00037	0.00018	0.00013
MEAN	0.000027	0.00007	0.00018	0.00033	0.00031	0.00026	0.00012	0.00004

APPENDIX O.2

MONTHLY WATER DEMANDS FOR 1PD (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00006	0.00013	0.00018	0.00022	0.00056	0.00049	0.00022	0.00000
1960/61	0.00000	0.00000	0.00000	0.00002	0.00039	0.00004	0.00001	0.00000
1961/62	0.00000	0.00011	0.00056	0.00051	0.00031	0.00048	0.00004	0.00000
1962/63	0.00000	0.00007	0.00006	0.00048	0.00023	0.00030	0.00007	0.00000
1963/64	0.00000	0.00006	0.00014	0.00039	0.00035	0.00067	0.00019	0.00000
1964/65	0.00000	0.00021	0.00023	0.00041	0.00054	0.00000	0.00000	0.00000
1965/66	0.00000	0.00006	0.00003	0.00012	0.00019	0.00022	0.00000	0.00000
1966/67	0.00000	0.00001	0.00007	0.00022	0.00028	0.00052	0.00019	0.00002
1967/68	0.00000	0.00000	0.00002	0.00034	0.00040	0.00003	0.00020	0.00002
1968/69	0.00007	0.00013	0.00026	0.00026	0.00043	0.00027	0.00039	0.00018
1969/70	0.00004	0.00010	0.00038	0.00013	0.00015	0.00023	0.00024	0.00000
1970/71	0.00000	0.00000	0.00014	0.00058	0.00047	0.00054	0.00031	0.00006
1971/72	0.00000	0.00001	0.00000	0.00035	0.00041	0.00020	0.00028	0.00008
1972/73	0.00000	0.00000	0.00019	0.00013	0.00043	0.00059	0.00031	0.00008
1973/74	0.00000	0.00015	0.00018	0.00044	0.00035	0.00026	0.00000	0.00000
1974/75	0.00000	0.00000	0.00003	0.00041	0.00038	0.00004	0.00000	0.00000
1975/76	0.00000	0.00000	0.00000	0.00032	0.00029	0.00013	0.00023	0.00012
1976/77	0.00000	0.00000	0.00007	0.00009	0.00000	0.00027	0.00025	0.00017
1977/78	0.00000	0.00001	0.00031	0.00029	0.00027	0.00052	0.00036	0.00006
1978/79	0.00000	0.00000	0.00002	0.00017	0.00040	0.00064	0.00010	0.00000
1979/80	0.00000	0.00000	0.00000	0.00038	0.00016	0.00026	0.00000	0.00000
1980/81	0.00003	0.00025	0.00010	0.00015	0.00053	0.00058	0.00025	0.00000
1981/82	0.00000	0.00000	0.00004	0.00045	0.00062	0.00074	0.00040	0.00004
1982/83	0.00000	0.00000	0.00015	0.00016	0.00043	0.00049	0.00025	0.00014
MEAN	0.00001	0.00005	0.00013	0.00029	0.00036	0.00035	0.00018	0.00004

APPENDIX O.3

MONTHLY WATER DEMANDS FOR 1CHB (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00006	0.00006	0.00012	0.00012	0.00028	0.00042	0.00009	0.00000
1960/61	0.00000	0.00003	0.00007	0.00003	0.00030	0.00000	0.00000	0.00000
1961/62	0.00000	0.00010	0.00051	0.00033	0.00023	0.00031	0.00000	0.00000
1962/63	0.00000	0.00004	0.00004	0.00032	0.00015	0.00013	0.00002	0.00000
1963/64	0.00000	0.00009	0.00011	0.00018	0.00028	0.00052	0.00009	0.00001
1964/65	0.00000	0.00008	0.00012	0.00031	0.00055	0.00000	0.00000	0.00000
1965/66	0.00000	0.00003	0.00000	0.00013	0.00016	0.00018	0.00000	0.00000
1966/67	0.00000	0.00004	0.00010	0.00022	0.00016	0.00026	0.00007	0.00000
1967/68	0.00000	0.00003	0.00002	0.00022	0.00040	0.00004	0.00009	0.00002
1968/69	0.00003	0.00003	0.00008	0.00028	0.00023	0.00007	0.00011	0.00003
1969/70	0.00000	0.00003	0.00027	0.00006	0.00001	0.00000	0.00000	0.00000
1970/71	0.00000	0.00000	0.00004	0.00036	0.00023	0.00032	0.00017	.00000
1971/72	0.00000	0.00000	0.00003	0.00032	0.00046	0.00008	0.00022	0.00005
1972/73	0.00000	0.00003	0.00020	0.00017	0.00034	0.00030	0.00015	0.00000
1973/74	0.00000	0.00011	0.00011	0.00037	0.00019	0.00017	0.00000	0.00000
1974/75	0.00000	0.00000	0.00005	0.00048	0.00036	0.00002	0.00000	0.00000
1975/76	0.00000	0.00000	0.00002	0.00027	0.00015	0.00010	0.00012	0.00005
1976/77	0.00000	0.00000	0.00008	0.00008	0.00000	0.00011	0.00011	0.00014
1977/78	0.00000	0.00002	0.00025	0.00034	0.00014	0.00031	0.00018	0.00003
1978/79	0.00000	0.00000	0.00005	0.00018	0.00019	0.00038	0.00001	0.00000
1979/80	0.00000	0.00000	0.00000	0.00023	0.00010	0.00019	0.00000	0.00000
1980/81	0.00000	0.00006	0.00015	0.00007	0.00034	0.00043	0.00009	0.00001
1981/82	0.00000	0.00003	0.00008	0.00043	0.00052	0.00048	0.00024	0.00002
1982/83	0.00000	0.00001	0.00010	0.00012	0.00025	0.00028	0.00010	0.00009
MEAN	0.000004	0.00003	0.00011	0.00023	0.00025	0.00021	0.00008	0.00002

APPENDIX O.4

MONTHLY WATER DEMANDS FOR 1PHB (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00002	0.00005	0.00007	0.00008	0.00034	0.00056	0.00015	0.00000
1960/61	0.00000	0.00000	0.00002	0.00001	0.00034	0.00000	0.00000	0.00000
1961/62	0.00000	0.00006	0.00046	0.00030	0.00028	0.00042	0.00002	0.00000
1962/63	0.00000	0.00000	0.00002	0.00029	0.00019	0.00019	0.00008	0.00000
1963/64	0.00000	0.00006	0.00009	0.00015	0.00033	0.00066	0.00015	0.00000
1964/65	0.00000	0.00003	0.00011	0.00028	0.00060	0.00000	0.00000	0.00000
1965/66	0.00000	0.00000	0.00000	0.00009	0.00021	0.00024	0.00000	0.00000
1966/67	0.00000	0.00000	0.00005	0.00021	0.00019	0.00038	0.00016	0.00000
1967/68	0.00000	0.00000	0.00000	0.00021	0.00045	0.00008	0.00013	0.00002
1968/69	0.00000	0.00000	0.00005	0.00024	0.00027	0.00014	0.00017	0.00001
1969/70	0.00000	0.00000	0.00020	0.00005	0.00001	0.00000	0.00005	0.00000
1970/71	0.00000	0.00000	0.00002	0.00033	0.00027	0.00045	0.00024	0.00000
1971/72	0.00000	0.00000	0.00000	0.00029	0.00051	0.00016	0.00025	0.00007
1972/73	0.00000	0.00000	0.00015	0.00012	0.00041	0.00043	0.00022	0.00000
1973/74	0.00000	0.00008	0.00008	0.00033	0.00023	0.00017	0.00000	0.00000
1974/75	0.00000	0.00000	0.00001	0.00045	0.00038	0.00005	0.00000	0.00000
1975/76	0.00000	0.00000	0.00000	0.00023	0.00018	0.00012	0.00015	0.00011
1976/77	0.00000	0.00000	0.00005	0.00006	0.00000	0.00018	0.00019	0.00014
1977/78	0.00000	0.00000	0.00020	0.00030	0.00020	0.00043	0.00028	0.00003
1978/79	0.00000	0.00000	0.00002	0.00013	0.00024	0.00053	0.00007	0.00000
1979/80	0.00000	0.00000	0.00000	0.00019	0.00012	0.00029	0.00000	0.00000
1980/81	0.00000	0.00001	0.00014	0.00004	0.00039	0.00055	0.00019	0.00000
1981/82	0.00000	0.00000	0.00002	0.00040	0.00059	0.00065	0.00032	0.00004
1982/83	0.00000	0.00000	0.00005	0.00007	0.00033	0.00039	0.00016	0.00008
MEAN	0.000001	0.00001	0.00008	0.00020	0.00029	0.00029	0.00012	0.00002

APPENDIX O.5

MONTHLY WATER DEMANDS FOR 1CW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00010	0.00010	0.00031	0.00023	0.00044	0.00042	0.00013	0.00001
1960/61	0.00000	0.00007	0.00018	0.00007	0.00041	0.00001	0.00000	0.00000
1961/62	0.00000	0.00015	0.00059	0.00051	0.00032	0.00037	0.00001	0.00000
1962/63	0.00000	0.00009	0.00006	0.00040	0.00028	0.00024	0.00000	0.00005
1963/64	0.00000	0.00011	0.00017	0.00044	0.00037	0.00056	0.00016	0.00002
1964/65	0.00000	0.00017	0.00028	0.00040	0.00055	0.00000	0.00000	0.00000
1965/66	0.00000	0.00015	0.00005	0.00026	0.00025	0.00027	0.00000	0.00001
1966/67	0.00000	0.00005	0.00014	0.00031	0.00022	0.00037	0.00013	0.00004
1967/68	0.00007	0.00007	0.00003	0.00035	0.00046	0.00005	0.00015	0.00002
1968/69	0.00004	0.00003	0.00029	0.00033	0.00032	0.00021	0.00025	0.00020
1969/70	0.00021	0.00012	0.00052	0.00019	0.00009	0.00016	0.00018	0.00000
1970/71	0.00000	0.00001	0.00016	0.00049	0.00038	0.00040	0.00018	0.00004
1971/72	0.00000	0.00008	0.00021	0.00041	0.00041	0.00014	0.00021	0.00008
1972/73	0.00004	0.00008	0.00026	0.00021	0.00044	0.00041	0.00017	0.00006
1973/74	0.00001	0.00018	0.00029	0.00048	0.00026	0.00017	0.00000	0.00000
1974/75	0.00000	0.00000	0.00007	0.00050	0.00040	0.00005	0.00000	0.00000
1975/76	0.00000	0.00004	0.00011	0.00046	0.00034	0.00016	0.00023	0.00006
1976/77	0.00000	0.00000	0.00005	0.00010	0.00001	0.00015	0.00016	0.00011
1977/78	0.00000	0.00004	0.00039	0.00044	0.00032	0.00034	0.00024	0.00006
1978/79	0.00000	0.00001	0.00008	0.00025	0.00020	0.00048	0.00006	0.00000
1979/80	0.00000	0.00000	0.00001	0.00032	0.00010	0.00020	0.00000	0.00000
1980/81	0.00008	0.00022	0.00020	0.00018	0.00049	0.00046	0.00014	0.00004
1981/82	0.00002	0.00004	0.00017	0.00044	0.00054	0.00047	0.00031	0.00002
1982/83	0.00015	0.00005	0.00021	0.00023	0.00044	0.00038	0.00014	0.00017
MEAN	0.00003	0.00008	0.00020	0.00033	0.00034	0.00027	0.00012	0.00004

APPENDIX O.6

MONTHLY WATER DEMANDS FOR 1PW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00007	0.00018	0.00024	0.00021	0.00049	0.00057	0.00021	0.00000
1960/61	0.00000	0.00003	0.00016	0.00004	0.00046	0.00003	0.00000	0.00000
1961/62	0.00000	0.00012	0.00056	0.00049	0.00037	0.00048	0.00004	0.00000
1962/63	0.00000	0.00005	0.00005	0.00037	0.00032	0.00032	0.00000	0.00000
1963/64	0.00000	0.00008	0.00014	0.00042	0.00041	0.00070	0.00028	0.00002
1964/65	0.00000	0.00015	0.00024	0.00037	0.00060	0.00002	0.00001	0.00000
1965/66	0.00000	0.00014	0.00001	0.00018	0.00031	0.00039	0.00000	0.00000
1966/67	0.00000	0.00000	0.00010	0.00028	0.00024	0.00051	0.00024	0.00002
1967/68	0.00000	0.00001	0.00000	0.00033	0.00050	0.00009	0.00022	0.00002
1968/69	0.00000	0.00001	0.00025	0.00029	0.00037	0.00028	0.00038	0.00019
1969/70	0.00001	0.00010	0.00046	0.00016	0.00013	0.00025	0.00027	0.00000
1970/71	0.00000	0.00000	0.00009	0.00046	0.00044	0.00054	0.00025	0.00007
1971/72	0.00000	0.00003	0.00017	0.00039	0.00047	0.00021	0.00028	0.00009
1972/73	0.00000	0.00008	0.00017	0.00016	0.00051	0.00055	0.00027	0.00005
1973/74	0.00000	0.00018	0.00025	0.00045	0.00030	0.00022	0.00000	0.00000
1974/75	0.00000	0.00000	0.00003	0.00046	0.00043	0.00008	0.00000	0.00000
1975/76	0.00000	0.00000	0.00007	0.00044	0.00038	0.00024	0.00027	0.00010
1976/77	0.00000	0.00000	0.00000	0.00007	0.00001	0.00024	0.00022	0.00015
1977/78	0.00000	0.00002	0.00034	0.00041	0.00038	0.00045	0.00036	0.00006
1978/79	0.00000	0.00000	0.00004	0.00021	0.00025	0.00065	0.00014	0.00000
1979/80	0.00000	0.00000	0.00000	0.00028	0.00011	0.00032	0.00001	0.00000
1980/81	0.00005	0.00027	0.00014	0.00014	0.00055	0.00058	0.00023	0.00004
1981/82	0.00000	0.00001	0.00015	0.00042	0.00060	0.00064	0.00041	0.00004
1982/83	0.00000	0.00000	0.00015	0.00020	0.00050	0.00050	0.00021	0.00019
MEAN	0.00001	0.00006	0.00016	0.00030	0.00038	0.00037	0.00018	0.00004

APPENDIX O.7

MONTHLY WATER DEMANDS FOR 1BW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00036	0.00000	0.00049	0.00030	0.00073	0.00076	0.00000	0.00000
1960/61	0.00000	0.00009	0.00032	0.00017	0.00060	0.00002	0.00002	0.00019
1961/62	0.00000	0.00039	0.00072	0.00066	0.00052	0.00037	0.00002	0.00000
1962/63	0.00000	0.00016	0.00029	0.00055	0.00040	0.00035	0.00035	0.00000
1963/64	0.00000	0.00041	0.00005	0.00054	0.00063	0.00083	0.00010	0.00019
1964/65	0.00000	0.00035	0.00029	0.00070	0.00071	0.00025	0.00007	0.00000
1965/66	0.00002	0.00007	0.00000	0.00038	0.00053	0.00057	0.00021	0.00012
1966/67	0.00000	0.00023	0.00026	0.00063	0.00046	0.00060	0.00009	0.00000
1967/68	0.00000	0.00009	0.00014	0.00058	0.00063	0.00042	0.00028	0.00005
1968/69	0.00017	0.00007	0.00035	0.00052	0.00059	0.00027	0.00027	0.00013
1969/70	0.00007	0.00007	0.00050	0.00004	0.00023	0.00013	0.00027	0.00010
1970/71	0.00000	0.00000	0.00035	0.00048	0.00065	0.00064	0.00036	0.00000
1971/72	0.00000	0.00000	0.00017	0.00072	0.00080	0.00019	0.00044	0.00010
1972/73	0.00000	0.00021	0.00054	0.00026	0.00067	0.00074	0.00026	0.00000
1973/74	0.00000	0.00038	0.00015	0.00061	0.00053	0.00027	0.00000	0.00000
1974/75	0.00000	0.00000	0.00024	0.00086	0.00049	0.00042	0.00000	0.00000
1975/76	0.00000	0.00000	0.00007	0.00060	0.00042	0.00033	0.00049	0.00017
1976/77	0.00000	0.00000	0.00042	0.00006	0.00011	0.00038	0.00037	0.00016
1977/78	0.00000	0.00014	0.00051	0.00037	0.00045	0.00078	0.00023	0.00005
1978/79	0.00000	0.00000	0.00024	0.00044	0.00070	0.00074	0.00004	0.00000
1979/80	0.00000	0.00000	0.00011	0.00069	0.00041	0.00035	0.00000	0.00000
1980/81	0.00000	0.00030	0.00032	0.00032	0.00061	0.00083	0.00009	0.00007
1981/82	0.00000	0.00007	0.00039	0.00071	0.00087	0.00079	0.00038	0.00000
1982/83	0.00000	0.00000	0.00044	0.00022	0.00071	0.00052	0.00025	0.00032
MEAN	0.00003	0.00013	0.00031	0.00048	0.00056	0.00048	0.00019	0.00007

APPENDIX O.8

MONTHLY WATER DEMANDS FOR 2CD (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00017	0.00009	0.00039	0.00023	0.00057	0.00028	0.00015	0.00001
1960/61	0.00000	0.00006	0.00009	0.00008	0.00044	0.00000	0.00000	0.00010
1961/62	0.00000	0.00029	0.00064	0.00051	0.00029	0.00026	0.00003	0.00000
1962/63	0.00000	0.00023	0.00017	0.00056	0.00016	0.00021	0.00013	0.00001
1963/64	0.00000	0.00022	0.00017	0.00043	0.00035	0.00051	0.00010	0.00002
1964/65	0.00006	0.00026	0.00027	0.00049	0.00043	0.00005	0.00000	0.00000
1965/66	0.00002	0.00017	0.00004	0.00020	0.00019	0.00026	0.00003	0.00012
1966/67	.00000	0.00012	0.00015	0.00039	0.00034	0.00036	0.00007	0.00005
1967/68	0.00000	0.00008	0.00012	0.00047	0.00035	0.00006	0.00017	0.00002
1968/69	0.00018	0.00010	0.00032	0.00038	0.00039	0.00016	0.00027	0.00020
1969/70	0.00015	0.00011	0.00046	0.00013	0.00016	0.00015	0.00015	0.00003
1970/71	0.00000	0.00002	0.00035	0.00056	0.00044	0.00035	0.00019	0.00005
1971/72	0.00002	0.00009	0.00011	0.00047	0.00033	0.00009	0.00024	0.00006
1972/73	0.00004	0.00008	0.00039	0.00013	0.00038	0.00044	0.00021	0.00008
1973/74	0.00002	0.00028	0.00020	0.00047	0.00031	0.00019	0.00000	0.00000
1974/75	0.00001	0.00001	0.00017	0.00050	0.00038	0.00010	0.00000	0.00003
1975/76	0.00000	0.00005	0.00010	0.00043	0.00021	0.00010	0.00025	0.00005
1976/77	0.00000	0.00002	0.00024	0.00010	0.00002	0.00023	0.00024	0.00013
1977/78	0.00000	0.00009	0.00047	0.00003	0.00028	0.00039	0.00022	0.00010
1978/79	0.00000	0.00005	0.00013	0.00028	0.00046	0.00042	0.00002	0.00000
1979/80	0.00002	0.00001	0.00005	0.00055	0.00011	0.00019	0.00000	0.00000
1980/81	0.00014	0.00023	0.00019	0.00025	0.00039	0.00045	0.00016	0.00001
1981/82	0.00003	0.00006	0.00016	0.00051	0.00057	0.00052	0.00028	0.00002
1982/83	0.00002	0.00003	0.00035	0.00014	0.00043	0.00032	0.00022	0.00015
MEAN	0.00004	0.00011	0.00024	0.00035	0.00033	0.00025	0.00013	0.00005

APPENDIX O.9

MONTHLY WATER DEMANDS FOR 2PD (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00022	0.00007	0.00033	0.00019	0.00065	0.00043	0.00020	0.00000
1960/61	0.00000	0.00001	0.00005	0.00006	0.00049	0.00004	0.00001	0.00007
1961/62	0.00000	0.00026	0.00059	0.00050	0.00035	0.00036	0.00004	0.00000
1962/63	0.00000	0.00019	0.00013	0.00055	0.00019	0.00030	0.00014	0.00001
1963/64	0.00000	0.00018	0.00013	0.00041	0.00040	0.00065	0.00014	0.00002
1964/65	0.00003	0.00029	0.00022	0.00047	0.00048	0.00009	0.00001	0.00000
1965/66	0.00000	0.00015	0.00001	0.00018	0.00022	0.00036	0.00001	0.00014
1966/67	0.00000	0.00009	0.00012	0.00038	0.00039	0.00050	0.00013	0.00001
1967/68	0.00000	0.00004	0.00009	0.00046	0.00041	0.00011	0.00022	0.00002
1968/69	0.00024	0.00007	0.00027	0.00034	0.00044	0.00024	0.00035	0.00023
1969/70	0.00015	0.00009	0.00049	0.00011	0.00021	0.00024	0.00024	0.00000
1970/71	0.00000	0.00000	0.00030	0.00056	0.00050	0.00051	0.00028	0.00005
1971/72	0.00000	0.00007	0.00005	0.00048	0.00039	0.00018	0.00028	0.00007
1972/73	0.00001	0.00009	0.00034	0.00011	0.00044	0.00061	0.00028	0.00009
1973/74	0.00000	0.00028	0.00015	0.00044	0.00036	0.00026	0.00000	0.00000
1974/75	0.00000	0.00000	0.00013	0.00047	0.00041	0.00016	0.00000	0.00000
1975/76	0.00000	0.00000	0.00005	0.00042	0.00025	0.00014	0.00030	0.00007
1976/77	0.00000	0.00000	0.00018	0.00008	0.00003	0.00036	0.00028	0.00015
1977/78	0.00000	0.00006	0.00041	0.00031	0.00035	0.00056	0.00029	0.00011
1978/79	0.00000	0.00002	0.00008	0.00025	0.00053	0.00058	0.00006	0.00000
1979/80	0.00000	0.00000	0.00002	0.00053	0.00014	0.00028	0.00000	0.00000
1980/81	0.00017	0.00022	0.00013	0.00024	0.00053	0.00062	0.00022	0.00002
1981/82	.00000	0.00005	0.00012	0.00050	0.00064	0.00072	0.00035	0.00002
1982/83	0.00000	0.00000	0.00029	0.00012	0.00049	0.00045	0.00022	0.00018
MEAN	0.00003	0.00009	0.00020	0.00034	0.00039	0.00036	0.00017	0.00005

APPENDIX O.10

MONTHLY WATER DEMANDS FOR 2CL (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00016	0.00006	0.00034	0.00018	0.00051	0.00025	0.00009	0.00000
1960/61	0.00000	0.00004	0.00018	0.00009	0.00044	0.00000	0.00000	0.00008
1961/62	0.00000	0.00027	0.00062	0.00047	0.00031	0.00025	0.00000	0.00000
1962/63	0.00000	0.00014	0.00015	0.00051	0.00017	0.00015	0.00012	0.00000
1963/64	0.00000	0.00022	0.00013	0.00038	0.00034	0.00052	0.00010	0.00002
1964/65	0.00004	0.00024	0.00019	0.00044	0.00055	0.00003	0.00003	0.00000
1965/66	0.00002	0.00012	0.00005	0.00031	0.00017	0.00025	0.00003	0.00011
1966/67	0.00000	0.00010	0.00017	0.00041	0.00029	0.00032	0.00005	0.00002
1967/68	0.00000	0.00006	0.00010	0.00040	0.00042	0.00006	0.00014	0.00002
1968/69	0.00015	0.00006	0.00028	0.00037	0.00036	0.00006	0.00020	0.00016
1969/70	0.00004	0.00006	0.00045	0.00005	0.00009	0.00002	0.00012	0.00004
1970/71	0.00000	0.00000	0.00015	0.00040	0.00038	0.00032	0.00019	0.00002
1971/72	0.00002	0.00006	0.00010	0.00041	0.00022	0.00015	0.00024	0.00004
1972/73	0.00004	0.00007	0.00036	0.00011	0.00034	0.00033	0.00016	0.00005
1973/74	0.00002	0.00026	0.00015	0.00039	0.00019	0.00012	0.00000	0.00000
1974/75	0.00000	0.00001	0.00015	0.00053	0.00037	0.00010	0.00000	0.00004
1975/76	0.00000	0.00007	0.00015	0.00044	0.00016	0.00011	0.00030	0.00004
1976/77	0.00000	0.00000	0.00024	0.00007	0.00002	0.00022	0.00022	0.00013
1977/78	0.00000	0.00008	0.00039	0.00041	0.00026	0.00033	0.00019	0.00009
1978/79	0.00000	0.00003	0.00015	0.00035	0.00049	0.00040	0.00001	0.00000
1979/80	0.00004	0.00001	0.00006	0.00052	0.00009	0.00017	0.00000	0.00000
1980/81	0.00014	0.00019	0.00025	0.00015	0.00041	0.00043	0.00013	0.00005
1981/82	0.00002	0.00001	0.00014	0.00051	0.00056	0.00048	0.00028	0.00001
1982/83	0.00002	0.00003	0.00028	0.00015	0.00034	0.00029	0.00012	0.00014
MEAN	0.00003	0.00009	0.00022	0.00034	0.00031	0.00022	0.00011	0.00004

APPENDIX O.11

MONTHLY WATER DEMANDS FOR 2PL (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00024	0.00016	0.00044	0.00021	0.00056	0.00050	0.00024	0.00000
1960/61	0.00000	0.00015	0.00022	0.00014	0.00050	0.00008	0.00012	0.00019
1961/62	0.00000	0.00027	0.00057	0.00058	0.00056	0.00034	0.00002	0.00000
1962/63	0.00002	0.00031	0.00015	0.00033	0.00027	0.00038	0.00000	0.00001
1963/64	0.00000	0.00020	0.00015	0.00042	0.00046	0.00062	0.00017	0.00002
1964/65	0.00001	0.00030	0.00026	0.00055	0.00070	0.00027	0.00001	0.00000
1965/66	0.00000	0.00025	0.00006	0.00025	0.00038	0.00042	0.00003	0.00002
1966/67	0.00000	0.00009	0.00017	0.00032	0.00040	0.00057	0.00013	0.00016
1967/68	0.00000	0.00013	0.00013	0.00051	0.00023	0.00004	0.00021	0.00006
1968/69	0.00026	0.00007	0.00036	0.00040	0.00039	0.00029	0.00043	0.00027
1969/70	0.00014	0.00016	0.00045	0.00018	0.00039	0.00040	0.00028	0.00000
1970/71	0.00000	0.00000	0.00020	0.00052	0.00062	0.00056	0.00028	0.00007
1971/72	0.00001	0.00029	0.00016	0.00044	0.00053	0.00024	0.00032	0.00009
1972/73	0.00007	0.00016	0.00039	0.00032	0.00053	0.00048	0.00028	0.00016
1973/74	0.00001	0.00029	0.00027	0.00049	0.00037	0.00034	0.00000	0.00000
1974/75	0.00000	0.00000	0.00015	0.00066	0.00041	0.00034	0.00000	0.00010
1975/76	0.00000	0.00007	0.00011	0.00050	0.00024	0.00029	0.00036	0.00007
1976/77	0.00000	0.00000	0.00016	0.00012	0.00002	0.00038	0.00028	0.00017
1977/78	0.00000	0.00010	0.00046	0.00038	0.00049	0.00050	0.00036	0.00016
1978/79	0.00000	0.00006	0.00013	0.00027	0.00051	0.00063	0.00006	0.00000
1979/80	0.00001	0.00003	0.00002	0.00060	0.00021	0.00044	0.00003	0.00000
1980/81	0.00026	0.00033	0.00031	0.00041	0.00058	0.00064	0.00029	0.00007
1981/82	0.00002	0.00011	0.00017	0.00054	0.00068	0.00072	0.00039	0.00002
1982/83	0.00012	0.00018	0.00034	0.00015	0.00051	0.00044	0.00031	0.00019
MEAN	0.00005	0.00015	0.00024	0.00039	0.00044	0.00041	0.00019	0.00008

APPENDIX O.12

MONTHLY WATER DEMANDS FOR 2CW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00018	0.00015	0.00044	0.00023	0.00052	0.00037	0.00012	.00000
1960/61	0.00000	0.00015	0.00021	0.00012	0.00051	0.00000	0.00000	0.00014
1961/62	0.00001	0.00029	0.00064	0.00048	0.00035	0.00031	0.00001	0.00001
1962/63	0.00003	0.00016	0.00011	0.00047	0.00025	0.00020	0.00009	0.00006
1963/64	0.00000	0.00025	0.00016	0.00044	0.00042	0.00053	0.00014	0.00004
1964/65	0.00002	0.00027	0.00026	0.00046	0.00051	0.00008	0.00002	0.00000
1965/66	0.00002	0.00024	0.00005	0.00026	0.00027	0.00030	0.00007	0.00005
1966/67	0.00001	0.00013	0.00019	0.00038	0.00029	0.00036	0.00011	0.00004
1967/68	0.00000	0.00011	0.00008	0.00050	0.00043	0.00012	0.00017	0.00003
1968/69	0.00013	0.00007	0.00033	0.00035	0.00039	0.00017	0.00026	0.00022
1969/70	0.00011	0.00015	0.00056	0.00013	0.00018	0.00016	0.00017	0.00003
1970/71	0.00000	0.00004	0.00029	0.00044	0.00042	0.00035	0.00019	0.00006
1971/72	0.00000	0.00017	0.00021	0.00047	0.00039	0.00011	0.00024	0.00005
1972/73	0.00010	0.00010	0.00041	0.00018	0.00046	0.00038	0.00019	0.00009
1973/74	0.00005	0.00028	0.00029	0.00044	0.00027	0.00015	0.00000	0.00000
1974/75	0.00001	0.00001	0.00018	0.00056	0.00038	0.00012	0.00000	0.00003
1975/76	0.00002	0.00005	0.00019	0.00050	0.00030	0.00019	0.00030	0.00004
1976/77	0.00000	0.00001	0.00011	0.00013	0.00003	0.00021	0.00021	0.00011
1977/78	0.00000	0.00012	0.00049	0.00037	0.00032	0.00037	0.00023	0.00007
1978/79	0.00000	0.00003	0.00019	0.00029	0.00035	0.00045	0.00003	0.00000
1979/80	0.00003	0.00001	0.00003	0.00047	0.00010	0.00023	0.00000	0.00000
1980/81	0.00016	0.00024	0.00021	0.00025	0.00047	0.00045	0.00014	0.00005
1981/82	0.00007	0.00006	0.00025	0.00048	0.00055	0.00043	0.00030	0.00001
1982/83	0.00008	0.00004	0.00037	0.00021	0.00044	0.00035	0.00015	0.00017
MEAN	0.00004	0.00013	0.00026	0.00036	0.00036	0.00027	0.00013	0.00005

APPENDIX O.13

MONTHLY WATER DEMANDS FOR 2PW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00023	0.00013	0.00037	0.00020	0.00059	0.00053	0.00016	0.00000
1960/61	0.00000	0.00013	0.00016	0.00010	0.00055	0.00002	0.00000	0.00014
1961/62	0.00000	0.00027	0.00058	0.00047	0.00041	0.00039	0.00002	0.00000
1962/63	0.00000	0.00017	0.00008	0.00046	0.00030	0.00029	0.00009	0.00009
1963/64	0.00000	0.00022	0.00012	0.00042	0.00047	0.00068	0.00021	0.00002
1964/65	0.00000	0.00027	0.00022	0.00043	0.00057	0.00015	0.00004	0.00000
1965/66	0.00000	0.00024	0.00001	0.00025	0.00032	0.00041	0.00005	0.00008
1966/67	0.00000	0.00009	0.00015	0.00037	0.00035	0.00051	0.00017	0.00002
1967/68	0.00000	0.00008	0.00003	0.00048	0.00049	0.00019	0.00023	0.00003
1968/69	0.00014	0.00004	0.00028	0.00032	0.00044	0.00026	0.00033	0.00026
1969/70	0.00005	0.00016	0.00049	0.00013	0.00023	0.00024	0.00026	0.00000
1970/71	0.00000	0.00000	0.00023	0.00041	0.00050	0.00052	0.00023	0.00005
1971/72	0.00000	0.00014	0.00017	0.00046	0.00045	0.00020	0.00028	0.00007
1972/73	0.00009	0.00015	0.00036	0.00016	0.00052	0.00052	0.00026	0.00008
1973/74	0.00002	0.00029	0.00024	0.00043	0.00032	0.00021	0.00000	0.00000
1974/75	0.00000	0.00000	0.00014	0.00053	0.00041	0.00018	0.00000	0.00000
1975/76	0.00000	0.00003	0.00016	0.00049	0.00034	0.00026	0.00035	0.00006
1976/77	0.00000	0.00000	0.00007	0.00011	0.00003	0.00033	0.00026	0.00014
1977/78	0.00000	0.00008	0.00044	0.00035	0.00040	0.00052	0.00031	0.00008
1978/79	0.00000	0.00000	0.00013	0.00025	0.00041	0.00062	0.00009	0.00000
1979/80	0.00000	0.00000	0.00001	0.00046	0.00014	0.00033	0.00002	0.00000
1980/81	0.00020	0.00021	0.00015	0.00024	0.00053	0.00061	0.00019	0.00007
1981/82	0.00004	0.00010	0.00020	0.00047	0.00063	0.00062	0.00037	0.00002
1982/83	0.00000	0.00001	0.00031	0.00018	0.00052	0.00050	0.00019	0.00020
MEAN	0.00003	0.00012	0.00021	0.00034	0.00041	0.00038	0.00017	0.00006

APPENDIX O.14

MONTHLY WATER DEMANDS FOR 2BW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00027	0.00018	0.00052	0.00025	0.00072	0.00064	0.00021	0.00000
1960/61	0.00000	0.00014	0.00030	0.00014	0.00058	0.00000	0.00000	0.00008
1961/62	0.00000	0.00031	0.00065	0.00062	0.00047	0.00038	0.00004	0.00000
1962/63	0.00000	0.00028	0.00013	0.00068	0.00042	0.00043	0.00005	0.00029
1963/64	0.00000	0.00024	0.00022	0.00065	0.00054	0.00072	0.00025	0.00002
1964/65	0.00000	0.00041	0.00027	0.00056	0.00060	0.00020	0.00006	0.00000
1965/66	0.00000	0.00039	0.00000	0.00039	0.00044	0.00049	0.00000	0.00010
1966/67	0.00000	0.00003	0.00036	0.00049	0.00047	0.00063	0.00022	0.00008
1967/68	0.00000	0.00009	0.00000	0.00059	0.00058	0.00023	0.00031	0.00000
1968/69	0.00012	0.00005	0.00040	0.00051	0.00055	0.00021	0.00047	0.00026
1969/70	0.00000	0.00029	0.00063	0.00019	0.00038	0.00026	0.00033	0.00000
1970/71	0.00000	0.00000	0.00033	0.00057	0.00063	0.00061	0.00018	0.00026
1971/72	0.00000	0.00018	0.00030	0.00056	0.00062	0.00017	0.00026	0.00009
1972/73	0.00006	0.00024	0.00046	0.00024	0.00060	0.00064	0.00014	0.00027
1973/74	0.00000	0.00043	0.00024	0.00056	0.00047	0.00028	0.00000	0.00000
1974/75	0.00000	0.00000	0.00017	0.00069	0.00040	0.00024	0.00000	0.00000
1975/76	0.00000	0.00000	0.00034	0.00056	0.00050	0.00028	0.00055	0.00008
1976/77	0.00000	0.00000	0.00008	0.00030	0.00004	0.00048	0.00028	0.00017
1977/78	0.00000	0.00009	0.00059	0.00044	0.00051	0.00060	0.00037	0.00004
1978/79	0.00000	0.00000	0.00015	0.00035	0.00050	0.00068	0.00004	0.00000
1979/80	0.00000	0.00000	0.00000	0.00057	0.00024	0.00050	0.00000	0.00000
1980/81	0.00022	0.00023	0.00021	0.00035	0.00048	0.00066	0.00023	0.00004
1981/82	0.00000	0.00012	0.00045	0.00054	0.00071	0.00069	0.00051	0.00000
1982/83	0.00000	0.00000	0.00042	0.00026	0.00069	0.00059	0.00019	0.00023
MEAN	0.00003	0.00015	0.00030	0.00046	0.00051	0.00044	0.00020	0.00008

APPENDIX O.15

MONTHLY WATER DEMANDS FOR 2CHB (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00013	0.00004	0.00025	0.00013	0.00042	0.00036	0.00007	0.00000
1960/61	0.00000	0.00005	0.00014	0.00008	0.00041	0.00000	0.00000	0.00004
1961/62	0.00000	0.00022	0.00057	0.00036	0.00030	0.00023	0.00000	0.00000
1962/63	0.00000	0.00009	0.00013	0.00040	0.00014	0.00015	0.00012	0.00001
1963/64	0.00000	0.00020	0.00010	0.00027	0.00034	0.00051	0.00007	0.00002
1964/65	0.00002	0.00014	0.00014	0.00042	0.00051	0.00001	0.00003	0.00000
1965/66	0.00002	0.00004	0.00001	0.00023	0.00018	0.00025	0.00004	0.00004
1966/67	0.00000	0.00011	0.00016	0.00035	0.00022	0.00029	0.00005	0.00002
1967/68	0.00000	0.00006	0.00006	0.00036	0.00038	0.00010	0.00016	0.00001
1968/69	0.00007	0.00005	0.00016	0.00031	0.00029	0.00004	0.00014	0.00004
1969/70	0.00003	0.00004	0.00038	0.00003	0.00005	0.00002	0.00009	0.00004
1970/71	0.00000	0.00001	0.00014	0.00037	0.00029	0.00029	0.00019	0.00000
1971/72	0.00001	0.00003	0.00009	0.00043	0.00042	0.00005	0.00023	0.00005
1972/73	0.00003	0.00006	0.00034	0.00013	0.00033	0.00030	0.00015	.00000
1973/74	0.00002	0.00020	0.00011	0.00040	0.00019	0.00011	0.00000	0.00000
1974/75	0.00000	0.00000	0.00012	0.00057	0.00038	0.00010	0.00000	0.00000
1975/76	0.00000	0.00002	0.00005	0.00035	0.00012	0.00012	0.00024	0.00002
1976/77	0.00000	0.00000	0.00021	0.00006	0.00001	0.00017	0.00017	0.00012
1977/78	0.00000	0.00007	0.00034	0.00031	0.00016	0.00035	0.00016	0.00004
1978/79	0.00000	0.00000	0.00010	0.00026	0.00032	0.00033	0.00000	0.00000
1979/80	0.00002	0.00001	0.00005	0.00036	0.00010	0.00020	0.00000	0.00000
1980/81	0.00002	0.00010	0.00021	0.00014	0.00037	0.00045	0.00007	0.00002
1981/82	0.00002	0.00002	0.00018	0.00047	0.00054	0.00042	0.00026	0.00001
1982/83	0.00000	0.00003	0.00023	0.00010	0.00029	0.00026	0.00012	0.00010
MEAN	0.00002	0.00007	0.00018	0.00029	0.00028	0.00021	0.00010	0.00002

APPENDIX O.16

MONTHLY WATER DEMANDS FOR 2PHB (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00018	0.00003	0.00019	0.00010	0.00050	0.00053	0.00012	0.00000
1960/61	0.00000	0.00001	0.00010	0.00006	0.00045	0.00000	0.00000	0.00001
1961/62	0.00000	0.00019	0.00050	0.00036	0.00035	0.00031	0.00002	0.00000
1962/63	0.00000	0.00007	0.00010	0.00038	0.00015	0.00021	0.00014	0.00000
1963/64	0.00000	0.00018	0.00008	0.00025	0.00040	0.00066	0.00012	0.00000
1964/65	0.00000	0.00016	0.00010	0.00040	0.00057	0.00006	0.00005	0.00000
1965/66	0.00000	0.00002	0.00000	0.00021	0.00021	0.00035	0.00001	0.00002
1966/67	0.00000	0.00006	0.00012	0.00034	0.00028	0.00043	0.00010	0.00000
1967/68	0.00000	0.00003	0.00002	0.00034	0.00044	0.00016	0.00019	0.00000
1968/69	0.00004	0.00002	0.00012	0.00027	0.00035	0.00010	0.00019	0.00003
1969/70	0.00000	0.00002	0.00029	0.00003	0.00006	0.00003	0.00017	0.00000
1970/71	0.00000	0.00000	0.00010	0.00036	0.00034	0.00044	0.00022	0.00000
1971/72	0.00000	0.00000	0.00004	0.00042	0.00048	0.00012	0.00028	0.00005
1972/73	0.00000	0.00005	0.00029	0.00012	0.00040	0.00045	0.00021	0.00000
1973/74	0.00000	0.00020	0.00007	0.00036	0.00025	0.00015	0.00000	0.00000
1974/75	0.00000	0.00000	0.00007	0.00055	0.00041	0.00017	0.00000	0.00000
1975/76	0.00000	0.00000	0.00001	0.00034	0.00016	0.00017	0.00030	0.00002
1976/77	0.00000	0.00000	0.00017	0.00004	0.00002	0.00027	0.00021	0.00013
1977/78	0.00000	0.00004	0.00029	0.00028	0.00022	0.00050	0.00022	0.00004
1978/79	0.00000	0.00000	0.00006	0.00022	0.00039	0.00048	0.00004	0.00000
1979/80	0.00000	0.00000	0.00002	0.00034	0.00014	0.00028	0.00000	0.00000
1980/81	0.00000	0.00010	0.00017	0.00012	0.00043	0.00062	0.00011	0.00000
1981/82	0.00000	0.00002	0.00012	0.00046	0.00062	0.00062	0.00029	0.00002
1982/83	0.00000	0.00000	0.00016	0.00007	0.00036	0.00039	0.00015	0.00011
MEAN	0.00001	0.00005	0.00013	0.00027	0.00033	0.00031	0.00013	0.00002

APPENDIX O.17

MONTHLY WATER DEMANDS FOR 3PD (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00037	0.00020	0.00070	0.00037	0.00092	0.00059	0.00025	0.00000
1960/61	0.00000	0.00004	0.00027	0.00019	0.00063	0.00014	0.00007	0.00036
1961/62	0.00000	0.00054	0.00077	0.00071	0.00051	0.00041	0.00012	0.00000
1962/63	0.00000	0.00035	0.00031	0.00071	0.00046	0.00039	0.00035	0.00000
1963/64	0.00000	0.00040	0.00014	0.00066	0.00071	0.00083	0.00016	0.00017
1964/65	0.00012	0.00040	0.00035	0.00072	0.00058	0.00029	0.00005	0.00000
1965/66	0.00002	0.00031	0.00004	0.00039	0.00050	0.00057	0.00018	0.00014
1966/67	0.00000	0.00028	0.00024	0.00067	0.00063	0.00068	0.00012	0.00017
1967/68	0.00000	0.00014	0.00032	0.00071	0.00062	0.00034	0.00033	0.00019
1968/69	0.00021	0.00009	0.00050	0.00063	0.00068	0.00043	0.00041	0.00034
1969/70	0.00036	0.00012	0.00062	0.00018	0.00050	0.00047	0.00031	0.00010
1970/71	0.00000	0.00000	0.00063	0.00074	0.00069	0.00070	0.00038	0.00005
1971/72	0.00000	0.00022	0.00019	0.00074	0.00061	0.00037	0.00042	0.00000
1972/73	0.00005	0.00029	0.00065	0.00028	0.00069	0.00082	0.00032	0.00017
1973/74	0.00002	0.00048	0.00025	0.00077	0.00061	0.00043	0.00000	0.00000
1974/75	0.00000	0.00000	0.00036	0.00069	0.00049	0.00041	0.00000	0.00007
1975/76	0.00000	0.00004	0.00019	0.00061	0.00046	0.00028	0.00056	0.00009
1976/77	0.00000	0.00000	0.00043	0.00013	0.00015	0.00058	0.00041	0.00019
1977/78	0.00000	0.00017	0.00063	0.00052	0.00065	0.00079	0.00032	0.00012
1978/79	0.00000	0.00009	0.00034	0.00044	0.00077	0.00080	0.00002	0.00000
1979/80	0.00000	0.00000	0.00013	0.00084	0.00037	0.00040	0.00000	0.00000
1980/81	0.00036	0.00026	0.00032	0.00057	0.00072	0.00083	0.00027	0.00002
1981/82	0.00005	0.00012	0.00028	0.00073	0.00089	0.00088	0.00041	0.00000
1982/83	0.00000	0.00000	0.00062	0.00015	0.00074	0.00055	0.00036	0.00031
MEAN	0.00006	0.00019	0.00039	0.00055	0.00061	0.00054	0.00024	0.00010

APPENDIX O.18

MONTHLY WATER DEMANDS FOR 3BL (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00037	0.00026	0.00081	0.00034	0.00080	0.00069	0.00025	0.00000
1960/61	0.00000	0.00038	0.00046	0.00032	0.00066	0.00029	0.00016	0.00033
1961/62	0.00000	0.00055	0.00076	0.00072	0.00074	0.00042	0.00014	0.00005
1962/63	0.00009	0.00035	0.00041	0.00047	0.00061	0.00054	0.00021	0.00002
1963/64	0.00000	0.00041	0.00014	0.00069	0.00074	0.00081	0.00023	0.00013
1964/65	0.00005	0.00044	0.00046	0.00083	0.00088	0.00047	0.00000	0.00000
1965/66	0.00000	0.00044	0.00017	0.00054	0.00059	0.00057	0.00019	0.00010
1966/67	0.00000	0.00028	0.00027	0.00064	0.00065	0.00062	0.00017	0.00037
1967/68	0.00000	0.00034	0.00019	0.00087	0.00037	0.00017	0.00035	0.00021
1968/69	0.00036	0.00014	0.00056	0.00067	0.00045	0.00045	0.00056	0.00039
1969/70	0.00035	0.00018	0.00075	0.00037	0.00066	0.00064	0.00030	0.00010
1970/71	0.00000	0.00004	0.00052	0.00072	0.00078	0.00073	0.00038	0.00005
1971/72	0.00012	0.00047	0.00025	0.00073	0.00083	0.00039	0.00040	0.00022
1972/73	0.00028	0.00010	0.00072	0.00051	0.00073	0.00071	0.00028	0.00029
1973/74	0.00005	0.00038	0.00045	0.00077	0.00066	0.00049	0.00000	0.00000
1974/75	0.00000	0.00000	0.00040	0.00090	0.00050	0.00068	0.00000	0.00033
1975/76	0.00000	0.00021	0.00040	0.00071	0.00045	0.00052	0.00046	0.00006
1976/77	0.00000	0.00002	0.00033	0.00028	0.00009	0.00060	0.00041	0.00037
1977/78	0.00000	0.00027	0.00070	0.00056	0.00074	0.00078	0.00047	0.00027
1978/79	0.00000	0.00019	0.00039	0.00046	0.00076	0.00078	0.00007	0.00000
1979/80	0.00007	0.00011	0.00015	0.00090	0.00049	0.00046	0.00007	0.00002
1980/81	0.00045	0.00036	0.00047	0.00070	0.00075	0.00083	0.00043	0.00008
1981/82	0.00014	0.00015	0.00043	0.00075	0.00091	0.00087	0.00045	0.00000
1982/83	0.00035	0.00025	0.00064	0.00032	0.00078	0.00060	0.00037	0.00025
MEAN	0.00011	0.00026	0.00045	0.00062	0.00065	0.00059	0.00026	0.00015

APPENDIX O.19

MONTHLY WATER DEMANDS FOR 3BW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00037	0.00000	0.00057	0.00037	0.00078	0.00052	0.00018	0.00000
1960/61	0.00000	0.00002	0.00037	0.00017	0.00064	0.00007	0.00002	0.00036
1961/62	0.00000	0.00052	0.00076	0.00068	0.00053	0.00038	0.00002	0.00000
1962/63	0.00000	0.00032	0.00030	0.00065	0.00046	0.00030	0.00035	0.00000
1963/64	0.00000	0.00041	0.00012	0.00065	0.00062	0.00084	0.00021	0.00020
1964/65	0.00005	0.00044	0.00029	0.00071	0.00073	0.00023	0.00007	0.00000
1965/66	0.00000	0.00030	0.00013	0.00048	0.00051	0.00057	0.00021	0.00012
1966/67	0.00000	0.00015	0.00026	0.00067	0.00053	0.00062	0.00010	0.00000
1967/68	0.00000	0.00011	0.00030	0.00068	0.00065	0.00033	0.00027	0.00007
1968/69	0.00036	0.00000	0.00042	0.00063	0.00067	0.00023	0.00043	0.00028
1969/70	0.00012	0.00009	0.00074	0.00008	0.00034	0.00018	0.00029	0.00010
1970/71	0.00000	0.00000	0.00036	0.00050	0.00071	0.00066	0.00036	0.00000
1971/72	0.00000	0.00017	0.00019	0.00071	0.00054	0.00041	0.00041	0.00000
1972/73	0.00007	0.00027	0.00062	0.00020	0.00068	0.00075	0.00026	0.00005
1973/74	0.00000	0.00047	0.00020	0.00070	0.00041	0.00038	0.00000	0.00000
1974/75	0.00000	0.00000	0.00035	0.00069	0.00049	0.00041	0.00000	0.00000
1975/76	0.00000	0.00009	0.00029	0.00062	0.00046	0.00044	0.00047	0.00008
1976/77	0.00000	0.00000	0.00044	0.00008	0.00011	0.00057	0.00040	0.00024
1977/78	0.00000	0.00017	0.00053	0.00056	0.00052	0.00079	0.00024	0.00020
1978/79	0.00000	0.00002	0.00033	0.00052	0.00077	0.00078	0.00002	0.00000
1979/80	0.00010	0.00000	0.00015	0.00082	0.00039	0.00036	0.00000	0.00000
1980/81	0.00037	0.00014	0.00033	0.00034	0.00069	0.00080	0.00022	0.00002
1981/82	0.00000	0.00004	0.00034	0.00073	0.00088	0.00083	0.00037	0.00000
1982/83	0.00000	0.00002	0.00052	0.00034	0.00070	0.00060	0.00021	0.00034
MEAN	0.00006	0.00016	0.00037	0.00052	0.00058	0.00050	0.00021	0.00009

APPENDIX O.20

MONTHLY WATER DEMANDS FOR 4BL (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00042	0.00025	0.00083	0.00037	0.00084	0.00075	0.00030	0.00000
1960/61	0.00010	0.00034	0.00051	0.00039	0.00071	0.00040	0.00021	0.00029
1961/62	0.00003	0.00064	0.00082	0.00080	0.00080	0.00052	0.00016	0.00008
1962/63	0.00022	0.00043	0.00038	0.00053	0.00066	0.00056	0.00034	0.00005
1963/64	0.00000	0.00052	0.00024	0.00075	0.00080	0.00087	0.00029	0.00015
1964/65	0.00014	0.00046	0.00056	0.00081	0.00092	0.00050	0.00000	0.00000
1965/66	0.00013	0.00050	0.00015	0.00061	0.00063	0.00062	0.00024	0.00011
1966/67	0.00000	0.00040	0.00033	0.00073	0.00076	0.00086	0.00021	0.00033
1967/68	0.00000	0.00033	0.00036	0.00094	0.00044	0.00022	0.00046	0.00015
1968/69	0.00038	0.00022	0.00052	0.00074	0.00061	0.00059	0.00061	0.00040
1969/70	0.00035	0.00036	0.00055	0.00045	0.00067	0.00074	0.00030	0.00022
1970/71	0.00015	0.00015	0.00065	0.00073	0.00085	0.00077	0.00034	0.00019
1971/72	0.00027	0.00038	0.00036	0.00078	0.00088	0.00046	0.00050	0.00012
1972/73	0.00033	0.00013	0.00078	0.00053	0.00080	0.00067	0.00037	0.00037
1973/74	0.00008	0.00050	0.00045	0.00084	0.00072	0.00053	0.00000	0.00000
1974/75	0.00000	0.00002	0.00048	0.00099	0.00057	0.00075	0.00000	0.00033
1975/76	0.00003	0.00027	0.00044	0.00074	0.00047	0.00058	0.00049	0.00011
1976/77	0.00000	0.00019	0.00031	0.00029	0.00015	0.00065	0.00058	0.00035
1977/78	0.00000	0.00034	0.00075	0.00061	0.00080	0.00085	0.00051	0.00030
1978/79	0.00000	0.00025	0.00048	0.00050	0.00082	0.00078	0.00010	0.00022
1979/80	0.00011	0.00018	0.00020	0.00098	0.00053	0.00056	0.00010	0.00016
1980/81	0.00042	0.00047	0.00052	0.00076	0.00080	0.00090	0.00046	0.00005
1981/82	0.00030	0.00003	0.00045	0.00081	0.00099	0.00090	0.00044	0.00005
1982/83	0.00032	0.00032	0.00071	0.00034	0.00083	0.00067	0.00044	0.00029
MEAN	0.00016	0.00032	0.00049	0.00067	0.00071	0.00065	0.00031	0.00018

APPENDIX O.21

MONTHLY WATER DEMANDS FOR 4BW (cumecs)

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1959/60	0.00034	0.00008	0.00064	0.00043	0.00083	0.00062	0.00014	0.00000
1960/61	0.00000	0.00005	0.00044	0.00021	0.00066	0.00016	0.00003	0.00034
1961/62	0.00000	0.00056	0.00083	0.00078	0.00058	0.00048	0.00012	0.00000
1962/63	0.00000	0.00034	0.00037	0.00065	0.00053	0.00032	0.00043	0.00000
1963/64	0.00000	0.00047	0.00016	0.00063	0.00067	0.00090	0.00026	0.00020
1964/65	0.00013	0.00045	0.00037	0.00077	0.00072	0.00029	0.00006	0.00000
1965/66	0.00010	0.00021	0.00015	0.00056	0.00058	0.00062	0.00029	0.00003
1966/67	0.00000	0.00031	0.00023	0.00075	0.00062	0.00067	0.00006	0.00000
1967/68	0.00000	0.00016	0.00053	0.00077	0.00072	0.00043	0.00046	0.00013
1968/69	0.00034	0.00000	0.00047	0.00060	0.00074	0.00026	0.00046	0.00035
1969/70	0.00020	0.00011	0.00073	0.00014	0.00040	0.00026	0.00031	0.00022
1970/71	0.00000	0.00000	0.00050	0.00053	0.00074	0.00069	0.00037	0.00000
1971/72	0.00003	0.00024	0.00029	0.00075	0.00062	0.00036	0.00043	0.00010
1972/73	0.00024	0.00009	0.00066	0.00031	0.00067	0.00082	0.00033	0.00008
1973/74	0.00005	0.00056	0.00027	0.00077	0.00050	0.00037	0.00000	0.00000
1974/75	0.00000	0.00000	0.00040	0.00079	0.00051	0.00048	0.00000	0.00005
1975/76	0.00000	0.00018	0.00037	0.00066	0.00048	0.00051	0.00050	0.00005
1976/77	0.00000	0.00000	0.00050	0.00012	0.00017	0.00060	0.00046	0.00021
1977/78	0.00000	0.00027	0.00054	0.00055	0.00056	0.00085	0.00031	0.00014
1978/79	0.00000	0.00007	0.00037	0.00062	0.00083	0.00084	0.00002	0.00000
1979/80	0.00019	0.00005	0.00018	0.00092	0.00040	0.00040	0.00000	0.00000
1980/81	0.00034	0.00032	0.00036	0.00041	0.00071	0.00088	0.00027	0.00012
1981/82	0.00003	0.00008	0.00041	0.00079	0.00097	0.00085	0.00042	0.00000
1982/83	0.00000	0.00005	0.00060	0.00034	0.00077	0.00059	0.00027	0.00034
MEAN	0.00008	0.00019	0.00043	0.00058	0.00062	0.00055	0.00025	0.00010

APPENDIX P.1

DRYLAND WHEAT YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	2867	3577	2521	2673	2914	2456	2485
1960/61	4253	4319	3009	3049	3192	2583	2705
1961/62	2474	2670	2469	2515	2652	2484	2510
1962/63	3489	5185	3541	3241	4335	2747	3345
1963/64	3109	3836	2891	2814	3461	2716	2785
1964/65	2677	3191	2667	2818	3172	2688	2791
1965/66	3678	5139	3333	3243	4145	3171	3245
1966/67	4462	4046	4087	3600	3485	3308	3109
1967/68	4187	5410	4309	4121	4596	3931	4421
1968/69	2611	3022	2601	2721	2645	2530	2657
1969/70	2501	3191	2426	2538	2665	2469	2428
1970/71	5047	5456	3833	4066	4663	3031	2810
1971/72	4182	5550	2875	3240	4815	3129	2639
1972/73	3840	3996	3086	2908	2948	2453	2680
1973/74	2690	3016	2522	2825	2958	2548	2557
1974/75	4949	4945	4756	3961	3914	3077	3711
1975/76	4990	5714	3597	3918	5085	2821	2606
1976/77	4435	5020	5003	3250	3957	2893	3919
1977/78	2934	3464	2776	2464	2610	2460	2455
1978/79	4794	5152	4834	3720	4212	3045	3849
1979/80	5785	5849	5954	5203	5309	3876	5481
1980/81	3283	3341	3139	3841	3901	2953	3599
1981/82	3506	4071	3096	2680	2836	2529	2501
1982/83	2839	4930	2771	2922	3933	2815	2955
MEAN	3733	4337	3421	3264	3683	2863	3093
MAXIMUM	5785	5849	5954	5203	5309	3931	5481
MINIMUM	2474	2670	2426	2464	2610	2453	2428

APPENDIX P.2

DRYLAND BARLEY YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	4163	4930	3402	2636	3504	1221	1919
1960/61	5740	5670	4390	4825	4710	2692	2727
1961/62	1664	2035	1679	1266	1479	1223	1259
1962/63	4761	5660	5470	3363	4696	1916	4392
1963/64	3767	4806	3641	2026	3310	2026	1878
1964/65	3130	5167	3037	1738	3882	1542	1691
1965/66	5670	6598	5160	4710	6239	2870	3871
1966/67	5139	5148	4587	3847	3864	3318	2966
1967/68	5746	6254	6122	4835	5672	4016	5455
1968/69	3206	4924	3362	1757	3539	1343	1707
1969/70	2317	4103	2087	1945	2523	1417	1452
1970/71	5495	5815	4849	4430	4950	4399	3442
1971/72	5659	5781	4136	4693	4893	2368	2353
1972/73	3988	4264	3817	2416	2592	2022	2266
1973/74	3162	4558	2522	1756	2900	1325	1349
1974/75	5201	5464	5178	3983	4375	3585	3946
1975/76	6015	6396	5273	5279	5906	4515	4057
1976/77	5016	5172	5764	3635	3892	4008	4865
1977/78	2921	3689	2673	1556	2061	1377	1415
1978/79	5292	5537	5087	4098	4493	3665	3829
1979/80	6039	6130	6240	5319	5469	5268	5649
1980/81	4055	5271	3421	3301	4067	1943	2948
1981/82	5381	5314	4902	4235	4124	3808	3480
1982/83	4388	5046	4335	3072	3718	2884	3051
MEAN	4496	5156	4214	3363	4036	2698	2999
MAXIMUM	6039	6598	6240	5319	6239	5268	5649
MINIMUM	1664	2035	1679	1266	1479	1221	1259

APPENDIX P.3

DRYLAND GARDEN PEA YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	3317	3812	3137	2639	3584	2018	2583
1960/61	3839	3839	3838	3779	3832	3487	3452
1961/62	2256	3078	2353	1719	2561	1451	1826
1962/63	3213	4076	3770	2428	3181	2695	2890
1963/64	3279	4106	3214	2561	3409	2446	2532
1964/65	2528	3765	2748	1912	2853	1569	2122
1965/66	3913	3913	3873	3466	3537	2664	3066
1966/67	3791	3926	3548	2926	3089	2909	2678
1967/68	3929	3979	3920	3098	3517	2992	3078
1968/69	3502	4184	3650	2971	3613	2507	3075
1969/70	2910	3927	2800	2924	3585	2396	2733
1970/71	3371	3923	3136	2481	3031	2124	2339
1971/72	3356	3600	2772	2471	2731	1838	2030
1972/73	3551	3620	3293	2800	2839	2067	2566
1973/74	2890	3821	2812	2255	2980	2130	2299
1974/75	3103	3012	2901	2273	2110	1643	2058
1975/76	3790	3936	3292	2932	3221	2606	2418
1976/77	3222	3222	3222	2920	3189	2964	3146
1977/78	3200	3614	2743	2699	3023	2066	2215
1978/79	3907	3907	3905	3549	3680	3282	3424
1979/80	3725	4275	4035	2857	3486	2634	3169
1980/81	4013	4371	3709	3254	4173	1767	3021
1981/82	3315	3439	3232	2416	2541	2083	2396
1982/83	4254	4306	3970	3649	4018	3430	3371
MEAN	3424	3819	3328	2791	3241	2407	2687
MAXIMUM	4254	4371	4035	3779	4173	3487	3452
MINIMUM	2256	3012	2353	1719	2110	1451	1826

APPENDIX P.4

DRYLAND WHITE CLOVER YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	297	370	245	198	337	63	164
1960/61	349	348	386	355	357	284	319
1961/62	169	217	172	120	174	107	122
1962/63	313	370	344	229	331	162	274
1963/64	303	381	295	213	300	202	181
1964/65	216	342	249	89	254	71	114
1965/66	388	373	362	327	368	209	264
1966/67	351	358	329	301	312	282	268
1967/68	372	366	358	317	337	283	311
1968/69	213	370	298	132	336	85	218
1969/70	95	359	97	134	287	99	134
1970/71	286	327	273	262	286	260	250
1971/72	333	325	289	278	270	147	206
1972/73	352	358	339	243	254	171	215
1973/74	260	323	222	135	228	111	107
1974/75	293	300	286	245	250	233	237
1975/76	341	354	309	291	318	278	273
1976/77	362	333	351	337	329	356	357
1977/78	267	289	220	226	258	154	163
1978/79	364	339	351	326	323	308	313
1979/80	328	350	343	296	330	286	318
1980/81	271	389	231	193	350	70	177
1981/82	306	305	295	269	251	237	241
1982/83	278	360	234	285	349	165	267
MEAN	296	342	287	242	300	193	229
MAXIMUM	388	389	386	355	368	356	357
MINIMUM	95	217	97	89	174	63	107

APPENDIX P.5

DRYLAND RYEGRASS YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	816	1002	697	563	937	210	477
1960/61	973	971	1047	1005	1008	814	878
1961/62	470	606	480	351	499	313	359
1962/63	866	978	933	655	874	483	775
1963/64	835	1030	802	603	847	566	522
1964/65	571	949	640	276	685	233	343
1965/66	1050	918	1009	931	947	605	760
1966/67	950	968	913	817	854	769	717
1967/68	1001	938	977	849	896	757	830
1968/69	614	1012	820	412	905	284	631
1969/70	317	992	317	407	810	329	409
1970/71	768	875	747	692	758	677	678
1971/72	893	864	788	758	739	411	558
1972/73	966	973	939	687	717	477	621
1973/74	688	904	600	393	652	347	338
1974/75	800	805	776	652	653	610	625
1975/76	890	877	853	772	822	759	727
1976/77	966	926	932	917	931	982	975
1977/78	733	799	598	612	697	434	451
1978/79	964	904	946	888	873	867	839
1979/80	845	891	876	785	864	754	828
1980/81	803	1050	668	570	968	192	514
1981/82	844	842	813	722	678	641	644
1982/83	799	951	676	797	953	496	753
MEAN	809	918	785	671	815	542	636
MAXIMUM	1050	1050	1047	1005	1008	982	975
MINIMUM	317	606	317	276	499	192	338

APPENDIX P.6

DRYLAND PASTURE YIELD (kg DM/ha)

YEAR	1CD	1CHB	1CW	1PD	1PHB	1PW	2CD	2CHB	2CL	2CW	2PD	2PHB	2PL	2PW	3PD	3PL	3PW	4PL	4PW
1959/60	2143	3238	2400	5451	9544	5197	2033	6049	4717	3682	4274	7880	3912	4761	2074	2850	4158	1761	2887
1960/61	7033	8606	6744	10274	12032	9708	7751	8389	5311	7851	10858	11469	7712	9722	8813	5384	7451	3025	4774
1961/62	4986	5385	5006	5805	6437	5792	6092	6377	6233	6556	6008	6726	5511	6082	4537	4749	5354	3303	3723
1962/63	3952	5033	5709	6910	8320	8115	5015	5583	5527	6579	6426	8156	6017	7687	4556	5289	5740	3578	3609
1963/64	2399	2489	2143	6039	7557	5464	2696	3976	3330	3045	5271	6379	5228	4394	3404	3986	3383	2621	2231
1964/65	8473	8614	8243	7983	10182	8049	8566	8576	6233	8417	7193	8748	4969	7156	5037	4114	5337	2803	3611
1965/66	6600	7202	4812	10021	10833	8149	6971	7060	6758	6274	9133	10093	6915	7381	5768	5164	5366	3182	3348
1966/67	3086	5134	2794	7416	9441	6847	3754	5929	3283	3289	6852	8877	6272	6195	4758	4884	4730	2961	3017
1967/68	3796	4058	3155	8446	9417	7578	4575	7223	7501	6038	8734	9426	9354	8243	6519	6509	6613	4175	4210
1968/69	2568	3886	2650	4411	7799	5517	2664	4402	2841	3027	3525	7141	3199	4924	1481	2168	3834	1268	2516
1969/70	3299	8599	3312	3718	12326	3819	4800	8026	5577	4835	5341	11033	4953	5605	3866	3312	4730	1946	2617
1970/71	2246	3025	2432	5853	7010	5761	2450	3691	2564	2765	5589	6953	5339	5500	3623	4136	4289	2634	2858
1971/72	2440	2667	2402	6969	7418	6014	2798	4884	3032	4011	6666	7097	4024	5229	4740	3047	3879	1843	2544
1972/73	2462	2532	2301	6483	7212	6057	2756	3545	2543	2360	5231	6125	4082	4641	3073	2974	3204	1860	1920
1973/74	7016	7774	6437	7201	8900	6454	7808	7993	7313	7730	6647	7816	6134	6339	4713	5090	5184	3533	3495
1974/75	8611	8614	8072	10726	10825	9735	8191	8489	6547	7929	9858	9892	8577	9652	7601	6825	7853	4459	5430
1975/76	2451	3964	2487	7013	8799	6390	2764	5095	2706	3295	6659	8457	5843	6115	4934	4252	4669	2561	2730
1976/77	4515	6422	4688	9964	11338	10205	3652	4884	3205	3756	8353	9490	7762	9150	6176	6322	7364	4096	4925
1977/78	3921	4096	3915	6301	6713	5628	4080	4262	3965	4086	6113	6377	4865	5143	4130	3823	4030	2572	2704
1978/79	6053	6319	5908	9187	10098	9289	6206	6487	6096	5980	8070	9131	8621	8338	6161	6690	6991	4226	4647
1979/80	4474	4921	4588	9980	10838	9961	4634	7571	5721	7410	10041	10266	9312	10235	8196	7437	8326	4743	5637
1980/81	2500	2682	2293	4802	7531	4165	2636	2999	2282	2278	4265	6580	2560	3761	2655	1842	3059	1081	1992
1981/82	2752	3572	2940	6175	6757	5888	3361	4435	2575	3670	5845	6442	4852	5368	3559	3380	3784	2178	2538
1982/83	2744	3579	2534	5106	8392	4202	3564	4075	2878	3584	6136	7369	3521	5693	4348	3181	4687	1911	2995
MEAN	4188	5100	4082	7176	8988	6833	4576	5833	4531	4935	6795	8247	5814	6555	4780	4475	5167	2847	3373
MAXIMUM	8611	8614	8243	10726	12326	10205	8566	8576	7501	8417	10858	11469	9354	10235	8813	7437	8326	4743	5637
MINIMUM	2143	2489	2143	3718	6437	3819	2033	2999	2282	2278	3525	6125	2560	3761	1481	1842	3059	1081	1920

APPENDIX Q.1

IRRIGATED WHEAT YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	5426	5737	5422	5420	5753	5352	5393
1960/61	6042	5942	5894	5929	5886	5712	5847
1961/62	5048	5228	5048	5110	5308	5148	5099
1962/63	5808	5882	5975	5691	5769	5821	5816
1963/64	5892	6123	5932	5784	6034	5775	5822
1964/65	5971	6107	5943	5957	6052	5850	5913
1965/66	6193	6281	6188	6073	6135	6028	6053
1966/67	6001	6030	5904	6000	6011	5909	5911
1967/68	5989	6118	6063	5873	5995	5827	5905
1968/69	5603	5787	5601	5520	5646	5465	5563
1969/70	5499	5541	5413	5508	5546	5506	5411
1970/71	5745	5908	5712	5657	5815	5670	5701
1971/72	5970	5965	5873	5844	5818	5829	5780
1972/73	5474	5567	5520	5557	5669	5454	5564
1973/74	5904	5960	5694	5798	5777	5618	5625
1974/75	5632	5760	5587	5596	5786	5696	5615
1975/76	6071	6078	5986	5999	6071	5932	5940
1976/77	5712	5805	5914	5757	5814	5945	5984
1977/78	5257	5497	5235	5301	5506	5302	5298
1978/79	5723	5786	5655	5590	5625	5569	5535
1979/80	6066	6089	6140	5955	5941	5903	6061
1980/81	5961	5992	5953	5833	5915	5734	5890
1981/82	5925	5893	5712	5847	5762	5692	5603
1982/83	5462	5663	5393	5283	5566	5150	5236
MEAN	5766	5864	5740	5703	5800	5662	5690
MAXIMUM	6193	6281	6188	6073	6135	6028	6061
MINIMUM	5048	5228	5048	5110	5308	5148	5099

APPENDIX Q.2

IRRIGATED BARLEY YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	5594	6007	5457	5516	5988	5425	5522
1960/61	6257	6149	6113	6168	6065	5831	6051
1961/62	5072	5348	5071	5158	5426	5215	5143
1962/63	5980	6089	6106	5801	5885	5947	5993
1963/64	6122	6426	6170	5989	6338	5972	6039
1964/65	6348	6414	6314	6179	6328	6137	6154
1965/66	6365	6631	6452	6080	6385	6272	6288
1966/67	6297	6290	6177	6271	6285	6168	6185
1967/68	6233	6422	6351	6149	6261	6102	6152
1968/69	5642	5925	5748	5699	5783	5658	5743
1969/70	5228	5571	5324	5645	5651	5657	5526
1970/71	5985	6146	5810	5806	6018	5802	5837
1971/72	6181	6140	6129	6039	6010	6068	6011
1972/73	5606	5726	5587	5654	5823	5553	5691
1973/74	6207	6237	5962	6047	6019	5832	5836
1974/75	5841	5978	5861	5696	5872	5691	5695
1975/76	6234	6478	6143	6018	6191	6132	6156
1976/77	5914	6000	6137	5999	6052	6219	6241
1977/78	5383	5654	5361	5408	5692	5425	5413
1978/79	5854	5929	5789	5680	5799	5688	5698
1979/80	6305	6326	6409	6182	6145	6170	6300
1980/81	6252	6262	6292	6065	6100	6020	6112
1981/82	6181	6080	5883	6037	5956	5899	5805
1982/83	5534	5843	5458	5349	5736	5166	5283
MEAN	5942	6086	5921	5860	5992	5835	5870
MAXIMUM	6365	6631	6452	6271	6385	6272	6300
MINIMUM	5072	5348	5071	5158	5426	5166	5143

APPENDIX Q.3

IRRIGATED GARDEN PEA YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	3812	3812	3812	3812	3812	3812	3812
1960/61	3839	3839	3839	3839	3839	3838	3838
1961/62	4584	4584	4584	4584	4584	4584	4584
1962/63	4250	4250	4250	4237	4247	4239	4243
1963/64	4116	4116	4116	4116	4116	4116	4116
1964/65	4299	4299	4299	4299	4299	4299	4299
1965/66	3913	3913	3913	3913	3913	3913	3913
1966/67	4020	4020	4020	4020	4020	4020	4020
1967/68	3979	3979	3979	3979	3979	3979	3979
1968/69	4188	4188	4188	4187	4188	4188	4188
1969/70	3899	3927	3918	3927	3927	3927	3927
1970/71	4248	4248	4248	4242	4246	4241	4243
1971/72	3775	3775	3775	3775	3775	3775	3775
1972/73	3669	3669	3669	3669	3669	3669	3669
1973/74	4119	4119	4119	4119	4119	4119	4119
1974/75	3888	3888	3888	3888	3888	3888	3888
1975/76	3944	3944	3944	3944	3944	3944	3944
1976/77	3222	3222	3222	3222	3222	3222	3222
1977/78	4097	4097	4097	4097	4097	4097	4097
1978/79	3907	3907	3907	3907	3907	3906	3907
1979/80	4308	4309	4309	4285	4303	4282	4295
1980/81	4371	4371	4371	4371	4371	4371	4371
1981/82	3972	3972	3972	3972	3972	3972	3972
1982/83	4306	4306	4306	4306	4306	4305	4306
MEAN	4030	4031	4031	4030	4031	4029	4030
MAXIMUM	4584	4584	4584	4584	4584	4584	4584
MINIMUM	3222	3222	3222	3222	3222	3222	3222

APPENDIX Q.4

IRRIGATED WHITE CLOVER YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	352	347	356	356	345	356	359
1960/61	345	345	366	361	357	365	366
1961/62	385	373	386	387	381	388	387
1962/63	385	374	381	373	366	366	370
1963/64	377	372	380	379	377	381	378
1964/65	388	387	391	385	380	384	382
1965/66	374	363	375	368	368	375	372
1966/67	374	369	371	377	372	375	372
1967/68	374	360	383	373	366	381	380
1968/69	366	362	372	372	364	375	374
1969/70	346	328	357	352	341	370	355
1970/71	357	347	358	361	353	382	362
1971/72	375	349	384	378	352	386	378
1972/73	335	332	341	346	343	356	347
1973/74	388	378	380	380	373	380	373
1974/75	349	355	355	357	364	378	364
1975/76	362	350	377	369	359	380	380
1976/77	329	311	325	344	322	360	339
1977/78	353	343	355	362	350	370	357
1978/79	345	326	339	353	332	359	350
1979/80	359	345	357	369	352	373	369
1980/81	368	371	365	368	364	385	368
1981/82	375	357	384	373	362	370	365
1982/83	360	331	369	344	343	362	349
MEAN	363	353	367	366	358	373	367
MAXIMUM	388	387	391	387	381	388	387
MINIMUM	329	311	325	344	322	356	339

APPENDIX Q.5

IRRIGATED RYEGRASS YIELDS (kg/ha)

YEAR	1CD	1CHB	1CW	2CD	2CHB	2CL	2CW
1959/60	1031	975	1051	1016	978	1003	1007
1960/61	941	959	1018	978	985	1035	1010
1961/62	1040	1020	1044	1044	1028	1047	1047
1962/63	1009	993	1022	1003	1011	996	1004
1963/64	995	971	997	998	977	1005	999
1964/65	987	993	994	976	981	980	979
1965/66	1001	916	987	1017	969	986	979
1966/67	950	946	955	962	957	975	964
1967/68	990	926	1007	973	960	995	982
1968/69	1034	1010	1020	1005	1020	1033	1022
1969/70	866	960	903	929	972	1004	996
1970/71	936	913	954	971	944	1012	975
1971/72	956	893	999	979	914	998	995
1972/73	971	966	981	982	977	1035	993
1973/74	1002	996	1025	992	997	1015	1006
1974/75	922	917	931	960	956	996	970
1975/76	915	874	988	961	921	998	992
1976/77	954	909	915	978	921	998	939
1977/78	981	967	988	989	970	1013	998
1978/79	952	897	942	975	919	987	964
1979/80	901	882	898	941	922	960	942
1980/81	991	991	990	976	997	991	976
1981/82	977	923	1038	998	942	1019	1026
1982/83	1051	937	1028	989	957	909	1023
MEAN	973	947	986	983	966	1000	991
MAXIMUM	1051	1020	1051	1044	1028	1047	1047
MINIMUM	866	874	898	929	914	909	939

APPENDIX Q.6

IRRIGATED PASTURE YIELDS (kg DM/ha)

YEAR	1BW	1CD	1CHB	1CW	1PD	1PHB	1PW	2BW	2CD	2CHB	2CL	2CW	2PD	2PHB	2PL	2PW	3BL	3BW	3PD	4BL	4BW
1959/60	11744	8565	8625	8567	12670	12750	12616	11586	8246	8447	8201	8372	12574	12625	12583	12537	10060	10170	11120	7226	7187
1960/61	12275	8504	8610	8547	12728	12760	12677	12161	8453	8450	8270	8497	12625	12697	12629	12556	10337	10560	11159	7445	7450
1961/62	11521	8568	8579	8542	12414	12524	12361	11813	8579	8592	8490	8538	12330	12392	12221	12269	10112	10197	10840	7231	7247
1962/63	11986	8500	8570	8458	12726	12791	12741	11649	8461	8514	8498	8447	12550	12643	12562	12589	10261	10320	11098	7412	7401
1963/64	11546	8500	8515	8257	12618	12660	12553	11847	8423	7908	8320	8339	12419	12496	12442	12323	10273	10243	10989	7127	7372
1964/65	12064	8614	8614	8614	12613	12670	12606	11717	8577	8595	8447	8598	12530	12556	12433	12511	10415	10440	11069	7343	7269
1965/66	12066	8453	8531	8481	12768	12781	12762	11819	8436	8519	8505	8466	12639	12674	12604	12626	10417	10480	11140	7437	7592
1966/67	11968	8555	8608	8512	12650	12741	12660	11659	8091	8574	8400	7889	12458	12588	12462	12479	10155	10144	10942	7182	7222
1967/68	12093	8437	8589	8165	12702	12740	12682	11994	8509	8563	8314	8467	12611	12675	12658	12599	10475	10301	11069	7484	7284
1968/69	11935	8440	8511	8497	12727	12767	12721	11627	8149	8433	8222	8443	12618	12690	12597	12580	10061	10014	11071	6934	7208
1969/70	11876	7808	8611	7897	12820	12807	12783	11771	7886	8346	8230	7976	12654	12730	12642	12658	10047	10277	11160	7174	7401
1970/71	11632	8457	8605	8357	12642	12757	12635	11876	8537	8599	8310	8338	12525	12613	12427	12529	10196	10369	11022	7195	7303
1971/72	11960	8573	8567	8558	12833	12824	12850	11769	8587	8538	8455	8613	12765	12798	12730	12776	10247	10285	11307	7120	7446
1972/73	11750	8370	8586	8498	12633	12741	12689	11744	8289	8578	8217	8355	12554	12666	12458	12497	10197	10199	11068	7116	7108
1973/74	11823	8573	8614	8461	12746	12800	12748	12008	8612	8614	8470	8578	12726	12750	12667	12736	10695	10704	11257	7565	7653
1974/75	12211	8611	8614	8565	12662	12674	12651	12113	8274	8602	8377	8071	12568	12594	12484	12550	10626	10626	11085	7630	7613
1975/76	11866	8405	8442	8265	12781	12759	12756	11758	8387	8537	8400	8437	12801	12792	12730	12732	10294	10349	11343	7321	7097
1976/77	12292	8313	8274	8236	12769	12758	12768	12257	8286	8339	8333	8268	12732	12732	12712	12717	10615	10830	11304	7436	7773
1977/78	11797	8568	8574	8591	12645	12759	12671	11620	8530	8536	8519	8549	12546	12676	12577	12594	9995	10236	11063	7115	7364
1978/79	12284	8562	8590	8566	12588	12713	12623	12211	8511	8559	8453	8482	12523	12647	12429	12557	10419	10615	10983	7529	7447
1979/80	12250	8656	8657	8653	12782	12858	12795	12356	8623	8650	8243	8610	12671	12770	12588	12677	10585	10838	11189	7615	7794
1980/81	11789	8274	8483	7811	12496	12662	12503	11544	7706	7935	8113	8074	12407	12556	12329	12338	9985	10306	10913	6944	7254
1981/82	11381	8458	8494	8496	12407	12550	12557	11551	8485	8536	8366	8354	12340	12468	12297	12431	10165	10271	10874	7208	7105
1982/83	11795	8251	8483	7891	12708	12827	12720	11882	8376	8439	7659	8252	12627	12769	12577	12625	9989	10204	11074	7213	6959
MEAN	11913	8459	8556	8395	12672	12736	12672	11847	8376	8475	8326	8376	12575	12650	12535	12562	10276	10374	11089	7292	7356
MAXIMUM	12292	8656	8657	8653	12833	12858	12850	12356	8623	8650	8519	8613	12801	12798	12730	12776	10695	10838	11343	7630	7794
MINIMUM	11381	7808	8274	7811	12407	12524	12361	11544	7706	7908	7659	7889	12330	12392	12221	12269	9985	10014	10840	6934	6959

APPENDIX R

EMPLOYMENT MULTIPLIERS

In the three counties where irrigation development could occur with water from the Rakaia River; Ashburton, Malvern and Ellesmere, permanent on-farm employment has been declining, with full-time positions falling from 1372 to 941 (31%) during the period 1978-81, and part-time positions from 425-330 (22%) during the same period, Brown (1983). Brown estimated that unrestricted irrigation could increase stock levels across 96,600 hectares of net irrigable area by 660,00 stock units. The estimated impact on full-time on-farm employment was 270 persons (0.002795/ha irrigated) and a further 47 jobs (0.0004865/ha irrigated) would be generated for scheme operation and maintenance. the total direct effect is therefore 317 additional jobs or 0.0032815 per hectare irrigated. The strong economic linkages farming has with the regional economy mean that a similar number, 317 jobs, would be made available within the region. The total impact of irrigation development on employment is estimated to be 634 jobs or 0.0065631 jobs per hectare irrigated. This would help offset the current decline in employment being felt in the counties and help maintain some social services which may have other-wise been lost.

APPENDIX S

NET RETURNS FROM AGRICULTURAL PRODUCTS AND COSTS OF PASTURE REPLACEMENT AND RENEWAL

The values used in this analysis are as at December 1985. Farm costs have been derived from the Lincoln College Farm Budget Manual, Clark and Burtt (1986). Farmer product prices were obtained from market reports in December 1985 and national product prices are the product price assumptions produced by MAF Economics Division, MAF (1986) for use in the analysis of land betterment schemes in 1986.

FARMER			NATIONAL	
Wheat (per tonne)				
Revenue	250.00		253.00	
Direct costs	142.85		142.85	
Net Revenue		$107.15		$110.15
Barley (per tonne)				
Revenue	165.00		234.50	
Direct costs	105.84		105.84	
Net Revenue		$ 59.16		$128.66
Peas (per tonne)				
Revenue	392.00		400.00	
Direct costs	285.79		285.79	
Net Revenue		$106.21		$156.21
White Clover (per kilogram)				
Revenue	3.50		2.73	
Direct costs	1.66		1.66	
Net Revenue		$ 1.84		$ 1.07
Ryegrass (per kilogram)				
Revenue	1.41		1.56	
Direct costs	1.10		1.10	
Net Revenue		$0.31		$0.46
Lambs (per lamb)				
Revenue	13.24		21.90	
Direct costs	2.97		2.97	
Net Revenue		$10.27		$18.93
Mutton (per ewe)				
Revenue	10.27		9.10	
Direct costs	2.57		2.57	
Net Revenue		$7.70		$6.53

FARMER			NATIONAL	
Wool (per kilogram)				
Revenue	3.50		3.67	
Direct costs	0.43		0.43	
Net Revenue		$3.07		$3.24

Pasture (per hectare)

Dryland grazing	-	$99.76
Dryland cropping	-	$70.30
Irrigated grazing	-	$114.65
Irrigated cropping	-	$107.28

APPENDIX T
SAMPLE GOAL PROGRAMMING MODEL PRINTOUT

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STRT

NAME
: 1962-63 : RUN A : FLOW>65 :

CHNG

    FREQ2    20000.00000000

RHS

END

MTRX

END

SOLV
FEASIBLE ON ITERATION    41

REINVERSION BECAUSE OF SPACE AT ITERATION  1001

THESE ARE THE NUMBERS OF THE COLUMNS IN SOLUTION.
       1    2    3    4    5    6    7    8    9   10   11
      12   13   14   15   16   17   18   19   20   21   22
      23   24   25   26   27   28   29   30   31   32   33
      34   35   36   37   38   39   40   41   42   43   44
      45   47   48   51   52   58   59   60   61   62   63
      64   65   66   67   68   69   70   71   72   73   74
      75   76   77   78   79   80   81   82   83   84   85
      86   87   88   89   90   91   92   93   94   95   96
      97   98   99  100  101  102  103  104  105  106  107
     108  109  110  111  112  113  114  115  116  117  118
     119  120  121  122  123  124  125  126  127  128  129
     130  131  132  133  134  135  136  137  146  147  148
     149  150  151  152  153  154  155  156  157  159  160
     161  162  163  165  166  167  169  170  171  172  177
     178  179  180  181  182  183  184  185  187  191  194
     195  196  197  198  199  200  201  202  203  205  206
     207  208  209  210  211  213  215  217  221  223  226
     228  229  230  231  232  233  234  235  236  237  238
     239  240  241  242  243  244  245  246  247  248  253
     254  272  273  276  277  279  280  296  297  298  299
     300  301  302  303  320  321  322  323  324  325  326

THESE ARE NUMBERS OF THE ROWS WITH ARTIFICIALS IN SOLUTION.
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GOAL PROGRAMMING SOLUTION

-PROBLEM DESCRIPTION-
: 1962-63 : RUN A : FLOW>65 :

-DATE-
28/05/86
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CONSTRAINT SUMMARY

ROW NO.	ROW RIGHT-HAND-SIDE VALUE	ROW DESCRIPTION	ROW TYPE	NEGATIVE DEVIATIONS PRIORITY	NEGATIVE DEVIATIONS WEIGHT	POSITIVE DEVIATIONS PRIORITY	POSITIVE DEVIATIONS WEIGHT
SFLO	0.00	SEPTEMBER FLOW	E	0	0.00	0	0.00
OFLO	0.00		E	0	0.00	0	0.00
NFLO	0.00		E	0	0.00	0	0.00
DFLO	0.00		E	0	0.00	0	0.00
JFLO	0.00		E	0	0.00	0	0.00
FFLO	0.00		E	0	0.00	0	0.00
MFLO	0.00		E	0	0.00	0	0.00
AFLO	0.00		E	0	0.00	0	0.00
HBFS	23.36	HIGHBANK FLOW	E	0	0.00	0	0.00
HBFO	13.50		E	0	0.00	0	0.00
HBFN	6.42		E	0	0.00	0	0.00
HBFD	5.56		E	0	0.00	0	0.00
HBFJ	4.63		E	0	0.00	0	0.00
HBFF	3.00		E	0	0.00	0	0.00
HBFM	2.23		E	0	0.00	0	0.00
HBFA	6.99		E	0	0.00	0	0.00
SRUL	0.00	SEP ALLOCATION R	E	0	0.00	0	0.00
ORUL	0.00	OCT ALLOCATION R	E	0	0.00	0	0.00
NRUL	0.00	NOV ALLOCATION R	E	0	0.00	0	0.00
DRUL	0.00	DEC ALLOCATION R	E	0	0.00	0	0.00
JRUL	0.00	JAN ALLOCATION R	E	0	0.00	0	0.00
FRUL	0.00	FEB ALLOCATION R	E	0	0.00	0	0.00
MRUL	0.00	MAR ALLOCATION R	E	0	0.00	0	0.00
ARUL	0.00	APR ALLOCATION R	E	0	0.00	0	0.00
SALL	20.00	MAXIMUM FLOW 20	E	0	0.00	0	0.00
OALL	20.00		E	0	0.00	0	0.00
NALL	20.00		E	0	0.00	0	0.00
DALL	20.00		E	0	0.00	0	0.00
JALL	20.00		E	0	0.00	0	0.00
FALL	20.00		E	0	0.00	0	0.00
MALL	20.00		E	0	0.00	0	0.00
AALL	20.00		E	0	0.00	0	0.00
SAGD	0.00	SEP AGRIC. DEMAN	E	0	0.00	0	0.00
OAGD	0.00		E	0	0.00	0	0.00
NAGD	0.00		E	0	0.00	0	0.00
DAGD	0.00		E	0	0.00	0	0.00
JAGD	0.00		E	0	0.00	0	0.00
FAGD	0.00		E	0	0.00	0	0.00
MAGD	0.00		E	0	0.00	0	0.00
AAGD	0.00		E	0	0.00	0	0.00
SFC	0.00		E	0	0.00	0	0.00
OFC	0.00		E	0	0.00	0	0.00
NFC	0.00		E	0	0.00	0	0.00
DFC	0.00		E	0	0.00	0	0.00
JFC	0.00		E	0	0.00	0	0.00
FFC	0.00		E	0	0.00	0	0.00
MFC	0.00		E	0	0.00	0	0.00
AFC	0.00		E	0	0.00	0	0.00
SWD	0.00		E	0	0.00	0	0.00
OWD	0.00		E	0	0.00	0	0.00
NWD	0.00		E	0	0.00	0	0.00
DWD	0.00		E	0	0.00	0	0.00
JWD	0.00		E	0	0.00	0	0.00
FWD	0.00		E	0	0.00	0	0.00
MWD	0.00		E	0	0.00	0	0.00
AWD	0.00		E	0	0.00	0	0.00
SWDE	0.00	WATER DEPTH TIES	L	0	0.00	0	0.00
OWDE	0.00		L	0	0.00	0	0.00
NWDE	0.00		L	0	0.00	0	0.00
DWDE	0.00		L	0	0.00	0	0.00
JWDE	0.00		L	0	0.00	0	0.00
FWDE	0.00		L	0	0.00	0	0.00
MWDE	0.00		L	0	0.00	0	0.00
AWDE	0.00		L	0	0.00	0	0.00
SM70	50.00	MAXIMUM FLOW 70	L	0	0.00	0	0.00
OM70	50.00		L	0	0.00	0	0.00
NM70	50.00		L	0	0.00	0	0.00
DM70	50.00		L	0	0.00	0	0.00
JM70	50.00		L	0	0.00	0	0.00
FM70	50.00		L	0	0.00	0	0.00
MM70	50.00		L	0	0.00	0	0.00
AM70	50.00		L	0	0.00	0	0.00

SM10	30.00	MAXIMUM FLOW 100	L	0	0.00	0	0.00
OM10	30.00		L	0	0.00	0	0.00
NM10	30.00		L	0	0.00	0	0.00
DM10	30.00		L	0	0.00	0	0.00
JM10	30.00		L	0	0.00	0	0.00
FM10	30.00		L	0	0.00	0	0.00
MM10	30.00		L	0	0.00	0	0.00
AM10	30.00		L	0	0.00	0	0.00
SM16	60.00	MAXIMUM FLOW 160	L	0	0.00	0	0.00
OM16	60.00		L	0	0.00	0	0.00
NM16	60.00		L	0	0.00	0	0.00
DM16	60.00		L	0	0.00	0	0.00
JM16	60.00		L	0	0.00	0	0.00
FM16	60.00		L	0	0.00	0	0.00
MM16	60.00		L	0	0.00	0	0.00
AM16	60.00		L	0	0.00	0	0.00
SM24	80.00	MAXIMUM FLOW 240	L	0	0.00	0	0.00
OM24	80.00		L	0	0.00	0	0.00
NM24	80.00		L	0	0.00	0	0.00
DM24	80.00		L	0	0.00	0	0.00
JM24	80.00		L	0	0.00	0	0.00
FM24	80.00		L	0	0.00	0	0.00
MM24	80.00		L	0	0.00	0	0.00
AM24	80.00		L	0	0.00	0	0.00
SDJB	0.00	SALMON DIRECT JO	L	0	0.00	0	0.00
STJB	0.00	SALMON TOTAL JOB	L	0	0.00	0	0.00
INST	0.00	INSTREAM RECON	E	0	0.00	0	0.00
DJOB	0.00	DIRECT JOBS	L	0	0.00	0	0.00
TJOB	0.00	TOTAL JOBS	L	0	0.00	0	0.00
DSL$	0.00	DIRECT COM SALMO	L	0	0.00	0	0.00
RSL$	0.00	TOTAL COM SALMON	L	0	0.00	0	0.00
REC$	0.00	RECREATIONAL $	L	0	0.00	0	0.00
SIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
OIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
NIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
DIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
JIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
FIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
MIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
AIT	0.00	INSREAM ALLOCAT.	L	0	0.00	0	0.00
RCON	1.00	RIVER CONSTRAINT	E	0	0.00	0	0.00
SINT	0.00	SEP INSTREAM TRA	L	0	0.00	0	0.00
OINT	0.00	OCT INSTREAM TRA	L	0	0.00	0	0.00
NINT	0.00	NOV INSTREAM TRA	L	0	0.00	0	0.00
DINT	0.00	DEC INSTREAM TRA	L	0	0.00	0	0.00
JINT	0.00	JAN INSTREAM TRA	L	0	0.00	0	0.00
FINT	0.00	FEB INSTREAM TRA	L	0	0.00	0	0.00
MINT	0.00	MAR INSTREAM TRA	L	0	0.00	0	0.00
AINT	0.00	APR INSTREAM TRA	L	0	0.00	0	0.00
CP11	2640.00	C.PLAINS CLASS 1	E	0	0.00	0	0.00
CP12	1761.00	C.PLAINS CLASS 1	E	0	0.00	0	0.00
CP21	8285.00	C.PLAINS CLASS 2	E	0	0.00	0	0.00
CP23	1469.00	C.PLAINS CLASS 2	E	0	0.00	0	0.00
CP22	8285.00	C.PLAINS CLASS 2	E	0	0.00	0	0.00
CP24	1469.00	C.PLAINS CLASS 2	E	0	0.00	0	0.00
CP32	2282.00	C.PLAINS CLASS 3	E	0	0.00	0	0.00
CP33	2559.00	C.PLAINS CLASS 3	E	0	0.00	0	0.00
NCD	0.00	NTH C PLAINS DRY	E	0	0.00	0	0.00
NCI	0.00	NTH C PLAINS IRR	E	0	0.00	0	0.00
NCF$	0.00	NTH C PLAINS ON	E	0	0.00	0	0.00
NCO$	0.00	NTH C PLAINS OFF	E	0	0.00	0	0.00
SCXL	6063.00	STH C PLAINS X L	E	0	0.00	0	0.00
SXL3	812.00	STH C PLAINS X L	E	0	0.00	0	0.00
SCXD	0.00	STH C PLAINS X D	E	0	0.00	0	0.00
SCXI	0.00	STH C PLAINS X I	E	0	0.00	0	0.00
SXF$	0.00	STH C PLAINS X O	E	0	0.00	0	0.00
SXO$	0.00	STH C PLAINS X O	E	0	0.00	0	0.00
SCPL	25000.00	STH C PLAINS LAN	E	0	0.00	0	0.00
SCPD	0.00	STH C PLAINS DRY	E	0	0.00	0	0.00
SCPI	0.00	STH C PLAINS IRR	E	0	0.00	0	0.00
SCF$	0.00	STH C PLAINS ON	E	0	0.00	0	0.00
SCO$	0.00	STH C PLAINS OFF	E	0	0.00	0	0.00
CPD	0.00	C.PLAINS DRYLAND	E	0	0.00	0	0.00
CPI	0.00	C.PLAINS IRRIGAT	E	0	0.00	0	0.00
NC11	866.00	N PUMP CLASS 1 T	E	0	0.00	0	0.00
NP12	577.00	N PUMP CLASS 1 T	E	0	0.00	0	0.00
NP21	2716.00	N PUMP CLASS 2 T	E	0	0.00	0	0.00
NP22	2716.00	N PUMP CLASS 2 T	E	0	0.00	0	0.00
NPF$	0.00	N PUMP ON $	E	0	0.00	0	0.00
NPO$	0.00	N PUMP OFF $	E	0	0.00	0	0.00
NPD	0.00	N PUMP DRYLAND T	E	0	0.00	0	0.00

NPI	0.00	N PUMP IRRIGATED	E	0	0.00	0	0.00
BH11	298.00	BARRHILL CLASS 1	E	0	0.00	0	0.00
BH12	3660.00	BARRHILL CLASS 1	E	0	0.00	0	0.00
BH13	2440.00	BARRHILL CLASS 1	E	0	0.00	0	0.00
BH14	446.00	BARRHILL CLASS 1	E	0	0.00	0	0.00
BH21	2406.00	BARRHILL CLASS 2	E	0	0.00	0	0.00
BH22	422.00	BARRHILL CLASS 2	E	0	0.00	0	0.00
BH23	422.00	BARRHILL CLASS 2	E	0	0.00	0	0.00
BH24	2406.00	BARRHILL CLASS 2	E	0	0.00	0	0.00
BHF$	0.00	BARRHILL ON $	E	0	0.00	0	0.00
BHO$	0.00	BARRHILL OFF $	E	0	0.00	0	0.00
BHD	0.00	BARRHILL DRYLAND	E	0	0.00	0	0.00
BHI	0.00	BARRHILL IRRIGAT	E	0	0.00	0	0.00
SRK1	1001.00	STH. RAKAIA AREA	E	0	0.00	0	0.00
SRI	0.00	STH. RAKAIA IRR	E	0	0.00	0	0.00
NRK1	2000.00	NTH. RAKAIA AREA	E	0	0.00	0	0.00
NRI	0.00	NTH. RAKAIA IRR	E	0	0.00	0	0.00
TEP1	3126.00	TE PIRITA AREA T	E	0	0.00	0	0.00
TPD	0.00	TE PIRITA DRY TI	E	0	0.00	0	0.00
TPI	0.00	TE PIRITA IRR TI	E	0	0.00	0	0.00
TPF$	0.00	TE PIRITA ON $	E	0	0.00	0	0.00
TPO$	0.00	TE PIRITA OFF $	E	0	0.00	0	0.00
FER1	3283.00	FEREDAY AREA TIE	E	0	0.00	0	0.00
FEI	0.00	FEREDAY IRRIGATE	E	0	0.00	0	0.00
LR11	2941.00	L.RAKAIA CLASS 1	E	0	0.00	0	0.00
LR12	4413.00	L.RAKAIA CLASS 1	E	0	0.00	0	0.00
LR21	8823.00	L.RAKAIA CLASS 1	E	0	0.00	0	0.00
LR22	8823.00	L.RAKAIA CLASS 1	E	0	0.00	0	0.00
LRF$	0.00	L.RAKAIA ON $	E	0	0.00	0	0.00
LRO$	0.00	L.RAKAIA OFF $	E	0	0.00	0	0.00
LRD	0.00	L.RAKAIA DRYLAND	E	0	0.00	0	0.00
LRI	0.00	L.RAKAIA IRRIGAT	E	0	0.00	0	0.00
DLAN	0.00	TOTAL DRYLAND TI	E	0	0.00	0	0.00
ILAN	0.00	TOTAL IRRIGATED	E	0	0.00	0	0.00
WHEA	0.00	WHEAT PRODUCTION	L	0	0.00	0	0.00
BARL	0.00	BARLEY PRODUCTIO	L	0	0.00	0	0.00
PEAS	0.00	PEA PRODUCTION	L	0	0.00	0	0.00
WHCL	0.00	WHITE CLOVER PRO	L	0	0.00	0	0.00
RYEG	0.00	RYEGRASS PRODUCT	L	0	0.00	0	0.00
LSPD	0.00	L & S RAK DRY PA	L	0	0.00	0	0.00
LSPI	0.00	L & S RAK IRR PA	L	0	0.00	0	0.00
CPPD	0.00	C. PLAINS DRY PA	L	0	0.00	0	0.00
CPPI	0.00	C. PLAINS IRR PA	L	0	0.00	0	0.00
BHPD	0.00	BARRHILL DRY PAS	L	0	0.00	0	0.00
BHPI	0.00	BARRHILL IRR PAS	L	0	0.00	0	0.00
TNPD	0.00	TP,NR & FER DRY	L	0	0.00	0	0.00
TNPI	0.00	TP,NR & FER IRR	L	0	0.00	0	0.00
LAMB	0.00	LAMB PRODUCTION	L	0	0.00	0	0.00
EWES	0.00	MUTTON PRODUCTIO	L	0	0.00	0	0.00
WOOL	0.00	WOOL PRODUCTION	L	0	0.00	0	0.00
OFF$	0.00	OFF FARM CAPITAL	E	0	0.00	0	0.00
ON$	0.00	ON FARM CAPITAL	E	0	0.00	0	0.00
OF$G	0.00	OFF FARM CAPITAL	G	0	0.00	1	1.00
ON$G	0.00	ON FARM CAPITAL	G	0	0.00	5	1.00
NATY	0.00	NATIONAL INCOME	E	0	0.00	0	0.00
FARY	0.00	FARMER INCOME TI	E	0	0.00	0	0.00
R$	0.00	REGIONAL INCOME	E	0	0.00	0	0.00
NT$G	200000000.00	NATIONAL INCOME	L	1	20.00	0	0.00
FM$G	200000000.00	FARMER INCOME	L	5	20.00	0	0.00
RE$G	200000000.00	REGIONAL INCOME	L	6	1.00	0	0.00
DJBG	1000.00	DIRECT JOB GOAL	L	4	1.00	0	0.00
TJBG	1000.00	TOTAL JOB GOAL	L	4	1.00	0	0.00
SWDG	0.25	SEP WATER DEPTH	G	0	0.00	3	1.00
OWDG	0.25	OCT WATER DEPTH	G	0	0.00	3	1.00
NWDG	0.25	NOV WATER DEPTH	G	0	0.00	3	1.00
DWDG	0.25	DEC WATER DEPTH	G	0	0.00	3	1.00
JWDG	0.25	JAN WATER DEPTH	G	0	0.00	3	1.00
FWDG	0.25	FEB WATER DEPTH	G	0	0.00	3	1.00
MWDG	0.25	MAR WATER DEPTH	G	0	0.00	3	1.00
AWDG	0.25	APR WATER DEPTH	G	0	0.00	3	1.00
SIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
OIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
NIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
DIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
JIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
FIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
MIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00
AIFG	65.00	MIN FLOW GOAL	G	0	0.00	2	1.00

SUMMARY OF INPUT INFORMATION

NUMBER OF CONSTRAINT ROWS.....	231
NUMBER OF NON-ZERO MATRIX ENTRIES.....	1476
NUMBER OF VARIABLES(INCLUDING SLACK).....	342
NUMBER OF PRIORITIES.....	6
NUMBER OF DECISION VARIABLES.....	240
NUMBER OF POSITIVE DEVIATIONAL VARIABLES...	18
NUMBER OF NEGATIVE DEVIATIONAL VARIABLES...	84
NUMBER OF ARTIFICIAL VARIABLES.....	147
NUMBER OF ITERATIONS TO FIND THE SOLUTION..	1005

OPTIMAL VALUE OF DECISION VARIABLES

VARIABLE	DESCRIPTION	AMOUNT
RIMN	MEAN RIVER FLOW	1.00
SHIB	HIGHBANK FLOW SEP	23.36
OHIB	HIGHBANK FLOW OCT	13.50
NHIB	HIGHBANK FLOW NOV	6.42
DHIB	HIGHBANK FLOW DEC	5.56
JHIB	HIGHBANK FLOW JAN	4.63
FHIB	HIGHBANK FLOW FEB	3.00
MHIB	HIGHBANK FLOW MAR	2.23
AHIB	HIGHBANK FLOW APR	6.99
S20	SEP DEMAND - 20 CUM	20.00
O20	OCT DEMAND - 20 CUM	20.00
N20	NOV DEMAND - 20 CUM	20.00
D20	DEC DEMAND - 20 CUM	20.00
J20	JAN DEMAND - 20 CUM	20.00
F20	FEB DEMAND - 20 CUM	20.00
M20	MAR DEMAND - 20 CUM	20.00
A20	APR DEMAND - 20 CUM	20.00
S70	SEP DEMAND - 70 CUM	50.00
O70	OCT DEMAND - 70 CUM	50.00
N70	NOV DEMAND - 70 CUM	50.00
D70	DEC DEMAND - 70 CUM	50.00
J70	JAN DEMAND - 70 CUM	50.00
F70	FEB DEMAND - 70 CUM	50.00
M70	MAR DEMAND - 70 CUM	50.00
A70	APR DEMAND - 70 CUM	50.00
S100	SEP DEMAND -100 CUM	30.00
O100	OCT DEMAND -100 CUM	30.00
N100	NOV DEMAND -100 CUM	30.00
D100	DEC DEMAND -100 CUM	30.00
J100	JAN DEMAND -100 CUM	30.00
F100	FEB DEMAND -100 CUM	30.00
M100	MAR DEMAND -100 CUM	30.00
A100	APR DEMAND -100 CUM	30.00
S160	SEP DEMAND - 160 CUM	60.00
O160	OCT DEMAND -160 CUM	60.00
N160	NOV DEMAND -160 CUM	60.00
D160	DEC DEMAND -160 CUM	60.00
J160	JAN DEMAND -160 CUM	60.00
F160	FEB DEMAND -160 CUM	60.00
M160	MAR DEMAND -160 CUM	60.00
A160	APR DEMAND -160 CUM	50.03
S1-2	SEP DEMAND 160-240	38.32
O1-2	OCT DEMAND 160-240	80.00
N1-2	NOV DEMAND 160-240	80.00
D1-2	DEC DEMAND 160-240	4.16
F1-2	FEB DEMAND 160-240	80.00
M1-2	MAR DEMAND 160-240	16.16
O2+	OCT DEMAND 240+	34.50
N2+	NOV DEMAND 240+	72.69
SFCT	SEP FLOW COUNT	198.32
OFCT	OCT FLOW COUNT	274.50
NFCT	NOV FLOW COUNT	312.69
DFCT	DEC FLOW COUNT	164.16
JFCT	JAN FLOW COUNT	148.11
FFCT	FEB FLOW COUNT	218.45
MFCT	MAR FLOW COUNT	226.16
AFCT	APR FLOW COUNT	100.03

SDPT	SEP WATER DEPTH	0.33
ODPT	OCT WATER DEPTH	0.34
NDPT	NOV WATER DEPTH	0.35
DDPT	DEC WATER DEPTH	0.32
JDPT	JAN WATER DEPTH	0.31
FDPT	FEB WATER DEPTH	0.33
MDPT	MAR WATER DEPTH	0.32
ADPT	APR WATER DEPTH	0.31
SEAS	SEASONS FLOW COUNT	1642.43
SDJO	SALMON DIRECT JOBS	27.51
STJO	SALMON TOTAL JOBS	91.70
TDJO	TOTAL DIRECT JOBS	302.11
TTJO	TOTAL JOBS	640.91
TNS$	TOT. DIRECT SALMON $	5227154.50
TRS$	TOTAL SALMON $	8069996.50
TRE$	TOTAL RECREATIONAL $	4640247.50
SWDP	SEP WATER DEPTH (m)	0.25
OWDP	OCT WATER DEPTH (m)	0.25
NWDP	NOV WATER DEPTH (m)	0.25
DWDP	DEC WATER DEPTH (m)	0.25
JWDP	JAN WATER DEPTH (m)	0.25
FWDP	FEB WATER DEPTH (m)	0.25
MWDP	MAR WATER DEPTH (m)	0.25
AWDP	APR WATER DEPTH (m)	0.25
SINA	SEP INSTREAM ALLOCAT	89.68
OINA	OCT INSTREAM ALLOCAT	137.25
NINA	NOV INSTREAM ALLOCAT	154.71
DINA	DEC INSTREAM ALLOCAT	95.28
JINA	JAN INSTREAM ALLOCAT	78.32
FINA	FEB INSTREAM ALLOCAT	111.50
MINA	MAR INSTREAM ALLOCAT	86.61
AINA	APR INSTREAM ALLOCAT	66.00
SIAT	SEP IN-AG TRANSFER	88.64
OIAT	OCT IN-AG TRANSFER	117.25
NIAT	NOV IN-AG TRANSFER	137.98
DIAT	DEC IN-AG TRANSFER	48.88
JIAT	JAN IN-AG TRANSFER	49.80
FIAT	FEB IN-AG TRANSFER	86.95
MIAT	MAR IN-AG TRANSFER	69.54
AIAT	APR IN-AG TRANSFER	64.04
SINS	SEP INSTREAM USE	65.00
OINS	OCT INSTREAM USE	65.00
NINS	NOV INSTREAM USE	65.00
DINS	DEC INSTREAM USE	65.00
JINS	JAN INSTREAM USE	65.00
FINS	FEB INSTREAM USE	65.00
MINS	MAR INSTREAM USE	65.00
AINS	APR INSTREAM USE	65.00
SAGA	SEP AG ALLOCATION	89.68
OAGA	OCT AG ALLOCATION	137.25
NAGA	NOV AG ALLOCATION	154.71
DAGA	DEC AG ALLOCATION	95.28
JAGA	JAN AG ALLOCATION	78.32
FAGA	FEB AG ALLOCATION	111.50
MAGA	MAR AG ALLOCATION	86.61
AAGA	APR AG ALLOCATION	66.00
SLWH	SELL WHEAT	32494.53
SLBA	SELL BARLEY	35581.50
SLPE	SELL PEAS	25344.77
SLWC	SELL WHITE CLOVER	2257232.50
SLRG	SELL RYEGRASS	6154462.50
DPLS	DRY PAST L & S RAK.	5038.76
IPLS	IRR PAST L & S RAK.	140088.20
DPCP	DRY PAST C. PLAINS	684.49
IPCP	IRR PAST C. PLAINS	476289.31
DPBH	DRY PAST BARRHILL	4664.60
IPBH	IRR PAST BARRHILL	59756.83
IPTN	IRR PAST TP,NR & FER	57116.73
SLLB	SELL LAMB	1053022.00
SLMN	SELL MUTTON	190613.95
SLWL	SELL WOOL	7582848.00
C1IA	N. C. PLAINS 1CD IRR	2112.00
C1IB	N. C. PLAINS 1PD IRR	1408.80
C2IA	N. C. PLAINS 2CD IRR	6628.00
C2IY	N. C. PLAINS 2CL IRR	1175.20
C2IB	N. C. PLAINS 2PD IRR	6628.00
C2IZ	N. C. PLAINS 2PL IRR	1175.20
C3IB	N. C. PLAINS 3BL IRR	1825.60
C3IC	S. C. PLAINS 3BW IRR	2047.20

NCIR	N. C. PLAINS IRRIG.	28750.00
NCON	N. C. PLAINS ON $	29900000.00
NCOF	N. C. PLAINS OFF $	38812500.00
SC3I	S. C. PLAINS 3BW IRR	20000.00
SCIR	S. C. PLAINS IRRIG.	25000.00
SCON	S. C. PLAINS ON $	26000000.00
SCOF	S. C. PLAINS OFF $	31250000.00
SCXI	S.C.PLAINS X 3PD IRR	4850.40
SXI3	S.C.PLAINS X 3BW IRR	649.60
SXIR	S.C.PLAINS X IRRIG.	6875.00
SXON	S.C.PLAINS X ON $	7150000.00
SXOF	S.C.PLAINS X OFF $	30937500.00
NPD1	N.C.PLAINS X 1CD DRY	866.00
NPI2	N.C.PLAINS X 1PD IRR	461.60
NPI3	N.C.PLAINS X 2PD IRR	2172.80
NPI4	N.C.PLAINS X 2CD IRR	2172.80
NPDR	N.C.PLAINS X DRYLAND	866.00
NPIR	N.C.PLAINS X IRRIG.	6009.00
NPON	N.C.PLAINS X ON $	5768640.00
NPOF	N.C.PLAINS X OFF $	15022500.00
CPDR	C. PLAINS DRY COUNT	866.00
CPIR	C. PLAINS IRR COUNT	92825.00
L1DZ	L. RAKAIA 1CW DRY	4413.00
L1IB	L. RAKAIA 1PW IRR	2352.80
L2IB	L. RAKAIA 2PW IRR	7058.40
L2IZ	L. RAKAIA 2CW IRR	7058.40
LRON	L. RAKAIA ON $	23057440.00
LROF	L. RAKAIA OFF $	26763100.00
LRDR	L. RAKAIA DRY COUNT	4413.00
LRIR	L. RAKAIA IRR COUNT	20587.00
SR2I	S. RAKAIA 2BW IRR	800.80
SRIR	S. RAKAIA IRR COUNT	1001.00
NR4I	N. RAKAIA 4PW IRR	1600.00
NRIR	N. RAKAIA IRR COUNT	2000.00
TP3I	T. PIRITA 3BW IRR	2500.80
TPON	T. PIRITA ON FARM $	3501120.00
TPOF	T. PIRITA OFF FARM $	3594900.00
TPIR	T. PIRITA IRR COUNT	3126.00
FE4I	FEREDAY 4BL IRR	2626.40
FEIR	FEREDAY IRR COUNT	3283.00
B1DY	BARRHILL 1CHB DRY	3660.00
B1DB	BARRHILL 1CW DRY	446.00
B2DA	BARRHILL 2CHB DRY	422.00
B1IB	BARRHILL 1PW IRR	238.40
B1IZ	BARRHILL 1PHB IRR	1952.00
B2IB	BARRHILL 2PW IRR	1924.80
B2IC	BARRHILL 2PHB IRR	337.60
B2IZ	BARRHILL 2CW IRR	1924.80
BHON	BARRHILL ON FARM $	8290880.00
BHOF	BARRHILL OFF FARM $	15944010.00
BHDR	BARRHILL DRY COUNT	4528.00
BHIR	BARRHILL IRR COUNT	7972.00
TDRY	TOTAL DRYLAND	9807.00
TIRR	TOTAL IRRIGATED	104603.00
TO$	TOTAL ON FARM CAP.	103668080.00
TOF$	TOTAL OFF FARM CAP.	162324528.00
TNT$	TOT. NATIONAL INCOME	142925568.00
TFM$	TOTAL FARMER INCOME	83913304.00
REG$	TOT. REGIONAL IMPACT	176217936.00

GOAL ACHIEVEMENT

```
GOAL LEVEL      1 IS NOT ACHIEVED IN THE FOLLOWING CONSTRAINTS-
        *       OF$G, OFF FARM CAPITAL EXP,
                IS OVERACHIEVED BY   162324528. UNITS.
        *       NT$G, NATIONAL INCOME
                IS UNDERACHIEVED BY    57074440. UNITS.
        * SUMMARY-
           GOAL     1 IS NOT ACHIEVED BY  1303813248. WGTD UNITS.

GOAL LEVEL      2 MIN FLOW GOAL        COMPLETELY ACHIEVED.

GOAL LEVEL      3 APR WATER DEPTH GOAL COMPLETELY ACHIEVED.

GOAL LEVEL      4 IS NOT ACHIEVED IN THE FOLLOWING CONSTRAINTS-
        *       DJBG, DIRECT JOB GOAL
                IS UNDERACHIEVED BY        698. UNITS.
        *       TJBG, TOTAL JOB GOAL
                IS UNDERACHIEVED BY        359. UNITS.
        * SUMMARY-
           GOAL     4 IS NOT ACHIEVED BY        1057. WGTD UNITS.

GOAL LEVEL      5 IS NOT ACHIEVED IN THE FOLLOWING CONSTRAINTS-
        *       ON$G, ON FARM CAPITAL EXP
                IS OVERACHIEVED BY   103668080. UNITS.
        *       FM$G, FARMER INCOME
                IS UNDERACHIEVED BY   116086728. UNITS.
        * SUMMARY-
           GOAL     5 IS NOT ACHIEVED BY  2425402624. WGTD UNITS.

GOAL LEVEL      6 IS NOT ACHIEVED IN THE FOLLOWING CONSTRAINTS-
        *       RE$G, REGIONAL INCOME GOAL,
                IS UNDERACHIEVED BY    23782102. UNITS.
        * SUMMARY-
           GOAL     6 IS NOT ACHIEVED BY    23782102. WGTD UNITS.
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GOAL SLACK ANALYSIS

ALL GOALS WITH CONSTRAINT TYPE -B- WERE EITHER UNATTAINED AND TREATED IN THE GOAL ATTAINMENT SECTION, OR THE GOALS WERE MET AT THEIR SPECIFIED LEVEL. THEREFORE THIS SECTION OFANALYSIS IS NOT NEEDED.

RESOURCE UTILIZATION ANALYSIS

ROW NUMBER	RESOURCE DESCRIPTION	EXACT RESOURCE LEVEL	RESOURCE NOT-USED	RESOURCE OVER-PRODUCED
SWDE	WATER DEPTH TIES	0.00	0.08	0000.00
OWDE		0.00	0.09	0000.00
NWDE		0.00	0.10	0000.00
DWDE		0.00	0.07	0000.00
JWDE		0.00	0.06	0000.00
FWDE		0.00	0.08	0000.00
MWDE		0.00	0.07	0000.00
AWDE		0.00	0.06	0000.00
AM16		60.00	9.97	0000.00
SM24	MAXIMUM FLOW 240	80.00	41.68	0000.00
DM24		80.00	75.84	0000.00
JM24		80.00	80.00	0000.00
MM24		80.00	63.84	0000.00
AM24		80.00	80.00	0000.00
SINT	SEP INSTREAM TRANS	0.00	133.32	0000.00
OINT	OCT INSTREAM TRANS	0.00	209.50	0000.00
NINT	NOV INSTREAM TRANS	0.00	247.69	0000.00
DINT	DEC INSTREAM TRANS	0.00	99.16	0000.00
JINT	JAN INSTREAM TRANS	0.00	83.11	0000.00
FINT	FEB INSTREAM TRANS	0.00	153.45	0000.00
MINT	MAR INSTREAM TRANS	0.00	111.16	0000.00
AINT	APR INSTREAM TRANS	0.00	85.03	0000.00

STOP

APPENDIX U.1

AVERAGE FLOW YEAR (1962-63)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	65	75	95	115	125	145
MONTHLY FLOW RATE									
September	2	1	198.32	198.32	198.32	198.32	198.32	198.32	198.32
October	2	1	274.50	274.50	274.50	274.50	274.50	274.50	274.50
November	2	1	312.69	312.69	312.69	312.69	312.69	312.69	312.69
December	2	1	164.16	164.16	164.16	164.16	164.16	164.16	164.16
January	2	1	148.11	148.11	148.11	148.11	148.11	148.11	148.11
February	2	1	218.45	218.45	218.45	218.45	218.45	218.45	218.45
March	2	1	226.16	226.16	226.16	226.16	226.16	226.16	226.16
April	2	1	100.03	100.03	100.03	100.03	100.03	100.03	100.03
MONTHLY WATER DEPTH									
September	3	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
October	3	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34
November	3	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35
December	3	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
January	3	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
February	3	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
March	3	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
April	3	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT									
Direct	4	1	302	302	302	302	302	302	302
Total	4	1	641	641	641	641	641	641	641
FARMER INCOME ($mil.)	5	20	83.91	83.91	83.91	83.91	83.91	83.91	83.91
ON-FARM CAPITAL ($mil.)	5	1	103.67	103.67	103.67	103.67	103.67	103.67	103.67
NATIONAL INCOME ($mil.)	1	20	142.93	142.93	142.93	142.93	142.93	142.93	142.93
OFF-FARM CAPITAL ($mil.)	1	1	162.32	162.32	162.32	162.32	162.32	162.32	162.32
REGIONAL INCOME ($mil.)	6	1	176.22	176.22	176.22	176.22	176.22	176.22	176.22

APPENDIX U.1 (continued)

AVERAGE FLOW YEAR (1962-63)

	MINIMUM FLOW (cumecs)						
	N.C.O.	65	75	95	115	125	145
AREA IRRIGATED							
Nth. Central Plains	28750	28750	28750	28750	28750	28750	28750
Sth. Central Plains	25000	25000	25000	25000	25000	25000	25000
Sth. Central Plains Ext.	6875	6875	6875	6875	6875	6875	6875
Nth. Central Plains Ext.	6009	6009	6009	6009	6009	6009	6009
Total Central Plains	66634	66634	66634	66634	66634	66634	66634
Lower Rakaia	20587	20587	20587	20587	20587	20587	20587
Te Pirita	3126	3126	3126	3126	3126	3126	3126
Barrhill	7972	7972	7972	7972	7972	7972	7972
Fereday	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	104603	104603	104603	104603	104603	104603	104603
AREA DRYLAND							
Nth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains Ext.	-	-	-	-	-	-	-
Nth. Central Plains Ext.	866	866	866	866	866	866	866
Total Central Plains	866	866	866	866	866	866	866
Lower Rakaia	4413	4413	4413	4413	4413	4413	4413
Te Pirita							
Barrhill	4528	4528	4528	4528	4528	4528	4528
Total Dryland (ha.)	9807	9807	9807	9807	9807	9807	9807

APPENDIX U.2

AVERAGE FLOW YEAR (1962-63)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	65	75	95	115	125	145
MONTHLY FLOW RATE									
September	1	1	198.32	198.32	198.32	198.32	198.32	198.32	198.32
October	1	1	274.50	274.50	274.50	274.50	274.50	274.50	274.50
November	1	1	312.69	312.69	312.69	312.69	312.69	312.69	312.69
December	1	1	164.16	164.16	164.16	164.16	164.16	164.16	164.16
January	1	1	148.11	148.11	148.11	148.11	148.11	148.11	148.11
February	1	1	218.45	218.45	218.45	218.45	218.45	218.45	218.45
March	1	1	226.16	226.16	226.16	226.16	226.16	226.16	226.16
April	1	1	100.03	100.03	100.03	100.03	100.03	100.03	100.03
MONTHLY WATER DEPTH									
September	2	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
October	2	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34
November	2	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35
December	2	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
January	2	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
February	2	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
March	2	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
April	2	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT									
Direct	4	1	302	302	302	302	302	302	302
Total	4	1	641	641	641	641	641	641	641
FARMER INCOME ($mil.)	5	20	83.91	83.91	83.91	83.91	83.91	83.91	83.91
ON-FARM CAPITAL ($mil.)	5	1	103.67	103.67	103.67	103.67	103.67	103.67	103.67
NATIONAL INCOME ($mil.)	3	20	142.93	142.93	142.93	142.93	142.93	142.93	142.93
OFF-FARM CAPITAL ($mil.)	3	1	162.32	162.32	162.32	162.32	162.32	162.32	162.32
REGIONAL INCOME ($mil.)	6	1	176.22	176.22	176.22	176.22	176.22	176.22	176.22

APPENDIX U.2 (continued)

AVERAGE FLOW YEAR (1962-63)

	MINIMUM FLOW (cumecs)						
	N.C.O.	65	75	95	115	125	145
AREA IRRIGATED							
Nth. Central Plains	28750	28750	28750	28750	28750	28750	28750
Sth. Central Plains	25000	25000	25000	25000	25000	25000	25000
Sth. Central Plains Ext.	6875	6875	6875	6875	6875	6875	6875
Nth. Central Plains Ext.	6009	6009	6009	6009	6009	6009	6009
Total Central Plains	66634	66634	66634	66634	66634	66634	66634
Lower Rakaia	20587	20587	20587	20587	20587	20587	20587
Te Pirita	3126	3126	3126	3126	3126	3126	3126
Barrhill	7972	7972	7972	7972	7972	7972	7972
Fereday	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	104603	104603	104603	104603	104603	104603	104603
AREA DRYLAND							
Nth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains Ext.	-	-	-	-	-	-	-
Nth. Central Plains Ext.	866	866	866	866	866	866	866
Total Central Plains	866	866	866	866	866	866	866
Lower Rakaia	4413	4413	4413	4413	4413	4413	4413
Te Pirita							
Barrhill	4528	4528	4528	4528	4528	4528	4528
Total Dryland (ha.)	9807	9807	9807	9807	9807	9807	9807

APPENDIX U.3

AVERAGE FLOW YEAR (1962-63)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	65	75	95	115	125	145
MONTHLY FLOW RATE									
September	5	1	198.32	198.32	198.32	198.32	198.32	198.32	198.32
October	5	1	274.42	274.42	274.42	274.42	274.42	274.42	274.42
November	5	1	312.62	312.62	312.62	312.62	312.62	312.62	312.62
December	5	1	163.81	163.81	163.81	163.81	163.81	163.81	163.81
January	5	1	147.97	147.97	147.97	147.97	147.97	147.97	147.97
February	5	1	218.30	218.30	218.30	218.30	218.30	218.30	218.30
March	5	1	226.13	226.13	226.13	226.13	226.13	226.13	226.13
April	5	1	100.03	100.03	100.03	100.03	100.03	100.03	100.03
MONTHLY WATER DEPTH									
September	6	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
October	6	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34
November	6	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35
December	6	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
January	6	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
February	6	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33
March	6	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32
April	6	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT									
Direct	2	1	304.00	304.00	304.00	304.00	304.00	304.00	304.00
Total	2	1	645.00	645.00	645.00	645.00	645.00	645.00	645.00
FARMER INCOME ($mil.)	1	20	83.98	83.98	83.98	83.98	83.98	83.98	83.98
ON-FARM CAPITAL ($mil.)	1	1	104.50	104.50	104.50	104.50	104.50	104.50	104.50
NATIONAL INCOME ($mil.)	3	20	143.02	143.02	143.02	143.02	143.02	143.02	143.02
OFF-FARM CAPITAL ($mil.)	3	1	164.50	164.50	164.50	164.50	164.50	164.50	164.50
REGIONAL INCOME ($mil.)	4	1	176.35	176.35	176.35	176.35	176.35	176.35	176.35

APPENDIX U.3 (continued)

AVERAGE FLOW YEAR (1962-63)

	MINIMUM FLOW (cumecs)						
	N.C.O.	65	75	95	115	125	145
AREA IRRIGATED							
Nth. Central Plains	28750	28750	28750	28750	28750	28750	28750
Sth. Central Plains	25000	25000	25000	25000	25000	25000	25000
Sth. Central Plains Ext.	6875	6875	6875	6875	6875	6875	6875
Nth. Central Plains Ext.	6875	6875	6875	6875	6875	6875	6875
Total Central Plains	67500	67500	67500	67500	67500	67500	67500
Lower Rakaia	20587	20587	20587	20587	20587	20587	20587
Te Pirita	3126	3126	3126	3126	3126	3126	3126
Barrhill	7972	7972	7972	7972	7972	7972	7972
Fereday	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	105469	105469	105469	105469	105469	105469	105469
AREA DRYLAND							
Nth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains	-	-	-	-	-	-	-
Sth. Central Plains Ext.	-	-	-	-	-	-	-
Nth. Central Plains Ext.	-	-	-	-	-	-	-
Total Central Plains	-	-	-	-	-	-	-
Lower Rakaia	4413	4413	4413	4413	4413	4413	4413
Te Pirita							
Barrhill	4528	4528	4528	4528	4528	4528	4528
Total Dryland (ha.)	8941	8941	8941	8941	8941	8941	8941

APPENDIX U.4

LOW FLOW YEAR (1970-71)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) 45	65	75	77.5	80	85	90	92.5
MONTHLY FLOW RATE										
September	2	1	548.40	548.40	548.40	548.40	548.40	548.40	548.40	548.40
October	2	1	187.96	187.96	187.96	187.96	188.17	188.25	188.25	188.32
November	2	1	218.16	218.16	218.16	218.16	221.87	226.99	231.99	234.43
December	2	1	187.75	187.75	187.75	187.75	194.60	200.86	207.81	213.28
January	2	1	99.57	99.57	99.57	99.57	104.93	112.51	122.37	127.05
February	2	1	78.62	78.62	78.62	78.62	83.27	90.88	100.04	104.59
March	2	1	126.79	126.79	126.79	126.79	129.76	133.21	115.89	141.35
April	2	1	99.17	99.17	99.17	99.17	99.76	98.21	98.21	98.85
MONTHLY WATER DEPTH										
September	3	1	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
October	3	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
November	3	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
December	3	1	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33
January	3	1	0.29	0.29	0.29	0.29	0.29	0.30	0.30	0.30
February	3	1	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29
March	3	1	0.30	0.30	0.30	0.30	0.31	0.31	0.30	0.31
April	3	1	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
EMPLOYMENT										
Direct	4	1	306	306	306	306	264	224	179	119
Total	4	1	644	644	644	644	562	484	394	238
FARMER INCOME ($mil.)	5	20	82.88	82.88	82.88	82.88	80.29	74.48	68.80	64.19
ON-FARM CAPITAL ($mil.)	5	1	106.33	106.33	106.33	106.33	89.67	71.60	53.55	39.86
NATIONAL INCOME ($mil.)	1	20	140.08	140.08	140.08	140.08	136.80	127.08	117.69	110.47
OFF-FARM CAPITAL ($mil.)	1	1	165.39	165.39	165.39	165.39	140.68	98.76	77.05	58.11
REGIONAL INCOME ($mil.)	6	1	174.04	174.04	174.04	174.04	168.60	156.40	144.49	134.80

APPENDIX U.4 (continued)

LOW FLOW YEAR (1970-71)

	MINIMUM FLOW (cumecs)							
	45	65	75	77.5	80	85	90	92.5
AREA IRRIGATED								
Nth. Central Plains	26110	26110	26110	26110	17825	12984	12984	-
Sth. Central Plains	25000	25000	25000	25000	25000	21354	3993	9586
Sth. Central Plains Ext.	6875	6875	6875	6875	6851	-	-	-
Nth. Central Plains Ext.	6009	6009	6009	6009	3293	3293	3293	3293
Total Central Plains	63994	63994	63994	63994	52969	37631	20270	12879
Lower Rakaia	25000	25000	25000	25000	20587	20587	20587	20587
Te Pirita	3126	3126	3126	3126	3126	3126	3126	-
Barrhill	8418	8418	8418	8418	7972	7972	7972	5566
Fereday	3283	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	106822	106822	106822	106822	90938	75600	58239	45316
AREA DRYLAND								
Nth. Central Plains	2640	2640	2640	2640	10925	15766	15766	28750
Sth. Central Plains	-	-	-	-	-	3646	21007	15414
Sth. Central Plains Ext.	-	-	-	-	24	6875	6875	6875
Nth. Central Plains Ext.	866	866	866	866	3582	3582	3582	3582
Total Central Plains	3506	3506	3506	3506	14531	29869	47230	54621
Lower Rakaia	-	-	-	-	4413	4413	4413	4413
Te Pirita	-	-	-	-	-	-	-	3126
Barrhill	4082	4082	4082	4082	4528	4528	4528	6934
Total Dryland (ha.)	7588	7588	7588	7588	23472	38810	56171	69094

APPENDIX U.5

LOW FLOW YEAR (1970-71)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) 45	65	75	77.5	80	85	90	92.5
MONTHLY FLOW RATE										
September	1	1	548.40	548.40	548.40	548.40	548.40	548.40	548.40	548.40
October	1	1	187.96	187.96	187.96	187.96	188.17	188.25	188.25	188.32
November	1	1	218.16	218.16	218.16	218.16	221.87	226.99	231.99	234.43
December	1	1	187.75	187.75	187.75	187.75	194.60	200.86	207.81	213.28
January	1	1	99.57	99.57	99.57	99.57	104.93	112.51	122.37	127.05
February	1	1	78.62	78.62	78.62	78.62	83.27	90.88	100.04	104.59
March	1	1	126.79	126.79	126.79	126.79	129.76	133.21	115.89	141.35
April	1	1	99.17	99.17	99.17	99.17	99.76	98.21	98.21	98.85
MONTHLY WATER DEPTH										
September	2	1	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
October	2	1	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
November	2	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34
December	2	1	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33
January	2	1	0.29	0.29	0.29	0.29	0.29	0.30	0.30	0.30
February	2	1	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29
March	2	1	0.30	0.30	0.30	0.30	0.30	0.31	0.30	0.31
April	2	1	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
EMPLOYMENT										
Direct	4	1	306	306	306	306	264	224	179	119
Total	4	1	644	644	644	644	562	484	394	238
FARMER INCOME ($mil.)	5	20	82.88	82.88	82.88	82.88	80.29	74.48	68.80	64.19
ON-FARM CAPITAL ($mil.)	5	1	106.33	106.33	106.33	106.33	89.67	71.60	53.55	39.86
NATIONAL INCOME ($mil.)	3	20	140.08	140.08	140.08	140.08	136.80	127.08	117.69	110.47
OFF-FARM CAPITAL ($mil.)	3	1	165.39	165.39	165.39	165.39	140.68	98.76	77.05	58.11
REGIONAL INCOME ($mil.)	6	1	174.04	174.04	174.04	174.04	168.60	156.40	144.49	134.80

APPENDIX U.5 (continued)

LOW FLOW YEAR (1970-71)

	MINIMUM FLOW (cumecs)							
	45	65	75	77.5	80	85	90	92.5
AREA IRRIGATED								
Nth. Central Plains	26110	26110	26110	26110	17825	12984	12984	0
Sth. Central Plains	25000	25000	25000	25000	25000	21354	3993	9586
Sth. Central Plains Ext.	6875	6875	6875	6875	6851	0	0	0
Nth. Central Plains Ext.	6009	6009	6009	6009	3293	3293	3293	3293
Total Central Plains	63994	63994	63994	63994	52969	37631	20270	12879
Lower Rakaia	25000	25000	25000	25000	20587	20587	20587	20587
Te Pirita	3126	3126	3126	3126	3126	3126	3126	0
Barrhill	8418	8418	8418	8418	7972	7972	7972	5566
Fereday	3283	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	106822	106822	106822	106822	90938	75600	58239	45316
AREA DRYLAND								
Nth. Central Plains	2640.00	2640.00	2640.00	2640.00	10925.00	15766.00	15766.00	28750.00
Sth. Central Plains	-	-	-	-	-	3646.00	21007.00	15414.00
Sth. Central Plains Ext.	-	-	-	-	24.00	6875.00	6875.00	6875.00
Nth. Central Plains Ext.	866.00	866.00	866.00	866.00	3582.00	3582.00	3582.00	3582.00
Total Central Plains	3506	3506	3506	3506	14531	29869	47230	54621
Lower Rakaia	-	-	-	-	4413.00	4413.00	4413.00	4413.00
Te Pirita	-	-	-	-	-	-	-	3126.00
Barrhill	4082.00	4082.00	4082.00	4082.00	4528.00	4528.00	4528.00	6934.00
Total Dryland (ha.)	7588	7588	7588	7588	23472	38810	56171	69094

APPENDIX U.6

LOW FLOW YEAR (1970-71)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) 45	65	75	77.5	85	90
MONTHLY FLOW RATE								
September	5	1	548.40	548.40	548.40	548.40	548.40	548.40
October	5	1	187.96	187.96	187.96	187.96	188.25	188.25
November	5	1	218.11	218.11	218.11	218.11	225.78	230.78
December	5	1	187.63	187.63	187.63	187.63	199.83	206.78
January	5	1	99.47	99.47	99.47	99.47	112.79	122.66
February	5	1	78.52	78.52	78.52	78.52	90.86	100.03
March	5	1	126.72	126.72	126.72	126.72	135.00	140.00
April	5	1	99.17	99.17	99.17	99.17	97.97	97.97
MONTHLY WATER DEPTH								
September	6	1	0.39	0.39	0.39	0.39	0.39	0.39
October	6	1	0.32	0.32	0.32	0.32	0.32	0.32
November	6	1	0.33	0.33	0.33	0.33	0.33	0.33
December	6	1	0.32	0.32	0.32	0.32	0.33	0.33
January	6	1	0.29	0.29	0.29	0.29	0.30	0.30
February	6	1	0.28	0.28	0.28	0.28	0.29	0.29
March	6	1	0.30	0.30	0.30	0.30	0.31	0.31
April	6	1	0.29	0.29	0.29	0.29	0.29	0.29
EMPLOYMENT								
Direct	2	1	307	307	307	307	224	179
Total	2	1	647	647	647	647	482	392
FARMER INCOME ($mil.)	1	20	82.90	82.90	82.90	82.90	74.79	69.12
ON-FARM CAPITAL ($mil.)	1	1	106.77	106.77	106.77	106.77	71.00	52.95
NATIONAL INCOME ($mil.)	3	20	140.12	140.12	140.12	140.12	127.61	118.22
OFF-FARM CAPITAL ($mil.)	3	1	166.23	166.23	166.23	166.23	118.35	96.65
REGIONAL INCOME ($mil.)	4	1	174.10	174.10	174.10	174.10	157.07	145.15

APPENDIX U.6 (continued)

LOW FLOW YEAR (1970-71)

	MINIMUM FLOW (cumecs)					
	45	65	75	77.5	85	90
AREA IRRIGATED						
Nth. Central Plains	26110	26110	26110	26110	12984	12984
Sth. Central Plains	25000	25000	25000	25000	18080	719
Sth. Central Plains Ext.	6875	6875	6875	6875	6063	6063
Nth. Central Plains Ext.	462	462	462	462	3293	3293
Total Central Plains	58447	58447	58447	58447	40420	23059
Lower Rakaia	25000	25000	25000	25000	20587	20587
Te Pirita	3126	3126	3126	3126	-	-
Barrhill	8840	8840	8840	8840	7972	7972
Fereday	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	101697	101697	101697	101697	75263	57902
AREA DRYLAND						
Nth. Central Plains	2640	2640	2640	2640	15766	15766
Sth. Central Plains	-	-	-	-	6920	24281
Sth. Central Plains Ext.	-	-	-	-	812	812
Nth. Central Plains Ext.	866	866	866	866	3582	3582
Total Central Plains	3506	3506	3506	3506	27080	44441
Lower Rakaia	-	-	-	-	4413	4413
Te Pirita	-	-	-	-	3126	3126
Barrhill	3660	3660	3660	3660	4528	4528
Total Dryland (ha.)	7166	7166	7166	7166	39147	56508

APPENDIX U.7

LOW FLOW YEAR (1970-71)
RESTRICTING WATER DEPTH

	GOAL PRIORITY	WEIGHT	MINIMUM WATER DEPTH (m.) 0.25	0.26	0.27	0.28	0.285	0.29
MONTHLY FLOW RATE								
September	2	1	548.40	548.40	548.40	548.40	548.40	548.40
October	2	1	187.96	187.96	187.96	187.96	188.25	188.61
November	2	1	218.16	218.16	218.16	218.16	228.11	237.48
December	2	1	187.75	187.75	187.75	187.75	202.41	217.47
January	2	1	99.57	99.57	99.57	99.57	114.71	132.63
February	2	1	78.62	78.62	78.62	78.62	92.93	109.82
March	2	1	126.79	126.79	126.79	126.79	136.12	144.15
April	2	1	99.17	99.17	99.17	99.17	98.21	98.95
MONTHLY WATER DEPTH								
September	1	1	0.39	0.39	0.39	0.39	0.39	0.39
October	1	1	0.32	0.32	0.32	0.32	0.32	0.32
November	1	1	0.33	0.33	0.33	0.33	0.33	0.33
December	1	1	0.32	0.32	0.32	0.32	0.33	0.33
January	1	1	0.29	0.29	0.29	0.29	0.30	0.30
February	1	1	0.28	0.28	0.28	0.28	0.29	0.29
March	1	1	0.30	0.30	0.30	0.30	0.31	0.31
April	1	1	0.29	0.29	0.29	0.29	0.29	0.29
EMPLOYMENT								
Direct	4	1	306	306	306	306	214	112
Total	4	1	644	644	644	644	463	260
FARMER INCOME ($mil.)	5	20	82.88	82.88	82.88	82.88	73.21	60.61
ON-FARM CAPITAL ($mil.)	5	1	106.33	106.33	106.33	106.33	67.57	25.64
NATIONAL INCOME ($mil.)	3	20	140.01	140.01	140.01	140.01	124.98	105.72
OFF-FARM CAPITAL ($mil.)	3	1	165.39	165.39	165.39	165.39	93.90	37.80
REGIONAL INCOME ($mil.)	6	1	174.04	174.04	174.04	174.04	153.74	127.28

APPENDIX U.7 (continued)

LOW FLOW YEAR (1970-71)

	MINIMUM WATER DEPTH (m.)					
	0.25	0.26	0.27	0.28	0.285	0.29
AREA IRRIGATED						
Nth. Central Plains	26110	26110	26110	26110	12984	9754
Sth. Central Plains	25000	25000	25000	25000	17470	-
Sth. Central Plains Ext.	6875	6875	6875	6875	-	-
Nth. Central Plains Ext.	6009	6009	6009	6009	3293	1234
Total Central Plains	63994	63994	63994	63994	33747	10988
Lower Rakaia	25000	25000	25000	25000	20587	11764
Te Pirita	3126	3126	3126	3126	3126	-
Barrhill	8418	8418	8418	8418	7972	3126
Fereday	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	106822	106822	106822	106822	71716	32162
AREA DRYLAND						
Nth. Central Plains	2640	2640	2640	2640	15766	18996
Sth. Central Plains	-	-	-	-	7529	25000
Sth. Central Plains Ext.	-	-	-	-	6875	6875
Nth. Central Plains Ext.	866	866	866	866	3582	5641
Total Central Plains	3506	3506	3506	3506	33752	56512
Lower Rakaia	-	-	-	-	4413	13236
Te Pirita	-	-	-	-	-	3126
Barrhill	4082	4082	4082	4082	4528	3126
Total Dryland (ha.)	7588	7588	7588	7588	42693	76000

APPENDIX U.8

LOW FLOW YEAR (1970-71)
SHOWING UNDERACHIEVEMENT OF FLOW GOAL

	MINIMUM FLOW (cumecs)				
	100	125	150	175	200
FLOW UNDERACHIEVED					
September	-	-	-	-	-
October	-	-	-	-	12.04
November	-	-	-	-	-
December	-	-	-	-	12.25
January	0.43	25.43	50.43	75.43	100.43
February	21.38	46.38	71.38	96.38	121.38
March	-	-	23.21	48.21	73.21
April	0.83	25.83	50.83	75.83	100.83

APPENDIX U.9

LOW RAINFALL YEAR (1963-64)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	65	105	115	125	135	137.5	140	142.5	145
MONTHLY FLOW RATE												
September	2	1	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19
October	2	1	149.85	149.34	149.34	150.08	154.44	159.32	160.54	161.76	162.98	162.88
November	2	1	222.01	221.21	221.21	222.37	223.94	225.37	225.73	226.08	226.44	227.05
December	2	1	138.70	136.62	136.62	139.63	146.87	154.61	156.54	158.48	160.41	162.21
January	2	1	308.15	306.53	306.53	308.93	316.74	324.12	325.96	327.81	329.65	330.42
February	2	1	113.81	111.22	111.22	115.00	125.00	135.00	137.50	140.00	142.50	145.00
March	2	1	294.80	294.22	294.22	295.14	283.43	299.93	300.55	301.18	291.97	291.85
April	2	1	144.14	144.07	144.07	144.18	146.00	148.38	148.97	149.57	150.16	150.33
MONTHLY WATER DEPTH												
September	3	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
October	3	1	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
November	3	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
December	3	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32
January	3	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
February	3	1	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31
March	3	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
April	3	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT												
Direct	4	1	301.00	317.00	317.00	294.00	254.00	215.00	206.00	196.00	187.00	173.00
Total	4	1	637.00	669.00	669.00	624.00	543.00	467.00	449.00	430.00	410.00	384.00
FARMER INCOME ($mil.)	5	20	81.77	82.89	82.89	81.22	75.55	70.07	68.70	67.33	65.96	64.08
ON-FARM CAPITAL ($mil.)	5	1	103.97	110.34	110.34	101.00	84.79	69.32	65.45	61.58	57.52	52.36
NATIONAL INCOME ($mil.)	1	20	139.17	140.63	140.63	138.47	129.08	120.01	117.74	115.47	113.20	110.54
OFF-FARM CAPITAL ($mil.)	1	1	162.30	171.96	171.96	158.85	114.71	96.11	91.46	86.81	82.40	71.63
REGIONAL INCOME ($mil.)	6	1	171.71	174.06	174.06	170.56	158.66	147.16	144.28	141.40	138.52	134.57

APPENDIX U.9 (continued)

LOW RAINFALL YEAR (1963-64)

	MINIMUM FLOW (cumecs)									
	N.C.O.	65	105	115	125	135	137.5	140	142.5	145
AREA IRRIGATED										
Nth. Central Plains	26110	28750	28750	26110	21269	21269	21269	21269	21269	21269
Sth. Central Plains	25000	25000	25000	25000	23645	8764	5044	1324	-	-
Sth. Central Plains Ext.	6875	6875	6875	6875	-	-	-	-	-	-
Nth. Central Plains Ext.	6009	6875	6875	6009	6009	6009	6009	6009	6009	2716
Total Central Plains	63994	67500	67500	63994	50923	36042	32322	28602	27278	23985
Lower Rakaia	23311	25000	25000	20657	20587	20587	20587	20587	20587	19927
Te Pirita	3126	3126	3126	3126	3126	3126	3126	3126	730	-
Barrhill	7972	8840	8840	7972	5532	5532	5532	5532	5532	5110
Fereday	3283	3283	3283	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	104687	110750	110750	102033	86452	71571	67851	64131	60411	55306
AREA DRYLAND										
Nth. Central Plains	2640	-	-	2640	7481	7481	7481	7481	7481	7481
Sth. Central Plains	-	-	-	-	1354	16236	19956	23676	25000	25000
Sth. Central Plains Ext.	-	-	-	-	6875	6875	6875	6875	6875	6875
Nth. Central Plains Ext.	866	-	-	866	866	866	866	866	866	4159
Total Central Plains	3506	-	-	3506	16576	31458	35178	38898	40222	43515
Lower Rakaia	1689	-	-	4343	4413	4413	4413	4413	4413	5073
Te Pirita	-	-	-	-	-	-	-	-	2396	3126
Barrhill	4528	3660	3660	4528	6968	6968	6968	6968	6968	7390
Total Dryland (ha.)	9723	3660	3660	12377	27957	42839	46559	50279	53999	59104

APPENDIX U.10

LOW RAINFALL YEAR (1963-64)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	65	105	115	125	135	137.5	140	142.5	145
MONTHLY FLOW RATE												
September	1	1	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19	248.19
October	1	1	149.85	149.34	149.34	150.08	154.44	159.32	160.54	161.76	162.98	162.88
November	1	1	222.01	221.21	221.21	222.37	223.94	225.37	225.73	226.08	226.44	227.05
December	1	1	138.70	136.62	136.62	139.63	146.87	154.61	156.54	158.48	160.41	162.21
January	1	1	308.15	306.53	306.53	308.93	316.74	324.12	325.96	327.81	329.65	330.42
February	1	1	113.81	111.22	111.22	115.00	125.00	135.00	137.50	140.00	142.50	145.00
March	1	1	294.80	294.22	294.22	295.14	283.43	299.93	300.55	301.18	291.97	291.85
April	1	1	144.14	144.07	144.07	144.18	146.00	148.38	148.97	149.57	150.16	150.33
MONTHLY WATER DEPTH												
September	2	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
October	2	1	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
November	2	1	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
December	2	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32
January	2	1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
February	2	1	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31
March	2	1	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
April	2	1	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT												
Direct	4	1	301.00	317.00	317.00	294.00	254.00	215.00	206.00	196.00	187.00	173.00
Total	4	1	637.00	669.00	669.00	624.00	543.00	467.00	449.00	430.00	410.00	384.00
FARMER INCOME ($mil.)	5	20	81.77	82.89	82.89	81.22	75.55	70.07	68.70	67.33	65.96	64.08
ON-FARM CAPITAL ($mil.)	5	1	103.97	110.34	110.34	101.00	84.79	69.32	65.45	61.58	57.52	52.36
NATIONAL INCOME ($mil.)	3	20	139.17	140.63	140.63	138.47	129.08	120.01	117.74	115.47	113.20	110.54
OFF-FARM CAPITAL ($mil.)	3	1	162.30	171.96	171.96	158.85	114.71	96.11	91.46	86.81	82.40	71.63
REGIONAL INCOME ($mil.)	6	1	171.71	174.06	174.06	170.56	158.66	147.16	144.28	141.40	138.52	134.57

APPENDIX U.10 (continued)
LOW RAINFALL YEAR (1963-64)

	MINIMUM FLOW (cumecs)									
	N.C.O.	65	105	115	125	135	137.5	140	142.5	145
AREA IRRIGATED										
Nth. Central Plains	26110	28750	28750	26110	21269	21269	21269	21269	21269	21269
Sth. Central Plains	25000	25000	25000	25000	23645	8764	5044	1324	-	-
Sth. Central Plains Ext.	6875	6875	6875	6875	-	-	-	-	-	-
Nth. Central Plains Ext.	6009	6875	6875	6009	6009	6009	6009	6009	6009	2716
Total Central Plains	63994	67500	67500	63994	50923	36042	32322	28602	27278	23985
Lower Rakaia	23311	25000	25000	20657	20587	20587	20587	20587	20587	19927
Te Pirita	3126	3126	3126	3126	3126	3126	3126	3126	730	-
Barrhill	7972	8840	8840	7972	5532	5532	5532	5532	5532	5110
Fereday	3283	3283	3283	3283	3283	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Total Irrigated (ha.)	104687	110750	110750	102033	86452	71571	67851	64131	60411	55306
AREA DRYLAND										
Nth. Central Plains	2640	-	-	2640	7481	7481	7481	7481	7481	7481
Sth. Central Plains	-	-	-	-	1354	16236	19956	23676	25000	25000
Sth. Central Plains Ext.	-	-	-	-	6875	6875	6875	6875	6875	6875
Nth. Central Plains Ext.	866	-	-	866	866	866	866	866	866	4159
Total Central Plains	3506	-	-	3506	16576	31458	35178	38898	40222	43515
Lower Rakaia	1689	-	-	4343	4413	4413	4413	4413	4413	5073
Te Pirita	-	-	-	-	-	-	-	-	2396	3126
Barrhill	4528	3660	3660	4528	6968	6968	6968	6968	6968	7390
Total Dryland (ha.)	9723	3660	3660	12377	27957	42839	46559	50279	53999	59104

APPENDIX U.11

LOW RAINFALL YEAR (1963-64)

	GOAL PRIORITY	WEIGHT	MINIMUM FLOW (cumecs) N.C.O.	105	125	135	145
MONTHLY FLOW RATE							
September	5	1	248.19	248.19	248.19	248.19	248.19
October	5	1	149.34	149.34	154.47	159.35	163.49
November	5	1	221.21	221.21	223.84	225.27	226.90
December	5	1	136.62	136.62	146.78	154.52	161.95
January	5	1	306.53	306.53	316.27	323.65	331.19
February	5	1	111.22	111.22	125.00	135.00	145.00
March	5	1	294.22	294.22	297.66	300.16	302.67
April	5	1	144.07	144.07	146.13	148.51	150.33
MONTHLY WATER DEPTH							
September	6	1	0.34	0.34	0.34	0.34	0.34
October	6	1	0.31	0.31	0.31	0.31	0.32
November	6	1	0.33	0.33	0.33	0.33	0.33
December	6	1	0.31	0.31	0.31	0.31	0.32
January	6	1	0.35	0.35	0.35	0.35	0.35
February	6	1	0.30	0.30	0.30	0.31	0.31
March	6	1	0.34	0.34	0.34	0.34	0.34
April	6	1	0.31	0.31	0.31	0.31	0.31
EMPLOYMENT							
Direct	2	1	317.00	317.00	254.00	216.00	175.00
Total	2	1	669.00	669.00	544.00	468.00	388.00
FARMER INCOME ($mil.)	1	20	82.89	82.89	75.82	70.34	64.50
ON-FARM CAPITAL ($mil.)	1	1	110.34	110.34	84.62	69.39	52.69
NATIONAL INCOME ($mil.)	3	20	140.63	140.63	129.53	120.46	110.72
OFF-FARM CAPITAL ($mil.)	3	1	171.96	171.96	137.72	115.91	76.54
REGIONAL INCOME ($mil.)	4	1	174.06	174.06	159.21	147.70	135.44

APPENDIX U.11

LOW RAINFALL YEAR (1963-64)

	MINIMUM FLOW (cumecs)				
	N.C.O.	65	105	125	145
AREA IRRIGATED					
Nth. Central Plains	28750	28750	28750	23828	21008
Sth. Central Plains	25000	25000	25000	17409	-
Sth. Central Plains Ext.	6875	6875	6875	6875	-
Nth. Central Plains Ext.	6875	6875	6875	6009	6009
Total Central Plains	67500	67500	67500	54121	27017
Lower Rakaia	25000	25000	25000	20587	17646
Te Pirita	3126	3126	3126	-	-
Barrhill	8840	8840	8840	5532	5110
Fereday	3283	3283	3283	3283	3283
Sth. Rakaia	1001	1001	1001	1001	1001
Nth. Rakaia	2000	2000	2000	2000	2000
Total Irrigated (ha.)	110750	110750	110750	86524	56057
AREA DRYLAND					
Nth. Central Plains	-	-	-	4922	7742
Sth. Central Plains	-	-	-	7591	25000
Sth. Central Plains Ext.	-	-	-	-	6875
Nth. Central Plains Ext.	-	-	-	866	866
Total Central Plains	-	-	-	13379	40483
Lower Rakaia	-	-	-	4413	7354
Te Pirita	-	-	-	3126	3126
Barrhill	3660	3660	3660	6968	7390
Total Dryland (ha.)	3660	3660	3660	27886	58353

APPENDIX V

MAKAREWA RIVER FLOOD CONTROL SCHEME EX-POST STUDY[1]

V1 INTRODUCTION

1.1 Background

The Makarewa River Catchment is located to the north-east of Invercargill covering 1062 sq. km. between the Hokonui Hills and Wallacetown. The Catchment is bisected by a number of streams which join to form the Makarewa River which discharges into the Oreti River below Wallacetown.

From its inception in 1945 to the early 1960's the Southland Catchment Board vetted a number of river improvement and stopbanking schemes for the Makarewa River. None of these were approved until a comprehensive scheme could be prepared. This was done in 1962 largely as a result of a major flood in 1957.

In the ten year period prior to this there had been a noticeable increase in the frequency and severity of flooding while at the same time drainage outfalls deteriorated. The main reasons for this were:

1. heavy willow growth in the main streams,
2. larger areas within the catchment being drained,
3. continuous bush clearing in the Hokonui and Dunsdale districts, and
4. development of the red tussock areas in the Titipua area.

The need for a comprehensive scheme for the river was real. Much of the low land bordering the river was inundated four to five times per annum and for up to 40 days per year. The risk to stock and frequent damage to fences was a sufficient deterrent to make this country unattractive for development. In addition large areas of land had inadequate or not drainage outfall. Much of the affected land was covered in bush, scrub, flax or rushes and was only suited to running cattle or extensive grazing over the summer period. Flooding also affected 32 kilometres of road each year. Apart from the damage caused to these roads, many farms were isolated for short periods of time or access was impeded necessitating detours.

The principal objectives of the scheme outlined in the Classification Report which accompanied the main scheme report were:

1. Lower Wallacetown Area:
   (a) To substantially reduce the frequency of flooding by the removal of willow growth, by channel

1. Summary of an ex-post report prepared by McGregor and Pittaway (1985). Acknowledgement is given to the help received from S. F. Pittaway in the data collection, data analysis and writing up phases of this study. The economic analysis is solely my own work as is largely the write-up.

enlargement, and by the erection of a low training bank.

(b) To improve drainage outlet conditions by lowering the average winter flow in the river by several feet at the Riverton Highway, decreasing to a slight lowering at the junction with the Oreti River.

2. Middle and Upper Main Tributaries where Channel Improvement only is proposed:

(a) To reduce the incidence of flooding from four to five times per annum as at present, to about once in five years by improving the hydraulic capacity of the river and main streams by shortening, widening and dredging.

(b) To provide improved drainage conditions generally in the valley floor and improved drainage outfall for side drainage systems by substantial lowering of the average winter flow.

(c) To carry the improved outfall back into deficient areas by improvement and maintenance of certain side drainage systems and old river cut off bends.

3. Where Stopbanking is proposed:

(a) To provide a standard of flood protection of approximately double that provided for where channel improvement only is proposed.

(b) To assist flood delivery by discriminate clearing of willow and other growth from channel and berms, and easing acute bends where necessary.

(c) To provide and maintain floodgates and drainage outfalls for the lands protected by the stopbanks.

A total of 164.1 km of channel were improved by the scheme works. The breakdown of length and stream are shown below.

Main Makarewa River and Lower Hedgehope Stream	57.9 km
Otapiri Stream	32.2 km
Lora Stream	16.1 km
Hedgehope Stream	33.8 km
Titipua Stream	24.1 km

Specific features of the scheme were:

- The Makarewa/Hedgehope Flood Channel became the main Makarewa River.
- A new Hedgehope Stream was formed on the east side of the valley following the old flood channels to join the main Makarewa River below Tussock Creek.
- The Mako Gorge was cleared of snags only.
- Stopbanking of the Otapiri Stream between Tanner Road and Otapiri Gorge Road with no channel alterations except the clearing of snags.
- No stopbanking on any other part of the scheme.
- Floods such as the 1957 flood to be carried below ground level, i.e. 1:5 return period of 7,000 cusecs.

Scheme approval was gained in 1962 and work commenced in 1963/64. The scheme's main contract was completed in 1968

and major capital works were finished in the 1970/71 financial year.

Farmers in some areas were able to take immediate advantage of the 1.8m or more drop in normal water levels. The improved drainage outfalls meant large areas of previously wet and unproductive land were ploughed and sown down shortly after the excavator had passed the property. In other areas the progress was slower. This was because intensive drainage work and other development work such as clearing and fencing was necessary prior to sowing down.

The extent of flood and drainage benefit given by the scheme was summarised as follows:

Relief from flooding	7,540 hectares[1]
Drainage outfall improvements	4,285 hectares
Undeveloped land made available for development	4,385 hectares
Semi-developed land made available for development	4,895 hectares

(Source: N. A. McMillan (pers. comm.))

1.2 Background to Agriculture

The farms in the Makarewa Catchment are included in Class 7 of the New Zealand Meat and Wool Board Economic Service's Classification. Class 7 farms are described as "Intensive Finishing Farms, South Island high producing grassland farm carrying about thirteen stock units per hectare and with cash crop returns increasing in importance. Mainly in Southland, Southland West Otago".

The farms within the catchment may have higher performance and production levels than those represented in the Class 7 group. This is due to the predominance of higher producing soils within the catchment particularly the Makarewa, Waikiwi and Edendale soil types. The Makarewa soil is the dominant type on many farms. Once developed it is capable of high production, certainly much higher production than many other soils within the Class 7 survey. Many farms are either all Makarewa soils or have a proportion of them in association with terrace soils. In the latter cases the farms are able to achieve higher production from their terrace soils due to the combination with the Makarewa soil.

Stocking rates aside, the farms within the Catchment follow the trends shown for the Class 7 farms. Farm development occurred over the mid 1960's period and has continued through the 1970's. The development took the form of improved drainage and increased use of fertiliser. Farmers were able to bring in smaller areas of previously undeveloped land, e.g. peat, and increase the productivity of the already developed areas. Stocking rates increased

1. Note: All areas overlap.

and per head production was at least maintained. Over this period farm size has also shown an increase. In the mid 1960's average size was 150 ha and in 1980 the average size was 200 ha.

Farming practice has changed over the period as well. Better drainage and higher fertility pastures has also meant higher winter pasture growth rates. The result has been less dependence upon traditional winter fodder crops, viz. swedes and the development of sophisticated grassland systems. Cash cropping patterns have changed very little. Southland farmers tend to have a small proportion of their farm in cerials. Wheat is the main crop grown usually as part of a pasture renewal programme. Cattle are not a significant proportion of the farming enterprise. Their level tends to relate to the profitability of beef enterprises hence their numbers fluctuate.

V2 THE ECONOMIC ANALYSIS

2.1 General

An ex-post economic analysis aims at measuring the economic performance of a publicly funded scheme. This study of the Makarewa river Scheme has been carried out with the following objectives in mind:

- To identify resource use and timing.
- To assess the overall production changes that have occurred as a result of the scheme.
- To compare what has actually happened with what was assumed to occur in the original report in 1962.
- To determine the contribution of the project to the national income.
- To use the information gained to assist in the design and evaluation of future projects of a similar type.

2.2 Methods

There are three accepted methods of carrying out an ex-post analysis of a capital works scheme. These are using:

- costs and prices prevailing at the time of the analysis,
- costs and prices prevailing at the time of the original decision, or
- actual costs and prices.

The method of analysis presented in this report uses current costs and prices. This approach answers the question "What is the scheme's worth to the nation using current costs and prices?". The costs and returns used for this approach are those currently in use by the Economics Division of the Ministry of Agriculture and Fisheries for evaluating new agricultural projects. Scheme costs, both capital and associated, have been adjusted by using the

Ministry of Works and Development construction price index to CCI 2030.

The other methods using actual costs and prices and using costs prevailing at the time of approval, were not used because of the problem of obtaining reliable on-farm data over time.

Using the above scenario the analysis compares what would have occurred if the scheme was not implemented with what has and will occur since the scheme was approved. Costs and benefits are streamed to infinity and the internal rate of return (IRR) and the net present worth (NPW) are calculated.

V3 SURVEY

Farmers in each of the classified areas were personally surveyed. Most visits were made to farmers who had significant areas of land in the A, B, C, and D classifications. It is estimated that 80% of the farmers in these classifications were surveyed. Physical production data for the last three years were obtained, other physical data dating back to pre-scheme implementations was also obtained if available. A major problem with the survey was obtaining pre-scheme data. The majority of farms had changed hands since the early 1960's when the scheme was first implemented. The survey highlighted the problems of carrying out an ex-post study so long after the scheme was completed. The main problem was to obtain objective data upon which to base the analysis.

Where farmers had financial data (farm accounts) covering the period from pre-scheme implementation to the present, this was used. Unfortunately this was only available for a small number of farms. In many farm accounts, especially the early ones relating to the 1960's, capital expenditure on development was not well defined. This led to difficulties in assessing the amount spent on development due to the scheme. Farm accounts, however, were used to assess the current positions of farmers in each of the main definition classes, i.e A, B, C, and D.

The major public and commercial interests in the region were surveyed either personally or by letter. These were the Southland Catchment Board, Southland County Council, Electricity Authority, N.Z. Post Office, Ministry of Works and Development, Southland Acclimatisation Society, N.Z. Forest Service, Southland Electric Power Supply and the freezing companies.

V4. SCHEME COSTS

4.1 Off Farm Costs

The actual scheme costs (supplied by the Southland Catchment Board) have all be adjusted by the Ministry of Works and Development Construction Cost Index. The base values are a CCI of 2030 for the 1983 base year. Details of these values can be found in Appendix 1. A summary of the scheme capital (both capital and drainage) and maintenance cost assumptions, along with the actual annual expenditures are shown in Tables V.1 and V.2.

TABLE V.1

Scheme Capital Expenditure

SCHEME CAPITAL EXPENDITURE (S)		
YEAR	ACTUAL EXPENDITURE	UNWEIGHTED 1983 $ (CCI = 2030)
1964	1549	13730
1965	9878	81850
1966	126314	1013500
1967	217635	1667170
1968	209530	1575360
1969	111560	767690
1970	90124	577130
1971	50251	272020
1972	14098	69460
1973	11221	52240
1974	10853	45520
1975	1709	5910
1976	8508	23990
1977	29237	72030
1978	-	-
1979	-	-
1980	36948	56910
1981	5148	6570
TOTAL	934563	6301080

TABLE V.2

Scheme Maintenance Expenditure

SCHEME MAINTENANCE EXPENDITURE		
YEAR	ACTUAL EXPENDITURE	UNWEIGHTED 1983 $ (CCI = 2030)
1969	391	2690
1970	27583	176640
1971	19557	105870
1972	2560	12610
1973	3878	18050
1974	23883	100170
1975	7748	26790
1976	8165	23020
1977	19174	47240
1978	32818	71870
1979	86112	170210
1980	16989	26170
1981	99758	127370
1982	50198	54490
1983	63740	64380
AVERAGE 1969-83	$30835	$68505

Total capital costs (including drainage) amount to $934,500 in actual terms which equates to $6.3m in December 1983 dollar terms. Maintenance expenditure includes the cost of flood damage. The separable amounts are shown in Appendix 1. Maintenance expenditure has averaged $68,505 in 1983 dollar terms in the last ten years. This figure has been used in post-1983 cash flows.

4.2 On-Farm Costs

The total on farm costs for rating classes A, B and D are shown in Table V.3.

TABLE V.3

Summary Of On Farm Capital Costs

	RATING CLASS A	RATING CLASS B	RATING CLASS D	TOTAL COST $
Area developed (ha)	1,958	1,425	1,536	
Cost ($/ha)	2,110	1,810	1,785	9,452,390
Area retiled (ha)	400	320	306	
Cost ($/ha)	100	100	100	102,600
Stock increases (s.u.)	24,475	14,250	12,288	
cost ($/s.u.)	31.35	31.35	31.35	1,599,250
Maintenance Costs ($)	343,630	227,145	225,055	
TOTAL ON FARM CAPITAL COSTS				$11,154,240

Approximately 85% of the total costs are incurred because of land development. The development program for each rating class was slightly different but followed the following general format:

Year 1 - dig main drain, clearing and swamp ploughing, dig side drains and tile laying
Year 2 - fencing and root crop
Year 3 - either sowing of a cereal crop followed by new grass, or sowing of new grass.

Nine to ten years post development the developed areas required further tiling. This cost has been assessed at $100/ha and it is assumed that approximately 20% of the originally developed area would incur this cost.

The stock capital costs amount to $1.6m. This represents 14% of the total on farm costs. The timing and level of stock increases are discussed under Scheme Benefits (Section V5).

On farm maintenance costs are shown in Table V.3. These costs are the steady state values and include the maintenance of development work as well as the direct live stock costs.

V5. SCHEME BENEFITS

5.1 Class Features and Production Benefits

5.1.1 Class A

This rating class contains 1985.15 hectares[1] along the floodway of the river. Prior to the scheme properties falling into this class were subject to severe flooding

1. Source: Southland Catchment Board Rating Classification Roll for the Makarewa River.

several times per year. Development was minimal and the land was either extensively grazed or not grazed at all (see photographs). The scheme report noted eight problems experienced by properties in Class A. These are shown in Table V.4 with the 1983/84 situation alongside. Class A farms have doubled in size since the classification report was carried out and there has been a slight decrease in the proportion of the farm falling into Class A.

5.1.2 Class B

This rating class contains 1903.34 hectares[1] and was described in the scheme report as land that is "... likely to flood several times per annum sufficiently seriously to affect normal farming operations". The major benefits were described as for Class A but of less severity or duration. Land in this class also included:

1. "Lands in the Wallacetown area which may be expected to flood about once per year instead of several times as at present.
2. Lands above the Southland Frozen Meat Company's cuts, where drainage outfall is reasonably adequate and flooding of brief duration.
3. Lands on the Otapiri which have a limited degree of stopbank protection at present."

The benefits to land in this rating class are described in Table V.4.

Class B farms have increased only slightly in size since the classification report was produced but the area in Class B as a proportion of total farm area has approximately halved. The photographs show that without the scheme Class B land was poorly drained and had either a rush or light covering or scrub. Development costs of this land were consequently lower than Class A.

5.1.3 Class C

Class C consists of 1,862 hectares[1] which are situated mainly in the middle reaches of the Hedgehope and Titipua streams. The pre-scheme implementation report suggested that the problems of this class were light to medium flooding and no drainage outfall. Drainage development had occurred along the Hedgehope Stream before scheme implementation. The drainage outfall benefit did not occur and is overstated in the pre-implementation report and analysis.

When each flood occurred it took several days (5-7 days) for the flood waters to recede. Damage to fences occurred regularly with each flood. Since scheme implementation most of the problems caused by the floods have been overcome. The flood waters recede much more quickly but there is still some fencing damage. Occasional stock losses occur also.

1. Source: Southland Catchment Board Rating Classification Roll for the Makarewa River.

TABLE V.4

Benefit Assessments for Class A and B Land

Prior to Scheme	Class A 1983/84	Class B 1983/84
1. Topsoil could be washed off cultivated areas.	Topsoil can be washed off cultivated areas.	
2. Waterlogging, drowning or fouling of pastures and crops.	Water moves off faster. Dirty pastures put grazing pressure on the rest of the farm.	
	Still silting but waterlogging and drowning or pastures only in low-lying areas.	Silting not heavy. Does not pond long enough to damage pasture.
3. Risk of stock or crop loss.	Stock losses low because of adequate warning Crops lost in low-lying areas if grown.	
4. Fencing damage.	Some fencing damage but mainly re-erection of damaged fences.	
5. Drains silted, culverts and bridges scoured.	Not a significant problem	
6. Upset in farm management due to necessity to shift stock which may cause ill-thrift in lambs.	Threat of flooding means feed has to be set aside on flood free areas during periods of high flood risk. Very risky to lamb on this country. Flooding puts grazing pressure on flood free areas. Need to be able to shift stock quickly otherwise losses occur.	
7. Limitation of land utilisation for normal crop rotation.	Crops generally not grown on this land.	Still some limitation but a range of attitudes, e.g. - grow no crop - grow winter feed only - accept risk and grow cereals.

Table V.4 (continued)

Prior to Scheme	Class A 1983/84	Class B 1983/84
8. Frequent flooding and lack of outfall either prevents development or makes land uneconomic.	Improved drainage outfall has allowed development but threat of flooding still stops this country from achieving its potential.	
9. Stocking Rate:		
Classification Report:	11 s.u./ha	5.6 s.u./ha
1983/84 Survey	12.5 s.u./ha	10.0 s.u./ha
10. Average Farm Size:		
Classification Report:	88 ha	148 ha
1983/84 Survey:	163 ha	168 ha
11. Proportion of Farm in Class A or B:		
Classification Report:	68%	51%
1983/84 Survey:	54%	25%
12. Area Production Increase Assumed to Occur Over:	1958 ha (100%)	1425 (75%)
13. Development		
Year 1	Digging of main drains. Clearing and drainage. Fencing and root crops. Cereal crop (usually oats). Sowing new grass.	
14. Assumed Timing of Stocking Rate Increases:		
Year 1	0	0
Year 2	2.5	2
Year 3	2.5	2
Year 4	2.5	2
Year 5	5.0	4

Production achieved on Class C farms is very similar to the average situation as shown in the Meat and Wool Board's Economic Service data (Table V.5).

TABLE V.5

Physical Data 1980/81

	Class 7	Class C
Area	197	158
Sheep Wintered	2,606	2,175
Cattle Wintered	25	6
s.u./ha.	12.5	13.0
Lambing %	108	123

Further, the development of Class C farms is similar to that which has occurred on the Class 7 farms. Therefore, the increases in stocking rate cannot be attributed to the Makarewa scheme. The pattern of agriculture has not changed either since the scheme was completed. Cash cropping was practised before the scheme and has not significantly changed since.

There are no production benefits as a result of the scheme. The benefits which have occurred are due to the reduction of the impact of flooding upon the Class C Farms.

5.1.4 Class D

Class D consists of 1,935 hectares[1]. Land in Class D in lower Wallacetown, North Makarewa and along the upper reaches of the Hedgehope and Titipua Streams. The former areas received benefits from flood control and the latter from drainage outfall. The major benefit has been from drainage outfall. Flood control benefits are similar to those outlined for Class C.

Table V.6 shows that the proportion of Class D on each farm is relatively small. The land alongside the two streams is associated with rolling to undulating land. Since the pre-implementation report farm size has increased and the proportion of Class D land has become smaller.

TABLE V.6

Proportion of Class D Land

	Pre-Implementation Report	1983
Total Farm Area (ha.)	100	288
Class D (ha.)	42	30.5
Class D as a % of total farm area	42	9

1. Southland Catchment Board Rating Classification Roll for the Makarewa River.

Hence on each farm the influence of these areas is of less significance.

Table V.7 shows that Class D farms are larger and have more stock than the meat and wool Board Economic Services' Class 7 farm but have a lower stocking rate.

TABLE V.7

Comparison of Class 7 and Class D

	Class 7	Class D
Area	197	288
Sheep Wintered	2,606	2,923
Cattle Wintered	25	55
s.u./ha	12.5	12.9
Lambing %	108	112

Class D lands very rarely suffer from flooding. Only major floods have any real impact upon them. Farmers are concerned with the slumping of stream banks, but it is considered that this is not of economic significance to the farm.

Drainage benefits, as mentioned previously, are the most significant. The scheme gave drainage outfall which meant the potentially highly productive soils along the streams could be developed. Without drainage these areas had very limited use. Vegetation consisted of flax and rushes and was often used to run cattle over the summer period.

Once developed stocking rates may reach as high as 18 s.u./ha. with 14 s.u./ha. being a common level. Development has been affected through drainage, cultivation, two brassica crops, and then sown into pasture. Stocking rate increases on the developed areas have been 5 s.u./ha to 13 s.u./ha. It is assumed that clearing and drainage occurred in the first year with swamp ploughing. In the second year a brassica crop was sown which was followed by another brassica crop before being sown to pasture. The main stock increases occurred in the early years with the brassica crops and when the new pasture was established. Stock increases occur primarily from an increased number of replacements kept.

STOCK INCREASE (s.u.)

Year	s.u.
1	1
2	2
3	2
4	2

5.1.5 Class E and F

The Class E area consists of the Upper Otapiri gorge. Flooding caused this area to be cut off. It was considered that some second degree drainage benefits would occur as a result of the stream.

Class F consists of those areas that receive no direct benefit from the scheme, but they are associated with areas that do receive direct benefits.

It was considered that the scheme gave no significant productive benefits to Class E and F lands. Therefore, they have not been considered in the analysis. These areas, however, received indirect benefits in the form of reliable access to the affected properties.

5.2 Flood Control Benefits

Benefits and costs associated with flood control accrue to farmers in the A, B, C, and D classifications. These are in addition to the production benefits and costs which also occur. The main flooding benefit which farmers have received is the speed with which the flood waters recede. For the floods which commonly influenced the farms normally it took seven days for waters to recede. This is now reduced to two days.

The impact of flooding upon the farms differs at various times of the year. To fully analyse this feature the year has been subdivided into four seasons, viz.

Spring - September, October, November
Summer - December, January, February
Autumn - March, April, May
Winter - June, July, August

Probabilities of flooding occurring in the seasons has been calculated as follows:

Season	Probability of Flood
Spring	0.21
Summer	0.07
Autumn	0.58
Winter	0.14

5.2.1 Discussion of Benefits and Costs

(a) Stock Losses:
Stock losses, both ewes and lambs occurred before scheme implementation. Accurate assessment of numbers is difficult but it is estimated that losses were in the order of 0.01% of sheep numbers per-scheme and virtually nil post-scheme.

(b) Delay Reaching Prime Condition:
Liveweight gains are reduced when lambs have to be shifted due to flooding. Since the scheme,

lambs can return to pasture sooner and the delay before reaching prime condition is reduced. Flooding in summer and autumn influences the lambs most.

(c) Ewe Tupping Liveweights:
Flooding disrupts the grazing management leading up to and over tupping. Ewes require to gain weight over this period if lambing percentages are to be maximised. Therefore flooding can reduce lambing percentage.

(d) Decrease in Supplements Required:
Flooding during the winter interferes with the feeding management of the stock. The available feed supply is reduced by floods for a period. Farmers compensate for this by making extra supplements. Since the scheme was implemented the amount of supplements needed to be made has been reduced.

(e) Flood Damage:
The scheme has reduced flood damage on areas developed before the scheme. Flooding has been reduced from often three to four times per year down to one. Damage which commonly occurred was mainly to fencing, culvets, tracks and silting up of tile drains. The reduction in the number of floods has reduced the cost of flood repairs. On areas developed since the scheme the flooding does cause problems. The repairs associated with floods on the post-scheme problems. The repairs associated with floods on the post-scheme developed area are a cost against the scheme.

5.2.2 Access and Road Damage

Prior to the scheme every road crossing the Makarewa Basin was affected by flooding. The flooding caused two problems:

(a) scoured bitumen and surface gravel which in turn led to the general deterioration of the road structure, and
(b) isolation of residents for periods of up to 48 hours.

The annual cost of repairing roads prior to the scheme was assessed in the original scheme report to be in the order of $39,000 per annum (CCI = 2030). Information received from local authorities and Ministry of Works and Development would suggest that in 1983 dollar terms the annual savings in maintenance costs would be in the order of $30.000 per annum.

The isolation of residents, although a real problem, was not able to be assessed because of lack of data. Pre-scheme, approximately 32km of road were susceptible to flooding in 41 locations. This meant the certain areas, mainly the Hokonui and Hedgehope areas, were isolated for up to 48 hours. School buses, mail and other services were affected. There is no doubt that the scheme has improved this situation but some areas still have the threat of main

access being cut off. However, in the majority of cases properties have alternative access.

5.2.3 Summary of Flood Benefits and Timing

Total flood benefits have been assessed at $63,460 per annum once full protection has been given. This total is made up as follows:

Class A	-	6,175
Class B	-	16,950
Class C	-	9,645
Class D	-	690
Roading	-	30,000
Total	-	$63,460

The timing of the benefit is related to the proportion of capital expenditure to date to the total expenditure.

V6. INFLUENCE OF THE SCHEME ON WILDLIFE

The following comments are drawn from a letter from the Southland Acclimatisation Society. The major points are:

(a) The shortening of the river has meant the loss of many deep water ponding areas and consequently a reduction in fish numbers.

(b) The removal of large vegetation has meant that fish now have reduced areas of shade. This combined with significantly lower low flows in the river has lead to very high water temperatures at times. Temperatures as high as 29 degrees celsius have been recorded in the Hedghope stream. The very high temperatures have lead to substantial trout mortality.

(c) Mechanical work within the river has led to bank and bed instability which in turn has lead to siltation in the river. Siltation was obviously highest in the construction phase but is still a problem now with Catchment Board maintenance work.

(d) Increased peak flow velocities and an unstable river bed and banks have had a damaging effect on fish food supplies.

(e) Water enrichment has occurred as a result of the scheme. This manifests itself in two ways:

i) intensification of land use which resulted from scheme works has led to increased water enrichment, mainly from increased fertiliser use and additional livestock.

ii) considerably lower low flows have means that the dilution effect on industrial effluent in the lower reaches of the river has been reduced.

(f) Although the scheme improved access to the River it is now thought to be "... much less interesting and has been aesthetically degraded". (Sutton, pers. com.).

(g) The scheme has meant the loss of considerable areas of wetlands. This has had a significant effect on waterfowl such as the Pukeko, Bittern and Crake.

V7. RESULTS AND CONCLUSIONS

7.1 Terms of Reference

The terms of reference for this report were:

"To prepare an ex-post economic evaluation of the Makarewa River Scheme constructed by the Southland Catchment Board in the mid-1960's. The report is to analyse the economic methods and conventions used by the Ministry of Agriculture and Fisheries and the Soil and Water Division of the Ministry of Works and Development.

7.2 Economic Analysis

The economic analysis compared the situation with the present scheme to the situation that would have occurred if the scheme had not been implemented, i.e. without the scheme. Benefits and costs for the various rating classifications and for the scheme as a whole are discussed in Sections V.4 and V.5

The results of the analysis are:

IRR	approx. 6%
NPV (10%)	-$333,609,300

These results show the returns to the scheme are below the current guidelines set by Government for schemes of this type.

The low IRR could be considered to be a disappointing result. Two main factors contribute to this poor result:

(a) The high capital costs associated with on-farm development. The development process involves quite high levels of expenditure for clearing of bush and drainage.

(b) The timing of benefits. The first increases in stock numbers due to development occur on to two years after the initial large expenditure has taken place. Further increases occur more slowly after that.

It could therefore be asked why farmers developed at all if returns were so low? A financial analysis was carried out for each class where significant development occurred, viz. Classes A, B and D.

Results of this analysis are shown in Table V.8.

TABLE V.8

Results of Financial Analysis

Class	IRR	NPV (10%)
A	approx. 13%	$720
B	approx. 13%	$570
D	approx. 6%	-$762

The returns to on farm development are higher and increases in production that have occurred are quite large. Without development the carrying capacity was low. With the scheme, development could occur which meant that these areas became very productive. It is significant to note also that development occurred on a relatively small proportion of the farm area each year. The returns on the developed area are high but the benefits when spread over the whole classified area are lower, e.g. Class B farms 50% developed before scheme.

A further consequence of the scheme is that the Makarewa Catchment now carries an additional 51,000 stock units. The flow on effect of these additional stock has meant that the Southland regional economy has benefited by at least $830,000 per annum. This represents the costs auction/works to f.o.b. that would be spent in Southland. In addition the regional economy has benefited by the flow on effects of money spent on construction and maintenance of the scheme ($1.4m), farm development and ancillary services.

7.3 Sensitivity of Results

The cash flows are made up of three general benefits flows and six cost flows. These are listed below along with the net present value at 10%, and the proportion of total benefit or cost shown in brackets.

	Net Present Value at 10% ($)	
Scheme Benefits		
Increased Livestock Production	7,571,900	(80%)
Development income	1,429,700	(15%)
Saved Flood damage	438,750	(5%)
Total Present Value of Benefits	$9,440,350	(100%)
Scheme Costs		
Scheme capital costs	4,312,700	(33%)
Scheme maintenance costs	461,200	(3%)
Farm development costs	4,408,900	(34%)
Farm maintenance costs	1,777,250	(14%)
Stock capital costs	641,100	(5%)
Stock maintenance costs	1,448,500	(11%)
Total Present Value of Costs	$13,049,650	(100%)
Net Present Value (10%)	-$3,609,300	

It is clear from the above information that the major component which could have an effect on the results is the benefit related to increased livestock production. A simple sensitivity analysis was carried out on this benefit flow. The analysis involved increasing and decreasing the cash flow by ten and twenty per cent. The results are presented in Table V.9.

TABLE V.9

Sensitivity of Results to Changes in the Increased Livestock Benefit Cash Flow

CHANGE IN CASH FLOW	NET PRESENT VALUE AT 10% ($)	INTERNAL RATE OF RETURN (%)
Increase 20%	- 2,094,900	7.9
Increase 10%	- 2,852,050	7.1
Expected Value	- 3,609,300	6.2
Decrease 10%	- 4,366,430	5.3
Decrease 20%	- 5,123,620	4.3

The results show that an increase in the major benefit flow (increased livestock production) in excess of 20% would be needed to bring the result up to the 10% guideline laid down by Government. Such an occurrence is unlikely as the production levels are based on historical data obtained from those affected by the scheme.

7.4 Comparison with Original Economic Report

The original scheme Economic Report was presented as an integral part of the Report on the Makarewa Scheme produced

in 1962. It was prepared by T.P. Clearwater the Southland Catchment Board's Classifier at the time. The report was not a cost-benefit analysis but an attempt to justify the raising of the local share. This was done by assessing the likely annual benefits and relating these to the anticipated scheme charges.

The net benefits associated with the scheme were assessed at $25,470 per annum. Adjusted to December 1983 dollars this converts to $130,400. In comparison this report shows that the net annual benefit in the steady state to be $864,335.

The 1962 report gives two values as to the expected stock unit increase as a result of on-farm development associated with the scheme works. The two values are 60,300 s.u. and 26,358 stock units This report has used a value of 51,013 stock units.

Table V.10 shows a comparison of the results achieved in the current study with the original study. The ex-ante results were obtained by using the benefit and cost values used in 1962 in a cost-benefit framework. Two situations are presented:

(a) Using the actual 1962 dollar values, as presented in report, and
(b) Converting the 1962 dollar values, using Meat and Wool Board and the Construction Cost indices, to December 1983 dollar values.

TABLE V.10

Results of Current Study Compared to those Obtained in the Original Study

	Internal Rate of Return	Net Present Value (10%)
Current Study	6.2%	- $3.6m
Ex-ante ($ 1962)	6.7%	- $0.75m
Ex-ante ($ 1983)	4.6%	- $9.14m

The results show that at the time the decision was made (1962) the scheme had an internal rate of return of 6.2%. This is less that current Government guidelines, but as no such guidelines prevailed at the time no meaningful comment can be made. If the scheme was to be presented today, using the same benefit and cost cash flows, it would fall a long way short of the present guidelines of a 10% internal rate of return. However, the results of the current study show that the scheme has performed considerably better than the original analyst expected. The major areas of difference are presented in Table V.11.

TABLE V.11

Comparison of Cash Flows Used in Ex-Ante and Ex-Post Studies

CASH FLOW	1962 REPORT	CURRENT
Scheme Capital Cost ($ 1983)	$11.4m	$6.2m
Scheme Maintenance Cost ($ 1983)	$56,565	$68,505
Om-Farm Capital ($ 1983)	$10.7m	$9.6m
On-Farm Maintenance at Steady State ($ 1983)	$534,560[1]	$795,830
Total Benefits at Steady State ($ 1983)	$1.07m	$1.5m
Stock Unit Increase (stock units)	60,300 or 26,358	51,013

1. Net values were used to assess benefits therefore not directly comparable.

The major differences are that the scheme was completed for less than anticipated in real dollar terms and the benefits were under-estimated by approximately 50%.

7.5 Conclusion

The Makarewa River Scheme shows a rate of return that is lower than the guideline set by Government for the acceptance of a land betterment project. The main reasons for the low return are high cost of farm development and the delay until productive returns occurred.

Despite the low economic returns (from the national point of view) financial returns to on-farm development, particularly on Classes A and B are high.

The scheme with the improved drainage outfall, increased the speed of flood run-off and reduced the number of floods. This has given the farmers in the area the confidence to develop flood prone land leading to significant increases in production. An improved flood warning system has meant that farmers now receive adequate flood warning which has encouraged them to achieve high stocking rates on areas that were formerly subject to high flood risk.

The social benefits of the reduction in flood risk have not been addressed in this analysis.

Although the returns to the scheme fail to reach Government criteria for acceptance the scheme can be considered successful. It has enabled large areas of formerly unproductive land to be developed and has reduced the inconvenience of flooding to general public in a significant section of Southland.