REPORT

SELWYN DISTRICT COUNCIL & CANTERBURY REGIONAL COUNCIL

Central Plains Water Enhancement Scheme Report on Civil Works Safety Issues

Report prepared for:

SELWYN DISTRICT COUNCIL & CANTERBURY REGIONAL COUNCIL

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Distribution:

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January 2008

Job no: 23698 / Issue 1

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Executive summary

The Central Plains Water Trust and Central Plains Water Ltd (collectively referred to as CPW) have submitted applications for a number of resource consents to Environment Canterbury (ECan) and a Notice of Requirement for a designation with the Selwyn District Council (SDC) for the development of an irrigation scheme on the Canterbury Plains. This report discusses the assessment of the safety aspects of the civil engineering elements of the project in so far as they relate to environmental effects in normal and extreme events. The primary civil engineering elements of the scheme are:

- An intake on the right bank of the Waimakariri River at one of two locations.
- A conventional trapezoidal canal and a long tunnel to convey water to the storage reservoir.
- A 55 metre high embankment dam to form the storage reservoir for 280 million cubic metres of water in the Waianiwaniwa Valley.
- A network of conventional trapezoidal canals, approximately 400 kilometres in length, for distributing water to 60,000 hectares of the irrigable farmland.

The proposals for these civil engineering elements are currently at a stage that do not provide sufficient detail to establish their environmental effects, nor do they provide the detail necessary to assess whether they will meet the commonly accepted safety criteria for similar structures. Consequently, many of the matters than might normally be commented upon in assessing resource consents cannot be assessed; for example the following, which is not necessarily an exhaustive list:

- Construction related effects such as traffic, noise and dust generation.
- Sediment control during construction.
- Remediation of temporary work areas.
- Containment of hazardous materials during construction.
- Surface water discharges and flood control both during construction and from the permanent works.
- Scour effects at the points of discharge from spillways and canal outlets.
- Effects at water intakes on rivers both during construction and during operation of the scheme.
- Hazards and risks associated with canal embankments that are above the surround ground level.
- The shape, size and location of various structures which may have an effect on the visual environment.
- The effects on groundwater regimes from the dam, canals and tunnel.

This lack of information notwithstanding, the intake, canals and tunnel are common in civil engineering and irrigation schemes. Thus, providing that there are no severe foundation conditions and that they are designed and constructed in accordance with commonly accepted practice for such structures, they should meet the required criteria. In addition the design, construction, commissioning and operation of canals fall within the auspices of the Building Act 2004 and are to meet the same criteria as those for dams in New Zealand. This process provides additional

assurance of their safety and their ability to mitigate the possible effects of extreme events.

The proposed embankment dam is a dam type that is commonly adopted to provide water storage. However, it is a major structure, retaining a substantial volume of water above the level of the natural ground, and represents the single largest hazard of the scheme. It therefore warrants due consideration from its inception to the end of its operation.

The documents accompanying the applications provide an assessment of the hazard and risk posed by the dam, which is based on a dam break analysis and risk analysis, both of which are typical of current practice in New Zealand and overseas. From this assessment CPW conclude that the dam will be a High Potential Impact Category (PIC) dam thereby defining the safety criteria to be met by the design, construction, commissioning, maintenance and operation of the dam. CPW propose a number of dam safety criteria for the design of the dam and these are compatible with the recommendations of the New Zealand Society On Large Dams (NZSOLD, 2000, Dam Safety Guidelines). However, the supporting documents do not provide sufficient detail to assess whether the dam will indeed meet the safety criteria proposed and achieve the low value of risk determined in the risk analysis. CPW propose that these matters will be resolved through the subsequent design process.

CPW intends that the dam be designed, implemented and operated in accordance with the normal practices for such dams in New Zealand (The NZSOLD Dam Safety Guidelines form the basis for this practice) and that these be supplemented where necessary by international practice. This approach is reasonable and is consistent with practice in New Zealand.

Prior to the commencement of construction there are a number of other regulatory requirements that CPW must satisfy over and above obtaining resource consents and confirming a designation in the District Plan. These include providing the district council with an Outline Plan of Works (for works in the designated area to be included in the District Plan) and obtaining building consents required under the Building Act 2004. These requirements also address dam safety, amongst other issues. Thus, the regional authority, probably Canterbury Regional Council, will scrutinise the subsequent design process for the dam by assuming the responsibilities under the Building Act 2004 and its regulations for dams. In addition, Selwyn District Council may consider safety matters, as relevant, through the approval process for Outline Plan(s) of Works. These processes provide additional assurance that the design, as well as the eventual, construction, commissioning, maintenance and operation of the dam, will be undertaken in a manner that mitigates potential effects of normal and extreme events.

Consequently, resolving all matters and details relating to dam safety in the resource consent conditions is not necessary. However, the process for the future development of the design should be robust so that the required safety criteria and mitigation of effects are attained. To avoid unnecessary duplication of effort and avoid as far as possible matters of ultra vires, the conditions of the resource consents proposed by CPW should be amended to implement such a process for the design, construction, commissioning and operation of the dam. In so doing, the authorities administering the development of the dam can be assured that it will be consistent with good practice, meet dam safety norms and mitigate effects commensurate with the size, hazard potential and status of the dam.

Two areas that warrant further consideration in the resource consents and attendant proposed conditions requested of Canterbury Regional Council relate to Consent CRC 061845 and the final area appears to be an omission:

- The appointment of a single qualified and experienced engineer in the development of embankment dams to take overall responsibility for the development of the dam and its associated works.
- The appointment of an Independent Review Panel to review, comment and make recommendations at critical stages in the development of the dam and associated works.
- The inclusion of a Consent for the discharge of waters from the proposed spillway to a discharge channel, which is implied in the technical documents to be the remnants of the Waianiwaniwa River. At present this appears to be omitted from the list of requested consents.

The Notice of Requirement, for inclusion of a designation in the District Plan by Selwyn District Council, includes proposed conditions which focus primarily on the mitigation of environmental effects of construction activities. These conditions do not affect dam safety. However, the review of the proposed activities suggests that an area that does affect dam safety appears to have been omitted from consideration:

- An exclusion zone for future development within, or adjacent to, the current river Waianiwaniwa River course if this river course is to accept spill flows from the dam's spillway. Such spills are typically unpredictable, may be incrementally larger than current flows, and often require particular consideration for public safety.

In addition to the civil engineering aspects of the scheme, a generic draft of conditions for a bond agreement for the scheme has been reviewed. The intent of the bond appears reasonable; varying the amount from time to time to reflect the different stages of the scheme. However, the process being proposed should be reviewed to arrive at a practical procedure for deriving the amount and detailing the various circumstances for surrender of the bond during the operation of the scheme.

1 Introduction

The Central Plains Water Trust and Central Plains Water Ltd (collectively referred to as CPW) have submitted applications for a number of resource consents to Environment Canterbury (ECan) and a Notice of Requirement for a designation with the Selwyn District Council (SDC) for the development of an irrigation scheme on the Canterbury Plains. As part of the scheme there are number of civil engineering structures, all which are commonly adopted in various forms for many irrigation projects. Nonetheless, some are substantial and retain considerable water volumes above the level of the surrounding natural ground. Consequently, those administering the development of the dam require adequate assurance that measures are to be incorporated into the design, construction, commissioning and operation of the dam to preserve its integrity and safety thereby mitigating possible effects of normal and extreme events. This report reviews the current status of the design and the possible procedures that could be implemented through consent conditions to develop a satisfactory scheme.

This report is prepared for the reporting officers of both the Selwyn District Council (SDC) and Canterbury Regional Council (ECan) on matters relating to:

- Civil engineering structure safety, in so far as they relate to the environmental effects of the scheme. This includes discussion of fundamental design criteria or issues such as; seismic hazards, hydrological or hydrogeological matters, that would preclude the satisfactory completion of the civil engineering works in the locations proposed.
- the adequacy or otherwise of the conditions proposed by the applicant (both Central Plains Water Trust and Central Plains Water Ltd).

The relevant permit and consent applications are lodged with:

- Selwyn District Council (SDC) for Designation in the District Plan:
  - Notice of Requirement - As outlined in Schedule A.1 Waianiwaniwa dam and storage reservoir Map 1.
- Canterbury Regional Council (ECan) for the resource consents (Assessment of Environmental Effects, 23 June 2006, 42156547.66140\AEE R001C):
  - CRC 061845 Construction and maintenance of a dam
  - CRC 061939 Creation of a reservoir
  - CRC 061767 Diversion of waters during construction
  - CRC 061945 Discharge of stormwater
  - CRC 061975 Discharge of water from the reservoir to the headrace canal
  - CRC 061948 Use and storage of hazardous substances.

A number of documents prepared by the applicant have been reviewed to form the basis of the review. These are listed in the appropriate sections of the report. The review of the information provided indicates that it is not sufficient to form the basis of an assessment of many of the environmental effects commonly considered prior to the finalising the conditions of consents for similar projects. This is particularly the case for the proposed high hazard dam in the Waianiwaniwa valley.

The information provided for the relevant aspects of the Waianiwaniwa dam and reservoir is insufficient to form the basis of an assessment of the engineering safety of a dam and reservoir scheme. Consequently, this report focuses on processes which are, or could be, incorporated in the conditions of the resource consents and the designation to be included in the District Plan that would provide assurance that the scheme's design and its implementation will incorporate adequate dam safety mechanisms.

The granting of resource consents and the confirmation of any designation on the basis of the assessment of environmental effects is not the last opportunity for the regional authority and District Council to review the design, construction, commissioning and operation of the scheme. The submission of Outline Plan(s) of Works (detailing the works to be undertaken within the area of designation) and application for building consents under the Building Act 2004 are also required as part of the approval process for a dam. These processes provide further opportunities to assess risk and mitigation of potential effects. Therefore, in assessing the requirements for the resource consents and Notice of Requirement, the requirements of subsequent approval processes are incorporated in the consideration of the proposals presented in the documents by CPW.

2 Outline description of the scheme

The Central Plains Water Enhancement Scheme is a proposed irrigation project to the west of Christchurch in New Zealand's South Island. It is to take water from the Waimakariri River, transfer it to a storage reservoir in the Waianiwaniwa Valley and then distribute it through a network of canals to about 60,000 hectares of farmland (the area to be irrigated varies between reports and is also dependent upon the extent of the distribution network to be implemented). The primary components of the proposed scheme are:

- An intake on the right bank of the Waimakariri River at one of two locations. The upper option is upstream of the Kowai confluence and the lower option is downstream of the confluence.
- A short section of conventional trapezoidal canal and long tunnel to convey water to the storage reservoir. This includes control gates, sediment excluders/traps, and an inverted siphon.
- An embankment dam with appurtenant structures to form the storage reservoir for 280 million cubic metres of water in the Waianiwaniwa Valley (URS, 2006).
- A network of conventional trapezoidal canals, approximately 400 kilometres in length, for distributing water to the irrigable farmland.

The documents supporting the applications do provide outlines of the typical dimensions for the various elements of the scheme. However, the embankment dam poses the greatest single potential hazard and consequent effects. Consequently, the documents provide further discussion of the outline intent for this element of the scheme in particular. A brief description of the primary elements of the dam that are of relevance to its integrity and safety are (gleaned from various URS reports of various dates):

- Zoned embankment dam, which is to be in the order of 55 metre high with a crest length of approximately 2 kilometres. Seepage control is to be provided by a central core with filters in the embankment and a seepage cutoff below the mid section of the embankment. The dam safety assurance report suggests that the dam is in the High Potential Impact Category for dams (NZSOLD Dam Safety Guidelines, 2000).
- Spillway and an energy dissipater on an abutment (which abutment is not specified but probably the left abutment) to permit discharge of excess flow to the Waianiwaniwa River. The type of spillway to be adopted is also unclear. The documents suggest that a spillway arrangements incorporated into the outlet tower arrangement may be considered in subsequent designs.
- Spillway discharge channel, which may be the remnants of the Waianiwaniwa River close to the left abutment of the dam. However, justification of the capacity of the river to accept spill flows from the spillway is not provided by CPW.
- High level off-take for water abstraction. The Notice of Requirement (Urbis, 2006) suggests that the off-take will be an outlet tower within the reservoir margin. This would have intakes at various levels to allow abstraction of water from near the water surface when the reservoir is drawn down. The

tower arrangement and piped discharge from the tower through the embankment or abutment is not defined.

- The reservoir. The Dam Safety Assurance Report (URS, 2006) notes that the 280 million cubic metre capacity reservoir retained by the dam will form a substantial proportion of the total catchment, flooding a maximum of 12% of the catchment (Notice of Requirement, Urbis, 2006). The reservoir will extend approximately 8.5 kilometres upstream of the dam when the water elevation is at about 280 m above sea level. The surface area of the reservoir will be approximately 12 square kilometres. However, an overview of the hydrological response of the catchment is not provided in the documentation. One of the critical design criteria for the safety of the dam is the assessment of the Probable Maximum Flood (PMF). This flow may be solely dependent on the natural catchment of the reservoir, but other extreme conditions, such as a control gate failure on the intake canal, may also contribute to the determination of the PMF. In the absence of an estimate of the PMF the effects of discharge from the spillway cannot be assessed.

3 Dam safety

Dam safety is dependent upon factors that cross many technical disciplines such as: soil mechanics, hydrology, hydrogeology, geology, seismology, hydraulics, structural mechanics, mechanical engineering and control engineering; as well as functions of design, construction, commissioning, operation and maintenance. This is not a comprehensive list, nor is there a particular importance to any single discipline or function because each is related to one another through various interfaces. For illustration, this complexity is reflected in the event trees of the risk analysis for different conditions (Attachment C1 to Appendix C of the Dam Safety Assurance Report). These complex event trees are the summary of more detailed considerations of safety and risk for each of the items that have been assigned specific probabilities of occurrence.

Given the complexity of the factors that contribute to dam safety, matters of dam safety are generally under constant review throughout the development and implementation of a scheme. The resolution of these issues generally requires modifications and adaptations to the works as the design and construction phases of a dam progresses. Consequently, at the commencement of the process it is important to put in place a robust process whereby the development of the dam can be adequately reviewed and safety concerns addressed at the appropriate juncture.

Every dam is unique, governed by the particular circumstances of a site and the functionality required. Thus, there is heavy reliance on guidelines, precedent and experience in dam design and their implementation. The documents provide a few of the basic design criteria which would normally be supplemented by further criteria in more detailed phases of the design. In a subsequent phase the basic elements and a series of further criteria would be developed to provide guiding principles for the development of the details for design and construction. Some of the additional criteria and outlines that might be expected in a subsequent design phase for the scheme are:

- Additional dam safety criteria
- Seismic assessments and clarification of seismic criteria
- Hydrology and hydrogeology assessments determining discharge flow criteria
- Embankment outline arrangements
- Outlet tower outline arrangements
- Spillway and energy dissipater outline arrangements
- Spillway discharge channel outline arrangements.

Discussion of these subjects, with particular reference to the limited extent of information provided to date for the proposed dam, provides a context for the interpretation of the conditions for the resource consents and those for the Notice of Requirement proposed by CPW.

The documents used as the basis of the assessment of dam safety are:

- Central Plains Water Enhancement Scheme - AEE (URS dated 23 June 2006)
- Notice of Requirement (Urbis dated June 2006)
- Annexure I: Dam Safety Assurance Report (URS dated 30 March 2006)
- Central Plains Water Enhancement Feasibility Study (URS dated 31 January 2002)
- Waianiwaniwa Reservoir Feasibility (URS dated 7 November 2002).

3.1 Dam safety criteria

New Zealand and other nations do not have codes of practice governing the development of designs, undertaking construction, commissioning or operation of dams and reservoirs because of the complex nature of dams. Therefore, the profession places considerable reliance on the experience of the teams undertaking these projects as well as precedent and experience in comparable structures. Nonetheless, the International Commission on Large Dams (ICOLD) and the various world wide national committees provide guidance on the minimum standard of safety that is generally required. In this, the guidance on dam safety provided by the New Zealand Society on Large Dams (NZSOLD) is generally consistent with the guidance of other nations.

The NZSOLD Dam Safety Guidelines (2000) categorises dams by Potential Impact Category (PIC) and provide a range of criteria within each category. The criteria govern the design of basic features of a scheme such as the ability to pass flood flows or withstand earthquakes. It is for the proponent of a scheme to justify the adoption of a particular criterion.

In common with normal practice, both in New Zealand and elsewhere, the Dam Safety Assurance Report (URS, 2006) provides discussion of a dam break analysis to assess the effects of a hypothetical extreme event and a risk analysis for its occurrence. CPW concludes that the dam is a High PIC dam in accordance with the classification of NZSOLD (2000). Consequently, CPW propose criteria for use in the design of the dam, which can be compared against the standards suggested by a High PIC dam (Table 3.1). Although, some criteria are yet to be set, those that have been indicated within the Dam Safety Assurance Report are in accordance with the guidelines of NZSOLD.

Table 3.1 Comparison between NZSOLD typical criteria and Scheme criteria

Event or element	Condition	Value	
		High PIC Criterion	Proposed by Applicant
General			
Wind	Generation of waves for dam freeboard assessments	*1:100 AEP Flood event + Winds 1:100 AEP no overtopping and 0.5m freeboard	**Not provided**
		*MDF + Winds 1:10 AEP no overtopping and zero freeboard	**Not provided**
Flood event	Construction flood event		1:1000 AEP event
	Inflow Design Flood (IDF) – the maximum design flood (MDF)	1:10,000 AEP to Probable Maximum Flood (PMF)	PMF
OBE – Operating basis earthquake	Negligible deformation	1:150 AEP event	1:150 AEP event (=0.28g, Sterling 2000)
MDE – Maximum design earthquake	No catastrophic failure or complete dislocation of drainage and filter media	1:10,000 AEP to Maximum Credible Earthquake	1:10,000 AEP event (=0.65g, reference not provided)
Completion of construction	Static stability- including excess pore pressures generated in construction	FoS 1.3	**Not provided**
Downstream slope	Static stability- steady state seepage and maximum storage	FoS 1.5	1.5
Embankment	Static stability – steady state	FoS 1.5	1.5
Upstream slope	Static stability – full or partial rapid drawdown	FoS 1.2 to 1.3 - Higher factors of safety may be required if drawdown occurs relatively frequently during normal operation	**Not provided**

* Not stated explicitly in NZSOLD 2000 – but commonly used in NZ

3.2 Seismic assessments

The assessment of the seismic hazard for a scheme is of critical importance in establishing various criteria for the structural stability of various components of a scheme. An assessment of seismic hazard is provided in Geotechnical Investigation for the Proposed Waianiwaniwa Water Storage Dam (URS, 2002). This outlines the seismic hazard both within and in the area surrounding the reservoir. In addition, a further outline seismic assessment is provided in the Dam Safety Assurance Report (URS, 2006). This includes a consideration of the nearby Hororata Fault, some 2 to 4 kilometres from the dam. However, the assessment of the possible seismic ground accelerations for a 1:150 Annual Exceedance Probability (AEP) event at the dam site is different in the two reports (0.31g – 2002 report and 0.28g – 2006 report).

The draft regulations to support the Building Act 2004 suggest that the methods for assessing seismic criteria for dams of high PIC are not applicable and that site specific studies may be required to determine suitable criteria. Consequently, a subsequent design phase might include:

- A more detailed seismic assessment to provide seismic criteria; and
- Given the importance of consequences of the outcome from such a seismic assessment, this assessment might reasonably be expected to be subject to external peer review.

3.3 Hydrology and hydrogeology

One of the critical design criteria for the safety of a dam is the assessment of the flood flow to be accommodated by the spillway(s). CPW indicate that the criterion for this scheme is the Probable Maximum Flood (PMF). There is considerable discussion within the profession on how the PMF should be estimated. The estimates from different methods can differ substantially. Approaches in the UK, USA and NZ differ for a number of reasons and the approaches adopted within New Zealand also differ. Therefore, one of the principal steps in deriving a flow estimate for the PMF is to establish the method to be adopted, and defining any other extreme condition that might contribute to the PMF.

The Dam Safety Assurance Report (URS, 2006) notes that the reservoir will form a substantial proportion of the total catchment, flooding a maximum of 12% of the catchment (Notice of Requirement, Urbis, 2006). However, an overview of the hydrological response of the catchment is not provided. A subsequent design phase might be expected to cover:

- Justification for the approach to adopted in deriving the PMF for the natural catchment contributing to the reservoir.
- Establishing any other conditions that might contribute to the flow to be passed through a spillway, such as a control failure on the intake canal from the Waimakariri River.
- Derivation of the PMF to be passed through the spillway as a consequence of the a PMF in the catchment, the water level in the reservoir and any other contributing conditions.

The hydrogeology of the reservoir also has a bearing on the safety of the dam. This relates to possible routes for water seepage through the foundations and around the abutments of the dam. Excessive seepage can lead to instability of the abutments or

the embankment itself. The Proposed Waianiwaniwa Water Storage Dam (URS, 2002) report suggests that:

- The assessment for the low permeability materials provided by CPW is based on experience in other catchments. However, the single Site Investigation result WN2 suggests that the permeability of this stratum is considerably higher. Further site investigations would be expected to clarify the extent and properties of materials present on the site. Such investigations could then provide substantiation to support a Building Consent application.
- The assessment by CPW of underground coal workings, which are possible seepage routes beneath the reservoir, are considered by CPW not to be "a significant likelihood". Further investigations might be expected to clarify the possibility of adverse seepage routes in greater detail. Greater certainty could then be provided and might reasonably be expected in documents supporting a Building Consent application.

3.4 Embankment arrangements

The proposed broad zoned embankment with internal filter and drainage zones is conceptually a robust approach to providing a stable embankment that is resilient to earthquake forces. However, the integrity of such dams is dependent on their details, which include both the embankment geometry and the foundation soil profile. The documents suggest that the proportions of the embankment are:

- Crest length 2 kilometres
- Crest width 10 metres
- Freeboard 2 t o 3 metres
- Outer side slopes of 1 vertical to 2.5 horizontal
- Total fill requirement of 5,494,500 cubic metres.

The documents suggest that the foundation conditions are anticipated to be:

- Loess deposits that are susceptible to settlement. These are to be excavated and removed, but the full extent of these deposits does not appear to have been explored
- Outwash gravels that are highly permeable
- Tertiary sediments
- Fault structures within the dam foot print are not anticipated.

Given the relatively steep gradient of the outer shell of the embankment, outline site investigation of the foundation materials and as yet unspecified geotechnical characteristics of the materials to be adopted in the embankment, a number of dam safety matters remain to be resolved by CPW. These relate to how the design will proceed, which might include:

- Further site investigation to prove the geotechnical nature of the foundations. The spacing between investigation holes and the type of site and laboratory tests is generally crucial in developing a reliable understanding of a foundation.
- A detailed assessment of the liquefaction potential of foundation materials.

- Stability analyses of the steep sided embankment configuration to assess the viability of the configuration and if necessary the alteration of the profile to meet stability criteria.
- Assessment of the seepage gradients below the dam foundation and the impact of these on the integrity of the proposed Slurry Concrete Bentonite cutoff trench.
- Assessments of the pore-pressures in the upstream shoulder of the dam during draw down of the reservoir. These pressures can reduce the stability of the upstream face of the dam. If the calculated factors of safety fall below the criteria adopted, alternative arrangements for the upstream shoulder might be considered. The Geotechnical Investigation of the Proposed Waianiwaniwa Water Storage Dam (URS, 2002) suggested that an upstream low permeability blanket at the upstream toe may be required.
- Filter compatibility between the various zones of the embankment are of crucial importance to the stability and safety of this type of dam. Investigations of potential material sources could be undertaken to establish particle size distribution curves and other properties of the materials for use in internal erosion assessments.
- The documents provide an estimate of the volume of different material types that might be required for the embankment. They also suggest possible sources of suitable materials for each zone. However, they do not indicate whether these materials provide filter compatibility. Nor do they indicate whether there is sufficient volume in the proposed borrow areas. Future studies would be expected to prove the source of suitable materials.
- The interfaces with the abutment formations are often critical for seepage control and the integrity of a dam of this nature. The reports imply that the spillway and the outlet tower will both be at or close to the left abutment. Subsequent design would be expected to outline the means by which seepage will be controlled at these difficult interfaces to preserve the stability of the dam.

3.5 Outlet tower

The arrangement of the water outlet from a reservoir generally has a profound effect on the safety of the dam as a whole. However, the documents do not provide any detail of the intended arrangement of the outlet tower or its potential interfaces with other elements of the dam. Nonetheless, the documents do suggest that the outlet tower will have water inlets to the tower at various levels to draw off the water of higher quality near the surface. The documents also suggest that the spillway may be incorporated within the same structure. In subsequent design phase the following might reasonably be resolved:

- Static and seismic stability criteria for the outlet tower.
- The route of the discharge conduit for the outlet, whether it is to be through the in situ abutment materials or within the foundation of the dam. Both arrangements have attendant dam safety considerations that would be addressed differently in a detailed design.
- If spillway arrangements are to be included within this outlet tower the design would necessarily consider air entrainment; air demand; prevention of

cavitation that might lead to damage of the outlet conduit and possibly compromise the integrity of the dam embankment.

3.6 Spillway and energy dissipater

The Dam Safety Assurance Report (URS, 2006) indicates that a spillway will be constructed on one of the dam's abutments and that this will be designed to accommodate the PMF. No general arrangement of this spillway is provided. The conceptual cross section of the embankment suggests that the spillway may be a surface structure on the face of the dam. By contrast, the text of the document suggests that it may be on an abutment, presumably the left abutment and discharge into the Waianiwaniwa River or headrace canal. Other statements in the reports suggest that spillway might be incorporated within the outlet tower.

The Dam Safety Assurance Report (URS, 2006) alludes to the use of a surface, open chute spillway with energy dissipater at the toe. It also states that the design will be augmented by either a computation flow dynamics model or a physical model. For a spillway of this height this is common. This notwithstanding, a future design phase might be expected to consider:

- Whether only one service spillway, or a combination of service and auxiliary spillways is to be adopted. There are different safety implications depending upon the arrangement adopted. In addition, if an auxiliary spillway is adopted an additional consent may be required for discharge of flow and possibly sediment discharge.
- The spillway could be a free overflow crest or a gated spillway. If gated the safety features incorporated in the control systems are important in achieving the desired level of safety. Normally, multiple backup systems using different modes of activation are provided for surety of operation if gated spillways are adopted.
- Typically the details of interfaces with the abutments and the embankment are crucial to the integrity of a dam of this nature.
- The Dam Safety Assurance Report (URS, 2006) suggests that even if a failure of the spillway dissipater were to occur "it is unlikely to lead to a dam breach". The effects of a dissipater failure are highly dependent upon the configuration of the dissipater and dam alignment. No details of the general arrangement are provided. Therefore, the future design would be expected to develop an arrangement that complies with this intention.

3.7 Spillway discharge channel

The documents suggest that the spillway may discharge to the remnants of the Waianiwaniwa River downstream of the dam or to the headrace at the dam's toe. However, the documents provide no justification for the capacity of either channel downstream of the dam site. Nor do the documents provide an indication for the ability of the channel to accommodate the design flow discharging from the spillway. Although a subsequent design phase would be expected to address this matter and confirm that the discharge can be safely passed down stream away from the dam, a resource consent may be required for such a discharge.

3.8 Summary

CPW presents a hazard assessment for the dam, using the commonly adopted technique of a dam break analysis, to determine that the dam is in the High PIC category; from which a number of design criteria are derived and these are consistent with New Zealand norms. In addition a low risk of dam failure is determined through a commonly adopted method. However, CPW does not present sufficient information to demonstrate that the arrangement of the dam and its appurtenant structures will achieve this assessment of low risk. Nonetheless, there are no apparent constraints in the ground conditions, seismology, hydrology and hydrogeology that would prevent adequate future studies and design from resolving these matters.

Although design matters might not be a constraint to the progression of the dam's design, insufficient information is provided by CPW to comment upon matters such as:

- Construction related effects such as traffic, noise and dust generation.
- Sediment control during construction.
- Remediation of temporary work areas.
- Containment of hazardous materials during construction.
- Surface water discharges and flood control both during construction and from the permanent works.
- Scour effects at the points of discharge from spillways.
- The shape, size and location of various structures which may have an effect on the visual environment.
- The effects on groundwater regimes from the dam.

4 Canals and ancillary structures

The project incorporates an extensive system of canals and ancillary structures to convey the water from the river intake to the reservoir and then distribute the water from the reservoir to the downstream farmland. The canal distribution network is extensive and complex. The Assessment of Environmental Effects for Resource Consent Applications to Canterbury Regional Council (URS, 2006) provides an outline of each of the major components.

There are two options for the water intake from the right bank of the Waimakariri River; the upper and lower intakes. The upper intake, which is preferred by CPW (Notice of Requirement, June 2006), permits water to be conveyed by gravity to the reservoir. The arrangement currently being pursued by CPW is a short canal from the upper intake prior to a long tunnel to convey water, by gravity, to the north-eastern arm of the reservoir. By contrast, the lower intake requires the water to be pumped to the reservoir.

The canal network, including approximately 400 kilometres of canals, downstream of the reservoir distributes the water to an area of 60,000 hectares. This proposed network includes control gates and bywashes as outlets for excess flows. All of the elements for the proposed works are common hydraulic engineering facilities that are commonly used in irrigation works. Consequently, the magnitude of risk and the effects of extreme events will be determined by the design and detailing of the works as well as procedures adopted in the operation of the scheme.

4.1 Failure risk and low probability effects

The application proposes, in lieu of a risk analysis, to adopt a fail safe operational control philosophy to minimise the potential for canal overtopping in extreme events (such as electrical failure in the region). Part of this philosophy is the inclusion of bywash outlets to discharge excess flow. In a subsequent design CPW suggests that a risk analysis may be undertaken to minimise the construction of these facilities.

Notwithstanding the general approach to minimising risk and maximising the safety of the system, the Building Act 2004 requires that canals be governed by the same regulations as those required for dams. Consequently, the design of the canals, their maintenance and operation will be scrutinised and approved by the regional authority for administering dams.

Consequently, the design of the canals should incorporate the same degree of safety that would be afforded to dams in similar circumstances; providing the commensurate protection to life and property.

However, CPW does not provide information on a hazard assessment for the canals, detailing where the most significant effects of a breach occur. Such an assessment would provide design criteria for the canals in different locations. In addition a risk assessment is commonly required to indicate the level of safety to be achieved in the design. Both a hazard assessment and risk analysis would normally be required for prior to the finalisation of consents.

4.2 Canals

The proposal indicates that the intake and distribution canals will be conventional excavated trapezoidal cross sections and, where necessary lined with low permeability natural soils or a geosynthetic membrane to prevent excessive water loss from the canal. Additional excavation through natural ground would be required along particular sections of the canal to maintain the gradient for flow in the canal.

Outline dimensions for the hydraulic section of the major canals are provided in the documents submitted by CPW. However, the consequences of canal embankment failure to assess possible effects and to determine design criteria governing their integrity and safety are not. In the subsequent design process the following, amongst other considerations, would typical be considered:

- Static stability of embankments and side slopes in normal and extreme conditions.
- Seepage from the canal for operational considerations and its affect on the integrity of the canal.
- Seismic stability under normal operating conditions. The seismic hazard assessments suggest that some of the canals will cross active faults in the region. Although there is no indication in the proposal of how or where the design of the canals will be modified in relevant sections to accommodate fault dislocation in the event of an earthquake, such details have been developed for other schemes in New Zealand.

The documents do not provide extensive detail for the canals to determine how potential effects will be mitigated. However, the subsequent design process and scrutiny by the regulatory authority through the processes of the Building Act 2004 will provide sufficient assurance that the canals will be implemented, maintained and operated satisfactorily.

4.3 Ancillary structures

The ancillary structures include river intakes, sediment excluders, fish screens, siphons to cross below river beds, and outlet structures (ten radial outlet gate structures). In addition bridges are to be constructed to carry roads and railways across the canal network at particular locations. Of these structures the two types of structure that affect the safety of the scheme and consequent effects on it surroundings are the reliable operation of the outlet structures and the long-term reliable operation of inverted siphons.

- An inverted siphon is proposed downstream of the upper intake on the Waimakariri River to cross the Kowai River. Inverted siphons can be vulnerable to washout in braided rivers if the depth of burial is insufficient. In high flows the beds of braided rivers can become mobile to a considerable depth and cause scour around structures such as inverted siphons. The proposal suggests that the depth of burial will be at least 3 metres, the actual depth of burial should be determined in subsequent design stages and assessed against the anticipated depth of scour.

  In addition, inverted siphons are also vulnerable to blockage by sedimentation where sediment is not been excluded from the upstream canal flow. The

proposals include sediment excluder structures upstream of the siphon on the Kowai River which should be designed to effectively remove sediment from the flow.

- The outlet structures from the distribution canal network provide for normal flow distribution and control as well as discharge of excess flow in extreme circumstances. Consequently the reliable operation of these facilities is important in protecting the integrity of network, particularly in extreme conditions. The proposed radial gate arrangement for these structures is common and, depending on the details, can provide a reliable means of flow control and discharge under extreme circumstances.

The proposals do not provide details of the ancillary structures. However, the concepts include structures that are commonly adopted in similar circumstances that can be developed in subsequent design stages to form a reliable system that minimises the risk of effects on the surrounding environment in extreme conditions.

4.4 Summary

CPW does not present a hazard assessment for the canal to determine safety criteria for the design of the canals in different locations. Nor does CPW provide a risk assessment for the canals or sufficient information to demonstrate that the arrangement of the canal will achieve a low level of risk. Nonetheless, there are no apparent constraints in the ground conditions, seismology, hydrology and hydrogeology that would prevent adequate future studies and design from resolving these matters.

Although design matters might not be a constraint to the progression of the canals' design, insufficient information is provided by CPW to comment upon matters such as:

- Construction related effects such as traffic, noise and dust generation.
- Sediment control during construction.
- Remediation of temporary work areas.
- Containment of hazardous materials during construction.
- Surface water discharges and flood control both during construction and from the permanent works.
- Scour effects at the discharges points from canal outlets.
- Effects at water intakes on rivers both during construction and during operation of the scheme.
- Hazards and risks associated with canal embankments that are above the surround ground level.
- The shape, size and location of various structures which may have an effect on the visual environment.
- The effects on groundwater regimes from the canals.

5 Long tunnel

CPW proposes a 10 kilometre long tunnel for conveying water along the majority of the route from the upper river intake on the right bank of the Waimakariri River to the reservoir. The upstream tunnel portal would be just downstream of the confluence between the Waimakariri River and the Kowai River. The assessment of this long tunnel is based on the following documents:

- Central Plains Water enhancement Scheme: Assessment of Effects on the Environment for Long Tunnel Option URS 13 March 2007
- Geological cross section Rev A URS Feb 2007
- Long Tunnel Designation Map 1 Rev B 12 March 2007
- URS letter "Notice of Requirement for Long Tunnel Application" 23 April 2007.

The lined tunnel is proposed to be 3.5 metres in diameter, with its upstream portal downstream of the Kowai River, and its downstream at the Waianiwaniwa reservoir. The depth of the tunnel below ground level will be a maximum of 200 metres below the Malvern Hills and a minimum of approximately 30 metres below the Hawkins River. The route passes through approximately 7.7 kilometres of the Woodlands Formation gravels, 1.7 kilometres of greywacke rock with significant fault zones and approximately 0.6 kilometres of gravel and weak sedimentary rock. Tunnels have been completed through similar ground formations in various locations around the world.

The tunnel option is proposed by CPW to avoid the impacts associated with a canal at the ground surface, particularly those of bulk earthworks during construction and the social impact of farm displacement and dislocation. By comparison, the long tunnel proposal now being pursued has less of an environmental impact during construction than the option of a canal across the countryside. In addition it probably has less of a long-term environmental impact on energy usage than pumping the water in a pipeline.

A deep lined tunnel, such as that proposed, provides a very low risk of failure and hence a low environmental effect, once it is operational. However, there are impacts associated with a tunnel option, which relate to the construction activities associated with a tunnel.

5.1 Construction method

Those sections of the tunnel that pass through rock could be constructed using a drill and blast method. However, a more likely approach to construction is that most, if not all, of the tunnel would be built using a tunnel boring machine (TBM). CPW propose a TBM with a balanced shield as the method of construction. A balanced shield provides a pressure against the tunnel face that matches the pressure exerted by the ground at the face. In so doing the method, in combination with modern tunnelling techniques provides, a low risk of failure of the tunnel face and consequent loss of ground that can be manifest as surface settlement. However, application's supporting documents do not address some of the effects that are often associated with a balanced shield TBM construction method:

- Water separation – The water and slurry used in the tunnelling operation does become contaminated with use. Consequently, some water is periodically discharged during normal operations. However, only sedimentation is proposed as the means of separating water from solid particles. There is no mention of additional treatment such as cyclones or belt presses to improve the extent of separation that can be achieved. In addition, the proposals should explicitly state the proposed discharge standards (oils and sediment concentrations) to be met for water discharge, nor the eventual route for discharge to the Waianiwaniwa River.
- The slurry tends to become contaminated with hydraulic oil from various parts of the machinery involved. The proposal does not explicitly state the type of hydraulic oils to be adopted (biodegradable or otherwise). Also the proposal does not estimate the quantity of slurry that might be lost into the surrounding formations, particularly the gravels, and their potential effects on the surface and groundwater environment.
- The disposal route for all fluids at the end of the construction period should be provided.

5.2 Construction activities

A tunnel construction requires surface facilities to support the operation, which includes both the mechanical and electrical equipment as well as facilities for an estimated peak workforce of 190. The proposal provides an estimate of 1 hectare for the construction site area. There are a number of activities and facilities that are required, some of which can be placed vertically one above another to reduce the land area required. However, the proposal does not provide sufficient information to assess whether the proposed area is adequate or not. In addition the proposal does not provide information on:

- Waste water treatment for the construction site sewerage.
- Discharge arrangements for waste water flows or their potential magnitude.
- Double containment arrangements for oils, diesel and other liquids, and surface water discharge arrangements from these areas.

5.3 Construction spoil

The spoil produced by a TBM is dependent on both the design of the TBM, its cutting head and the geological formation through which it passes. In some cases the spoil particles may be of sufficient size to be used as engineering fill. However, it might otherwise have a high fines content and high water content making it unsuitable as engineering fill. Without a performance specification for a TBM the nature of the spoil is not determinable. If there is excessive fines and water in the spoil a tailings dam may be required to accommodate the spoil.

The total volume of spoil to be removed is estimated to be 130,000 m^3 and the tunnel advance is estimated to be 20 metres per day. However, the water content of the spoil to be taken off site is not estimated and the consequent number of truck movements is not discussed. The total number of truck movements is a combination of spoil trucks, trucks carrying precast tunnel linings and other materials. Consequently the potential truck movements on the local road network around the site cannot be assessed.

5.4 Groundwater effects

The proposal provides an understanding of the shallow groundwater regime in the areas of the tunnel route, but notes that little is known of the deeper groundwater regime through which the tunnel will pass. The potential effects on the deeper groundwater regime are not estimated. Even if a balanced shield is adopted, there could be groundwater inflow to the tunnel. The potential temporary lowering of the groundwater regime should be estimated and presented.

The tunnel route passes below Hawkins River at a relatively shallow depth (the exact clearance depth is not stated but it is apparently less than the maximum tunnel depth). Justification for the statement that there will be no dewatering of surface waters should be provided.

5.5 Ground settlement

Based on the anticipated drawdown effect on the groundwater regime during construction, the potential settlement of the surface should be presented. Depending upon the results, consideration of mitigation works, particularly where the tunnel passes below state highways, should be provided.

Potential additional staging areas along the tunnel route are mentioned, but no details of their location, potential size or activities that will occur at the points are provided. These details should be outlined in sufficient detail for an environmental assessment of their effects.

5.6 Summary

The long tunnel proposal probably alleviates many of the environmental effects that would otherwise be presented by an above ground canal for much of the route from the upper Waimakariri River intake to the reservoir. In the absence of detailed subsurface investigation, modern tunnelling techniques and the use of a balanced shield TBM for much, if not all of the tunnel route, is probably a viable means of forming the lined tunnel. However, tunnels often encounter unforeseen ground conditions during construction that make conditions more difficult than envisaged at the outset.

Notwithstanding these possible difficulties, the information provided by CPW does not provide sufficient information to comment upon matters such as:

- Construction related effects such as traffic, noise and dust generation.
- Disposal of spoil from the tunnel.
- Sediment control during construction.
- Remediation of temporary work areas.
- Containment of hazardous materials during construction.
- Surface water discharges during construction.
- The shape, size and location of various temporary structures which may have an effect on the visual environment.
- The effects on groundwater regimes from the tunnel.
- The possible effects of ground settlement.

6 Proposed resource consent conditions for ECan consideration

The element of the scheme that presents the greatest single hazard is the dam. The effects and safety of other elements can be accommodated through processes and procedures that are commonly encountered and covered by the consent conditions proposed by CPW or similar conditions. Thus, given the lack of definition for the dam and its hazard category, the consent conditions relating to the dam warrant the greatest attention.

There are a limited number of proposed resource consents relating to the dam and reservoir which might impact their safety; their commissioning, construction and operation. These are (Assessment of Environmental Effects, 23 June 2006, 42156547.66140\AEE R001C):

- CRC 061845 Construction and maintenance of a dam
- CRC 061939 Creation of a reservoir
- CRC 061767 Diversion of waters during construction
- CRC 061945 Discharge of stormwater
- CRC 061975 Discharge of water from the reservoir to the headrace canal
- CRC 061948 Use and storage of hazardous substances.

The listed resource consents cover most of the primary aspects of the dam and reservoir. The discussion below considers the proposed conditions for the consents, with relevance solely to the safety aspects of the dam and reservoir. In addition, discussion is provided on the apparent omission of a consent application for discharges from the dam spillway.

6.1 Proposed conditions for resource consent CRC 061845

The proposed consent conditions for CRC 061845 address much of the proposed procedure for the design and operation of the dam, which includes safety matters for the dam. The conditions indicate that the dam will be designed, built and operated in "general accordance with the principles" presented in the technical documents. However, the documents provide insufficient details of the principles to be adopted. Therefore, the process for the development of the design, construction, commissioning and operation of the dam should be clarified in the final conditions.

The conditions should include sufficient detail covering the intended development of the dam's design and construction to provide assurance that the safety of the dam will be adequately addressed. In addition, for a dam of the proposed magnitude, the NZSOLD guidelines on dam safety (2000) indicate that an independent review of the design and construction is appropriate. For these reasons our suggested amendments to the proposed conditions identify a single individual with the responsibility for the dam's development and an independent panel of suitably qualified and experienced engineers to oversee the development of the dam.

The changes to the conditions we suggest are based on the premise that one named individual (which should transferrable on agreement by various parties), "The

Engineer", is responsible for directing the project from initial design to completion. This is not consistent with practice in New Zealand, but is similar to practice elsewhere, and is suggested here because of the magnitude of the scheme and current lack of project definition of the scheme. If this approach is not appropriate the suggested conditions below could be altered to reflect a desired project structure without compromising the intent.

The conditions we suggest presume that regulations and procedures will be in place to administer the provisions of the Building Act 2004 for dams. By making reference to the regional authority with respect to the Building Act 2004, these suggested conditions introduce the possibility that the conditions are imposing conditions beyond the powers of the consenting authority. Therefore, the conditions, if adopted in some form, should be reviewed for ensure that they are "intra vires" and conversely there are no conditions that are "ultra vires".

In addition, there are a number of anomalies and inconsistencies in the conditions proposed by CPW. These relate to:

- references to "chartered engineer". Under the IPENZ system of registration there is no such class of membership. The closest class is the "Chartered Professional Engineer" or CPEng.
- confusion of the purpose, terminology and order of Conditions 13, 14, 15, and 16. These refer variously to the:
  - "dam safety surveillance and monitoring plan"
  - "dam safety surveillance and monitoring report"; and
  - "dam safety surveillance report".

  There should be a "dam safety surveillance and monitoring plan" prepared and submitted prior to the commencement of reservoir filling. Secondly, reports reviewing the annual safety of the dam and reservoir, "dam safety surveillance report", should be submitted annually. These documents would become part of the Dam Safety Assurance programme required under the Building Act 2004.
- references to specific versions of the NZSOLD guidelines on dam safety are removed to allow for the possibility that the guidelines are amended.
- Item 1 – the reference to a Reduced Level of 283 metres requires clarification as to whether it is intended that this refer only to the crest of the main embankment or in addition to all the dam's appurtenant structures.
- Item 8 & 9 – the intent of the references to certificates is unclear and requires clarification. These may refer to Producer Statements required under the Building Act. If so, they raise issues of ultra vires. Alternatively, the intent may be that these are additional certificates to those required under the Building Act.
- Item 15 (a) –the destination of the continuous telemetry data should be clarified; whether it is intended solely for the applicant or in addition for reception by the regional council and others.

Given the number of suggested amendments to the conditions, all the conditions are repeated here and our suggested amendments highlighted:

Subject to the following conditions:

1 The dam shall be located at or about map reference NZMS 260 L35: 274-478, and shall not rise above a Reduced Level of 283 metres with respect to the Lyttelton Datum (1937).

2 For the purposes of this consent the regional authority is that authority administering the compliance of the Waianiwaniwa Dam with the Building Act 2004 and its attendant Regulations.

3 The design, construction**, commissioning** and operation of the dam shall be in general accordance with the principles as presented in evidence to the hearing and as contained in the technical documents provided to the Canterbury Regional Council in support of this application or as a requirement of a condition of this consent.

4 The consent holder shall inform the Canterbury Regional Council one month in advance of the intended commencement of construction activities.

5 The works referred to in Condition (2) above shall be implemented under the supervision of persons with appropriate experience in the supervision **of embankment dam development. With the approval of the regional authority (under the Building Act 2004), the consent holder shall appoint a single person with suitable experience in the embankment dam development as having overall responsibility for the development of the dam. This person shall have the title of "The Engineer". With the approval of the regional authority, The Engineer may be changed from time to time**.

6 The consent holder shall appoint an Independent Review Panel comprising persons of suitable qualifications, experience and expertise for the duration of the design and construction of the dam and associated works.

(a) The members of the Independent Review Panel shall have sufficient experience and expertise to cover all facets, in so far as they relate to dam safety, of the intended form of the dam and appurtenant structures.

(b) All members of the Independent Review Panel shall be independent of the consent holder's and Engineer's organisations.

(c) The consent holder shall appoint a Chairperson for the Independent Review Panel.

(d) Each and every member of the Independent Review Panel shall be appointed with the approval of the regional authority.

(e) The Independent Review Panel shall review, comment and provide recommendations on any aspect of the dam works that affect dam safety, which includes but is not limited, design, design process, construction details, construction methodology and materials.

(f) Prior to progression of the design or construction the Engineer shall respond to all recommendations to the satisfaction of the Independent Review Panel.

(g) The Independent Review Panel shall, from time to time, be provided by the Engineer with all information that may be pertinent to dam safety.

(h) The Independent Review Panel shall convene, at the discretion of the Independent Review Panel and in consultation with the Engineer, at intervals during the design and construction process that corresponds to critical points in the dam's development which shall include, but not be limited to:

(i) The commencement of design

(ii) At a time during the design process

(iii) Near completion of the design but before submission of the design to the regional authority for approval

(iv) At commencement of construction

(v) On exposure of the foundation of the design

(vi) During the construction of interfaces between the dam embankment and appurtenant structures

(vii) Immediately prior to the application for the Certificate of Practical Completion.

7 The quantity and quality of the construction materials shall be proved as part of the dam design process or the design of any subsequent works. The records shall form part of the dam design documentation or the design documentation for any subsequent works, **all of which are to be retained by the consent holder**.

8 The consent holder shall provide a certificate, signed by **The Engineer**, to the Canterbury Regional Council stating that the dam or any subsequent works on the dam has been designed in accordance with accepted civil engineering practice and is such as to meet the conditions of this consent.

9 On completion of dam construction or any subsequent works the consent holder shall supply a **C**onstruction **C**ertificate, signed by **The Engineer** retained by the consent holde**r**, to the Canterbury Regional Council stating that the dam and associated works have been constructed in accordance with the design referred to in Condition (8) above.

10 The consent holder shall ensure that erosion control measures are in place prior to the exercise of this consent and that all practicable steps are taken to prevent contamination of natural run-off by suspended solids during the construction period.

11 The consent holder shall forward a copy of the Certificate of Practical Completion together with a copy of the final '**As Built**' plans for any works undertaken to the Canterbury Regional Council.

12 The consent holder shall have particular regard to avoiding the stranding of fish in pools or river braids.

13 The consent holder shall be responsible for the structural integrity and maintenance of all works associated with the exercise of this consent and for any erosion control works that become necessary as a consequence of the exercise of this consent.

14 If, following a major flood, any auxiliary spillway requires reinstatement such reinstatement shall be carried out under Conditions (1) through (11) of this consent. **No material excavated from channels containing flowing water shall be used for reinstatement.**

15 **The consent holder shall provide a Dam Safety Surveillance and Monitoring Plan, signed by the Engineer,** to the Canterbury Regional Council one month prior to the commencement of the filling of the Waianiwaniwa Reservoir. This plan shall follow the guidelines set out in Appendix E of the New Zealand Dam Safety Guidelines, produced by the New Zealand Society on Large Dams, as appended to these conditions, and in addition shall **include, but not be limited to,** the following:

(a) continuous **telemetry** measurement of the turbidity and rate of the combined discharge from the internal drainage system;

(b) a weekly visual inspection of the dam;

(c) weekly monitoring of the rate of discharge from each individual drain and the piezometric pressure within the dam;

(d) a weekly review of the internal drainage flow data by a suitably qualified and competent dam engineer, with immediate review capability if alert levels are exceeded;

16 The **Dam Safety Surveillance and Monitoring Plan,** referred to in Condition (14), shall identify alert levels for key performance indicators and precautionary actions to be taken if alert levels are reached or exceeded. The key performance indicators shall include, **but not be limited to**:

(a) rate of discharge from internal drainage systems;

(b) indicators for internal erosion of the dam;

(c) turbidity of discharge from the internal drainage;

(d) the maximum normal operating level in the reservoir; and

(e) the maximum design water level in the reservoir.

17 A **Monitoring Report** shall be prepared by a suitably qualified dam engineer **at a frequency of no greater than** two months. The report shall be certified by the dam engineer and submitted to Canterbury Regional Council within the first five working days of the month following preparation of the report. The report shall include, **but not limited to**, the following:

(a) A review of the compliance or otherwise with the monitoring and review programme;

(b) analysis and interpretation of the monitoring data;

(c) **identification of any adverse trends**;

(d) **analysis of discharge rates from internal drainage systems;**

(e) **identification discharge rates from internal drainage systems exceeding historic maxima. These shall be cross related to corresponding reservoir levels;**

(f) **identification of any circumstances when records of turbidity and discharge rates from internal drainage systems increase by more that 10 percent over historic maxima for a continuous period of seven days**;

(g) **the occasions on which the maximum normal operating level and the maximum design water level for the dam has been exceeded;**

(h) warnings or observation of relevance to dam safety; and

(i) assessment of the dam's performance identifying deviation from acceptable limits as set out in the **Dam Safety Surveillance and Monitoring Plan** pursuant to Conditions **(15) and (16)** above.

18 An **Annual Dam Safety Report** covering the previous year to 31 March and prepared by a suitably qualified and chartered professional engineer shall be prepared and submitted to Canterbury Regional Council by the last working day in April each year. The report shall be accompanied by a certificate from the consent holder that in its opinion and following due inquiries it is satisfied that the report is properly issued. Where the consent holder is a limited liability company, the certificate shall be signed by the directors of the company. The report shall include the following:

(a) results of a physical inspection of the dam undertaken within the previous three months;

(b) review of monitoring data obtained in exercising Condition 17 for the year, and a comparison with data from previous years;

(c) details of any mitigating actions taken or incidents of significance to dam safety in the year;

(d) review of the performance of the dam with respect to safety, and confirmation that the dam is operating within acceptable limits and

(e) any recommendations of relevance to dam safety.

19 An Emergency Action Plan shall be prepared in accordance with Appendix F of the New Zealand Dam Safety Guidelines produced by the New Zealand Society on Large Dams appended to these consents, and shall include an inundation map for potential dam break scenarios. The approved shall be **submitted to Canterbury Regional Council one month prior to the commencement of the filling of the Waianiwaniwa Reservoir. The Plan, and any subsequent amendments, shall:**

(a) be prepared in consultation with Canterbury Regional Council, and Selwyn District Council; and

(b) be maintained in a current state at all times such that it is accurate as to personnel and procedures.

20 **A Safety Review Team shall periodically undertake a Comprehensive Safety Review report of the dam** in accordance with Appendix G and all other relevant sections of the New Zealand Dam Safety Guidelines, produced by the New Zealand Society on Large Dams and appended to these conditions. The report shall be provided to the Canterbury Regional Council within five working days of the report becoming available to the consent holder. A Comprehensive Safety Review shall be undertaken:

(a) at least every five years and

(b) as soon as practicable following an unusual event **that shall include, but not be limited to:**

(i) a major flood, a "major flood" is a flood causing the loss of the dam's spillway; or

(ii) a major earthquake, a "major earthquake" is an earthquake producing an estimated intensity at the dam of IX or greater on the Modified Mercalli scale.

21 Within one year of the issuance of the **Comprehensive Safety Review Report**, the consent holder shall provide the Canterbury Regional Council with a report:

(a) stating how the recommendations in the report of the safety review have been addressed;

(b) accompanied by a certificate by a **C**hartered **Professional E**ngineer that all recommendations contained in the safety review have been addressed; and

(c) Signed by the company's directors where the consent holder is a limited liability company.

22 This consent is subject to the conditions listed in Schedule 2: Administrative Conditions.

6.2 Proposed conditions for resource consent CRC 061939

The proposed conditions relate to the construction of the dam and its maintenance for a period of 35 years. The activities and responsibilities under the conditions overlap with those of Consent CRC 061845. For this reason, the references to monitoring in particular, should refer to the same defined Plans and Reports in the proposed amendments to the conditions for Consent CRC 061845.

Consent condition 4 and subsequent conditions relate to water quality and its monitoring. These conditions do not relate to dam safety therefore no comment is passed on these conditions.

Our suggested amendments are:

Consent conditions:

Condition 3 **The consent holder shall prepare a Dam Safety Surveillance and Monitoring Plan to measure and report on parameters that shall include, but not be limited to, the following**:

6.3 Proposed conditions for resource consent CRC 061767

The consent relates to the effect of the dam's construction on water courses downstream, the risk of flooding, erosion and stability of structures.

Note that in Appendix D of the AEE the proposed consent is repeated on pages 13 and 16. However, the wording appears to be identical.

The list of obligations is sufficient in so far as they relate to dam safety. Substantiation for the proposed methods to be undertaken by the consent holder to achieve these objectives will be required by the regional authority administering compliance with the Building Act 2004 and its attendant Regulations. Therefore, we suggest no amendments to the proposed conditions of this resource consent.

6.4 Proposed conditions for resource consent CRC 061945

The consent relates to the discharge of storm water and contaminants from the dam and reservoir, as well as other facilities of the scheme, for a period of 35 years. This appears to relate to the discharge from hard standing and other surfaces of the scheme.

Where, and if, storm water from such facilities affect the safety of the dam, their design, construction and maintenance the details will be addressed under the procedures outlined in the proposed amendments to the conditions for Consent CRC 061845. Therefore, we suggest no amendments to the proposed conditions of this resource consent.

6.5 Proposed conditions for resource consent CRC 061975

The consent relates to the normal discharge of water to the headrace canal for the irrigation network. The procedures outlined for the proposed amendments to the conditions for Consent CRC 061845 will address the physical and operational arrangement of this discharge in so far as the design, construction and maintenance might affect dam safety. Therefore, we suggest no amendments to the proposed conditions of this resource consent.

6.6 Proposed conditions for resource consent CRC 061948

The consent relates to the use and storage of hazardous substances during the construction of the dam and reservoir. The proposed conditions do not affect dam safety and therefore we suggest no amendments to the conditions proposed.

6.7 Other

A review of the various resource consents indicates that there does not appear to be a proposed resource consent or conditions to a consent that address discharges from the dam's spillway or spillways. The potential discharge from such a spillway arrangement is not quantified in the documents supporting the application. Nonetheless, they do indicate that the capacity of the spillway facilities will be designed to accommodate the Probable Maximum Flood. Also the documentation is not specific regarding the intended location for the discharge or their arrangement. However, one inference is that the spillway(s) will discharge to the remnants of the Waianiwaniwa River on the left abutment of the dam. An alternative inference is that such discharges will be to the headrace at the toe of the dam.

The proposed Natural Resources Regional Plan Chapter 6 (Bed and Margins of Lakes and Rivers" Objective BLR1 suggests that activities should avoid risk of flooding surrounding land. The documentation supporting the AEE does not indicate the flow capacity of the river. Therefore, a resource consent should stipulate the intended discharge point for the spillway and attendant conditions require justification for the capacity of the receiving channel to accommodate the intended maximum flow from the spillway.

7 Proposed Notice for Requirement conditions for SDC consideration

The Notice of Requirement for the Selwyn District Council relates to land use designation. The request itself does not relate to dam safety. Accompanying the notice are conditions proposed by CPW (Notice of Requirement, Urbis June 2006). All of these are concerned with activities and their environmental effects in the construction of the scheme. None affect dam safety directly.

There may be an area that has not been included in a request for Designation that should be on the basis of dam safety. The details of the area necessary cannot be determined on the basis of the information provided. However, the discharge from the spillway facility can be inferred from the documents provided to be on the left abutment of the dam and discharge into the remnants of the Waianiwaniwa River. The flows in the river course are likely to be diminished as a result of the construction of the dam. However, flows in a river course downstream of a spillway can rise rapidly as a result of discharges from the spillway. Therefore, there is often an exclusion zone along the margins of such downstream river courses to prevent developments that might otherwise be at risk of flooding. The Trust and the SDC might wish to consider this facet of the scheme in greater depth and define in the District Plan a margin along the river banks precluding future development.

8 Bonding issues

CPW has provided a draft of proposed conditions of a performance bond which can be imposed by councils under section 108A of the RMA. As indicted by CPW, the bond is intended to comprise two parts:

- Secure compliance with the conditions of resource consents for the duration of the consents and 10 years beyond their expiry.
- Ensure appropriate remediation of the land used by the scheme in the event of the scheme's demise.

The draft is provided is noted as being generic with the intent that the content would be finalised through the hearing process. Nonetheless, the indicated intent is to alter the value of the bond from time to time as the scheme progresses through construction to scheme operation to reflect the different circumstances:

- In the initial phases of construction the bond value would reflect the cost of reinstating the land.
- In the latter part of the construction, the value would reflect the cost of completing the scheme and putting it into operation.
- During the operation of the scheme the value would relate to the assessment of the risks arising from the operation of the scheme.

These intentions for the bond appear reasonable. However, in developing the final text for the conditions of a bond the following could be considered:

- The practicality of assessing and agreeing annually an amount for the bond during the construction phase. An annual assessment introduces a considerable risk that an agreement will not be reached within the time frames proposed. If this annual time frame is to be maintained, an arbitration clause should also be included to resolve the issue. Alternatively, a longer time frame between assessments and period for agreement could be adopted to match the practicalities of achieving continuous coverage of the bond.
- During the operation and post closure of the scheme the amount of the bond is to be determined by an assessment of the risks accruing from the operation of the scheme. Each event will have a different risk of occurrence and different consequential cost. Therefore the conditions for surrendering the bond or part thereof should reflect the type of occurrence and consequential cost. The bond conditions should reflect these circumstances and could usefully state the percentage of the consequential costs that are to be covered by the bond.

The development of the final conditions for the bond should reflect the intent of the bond and be capable of implementation. In addition the wording should be reviewed carefully to add clarity and minimise ambiguity.

9 Conclusions

The documents supporting the applications for resource consents and Notice of Requirement for Designation in the District Plan for the Central Plains Water Enhancement scheme provide insufficient information on which to base an appropriate assessment of whether the works will adequately mitigate potential effects or dam safety. Consequently, many of the matters than might normally be commented upon in assessing resource consents cannot be assessed; for example the following, which is not necessarily an exhaustive list:

- Construction related effects such as traffic, noise and dust generation.
- Sediment control during construction.
- Remediation of temporary work areas.
- Containment of hazardous materials during construction.
- Surface water discharges and flood control both during construction and from the permanent works.
- Scour effects at the points of discharge from spillways and canal outlets.
- Effects at water intakes on rivers both during construction and during operation of the scheme.
- Hazards and risks associated with canal embankments that are above the surround ground level.
- The shape, size and location of various structures which may have an effect on the visual environment.
- The effects on groundwater regimes from the dam, canals and tunnel.

Nonetheless, all the elements of the civil engineering works are common features to other irrigation projects in New Zealand and elsewhere. In addition, there are no apparent constraints in the ground conditions, seismology, hydrology and hydrogeology that would prevent adequate future studies and design from resolving the outstanding design matters. The canals, tunnels and other minor structures, as described by CPW, are common civil engineering structures that are unlikely to present a significant risk when designed and implemented in accordance with commonly accepted methods. The most substantial element of the works is the embankment dam for the storage reservoir. It is the dam that presents the greatest single hazard for the scheme, and it is this element that warrants the greatest attention in the resource consents to minimise risk.

Irrespective of the lack of information provided by CPW for the proposed scheme, further approval processes will be required before construction can commence; including the consents required under the Building Act 2004 for the dam and the canals. The processes for these consents provide further opportunities to scrutinise more advanced designs, ensure that appropriate measures are incorporated to mitigate effects of extreme events and that the works meet safety criteria.

CPW concludes that this dam would be assigned to the high Potential Impact Category under the NZSOLD Dam Safety Guidelines (2000). CPW also provides some of the criteria that the design will incorporate. These criteria are compatible with the guidelines for a High PIC dam. However, the documents do not detail the measures to be incorporated within the works to meet these criteria. Nor do they

provide detailed procedures for the design and implementation of the works in subsequent stages of the project.

Consequently, the consent conditions should be drafted to provide sufficient reassurance to the various authorities administering the development of the project that appropriate dam safety measures will be incorporated into the design and implementation process. The relevant consents and proposed conditions have been reviewed and our suggestions for redrafting of the conditions for particular clauses provided herein.

The matters of greatest relevance to dam safety are:

- Resource consent CRC 061845. The conditions for this consent form the majority of the formal process for the development of the dam and reservoir. These conditions could be enhanced to require a process that is more inline with the NZSOLD guidelines. In addition, parts of the conditions should also be redrafted to clarify the intent of some of the conditions.
- The location and discharge channel from the spillway for the dam is not well defined in the supporting documents and this lack of clarity is reflected in the proposed resource consents and Designation. Consequently, the public safety aspects of the potentially high discharges from the spillway should be clarified in a resource consent for the discharge and perhaps in the area of Designation.

The generic draft for a bond reflects a reasonable approach in that the amount should reflect the stage of the project and the work to be covered if called upon. However, the development of the final conditions for the bond should be capable of implementation. In addition the wording should be reviewed carefully to add clarity and minimise ambiguity.

10 Applicability

This report has been prepared for the benefit of Selwyn District Council and Canterbury Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

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