

**Before the Commissioners appointed by Canterbury  
Regional Council**

**IN THE MATTER OF** The Resource Management Act  
1991

**AND**

**IN THE MATTER OF** Applications by the Central Plains  
Water Trust and Central Plains  
Water Ltd. to Take and Use Water  
for Irrigation in the Central Plains  
area.

**Section 42A Officer's Report**

**Date of Hearing:** 25 February 2008

**Report of ADRIAN SELWYN MEREDITH**

## INTRODUCTION

1. My full name is **Adrian Selwyn Meredith** and I hold the degrees of Bachelor of Science (First Class Honours) in animal physiology (1981) and Doctor of Philosophy in Zoology from the University of Canterbury (1985). I have been employed by the Canterbury Regional Council for eleven years, firstly as the southern area water quality scientist in Timaru for two years, and then as a Christchurch based water quality scientist. My areas of responsibility include monitoring, investigations, and technical advice on water quality and ecology of rivers, streams and lakes.
2. Prior to this I was employed for ten years as an environmental scientist in the areas of ecology, fisheries, coastal ecology and water quality by the Waikato Regional Council and its preceding authorities, and for two years as a freshwater fisheries scientist with the Fisheries Research Division of the Ministry of Agriculture and Fisheries. I am a member of the New Zealand Freshwater Sciences Society (formerly the NZ Limnological Society), and the American Fisheries Society
3. I acknowledge that I have read the code of conduct for expert witnesses contained in the Environment Court's Practice Note dated 31 March 2005. I have complied with it when preparing my written statement of evidence and I agree to comply with it when I give this oral evidence.
4. This report is prepared under the provisions of Section 42A of the Resource Management Act 1991 (RMA). This section allows a Council officer to provide a report to the decision-maker on a resource consent application made to the Council, and allows the decision-maker to consider the report at the hearing. Section 41(4) of the RMA allows the decision-maker to request and receive from any person who makes a report under Section 42A "*any information or advice that is relevant and reasonably necessary to determine the application*".
5. This report will provide information and advice related to three areas of the applications, notably effects on water quality and ecology of:
  - The diversion, abstraction, screening, and discharge of water to and from the Waimakariri River;
  - The diversion, abstraction, screening, and discharge of water to and from the Rakaia River;
  - The formation, filling, management, and discharge of water from a proposed reservoir in the Waianiwaniva valley.Such evidence is within my area of expertise. In forming the opinions I have expressed in this evidence, I have relied in part upon the evidence of other witnesses who are giving evidence for the Canterbury Regional Council, namely: Shirley Hayward, and Philip Grove of CRC, and Al McKerchar and Maurice Duncan of NIWA.
6. I also provide a brief 'executive summary' of the key conclusions I have reached, and how they differ from those reached by evidence for the Central Plains Water Scheme (CPW).

## SUMMARY

### Waimakariri River consents

7. The river type and characteristics of the Waimakariri River has been correctly described by the applicant. However assessments of consequential changes to flow regimes and effects are variable and inconsistent between different information provided. They are largely confused by poor treatment of cumulative effects with other abstractions.
8. The biggest potential effect arises from large increases in frequency and duration of low flows (both summer and overall). The resulting assessments of effect on habitats, water quality and ecology tend to over-simplify and under-rate effects of river ecological communities.

9. Habitat assessments indicate that almost all aquatic species and communities will show significant decreases in provision of habitat over the flow range most affected by the proposed abstractions (40-80 m<sup>3</sup>/s).
10. Effects of temperature increases and changes in water clarity at low flows have been incorrectly assessed and are likely to have significant effects on biota and the salmonid fisheries in particular if duration of low flow conditions are greatly increased as predicted.
11. Generation of fine sediment siltation and sediment associated algal growths as a result of sustained low flows have not been considered. Large increases in frequency and duration of low flows may significantly increase the incidence of silt and algae generated nuisance conditions. This will affect river ecology and recreational values.
12. The acceptability of the effects of the Waimakariri River 'in-river' gravel abstractions may be affected by the sustained reduction in summer flows.
13. The assessment of the additional effects on those of the PPCS (Belfast meatworks) discharges were simplistic and fail to acknowledge the scope of current complaints of adverse effects, and potential exacerbation of effects resulting from reduced flows and extended low flow durations.
14. The current Waimakariri River Plan flow controls are insufficient to address the suite of additional effects identified above. Additional controls on major abstractions to avoid or mitigate these risks and adverse effects include:
  - controls to delay increases in abstraction until 12 or 24 hours after the onset of a fresh or river stage level increases
  - 1:1 flow sharing for a period after the onset of a fresh
  - someretention of flow between the 'A' and 'B' allocations
15. Water intake designs and proposals have too little detail to be able to assess screening effectiveness or acceptability. Failure to specify objectives make assessment of appropriateness of screening strategies impossible.
16. Proposals to sluice fine settled sediment back to the river as *de minimis* activities are not supported, or considered to be without adverse effect. Summer flow conditions conducive of sediment sluicing are not routinely present in the Waimakariri River. Settled sediment should be mechanically removed and used or disposed of to land.
17. Fish screen bypass flow proposals have not been adequately developed or presented, by the applicant, and so cannot be assessed. Any such flows should be designed and constructed to be consistent with the NIWA/ECan "Fish Screening Good practice guidelines".
18. Issues associated with bywash discharges are poorly developed and do not identify or address a range of potential issues including mixing of waters, spread of undesirable organisms, attraction and/or repulsion effects, fish stranding.

### **Rakaia River consents**

19. The assessment of effects on flows on the Rakaia River was appropriate and did consider cumulative abstractions. The Rakaia River Water Conservation Order controls were identified and modelled, and result in minimal effect on flow regimes over low to median flow ranges. Significant levels of abstraction, and effects on flow regimes, are largely limited to higher (median and above) flows. As such it is agreed that in-stream effects are limited.

20. Assessments that effects on water quality are limited, are supported except for possible effects on water quality of Rakaia Lagoon reaches adjacent to intensified farming around Rakaia Island.
21. Overall, the effects of proposed abstractions on the Rakaia River are likely to be low due to the effectiveness of the existing NWCO controls.
22. As with the Waimakariri River proposals, the water intake operations have too little detail to assess screening effectiveness or acceptability. Failure to specify objectives make assessment of appropriateness of screening strategies impossible.
23. Proposals to sluice fine settled sediment back to the river as *de minimis* activities are not supported or considered to be without effect. Flow conditions to support sediment sluicing are not routinely present in the Rakaia River in summer, and should not be supported.
24. Similarly, fish intake screen flow bypass proposals have not been adequately developed or presented, and so cannot be considered. Any such flows should be consistent with the NIWA/ECan "Fish Screening Good practice guidelines".
25. As with the Waimakariri River proposals, issues associated with bywash discharges are poorly developed and do not identify or address a range of potential issues including mixing of waters, spread of undesirable organisms, attraction and/or repulsion effects, fish stranding.

#### **Damming and water storage consents**

26. There is a lack of any public benefit values (public access, fishing, boating etc.) or beneficial management objectives (level control etc.) explicitly offered for the reservoir waters. Therefore, none can be considered as mitigatory benefits of the scheme.
27. Water quality deterioration of reservoir waters has been acknowledged, but incompletely considered. Likelihood of water quality problems occurring and requiring action have largely been under-estimated and under-managed in proposals.
28. The likelihood and consequences of reservoir water stratification and deoxygenation have been under-estimated and inadequately planned for. Monitoring and treatment systems need to be more explicit, to prevent sustained adverse effects occurring.
29. Proposed monitoring of lake water quality is insufficient to identify and respond appropriately to high risks of dynamic water quality deterioration. Telemetered monitoring, trigger response conditions, and explicit response actions would be required to prevent regular adverse effects arising.
30. Steps to avoid or prevent eutrophication of reservoir waters are too simplistic and uncertain to adequately ensure water quality deterioration will not occur.
31. Management of reservoir water turbidity through lake bed sediment controls need more explicit consideration. Erosion of lake bed and shore sediments by wind and water should be managed by targeted management plan approaches.
32. Management on nuisance and exotic plant and animal species are inadequately considered. More explicit requirements for monitoring and responses are required.
33. Potential effects of coal mine inundation are poorly considered and are not adequately addressed by monitoring.

34. The implications of dam formation on the ecology of the Waianiwaniwa valley are inadequately addressed. The importance of the extensive natural mudfish population is understated and under considered. Mitigations for the substantive loss of the extensive endangered mudfish population are uncertain and largely inadequate.

## **MAIN BODY OF EVIDENCE**

### **Waimakariri River consents**

35. The effects of the proposed CPW activities on the Waimakariri River can be separated into four areas:
- Effects of construction activities
  - Effects of water abstraction including screening
  - Effects of the reduced flow regime in the Waimakariri River
  - Effects of discharges back to the Waimakariri River
36. My evidence on the Waimakariri River relates to consideration of the assessments provided on the latter three of these issues, and effects on the water quality and aquatic ecology (including fisheries). My assessment is based primarily on information provided in the original AEEs', a URS report dated June 2005, five KMA reports from September 2006, a KMA report dated December 2006, and subsequently a S92a response (Golder December 2007). Supplementary information was provided from a number of URS memo's provided as responses to S92a information requests.

### **River flow effects**

37. The KMA (December) 2006 report correctly described the characteristics and values of the Waimakariri River, and identified the natural flow regime of the river. However, it largely ignored the other authorised or proposed abstractions from the Waimakariri River and viewed the proposed CPW abstractions in isolation. In this, the assessments differed from those carried out for the Rakaia River (GKMA 2007) which assessed effects of five scenarios including those including all other takes. This omission made assessment of effects invalid, as the effects on river ecology and water quality are the result of all river takes are cumulatively, not in isolation from each other.
38. The recent Golder 2007 report addressed this deficiency by assessing three flow scenarios, including no abstractions, those with all existing abstractions, and those with both existing abstractions plus proposed CPW applications. This amended assessment more clearly identified more far ranging effects on the flow regime, especially ant low and minimum flows (durations). This report also stated that the maximum *likely* rate of take was now 25 m<sup>3</sup>/sec and not 40 m<sup>3</sup>/sec. This change in maximum rate has not been rationalised or substantiated elsewhere, or to my knowledge proposed as a change in application.
39. The KMA (and Golder) reports correctly identified that abstractions from the Waimakariri River are restricted by provisions of the Waimakariri River Regional Plan (WRRP) 2004. The WRRP sets out the regional council's policies objectives and rules for taking water from, and discharging contaminants into, the Waimakariri River and its tributaries. The WRRP became operative in October 2004. The key points relating to the taking of water are:
- (a) A minimum flow of 41 m<sup>3</sup>/s; and
  - (b) An "A" water allocation block of up to 22 m<sup>3</sup>/s for abstraction when the "unmodified flow" is between 41 m<sup>3</sup>/s and 63 m<sup>3</sup>/s; and
  - (c) All water in excess of the "unmodified flow" of 63 m<sup>3</sup>/s is available for abstraction as a "B" block allocation.

40. The WRRP made no provision for abstraction caps, flow sharing, or gaps between the “A” and “B” allocation blocks. As such, the only flow regime protection is based around the unmodified minimum flow control of 41 m<sup>3</sup>/s (which does not restrict stockwater takes, and so functionally may be 37 m<sup>3</sup>/sec).
41. The WRRP, developed during the 1990’s, may not have envisaged the level of abstraction pressure on the river proposed by the CPW and other recent proposals. Without any additional flow regime controls (such as those present in the Rakaia River’s NWCO), the potential effects of the additional proposed abstractions from the Waimakariri River are much more marked than those on the Rakaia River.
42. KMA (December 2006) analysed flow statistics and regimes for the Waimakariri river, but largely only considered the effect of the CPW abstractions in isolation from other takes, and did not consider the cumulative effects of all current and proposed abstractions. As such it concluded a limited range of changes in flow conditions and effects, and all effects being on flows above 63 m<sup>3</sup>/s.
43. I largely disagree with this assessment, as the resulting water quality and ecology of the Waimakariri River will be a product of all (abstractive) influences on the river, not just those selected in isolation. The hydrological statistics selected by the applicant include:
- median flow reduction
  - flow band most affected
  - change to MALF (Mean Annual Low Flow)
  - flood frequency
  - duration of smaller freshes
- These give an incomplete view of the hydrological changes that would occur in the Waimakariri River, and on which to conclude degree of effects.
44. Subsequent conclusions on effects on habitat availability are similarly related to “reductions in median flow”, or “flows >63 m<sup>3</sup>/s” and do not consider cumulative effects with ‘A band’ abstractions. Therefore many of the conclusions traversed by the applicant, of minor or negligible effects (on habitat availability for macroinvertebrates, fish and fish passage), are largely invalid.
45. A subsequent and more recent memo (URS December 2007) provided some further assessment on the proposed CPW effects on river flows, including combining existing and the proposed CPW abstractions. This largely illustrated that conditions such as periods at minimum flow and average periods of (inter-flood) accrual periods largely doubled between scenarios of “before” and “after” CPW – see also the evidence of Maurice Duncan for assessment of this evidence and independent evaluation.
46. It is notable that in these further scenarios, an “after CPW” summer median flow scenario of close to the river minimum flow (41 m<sup>3</sup>/sec (actual median 44 m<sup>3</sup>/s)) is adopted. Such a scenario largely indicates a river at or close to the minimum flow for at least 50% of the summer. This is a condition that would be unusual for an alpine braided river, and not beneficial to the normal functioning of such a river type. Such increased sustained minimum flow periods are more characteristic features of smaller foot-hill rivers, and potentially generate a suite of other management issues including siltation, periphyton (algal) proliferation, temperature increases, growth of woody vegetation, and other features of excessive riverbed stability.
47. The subsequent in-stream habitat modelling presented by KMA 2006a, Golders KMA2007a, and summarised in the Golders (December 2007) described decreases in mean river depth, and larger decreases in total wetted channel width at decreasing flows. These were then related to habitat suitability for a range of fish species, macroinvertebrate species (as fish and wildlife food), algae types, and activities such as angling. They subsequently argued that the effects on habitat suitability and area for many species were minor because of such small depth changes.

48. Very recently (25 January 2008), we were provided with an updated instream habitat analysis based on more detailed 2D surveys. This analysis was stated as differing from and superseding all previous analysis and surveys.
49. Modelled habitat area and suitability are commonly employed models that are largely used to assess effects upon areas of suitable water depth, velocity and substrate. In this case the models are based upon an analysis of water depth (>2 cm) and water velocity only. Such assessments are effective in determining degrees of gross change in habitat availability. However, as with any model, such 'habitat assessments' generally make a number of assumptions. Generally, they assume that all habitat of equivalent depth and velocity are of equal value, and that "*all other habitat attributes remain equal*" and so do not change or have any bearing on overall habitat quality or suitability over the range of modelled flows. Also implicit in the analysis is that quantity of habitat is the attribute that is most limiting populations and activities. In reality, these assumptions are often not totally valid, and careful and objective interpretation of modelled results are required.
50. The most recent 2-D habitat modelling results provided (25 January 2008) clearly illustrate that habitat area (weighted useable area – m<sup>2</sup>/m) changes over the resulting flow ranges that are most at issue in this application (40-80 m<sup>3</sup>/sec). In general all species modelled showed significant increases in provision of habitat over increasing flows in this flow range:
- Most common macroinvertebrate food organisms showed a close to linear increase in habitat area throughout the flow range
  - Common native freshwater fish species (common and upland bullies, Canterbury Galaxias) showed their greatest rate of increase in habitat between 40 and 80 m<sup>3</sup>/sec
  - Other native fish (Torrentfish, bluegilled bullies, both eel species) showed linear increases in habitat throughout the modelled flow range
51. Sports fish (salmon and trout) also illustrated similar patterns, again changing most steeply in the 40 -80 m<sup>3</sup>/sec range, and changes most marked for habitat for salmon fry (a limiting life stage for the salmon fishery).
52. The Waimakariri River is the most highly fished river in Canterbury, due to both its productive salmonid fish populations, and accessibility (close proximity to Christchurch). The flows suitable for optimal angling experiences or effectiveness are also of significance to the fishery. These were also modelled and showed at least a doubling of fishable area with each doubling of flow through the flow range.
53. Therefore, all modelled species and activities show that changes in flow (especially between 40 and 80 m<sup>3</sup>/sec) affect provision of habitat for almost all components of the river biological communities.
54. Golders (December 2007) generally downplayed these effects of flow reductions on provision of habitat for species and communities, mostly arguing on the basis of them being based upon very small reductions in water depth. However the inherent character of braided rivers is such that wetted area will be expected to change very rapidly with small depth changes (as compared to single thread rivers).
55. The consequent increased duration of these reduced flows is the most important point. The consequential flow scenarios (Golders December 2007) generally show a average (median) doubling of the duration of flows sustained at or close to the minimum flow (41 m<sup>3</sup>/sec). Thus, the habitat reductions modelled will be sustained for on average twice as long each summer (and considerably longer in dry summers). Therefore, over these periods production of macroinvertebrate food sources, production of native fish (both as intrinsic value and as sports fish food sources), and production and growth of sports fish will be significantly reduced by the extent of flow reduction and in particular by the duration of low flows.

56. As stated earlier these habitat methods rely on an assumption that “*all other habitat attributes remain equal*”. As such, in recent years, full IFIM (Incremental Flow In-stream Methods) have more comprehensively assessed other attributes such as water quality and habitat quality rather than just provision of gross habitat suitability. Several such features are relevant in the Waimakariri River. They have largely been dismissed or omitted during consideration by the applicants assessments. However, as discussed below, many are of particular significance.
57. KMA (2006f) discussed effects of water temperature as a result of the abstractions, and considered temperature increases to be minor and unlikely to affect the biota. They note that water temperature “*can get quite high in the middle of summer*”, but that relationships between flow and temperature are weak. They also dwelt on lethal temperatures, and thresholds of adverse effects (22-23 °C) in reaching these conclusions. However, I consider that when significant increases in durations of low flows (and therefore high temperatures) are involved, the most significant issues are the periods of time when temperatures are outside the environmental preferences of species and communities.
58. When fish, in particular, are outside their preference temperatures they exhibit a range of responses including repulsion, cessation of migration, cessation of feeding and/or breeding. These all result in significant reduction in production but not necessarily death. The clearest examples are for salmonid fish (salmon and trout). Above approximately 18°C they generally become increasingly stressed and cease feeding, cease migrating, and generally increasingly exhibit dormant or depressed states. In this state they lose condition, and are generally “unfishable”. It is well known amongst anglers that rivers ‘fish’ best on rising flows when temperatures have dropped, as it is under these conditions that fish recommence migration and/or feeding activities.
59. Therefore, decreases in flow, and/or increases in the duration of (low flow) periods, with temperatures greater than 18 °C or decreases in the number of “windows” of time with temperatures at or less than 18 °C will generally be very detrimental to salmonid fish stocks and angling. Recent research has also increasingly shown that the ‘energetics’ of salmonid fish populations are such that at higher temperatures (or outside the optimal temperatures) fish will lose condition irrespective of the availability of suitable food, suitable habitat, or other habitat attributes.
60. Therefore, as the temperature *regime* of the Waimakariri River is likely to be significantly changed as a result of the proposed abstraction regime, then the temperature regime should be further considered and significant elements of it protected. In particular, the periods of cooler water during small freshes are particularly important for allowing migration and/or redistribution of salmonids. The truncation or elimination of some of these events can potentially occur as a result of the proposed abstractions. Therefore controls are needed to limit the extent of this effect. Such controls can include the abstraction caps, variable monthly minimum flows, and flow sharing as in the Rakaia River, but not present in controls in the Waimakariri River Plan.
61. Temperature alone, is therefore one factor that could justify further abstraction controls beyond those stated in the Waimakariri River Plan. Controls on delaying increases in abstraction until 12 or 24 hours after the onset of a fresh or stages increases, and flow sharing are two mechanisms of achieving that, and providing maintenance of dynamic temperature regimes for fish and salmonids in particular.
62. Another water quality issue discussed by KMA (2006f) is water clarity. This is particularly important to angling suitability. KMA (2006f) argued that clarity reduction between the gorge and SH1 was independent of flow on the basis of analysis of existing water quality data. This analysis was conducted on the assumption that there were no other influences on clarity between the two points. However, extensive in-river gravel abstraction causes localised increases in turbidity (reduced clarity) for several km upstream of SH1. Therefore, it is not surprising that no relationship of clarity with flow was found. During low flows the effect of in-river gravel abstractions would be expected to increasingly (detrimentally) affect the clarity or the ‘clearing’ of the Waimakariri River. The KMA discussion is

therefore flawed and unlikely to be correct. In contrast, the Waimakariri River is likely to increasingly clear at lower flows, as sediments will increasingly settle out at lower flows down the length of the river. This will affect the duration of optimal 'fishability' of the river, and the fine sediment siltation, discussed later.

63. One further area where there is some potential for low flow or flow regime habitat effects (and not assessed by CPW) is in the risk of degradation in habitat quality, particularly in relation to habitat sedimentation, or periphyton (slime growth) accumulations associated with sedimentation. Neither are frequently observed issues in Canterbury's large gravel braided rivers, due to naturally high flood frequency and bed instability. However, over sustained periods without floods, fine sediment transported by braided rivers can visibly build up as layers on gravel and cobble surfaces. Periphyton (algal) layers can subsequently develop and cause nuisance issues. In particular, nuisance blue-green algae (Cyanobacteria) can preferentially grow on these thin silt layers deposited onto gravels, due to the cyanobacteria alga's motile (movement) ability to move up through deposited silt rather than be smothered by it. Cyanobacteria are considered a nuisance when common species such as *Phormidium* and *Oscillatoria* proliferate and produce tainting substances, offensive odours, and occasionally toxic substances (that have been implicated in dog deaths).
64. Cyanobacteria algae have been sporadically recorded as issues in braided rivers at any time of year, but particularly during key recreational periods (spring whitebaiting) following dry stable spring periods, or during swimming and salmon fishing following dry summers without north west floods. Generally, any circumstance or activity that lowers minimum flows or reduces flow variability/ flood frequency has the potential to exacerbate such siltation and frequency of nuisance algae issues.
65. This effect has not been identified or discussed by CPW. Discussion of periphyton issues (KMA 2006a) was confined to a relatively simplistic discussion of filamentous algal growth or mat growth due to nutrient concentrations and accrual periods alone. Siltation-associated nuisance growths could therefore be expected to occur more often, and/or be exacerbated throughout most of the length of the Waimakariri River. The greatest risk of such effects occurring or being exacerbated is in the tidal reaches at and below SH1, where water velocities drop and effects may be synergistic with the current enrichment from PPCS and inputs from enriched lowland tributaries.
66. Another major discharge to the river (also not considered by CPW) results from the "in-river" abstraction of gravel from Waimakariri River reaches at and above SH1. The Waimakariri River is the only major river in Canterbury where extraction of gravel from within flowing channels is allowed. Again this has largely been allowed because of the high flood frequency of the river effectively dissipating the plumes of fine sediment generated from these abstractions. Recent investigations during processing of gravel abstraction consents has illustrated that extensive turbid plumes and bed siltation often result from these activities and are particularly obvious at sustained low flow conditions. Generally, "in-river" gravel abstraction has least effect on river values at median or higher flows, but is least desirable at periods of low river flows. If, as illustrated by KMA 2006 and Golders 2007, that minimum flow durations and accrual periods will increase appreciably as a result of CPW, then effects of these in-river gravel abstractions will be exacerbated and may become unacceptable. The CPW abstractions could therefore render the current and extensive activity of in-river gravel abstractions unacceptable for extensive periods of the summer gravel extraction and construction period.
67. Water quality effects in general were also discussed by KMA 2006f and analysed a range of water quality data. They inferred a linear decrease in water quality downstream "due to the influence of diffuse pollution". I largely concur with their assessment, although also note that this analysis is simplistic in that throughout much of the reach the Waimakariri River is a water "losing" rather than water "gaining" river. Change in water quality as a result of in-river processes such as algal growth, sedimentation, and other in-river processing were also not considered. In reality, water quality degradation down the Waimakariri

River is likely to be a stepped function (change in relatively abrupt steps) rather than linearly (regularly) down the length of the river.

- 68.** The assessment of the effects of point source discharges (particularly PPCS (Belfast meatworks)) was likewise relatively simplistic, and failed to acknowledge that the receiving environment is tidal and not of the habitat types normally characterised by ANZECC 2000 trigger values. CPW therefore concluded somewhat simplistically, that there would be no more than minor effects on water quality downstream of PPCS. I disagree with this analysis. The analysis was based upon consideration of individual chemical determinands against inappropriate guidelines, rather than consideration of their overall effects. It is notable that there have been localised and widespread visible evidence of enrichment effects along shallow river margins and on tidal islands downstream of SH1 at times of stable and low river flow. These growths and discolorations generate widespread complaints from various river users such as whitebaiters, fishermen and other recreational users. These 'effects' are inevitably driven by a combination of, concentrations of contaminants discharged, and river (low) flow stability.
- 69.** The PPCS discharge was authorised in 2000 on the basis of effects being unlikely due to high river flow variability preventing adverse effects of nutrient and contaminant additions. However, the significant increases in periods of summer minimum flows and increased accrual periods now predicted, will in particular, increase the potential for nuisance growths effects as a result of the considerable concentrations of contaminants (particularly nutrients) discharged by PPCS into the lower Waimakariri River.
- 70.** Overall, the assessments of flows, habitat and water quality by the applicant tend to understate or omit issues that are likely to have adverse effects on in-stream values. Most relate to the effects of greatly increased durations of low flow periods as a result of the proposed abstractions, and lack of controls on flow regimes (a minimum flow alone). This lack of controls can potentially allow a doubling or more of periods when flows will be held at or near to minimum flows (41 m<sup>3</sup>/sec). During these extended periods:
- habitat areas for most biotic communities will be greatly reduced in area
  - water temperatures will be well above optimal or preferential temperature ranges
  - water clarity regimes will be changed with increasing periods of 'unfishable' water
  - increased degrees of fine sediment siltation and reduced frequency of disturbance/erosion of these deposits
  - increased likelihood of occurrence of nuisance algal growths, particularly of silt tolerant, objectionable, and potentially toxic cyanobacterial mats.
  - Increased adverse effects of existing in-river gravel abstraction activities
  - Increased adverse effects of effluent discharge from PPCS (SH1 meat works).
  - Increased sedimentation of fine sediments and persistence of fine sediments in the tidal zone of the river
- 71.** All of these effects will impact on the extensive biological communities of the Waimakariri River, and recreational uses of the river that often centre around them.. In particular the trout and salmon fishery is likely to be most affected by this range of effects, as salmonid fish and the conditions under which they thrive are most sensitive to the range of factors influence by sustained low flow s.
- 72.** Possible additional abstraction/flow controls that would address these effects are largely similar to the existing controls embodied in the Rakaia Rivers National Water Conservation Order. That is,
- varying minimum monthly flows,
  - a maximum allocation limit,
  - a 1:1 flow sharing regime,.
- 73.** However, a more simple regime that directly addressed the effects directly could be:

- controls to delay increases in abstraction until 12 or 24 hours after the onset of a fresh or river stage level increases
- 1:1 flow sharing for a period after the onset of a fresh
- some retention of flow between the 'A' and 'B' allocations to

## **Intakes.**

- 74.** Screening of river fish from water intakes is a significant issue for major water supply intakes. The applicant has acknowledged fish intake screening issues with a conceptual description of the two Waimakariri River water intakes sites (URS 2006), a description of fish communities in the Waimakariri River (KMA December 2006, 2006d), a description of fish screening issues (GKMA 2007), and a further discussion of the appropriateness of not specifying specific objectives or screen designs (URS, 7 December 2007).
- 75.** Despite these several documents (many generated as a result of repeated requests for specific information to consider), there remains insufficient information to determine what the objectives or requirements of fish screening are proposed to be, what type of structure is intended, and therefore whether it may be appropriate or effective in screening Waimakariri River fish and achieving pre-determined objectives.
- 76.** The applicant identified (in URS December 2007) that the ECan convened Canterbury Fish Screen Working Party, produced [draft] guidelines for good practice for fish screens on intakes in Canterbury. They noted that the report recommended that "Fish protection objectives should be established through a process of reviewing the fish community, and the potential impact on the fishery during the diversion operation".
- 77.** The applicant has produced reports that "review the fish community", and discussed the "potential impact on the fishery", and suggested one possible screen type ((URS 2006), yet has still failed to suggest or set any over-riding objectives. It is stated that these cannot be done until further steps are taken including:
- establishing objectives and requirements
  - site specific survey of fish activities
  - evaluation of engineering options
  - costings.
- 78.** However, if neither objectives nor designs are presented to a hearing, then no rationale and outcomes are being proposed. They are therefore presumably to be assessed and determined by an alternative process outside of the resource consent process, and following granting of consents. Such a process is potentially without active involvement of the other parties to the hearing, and pre-supposes that acceptable objectives and designs can be found.
- 79.** It is also appropriate that the applicant proposes clear fish screening objectives and requirements at the hearing stage, because the subsequent objectives also impact on operation of further systems through the whole irrigation scheme. That is, the accepted objectives or effectiveness of fish screens are needed to determine whether any further screening or specific screen performance is needed at subsequent intakes throughout the canal system, or in discharges to the reservoir, canals, or to different water bodies (rivers or streams).
- 80.** Without proposed fish screen objectives or performance, the downstream effects throughout the irrigation scheme cannot be determined, addressed, or be considered. Such effects include whether the reservoir is to be managed for mudfish values (total exclusion of all fish species (including eels and salmonids) required), as a salmonid fishery (some level of salmonid escape possibly acceptable), as an

eel habitat (eel and elver passage necessary or acceptable) or managed for 'no fishery value'? These also impact on design criteria for the variable height off-take, and spillway and whether they should "pass fish" or be screened also to prevent "loss of fish".

81. In the absence of any explicitly stated fish screening objectives, I believe, as a default, it must be considered that the applicant is aiming for effectively total fish exclusion at intakes. This would mean that no further issues need to be considered 'down canal'. Such screening systems would need to perform to the equivalent of 2mm slot, yet application documents talk of such mesh sizes being not feasible, and consideration of mesh sizes closer to 5 mm being considered. Therefore, overall, the fish intake screening issues are inadequately dealt with and cannot be adequately assessed.

## Discharges

82. It is concluded in the AEE that any coarse sediments that enter the intakes will quickly settle in designed detention areas, and can be flushed out or removed mechanically. It is not specified which, or if both of these options of sediment removal will be used.
83. Suspended sediment load in abstracted water is proposed to be managed through sediment traps 1km downstream of the initial intake. The traps are proposed to settle coarse suspended sediment (sands and coarse silts). It is expected the traps will collect about 20,000 m<sup>3</sup> of sediment per year.
84. The applicant has stated that the initial flow of any desilting discharge will be at least as much as 80 m<sup>3</sup>/s, as the flushing basin empties, but this would decline to an average 40 m<sup>3</sup>/s over a half to one hour period, and this could occur once per week. The applicant concludes that the flushing flow discharge would amount to <0.6% of the total volume of water taken and would be less than 25% of the total water volume discharged through the fish bypasses. It is further concluded by the applicant that any desilting discharge will be the return of material that already was in transport in the river. The potential for turbidity issues is identified, but the applicant concludes that as the discharge will be brief and localised into a river already carrying significant suspended loads, there are unlikely to be adverse effects. They therefore, note that the water is natural river water, and thus the effect of discharge is considered to be *de minimis*.
85. I disagree with this assessment, as the problem with the desilting flows proposed is that they do not suggest any operational limitation, and so can occur at times when the river is at low flows. This can lead to localised deposition of sand and silt in and on the gravel bed, and turbid plumes downstream. Deposition of sand and silt in and on the gravel bed of plains braided rivers are probably the greatest detrimental effect on in-stream values. They generate areas of higher river bed level where islands, woody and shrubby vegetation, and bars develop. These in turn are detrimental to the riverbed ecology of wading bird populations, and other wildlife. This is commented on further by Philip Grove.
86. Deposition of sand and silt in and on the flowing channels of the gravel bed of plains braided rivers also reduce the permeability of gravels, and clog the interstitial spaces between cobbles and gravel that are used by invertebrates and larval fish as diurnal and flood refuges. They also coat the upper gravel surfaces reducing the growth of beneficial periphyton films. Sand and silt accumulation on gravel surfaces also promote the development of filamentous blue-green algae that are motile and can migrate up through silt layers as they develop. Such growths are generally detrimental to river ecology and recreational values as they comprise poor fish and macroinvertebrate food source value, produce 'tainting' compounds, objectionable odours, and can produce toxins (as described earlier). Any effects that functionally promote cyanobacterial mats are some of the biggest threats to recreational values.
87. Similar desilting discharges are currently authorised in the Rangitata River for the RDR scheme consents. However, these only allow intermittent discharge, at high flows, on a rising flood, and to a river reach with considerably higher river bed level gradient than are available in the Waimakariri

catchment. The RDR discharges are therefore quite different to the CPW proposals and do not set a valid comparison or precedent for such desilting discharges. They also illustrate that if such CPW desilting discharges were to be allowed, they would need to be regulated to operate only under conditions where the rivers retained the power to dissipate and transport the discharged fine sediments. This would need to be:

- on a rising flood
- when river flows were considerable
- when the river was already discoloured by elevated suspended sediment bed load (no conspicuous change in clarity)
- and would need to be monitored to ensure that subsequent sediment deposition did not become a problem in the discharge zone.

**88.** Finally, the paths of any approved desilting discharges should be engineered to avoid adverse effects. The applicant has largely not supplied any details of discharge channels or considerations. Discharge channels should:

- discourage or prevent upstream fish passage/access into the holding pond; In the case of the RDR the discharge is initially through a steep concrete flume;
- do not cause fish stranding of either upstream or downstream passing fish, especially following the abrupt cessation of the discharge
- be into an active braid of the Waimakariri River so as to affect rapid mixing and sediment transport
- do not cause a conspicuous change in the colour or visual clarity of the receiving waters, and therefore on recreational and ecological values.

**89.** Overall, it is not generally advisable to allow desilting discharges to the river, except at times when there are adequate flood flows to transport the material without significant in-river deposition, without generation of turbid plumes, and so that they will not generate fish attraction or stranding, or other adverse effects. In-river flood conditions that would generate appropriate conditions, would be hydrologically rare in summer, can be difficult to predict and verify, and seriously limit the likelihood of the proposed 'weekly' desilting discharges being able to be actioned. Mechanical removal of deposited material is likely to be more feasible and appropriate, and not undesirable to the river.

#### **Other discharges.**

**90.** Other proposed discharges to the Waimakariri River include regular and emergency bywash discharges, and fish pass bypass flows. Unlike the proposed desilting discharges, these discharges should be of more natural (clean) water quality.

**91.** Fish bypass flows are not uncommon and are generally least problematic. They generally do not comprise 'mixing of waters' from different sources, and have little capacity to undergo changes in water quality or flow rate. Overall, their operation should be straight forward and should be required to comply with guidelines in the "Canterbury Fish Screen Working Party [draft] Guidelines for best practice for fish screens on intakes in Canterbury". This document gives a series of guidelines for design of optimal fish screen bypass flows including consideration of connectivity back to the river.

**92.** However, fish screen bypass flows for such large intakes may need to be appreciable flows in their own right, and may generate additional effects on overall river flows over the distance of their diversion.

**93.** Bywash flows are defined as flows in irrigation canals that are not required by irrigators and which are discharged into receiving waters or natural or artificial wetlands. Small ( $0.2-1.5 \text{ m}^3\text{s}^{-1}$ ) bywash flows are required in the normal course of operation of the scheme to ensure that the last irrigator from a supply race can draw their full allocation. Conversely emergency bywashes are considerably larger and can

occur as a result of generally unscheduled power outages or heavy rain when irrigation use is abruptly curtailed.

94. In both cases, the discharged water is of multiple origin and could have originated from the Rakaia River, Waimakariri River, or the Waianiwaniwa Reservoir, as all three can mix in the headraces. In particular the application indicates a priority sequence of water use from Rakaia > Waimakariri > Waianiwaniwa. Therefore, at any bywash discharge, to say the Waimakariri River, the water could primarily be characteristic of the Rakaia River. This highlights a series of issues that have largely not been addressed by the applicant. That is:
- intercatchment spread of undesirable organisms (i.e. the invasive algae *Didymo geminata*, that is now resident in the Rakaia River (as a result of spread through the RDR irrigation scheme) but absent from the Waimakariri River catchment). Also undesirable organisms liberated into the reservoir (i.e. problem waterweeds, noxious fish etc.) could subsequently be distributed throughout the two major (Rakaia and Waimakariri) and minor (Selwyn, Hawkins, Hororata) catchments.
  - Confusion, repulsion, or attraction of fish into flows of novel 'flavoured' water. Many fish species home to natal (origin) rivers (i.e. salmon), or rivers with odours of conspecific (same species of) fish (whitebait). Therefore "mixing of waters" can locally disrupt fish behaviour.
95. It is commendable that the applicant seeks to discharge most bywash water to ground seepage wetlands, however, as discussed by Maurice Duncan, the area and capacity of most identifiable wetland options are grossly insufficient and are likely to functionally be direct discharges.
96. Compared to bywash discharges to the smaller rivers and streams in the irrigation command area, discharges to the major rivers (Rakaia and Waimakariri) will, as stated by the applicant, be relatively small compared to river flows, and so on a discharge flow basis their effects should be comparatively small. However, the qualitative aspects of mixing of waters and distribution of undesirable organisms should be more thoroughly considered or addressed.

#### **Rakaia River consents**

97. Like the activities proposed on the Waimakariri River, the effects of the proposed CPW activities on the Rakaia River can be considered to fall into four areas:
- Effects of construction activities
  - Effects of water abstraction including screening
  - Effects of the reduced flow regime in the Rakaia River
  - Effects of discharges back to the Rakaia River
98. Again my evidence relates to consideration of the assessments provided on the latter three of these issues, and effects on the water quality and aquatic ecology (including fisheries). My assessment is based primarily on information provided in the five KMA reports from September 2006, and a Golders KMA report dated March 2007. Supplementary information was provided from a number of URS memo's provided as responses to S92a information requests.

#### **River flow effects**

99. The GKMA 2007 report correctly described the Rakaia River characteristics and values, identified the flow regime of the river, and the extent of other authorised takes on the river. It thus modelled 5 river flow scenarios including scenarios with and without the other simulated takes and with and without the simulated CPW take.
100. It should be noted that the scenarios were for a simulated take based upon irrigation demand modelling and not on maximum allowable take. I have no expertise to assess the appropriateness or reliability of

this modelling, and take it at face value, but note it is a modelled average abstraction and not a peak or 'worst case' assessment.

101. The GKMA 2007 report also correctly identified that abstractions from the Rakaia River are restricted by, or largely dictated by provisions of the Rakaia River National Water Conservation Order 1998 (NWCO), and that this order recognised and sought to protect the rivers outstanding natural character, wildlife habitat, fisheries, recreational angling, and jet boating features. It set in place varying minimum monthly flows, a maximum allocation limit, and a 1:1 flow sharing regime, when flows are up to 140 m<sup>3</sup>/sec above the monthly minimum flows.
102. The flow controls in the Rakaia NWCO were developed with applications such as CPW in mind, and so should be effective in maintaining in-stream habitat values (natural character, wildlife habitat, fisheries, recreational angling, and jet boating features) of the main river.
103. As a result of these (NWCO) flow regime controls, the maximum (40 m<sup>3</sup>/sec) rate of take will occur very infrequently, only at high river flows, and the median summer rate of take may only be 1.6 m<sup>3</sup>/sec. As such, the actual summer abstractions will be low and so I largely agree that the potential effect of the application on Rakaia River flows and flow regime is low.
104. The assessments of effect are largely based upon in-stream flow habitat modelling that largely assesses effects upon areas of suitable water depth, velocity and substrate. Such assessments are effective at determining degrees of gross change in habitat availability. However, such 'habitat assessments' assume "all other habitat attributes remain equal" and so do not change or have any bearing on overall habitat suitability. In recent years full IFIM (Incremental Flow In-stream Methods) have begun to assess other attributes such as water quality and habitat quality.
105. Water quality effects are also addressed by GKMA 2007 and I largely concur with their assessment. That is, that there are no major municipal or industrial discharges to the river, nor any tributaries downstream of the gorge that contribute poor water quality to the river. As such there is little scope for effects of reduced flows affecting capacity to assimilate wastes in the main reach of the river down to SH1.
106. However, in the reach adjacent to and below Rakaia Island, intensive dairy developments have proliferated and are potentially causing diffuse and direct runoff in groundwater-fed streams to the Rakaia lagoon. There are localised visible evidence of these discharges enriching margins and backwaters around the Rakaia lagoon. However, again, as NWCO flow controls ensure that abstraction rates will be low at low flows, there is also little scope for effects of reduced flows to further affect the capacity of the river and lagoon to assimilate these wastes.
107. The only area where there is some potential for low flow or flow regime habitat effects (and not assessed by CPW) is in risk of degradation in habitat quality, particularly in habitat sedimentation or periphyton (slime growth) accumulations (as already discussed for the Waimakariri River).
108. Again, this effect has not been identified or discussed by CPW, but also, the NWCO controls are such that there is little scope to significantly reduce low flows or changes to the low flow regime. These siltation and nuisance growths are therefore unlikely to appreciably occur or be exacerbated throughout most of the length of the Rakaia River. There is a small risk of such effects occurring or being exacerbated in the lagoon reaches where water velocities drop and effects may be synergistic with the enrichment from run-off from Rakaia Island intensive dairy developments.

## **Intakes.**

- 109.** The screening of river fish from the intake on the Rakaia River is a similar significant issue as discussed for the Waimakariri River intakes, and for major water supply intakes elsewhere. As for the Waimakariri intakes, the applicant has acknowledged fish intake screening issues with a conceptual description of intakes sites (URS 2006), a description of fish communities in the Rakaia River (KMA 2006d), a description of fish screening issues (GKMA 2007), and the further discussion of the appropriateness of not specifying specific objectives or screen designs (URS, 7 December 2007).
- 110.** Despite these several documents (as a result of repeated requests for specific information to consider), there remains insufficient information to determine what the objectives or requirements of fish screening are proposed to be, what type of structure is intended, and therefore whether it may be appropriate or effective in screening fish and achieving pre-determined objectives from any of the major intake structures.
- 111.** My comments relating to the applicants approach (or lack of approach) to the Rakaia River intake screen issues therefore largely mirrors my previous discussion of the Waimakariri River intakes. That is, in the absence of any explicitly stated fish screening objectives, I believe, as a default, it must be considered that the applicant is aiming for effectively total fish exclusion at intakes. This would mean that no further issues need to be considered 'down canal'. Such screening systems would need to perform to the equivalent of 2mm slot, yet application documents talk of such mesh sizes being not feasible, and consideration of mesh sizes closer to 5 mm being considered. Therefore, overall, the fish intake screening issues are inadequately dealt with and cannot be adequately assessed.

## **Bywashes**

- 112.** For both the Waimakariri and Rakaia River intakes it is concluded in the AEE that any coarse sediments that enter the intakes will quickly settle in designed detention areas, and can be flushed out or removed mechanically. It is not specified which, or if both of these options will be used.
- 113.** Again my previous discussion of this issue for the proposed Waimakariri intakes relates equally to the proposed Rakaia River intake and will not be repeated in full here. Suffice to say that: it is not generally advisable to allow desilting discharges to the Rakaia River, except at times when there are adequate flood flows to transport the material without significant in-river deposition, without generation of turbid plumes, so that they will not generate fish attraction or stranding, or other adverse effects. In-river flood conditions that would generate appropriate conditions, would be hydrologically rare in summer, and seriously limit the likelihood of the proposed 'weekly' desilting discharges being able to be actioned. Mechanical removal of deposited material is likely to be more feasible and appropriate, and not detrimental to the parent river.

## **Other discharges.**

- 114.** Other proposed discharges to the Rakaia River include regular and emergency bywash discharges, and fish pass intake bypass flows. Again treatment of these is largely identical to the proposed Waimakariri River discharges, and my previous comments on the Waimakariri River equally apply.
- 115.** There are few details of the design and operation of fish screen bypass flows provided in the application, and so little specific to comment upon. However, the design and operation should be required to comply with the recent draft guidelines in the "Canterbury Fish Screen Working Party", that were a compilation of best practice design for fish screens on intakes in Canterbury".

116. Bywash discharges to the Rakaia River will be relatively small compared to river flows, and so on a discharge flow basis their effects should be comparatively small. However, the qualitative aspects of mixing of waters and distribution of undesirable organisms should be more thoroughly considered, minimised, or addressed.

### **Damming and water storage consents**

117. The Waianiwaniwa catchment is in the eastern Malvern Hills and covers an area of approximately 55 square kilometres. The proposed dam is up to 55 metres in height, storing up to 280 million cubic metres of water, and covering 1, 200 hectares of land (12 square kilometres).
118. The formation and operation of a large water storage reservoir in the Waianiwaniwa Valley is a significant part of the CPWL proposal. Damming, and water storage can have a range of benefits and detriments that need to be considered. The storage of water is an integral part of the CPW proposal that generates the operational flexibility when run-of-river sources are under restrictions or otherwise unavailable. However, they also have detriments on existing natural resources of the valley, streams and wetlands, and generate responsibilities to maintain adequate water quality attributes of the stored and released water.
119. Central to consideration of assessing the effects of such an activity is understanding the range of objectives of operating the reservoir. Many reservoirs whether for water supply or irrigation are operated in such a manner as to additionally provide benefits to the community in relation to such things as recreational values associated with boating, fishing, picnicking, other amenity values, or wildlife and conservation values.
120. Commitment to these public benefit values are often by clear agreements or by consent conditions. Such objectives can constitute significant mitigations that offset other detriments of schemes on the environment. The many reports and memos provided by CPW frequently identify possibilities for such community benefits but do not commit to any, or explicitly offer any of them as tangible community benefits, or explicitly offer infrastructure such as boat ramps, access points or active recreational management. Furthermore, there is insufficient detail in the operation or infrastructure of the dam to determine whether any could be realistically offered/ operated. For example, there are no constraints suggested for operation of reservoir levels seasonally or in total such that values associated with recreational and ecological values would be reasonably provided or maintained (i.e. boat ramps, fish populations, or fishing opportunities in a lake with a proposed 30+ metre level variation). Furthermore, the absence of any clear management objectives for the reservoir make it difficult to determine reasonable objectives for issues such as water quality, water level control, or intake fish screening, other than for "maintaining water suitable for irrigation". Therefore, from existing information provided, no mitigatory community benefits can be readily ascribed to the dam/reservoir project itself to defray adverse effects or features.

### **Reservoir water quality**

121. Water quality issues in the proposed Waianiwaniwa reservoir have been discussed in the AEE and several applicant reports including NIWA 2002, KMA 2006 and most recently in Golder KMA (March 2007). They correctly identify that water quality issues may arise with the formation of a reservoir and storage of water. Such identified issues include:
- stratification
  - hypolimnetic deoxygenation
  - eutrophication (nutrient enrichment)
  - algal blooms

- potentially toxic cyanobacteria blooms
- turbid events
- microbiological contamination
- inundation of coal mining areas

**122.** These are, in turn, identified as potentially impacting on values and criteria such as:

- aquatic ecosystems
- aesthetic values
- human health
- animal (stockwater) health

**123.** A discrepancy between this assessment and that of CPW material, relates to the likelihood of the issues above arising and whether they need to be explicitly addressed (proactively, or reactively). The applicant identifies many of these 'limnological processes' as "possible" consequences of reservoir formation and operation, of probable short duration, and largely suggests that they can be addressed by monitoring water quality and reactively responding with investigations "if" they occur.

**124.** However, there have been hundreds of such reservoirs constructed around the world, and experience at other New Zealand reservoirs shows these processes and outcomes are predictable, are well known nationally and internationally, and are well documented. In New Zealand, reservoir water quality degradation issues are best known from the formation and subsequent management of Auckland's water supply reservoirs over the past 40 years, and most recently from the formation and operation of the Opuha irrigation reservoir in South Canterbury over the past 8-9 years.

### **Stratification and anoxia**

**125.** In the Auckland and Opuha reservoirs, the water quality degradation issues, particularly with regard to water stratification (layering) and anoxia (loss of dissolved oxygen), have been consistent and predictable with sustained long term issues needing to be addressed/ managed over the life of the reservoirs. After close to 40 years of operation, several of Auckland's reservoirs still routinely stratify and become oxygen depleted at consistent rates every summer, requiring aeration mechanisms. The Opuha reservoir, after almost 10 years of operation, still exhibits regular summer stratification and rates of deoxygenation that are very similar to those seen in the first 2 years following formation (i.e. they are not improving or becoming less pronounced).

**126.** Therefore, these issues are not "uncertain", and generally do not generally resolve themselves over time (even in the native bush forested Auckland reservoirs). Therefore, rather than monitoring being used to determine whether the processes occur, and then progressing to 'investigations', as suggested by the applicant, the proposed Waianiwaniwa reservoir should be managed by anticipating that these effects will naturally occur and will require routine installation of monitoring and treatment systems (as at Opuha and Auckland reservoirs).

**127.** These include a requirement for 'real time' (telemetered) monitoring for stratification and anoxia, so that the onset of these conditions can be rapidly and readily determined and responded to well before damaging water quality thresholds (10% dissolved oxygen) are reached. Aeration systems or other infrastructure to treat stratification are more cheaply and effectively installed prior to dam filling, and result in treatment systems being available to treat water quality degradation as immediately needed. In the case of Opuha and Auckland reservoirs, the identification of the stratification/anoxia issue, resulting 'investigations', and subsequent treatment, took at least 2-3 years to implement, during which time undesirable and adverse water quality effects persisted on the lakes and downstream water quality for 2-3 summers. In the case of the Waianiwaniwa dam such a delay in treating water quality degradation should be unacceptable as the effects can not now be considered to be "unanticipated".

- 128.** The monitoring that the applicant proposes, to enable them to 'understand' and 'respond' to lake issues include:
- Monitoring at two monthly intervals (during a period of settled weather) the quality of water in Waianiwaniwa Reservoir adjacent to the dam; and the water discharged to the headrace canal for the following determinands:
    - (a) Dissolved Oxygen
    - (b) Temperature
    - (c) Turbidity
    - (d) Electrical Conductivity
    - (e) Total Nitrogen
    - (f) Total Phosphorus
    - (g) Total Organic Carbon
    - (h) Chlorophyll A
- 129.** This is sufficient to routinely monitor (long term trend) the trophic state of a stable lake for routine monitoring purposes (i.e. MfE TLI (trophic state assessment), but insufficient to identify or respond to emerging water quality degradation issues. Such monitoring at a dynamic and new reservoir should be conducted at least monthly in the initial period, and key determinands measured continuously (in real time).
- 130.** As at Opuha, real time (telemetered) monitoring for a limited range of diagnostic parameters should be required (Temperature, dissolved oxygen saturation, electrical conductivity) at two water levels (within 5m of the water surface and within 5m of the lake bed near the dam and at the deepest point of the reservoir). This is to adequately characterize the onset and breakdown of stratification and oxygen depletion mechanisms. Thresholds of <40% DO saturation, and temperature difference between the two levels of >5°C should trigger a notification requirement and a requirement to operate treatment systems until such time as DO is sustained at >70% saturation (for 7 days) and temperature difference <2°C. Such conditions have worked well at Opuha since completion of consent reviews.
- 131.** The applicant has identified that they intend to operate a variable height off-take tower to enable selective withdrawal of epilimnetic (upper level) or other beneficial water layers, and leaving hypolimnetic (lower level water layer) undisturbed. Such systems are operated at many New Zealand and Australian reservoirs and allow selection of the best water quality for withdrawal (but generally for potable rather than irrigation purposes). However, it is not a comprehensive water quality solution alone, as suggested by the applicant.
- 132.** If stratification and hypolimnetic deoxygenation are allowed to develop and persist, then the resulting generation of reduction chemistry contaminants will still need to be dealt with at some stage, particularly following expected seasonal turnover or breakdown in stratification (generally March/April) when hypolimnetic contaminants will become fully mixed through the water column and cannot avoid subsequently being discharged. An anoxic hypolimnion will produce a wide range of reduction compounds (ammonia, methane, hydrogen sulphide, iron, manganese – of which the applicant only acknowledged/discussed hydrogen sulphide) many of which are toxicants and/or potent green house gases as well as exerting a high biochemical oxygen demand in their own right. Also under these conditions soil bound phosphorus becomes highly soluble, leading to pulses of excessive nutrient enrichment (eutrophication). Therefore, despite variable height off-take tower technology allowing the anoxic hypolimnion to be left undisturbed, untreated stratification will ultimately allow a range of in-reservoir effects to still occur regularly and episodically including:
- eutrophic pulses of nutrients
  - algal blooms

- toxic cyanobacterial blooms
- release of concentrations of odorous and toxic compounds
- deoxygenation events
- fish kills

133. Many of these are notoriously hard to treat, manage, and effectively monitor, and it is generally considered more effective to prevent such occurrences through prevention of sustained stratification and anoxia. It is therefore appropriate that monitoring, trigger conditions and appropriate stratification treatment systems are required by consent conditions.

#### **Eutrophication and algal blooms (nutrient enrichment)**

134. The Waimakariri River water proposed to be abstracted to fill the dam was identified by CPW as of a low nutrient status. However, they also identified that nutrient enrichment and associated effects were a likely consequence of reservoir formation due to decomposition of inundated soils and vegetation. They proposed a range of possible mitigations including:

- tree removal prior to filling
- cease grazing, pesticide and fertilizer use for at least 2 years prior to filling
- growth of nutrient stripping crops during the 2 years prior to filling
- livestock exclusion from the lake margins with lake margin fencing.

135. There is an apparent contradiction between tree removal to reduce organic loading, while also ceasing grazing for two years. Two years of ungrazed scrub and grassland could impart considerable organic load on the filling reservoir, and so would additionally need a strategy of 'cut and carry' removal of vegetation (as hay or baleage), or cessation of grazing for a lesser period. Cessation of grazing for a two year period could also impart a considerable seasonal fire risk in the valley prior to filling.

136. Overall, these and the prevention of stratification and anoxia are the only feasible mechanisms to reduce the risk of excessive eutrophication initially and long term in the reservoir.

#### **Potentially toxic cyanobacteria blooms**

137. Production of potentially toxic cyanobacteria (blue/green algae) blooms are a further risk in reservoirs, with their concomitant risks to human, wildlife, and livestock health. Their possible occurrence is identified by CPW in KMA 2006. Again they are generally more prevalent in eutrophic systems, and those with episodic 'turnover' of stratified conditions. Steps to reduce generalized eutrophication (as above), and the prevention of stratification and anoxia are the only feasible mechanisms to reduce the risk of toxic cyanobacterial blooms regularly occurring.

138. Monitoring should include surveillance for cyanobacterial blooms, and a requirement to test any identified blooms for toxicity to be able to warn potentially affected water users, whether irrigators, stockwater, or recreational users.

#### **Turbid events**

139. There are several situations that could cause the reservoir waters, and ultimately the released waters, to become coloured and/or turbid. Applicant reports identify that Waimakariri River waters can be turbid during and following flood conditions in the river. Settlement of fine glacial silts is slow, and so can lead to protracted periods of turbid reservoir waters. This can affect visual and amenity values but will not affect the suitability for the primary irrigation use.

140. Of more concern, are the consequences of protracted periods of reservoir drawdown when extensive silted reservoir margins can be sequentially exposed to erosive wave action? Resulting turbid events will affect any visual and amenity values but will not affect the suitability for the primary irrigation use. Limitation on the allowable extent or frequency of lake draw-down is often imposed on reservoir operators to prevent persistent or frequency of extreme effects, and to maintain ecological and amenity values in a reservoir. The applicant does not propose any controls on reservoir (minimum) levels, but in lake Opuha, an 8 metre operating range was approved, with extreme level reduction (up to 21 metres) allowable on average only once per 20 years. Such a rule has been difficult to implement but serves to indicate a limitation on the routine allowable degree of water level reduction, and concomitant effects.
141. Another consequence of protracted periods of reservoir drawdown is that extensive exposed silted reservoir margins can be exposed to erosive wind action. This can lead to excessive storms of wind blown dust and sand around the lake margins and on down-wind communities. This is known to happen around drawn down hydro-electric lakes such as Lake Tekapo. The issue is best minimized by ensuring that excessive drawdown does not occur routinely, and that exposed sediments remain consolidated and undisturbed. This allows exposed sediments to dry rapidly and smoothly to a more clay like consistency. Applicant proposals to fence the reservoir margins will assist this issue.
142. A further consequence of major level reductions are that influent waters from both natural catchment streams and the tunnel inflow may have to erode through fine lakebed silts to get to the residual lake. Again in Lake Opuha sustained level reduction resulted in influent rivers cutting channels up to 2 metres into lakebed sediments. This degree of channel erosion resulted in eroded sediments causing reservoir waters to become very turbid. Structures associated with the CPW inflow tunnel are currently poorly described, but should give consideration to the discharge pathways from the tunnel exit to the reservoir over the full range of allowable lake levels, to minimize potential lakebed erosion effects.
143. Finally livestock and vehicle intrusion onto silty lakeshores can exacerbate erosion of fine sediments. The applicant's proposal to fence of the reservoir margins as a feasible mechanism of controlling stock and vehicle disturbance and erosion. This is appropriate and necessary from a range of issues including erosion, and dust suppression.

### **Microbiological contamination**

144. The applicant identifies microbiological contamination as a potential effect on water uses if the reservoir is to be used for contact recreation. They identify livestock access into the reservoir and its margins as a significant potential source. They propose fencing of the reservoir margins as a feasible mechanism of controlling stock effluent.

### **Weed growth and control.**

145. As part of a reservoir management plan, the applicant proposes:
- Devising and carrying out a monitoring programme which measures and reports on the following
    - (a) to (d)
    - (e) Weed growth and control within the lake and on the lake margins;
146. Weed growth in reservoirs can be a major issue from a number of perspectives. Exotic and invasive weeds can be come established in reservoirs and subsequently be distributed to natural catchments in irrigation and bywash water. Reservoir operators are generally required to monitor for, and control, any invasions of undesirable exotic weed species.
147. Excessive growths of common exotic aquatic weeds can proliferate in reservoirs and cause a range of management problems including:

- reduction in mixing and circulation patterns
- encourage aggregations of waterfowl
- cause blockage of intake and outfall infrastructure, particularly variable height off-take towers proposed by the applicant.
- Stranding of high biomass of macrophytes following reduction in level resulting in rotting of vegetation leading to offensive odours, nuisance flies issues and deterioration in water quality from run-off.

**148.** Reservoir management objectives (and obligations) should be to monitor to identify any issues, avoid these issues where possible, and specifically address actions to address them (often in the proposed management plan).

**149.** In some reservoirs aquatic and riparian plants have accumulated soluble toxicants such as arsenic, mercury or other metals. These generally arise from distinct novel sources such as geothermal fluids, industrial or dumping sites, or novel geology. Other than the coal mining activity discussed below, there is no known or obvious source of novel contaminants such that toxic accumulation in plants, fish, or other biota would be expected and needed to be addressed in the proposed Waianiwaniwa reservoir.

### **Coal mine inundation**

**150** There is some concern that historic and current coal mine infrastructure (mine sites, shafts, tailings) in the Waianiwaniwa catchment will be inundated and result in unanticipated water quality degradation. Furthermore, the reservoir could unintentionally breach or connect to historic underground mine workings. The applicant addresses this as assessing the breaching of underground workings as highly unlikely given current knowledge of mine structures and history.

**151.** However, coal mining in general can result in a range of leachable contaminants from both mine seams and tailings. These can range from acidification (low pH), iron flocs, heavy metal accumulations, sedimentation, and other contaminants such as boron, strontium and fluoride. While there may be localized responses to sources of these contaminants around inundated mining are tailings sites, the volume of the dam 280 million cubic metres is very large compared to the small source area of contaminants.

**152.** Mobilisation of novel coal mining contaminants is however, a further justification for explicitly preventing lake stratification and hypolimnetic deoxygenation from being allowed to occur, as such conditions could readily mobilize such contaminants under reduced anoxic conditions on the lakebed.

### **Overall reservoir water quality effects**

**153.** Overall, there is a wide array of mechanisms by which water quality of the Waianiwaniwa reservoir may be degraded relative to natural catchment (Waianiwaniwa River) or influent (Waimakariri River) water. CPW does not identify or propose any controls on the extent or duration of such potential degradation, or on quality of the discharges from the dam.

**154.** The water quality of the dam is stated as primarily for 'irrigation purposes' and so should at least conform to irrigation use water quality guidelines (ANZECC 2000), however water quality should also conform to requirements of any environmental flow releases (to the residual Waianiwaniwa River?) or bywash discharges to the foothill and alpine rivers (see bywash discharges section).

**155.** The applicant largely proposes a limited range of mitigation actions to address water quality risks or concerns rather than water quality standards or criteria. I believe that a wider range of mitigation requirements are explicitly required to ensure that the reservoir water quality is maintained without

episodes of significant degradation. Water quality monitoring proposed is also of limited extent and would be likely to fail to identify the full range of water quality fluctuations and issues. It is appropriate that water quality monitoring of the reservoir be conducted more frequently (monthly for the first three years of the dam filling and operation), and then frequency be reduced, to the quarterly proposed, as the water quality of the reservoir stabilizes and is better understood.

### **Reservoir ecology and fisheries**

- 156.** The applicant has identified the fish populations present in the Waianiwaniwa Valley and likely to be affected by the dam formation. These show populations of native fish (Canterbury galaxias, upland bullies, eels, and an extensive population of Canterbury mudfish, but no significant sports fish populations.
- 157.** The management of the mudfish populations is the most significant issue. The Waianiwaniwa mudfish populations have been further characterized by University of Canterbury researchers in two University of Canterbury publications (Harding and McIntosh 2006; Harding et al. 2007) and subsequently in a published scientific paper (Harding, Norton and McIntosh 2007). These publications have not been cited by the applicant, but are not inconsistent with the applicant's description of a large mudfish population covering over 25 km of river channel length.
- 158.** The formation of the dam would therefore inundate a large proportion of the Waianiwaniwa mudfish population habitat, and fragment small areas remaining. The applicant agrees that a significant mudfish population exists, and (in the 14 December 2007 memo) has proposed a range of 10 proposals for monitoring and mitigation. In short, they propose to:
- (a) Create new mudfish habitat in the Waianiwaniwa Valley.
  - (b) Provide a captive management facility for holding, breeding and retaining mudfish stocks.
  - (c) Survey previously unsurveyed habitats in the Hororata River catchment.
  - (d) Undertake monitoring of key mudfish populations in the CPW area.
  - (e) Provide fencing and management of riparian habitat around Hororata mudfish sites.
  - (f) Enhance and increase size of wetland habitat in Hororata River catchment.
  - (g) Seek legal protection for populations by use of covenants.
  - (h) Manage predatory fish stocks associated with mudfish habitat.
  - (i) Provide additional pest fish incursion monitoring.
  - (j) Provide revegetation of riparian zones in the Hororata catchment.
- 159.** These mitigations are all largely beneficial, although the importance of the Waianiwaniwa population, and the degree to which they can compensate for the loss or fragmentation of the Waianiwaniwa population is debatable. Eight of the 10 mitigations offered relate to enhancement of currently poorly known or described populations in the neighbouring Hororata catchment. The remaining two relate to management within the Waianiwaniwa valley through residual habitat management and a captive management facility.
- 160.** The applicant has not fully characterized the importance of the intact Waianiwaniwa valley population, or specifically related it to the specific features of the reproductive biology of Canterbury mudfish. That is, unlike other mainland mudfish species (Northern, Black, Brown mudfishes) which produce small numbers of large eggs/larvae, the Canterbury mudfish utilizes a different breeding strategy of producing very large numbers of small eggs and larvae.
- 161.** This reproductive strategy, commonly found in other fish species, is one that utilises the production of large numbers of eggs/larvae to affect rapid repopulation of depleted populations in optimum conditions, or widespread dispersal of larvae, at the expense of high survivorship of a few individuals in the parent habitat. Therefore, this strategy presumably developed to enable mudfish populations in the foothill valleys and upper parts of the Canterbury Plains to repopulate potential habitats throughout the

downstream areas of the plains. This strategy results in maintenance, establishment, or re-establishment of populations in many areas extensively associated with wetlands, borrow pits, stockwater races, streams, drains, and ponds. This is further borne out by recent findings that there is low genetic differentiation between Canterbury mudfish populations (i.e. they genetically remain well mixed) (O'Brien, pers. com.). Therefore intact and stable headwater populations, such as Waianiwaniwa Valley, are particularly important for the ongoing maintenance of the distribution and integrity of the Canterbury mudfish populations across the Canterbury Plains.

162. The Waianiwaniwa Valley population is clearly the largest and most stable population of Canterbury mudfish in Canterbury and has the potential to distribute larvae (new recruits) through potential habits across the Canterbury Plains down to Lake Ellesmere. In contrast, other headwater populations performing similar functions are either small, poorly known, or absent (extinct). The only other well known and stable headwater population is in a very small area of Mounseys Stream in the Eyre River catchment in the Waimakariri district. Other poorly known or predicted populations are possibly in the adjacent Hororata River, and the mid-Canterbury Hinds River catchments.
163. Therefore, the Waianiwaniwa Valley population is by far the largest, and one of only 4 known remaining headwater populations capable of maintaining high population densities, and naturally repopulating areas of the Canterbury Plains through intermittent flood dispersal. It is therefore very unlikely that the mitigations offered, can adequately compensate for what is largely proposed to be the loss of the Waianiwaniwa population.
164. Residual populations that may be maintained in the Waianiwaniwa Valley will be isolated remnant populations that will be prevented from contributing to effective larval dispersal mechanisms by the presence of the reservoir and dam. Even if the applicant were to offer to maintain or establish a mudfish population in the residual Waianiwaniwa River below the dam down to SH73 (which is not explicitly offered), by maintaining a residual flow, this population would still be largely an isolated remnant population and be unlikely to contribute significantly to dispersal, because of an absence of a floodable headwater catchment other than the dam spillway (which is proposed to be unlikely to operate (if ever)).
165. The Hororata River catchment populations proposed to be part of the mitigation package (if still extant) are only surmised to be present and so are largely unknown, and may not be able to be rehabilitated or re-established. Finally, attempts to establish new mudfish populations over the past 30 years have been notoriously unsuccessful with only two new populations persisting. O'Brien and Dunn (2007) in a wide ranging literature review of mudfish biology concluded "*Thus, despite considerable effort, few new Neochanna [mudfish] populations have been established. This emphasizes the need to focus on the protection of habitats that currently contain Neochanna [mudfish]. Further understanding is also needed of the small scale and long-term seasonal characteristics of Neochanna habitats, in order to better guide the identification of potential translocation sites.*"
166. In the light of these issues, the destruction of Canterbury's largest and most abundant natural mudfish population, as a result of the construction of a water supply reservoir, appears unjustifiable, and unable to be adequately compensated, particularly by the range of uncertain mitigations currently offered by CPW.
167. Restricting such mitigation efforts to the CPW supply area also significantly restricts the possible extent and success of adequate mitigation. Appropriate and lasting mitigation is only likely to be significantly beneficial if it reliably achieves enhancement or establishment of further headwater mudfish populations in Canterbury. A range of options may be needed to ensure a reasonable chance of success, and so these options are likely to need to extend beyond the CPW area, in catchments to the north (for example the Hawkins River catchment), or to the south of the Rakaia River.

- 168.** A mudfish population in the Selwyn stockwater race network (O'Brien and Dunn 2006a,b), that probably arose from dispersal from headwater (Hororata or Waianiwaniwa) populations, is currently in imminent threat of extinction from stockwater race closure. It is in the middle of the CPW supply area but lacks commitment of an agency to underwrite the costs and efforts of maintaining a reduced network for mudfish purposes rather than for stockwater purposes. Despite the extensive scheme proposals and mitigation options, CPW has not currently been a proactive party to the discussions on this population to date. Therefore mitigation options continue to be reduced, and mudfish as a species, more endangered
- 169.** Overall, the Waianiwaniwa Valley has important ecological resources, primarily related to a very large and stable population of the nationally endangered Canterbury mudfish. The construction and operation of a reservoir must be weighed up against the effect of largely destroying this unique natural population, and uncertain opportunities to mitigate with management or establishment of other populations.

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