The Benefits of Water Storage to Irrigation

Tim Cookson 2009

For Kellogg Rural Leaders Programme

Acknowledgements:

- My wife Lucy who has helped out by "creating some time" for me to do this project. Also my father who has had to take a bit more time on the tractor when he could have been skiing during the winter.
- Irrigation New Zealand provided me with some great photo's
- Dr John Bright – Aqualinc helped to steer me in the right direction and provided a great source of information on where to start.
- Lincoln University Library
- CPW – directors, engineers, consultants, expert witnesses. All provided information.

Contents Page

List of Tables

List of Figures

Executive Summary

Irrigation and water storage has long been touted as a potential for improvements in productivity in dryland East Coast areas. Reports date back to the 1880's discussing the benefits water would bring to farmlands.

Currently there is 750,000ha of land irrigated in New Zealand with approximately 400,000ha in Canterbury. The total irrigated area in New Zealand has trebled since 1985. There is currently another 400,000ha of scheme proposals at various levels of development. For growth in irrigated area to continue water is going to have to come from storage as in many areas aquifers and river water availability are fully allocated, thus forcing the need for storage.

Agriculture currently contributes 56% of New Zealand's total exports. For New Zealand to maintain and grow the country's standard of living we quite simply have to raise the bar on exports. We have to export more to also rectify our unsustainable balance of payments situation. Our exporting strengths lie in agriculture.

The addition of storage to a proposed irrigation scheme in Canterbury covering 60,000ha would create an additional $700 million in export earnings per annum also creating an additional 1600 new jobs additional to that created by the irrigation alone. A recent study on the Opuha irrigation scheme found an extra $124m in output and $41m in value added produced per annum. 480 new jobs were created. 55% of the farmer expenditure was in small rural towns and 39% in Timaru. The social analysis highlighted "younger, better educated farmers, and greater employment are associated with reliable irrigation".

The Opuha Dam also has a significant role in maintaining minimum flows in the Opihi River. The river mouth used to be closed 100+ days per year, whereas it is now closed 4-5 days per year. This has turned the Opihi is very significant salmon and trout fishery. In 2004/05 more salmon were reported caught on the Opihi than all the other major salmon fisheries.

Many heavily irrigated areas especially in Canterbury have fully or over allocated aquifer water demand. This is putting pressure on lowland streams. Reducing the requirement from aquifers would allow low land stream regeneration and subsequent fishery benefits.

The development of reliable irrigation has been positive for many small rural communities. It has meant the retention and growth of country schools where previously falling rolls threatened closure. Medical facilities have been maintained and enhanced, trades people are able to maintain viable businesses. Club memberships benefit from the increase in population and the increase in people available to volunteer their time.

There are far reaching flow on effects from reliable irrigation in the form of additional processing & confidence within the agriculture service sector to expand due to the reliability of on farm supply. There can be a greater use of exiting capacity i.e. transport operators & development of new infrastructure i.e. expanded ports or hydro-electricity development if scheme design allows.

The Benefits of Water Storage to Irrigation

1. Introduction

1.1 Early attempts to obtain water

An initial step in water resource development in Canterbury was to provide domestic and stock water through a system of water races. These were designed in the late nineteenth century by George Ritso who was the county engineer for Malvern County Council (now Selwyn District Council, also there was no Canterbury Regional Council at that time).

In 1883 he wrote: *"No doubt, in a few years, works will be constructed for the purpose of using the waters of all principal rivers for irrigating the plains, thus making water meadows which will fatten probably five or six sheep, or a proportionate number of cattle to the acre, on land two acres of which will barely support one sheep"* Thus concepts around irrigation on the Canterbury Plains are not new!

1.2 Canterbury's climate & water problem

Canterbury (where the majority of current irrigation occurs) has a rainfall that is very similar throughout the year, the problem arises when you look at evapotranspiration with 1-2mm per day in the winter and up to 8-10mm/day in the summer. Added to this is quite a large area of soils with a low water holding capacity 50-70mm of water i.e. in mid summer soils can go from field capacity (full) to drought conditions in a week with the right sort of climate conditions. Also most of the run off from the rainfall fed rivers in Canterbury occurs in winter, and snow fed alpine rivers in early spring. These high river flows generally fall outside the main irrigation demand peaks, which is one major reason why water storage is required.

Limits to the groundwater resource have become apparent. Stresses to the environment in terms of falling groundwater levels and low flows in spring fed streams are evident. There are already controls across most of the Canterbury Plains (Red Zones) where it is deemed that the groundwater resource is fully allocated relative to supply.

There is still some supply of water available via run of the river however it is very unreliable (only able to be used above certain set flows) and there is likely to be minimal new irrigation development sourced directly from these surface water sources. Groundwater development is still increasing but is leveling off due to availability (red zones) and costs (deeper wells). Without the development of significant water storage to capture surplus surface water flows, the irrigated area in New Zealand (especially Canterbury) will plateau.

Looking forward in time the effects of climate change are predicted to increase the frequency and severity of drought conditions on the East Coast of New Zealand. This will also have effects lowland stream flows and rainfall recharge of groundwater, at the same time alpine fed rivers are expected to have increased flows. Thus the overall effect is we are still going to have as much water as we have had in the past however it will be in the wrong place at the wrong time.

1.3 Irrigation In New Zealand

The total area under irrigation has increased to about 750,000 ha, trebling since 1985. Canterbury alone has 400,000ha of the total. There has been a rapid increase in farmer initiatives to get new community schemes off the ground – led by farmers who do not have the opportunity to develop privately and who depend on communal development of water sources to deliver a reliable water supply. It is currently estimated that there is 400,000 ha of area in early stage community irrigation proposals.

New Zealand has a current irrigated are of approximately 750,000 ha and with 4 million people equates to 0.19ha per person. This is one of the highest per capita rates in the world (Heiler 2008). It is seen as being high due to;

- The relative abundance of groundwater accessible to individuals in Canterbury meaning private irrigation development has dominated growth since the 1980's
- More robust financial resources of New Zealand private farmers compared to their Australian counterparts enabling them to invest heavily in irrigation.
- Requirements in New Zealand of export market contracts to reduce production risks from soil moisture deficits that impact on quantity, quality and timeliness of agricultural products. This relates to current and foreseeable market realities.

Irrigated agriculture is now in the big league. In New Zealand the annual net farm gate contribution to the economy of 500,000 ha of irrigated land in 2002/03 was $920 million representing 11% of all farm gate GDP. Analyses carried out by MAF Policy show likely irrigation developments by 2013 of between 210,000ha and 470,000 ha would equate to additional annual net farm gate contributions of $330 - $660 million. Off farm benefits in terms of value add etc would double or treble these figures. To put these numbers into perspective the Rugby World Cup is expected to bring into the economy in 2011 $500 million however **this is a one off**.

2. Why Water Storage is required, a background:

2.1 Global Level.

World population is expected to get to 9.3 billion by 2050 (up from 6.7billion now), at the same time farmers around the world are being asked to produce more food/protein from the same area with less inputs in particular water and fertilizer.

2.2 National Level

For New Zealand to maintain and grow the country's standard of living we quite simply have to raise the bar on exports. We have to export more to also rectify our unsustainable balance of payments situation. Our exporting strengths lie in agriculture

Table 1. Agriculture and Total exports in New Zealand 2005-2008.

Year	2005	2006	2007	2008
Ag Exports $b	16.3 (55%)	16.3 (55%)	18.7 (56%)	20.6 (56%)
Total Exports $b	29.7	29.7	33.4	36.6

As can be seen in Table 1 over half of New Zealand's exports are from Agriculture. In this example Forestry has been excluded. If it were included the percentage would rise to approx 64% of exports (9% of total).

New Zealand has a farmed area of 14.7 million hectares of this 2 million hectares is dairying. Sheep and Beef farming make up 9.5 million hectares. However our farmed area is at a limit and won't increase much if any thus in order to export more from the same given area we have to intensify. Reliable irrigation of suitable areas is one option.

Agriculture is the mainstay of the national economy and will continue to be for the foreseeable future. It is clear that many products produced from farms can be enhanced and transformed by the application of knowledge and skill.

2.3 Local / Regional Level

Export income from Canterbury's rural sector accounts directly and indirectly for between 60-70% of Christchurch's economic activity – outstripping export income from the region's IT sector by a factor of 20 to 1. Canterbury farmers spend around $750 million every year on goods and services provided by Christchurch businesses.

If we take the proposed Central Plains Water proposed irrigation scheme, it allows us to look the current situation in terms of land use and output, and what would likely happen if a scheme was built with or without a storage reservoir (i.e. irrigation was "run of the river")

Table 2. Land use of Proposed CPW irrigation scheme, with and without storage

	Current	Scheme with storage	No Storage
Total affected area			
Dryland Livestock	55,250		9,250
Mixed livestock / arable (50% water)		20,500	32,000
Mixed livestock / arable (100% water)	8,000		
Finishing livestock / arable		3,000	
Dairy (100% water)	22,000	46,500	25,000
Arable and process crop		15,250	5,000
Arable / winter finishing			14,000
	82,250	82,250	82,250
Dryland			9,250
Total area affected by irrigation			76,000

The non storage results in a major change in on farm systems due to the unreliability of the water available, including:

- A significant increase in mixed irrigation systems, where 50% of the farm can be irrigated in any one season, but a mix of crop, beef and sheep allows strategic irrigation of high water priority areas (after crops in the pre January period and stock areas or green-feed in the post January period).

- A move away from process crops with a high mid summer water demand. In the model budget, we have replaced the process crop with 2nd year grass followed by green-feed to target winter lamb finishing.

- A very small (3000ha) increase in dairying over the current dairy areas, but dramatically less than proposed under a scenario with storage. The increase reflects a small number of farmers where good storage economics, reasonable soil moisture holding capacity (775mm) and semi reliable rainfall combine to create adequate water reliability.

- Elimination of intensive summer livestock finishing that is dependant on reliable pasture and/or green-feed growth in mid summer.

Hence as can be seen from above although a "run of the river" scheme would be good, a reliable irrigation scheme based on water storage is much better

2.3.1 Financial Performance – ex Opuha Dam Study. Regional Economy Effects.

Table 3. The Regional Financial benefits of the Opuha Dam

	Dryland	Irrigated Properties	Additional Impact from Irrigation
Output ($/year)	$75,000,000	$199,000,000	$124,000,000
Value Added ($/year)	$23,000,000	$64,000,000	$41,000,000
Household Income ($/year)	$13,000,000	$33,000,000	$20,000,000
Employment (FTE's)	404	884	480

Table 3 shows the increase in value added associated with irrigation from the whole Opuha Dam scheme was $41 million per year which is equivalent to 3.1% of the total value added in the Study Area. It also generated and additional 480 jobs which is 2.4% of total employment in the study area.

The application of science and technology to generate increased biologically driven economic transformation conjures the exiting vision of Canterbury being internationally renowned as responsive to global demand of natural bio-tech food, nutraceuticals and biomedical products. The health and well-being market segment is one of the fastest growing in the world. Demand for medication through natural foods as opposed to artificial chemicals represents and outstanding opportunity for our "clean green" sustainable competitive advantage.

2.4 An on Farm Level

Lets look at a typical dryland farm and some of the issues it faces.

In the dryland farming areas of the East Coast of New Zealand, conservative farming practices are carried out to minimize the risk of business failure because of intermittent droughts. This effectively puts a limit on productivity and profitability of farming systems, even in favourable climatic seasons. Production companies are now demanding more specific products produced egg 12 months of the year to for full their contracts, thus under this scenario reliable irrigation is essential. This relates specifically to egg meat and seed/vegetable companies.

Meat Companies – Gone are the days where NZ sends shiploads of frozen whole carcasses to the UK. Consumers via the supermarkets are now wanting chilled pre packaged meal sized cuts 52 weeks of the year. Thus we have to move some of our meat production away from the typical system of lambs born in spring and all sold by the end of the following autumn.

Seed Companies – NZ based seed company's contract seed production contra season to the Northern Hemisphere. The contracts are typically a set weight and quality delivered by a certain date. Thus for the Company based in NZ it is absolutely imperative that budgeted on farm seed yields are achieved. South Pacific Seeds (SPS) based in Mid Canterbury contract the production of much of the vegetable seed grown in New Zealand, most of which is exported. New Zealand is a major force in world vegetable seed production, producing 50%

of hybrid red radish seed, 25% of carrot seed and is a major producer of cabbage, Chinese cabbage spinach and beet seed. These are all high value crops that can return the grower per hectare incomes as high as $10,000/ha. Irrigation underpins the production of these crops and growers without irrigation struggle to get contracts. SPS is very typical of the type of downstream businesses that develop on the back of reliable irrigation. Sophisticated production systems, requiring significant technical input and business expertise.

Vegetable Companies – Vegetable production is high cost, high return type of business and requires a reliable irrigation water supply for it to work as the stakes are so high. Some companies have now gone as far as only farmers with certain types of irrigators can grow certain crops. They do not allow baby carrots to be grown under roto-rainer type irrigators as the drop size and rate of application is so high that some soil can be washed off the top of the carrot causing it to go green and therefore reducing the carrot quality. Centre pivot or lateral type irrigators are the preferred types in this case.

Land Use Changes – It has been proposed by Taylor (2009) that with reliable irrigation the current trend for dryland farmers to subdivide land for lifestyle blocks is likely to slow. However, without options for land-use change under irrigation further subdivision is likely in the command area, especially around Darfield and other townships.

Thus a reliable water system is the only real solution.

2.4.1 Financial Performance – ex Opuha Dam Study. A survey of 32 irrigated and 20 dryland properties.

Table 4. The On Farm Financial benefits of the Opuha Dam

	Dryland		Irrigated	
	% of Revenue	$/Eff ha	% of Revenue	$/Eff ha
Total Revenue		862		2073
Farm Working Expenses	76%	655	73%	1503
Cash Farm Surplus	24%	208	27%	570
Total Overheads		213		484
Net Trading Profit After Tax	-1%	-5	4%	86
Disposable Surplus (Deficit)		(142)		(153)

- Total revenue is 2.4 times as high at $2073/ha for the irrigated farms than the dryland at $862/ha.
- Farm working expenses as a percentage of Total Revenue are very similar for both irrigated and dryland farms. However an additional $848/ha is spent on the irrigated farms which has wide ranging benefits for the regional and national economy.
- Cash Farm surplus as a proportion of Total Revenue is similar for the two farm types, however the dollar value of the surplus is significantly greater on the irrigated farms by 175%.

- Sheep farming is the dominant income source on the dryland farms with 45% of the revenue while only contributing 18% of the revenue on the irrigated farms. Livestock revenue in total is 68% of revenue on dryland farms and 55% on the irrigated farms, with dairy farming providing more than half of the livestock revenue on the irrigated properties.
- Cropping is a much more significant revenue source on the irrigated farms than the dryland farms with 45% of the total revenue on irrigated farms coming from the arable and process crops grown. A large contributor to the impact of crop revenue in the command area of Opuha irrigation is process vegetable cropping. Process vegetable cropping accounts for approximately 23 of the cropped area on the irrigated farms but contributes 35-40% of the total crop revenue. The influence of the high total revenue per hectare cropped from process vegetables lifts the average returns from the total cropping area well above the gross return possible from any of the other individual cropping options. The influence of the land use choices made available by the process cropping industry in South Canterbury is only possible due to the Opuha Scheme being able to provide a reliable water supply via storage.

3. The Benefits of Water Storage to Irrigation

3.1 Financial

The wider ranging benefits of irrigation to NZ inc. are often not that well understood and all to often work has shown that a scheme can show a positive benefit of $x to a farm or to the particular scheme. However many people think that's as far as the money goes...

3.1.1 On Farm Level

An assessment of the lower Waitaki scheme was recently completed where on farm development costs of the current land use mix are estimated at $205.4 million. The net change in annual cash farm surplus from "dryland" to with scheme development is $28.9 million per annum. Therefore the scheme achieves a nominal 14.1 percent return on capital at the farm gate. Table 5 highlights the increase in extra output and subsequent increased labour requirement as compared to the previous dryland farming systems

Table 5. Net Increase in on farm economic parameters as a result of Waitaki Scheme Development (per 000 ha).

	Farm	District
Output ($ million)	2.5	3.4
Employment (FTE's)	7.5	12.6
Value Added ($ million)	1.5	1.8

3.1.2 Regional Level

a) What does a reliable scheme add to a regional economy

As can be seen in Table 6 there is a multiplier effect in all aspects measured as we move from on farm effects through to District and regional effects. This increase is caused by egg additional truck drivers to move the additional production, additional truck sales etc.

Table 6. Net Increase in regional economic parameters as a result of Waitaki Scheme Development (per 000 ha).

	Farm	District	Region
Output ($ million)	2.5	3.4	9.2
Employment (FTE's)	7.5	12.6	27
Value Added ($ million)	1.5	1.8	3.2

b) Constructing a scheme.

A scheme requires both on and off farm work during the construction phase. This generates economic activity in the region well before any water is applied to the ground.

Table 7. Expenditure and jobs created for CPW scheme comparing with and without storage.

Year	On/Off Farm Cost ($m)	Direct/Indirect Regional Output	Direct Jobs	Direct + Indirect Jobs
		With Storage		
1	$137	$272	566	1007
2	$164	$334	624	1234
3	$207	$427	535	1584
4	$86	$188	93	707
5	$73	$160	80	604
6	$30	$66	34	251
7	$2	$3	2	15
				7
Total	$699	$1453	1933	5412
		No Storage		
1	$48	$96	199	353
2	$77	$158	264	596
3	$110	$230	278	866
4	$47	$107	46	406
5	$29	$69	22	252
6	$13	$30	9	113
7	$1	$2	1	9
Total	$325	$693	818	2595

On/Off Farm Cost = Cost of building the scheme, plant & equipment, livestock, dairy sheds, milk co shares etc. Direct/Indirect regional output is output generated by the on/off farm expenditure.

The with storage option costs more to build and has a greater out put than compared to a run of the river type scheme. Similarly as can be seen in Table 7 a scheme with storage has a greater development cost and employs a lot more people both directly and indirectly during the construction phase.

3.1.3 National Level – GDP effects.

Table 8. Effects to the National economy of the CPW scheme with and without storage

	- Storage	+ Storage
Total Output ($m)	$592	$1,308
GDP ($b)	$1-$1.3	$2.2-$2.9
Jobs created	1130	2684

At a National Level this is equivalent to an expansion of around 2 percent in New Zealand's GDP with storage. Similarly an additional $1.3 billion could be added to our export earnings but just adding the storage component to the scheme.

Table 9. Effect of CPW scheme with and without storage on exports and irrigation area.

	Pre Scheme	Scheme no storage	Scheme with storage
Total Ag Exports	$20.6 b	$21.2 b	$21.9 b
		+2.9%	+6.3%
Ag Exports as % total	56%	58%	60%
Area Farmed	14.7 m ha	14.7 m ha	14.7 m ha
Area Irrigated (NZ)	750,000ha	810,000ha	810,000ha
Percentage of NZ irrigated	0.51%	0.55%	0.55%

As can be seen in Table 10 the CPW scheme on its own has the potential to really drive New Zealand export earnings particularly with the inclusion of storage, lifting Agriculture from 56%-60% of all exports. All this when there is only a very small change in the total irrigated area as a percentage of total farmed area in New Zealand.

Table 10. Net Increase in National economic parameters as a result of Waitaki Scheme Development (per 000 ha).

	Farm	District	Region	NZ
Output ($ million)	2.5	3.4	9.2	9.7
Employment (FTE's)	7.5	12.6	27	29.4
Value Added ($ million)	1.5	1.8	3.2	3.4

Looking at the Waitaki Scheme if we look at the initial on farm economic parameters and the parameters at a National level there is close to a 4 fold increase in all aspects.

3.2 Water Storage Costs

There is quite a debate about water storage either being on small on farm ponds or community based large reservoirs. The obvious advantage with storage ponds is they would be built on the land of those who use them thus there is no disruption to land or activities. However they do cost a lot more per unit of water stored.

On farms ponds:

- Capacity of pond: 30,000m^3 – 120,000m^3 (56,000m^3)
- Area of land pond will irrigate 56,000m^3 = 100ha @ 4mm/d * 14 days
- Capacity per ha: 250-770m^3/ha (560m^3/ha) storage per ha irrigated
- Area: 2-8ha. (2.2ha)
- Depth: up to 2.5m. Deeper ponds require lining which significantly increases costs.
- Lining: Typically with topsoil @ 100mm per metre depth of water.
- Capital Cost: average cost in last 4 years has been $2.80/m^3 ($1570/ha)
- Time to empty pond: Typical design is 14 days storage @ 4mm applied per day. Thus these ponds work well where water reliability is already quite high (80%+) (Lewthwaite 2008).

Community Based Reservoir: (egg CPW proposed Waianiwaniwa Valley Dam)

- Capacity of Dam: 240,000,000-280,000,000 m^3
- Area of land Dam will irrigate: 60,000ha
- Capacity per ha: 3667-4667m^3 storage per ha irrigated
- Area: 1200ha. (2ha per 100ha irrigated)
- Depth: up to 50m.
- Lining: not required due to soil type in valley floor.
- Capital Cost: $280 million ($4660/ha irrigated)
- Time to empty pond: 64 days at continuous maximum demand (Lewthwaite 2008)

Issues

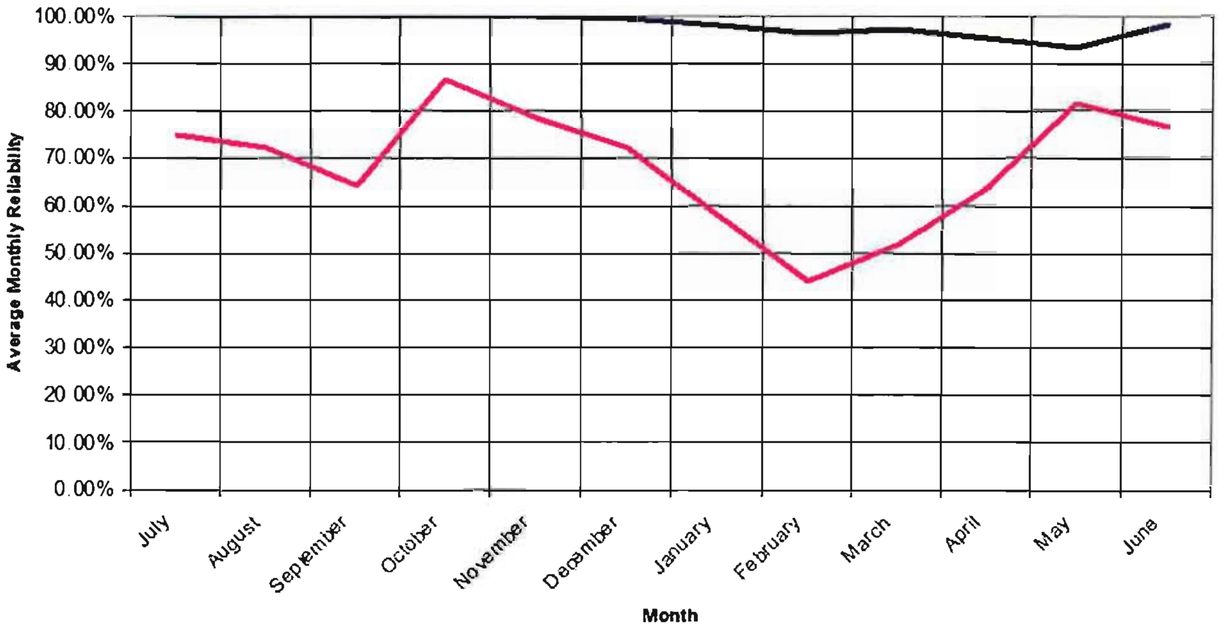
It is hard to compare on farm ponds with a scheme that has reliability of 80%+ with the proposed CPW scheme where reliability is low but is very high with the community based storage dam. However to get the same reliability for the CPW scheme via on farm storage the ponds would have to be:

- Capacity of pond: 3667-4667m^3 storage per ha irrigated * 100ha = 366700-466700m^3
- Area of land pond will irrigate 366700-466700m^3 = 100ha @ 4mm/d * 91-117 days
- Area: 14.7 – 18.7ha per 100ha irrigated c.f. 2ha per 100ha irrigated
- Capital Cost: $10,200-$13,000/ha irrigated) $612-780 million cf $280 million (for total scheme area)

3.3 Reliability

What does it look like. Figure 1 below shows the reliability for the CPW scheme based on community storage vs "run of the river" no storage. The dark blue line is pretty much a straight line indicating close to 100% reliability. The pink line is average reliability based on run of the river. What it does not show is the variation around the average which goes from 0-100% all months of the year depending on the river flows at the time.

Figure 1. CPW scheme reliability with and without storage.



A reliable water supply is essential in modern irrigated agriculture with high entry cost it is essential that farming businesses are able to perform close to their potential. It is also important to allow on farm production to meet the needs of our range of customers (many of whom are in the Northern Hemisphere) and are not interested in the fact that the irrigation stopped for a month in January because the river was too low. The reduction in farm productivity between years give farmers and businesses aligned with farming certainty to invest as opposed to unreliable schemes / dryland farming.

3.3.1 A case study of the costs of having low water reliability. (Donkers 2009).

BF Ltd is a 370 ha effective dairy farm milking 1100 cows in 2006/07 season. Soils are Lismore Stony Silt Loam (low water holding capacity). The farm was irrigated by 5 roto-rainers with an 11 day return period. The farm has a 160ha support block nearby, 130ha of this irrigated via centre pivot. The support block provided grazing for replacement stock, some supplementary feed for milking cows and winter grazing for 50% of the cows. The business set a conservative production budget of 400,000kgMS (1081kgMS/ha) for the 2006/07 season. By end of December 2006 (typically mid way point for production) production was slightly over 200,000kgMS. Water supply stopped on 17th February 2007 with no more for the rest of the month (61% reliability). March 2007 only 7 days watering was available (23% reliability). The effect of the low reliability was significant.

- MS production for the season was 28,000kgMS short of the 400,000kg (payout in 06/07 season was $4.59/kgMS) = $128,000
- 200t maize silage purchased to fill the feed supply gap = $40,000

- Feed on support block used for cows meant grazing out heifers for 12 weeks = $20,000
- The dry autumn followed a wet spring meaning damage from grass grub
  Damage was very severe. 100ha resown @ $2,000/ha = $20,000
  Direct Cost in that financial year = $208,000

The effects of restricted water supply are not just confined to the season in which they occur. Other effects often felt in subsequent seasons include:

- Reduced winter grass and subsequent milk production due to lower autumn pasture cover. This can be exacerbated by pasture insect damage from grass grub, porina and argentine stem weevil.
- Increased annual weed invasion (especially thistles) due to more open pastures
- Increased grass weed invasion such as browntop and couch. These grass species are much less productive and lower in feed quality than beneficial pasture species such as ryegrass.

3.4 Environmental

3.4.1 Wind Erosion

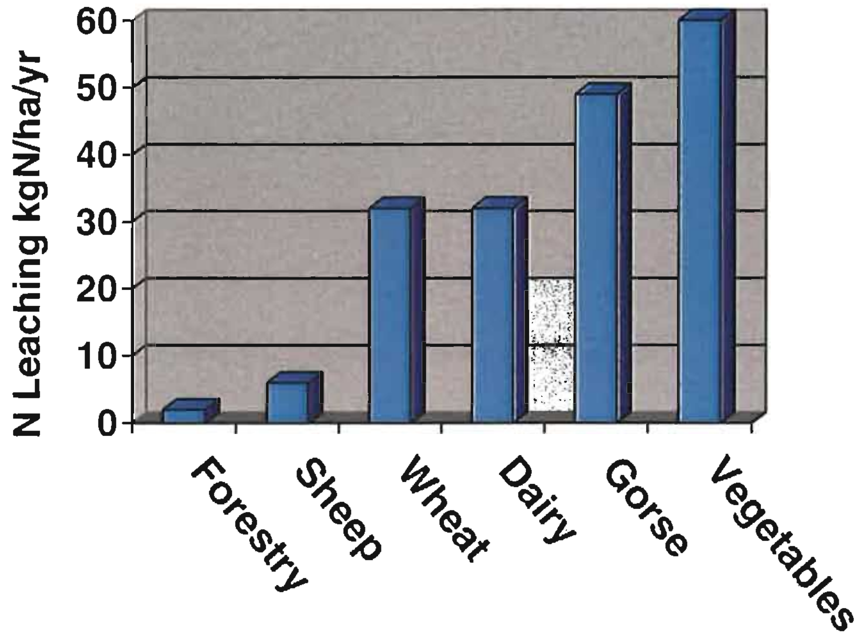
Up until the 1980's there were grants available from the then North Canterbury catchment board to plant shelter belts in order to provide shelter from the prevailing north west wind. Soil losses of 2mm per year have been measured.

Irrigation would reduce the erosion risk that is constantly present on the drought prone light soils on the Canterbury Plains.

3.4.2 Nitrogen & Leaching – putting things into perspective

Nitrate leaching from intensive irrigated agriculture is seen by some as being a potential health hazard as leached nitrogen enters under ground water aquifers. "Dirty Dairying" cops a lot of the blame for increases in nitrate levels in ground water. As can be seen in Figure 2 dairy farming is not always the major nitrate leaching culprit.

Figure 2: Nitrate Leaching from a range of farming situations. Francis 2009, Magesan et al 2008.



Irrigated based pasture production can also reduce N leaching losses. Work carried out by Cameron & Di (2005) and ongoing found the following after extensive field work on nitrogen useage on fully irrigated pasture.

- Irrigation applied at optimum rates and times for plant growth can enhance N uptake and reduce nitrate leaching losses.
- Under spray irrigation the majority of nitrate leaching still occurs during the late autumn/winter/early spring period.
- Spray irrigation systems have lower nitrate leaching losses cf. older flood irrigation systems.

3.4.2.1 N Leaching & the CPW Scheme

As part of the resource consent application for the CPW scheme, a mass balance calculation was conducted that looked at Nitrogen inputs and outputs from all sources. With the change in farming practices that would arise as a result of the introduction of the scheme there is a minimal change in nitrate leaching (Figure 2 & Table 11). Also what must be taken into account is that there will be more water through drainage and clean water sources entering the area, which dilutes the leached nitrate. Looking at the total increase in N leaching (table 11) shows that across the scheme area 762,000kg of additional nitrate will be leached per annum. However there is 900,000ha of gorse in New Zealand that leaches around 22,500,000kgN per year (Table 12), thus this is a much greater pool of Nitrogen that needs some attention.

Table 11: CPW Scheme – N Leaching & water inflow change (Tipler 2008)

	Change	Scheme Area
Water inflow	**+ 1500CM/ha/yr**	**90 MCM/yr**
N Leaching	**+ 12.7 kgN/yr**	**762,000kgN/yr**

Table 12: Nitrate leaching from Gorse per ha and nationally.

	Nitrate Leaching	Nationally
Gorse	**25 kgN/ha/yr ***	**22,500,000 kgN/yr ***

* There is 900,000+ ha of gorse covered land in New Zealand. The measured amount of nitrogen leached from gorse is 49kg/ha/yr (Magesan et al 2008). In this scenario a figure half of this has been used.

Thus as can be seen from this extrapolation, even if it is incorrect by a large factor gorse on its own plays a huge part in nitrate leaching in New Zealand.

3.5 Biodiversity

While the ecological character of the Canterbury Plains has been well documented no specific studies have been reported on the impacts of intensification on biodiversity values. Many areas within Canterbury are already protected via voluntary covenants. Irrigation is likely to provide the opportunity to enhance further areas.

3.5.1 Aquifer recharge and Lowland Streams

Using alpine water will increase the lowland stream flows. For example in regards to the CPW scheme the Irwell and Selwyn Rivers and the Doyleston Drain flows increases are predicted to be > 100% (Burrell 2009). Therefore this will have beneficial effects on the habitat. This comes about due to the reduced requirement for water from bores (wells) the amount of water abstracted from the ground will be significantly reduced. This reduces the local competition for groundwater resources and will increase flow in lowland streams, creating a healthier environment and more recreational opportunity downstream.

The implications of the increased flows as found by Brooker & Graynoth (2008) on the Selwyn river are:

- Predicted CPW flow increases will at least double habitat available for adult trout and their food.
- This will result in a significant increase in the abundance and size of adult trout present, compared with the status quo.

3.5.2 Opuha Environmental Impacts

The installation of a dam on the Opihi River for irrigation purposes has altered the river flow during the year, a set month by month flow is adhered to, to keep the river mouth open and enhance the fishery.

The net results are:

- Flows are more reliable.
- Although there was some initial problems with the lake becoming anaerobic due to flooding fertile farmland, this problem has reduced and has been managed by aeration.
- Initially flushing flows were not possible due to not being able to use the spillway. This meant sediment was not being added to the river and likely had effects on water quality.
- The salmon fishery has improved markedly with the greater number of days when the mouth is open and better flows in the river for salmon migration.

The Opihi is very significant salmon and trout fishery. In 2004/05 more salmon were reported caught on the Opihi than all the other major salmon fisheries. Fish and Game reported that the mouth has been kept open for many more days per year than previously (4-5 days per year closure per year compared with 100+ prior to the dam).

3.6 Social / Community Effects

There has been many research papers and work done to show that dryland farms with a variable climate and light soils are very prone to low and declining rural populations. This is due to the limited opportunities for employment and hence there is a net out migration of young people. Also the uncertainty of receiving and adequate rainfall each year and the need to increase the farm size to cope with drought leads to farm families leaving the district. Hence an irrigation scheme is the same with the need for reliability to ensure farm viability year on year and try to stop the boom bust cycle. A net migration of young people has dire consequences for a rural community as this leads to; a reducing population size and an ageing population. Less young people in a rural community also changes the services required. Less children means a lower requirement for schools. A study by Gillies (1977) compared 2 neighbouring districts (1 irrigated and 1 dryland) and found the dryland district to be more likely to involved in passive sports, have a lower community "spirit", less interest in progress of the district. Also in the dryland district local stores and trade services were closing and some families were about to or had left.

3.6.1 Well water effects

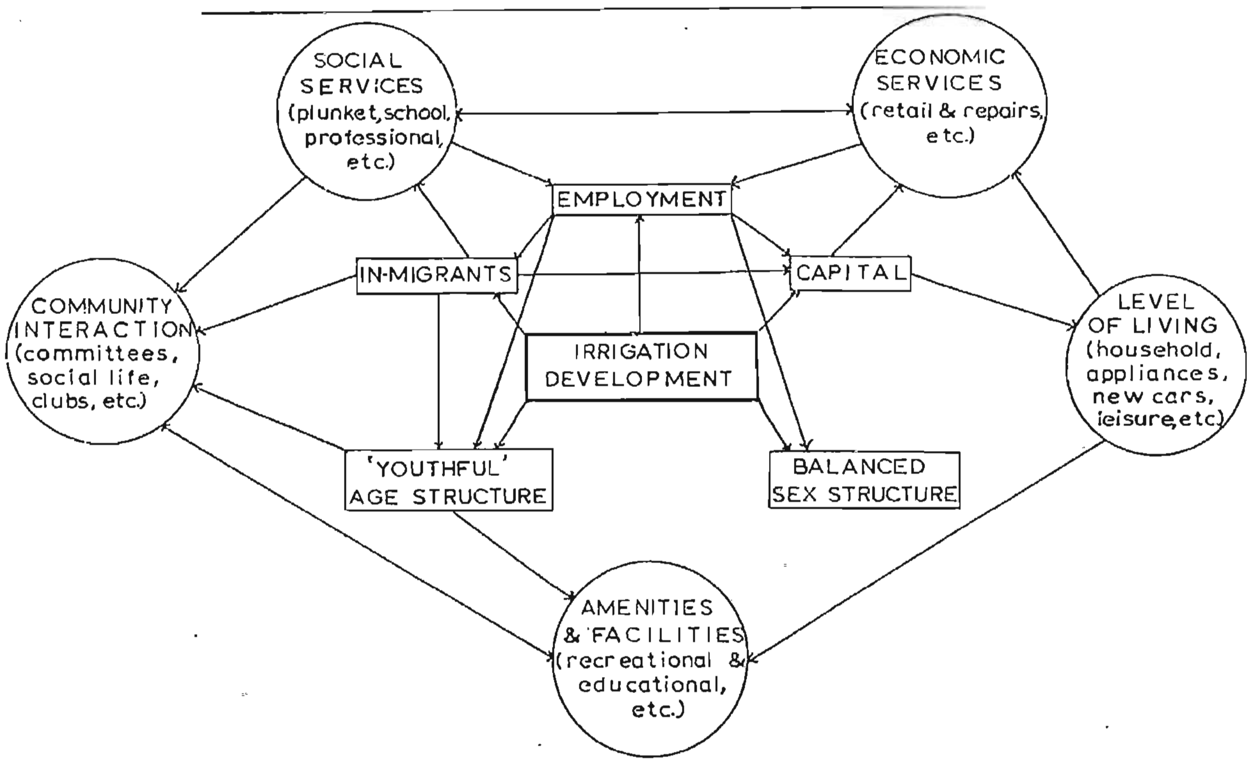
The small township of Hororata had a population decline of 23% between 1986 and 1996 as it suffered the fate of a dryland farming district and an ageing population. When reliable aquifer water and relatively cheap land was discovered in this area in the mid 1990's things changed quite rapidly. From 1996-2006 the township population has increased 48% and the local primary school roll has risen from 45-94 pupils over the same period, an increase directly attributed to the growth in dairying in the area.

3.6.2 Consequences of irrigation development

In the above mentioned study there was a measurable increase in the rural population in the irrigated district, due to the availability of an assured water supply with more family and non family labour employed.

Another consequence of irrigation development is a change in land ownership as many older farmers retire and move away due to the prospect of irrigation. The older families are subsequently replaced by younger farming families and their children. The effects of this are far reaching and there are many interactions as per Figure 3.

Figure 3: Demographic and Social Impacts of Irrigation. (Gillies 1977)



3.6.3 Level of living

Gilles (1977) surveyed farmers in both districts to determine their level of living. A selection of socio-economic indicators including vacations taken over 1 weeks duration, car purchased within last 4 years, tractor purchased within 5 years etc. The irrigated district had more than the dryland district in all indicators. The irrigated farm population had an improvement in their social well-being in terms of "their children's education, professional services and community interaction, as a result of irrigation development".

3.6.4 Age Structure of Farm Workers

The age structures of farmers and farmer workers of Lower Waitaki (irrigated), Rangitata (dryland) and New Zealand populations were collected from 1981 to 2001 censuses.

Table 13: Percentage of Farmers and Farm Workers Occupation Group under 30 years of age 1981-2001.

	1981	1986	1991	1996	2001
Lower Waitaki	24.5	27.5	30.1	35.9	36.5
Rangitata	29.6	29.6	19.1	22.4	21.0
New Zealand	34.1	31.0	24.4	24.7	22.2

The proportion of farmers and farm workers under 30 years of age in Lower Waitaki gradually increased from about 25 percent in 1981 to 37% in 2001. By contrast the proportion of farmers and farm workers in this age category in Rangitata steadily declined after 1986, and by 1991 was significantly lower than the national pattern.

A study by McCrostie Little et al (1998) of the Waitaki Plains notes that irrigation farming in the area is the domain of younger people. During the early years of the irrigation scheme these younger were from the North Otago down lands who intensified the cropping and grazing practices in the area, and later they were dairy families from the North Island.

Table 14: The Percentage change in resident population aged 15 years & over with no educational qualifications 1981-2001.

	1981-91	**1991-2001**
Lower Waitaki	**-21.6%**	**-6.3%**
Rangitata	**-16.2%**	**-6.8%**
New Zealand	**-13.3%**	**-7.4%**

There was a steady decline in the proportions of residents in all areas who reported they held no educational qualifications (Table 14). The declines followed the national trend although the greatest decrease over the full 20 year period occurred in the Lower Waitaki area. The difference between the Lower Waitaki and Rangitata is likely to be explained by the rapid shift to dairying in the 1980's which required a large input of skilled operators and managers.

3.6.5 Employment Status of Residents

Table 15: Wage & Salary Earners/Paid Employees as Percentage of Residents

	1981	1986	1991	1996	2001
Lower Waitaki	50.5	55.0	54.5	57.0	55.3
Rangitata	47.8	43.2	48.3	42.5	44.8
New Zealand	81.7	75.7	70.1	68.6	69.7

Table 16: Employers as Percentage of Residents

	1981	1986	1991	1996	2001
Lower Waitaki	19.7	17.1	15.9	21.2	24.0
Rangitata	21.7	18.9	11.7	17.2	21.8
New Zealand	5.9	6.8	6.9	6.9	6.9

Table 17: Self Employed as Percentage of Residents

	1981	1986	1991	1996	2001
Lower Waitaki	23.1	19.8	17.4	11.3	12.0
Rangitata	27.5	29.7	26.7	21.8	20.6
New Zealand	7.0	8.2	10.2	10.5	11.5

Looking at Tables 15 to 17 shows that the Lower Waitaki has increasing proportions of wage and salary earners and employers over the period, whereas the proportion of self employed residents nearly halved with the introduction of irrigation. This shows that the scale of the farming businesses has increased in the Lower Waitaki, there are more employers, wage and salary earners among the population, and that additional jobs have been created in the area.

3.6.6 Median of Household Incomes

Table 18: Median Household Income ($NZ) 1981-2001

	1981	1986	1991	1996	2001
Lower Waitaki	14,222	18,688	31,059	34,744	43,864
Rangitata	13,599	20,327	26,471	34,501	38,421
New Zealand	14,957	23,234	30,910	34,707	39,588

Table 18 reveals that the median household income for Lower Waitaki was higher than that for Rangitata at all censuses except for 1986. From 1991 onwards it was also higher than the median household income for New Zealand. Rangitata by comparison consistently had a lower median household income than New Zealand for the whole period. From 1981-2001 Lower Waitaki's households have improved their incomes relative to Rangitata and New Zealand.

3.6.7 Geographic Location of Impacts

A significant part of the first round farm multiplier effects and farm household spending effects will take place in the rural towns and the proportion of the expenditure taking place in these small towns has been estimated on the basis of survey work carried out by MAF in 1999. This survey showed that the approximate proportion of first round and household spending effects taking place locally are as shown in (Figure 4).

Figure 4. Location of spending by different farm types.

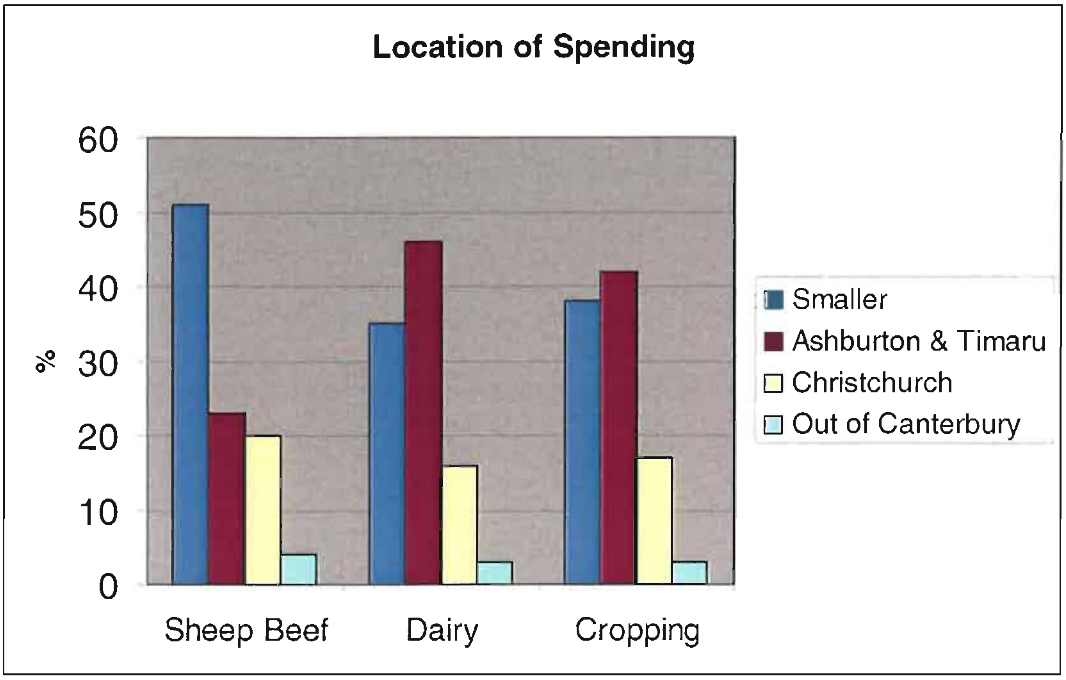


Figure 4 shows us that the different farm types have significantly different patterns of expenditure. Egg sheep and beef farmers spend more than 50% of their farm expenditure in smaller centres whereas dairy and cropping farmers spend between 30 and 40 percent. Significant differences in the total amounts spent could mean that, in dollar terms, impacts from dairying are higher than those for sheep and beef.

3.6.8 Spending Location ex Opuha report

Farmers were asked what proportion of their spending they did in rural areas small centres. The results indicate that expenditure patterns are similar for dryland and irrigated farms. The data shows from Table 19 that direct spending in rural areas and small towns by dryland farms was $383,000 per 000ha whereas irrigated farms it averages $927,000 per 000ha. Irrigation results in a 2.5 times as greater expenditure per hectare.

Table 19: Location of spending for farmers on the Opuha scheme.

	Rural & Small Towns	Timaru	Out of Area
Dryland	**54%**	**34%**	**12%**
Irrigated	**55%**	**39%**	**6%**

3.7 Flow On Effects

Survey data from the Opuha Dam Irrigation scheme looked at the multiplier and flow on effects of the increases in farm production. This study made the assumption that all milksoilds will be processed in the district at the Clandeboye plant, that all vegetables would be processed locally and ¼ of all cattle and ½ of all sheep meat production would be processed in the study area.

Table 20: Flow On Economic Impact per 000 ha.

	Dryland	Irrigated
Output ($m / yr)		
Direct on Farm	$0.86m	$2.07m
Direct in Processing	$0.67m	$2.04m
Indirect & Induced	$0.76m	$1.94m
Total	$2.29m	$6.05m
Employment (FTE's)		
Direct on Farm	5.1	9.6
Direct in Processing	1.8	4.8
Indirect & Induced	5.4	12.6
Total	12.3	26.9
Value Added ($m / yr)		
Direct on Farm	$0.25m	$0.75m
Direct in Processing	$0.14m	$0.38m
Indirect & Induced	$0.32m	$0.83m
Total	$0.71m	$1.96m
Household Income ($m / yr)		
Direct on Farm	$0.10m	$0.30m
Direct in Processing	$0.08m	$0.20m
Indirect & Induced	$0.20m	$0.49m
Total	$0.38m	$1.0m

3.7.1 Impacts on Businesses within Irrigation Districts

a) Confidence

Businesses report a significant increase in confidence in their business and in other businesses with which they deal. This is largely seen as being due to reliable irrigation development has proven a huge boost for the confidence to invest. There is certainty for investors in processing and transport operations in relation to future volumes, it is also giving the ability to plan ahead for growth due to the reliability in production that a reliable water supply gives.

b) Processors

In the irrigation area of the Opuha Dam there is a direct relationship with development and growth of dairy processing and vegetable processing. These particular processors are not specifically dependant on the Opuha Scheme itself but they are dependent on reliable irrigation in the wider area.

c) Flow on Infrastructure

This relates to infrastructure such as ports and electricity generation/useage. Greater productivity lead to more produce to be exported hence the greater need for ports. In some irrigation scheme cases a flow on effect can be the generation of electricity, via water leaving the storage area and if there is sufficient head.

d) Better Utilisation of Capacity

Dryland farming is often very unreliable and can sometimes be described as boom and bust. A good example of this is in sheep farming when climate conditions result in very low feed levels, all producers have to sell stock at once, this puts huge strain on transport and meat processing companies. Reliable irrigation however changes the peaks production through the season, so that more product is spread over a longer season and improves the processors to plan for product arrival. This results in better utilization of capacity and existing infrastructure.

e) Benefits to Dryland Farmers

Dryland farmers in the same area as irrigated properties receive benefits associated with greater competition for stock, even in bad (dry years) and opportunities for grazing and sale of feed. As described in (d) above when dryland farmers all have to sell stock, typically under this scenario everyone is affected by the dry conditions and there is no surplus feed available. With extra stock coming available and a lower than normal demand for stock, the two effects combine to have a major downwards effect on price. However having irrigated farmers in the immediate area provides a potential demand avenue for when these climate conditions occur.

3.7.2 Social Impacts of Farmers from the Opuha Dam

- Irrigated properties have significantly more employees (almost 4 times as many FTE's)
- Irrigated farmers are on average younger than their dryland counterparts
- Irrigated farmers tend to be better educated (egg University degree) than dryland farmers.
- Irrigated farmers have a much broader range of information sources regarding their farm businesses. In particular irrigation farmers use more specialist (and expert) sources.
- Most irrigated farmers have made major changes within the last 5 years (90%) compared to 70% for dryland farmers.

The information shows that most farming people live in rural areas or small centres which supports the data from expenditure patterns in drawing the conclusion that reliable irrigation development has a significant impact on the rural parts of the community.

These demographic characteristics are fundamental to maintaining a healthy, sustainable rural community. They provide the basis to maintain the necessary enrolments for schools, sports clubs etc that bind a community together. They also provide the basis to support older people in the community such as voluntary services egg Meals on Wheels. Its is the absence of schools, sports clubs and voluntary community services that have been identified as community decline and as a threat to the long term viability of rural communities (Rhodes et al 2002). Such demographic characteristics also greatly increase the spending power and the capacity to maintain commercial services.

3.8 Recreational

Irrigation development has potential to combine recreational facilities with irrigation structures. Planning for all aspects should be in a way that will give opportunity and encourage:

a) Utilise the water resource to enable maximum useage across a range of scenarios including;
    - Safe swimming areas
    - Amenity areas suitable for water edge picnics
    - Whitewater for canoeists
    - Additional mid river launching ramps and all weather access
    - Public access to areas of races and water storage area
    - Boat launching ramps on storage reservoirs
    - Water ski lanes in reservoirs
    - Introduction of suitable fish to storage reservoir.

b) Recreation activities must be compatible with each other and with other uses. Ie maintain adequate levels in storage dam over key holidaying periods (xmas holidays).

3.8.1 What do Christchurch people want to do?

A study of "Outdoor Recreation in Christchurch" by A M Neighbour (1973) showed that rural passive recreation was considerably more popular than active type recreation. Passive recreational activities relates to when the full enjoyment of the activity depends on the environmental quality of the site or locality. This includes picnicing, camping, tourism and driving for pleasure. Active recreational activities on the other hand were less popular and relate to when the activity depends on a physical attribute of the resource such as availability of Salmon for fishing. Quite often passive and active based activities are combined in the use of one site. Egg a family picnic outing that also involves swimming and boating. The most important factor in the use of areas is that they are pleasant areas of high environmental quality.

3.8.2 The main water related recreation activities

The main active water based activities in Canterbury are:

a) Fishing
b) Boating (includes water skiing etc)
c) Canoeing

Some passive activities are also associated such as swimming, picnics, camping.

Direct Possible Recreational Benefits of Water Storage.

a) Fishing

Thus this highlights the need to maintain the fishery should a storage based irrigation scheme be built. As described above in section 3.5.2 Harris (2006) found that with the Opuha Dam the salmon fishery has improved markedly with the greater number of days when the mouth is open and better flows in the river for salmon migration.

b) Boating

In the Central Canterbury area there is a current shortage of large freshwater areas suitable for recreational boating. Most of the lakes are over 1hrs drive from the main populated area Christchurch. Freshwater bodies that are currently used include lakes: Coleridge & Camp Recently Lake Hood was formed (East of Ashburton) it has proved a great success but probably may be too popular with very large numbers of users on it at any one time. (J Palmer, pers comm.) A water storage lake within the greater central Canterbury area would undoubtedly be very popular during the summer months with boaties.
Jet Boaters would benefit from the use of the lake are always looking for additional public access to rivers in the form of all weather launching ramps.

c) Canoeing

There is a lack of suitable white water near Christchurch, the major river on the plains such as the Rakaia and Waimakariri are not generally suitable for canoeing. Canoeists have to travel to Rangitata Gorge or Hurunui Gorge to get suitable water. Artificial rapids of a white water course have been identified by canoe clubs as a facility which would fill a major need.

d) Walkways

A water storage dam in the foothills would create an ideal environment in which to create a walkway system. It would be important that the walkway would be linked to areas of high scenic quality.

e) Wildfowl habitat

A water storage dam particularly one sited in the foothills would create a good environment for trout and water fowl. Similarly associated main canals and to a much lesser extent feeder races would be of benefit to. General requirements for wildfowl are a continuous flow of water and adequate shelter nearby for nesting.

f) Shooting

The presence of a storage facility and additional waterways would allow for in increased provision of habitat thus increasing the number of waterfowl in the area. The other requirement for shooting waterfowl is access to the water bodies.

g) Other Uses

The irrigation system (storage dams and races) has a considerable potential for casual use particularly when the waterway and surrounding environment create a high quality setting that encourages passersby to stop. The inclusion of well presented engineering works within the scheme create a high tourist value particularly when placed close to main roads. If there are several recreational opportunities occurring near to each other, there will almost certainly be associated demands for retail services and accommodation.

3.9 Rural Landscape

Irrigation will bring more variation to the rural landscape. It will reduce the summer burnt off appearance, giving greenness; patterns of races will bring a formality to paddocks (Douglas et al 1979).

The Canterbury Plains is a very modified environment with a very diverse use of land including arable, vegetable, horticulture, pastoral. Within and between farms the mix and balance as to what the land is used has changed a lot in the past as a reaction to changing markets, this change will continue.

4. Conclusions

To allow further reliable irrigation development in New Zealand water storage is a necessity, due to large areas of over allocated aquifers and many rivers that are reaching upper allocation limits as well.

Water storage has the ability to create large amounts of additional export earnings and jobs particularly at a time when our National economy has a unsustainable balance of payments. The Opuha irrigation scheme alone creates $124m in on farm output per annum and has created 480 new jobs. The addition of storage to the proposed CPW scheme adds $700 in export earnings per annum and creates an additional 1600 jobs on top of that created by a run of the river scheme.

A reliable water supply is essential in modern irrigated agriculture with high entry cost it is essential that farming businesses are able to perform close to their potential. It is also important to allow on farm production to meet the needs of our range of customers (many of whom are in the Northern Hemisphere) and are not interested in the fact that the irrigation stopped for a month in January because the river was too low. The reduction in farm productivity between years give farmers and businesses aligned with farming certainty to invest as opposed to unreliable schemes / dryland farming.

Water storage also has been shown to have large benefits in terms of enhancing river flows in some situations by adding water directly to waterways when river-flows are typically low or by taking the pressure off aquifers and therefore allowing lowland stream flows to improve. This in turn has benefits to river ecology and recreation (egg fishing).

Reliable water for irrigation purposes has boosted many rural communities by bringing more young people and their families into districts. This fills the school rolls and generally aids to the "community health".

There are many far reaching flow on effects from a reliable water supply in the form of additional jobs in processing and greater confidence to invest in the agriculture service industry. Storage can also allow for uses such as hydro-electric development if design allows.

Appendix:

Definitions

Employment: Employment is work done by employees and self employed persons and is measured in Full Time Equivalent jobs (FTE's). A FTE is based on someone working full time for 40 hours per week.

Output: Output is the value of sales by a business. In the case of wholesale and retail trade, it is the total value of turnover.

Value Added: Value added includes household income (wages and salaries and self employed income), and returns to capital (including interest, depreciation and profits). It also includes all direct and indirect taxes.

Household Income: Is the gross income of households, it includes the income of self employed persons. With farms there is often considerable uncertainty as to the proportion of business income which goes to households. This is due to tax accounts are likely to show various forms of income and drawings which are tax effective as opposed to flows of funds during the year.

Direct Economic Impacts: The direct impact arises from the production by farmers of goods and services.

- The direct employment is of people who work on the farms.
- The direct output is the value of sales made by farmers at their point of sale.
- The direct value-added is the value added in those farming businesses.
- EBIT = Returns to land labour and capital.

Indirect Economic Impacts: The indirect impact arises from increased spending by businesses as they buy additional inputs so they can increase production. This indirect effect can be envisaged as an expanding ripple effect. Ie a farmer sells milk but has to buy fertilizer and hire a contractor to spread it. The contractor has to buy fuel and get his truck serviced. The mechanic has to buy electricity and waste disposal services to operate his businesses. All these businesses have to employ more staff to cope with the increase in workload. All the increased employment, output and value added (apart from that on the farm) is the indirect effect. Note that the indirect effects only include upstream effects (buying more inputs)

Induced Economic Impact: The induced impact is the result of increased household income being earned and spent, and leading to a further ripple effect of increased employment, output and income.

Downstream Impacts: Impacts which are not driven by an activity's demand for extra inputs, but which might arise as a result of a particular activity, are sometimes called the downstream impacts. Egg meat processing because the increase in farm output leads to increased activity in the processing works. The processing industries do not provide an input into farming, and hence are not an indirect or induced effect of the farming. They are a downstream effect and have been estimated separately in this study.

Total Economic Impacts: The total impact is the sum of direct, indirect and induced impacts.

References:

Brooker DJ, Graynoth E (2008): Instream habitat and flow regime requirements in the Lower Selwyn River. Environment Canterbury Report U08/8, Prepared by NIWA, February 2008.

Brown I, (2005): Environmental, Economic and Social Impacts of Irrigation in the Mackenzie Basin. Report for the Ministry For The Environment.

Burrell GP, (2009): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Cameron K, Di HJ (2005): Nitrate leaching under irrigated farming. Lincoln University.

Donkers J W, (2009): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Douglas M, Robson S, Wilson A & Worth MJ (1979): Rakaia Water Use and Irrigation Development. Recreation, Landscape, Planning.

Ford S, (2002): Economic and Social Assessment of Community Irrigation Projects. MAF Technical Paper 2002/13

Francis G, (2009): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Gillies A, (1977): Social and demographic consequences of irrigation development in the Kakanui-Waireka catchments, and lower Waitaki Plains, North Otago, New Zealand: A Comparative Study.

Harris S, (2006): The Opuha Dam: An ex post study of its impacts on the provincial economy and community.

Heiler T D, (2008): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Lewthwaite W (2008): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Magesan G N, Wang H, (2008): Nitrogen Leaching from gorse – Final Report. SCION.

Neighbour AM (1973): Outdoor Recreation in Christchurch: A survey of activity patterns. Department of Geography, University of Canterbury.

Rhodes T, Willis BH, Smith W & McCann J (2002): Farm adjustments and restructuring in the North Island hill country. MAF Technical Paper 2003/2.

Taylor CN, (2009): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.

Tipler CJM, (2009): Applications by Central Plains Water Trust to: Environment Canterbury for Resource consents to take and use water from Waimakariri & Rakaia Rivers.