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To: Gavin Kemble, **Ryder Consulting**

From: Greg Ryder

Date: 2 September 2016

Subject: **Klondyke Storage Reservoir – response to Environment Canterbury s92 information request**

Dear Gavin,

Attached is my response to particular questions contained in Environment Canterbury's s92 information request. This response has been prepared following a meeting with Environment Canterbury staff at their Christchurch offices today. I note that Saskia Ball, Jackie Todd and Adrian Meredith from Environmental Canterbury attended the meeting. Steven Woods (MWH), Paul Morgan (Riley Consultants), Ben Curry (RDRML) and I attended on behalf of the Applicant.

Please let me know if you have further questions.

Regards,

Greg Ryder
Environmental Scientist/Consultant

Water Quality of the Klondyke Storage Pond (informal information request)

"During periods of time when the inflow/outflow appear to match closely during the irrigation season, there is very little change in the reservoir volume. It is during these periods of time that it is important that the water does not pass directly from the inflow to the outflow such as by surface water sheet flow. Could you please address this risk and propose potential mitigation measures."

Response

There are a number of factors that indicate that water sheeting is unlikely to occur.

First, the reservoir is large and will have a correspondingly large expanse of open water. The inlet and outlet are situated more or less diagonally opposite each other in a NN-E to SS-W orientation, meaning that distance between them is nearly 2 km, allowing plenty of opportunity for water to disperse before being drawn through the outlet.

Second, the prevailing wind direction, and strongest winds, are from the northwest quarter (winds are likely to be channelled down the Rangitata River Valley) and so are more or less at right angles to the direction of water flow if water sheeting was to occur (Figure 1). Therefore wind direction, frequency and strength are all likely to act to counter any potential direct routing of surface water and act to mix water across the reservoir.

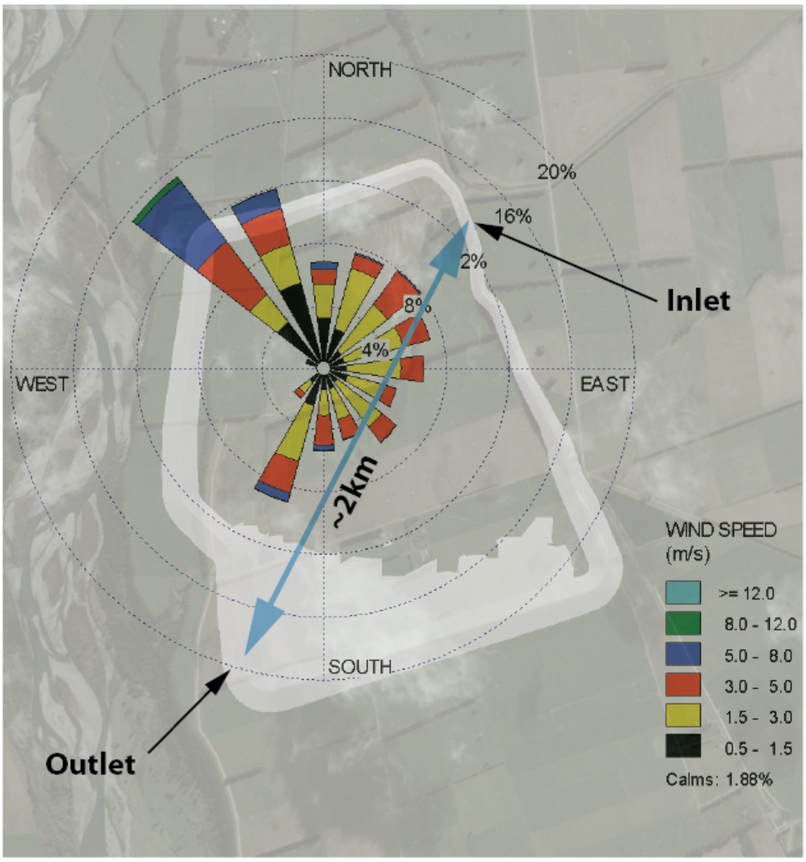

Figure 1. Windrose of hourly average wind speeds and direction measured at the Lismore climate station (approximately 17km from the reservoir location), October 2012 to December 2014, with the Klondyke reservoir superimposed over it (wind data sourced from NIWA Cliflo database and presented in Beca 2016[1]).

[1] Beca. 2016. Klondyke Water Storage Facility and Associated Activities - Dust Management Plan. Prepared for Hobec Lawyers on behalf of Rangitata Diversion Race Management Limited.

Third, during the warmer months of the year, the temperature of RDR inflow water (i.e., Rangitata River alpine water) is predicted to be generally cooler than the water in the reservoir, particular near the surface, as shown in Figure 2. This difference in temperatures would tend to encourage the inflow to sink rather than move across the surface of the reservoir.

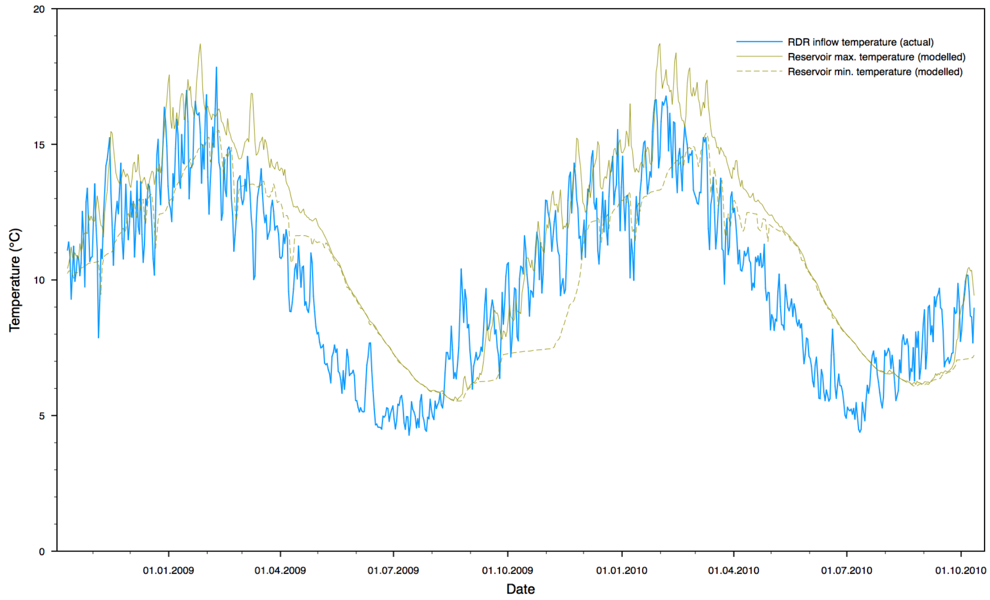

Figure 2. Inflow temperatures (actual data) and modelled reservoir temperatures (see Ryder & Goldsmith 2016[2]).

Fourth, contrary to the comment in the Environment Canterbury s92 request, reservoir volume, and so the reservoir water level, will change during the irrigation season. As shown in Figure 3, water level can change quite markedly over the irrigation season, associated with differences between inflow and outflow rates, and this is likely to further assist with the mixing of water.

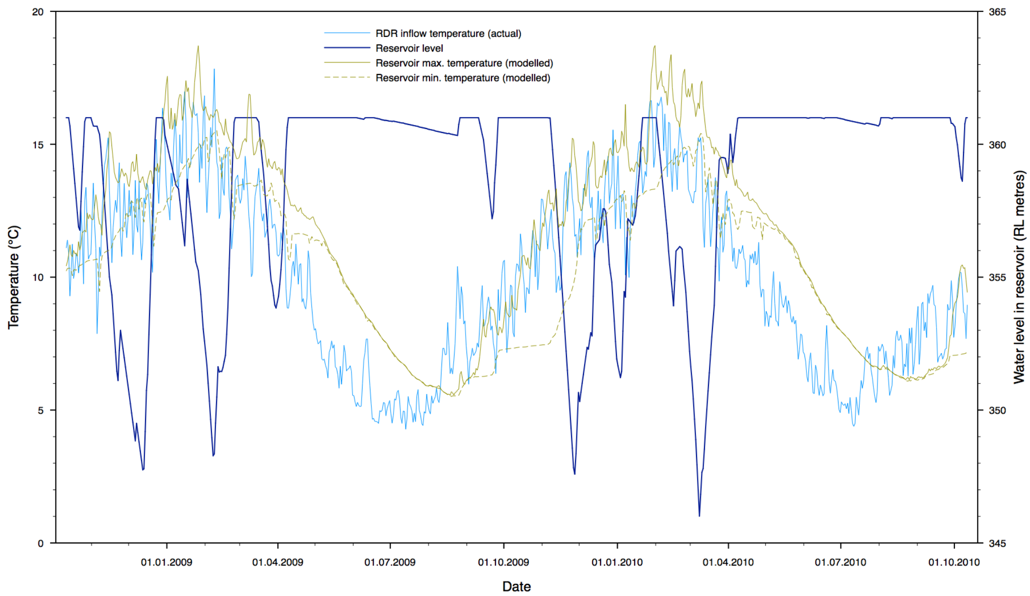

Figure 3. Inflow temperatures (actual data) and modelled reservoir temperatures (see Ryder & Goldsmith 2016).

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[2] Ryder, G.I. and Goldsmith, R.J. 2016. Klondyke Storage Proposal: Water Quality and Aquatic Ecology Assessment. Prepared by Ryder Consulting for Hobec Lawyers on behalf of Rangitata Diversion Race Management Limited.

Fifth, the invert of the pond outlet is 28 metres below the maximum operating water level. So inflow water arriving at the surface of the reservoir must be drawn down through the water column in order to exit the reservoir, and must undergo some mixing as it does so. As the reservoir is drawn down, this pathway becomes more direct, however at lower water levels, water within the reservoir is less likely to be thermally stratified.

Based on the above features of the site and the seasonal demand for water, the risk of 'sheet flow' is considered very unlikely. While these features can be regarded as 'natural' mitigation measures, monitoring of reservoir is proposed to assess water quality and this will provide feed back on the degree of water mixing and whether this is affecting water quality. If adverse water quality is detected, the resource consent could be reviewed and mitigation strategies developed and applied.

At our meeting at ECan today, Dr Adrian Meredith expressed some caution around the water quality and bottom sediment quality of reservoirs, citing the Opuha Reservoir as an example. His primary concern was not so much the effect of that water within the reservoir itself, but if it was to be discharged to a receiving environment such as the Rangitata River (through sluicing). Dr Meredith advised RDRML to consider improving the dispersion of the inflow water to improve mixing and avoid 'dead' spaces within the reservoir.

Dr Meredith also noted that there could be potential for nutrient enrichment of reservoir sediments and possible dexoygenation if sediments accumulate for extended periods of time. RDRML intend to assess sediment quality in other established ponds receiving Rangitata River water to determine what this risk is. Further, a monitoring programme will be forwarded in due course as part of a suite of proposed consent conditions ('Water Quality Monitoring Plan' for the Klondyke Pond) and that sediment monitoring would form a part of this plan along with water quality monitoring.

The purpose of this plan would be to assess key water and sediment characteristics of the reservoir well in advance of initiating sluicing discharges back to the Rangitata River or advance of permitting activities where humans may come into contact with the water (e.g., kayaking). The objective would be to ensure that any discharge meets the requirements of the Rangitata Water Conservation Order relating to water quality standards and that any potential risk to human health as a result of water quality is minimised.

Detailed description of the proposed fish screen:

2(b) "***In addition, please provide a more detailed assessment of the proposed fish screen against each of the seven NIWA best practice guidelines. This should include a description of proposed maintenance methods for the fish screen.***"

Fish Screen (informal information request)

- The reports retain a distinct emphasis on a structure and bypass channel designed to exclude juvenile salmonid fish, however as has been communicated previously, the fish screen and bypass channel should also focus on the native fisheries in the river and mahinga kai species.

- What design objectives has the fish screen been assessed against?

Response

Rileys have provided Environment Canterbury a detailed description of the proposed fish screen. The key elements of the design are:

- an engineered elongated rock bund approximately 350m in length;
- approximately 4.5m in height, 14m wide at the base, and 3m wide at the maximum water level;
- rock to be used in the bund will include an upper screening layer 50-100mm diameter rock underlain by the main rock comprising 100-200m diameter material;
- mesh pipes positioned beneath the end section of the bund;
- a void space to rock ratio sufficient to create a flow velocity though the bund of approximately 0.03 m/sec;

- a sweep velocity across the bund upstream outside wall of approximately 1.2 m/sec at a peak canal flow of 42 m^3/s;
- a fish bypass channel back to the Rangitata River, approximately 460m in length, that can convey up to approximately 3 m^3/s and incorporate design features to prevent upstream fish passage.

The Canterbury good practice fish screening guidelines (Jamieson *et al.* 2007[3]) contains several factors to be considered in assessing best practice for fish screening:

(i) Location

The guidelines state: "*The location of an intake should be chosen to allow good design attributes for all following factors to be achieved* [i.e., the factors listed under the next six roman numerals]. *A number of options may need to be considered to identify which gives the best mix of fish protection and operational characteristics.*"

Considerable thought has gone into the location of the fish screen. The Rangitata River carries a considerable suspended sediment load at times and this resulted in the need for a sand trap to settle out coarser fractions of fine sediment before being transported further along the RDR's distribution network. Fine sediment deposition is thought to be one of the causes of the relatively poor performance of the existing BAFF screen, which is situated upstream of the sand trap. Having to deal with a high sediment load has previously led to other fish screen options being discounted. Consequently, it has been considered important that any new fish screen be located downstream of the sand trap. The rock bund design proposed by Rileys is situated at the downstream end of the sand trap. This has three advantages;

1) Water reaching the rock bund carries less coarse sediment and therefore design considerations, flow efficiency through the bund and maintenance issues are improved by not having to deal with greater sediment deposition if the screen was positioned further upstream towards the intake from the river.

2) It capitalises on the reduced velocities created by the pond-like character of the sand trap. This assists in reducing the approach velocity to the bund wall.

3) It provides more room to build a longer bund wall within the existing canal structure. A longer bund enables approach velocities to be greatly reduced.

(ii) Approach velocity (the velocity of water moving through the screen)

The fish screen guidelines note that, in most situations in Canterbury, the smallest salmonid fish at an intake would be about 30mm in length. Consequently, the maximum approach velocity to the infiltration gallery should not exceed 0.12 m/sec (four times the body length). For native fish, Mitchell and Saxton (1987[4]) found that a range of juvenile native fish were found able to swim for hours against a water velocity of 0.3 m/sec and indefinitely against 0.1 m/sec.

The estimated typical approach velocity of approximately 0.03m/s compares very favourably with the maximum of 0.12 m/sec recommended in New Zealand fish screening guidelines.

(iii) Sweep velocity (the velocity of water moving across the screen)

The fish screen guidelines state that the sweep velocity should carry the fish away from the screen and back to the main flow/channel either directly or via a bypass. Sweep velocity should typically be much greater than the approach velocity and be at an angle that efficiently sweeps the fish past the screen towards the bypass. The guidelines also state that: "*Placing the screen correctly as close to parallel with the supply flow will create a sweep velocity across the screen and effectively "bypass" the fish downstream of the screen – avoiding over-reliance on appropriate mesh sizes, approach velocities, and bypass systems".*

[3] Jamieson, D., Bonnett, M., Jellyman, D., and Unwin, M. 2007. Fish screening: good practice guidelines for Canterbury. Prepared for the Fish Screen Working Party by NIWA. NIWA Client Report: CHC2007-092, October 2007.
[4] Mitchell C.P. and Saxton, B.A. 1989. Swimming performances of some native freshwater fishes. *New Zealand Journal of Marine and Freshwater Research 23*: 181-187.

The approximate angle of the sweep velocity relative to the approach velocity is in keeping with the guidelines.

The guidelines do not specify a value for sweep velocity but indicate that the sweep velocity should be greater than the approach velocity. The sweep velocity at the proposed peak race flow of $42m^3$/sec has been estimated at approximately 1.2m/s which is considerably greater than the approach velocity and should be highly effective at drawing fish across the face of the bund wall towards the bypass.

(iv) Fish bypass

The guidelines state:

"Fish moving downstream, either voluntarily or involuntarily, toward an irrigation intake need to be transported (bypassed) back into the main or supply flow, rather than being impinged on the screen or penetrating the screen and getting into the irrigation supply. Thus the objective of a bypass is to safely transport the fish away from the screen back into the main flow; and general requirements of a bypass are:

- *Entrances to the bypass should be easily located by fish, and preferably they would be situated on the downstream end and flush with or close to the screen (or on both sides/ends when screen is placed across the intake flow). If there is a strong sweep velocity across the face of the screen for smaller intakes, one entrance on the downstream side/end may be sufficient, but for large screens several by-pass entrances might be necessary. Obviously, a bypass should work in tandem with the sweep velocity across the screen – fish should be swept across and away from the screen and into a bypass.*
- *Bypass entrances should extend from the floor or base of the intake channel to the water surface – i.e., a slot rather than a pipe. As some fish, particularly juvenile salmonids, tend to avoid enclosed/darkened spaces, the entrance should be open at the top to provide ambient light conditions.*
- *The flow velocity should draw the fish into the bypass entrance, and there should be sufficient flow into and through the bypass to prevent fish returning – i.e., once a fish enters the bypass it cannot easily get back to the screen face."*

The proposed fish bypass is situated at the distal end of the rock bund and will be able to carry up to 3 cumecs of water, or approximately 7% of the maximum flow at this point in the RDR. The design of the screen is such that the sweep velocity will increase significantly relative to the velocity through the rock bund near the entrance of the bypass.

The proposed design meets the requirements of the first bullet point. The bypass entrance is situated adjacent to the most downstream end of the rock bund. The sweep velocity is very strong relative to the approach velocity. While one bypass entrance is considered sufficient given the robustness of the proposed design, in particular the magnitude of the sweep velocity relative to the approach velocity, and its location relative to the screen, it may be possible to construct another entrance further upstream (say, opposite the middle section of the bund wall) should this be necessary to encourage some fish to leave the race. If a second entrance is deemed necessary, it will need to be the subject to a separate authorisation process.

Final design of the bypass entrance has not commenced, however there is no reason why the second bullet point cannot be met. The bypass entrance will be an open structure. A condition of consent could be imposed to ensure that an open slot, rather than a pipe entrance, is constructed.

It is possible to design the bypass entrance to create an exit velocity that will make it extremely difficult for fish to swim back upstream and away from the bypass. I expect that this far down the RDR are more than likely to move with current. Consequently, the bypass will provide a desirable flow pathway. Velocities in front of and through the bypass entrance will be strong given the size of the flow (up to 3 cumecs) and be attractive for fish actively migrating downstream and of sufficient force to prevent weak swimmers from moving back upstream (e.g., salmon smolt, juvenile bully and torrentfish).

Fish in the bypass need to be conveyed safely back to the Rangitata River. The bypass will be approximately 460m in length in order to get back to the river. This length is not ideal, but is necessary given the logical requirement to position the screen downstream of the sand trap, and for the bypass exit to be positioned upstream of the sand trap sluicing channel outlet (which is considered necessary to avoid potential effects of occasional sand trap discharges on fish leaving the bypass). It is proposed that the bypass exit will be position by the exit of the existing bypass associated with the BAFF.

The bypass is intended to be an open channel apart from a 20m section that will need to be constructed as a buried 300mm diameter pipe to convey flow across the existing sluice channel of the sand trap.

All surfaces of the bypass will need to be smooth and sharp corners avoided. Given the gradient between the sand trap and the Rangitata River, it will be possible to design the bypass to ensure that water conveyed by it has sufficient velocity to prevent fish from swimming back upstream. A non-return hydraulic feature located well downstream of the entrance is proposed to further ensure upstream passage is restricted.

The bypass exit will be designed to prevent entry by potential upstream migrants capable of climbing; elvers and koaro being the most obvious candidates. This, together with a non-return hydraulic feature and strong velocity will also prevent passage of upstream migrating adult salmon.

(v) Connectivity
The fish screen guidelines state:

"Once a fish has been diverted from a screen and entered a bypass, it is important that it is then delivered safely back to its source river. To ensure this:

- *The interior of the bypass should pose no risks to fish travelling through, so that extreme bends, obstacles, rough surfaces, hydraulic jumps and free-falls should be avoided.*
- *The bypass outfall, where the water and fish from the bypass re-join the main flow downstream from the screened intake, should also not pose risks to the fish. Generally this means the fish should not be exposed to an excessive free fall, or impact onto hard surfaces and/or shallow water. The bypass outfall should also return fish to active water and generally avoid returning fish to the mainstem in such a way as to expose the fish to predation from other (larger) fish or from birds."*

These issues have been partly addressed in the previous section. One hydraulic jump is currently proposed in RDR bypass. This may be unnecessary given the potential gradient and velocities within the bypass channel, and the design of the exit to prevent entrance by upstream migrating fish. Some excavation of the channel immediately surrounding the exit point to the river (where the existing BAFF bypass discharges) may be necessary to ensure excessive turbulence and predator habitat are minimised, and movement back to the main flow is efficient. These matters would form part of more detailed design, but there is no reason why suitable connectivity cannot be met. Again, conditions of consent can be imposed to ensure that such responses are a feature of the final design,

(vi) Screening material
Rock bunds are a matrix of rock material and not a single layer as in manufactured mesh screens. Rileys report that rock material 50mm to 200mm in diameter in two layers would be use in the RDR screen: an upper 'screening layer' of 50mm to 100mm diameter rock underlain by a main rock layer comprising 100mm to 200mm diameter rock. While spaces through this material may be accessible by small fish species and younger life stages, the thickness of the bund further acts to restrict access and deter movement though to the other side. The bund design is 3m wide at maximum water level and 14m wide at the base. While it is conceivable that some small fish may take up residence in the bund wall (e.g., bully and possibly elver), the behavioural tendencies of migrating fish would indicate that they will move with the strong sweep velocity to the bypass. Salmon smolt and juvenile trout are unlikely to take up residence in the bund wall given their preference for more open water and no evidence of having a preference for living within gravels. The material will be adequate for screening adult eels and trout. Consequently, it is considered that the combination of proposed screen material and the thickness of bund wall will be adequate for screening out fish species likely to be encountered in this section of the Rangitata River.

(vii) Operation and maintenance
The fish screen guidelines state:

"*The principal objective of designing and installing fish screens on irrigation screens is to exclude and divert fish from the intake with minimal impact. Whatever features are incorporated into an intake, it is important they work effectively and efficiently at all times, so that:*

- *Maintenance of the fish screening features will be necessary. Generally this means checking, repairing or replacing screen mesh, seals and bypasses regularly. Sediment deposits that alter the flow characteristics of the channel will need to be dispersed, and debris that collects in or near the structure will need to be removed particularly if these changes lead to inappropriate increases in approach velocity or lowered sweep velocity.*
- *The design and installation will need to incorporate some leeway to ensure that the screen and bypasses operate efficiently under all conditions – e.g., extremes of flow and/or water level, or periods when there are high sediment loads, lots of debris etc. This is partly an issue of capacity; screening structures need to be able to cope with higher water levels that may occur during floods and freshes, without fish overtopping screens. This is particularly important for salmonid fry which migrate in larger numbers during fresh events, and are therefore at greater risk of entrainment or impingement during higher flow periods.*
- *Contingency plans need to be negotiated in advance with relevant authorities where damage from floods and freshes is foreseeable. These contingency plans need to be practical while providing reasonable ongoing protection for the fishery. It is recommended that such plans be documented for all intakes.*
- *Monitoring of the effectiveness of intakes is important to build knowledge on actual field performance of intake designs. Lack of information of fish species and how they behave in New Zealand is a critical information gap and monitoring information will help fill this gap and ensure that future screening requirements are efficient and effective.*"

The risk of sediment build-up has been an important consideration in the proposed design, hence the placement of the bund at the downstream end of the sand trap. Coarser sediment fractions (>50µm) settle out in the sand trap. Back-flow created by occasional sand trap flushing may assist in the removal of same material from the rock interstices. It has also been proposed that any maintenance of the rock bund would be undertaken during RDR shutdowns, which would mean water is not being actively abstracted from the river.

The location of the screen within the RDR and downstream of the sand trap means that issues associated with floods (extreme water variations, debris and heavy sediment loads) will be avoided.

Didymo is present in the Rangitata River but to date not been a significant problem with other existing rock bunds intakes on the river. If rocks were required to be cleaned, this should be undertaken during shutdown periods to minimize the effectiveness of the bund at screening fish.

A verification programme will be developed to confirm the design specifications of the fish screen with respect to the Canterbury fish screen guidelines, with particular emphasis on:

- confirming approach velocity;
- confirming sweep velocity;
- confirming the efficiency of the bypass at attracting and conveying fish back to the Rangitata River.

The primary objective of the verification programme is to confirm that the fish screen and fish bypass channel operate in a manner consistent with the best practice measures outlined in the Canterbury fish screening guidelines[5].

Effective monitoring fish on the downstream side of the bund is not recommended given the proven difficulties in detecting fish movement in the RDR, which is a large waterbody in its own right. Verifying the effectiveness of the bypass is considered a suitable surrogate for the rock bund's fish screening ability, and fish trapping or detection in the bypass is also more readily achievable than in the RDR.

[5] Jamieson, D., Bonnett, M., Jellyman, D. and Unwin, M. 2007. Fish screening: good practice guidelines for Canterbury. Prepared for the Fish Screen Working Party by NIWA. NIWA Client Report: CHC2007-092, October 2007.

A maintenance plan is to be developed for the proposed fish screen. However the details of such a plan are best developed once the screen is constructed and operating. Key aspects of the plan should be ensure that a suitably low approach velocity is maintained throughout the bund and the sweep velocity and fish bypass are effectively removing fish from the RDR and conveying them safely back to the Rangitata River. A condition of consent could be advanced to require this plan to be prepared within 6 months of the fish screen operating.

At our meeting at ECan today, Dr Meredith urged that a proactive maintenance programme be adopted for the proposed fish screen, to ensure that it functions as per the design specifications. This has been addressed by Mr Paul Morgan (Riley Consultants). It is considered that the proposed monitoring approach set out above would be undertaken in conjunction with a maintenance programme and compliment it with respect to verification that the screen and bypass are functioning as designed.

Greg Ryder
Environmental Scientist