TE WAIHORA/LAKE ELLESMERE

State of the Lake and Future Management

Edited by KENNETH F.D. HUGHEY and KENNETH J.W. TAYLOR

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Lincoln University Environment Canterbury

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SHELLEY McMURTRIE

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- Environment Canterbury
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- NIWA
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- Waihora Ellesmere Trust
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SHELLEY McMURTRIE

SHUTTERSTOCK

01 INTRODUCTION

KENNETH F.D. HUGHEY Lincoln University **KENNETH J.W. TAYLOR** Environment Canterbury

Te Waihora/Lake Ellesmere[1] is a large coastal lake, intermittently open to the sea. It is highly regarded for its conservation and related values, some of which are of international significance. Its function as a sink for nutrients from its large predominantly agriculturally based catchment, currently undergoing accelerated intensification, is also recognised, at least implicitly. It is the resulting conflict from these value sets which is mainly responsible for the ongoing debate about the future of the lake, a debate long fuelled by rhetoric and informed by a body of science which highlights the lake's complexity as a biophysical system, but has many gaps. It is a debate that now has substantial statutory implications, arising from factors which include:

- the requirements of conservation, and indigenous needs and entitlements which are growing in prominence and statutory (including property rights based) legitimacy;
- public interest in legal processes associated with further major intensification of agriculture planned for the catchment;
- a recent Environment Court decision in which serious questions about the overall biological health of the lake were raised; and
- the consequences arising from the need for Environment Canterbury to obtain resource consents for the lake operating regime.

In addition, in recent times the Waihora Ellesmere Trust (WET), a community based group advocating for improved management of the lake, has been established. It is within these diverse contexts that this State of Te Waihora/Lake Ellesmere report has been prepared—it results from the 2007 Waihora/Ellesmere Living Lake Symposium, held from 31 October-3 November 2007 at Lincoln University, Canterbury. The symposium was initiated and organised by the WET (see www.wet.org.nz).

The Living Lake Symposium had several key objectives:

- To determine the overall state of the lake, by first defining the key value sets, and indicators that could be reported against;
- To suggest future management actions that would address key issues affecting the defined values;
- To provide a forum within which lay individuals, scientists and managers could openly debate issues; and
- To provide a launching pad for integrated and focused future management of the lake and its environs.

The programme incorporated three keynote speakers: Dr Larry Hildebrand from Environment Canada, Dr Hamish Rennie from Lincoln University, and Dr Bryan Jenkins from Environment Canterbury—their addresses made a major contribution to the symposium although none are included in this report, because it is focused primarily on the science and the management options associated with the lake.

The format of this report is designed to be readily updateable. Ten of the principal presentations in the main sessions of day two of the symposium are included in this report—two Power Point presentations (both regarding water quantity and related issues) are provided as appendices to improve completeness. Over time, however, topic areas not available as full papers for this report, e.g., surface water quantity, will be written up and included in detail. Similarly, the papers herein will themselves be updated as new and significant data become available. Each subject area will be reconsidered within the same structure and context as has been provided here. One paper, 'Te Waihora/Lake Ellesmere: An integrated view of the current state and possible futures', was presented on the final formal day of the symposium and it is included as the concluding chapter of this report.

Finally, the Waihora Ellesmere Trust and many of the others attending the symposium saw merit in reconvening the event around two years after the initial symposium, to report on progress with management, indicator monitoring, scientific understanding and other matters. We support that suggestion.

In terms of report format it is important that readers note the following:

- All authors were provided with 'briefs of work' and were requested to contextualise their work with that contained within the Taylor (1996) report on the lake—this was more easily achievable for some than others. Given some lack of consistency between symposium presentations and final papers it is our intention that a revised set of agreed indicators will be considered and included in any follow-up symposium and associated reports—some considerable work will be required in some areas to achieve this objective;
- Only the wildlife and integration papers included in this report have been formally peer reviewed; and
- All other papers have been standardised and style edited-some changes have been suggested by the report editors and made by the paper authors.

Finally, an attempt has been made to present the papers in a logical sequence of 11 chapters: chapter 1 sets the scene; chapters 2-7 cover the biophysical science dimensions (groundwater, water quality, native vegetation, native fisheries, trout, wildlife); chapters 8-10 deal with the human dimensions (Ngāi Tahu, recreation, economics); and chapter 11 deals with integration of the findings from the previous chapters and setting the scene for future management.

[1] Note that the Geographic Place Names Board has defined the name as Lake Ellesmere (Te Waihora). It is not our intention to debate the nomenclature, but rather to put the focus where we consider it should lie, within the lake's initial historical and cultural context for indigenous Maori.

CLIVE HOWARD-WILLIAMS NIWA **SCOTT LARNED** NIWA

Appendix A: Water Resource Management Presentation.
Powerpoint presented at the Living Lake Symposium,
Lincoln University, 31 October - 3 November 2007

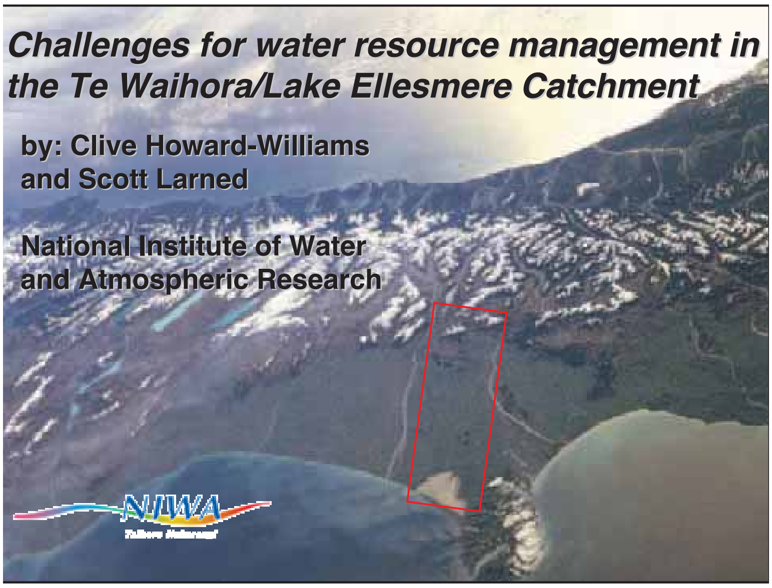
HUGH THORPE Environment Canterbury

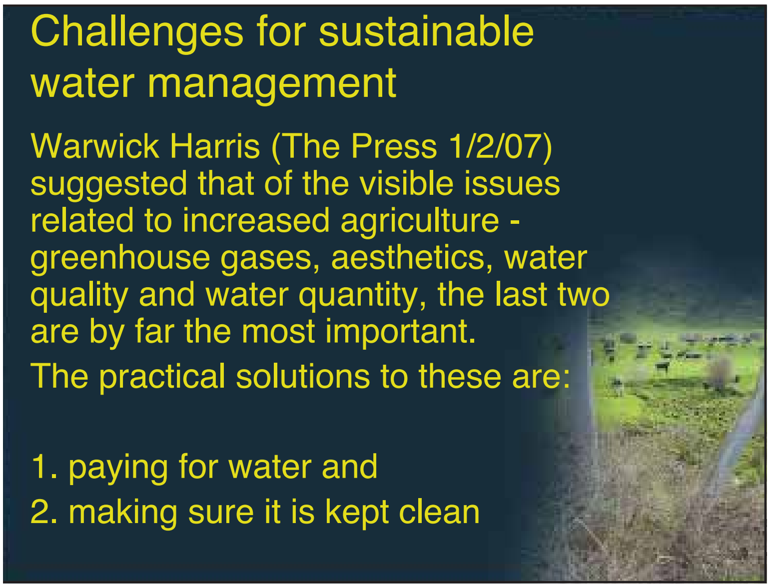
Appendix B: Hydrology Presentation.
Powerpoint presented at the Living Lake Symposium,
Lincoln University, 31 October - 3 November 2007

<< 12.1 Appendix A

Water Resource Management Presentation

Clive Howard-Williams and Scott Larned





To make Paying for water work in a sustainable way we need to know the total amount, how it is distributed, and its sustainable "yield". ie we need 'accounts' that give information at any one time on how much is there and how much is available for purchase at different points. (see Statistics New Zealand)

To keep it clean we have to know who is contaminating and where and by how much

There are special challenges in addressing these in Canterbury

NIWA

Outline: Challenges for the Te Waihora catchment:

1. What water is available for allocation? The concept of environmental flows
2. Climate and water resources in a changing environment: Interdecadal variations
3. Linked groundwater-surface water systems and intermittent flows
4. Defining nutrient sources in a catchment with linked groundwater and surface water
5. Defining acceptable nutrient loads in a turbid shallow lake

Challenge 1. What water is available for allocation? The concept of environmental flows

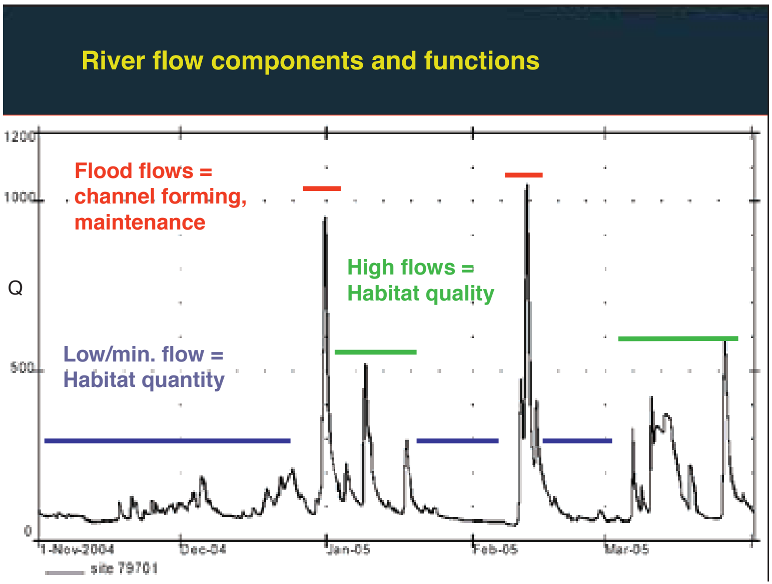
Available flows = Total flows – Environmental Flows

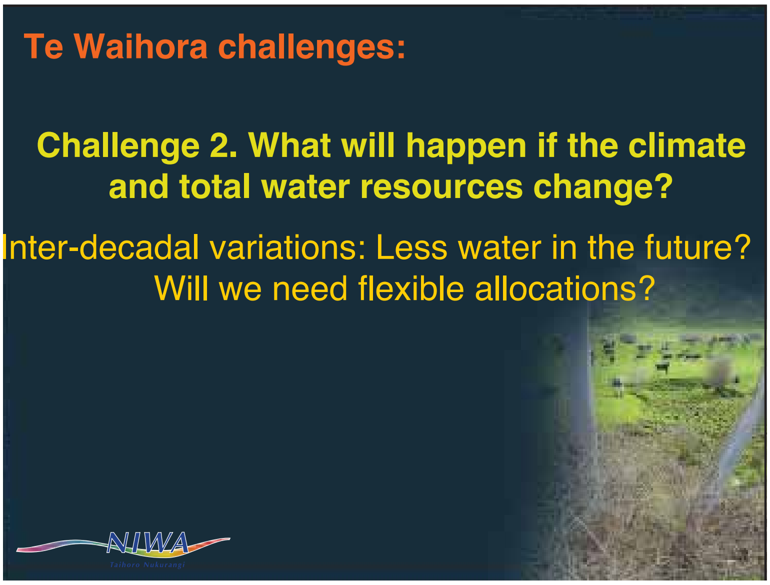
What are Environmental flows? (WPoA - *NES*)

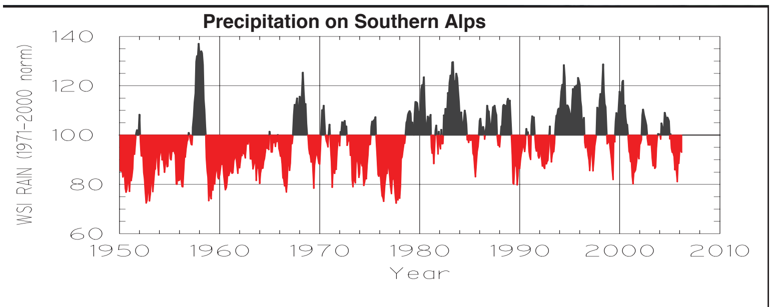
"Safeguard the life supporting capacity of [freshwater] …..ecosystems". **(NZ RMA 1992)**

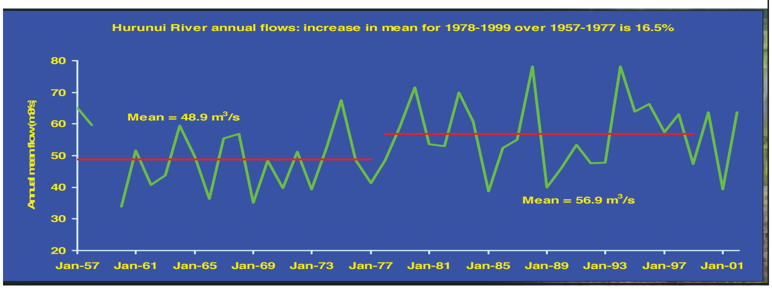
"Water governance should……preserve or restore the ecological integrity of groundwater, rivers, lakes and wetlands" (***UNESCO: Bonn Declaration 2001)***

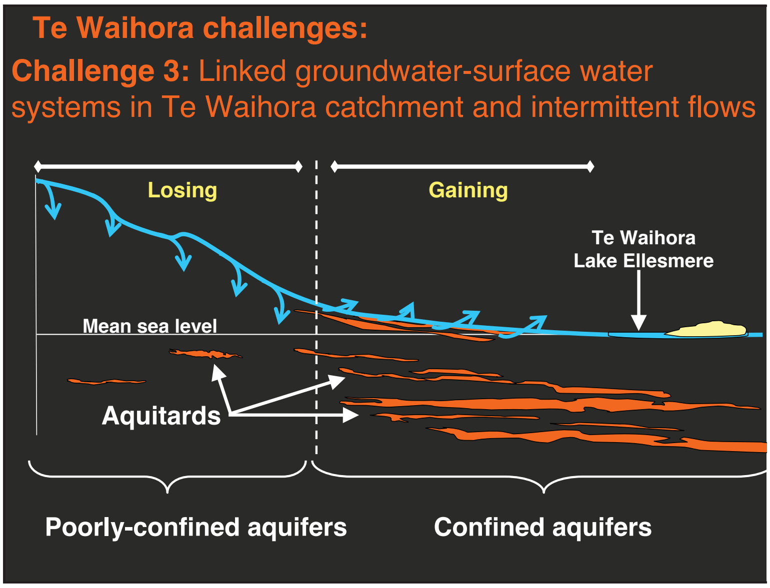
Maori cultural values

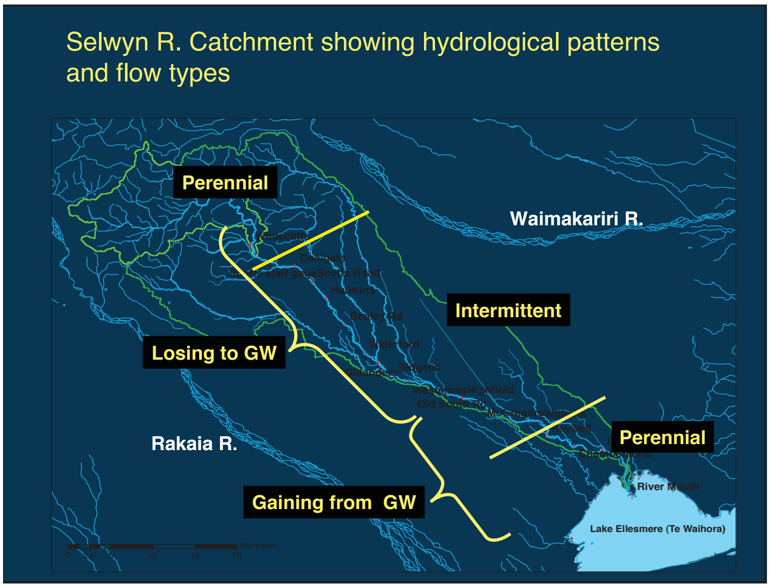

River flow components and functions
Flood flows =
channel forming,
maintenance
High flows =
Habitat quality
Low/min. flow =
Habitat quantity
Q
1200
1000
500
0
1-Nov-2004
Dec-04
Jan-05
Feb-05
Mar-05
site 79701


Te Waihora challenges:
Challenge 2. What will happen if the climate and total water resources change?
Inter-decadal variations: Less water in the future?
Will we need flexible allocations?
NIWA


Precipitation on Southern Alps
WSI RAIN (1971–2000 norm)
140
120
100
80
60
1950
1960
1970
1980
1990
2000
2010
Year

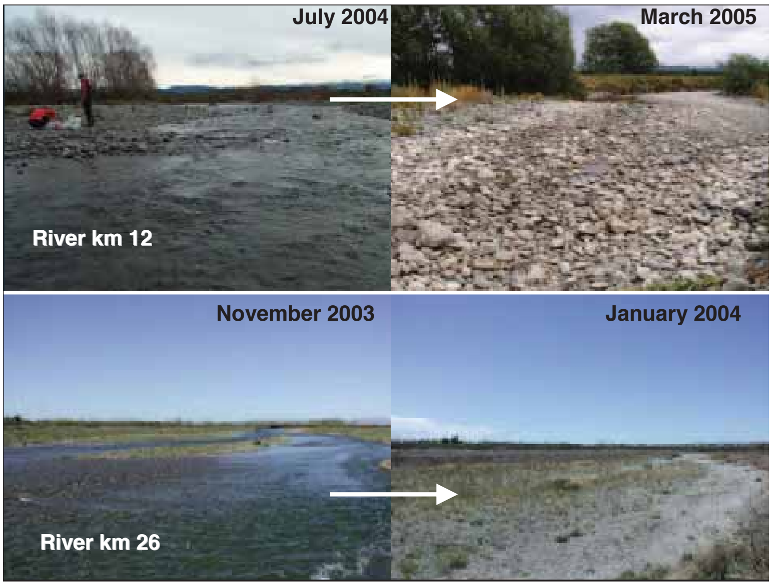

Hurunui River annual flows: increase in mean for 1978-1999 over 1957-1977 is 16.5%
Mean = 48.9 m³/s
Mean = 56.9 m³/s
80
70
60
50
40
30
20
Jan-57
Jan-61
Jan-65
Jan-69
Jan-73
Jan-77
Jan-81
Jan-85
Jan-89
Jan-93
Jan-97
Jan-01

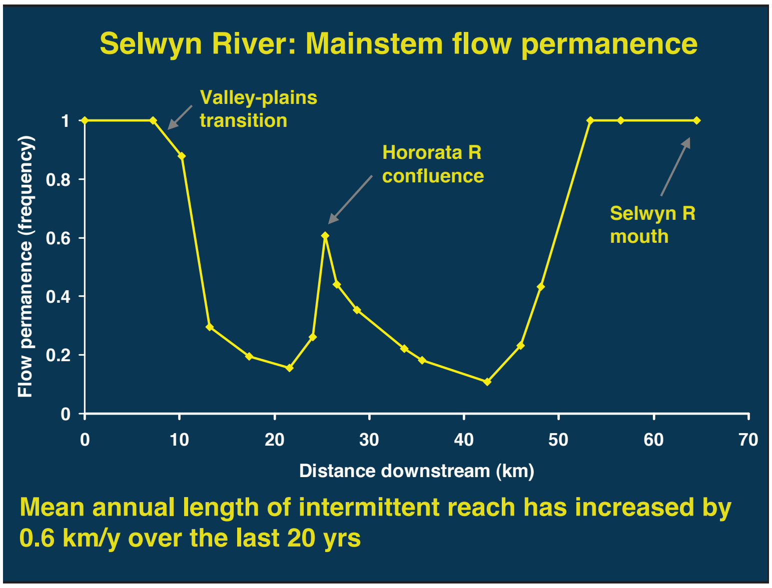

Te Waihora challenges:
Challenge 3: Linked groundwater-surface water systems in Te Waihora catchment and intermittent flows
Losing
Gaining
Te Waihora
Lake Ellesmere
Mean sea level
Aquitards
Poorly-confined aquifers
Confined aquifers

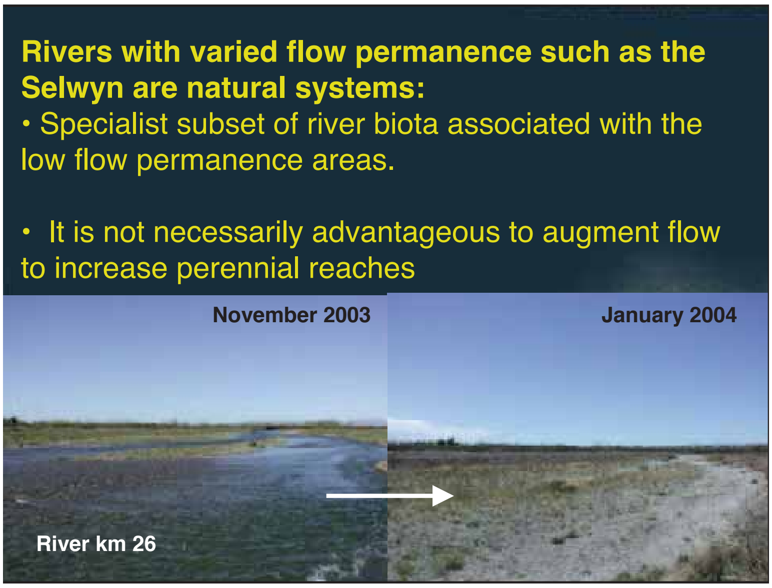

Selwyn R. Catchment showing hydrological patterns and flow types
Perennial
Waimakariri R.
Intermittent
Losing to GW
Perennial
Rakaia R.
Gaining from GW
River Mouth
Lake Ellesmere (Te Waihora)

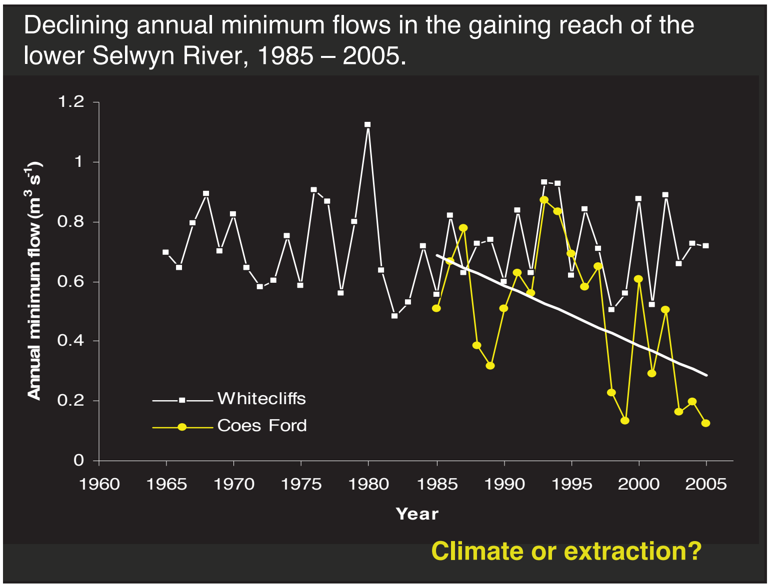

Spring-fed lowland tributaries
L-II River
Harts Creek

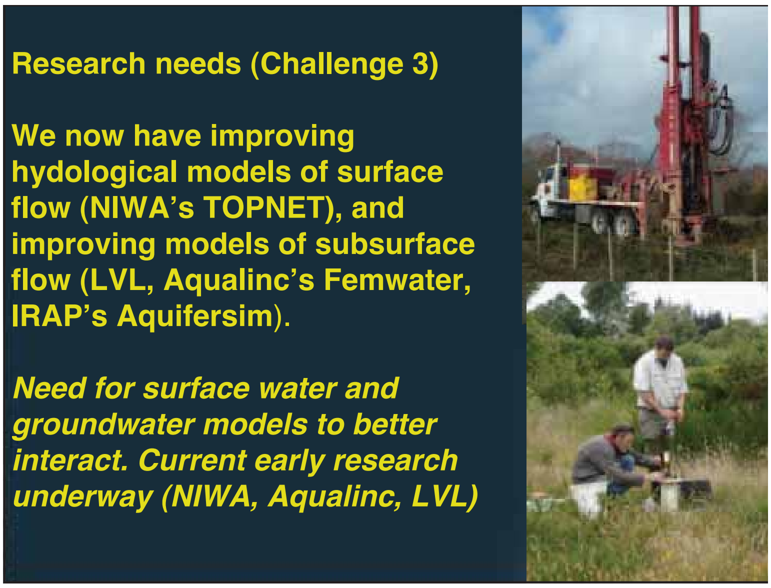

Selwyn River: mix of spring fed and hill fed water sources
Intermittent flows

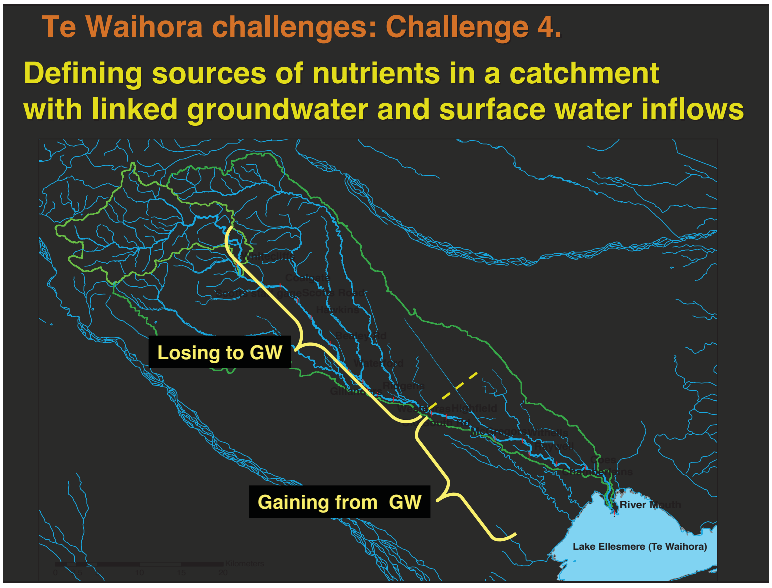

July 2004
March 2005
River km 12
November 2003
January 2004
River km 26

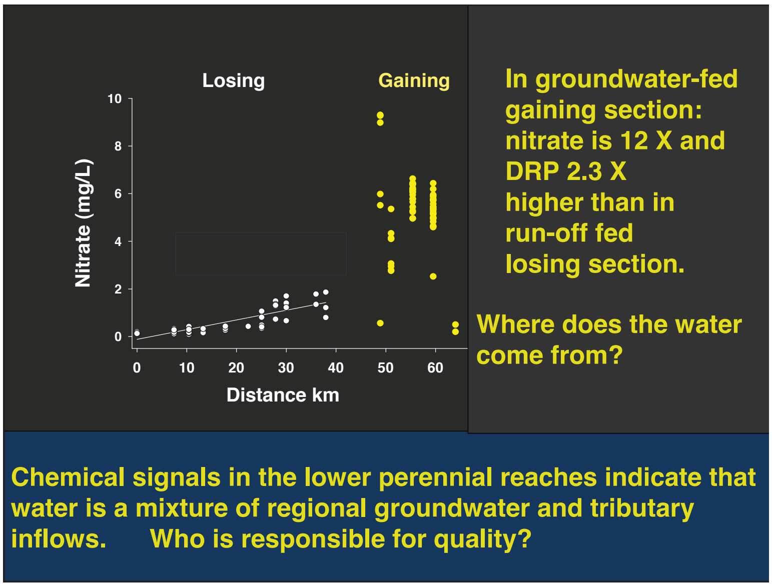

Selwyn River: Mainstem flow permanence
Valley-plains transition
Hororata R confluence
Selwyn R mouth
Flow permanence (frequency)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
Distance downstream (km)
Mean annual length of intermittent reach has increased by 0.6 km/y over the last 20 yrs

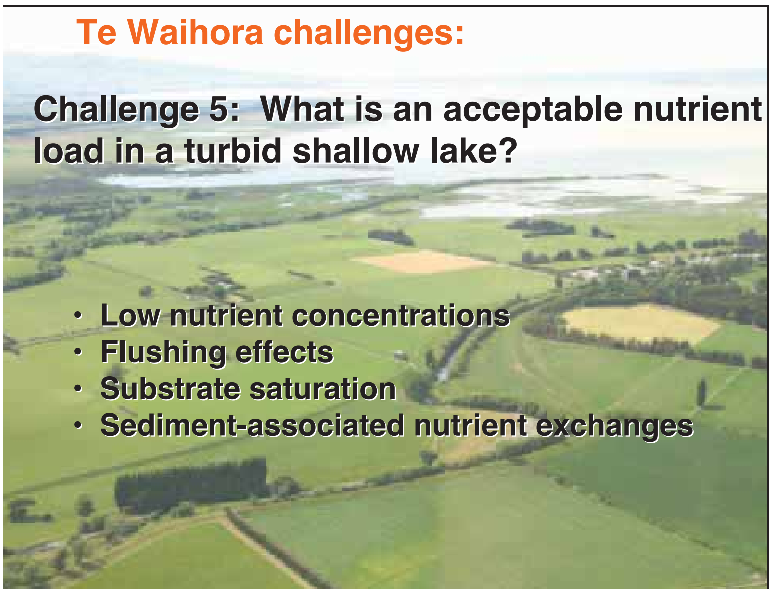

Rivers with varied flow permanence such as the Selwyn are natural systems:
• Specialist subset of river biota associated with the low flow permanence areas.
• It is not necessarily advantageous to augment flow to increase perennial reaches
November 2003
January 2004
River km 26


Declining annual minimum flows in the gaining reach of the lower Selwyn River, 1985 – 2005.
Annual minimum flow ($m^3 s^{-1}$)
0
0.2
0.4
0.6
0.8
1
1.2
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Whitecliffs
Coes Ford
Climate or extraction?


Research needs (Challenge 3)
We now have improving hydrological models of surface flow (NIWA's TOPNET), and improving models of subsurface flow (LVL, Aqualinc's Femwater, IRAP's Aquifersim).
Need for surface water and groundwater models to better interact. Current early research underway (NIWA, Aqualinc, LVL)


Te Waihora challenges: Challenge 4.
Defining sources of nutrients in a catchment with linked groundwater and surface water inflows
Losing to GW
Gaining from GW
River Mouth
Lake Ellesmere (Te Waihora)


Losing
Gaining
Nitrate (mg/L)
0
2
4
6
8
10
0
10
20
30
40
50
60
Distance km
In groundwater-fed gaining section: nitrate is 12 X and DRP 2.3 X higher than in run-off fed losing section.
Where does the water come from?
Chemical signals in the lower perennial reaches indicate that water is a mixture of regional groundwater and tributary inflows. Who is responsible for quality?


Te Waihora challenges:
Challenge 5: What is an acceptable nutrient load in a turbid shallow lake?
• Low nutrient concentrations
• Flushing effects
• Substrate saturation
• Sediment-associated nutrient exchanges

What are low nutrient concentrations ? - the sensitivity of waters to nutrient additions

Farmers, and agricultural scientists think in terms of tonnes of nitrogen per ha, or kg of nitrogen per cubic metre of soil.

- Limnologists think in terms of milligrams per cubic metre of water (ppb) - up to I million times lower.
- Algal problems may occur at water concentrations of 10 ppb of DIN, or above 1 ppb of DRP.

Challenge 5 cont.: Flushing effects

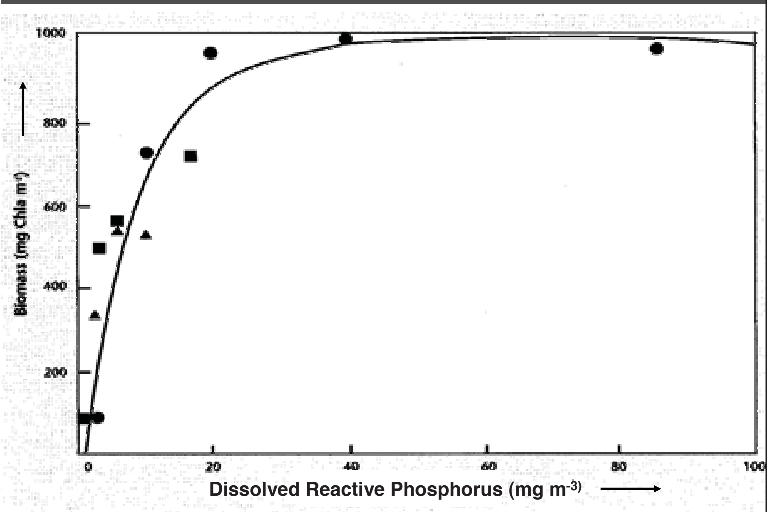
Phytoplankton biomass is a function of the amount of nutrient entering a lake and how quickly it is flushed through the system (OECD Models).

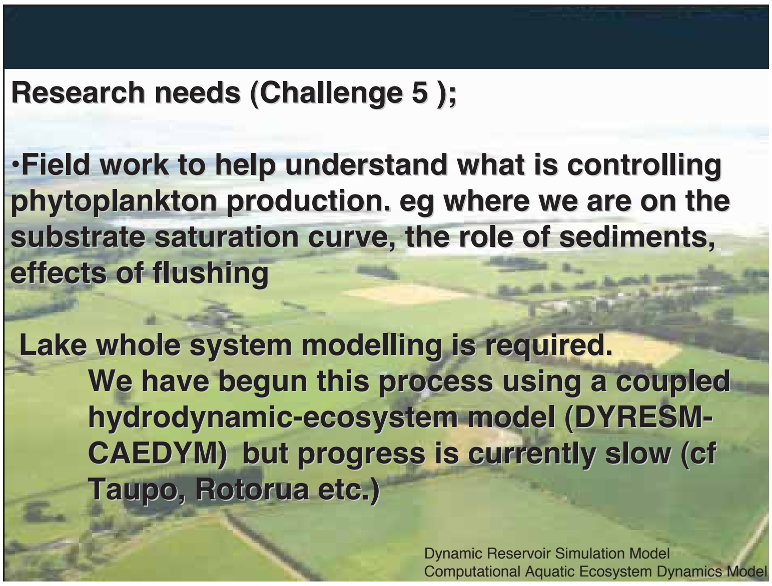
How do we calculate effects of nutrient additions in shallow lakes of flushing times of less than a year?

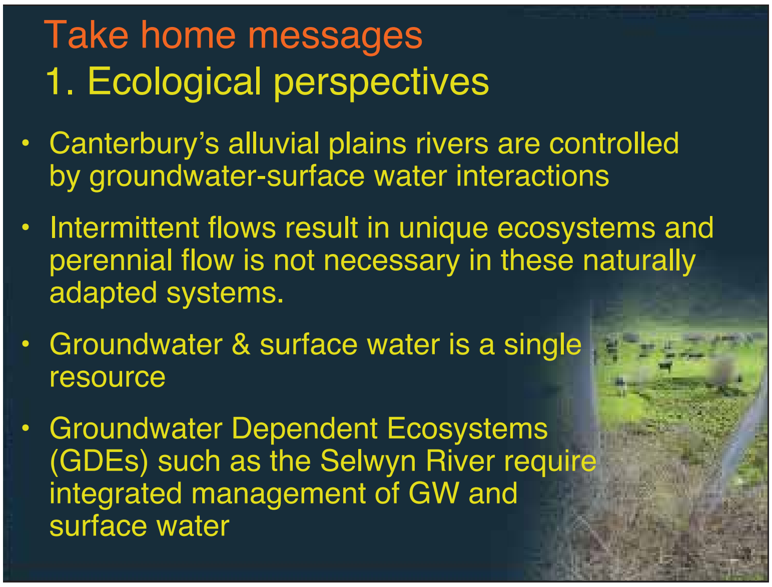
In shallow lakes the quicker the flushing, the less time there is for the nutrients to be assimilated. Faster flushing in shallow lakes tends to reduce phytoplankton biomass. However, increased nutrients tend to increase phytoplankton biomass.

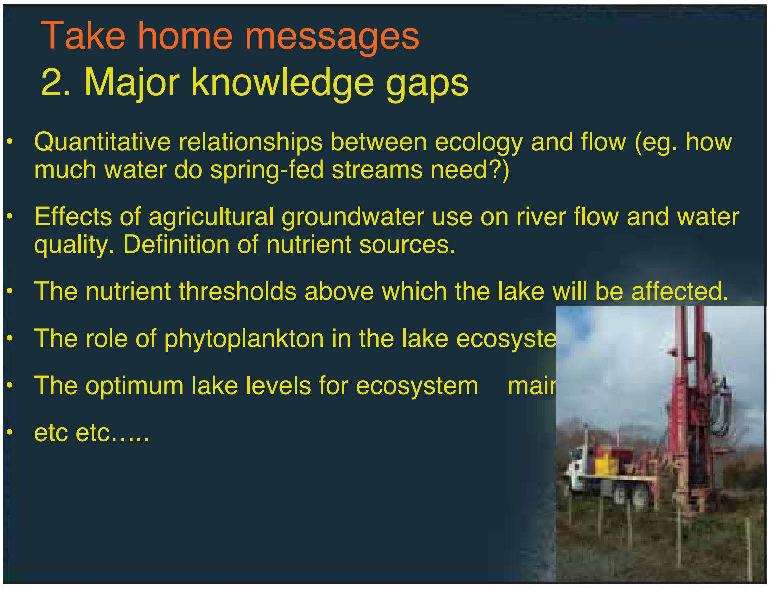
This is complex in Te Waihora where the nutrients may be flushed through in days (river flood + open lake) or up to a year (low flows and mouth closed).

It is also complex because of nutrient saturation:

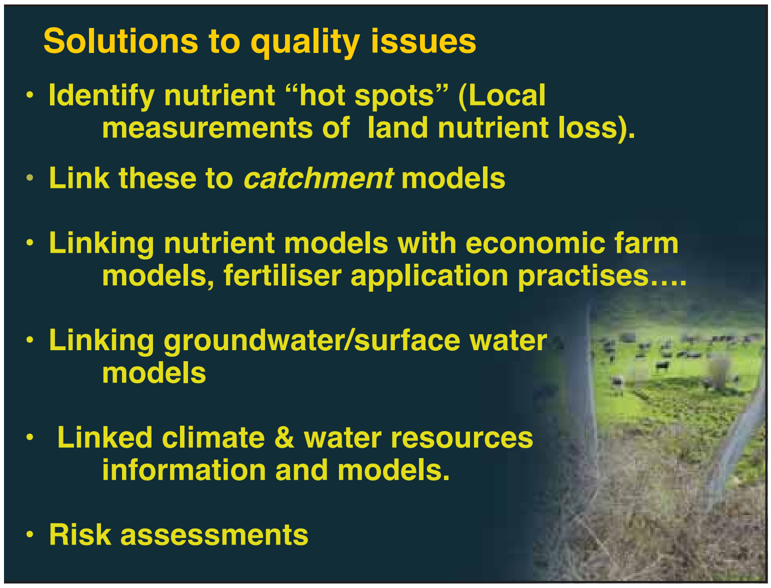



Research needs (Challenge 5);
•Field work to help understand what is controlling phytoplankton production. eg where we are on the substrate saturation curve, the role of sediments, effects of flushing
Lake whole system modelling is required.
We have begun this process using a coupled hydrodynamic-ecosystem model (DYRESM-CAEDYM) but progress is currently slow (cf Taupo, Rotorua etc.)
Dynamic Reservoir Simulation Model
Computational Aquatic Ecosystem Dynamics Model

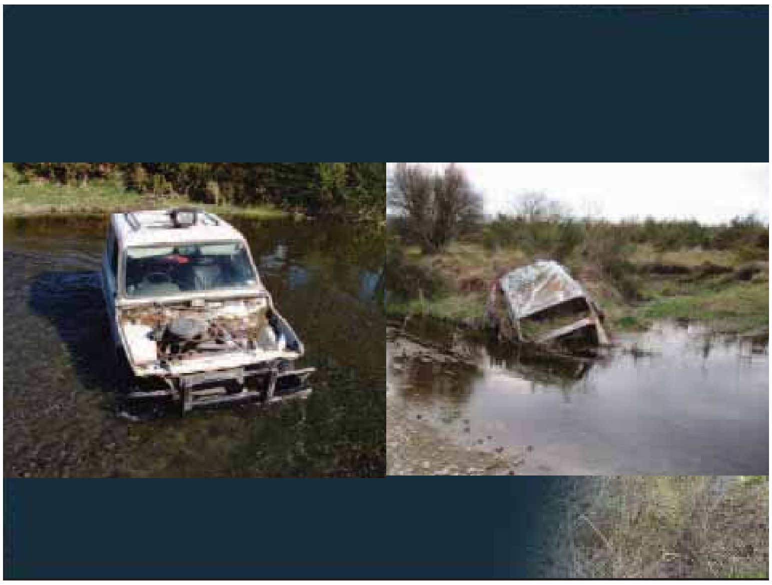

Take home messages
1. Ecological perspectives
• Canterbury's alluvial plains rivers are controlled by groundwater-surface water interactions
• Intermittent flows result in unique ecosystems and perennial flow is not necessary in these naturally adapted systems.
• Groundwater & surface water is a single resource
• Groundwater Dependent Ecosystems (GDEs) such as the Selwyn River require integrated management of GW and surface water


Take home messages
2. Major knowledge gaps
• Quantitative relationships between ecology and flow (eg. how much water do spring-fed streams need?)
• Effects of agricultural groundwater use on river flow and water quality. Definition of nutrient sources.
• The nutrient thresholds above which the lake will be affected.
• The role of phytoplankton in the lake ecosyste
• The optimum lake levels for ecosystem mair
• etc etc…..

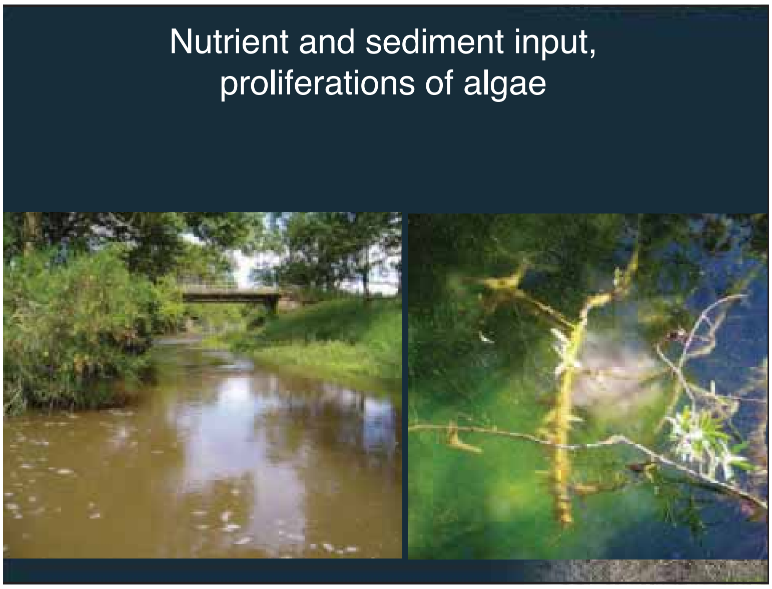

Predictions for the future?
Increase in intensity of agriculture
vs.
Increase in mitigation and improved practices
Will they balance ???
THE END
Selwyn River at Highfield Rd Ford
19 December 2006

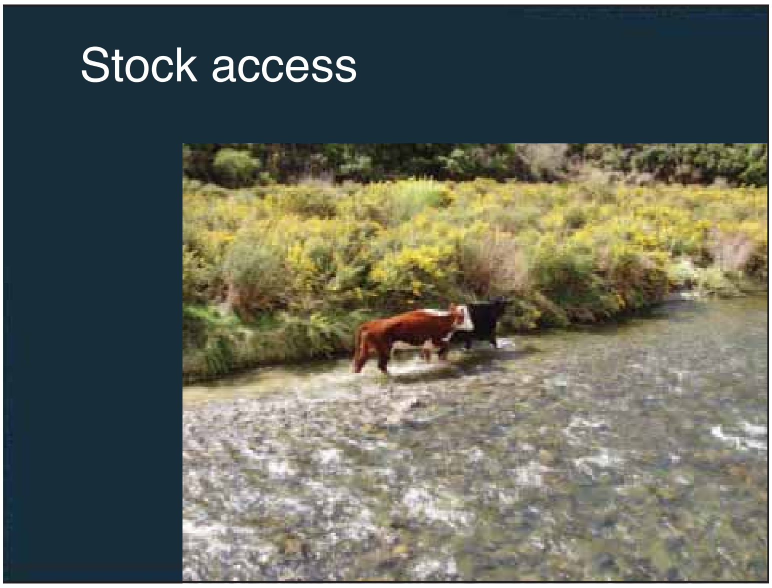

Solutions to quality issues
• Identify nutrient "hot spots" (Local measurements of land nutrient loss).
• Link these to *catchment* models
• Linking nutrient models with economic farm models, fertiliser application practises….
• Linking groundwater/surface water models
• Linked climate & water resources information and models.
• Risk assessments


Solutions to quality issues (cont.)
On farm/forest:
• Riparian and farm drain management to maximise nutrient retention.
• Slow release fertilizers.
• Nitrification inhibitors.
• Constructed wetlands and Advanced Pond Systems.
• Data sets of quality assured information at appropriate time scales.
• Community driven water resource initiatives




Flood control & river works
Gravel extraction
Sediment starvation affects downstream river channels and lake deltas. Research urgently needed on sediment mass balance


Nutrient and sediment input, proliferations of algae



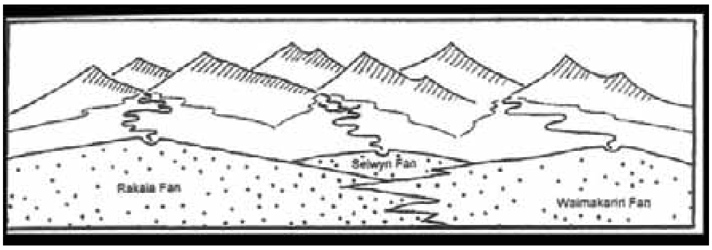
12.2 Appendix B >>

Hydrology Presentation

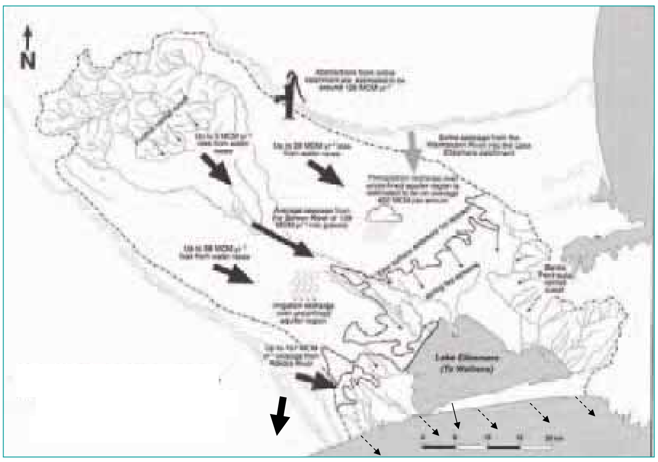
Hugh Thorpe

THE HYDROLOGY OF TE WAIHORA / LAKE ELLESMERE CATCHMENT.

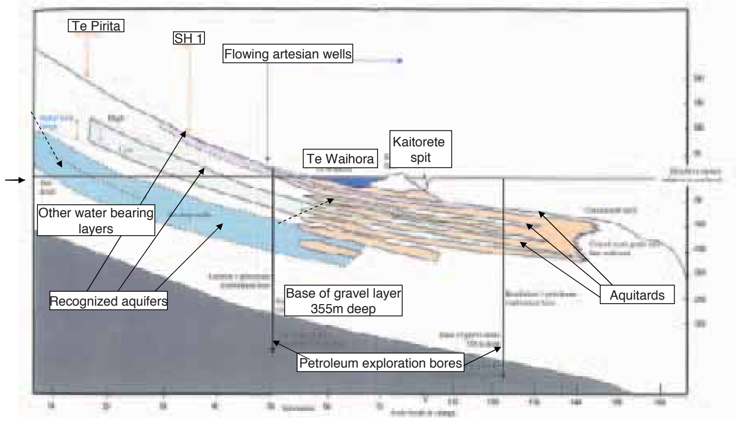
Hugh Thorpe



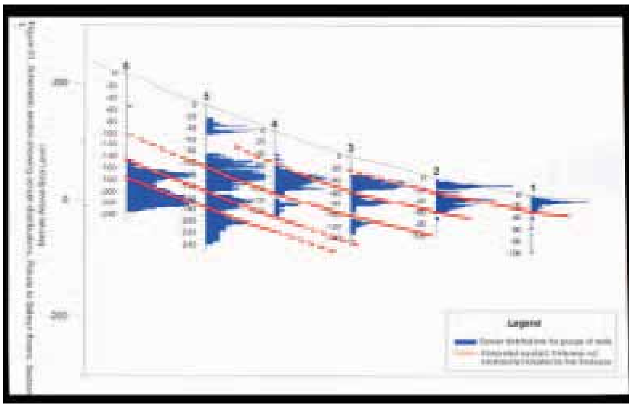
Elements of the groundwater balance in the Te Waihora/Ellesmere catchment
(Taylor (ed.) 1996)



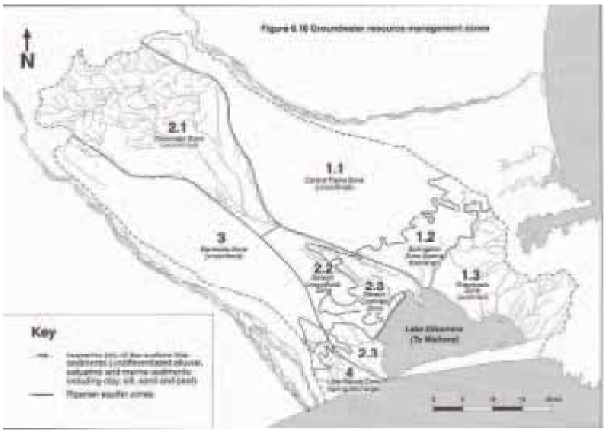
Geological cross-section from Te Pirita to Kaitorete spit showing aquifer and aquitard structure.
(Wiliams 2006)



Schematic X-section showing well screen distributions and hence aquifer sequence in Rakaia-Selwyn zone.
(Davey 2006)

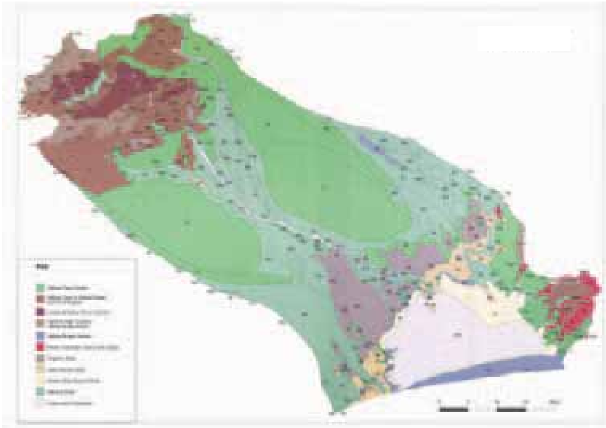


Groundwater resource management zones.
Taylor (ed.) 1996)

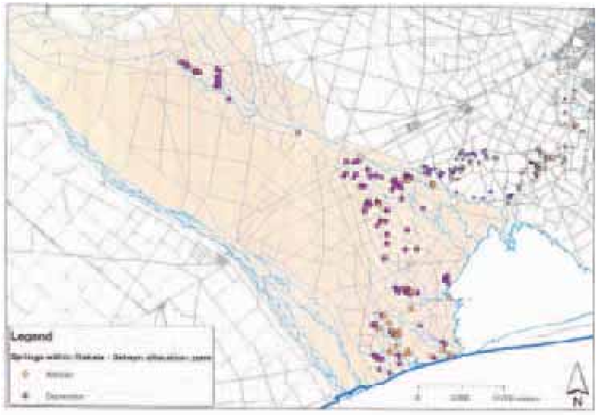


Distribution of soils in the Ellesmere catchment.

(Taylor (ed.) 1996)

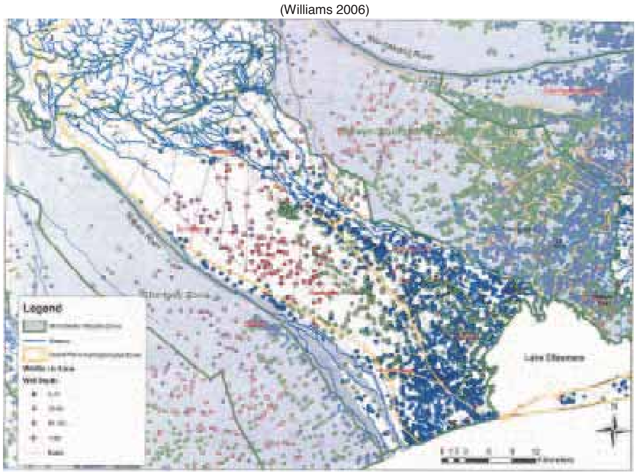


Springs within the Te Waihora /Lake Ellesmere catchment

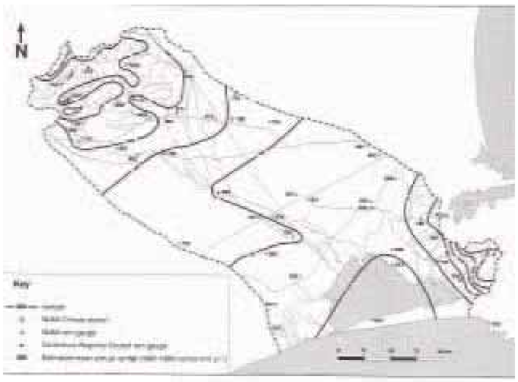


Well distribution in the Te Waihora / Lake Ellesmere catchment.

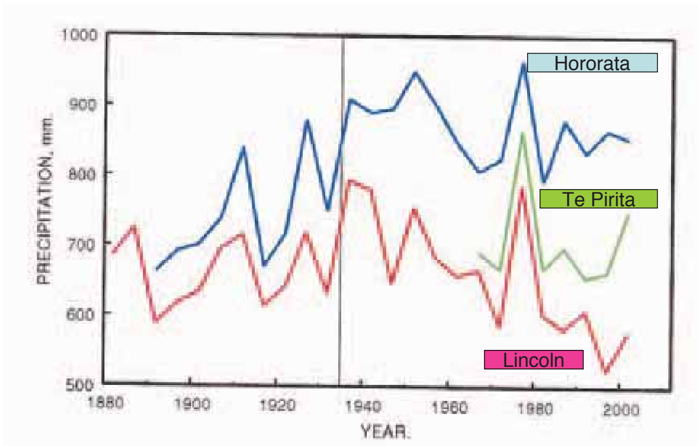
(Williams 2006)



Mean annual rainfall (mm) in Te Waihora/Lake Ellesmere catchment
(Taylor (ed) 1996)

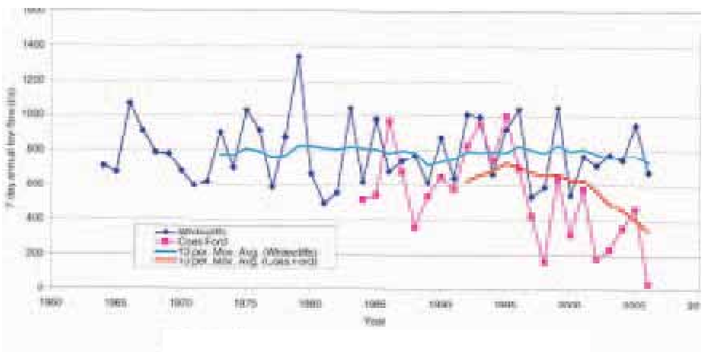


Pentads of means of precipitation
(Larsen 2006)

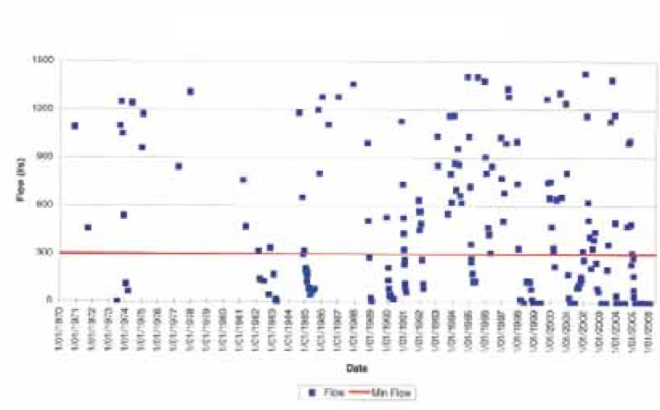


Selwyn River:
7-day annual low flows at Whitecliffs and Coes Ford.
1964-2006

(Horrel 2006)

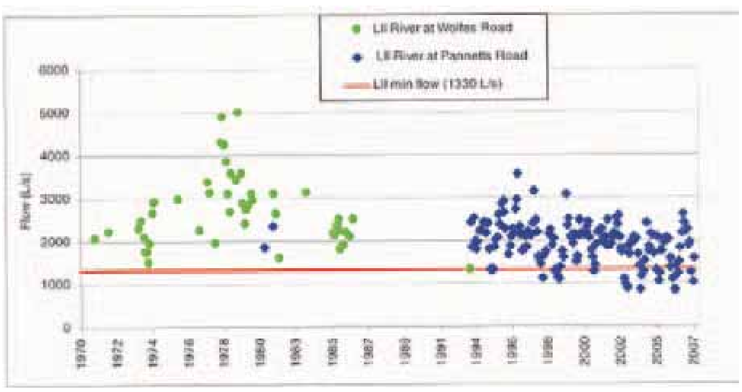


Irwell River spot gaugings and minimum flow
1970-2006
(Horrell 2006)

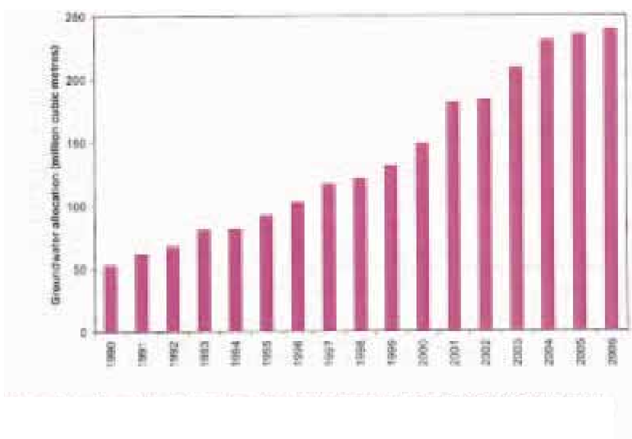


Gauged flows for two sites on the LII River
1970-2007

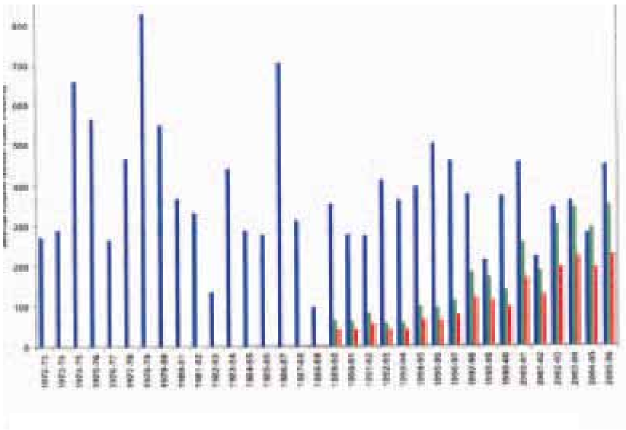
(Gabites 2007)



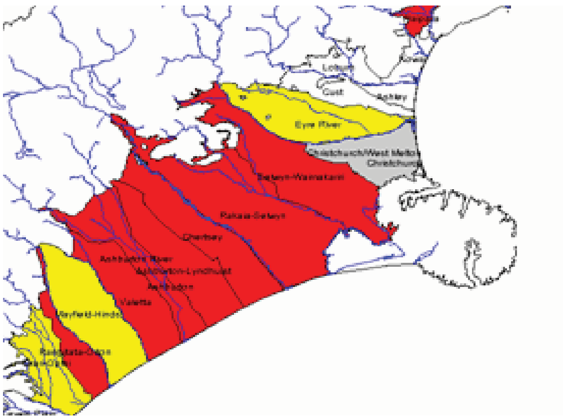
Annual allocation volume from groundwater in the
Rakaia-Selwyn zone: 1990-2006
(Scott 2006)



Calculated land-surface recharge (blue): 1972-2006
Estimated irrigation demand (green) and actual use (red) since 1989/1990
(Scott 2006)



Environment Canterbury's
groundwater allocation zones



SUMMARY

- The water balance of the catchment is still somewhat imprecise.
- Stream flows have been measured and observed to be decreasing over the last decade.
- The main reason for such decreases is climate variability.
- Irrigation takes from groundwater have increased almost 5-fold since 1990.
- The rainfall over this period has not been especially low.
- Statistical analysis of rainfall, and flows at Coes Ford strongly suggest that the low flows are exacerbated by irrigation takes.
- The arbitrary allocation by Ecan of 50% of assessed recharge as available for taking should be reconsidered. It may be too high **in the Te Waihora catchment.**
- The proposed review of present consents should be supported.

Te Waihora/Lake Ellesmere is a large coastal lake, intermittently open to the sea. It is highly regarded for its conservation and related values, some of which are of international significance. Its function as a sink for nutrients from its large predominantly agriculturally based catchment, currently undergoing accelerated intensification, is also recognised, at least implicitly. It is the resulting conflict from these value sets which is mainly responsible for the on-going debate about the future of the lake.

This book serves to quantify the nature of this debate by documenting changes to lake values, both over time and spatially. It provides a standardised approach to reporting these changes, set against indicators that are value-specific. Ultimately, it provides a template for thinking about future management scenarios for the lake and its environs. Given this approach the book ultimately serves as a resource for helping understand the ever-changing and current and possible future states of the lake, under a variety of management requirements and implications.