(irrig_09)

RESOURCE CONSENT APPLICATIONS
UPPER WAITAKI CATCHMENT

Submitter

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Resume

I submitted in support of all consent applications in the Upper Waitaki.

I am advocating for the granting of all consent applications as a means of increasing the agricultural production of the area.

Background

I come from the position of being brought up on a sheep-station in the Lake Tekapo area and for most of my professional life being an agricultural research scientist investigating the various options for increasing the agricultural output of the New Zealand high country in general, with most of that research being based in the Mackenzie Country.

Interest in the potential for irrigation in the Mackenzie Basin arose from three sources in the 1950's. One was the start of the hydro-electric system with its proposed canals carrying large volumes of water past land with potential for irrigation. The second was the move to retire the higher altitude land from the conception (but subsequently shown to be a misconception) that they were the sources of down-stream flooding. This led to the need to develop alternative feed supplies within runs to adjust for those land retirements. The third was that within that there was a particular need to increase winter conserved feed supply, because with the introduction of fertiliser and over-sowing, while there was an increase in general annual pasture production, the dominance of the introduced summer growing legumes in that increase was tending to increase the disparity between summer and winter feed supplies.

Much of the discussion of the potential of irrigation from the canals took place during my father's period on the Waitaki Catchment Commission and Regional Water Board, and for a time chairman. My recollections of the discussion at the time, was that all parties saw the potential for irrigation, even though it might be slow in uptake, but that it was sensible to make allowance for it in the design of the canal systems. I believe that was the basis of the original Order-in Council to ear-mark the top portion of the canal water for potential irrigation use and that it was done in good faith by all parties. The original letter from the Minister of Works notifying this is lodged with the records of the Mackenzie Branch of the Federated Farmers of New Zealand in the Timaru office.

The slow uptake of using irrigation water from the canal, and its possible present loss of opportunity, has been a disappointment to me. The slow uptake is probably related to normal prolonged period fluctuations in wool prices, the uncertainty in tenure of land (leasehold versus freehold) to make the necessary capital investment, and difference of opinion on which party should be responsible for the initial outlet structures.

A good proportion of the present irrigation development that has been done is from water sources away from the canal system, but these are increasingly coming under objection from other parties. Most of the present consent applications are also from non-canal sources.

There is also some movement into different form of agricultural systems: – dairying depending on pasture growth throughout the growing season; farm-within-farm for properties that have larger areas of potentially irrigatable land; and specialized crops.

I believe the principal use of irrigation in the Mackenzie Basin is likely to be for ‘special purpose pastures’.

Many will still be within continued sheep/cattle pastoral systems to enhance the general production of the whole property. These critical feed periods, to be accommodated by ‘special purpose pastures’ are likely to be, in order of priority: firstly provide winter feed either as summer saved conserved feed like hay or silage, or perhaps winter feed crops, or standing winter feed; secondly spring or early summer feed for young stock; thirdly late summer/early autumn lamb finishing feed; and fourthly autumn ewe flushing feed.

While there is already some dairying using irrigation, the need to supply large quantities of conserved feed for the winter no-growth period is likely to be a severe restraint. It is not envisaged that cropping under irrigation is ever likely to be a widespread option until soil organic matter contents have been increased probably over decades.

Already, where there are large areas of potentially irrigatable land within one property, there is, or will tend to be, the development of a ‘farm within a farm’, almost treated as a separate enterprise in terms of type of stock, management and objectives.

In the past stock water has been of little concern because it could generally be taken ‘as of right’. That is changing, with the present trend in requiring fencing off of road-ways, lake edges, wetlands, stock-crossings, etc. Access to water for stock must be formally recognised and allowed for in any water allocation.

Overview of Mackenzie Basin environment, agricultural potential and irrigation

The Mackenzie is of one rock type, namely sedimentary greywacke, and only merging into the early forms of schist in the south-west corner. From continental drift these rocks are going up fast to form the Southern Alps, and coming down fast through erosion. New Zealand is an island with an island type climate with no large pattern in seasonal rainfall or temperatures. The Mackenzie is near the 45^o latitude of the 'roaring forties' with a very large rainfall gradient. Its topography has been determined by the last glaciation:- the steep ice-shorn mountains of gorge runs, the ill-sorted irregular rolling topography of the lateral moraines between the lake and extending slightly out into the basins as terminal moraines. The present lakes were the centre of those glaciers with their southern tip being the point at which they just melted. A line through the southern point of the lakes is a good approximation of the 500mm rainfall isohyet, that through the northern edge a 1000mm, the first sky- line c2000mm, the back range c5000mm, and low in the south-east of the basin. Beyond that is the gentler topography of the extensive areas of the shallow rocky soils from the last ice-advance of the central basin, surrounded by the higher terrace remaining from earlier ice advances and were accumulating wind-blown material during later advances. There was also the extensive accumulation of un-weathered loess material on the foothills that were outside glaciation influence as along the foot of the Grampians range. At the south-east extreme of the Mackenzie is the slightly increasing rainfall from southerly fronts moving up the coast.

By world standards all the soils are young, from a single parent rock material and variable in depth. They differ in subsequent weathering as related to the strong rainfall gradient.

Potential irrigation areas

Several earlier assessments had been made of the potential for irrigation development within the Upper Waitaki Basin (Kerr & Ives 1973; Kerr 1979; Waitaki Catchment Commission and Regional Water Board 1982). The most complete assessment is that of Webb (1981, 1992) following a detailed remapping of all the soils of the area and much of what follows in this section is paraphrased from that report. Within that report the suitability of all the land and soil types was assessed by a system designed for New Zealand wide conditions by Griffiths (1975) with a five class subdivision. The basic factors affecting the suitability of land for irrigation are topography, drainage and soils.

Table 1: Areas suitable for irrigation in the Upper Waitaki Basin (from Webb 1992).

	Area (ha)	
'Suitable' for irrigation (Class 2)		
- with slight drainage limitations	520	
- with slight slow permeability limitations	590	
- with slight soil limitations	6 660	
- with slight topographic limitations	100	/ 7 950

‘Moderately suitable’ for irrigation (Class 3)		
- with some drainage limitations	4 030	
- with some slow permeability limitations	4 080	
- with some soil limitations	19 950	
- with some topographic limitations	9 920	/ 37 980
‘Marginally suitable’ for irrigation (Class 4)		
- with some drainage limitations	4 960	
- with some slow permeability limitations	2 100	
- with some soil limitations	44 870	
- with some topographic limitations	3 130	/ 55 070
‘Unsuitable’ for irrigation (Class 5)		
- with some drainage limitations	3 080	
- with some soil limitations	31 260	
- with some topographic limitations	19 810	/ 54 150

About 30% of the Basin area has areas qualifying as soils ‘suitable’ to ‘moderately suitable’ for irrigation development, with that area in excess of 45 000ha.

It is notable that 70% of the Basin area soils are within the Classes 4 and 5. Those units are mainly composed of shallow and stony soils with low or very low soil profile water holding capacity.

However, it is to be noted those assessments were made in the early 1990’s when the anticipated form of irrigation was border-dyke irrigation. With the current trend toward central-pivot irrigation, with its potentiality of low application rates but fast return period for shallow soils, it is probable that many of the ‘marginally suitable’ sites could be upgraded to ‘moderately suitable’ sites.

Similarly, some of the ‘moderately suitable and ‘suitable’ soils with ‘some topographic limitations’, particularly those of the undulating topography of the south-east Mackenzie which had accumulated deep un-weathered soils, have greater potential when viewed from the technology of central pivot or K-line irrigation than from border-dyke technology.

The reports tabled to the hearings indicate that currently 7,600ha are irrigated, that slightly more is being proposed in the current consent hearings, and that the modelling of the effects was for a total irrigated area of 25,000 ha.

Environmental gradients and potential pasture production with irrigation

There is a moderately large body of scientific investigation of the agricultural development options for the Mackenzie Basin, including irrigation, from the past location of the government research agencies of Grasslands Division, DSIR at Tekapo, and MAF from Tara Hills at Omarama (both now within AgResearch), as well as specialized surveys by other research groups such as Soil Bureau, DSIR (now Landcare) as in the previous section.

In a synthesis of existing information of trials on native tussock grassland and developed pastures, and on the relationship of high country agriculture to that in other areas of New Zealand and the world we developed the concept of seeing the landscape in terms of four environmental factors or gradients which influence pasture growth (Scott et al. 1995). Theses are:

1) Soil moisture as related rainfall, evaporation, drainage (and particularly in the present context - irrigation).
2) Temperature as is indirectly represented in most presentations as latitude, altitude, aspect and slope.
3) Soil fertility either natural or applied.
4) Grazing management in the sense of the interaction of animal treading and grazing with the location of plant growing points.

Collectively these are considered to determine the potential pasture productivity of a site, its seasonal pattern and for that potential to be unique for each combination of the four environmental factors (Fig 4 – for NZ as a whole with consent application areas indicated).

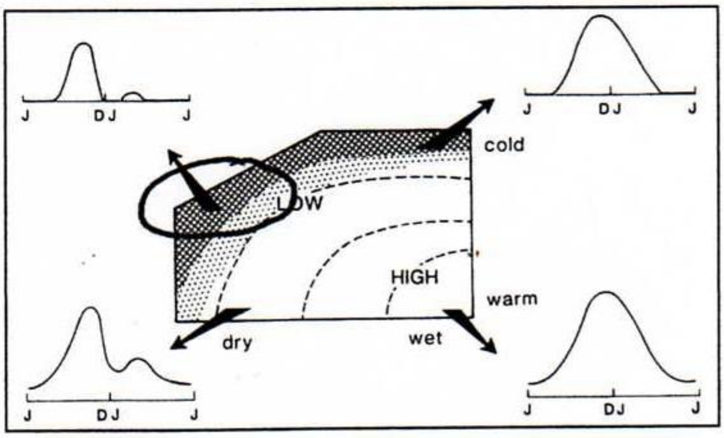


Figure 4: Variation in annual pasture yields and seasonal growth patterns with variation in annual temperature and moisture.

The temperature is a particular characteristics of each site, and generally and not amenable to management change or choice other than selection of the site. Moisture as rainfall is not manageable other than selection of site, but is amenable through management by irrigation or drainage. The feature of those two factors is the rapid decrease in potential pasture productivity as moisture levels (rainfall) decreases, and as temperature (altitude) decrease, with the decrease tending logarithmic rather than linear.

The lower temperatures of the Mackenzie Basin and a more semi-continental climate are alluded to in a number of reports. Aviemore at 300 m is the lowest altitude consent site and Lilybank at 800 m the highest altitude consent site. I am not sure that such decreases of temperature with altitude have been fully taken into account in the various modelling assessments. As suggested above the decrease in pasture productivity altitude/temperature is probably logarithmic rather than linear.

It is the second two factors of soil fertility and grazing which are most amenable to management, or in the present context irrigation on suitable soils.

From that over-view of existing information we derived the generalisation, or rule-of-thumb, of the effect of different forms of pasture development on any given site (Fig 5).

These were:

±*x*2-3 fold for pasture management
*x*4-5 fold for Sulphur and Phosphate fertiliser
*x*2-3 fold for the water component of irrigation
*x*10 fold for irrigation plus fertiliser
*x*2-3? fold for Nitrogen fertiliser (factor not well established yet)

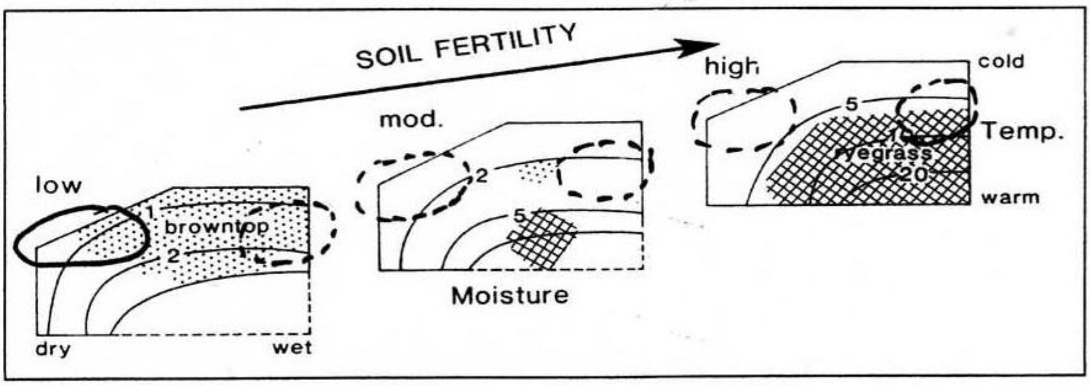


Figure 5: Estimated potential annual pasture yields (t DM/ha/year) in relation to temperature, moisture and three levels of soil fertility. Ranges of temperature and moisture are the same as earlier diagrams. The best zones for two grasses, browntop and perennial ryegrass, are indicated.

For New Zealand I consider that fertiliser, in the form of S and P fertilisation of legumes for nitrogen fixation can increases potential pasture production by *x*4-5 fold relative to the un-amended natural soils. This compares with the only *x*2-3 fold increase for the water component of irrigation where that is appropriate in the driest areas. However, S and P fertilisation will generally always accompany irrigation, to give the generally more realistic *x*10 fold increase with irrigation development. There may be a further *x*2-3 fold potential increase from the use of N fertilisers.

The past pasture development sequence in New Zealand, principally developed for the ex forest country of the North Island, has been the use of superphosphate to supply P to introduced legumes, to fix N, to grow grass, to feed sheep or cattle.

Research from the lower rainfall inland areas of Otago and the Mackenzie Basin has established that Sulphur is also deficient for pasture growth. In the gradient soil weathering gradient from low to high rainfall there is a slowly increasing more deficit S requirements and a rapidly increasing P requirement. Through much of the area covered by the consent application S is likely to be more required, or equal to that for P requirement. Super-phosphate supplies both. In the South Island there are different grades of elemental S augmented super-phosphate (8%, 20% and 50%) to accommodate the changing requirements along the rainfall gradient. One study concluded that after consideration of bulk depot costs, transport costs to the more remote areas, and spreading costs that elemental S may be the most cost efficient fertiliser for these areas (Scott 2000g, 2002). Liming, though desirable, is not a cheap on-the-ground fertiliser. The cost effectiveness of different fertiliser regimes have to be considered.

The role of sulphur and sulphur fertiliser has not been taken into consideration in pasture response, irrigation development and water quality issues in the present proceedings.

Also developed from research in these same areas is the need to introduce the appropriate rhizobia strain for N fixation along with the legume seed.

N fertiliser is the ‘new-kid-on-the-block’ and probably likely to be common in any dairy farming irrigation operation. It is possibly starting to infiltrate into use in some sheep farming special purpose pastures. Care will be needed in the use of N fertiliser in the lower temperatures of the high country as there are temperature thresholds for both plant uptake from the soil and its utilization for growth within the plant. Also that N fertiliser becomes a substitute rather than an addition to legume fixated N, with legume components of pastures reverting to feed quality considerations rather than combined feed quality and N fixing components.

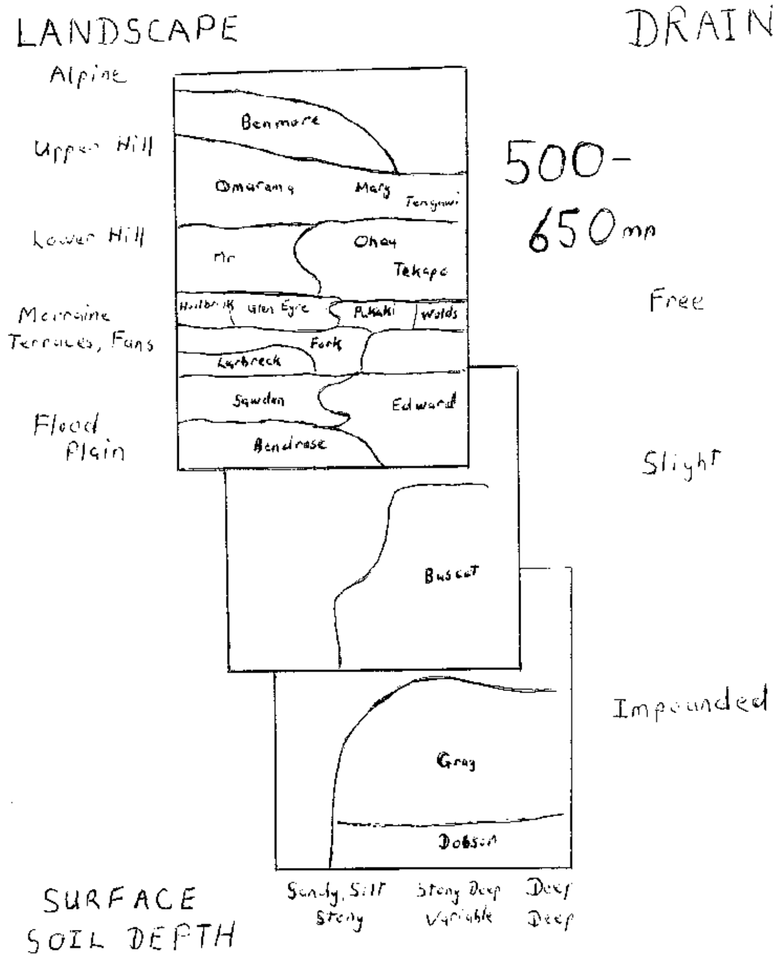
The changing face of type, use and response of different fertiliser options implies caution in understanding what is meant by ‘fertiliser’ in particular contexts.

The grazing management effect I estimate to be ±*x*2-3 fold, with the deliberate inclusion of the ± to emphasis that while the fertiliser and irrigation response will almost always be positive that the difference between good and bad pasture management can be large.

There is specific empirical irrigation pasture production data from a range of different fertilised soils in the Mackenzie Basin (Scott et al. 1975; Cossens, 1981; Greenwood, 1982; Scott et al. 1982; Scott & Maunsell, 1981, 1986a, 1986b; Pollock, et al. 1994; Scott, D. 2000). These range from as high as c 17 tonne DM/ha/yr on the deep slightly weathered irrigated Streamlands soils as at Haldon Stn. to low as only 4-5 t DM/ha/yr on shallow outwash soils.

Soil types integrate the effects temperature, natural rainfall and drainage moisture and natural fertility gradients together with soil depth. This has been done for the Mackenzie for the different landscape unit and rainfall zone (see following example).

Fig. Example of distribution of soil type by landform, drainage, soil depth and texture for the 500-650mm rainfall zone.



From these empirical measurements from trials on specific sites combined with the soil survey results, particularly as they related to soil depth and natural drainage, with both related to environmental gradients and concepts outlined above it was possible to make good first approximations of the pasture productions characteristics of all soil types (Webb 1992; Scott in Webb 1992, Fig. 27).

I believe that approach combined with empirical measurements would give more pasture production estimates for the soils of the different sites in the consent areas and consequent estimated top-soil leaching. The yield estimates would probably be more reliable than those used in the modelling, and show more differences between the sites, though the overall mean would be probably similar. The down-stream effects are probably more influence by the total irrigation area than any differences in the assumed unit area leaching parameters.

One of the major enabling effects of irrigation is to extend high pasture growth into the summer and autumn.

The potential total pasture production of a site is determined by its relative position within the gradients of temperature, soil moisture including irrigation, soil fertility- natural or applied, and form of grazing management. Within those environmental gradients is an allied concept that for each combination of factors there is a small group of pastures species which are best at releasing that potential production. Over recent decades research has established where each species fits within those gradients (Scott et al. 1995 – Fig 6).

The records from irrigation trials in the area suggest initial good production (possibly due to initial mobilisation of disturbed soil organic matter), a decline for a few year before a rise to sustainable levels.

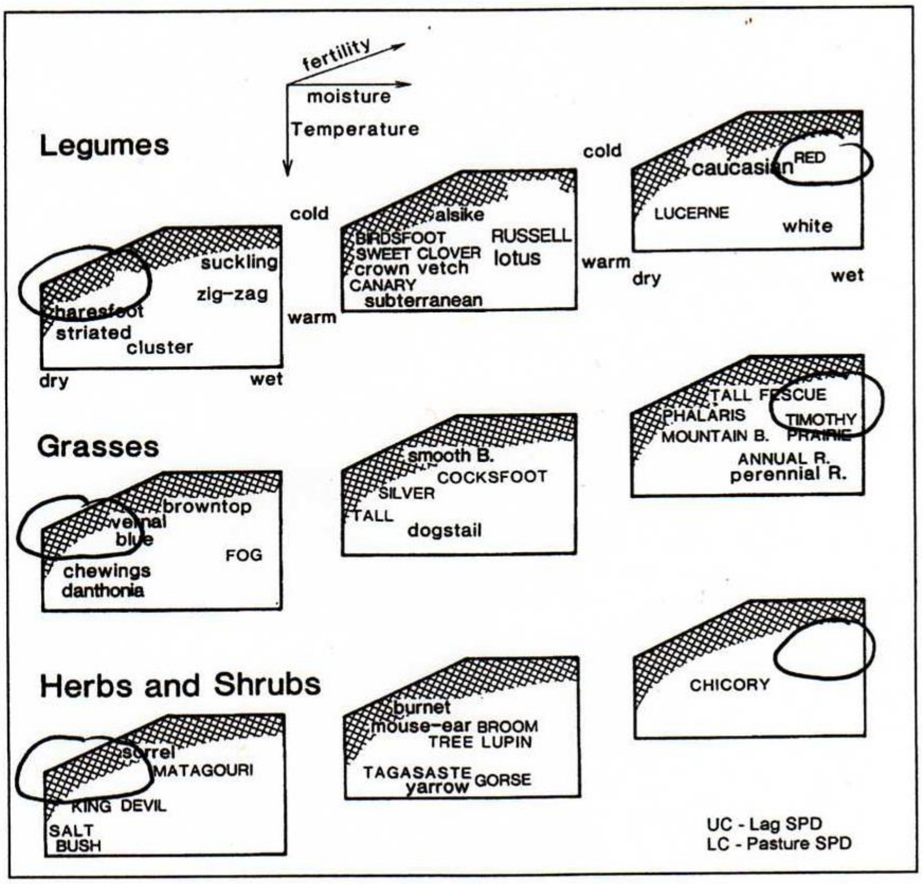


Figure 6: The most suitable role of some pasture species in relation to the environmental factors of temperature, soil moisture and three levels of soil fertility. The name is placed in the environment in which it has its optimum role, but like browntop and perennial ryegrass, there is a range of adjacent environments in which each is also suitable. Species more suited to lax grazing are given capital letters.

Another feature of these inland basins is the tendency towards semi-content ental climate with a greater contrast between summer and winter conditions than elsewhere in New Zealand, with a consequential greater need for winter feed supplies, but greater potential (with irrigation) for summer growth.

Thus for the Mackenzie Basin there is reasonable knowledge of where each particular type of soils exists and its potential pastures productions under different development scenarios, including irrigation, and the pasture species to accompany those developments.

Forms of irrigation

The possible irrigation method is partly determined by topography and soil type, and partly by the difference between allowable initial capital costs versus continuing labour and maintenance costs. In the medium term (decades) there is probably little difference in the total combined capital and labour cost of different systems.

I have not assed and enumerated the type of irrigation systems proposed in the different consent applications.

Features of the different options are:

Border-dyke: ‘traditional’ system with established technology; require and only applicable to gentle slope; high initial cost – especially if a lot of earth movement is required; can increase soil variability; need daily attention.

Central pivot: little soil disturbance; usable on a range of topographies; high initial cost but components re-saleable; variable rotation/return speed to accommodate difference in soil depth and consequent irrigation return intervals; flexible in needed time attendance; potential wind damage; currently all new equipment; getting vibes to not underestimate longer term maintenance costs..

K-line: little soil disturbance; usable on a range of topographies; initial cheap; labour intensive; need daily attention.

Big gun or travelling irrigator: Intermediate between K-line and central pivot.

Wild flooding: topography dependent; cheap; uneven; inefficient; very few Mackenzie soils suitable; would be unacceptable in present era.

Trickle irrigation: Appropriate and probably most efficient for shelter belts, any orcharding, and viticulture or like crops.

Water sources

Much of the water for present irrigation systems and for most of the proposed systems is not from the hydro-electric canal systems.

What the high country in general and the Mackenzie Basin in particular has is topography, with the potential of altitudinal differences to have sufficient water supply and hydraulic heads within a small distances, to give the required water pressure for spray irrigation without motors. Such zero-cost running systems already occur in Otago, and in the Mackenzie at Godley Peaks Stn. There are other potential sites for such systems.

Where there are lesser natural hydraulic heads, there is the potential for hybrid systems of combining water wheels with water pumps to use most of the water through a water wheel to pump a proportion of it up to the required pressure for spray irrigation. AgResearch has operated such a hybrid systems at its Lake Tekapo trial site for twenty-eight years. Another property has used a water supply with some natural head to reduce pumping costs. A paper exercise with random sampling of maps demonstrate that there are many instances where there are adequate water supplies, possible reasonable race lengths where such hybrid low-running-cost systems might be possible.

The benefits of gravity-fed systems for on-farm running costs (as well as regional and national energy costs) have not been referred to in the consent appraisals.

Similar considerations arise with the increase of electricity line charges and the reappraisal of the economics of small-scale hydro-electric systems for more remote farms. Both considerations lead to a need for more flexibility in simultaneous water-take and water-discharge rights i.e. the temporary use of water - as Meridian has.

Mitigation procedures

Mitigation procedures relate to the possible loss of water, soil and nutrients from a consent area.

Water takes will probably be set assuming particular efficiencies for the irrigation method proposed. Loss of efficiencies would be a loss to the water right holder. A loss through irrigating in inappropriate conditions e.g. windy conditions would be a general loss of water. Loss through excessive drainage would be a loss to the right holder, but by the closed catchment nature of the area would drain back into the area e.g. Lake Benmore, and not a net loss to the water resources of the area.

Soil loss from wind-blow during site preparation or during a subsequent rotation cultivation, is a major rare risk. Much of this development may occur during the equinox gales of October. The need is to consider non-tillage or coarse cultivation establishment methods, early establishment of shelter belts, and use a component of tall nurse-crops (e.g. ryecorn, oats)

A particular feature of the Mackenzie Basin (and Central Otago) is fine textured soils overlaying gravels, with the possibility under irrigation of downward movement of the fine materials with infiltration. Thus the need for adequate compaction of any constructed waterways before use, and possible initial compaction of developed areas until soil organic matter and root systems develop. The latter compaction may adversely affect initial pasture development. With the sediment load in some water sources the adverse effect tends to self-correct over time (as epitomised by the periodic need to clear water-races).

Nutrient loss would be undesirable to both the consent holder and other parties. It would be desirable to capture any surplus infiltration, run-off water, sediments and nutrients and recycle (i.e. move them back up hill!).

This could be done by a cut-and-remove hay paddock, shelter belts, production forestry blocks and grazing on the down stream side of any irrigation development.

Report 5.6.3 on mitigation options suggests creation of down-stream wetlands. But they point out and I agree they are only medium term options unless the accumulating material is periodically removed. They considered wet-land species. A better option would be agricultural species which are harvestable, perennial, moist terrain, low or non-fertiliser requiring or tolerant species e.g. timothy, cocksfoot, lotus, lupin, or harvestable plantation..

The same reports section on mitigation through limiting stock access to water courses (5.6.2) needs reappraisal. Stock at low density is very efficient movers of nutrients i.e. stock camps. . Sheep, particularly Merino, camp on the highest part of a site and move nutrients to there. This beneficial effect could be incorporated by a suitable design of associated run-off paddocks. Cattle are more suited to wet areas.

There is increasing requirement to fence off associated waterways to achieve this in irrigation and other contexts. Unless there is cut-and-remove this is only a short to medium term solution. In the longer term there will be a new equilibrium with similar inflows and outflows of nutrients as was used in nutrient modelling in other reports.

Mitigation measures refer to fertiligation i.e. fertiliser application through the spray irrigation system. Conceptually it is a very desirable approach. Practically, I am told, it has a down-side of greater internal corrosion and hence life-span of irrigation equipment.

There seems to be few mentions in mitigation procedures of water deficit monitoring to match irrigation timing and rate with plant requirements, either by direct on-site soil monitoring or on-site or community climate water-balance estimation.

Officer report 4B comments on the initial leaching of nutrient from topsoil, particularly nitrogen, as estimated from the models used. He believes they may to be low and that the Green’s estimates for double the rate are probably more realistic.

He also suggests, from more detailed analysis of the Tara Hills climate records, that there will be more occasions, particularly during the winter periods when there will be leaching loss. However, the same climate conditions that lead to greater on-site leaching will also give greater inflows into the receiving streams and lakes and there were tend to be a self-adjusting dilution effect.

Water quality

I am not qualified to comment on water quality aspects but would just make some comments.

The consent hearings should strictly be only about water take. The water quality issues mainly relate to the assumed form of agricultural development and associated fertiliser use that would accompany development from that water take.

What is the fertiliser response curve for trout and salmon? They would certainly not survive in distilled water. There is the speculation that the relatively low population of fish in the main waters of Lake Tekapo and Pukaki is due to its low nutrient status, and the relatively high population in Lake Benmore is related to nutrients from the drowned organic matter.

There is an adage that 'Pollution is a matter of dilution". Most of the consent applications are from the low rainfall sector of the Mackenzie, so natural leaching is probably low. Is the through-flow of the main water system not a sufficient dilution factor to maintain acceptable levels in the lower river systems? Yes there are likely to be issues relative to some of the smaller streams and sectors of the lower lakes. There are few consent applications for water take above the mouths of the main lakes and low potential future applications because of topographic and natural rainfall restraints limit possible irrigatable areas.

The consent applications of water take for irrigation are probably proceeding on the unstated assumption that there would be the associated use of fertilisers. An extreme form of mitigation would be to place restraints on the types and rates of fertiliser use. As indicated above the fertiliser component of the irrigation response is generally larger than the water per. se. response but with water increasing the growing season in summer and autumn. Without the fertiliser component many of the irrigation proposals would probably not be viable.

An aside is that nutrient disposal from current community sewage schemes is into the river systems. There should be similar consideration of land disposal with growth of a harvestable source for cut and removal.

In relation to water quality considerations it is appropriate to repeat two quotes from a recent review by Stout & Winterbourn (2008):

(large upper Waitaki lakes – p571)
" The Waitaki lakes are monomictic, with one mixing and one stratified period each year, and their annual temperature pattern s are strongly influenced by strong winds, especially summer nor'easter's. ----The lakes are well oxygenated at all depths, and have low concentration of ions, including plant nutrients. Specific conductivity is about 25-70 S/cm. The concentration of silica is high (4.2-4.9 g/m3) reflecting the abundance of silica in the greywacke rocks of the lake catchments."

(hydro-electric impoundments – p574)
"Like many lakes formed for the production of hydro-electricity, those in the Waitaki system differ from most natural lakes in a number of ways. In addition to the rapid flow-through of water and the associated occurrence of distinct water currents, is the fact the deepest part of each lake is close to the dam, rather than near the centre. Furthermore, water flow out of the lakes from the depths rather than near the surface, and because creation of the impoundments involves the flooding of fertile land, nutrients enter the water rapidly."

General discussion

There are some curious aspects of the consent hearing process. The hearings are nominally about water **quantity** take, but the main issues in contention seem to relate to the down-stream effects on water **quality** of such takes**.** Also the issues, though nominally about water quantity take, are more related to the assumed form of subsequent agricultural development (dairying, conserved feed, sheep or cattle, rose-hips, golf courses, etc.) and consequent assumed rates, types and modes of fertiliser inputs, particularly nitrogen.

Also there are many sections relating to assessment of **adverse** effects of such takes e.g. landscape, recreation fishing, cultural features, etc. But there are no equivalent sections assessing the **beneficial** effects of the water take e.g. increased livelihoods, population, agricultural production, infrastructure, etc. It is curious that the well-being of exotic harvestable fish (trout and salmon) have to be taken into consideration, but not those of domestic stock. There will always be trade-offs – one of the fundamental concepts of ecology is that you can never change just one thing. There is no general assessment of what those trade-offs are.

In my professional capacity there are many technical aspects in the submitters' applications and the officers' replies which I would have liked to have had further details on, or differed with, or have done a different way – as indicated in some of the material above. However, overall I believe them to be a sufficient fair assessment giving values the right ball-parks for granting water rights. The most difficult ones will be for the large area consents which drain into the Ahuriri and Northern Arm's of Lake Benmore

I would advocate for the granting of all consent applications as a means of increasing the agricultural production of the Mackenzie Basin

Annotated reference list

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(Tara Hills results referred to in Scott 1992 summary)

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(Wolds Stn. Upper Waitaki, border-dyke irrigation. 6 year trial on use of superphosphate and nitrogen fertiliser for summer hay crop and standing winter feed)

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(Full description of all NZ sites in the MAF 'rate of growth" pasture series and regression model analyses of climate/growth relationships. Includes irrigated sites – particularly Winchmore. Main data base for several subsequent pasture growth/environment studies. Different groups of sites published were published as separate papers)

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Scott, D. 1992: Agricultural production. Pp. 65-74 *in*: Soils of the Upper Waitaki Basin, South Island, New Zealand. *DSIR Land Resources Scientific ReportNo 3.*

(Summary and generalization of pasture production trials at that time – including irrigation – accompanying the detailed soil survey)

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(AgResearch Mt John trial site - description, background topography, soils and climate perspectives, contrasting fertiliser levels, irrigation stocking rates and grazing methods. 28 years to date. Series of papers)

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(Macro and micro nutrients after 10-15yrs measured to 40 cm – relevant to issues of nutrient leaching as to how far down soil profile nutrient level change)

Scott, D. 2000: Sustainability of New Zealand high-country pastures under contrasting development inputs. 3. Sheep carrying capacity. *New Zealand Journal of Agricultural Research 43*: 175-185.
(AgResearch Mt John trial site, Lake Tekapo – pasture production under contrasting sulphur and phosphate fertiliser rates including irrigation at the highest rate. Sheep production data at the 14 year stage of a now 28 year trial. Estimated stock unit/ha – 0.8 non-fertilised, 2.7 high fertiliser, dryland, and 8.0 high fertiliser irrigated. Animal response with sulphur fertiliser).

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