1 Intro

- My name is Tim Morris. I am a Chartered Professional Engineer employed by Tonkin and Taylor. I specialise in dam engineering.
- Environment Canterbury has engaged Tonkin and Taylor to provide advice on civil engineering aspects of the proposed dam storage.
- The advice is set out in two memos to ECan, as well as the joint witness statement of 28 March 2018.
- I will now outline some key issues arising from our assessment as described in our advice to you.

2. Key issues

- I use the joint witness statement as a starting point for my comments.
- From a civil engineering perspective The New Zealand Dam Safety Guidelines are the appropriate baseline for the dam to be assessed against.
- The Guidelines are based on a number of key principles. I will read Principle 1:

  Principle 1 – The consequences of a dam failure should be understood so that appropriate design, construction and management actions can be applied to protect people, property and the environment.

- The Guidelines also state that "The potential consequences of dam failure may include loss of life, injury, damage to infrastructure and property, damage to environmental values, and economic and social impacts".

- We have found that there is uncertainty in the present Stantec estimate of Population At Risk, Potential Loss of Life and damage arising from a hypothetical dam break scenario.
- Population at Risk is all individuals within the zone of potential inundation defined as the area where depth of water may exceed 0.5 m.
- An estimate of Potential Loss of Life, based on the method used by Stantec, is directly proportional to the Population at Risk estimate and the Depth Velocity parameter.
- We have found that the Population at Risk is uncertain. For example at one point the PAR is stated by Stantec to be "*more than 100*". Whereas, elsewhere, values of 80 and 100 are reported. These exclude itinerants. These values appear to have been used to estimate Potential Loss of Life. Increases in Population at Risk, for example to account for itinerants, may increase Potential Loss of Life estimates. This uncertainty is significant.
- We take the view that the estimate should be more precise and include specific consideration of itinerants.
- There are recognised techniques to determine these estimates.
- Slides
- The slides illustrate Stantec DV estimates.
- Depth Velocity is the depth of flow multiplied by the flow velocity. We have found that the information has been presented at a scale that is too coarse. That is, these data lack detail. We cannot understand the particular DV estimate at a specific location. For example at a particular individuals dwelling.

- It is difficult for individuals downstream of the proposed dam to understand potential effects in the event of a dam break event.
- Moving on, we do not consider that an assessment of Potential Loss of Life is limited to differentiating between Medium and High Potential Impact Category.
- An estimate of Potential Loss of Life is used to understand effects as outlined in Appendix A of the 27 April memo, and to inform Emergency Action Planning.
- Matters relevant to the EAP include the area subject to evacuation and sequencing of evacuation as well as matters such as potential for cascade failure.

3. Evidence from others

- Table 1 from our 27 April memo comments on aspects of evidence relevant to our scope of work.
- Key matters relate to the following:
  - Based on the Guidelines, there is a need for a Dam Safety Management System for the canal enhancement works.
  - Consideration of canal capacity downstream of the bifurcation to the proposed dam, given the potential for an additional 10 m^3/s flow.
  - Population At Risk, damage and Potential Loss of Life as already discussed.
  - Based on evidence of 28 March, there is a need to amend proposed resource consent conditions. I note that this has recently been progressed. I will come to these later.

4. Emergency Action Plan

- We received an amended Emergency Action Plan, revision number 7, on 3 May. Yesterday.
- We have assumed that this is identical to the revision 5 except where indicated otherwise by track changes and our comments are made on this basis.
- This Emergency Action Plan refers to amended proposed draft resource consent conditions. I will come to these later.
- Section 6.6.1. Amendments to Table 5.1. In a genuine emergency the basis of including the likes of Jet Boating New Zealand is unclear. In an emergency situation the focus necessarily needs to be evacuation of individuals at imminent risk. In a genuine emergency NZ Police will be tasked with this responsibility. Initially, it will be more or less up to the Police, with the EAP informing their work. As an example it is difficult to see the value in contacting Jet Boat NZ in these circumstances. Some consultation with NZ Police appears to be appropriate.
- Section 6.6.2. It is appropriate to outline requirements for material to have on hand. However, quantities require some further thought. For example, based on my July 2017 experience fifty sandbags is insufficient. Hundreds may be required.
- The draft EAP is incomplete. We acknowledge that this is because the design is incomplete. It is very important that, if consent is granted, that the operative version is in accordance with the NZSOLD Guidelines and the proposed draft consent conditions. There is provision for a certification process.

5. Proposed consent conditions relating to dam engineering

- The 27 April memo refers to consent conditions dated 28 March, current at the time of writing.
- These matters were discussed with Stantec and David Greaves on 24 April.
- Three iterations of proposed consent conditions have been received since that meeting. The 1 May revision relates to the dam only.
- The last comments were provided on 2 May. Most matters discussed on 24 April have now been incorporated into the proposed conditions. Remaining comments mostly relate to matters such as incomplete definitions and inconsistency of references.
- I understand you have these comments. There is substantial agreement on the conditions.
- Further to the 2 May comments:
- Condition 10 considers height of the proposed dam. We understand that the proposal is the same and 31.5 m rather than 30.5 m arises because of ambiguity in the engineering report. That is the arrangement is the same as assessed. For example in regard to volume and dam break scenarios.
- Condition 12 addresses certification. We have commented that 12A. a. requires clarification in regard to design certification including the timing provision.
- Condition 0 includes a definition for "*Certifies and certification*". Regarding this definition, it is recommended that the words "the NZSOLD requirements" are replaced with a reference to Condition 12.

- Proposed consent conditions for the canal enhancement were not included in conditions received 1 May.
- I am now happy to respond to questions.

Tonkin+Taylor

Memo

To:	**Environment Canterbury, Attn: Natalia Ford**	**Job No:**	**51344.012**
From:	**Tonkin and Taylor Ltd.**	**Date:**	**27 April 2018**
Subject:	**Review of resource consent application to dam water in a large water storage facility and modify a canal by Rangitata Diversion Race Management Ltd.**		

Natalia,

Further to recent discussions and as requested, please find below a summary of:

- Key points of interest from relevant evidence provided by ECan to T+T regarding dam engineering.
- Comments on proposed resource consent conditions recently proposed by Mr David Greaves.

It is intended that this memo is read in conjunction with our memo to ECan dated 7 March 2018 (further copy accompanying this memo).

1 Introduction

A key unresolved technical issue that has not been agreed between the parties relates to uncertainty in estimates of Population at Risk (PAR) and Potential Loss of Life (PLL). These are two potentially very significant effects of a dam break event. These uncertainties may mean that the potential effects of a dam break situation are not as well understood as they may otherwise be.

It is important to recognise that the New Zealand Dam Safety Guidelines (the Guidelines), the baseline that the project should be assessed against, are based on several key principles. Principle 1 is repeated below:

Principle 1 – The consequences of a dam failure should be understood so that appropriate design, construction and management actions can be applied to protect people, property and the environment.

The Guidelines also state that ***"The potential consequences of dam failure may include loss of life, injury, damage to infrastructure and property, damage to environmental values, and economic and social impacts".***

Clearly appropriate understanding of PAR and PLL is therefore essential in order to understand effects. **Tables A1 and A2 included in Appendix A provide some more specific context regarding the requirements of the Guidelines.** Table A1 relates to the RMA process.

2 Qualifications and experience

Tim Morris is a Senior Civil Engineer and Project Director, with twenty years industry experience. In addition to numerous dam safety inspection roles, Tim has managed or contributed to investigation stages as well as detailed design and construction of many hydroelectric and irrigation projects. Projects often involve complex water storage and distribution infrastructure; including schemes featuring intakes, canals, pipelines and dams of various types.

Tim is a Chartered Professional Engineer (CPEng.) and a member of the New Zealand Society On Large Dams (NZSOLD). Prior to discontinuation of the register, he was a Category A Recognised Engineer. Tim has led or contributed to numerous dam inspections and safety review projects for Low to High or equivalent Potential Impact Category (PIC) dams.

In addition, Tim has substantial review experience with input into many major projects involving multifaceted water storage and transmission infrastructure. Some examples include various stages of the Central Plains Water scheme, Deep Stream hydroelectric project and the Akarana Pond presently under construction. Tim has also acted as expert witness for the EPA board of inquiry considering the application for resource consent for the Ruataniwha Water Storage project.

Tim has led and undertaken the majority of the assessment of dam engineering aspects of the application as outlined in this memo.

3 Evidence prepared by others supplied to T+T

We have read and commented on evidence provided by the following individuals:

- David Barrell – geology and fault lines.
- Dr Graeme McVerry – seismic effects.
- Steven Woods – engineering report. Two versions have been provided.
- Nathan Fletcher – dam break.
- Bryan Peters – construction methodology (T+T comments only as relates to dam engineering and excluding other matters such as erosion and sediment control, traffic, noise and dust).
- Paul Morgan – construction (T+T comments only as relates to canal upgrade and excluding other matters such as kayak course and fish screen). Two versions have been provided.

Set out in Table 1 are our comments on the evidence prepared by these individuals.

Table 1 Comments on evidence

Item	Paragraph reference	Description
1.0	**David Barrell – geology and fault lines**	
1.1	All.	Further to our 7 March memo[1], we have no additional comments on the provided evidence regarding this topic.
2.0	**Dr Graeme McVerry – seismic effects (KSD)**	
2.1	57	We do not necessarily agree with the comment that it "*is not common to consider vertical earthquake motions in engineering design*". The Guidelines include requirements to consider vertical accelerations in certain circumstances. Also, in this instance this matter may be of interest in regard to the liner and estimated crest displacement. That said, this is a matter best considered at detailed design.
2.2	65	Dr McVerry concurs with the comment from our 7 March memo that "*a number of matters may require further work as part of the detailed design.*"
3.0	**Steven Woods – engineering report**	
3.1	3.5, 6.15 & 6.16	At this point specific details of the inlet and gate arrangement are unclear. This matter will require further work. It is appropriate to address these matters at the project detailed design stage, so long as facilities to High PIC standard are provided.

[1] Tonkin & Taylor Ltd; Review of resource consent application to dam water in a large water storage facility and modify a canal by Rangitata Diversion Race Management Ltd.

Item	Paragraph reference	Description
		Based on the application we recommend that there are consent conditions to: • Limit inflow/diversion from the RDR canal to the proposed Klondyke Storage Dam (KSD) to 40.7 m^3/s. • Provide the spillway arrangements described in the application to High PIC standard. • Ensure that the necessary freeboard criteria are provided during extreme events.
3.2	3.6	The application has been assessed on the basis that there will be two low level reservoir outlets available to dewater the reservoir. Previously one was also to be used for sediment flushing. Mr Woods indicates that approval for sediment flushing is no longer sought. It is important that appropriate low level out facilities are provided that have adequate dewatering capacity. It is important that the gully channel is appropriately designed and constructed (e.g. rock channels on steep slopes can be problematic and the design flow rate is suitable and takes account of the various flow combinations variously arising at the head of the gully in an extreme event). Mr Woods outlines how appreciable volumes of sediment may accumulate within the KSD. At this stage it is unclear how the facility will be designed and operated to prevent entrainment and release of sediment by way of the low level outlets. For example, operation of the low level outlets at a future time when an appreciable volume of sediment has accumulated within the storage at a time of low reservoir level. There may be some value in clarifying what concentration of suspended sediment in a discharge constitutes flushing.
3.3	3.7, 6.17	Mr Woods refers to a situation that may involve water spilling from the proposed KSD back to the RDR. We commentated in our memo that Stantec/MWH acknowledged that the capacity of the RDR downstream of the proposed KSD to RDR spillway points was subject to checking. It is important that this work occurs, for example, during detailed design.
3.4	5.5	It is important that the stability and potential retreat of the terrace riser is appropriately considered by the Dam Safety Management System including as part of the Intermediate and Comprehensive Dam Safety Review process and following major Rangitata River flood events.
3.5	6.3 & 6.4	It is worth noting that the selected liner must be capable of accommodating estimated embankment displacements.
3.6	6.26 – 6.31	Possible pond staging is considered by these paragraphs. Staging is not covered by the MWH/Stantec engineering report. Arrangements presented appear to be options rather than stages. Options included in Appendix D feature the same invert level as the 53 Mm^3 option that is the subject of the engineering report. Based on high level information included in the evidence, in a general sense engineering issues appear more or less similar to the 53 Mm^3 option that is the subject of the engineering report
3.7	6.35	It is important that the low level conduits are not under pressure/open channel flow exists in the conduits.
3.8	9.3	We do not agree with all of the daft resource consent condition changes proposed by Mr Woods. Refer to section 4.0 of this memo for further clarification. These matters were discussed with Mr Steven Woods, Mr Nathan Fletcher and Mr David Greaves on Tuesday 24 April and are discussed further in Section 4 of this memo.

Item	Paragraph reference	Description
4.0	**Nathan Fletcher – dam break**	
4.1	various	There is liberal use of the phrase "worst case" and/or "critical scenario". While the circumstances described by Mr Fletcher are generally an appropriate basis for assessment, they are almost always not the "worst case" in the strict sense. For example, different potential breach locations may result in different "worst case" scenarios for different individuals and/or members of the public. Also, whilst improbable, coincident Safety Evaluation Earthquake and Inflow Design Flood events are possible.
4.2	4.6	It is worthwhile to clarify that the failure modes workshop on 6 November 2017 was undertaken subsequent to the dam break analyses. That is it was not a basis to inform the dam break study. Our attendance at the potential failure modes workshop was considered to be in the capacity of observer status only.
4.3	4.14	This paragraph addresses the matter of the KSD spillway arrangements. As mentioned above, we consider that it is appropriate to include a consent condition requiring an auxiliary spillway and controls to limit any inflow to the KSD from the RDR to not more than 40.7 m^3/s.
4.4	4.25	The explanation of roughness values discussed differs a little from that described in the dam break study.
4.5	5.3 5.8	**Whilst estimation of PLL involves some uncertainty there are recognised methods and techniques available to quantify this estimate.**
4.6	5.5 5.13	**Mr Fletcher advises in paragraph 5.5 "*I have assumed a PAR of more than 100 as a worst case*". This PAR estimate is at odds with Mr Fletcher's paragraph 5.13, where Mr Fletcher advises PLL estimates of 1 and 2 respectively. This is because the PLL estimates of 1 and 2 apparently correspond to PAR values of 100 and 80 for the southeast and west scenarios that he has adopted, as outlined in the MWH/Stantec letter of 1 September 2016. Clearly PAR values of 80 and 100 are not more than 100.**
4.7	5.9	**The PLL parameter is used for matters other than differentiating between Medium and High PIC.** Arguably, consideration of the quote provided by Mr Fletcher alone, may be taking the NZSOLD guidelines out of context. For example, as described by NZSOLD (and further to Principle 1 of the Guidelines outlined on page 1 of this memo: • *"consequence assessments assist Owners in emergency planning and preparedness, in understanding the risks posed by the presence of the dam, and in developing risk reduction measures to address unacceptable risks"* • *"The potential consequences* (of the release of stored contents) *are:* - *Injury or loss of life.* - *Damage to property and infrastructure.* - *Damage to the environment.* - *Social and economic disruption."* • *"Assess Population at Risk (PAR) and likelihood of injury or loss of life for each breach scenario (or Potential Failure Mode for Comprehensive)"* • *Dam-break flood hazard and consequence assessments are also useful in:* - *Emergency planning and preparedness, by identifying the potential consequences of failure and response actions to avert failure or mitigate the consequences of failure (refer Module 6: Emergency Preparedness).* - *Understanding the risks posed by the presence of the dam, and developing rehabilitation works to reduce any unacceptable risks."* It is our view that the risks posed by the KSD are directly proportional to PAR and PLL, and it is necessary to have a good understanding of these parameters to understand these risks. Refer to Appendix A for further discussion.

Item	Paragraph reference	Description
4.8	5.11	**We do not consider the PLL estimate undertaken by MWH/Stantec to be as thorough as it should be.** PLL is proportional to two considerations that we consider to be unclear: • PAR – this is uncertain as outlined. • Depth velocity or DV (as presented in the MWH letter of 1 September 2016, also depth per Appendix B of the draft EAP) – the scale of the presented data is too coarse to clearly understand the hazard at specific locations, a finer scale is recommended.
4.9	7.13	The topics covered during expert conferencing were certain paragraphs from the T+T memo of 7 March 2018. For example, the 7 march memo does not specifically consider potential resource consent conditions.
4.10	8.10	We do not agree with all of the daft resource consent condition changes proposed by Mr Fletcher. Refer to section 4.0 of this memo for further clarification. These matters were discussed with Mr Steven Woods, Mr Nathan Fletcher and Mr David Greaves on Tuesday 24 April and are discussed further in Section 4 of this memo.
5.0	**Bryan Peters – construction methodology (T+T comments only as relates to dam engineering and excluding other matters such as erosion and sediment control, traffic, noise and dust).**	
5.1	All	Further to our 7 March memo[2] and the provided evidence, we have no additional comments on this topic. The 7 March memo notes that consideration of important matters related to the necessary construction diversion works could be included in the Construction Management Plan to an appropriate level of detail that recognise dam safety risks. The construction diversion works include diversion of the RDR around the proposed gate structure and diversion of the Mayfield Hinds Irrigation main race.
6.0	**Paul Morgan – construction (T+T comments only as relates to canal upgrade and excluding other matters such as kayak course and fish screen).**	
6.1	13	We do not necessarily agree that the Guidelines do not provide Guidance on freeboard for existing embankment dams. We have observed that Mr Morgan has nominated 0.5 m freeboard that he advises is for the purposes of his preliminary assessment. It is important that uncertainty with the modified canal freeboard is resolved during detailed design and freeboard takes appropriate account of unusual occurrence situations (for example malfunction of the Rangitata River gate).
	20	There is some uncertainty about how the intake to the dam will be arranged. Consequently there are likely further appurtenant structures additional to the three described. For example structures to accommodate discharge from the RDR canal of the additional 10 m^3/s if flow passes down the RDR past the proposed dam and/or flow is diverted from the dam to the RDR.
	29	Individuals in proximity to the river bank are not necessarily limited to fishers.
	32	Mr Morgan indicates he does not consider that a Dam Safety Management System is required for the modified canal. We do not agree. **We agree with Ms Ford and are of the view that a Dam Safety Management System is appropriate for the modified canal.** This may include provision for inspections similar to those that are reported to occur at present, albeit modified to take account of the proposed modifications to the canal. For further clarification please refer to Item 10 and Condition 11A.2 from Table 2 following.

[2] Tonkin & Taylor Ltd; Review of resource consent application to dam water in a large water storage facility and modify a canal by Rangitata Diversion Race Management Ltd..

4 Comments on potential resource consent conditions for CRC170657

We have been asked to comment on potential conditions to proposed resource consent CRC170657 that relate to dam engineering matters that have been suggested by Mr David Greaves[3].

The conditions proposed by Mr Greaves build on other prior correspondence between the parties. The following comments on dam engineering matters are mostly limited to late amendments recently suggested by Mr Greaves. Other potential conditions suggested by Mr Greaves to proposed resource consent 170657 that relate to other issues, for example: planning, water quality, insurance, ongoing engagement, administration and waterfowl, have not been considered by T+T. All these other non-dam engineering related matters are excluded from Table 2. All other aspects of Mr Greaves' evidence are also outside of our scope and have not been read.

The matters listed in Table 2 were discussed with Mr Steven Woods, Mr Nathan Fletcher and Mr David Greaves on Tuesday 24 April.

Table 2 Comments on suggested conditions to proposed resource consent CRC170657 that relate to dam engineering matters.

Item	Condition	Issue	Comment
1	Various	References to other conditions.	Various conditions contain references to other conditions that appear to be incorrect.
2	Various	Completeness of abbreviations and defined terms.	The glossary proposed by Mr Greaves appears incomplete. Also, "*RL*" refers to reduced level and not the true right hand side of a river.
3	Various	Scope of proposed consent and PIC of the dam and canal.	The consent title now has the words "*and associated modifications to the RDR canal*" added, whereas previously the consent was to "*dam up to 53 Mm^3 of water*". The applicant has assessed that the dam storage is High PIC and the modified canal is Low PIC. **It is unclear if the proposed consent conditions (inadvertently) applies High PIC standards to the modified canal**. For example proposed conditions 29 through 35. We suggest that this matter should be clarified. Inadvertent application of High PIC standards to the canal may result in unnecessary cost to the applicant. From a dam safety perspective we recommend that **the consent dealing with the canal modification includes a condition to limit the maximum possible diversion from the modified RDR canal and inflow to the proposed dam to 40.7 m^3/s**. This advice is further to the 7 March memo.
4	0, 0A.1, 6, 12, 15, 18, 31 & 40	Certification process.	If consent is granted it is appropriate that key aspects of the project are appropriately certified by an independent expert and evidence of that certification be provided to ECan. Conditions recently proposed by Mr Greaves include significant changes to the certification process, and appear to be contradictory and/or overly complex and/or

[3] Greaves; statement of evidence of David John Greaves; 28 March 2018.

Item	Condition	Issue	Comment
			inconsistent with other broadly similar resource consent conditions. We suggest that the words *"as agreed between the Consent Holder and the certifier"* are not added to 12 d. **As discussed with ECan, there is still work required to clarify specific and clear requirements for a certification process.** Aspects of the project, including both the canal modification and dam storage, that require certification include: • Design including necessary investigations to inform the design. • Construction prior to the commencement of first filling. • Water Storage Commissioning Plan. • Dam Safety Management System (including, from time to time revisions to the Dam Safety Management System). • Emergency Action Plan (including, from time to time revisions to the Emergency Action Plan).
5	1B	Scope	Annexures have not been sighted.
6	6	Peer review and staging	Item 4 above addresses certification. Mr Greaves proposes replacing a condition for certification with a condition on staging. The proposed condition to accommodate staging is not inappropriate.
7	9	Maximum volume and water depth	We recommend that **a consent condition to limit the maximum possible inflow to the proposed dam to 40.7 m^3/s from all sources other than rain fall directly on to the reservoir**. This advice is further to the 7 March memo.
8	10	Size of dam and depth of water.	**We do not agree with the changes proposed by Mr Greaves**. The condition without the suggested alterations is entirely consistent with the proposal described by the applicant. Based on information provided, all three options for staging of the project (MWH/Stantec drawings C005, C016 and C204) have an invert level at 337.0 m RL, consistent with the condition initially proposed. We expect that the final design will include nominal slope on the dam floor. In regard to the dam invert, for clarity and to address Mr Greaves' concerns, it is appropriate to add to 10 c. in lieu of the change suggested by Mr greaves and after the words *"337 metres RL" "except locally in the immediate vicinity of Appurtenant Structures."* Also, to alleviate the applicant's concern about uncertainty in survey data in regard to dam height, it is not unreasonable to replace *"shall not exceed*

Item	Condition	Issue	Comment
			30.5 m" with *"shall not exceed 30.7 m"* i.e. provision for a tolerance of 0.2 m.
9	11	Spillway	We suggest a consent condition to provide the spillway arrangement, comprising two separate spillway structures from the dam to the RDR and the Rangitata River, as described in the application. This advice is further to the 7 March memo.
10	11A.2	Canal modification.	This is the only condition that appears to make specific reference to the canal modification. It is our view that while visual inspections are appropriate, **a Dam Safety Management System is required.** This view is consistent with the NZSOLD Guidelines even if the PIC is Low. For example **Principle 5 of the Guidelines** repeated in Module 5 section 1.1 states that "**A dam safety management system, commensurate with the consequences of dam failure and incorporating policies, procedures and responsibilities, should be in place for all dams.**" It I also stated that "*This Module is applicable to the safety management of dams, ranging from small Low PIC dams through to a portfolio of Medium or High PIC dams on a river system.*" That said, it is important that the DSMS be appropriate to the type, size and PIC of the dam. It is unclear how the existing inspection regime will take account of all modifications, for example new engineered fill. The inspections mentioned by Mr Morgan in his paragraph 33.2 should be included in the Dam Safety Management System. It is also appropriate that the channel of the canal side spillway has appropriate durability and this should be assessed and, if required, modified (in addition to crest level and width modification).
11	19	Commissioning	We do not agree with the proposal to delete proposed condition 19 b. We suggest that this condition is retained although it may be appropriate to replace the word "*procure*" with "*ensure*" or "*make best endeavours to ensure*"
12	30 g.	Dam Safety Management System	We suggest that the consent conditions include provision for a seismograph to be installed at a suitable location at the dam site. The main purpose would be to inform assessment of dam performance relative to particular recorded accelerations. This advice is further to the 7 March memo.
13	30 j.	Dam Safety Management System	Mr Greaves suggests the work "*Annual*" is deleted. Instead, we suggest that "*Annual*" is replaced with "*annual*".
14	32	Dam Safety Management System	It is our view that it is appropriate to review the DSMS in the event:

Item	Condition	Issue	Comment
			• That trigger/design level events are exceeded i.e. recorded dam performance of the dam is beyond that predicted by the design. • Within three months of first filling to take account of commissioning experience. • Coincident with the CDSR as mentioned by Mr Greaves.
15	35	Dam Safety Management System	We agree the minor wording change is appropriate.
16	36, 38	Emergency Action Plan	Reference to Timaru District Council has been added.
17	39	Emergency Action Plan	We prefer that the reference to peak velocity is retained. The proposed reference to the District and Regional plans is noted. However, we suggest that "*or*" is replaced with "*and/or*" as relates to the three plans now mentioned.

5 Applicability

This report has been prepared for the exclusive use of our client Environment Canterbury, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Memo prepared by:

Tim Morris (CPEng, CMEngNZ)

Senior Civil Engineer

Authorised for Tonkin & Taylor Ltd by:

Peter Cochrane

Project Director

27-Apr-18
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Appendix A: Some relevant guidance from the New Zealand Dam Safety Guidelines

Table A1 Summary of some guidance provided by and outlined in Module 1 – Legal Requirements from The New Zealand Dam Safety Guidelines (May 2015)

Item	Section	Page number	Guidance	Comment
1	3.2 The Resource Management Act (1991)	10	*"**Dam safety planning for new projects starts with the assessment of potential effects, their likelihoods of occurrence and how to design for them to a standard society will accept via the RMA process**. It is important to recognise the hazards and risks which apply during construction of the dam and during the long term in-service condition."* NZSOLD also state *"hazard is related to the potential for damage, and risk is related to the probability and consequence of that potential being realised."*	The Guidelines outline requirements to address during the resource consent process for a large dam project. These include the downstream effects of a potential dam failure. The effects include PAR and PLL.
2			*"**Typical design, construction and operation issues that need to be addressed in consent application documents include*** (among others): • ***The downstream effects of a potential dam failure** and strategies for emergency management should the integrity of the dam be in doubt."*	

Table A2 Summary of some guidance provided by and outlined in Module 2 – Consequence Assessment and dam Potential Impact Classification from The New Zealand Dam Safety Guidelines (May 2015)

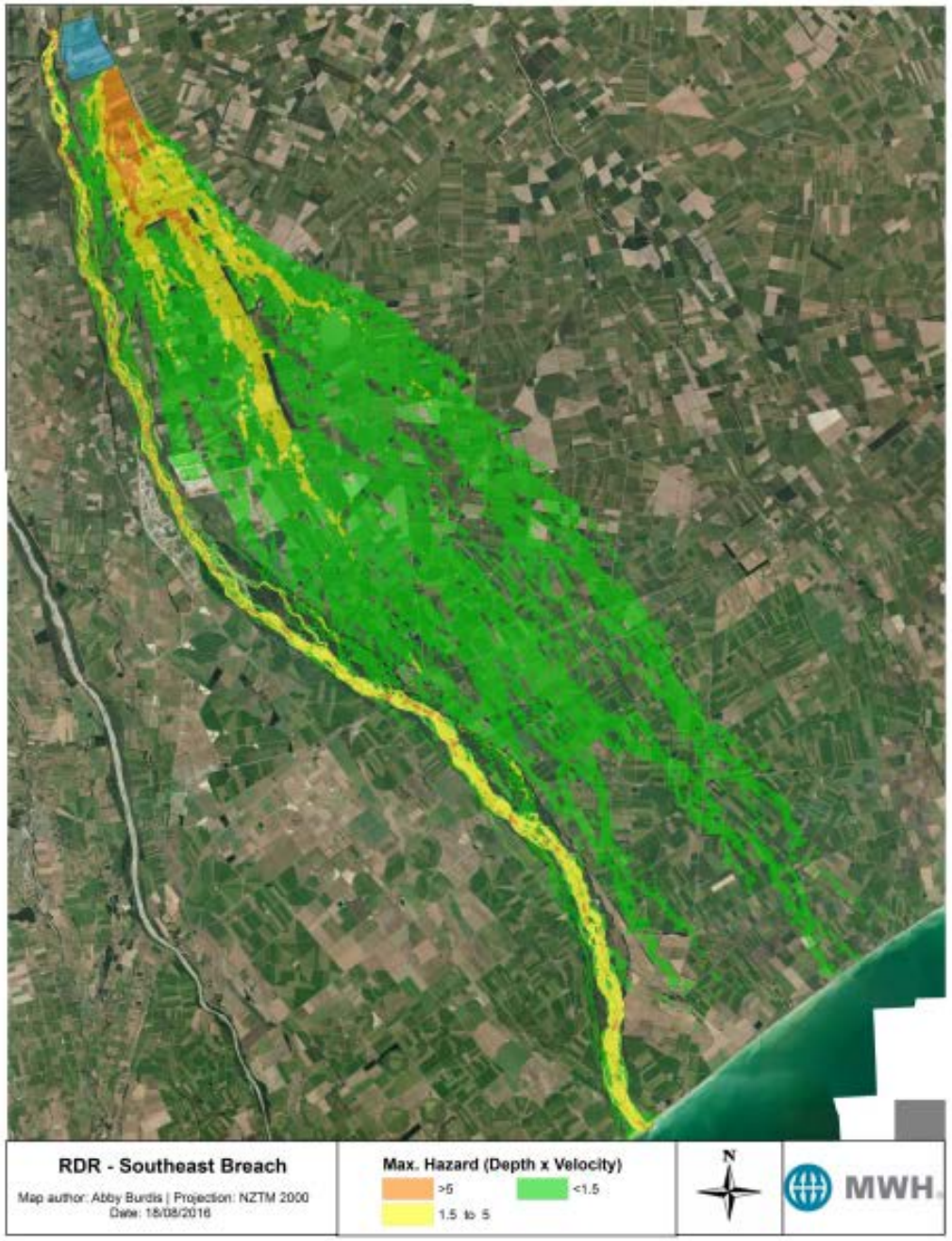
Item	Section	Page number	Guidance	Comment
1	Abstract	2	*"consequence assessments assist Owners in emergency planning and preparedness, in understanding the risks posed by the presence of the dam, and in developing risk reduction measures to address unacceptable risks"*	It is our view that the risks posed by the PKD are directly proportional to PAR and PLL and it is necessary to have a good understanding of these parameters to understand these risks.
2	1.1 Principles and Objectives	4		
3			*"The potential consequences* (of the release of stored contents) *are:* • *Injury or loss of life.* • *Damage to property and infrastructure.* • *Damage to the environment.* • *Social and economic disruption."*	Injury and/or loss of life are important consequences of a potential dam break scenario. We therefore consider it important that they are well understood.
4	Figure 1.1	5	*"Assess Population at Risk (PAR) and likelihood of injury or loss of life for each breach scenario (or Potential Failure Mode for Comprehensive)"*	Figure 1.1 overviews the dam classification process and we consider this indicates a requirement to understand PAR and PLL.
5	2.1 Overview	6	***"Dam-break flood hazard and consequence assessments are also useful in:*** • *Emergency planning and preparedness, by identifying the potential consequences of failure and response actions to avert failure or mitigate the consequences of failure (refer Module 6: Emergency Preparedness).* • *Understanding the risks posed by the presence of the dam, and developing rehabilitation works to reduce any unacceptable risks."*	It is our view that the risks posed by the PKD are directly proportional to PAR and PLL and it is necessary to have a good understanding of these parameters to understand these risks.

Item	Section	Page number	Guidance	Comment
6	2.2 Levels of Assessment	6	The level of assessment *"is influenced primarily by the population exposed to the potential dam failure hazard (termed the population at risk (PAR)), the amount of downstream development and the severity of the flooding (depth, velocity and duration). However, secondary factors such as the amount of warning time and the effectiveness of escape routes can greatly influence the Potential Loss of Life (refer section 2.8). If the anticipated level of consequence is high then a comprehensive assessment should be completed."*	
7	2.2.3 Comprehensive	7	*"A comprehensive assessment is typically required for dams that have high consequences, and therefore typically require detailed consequence outputs for emergency planning and preparedness, or the development of risk reduction measures."*	Indicates that thorough understanding of PLL and PAR is required to inform EAP planning.
8			*"the completion of a comprehensive assessment usually requires the identification and consideration of potential failure modes (refer section 2.5), dam-break flood routing, mapping of the extent of flood inundation, and evaluation of the peak flood depth, flow velocity, time of flood arrival, time of flood peak and inundation duration at key locations (e.g. buildings and infrastructure). It would usually also require the completion of a detailed damage and loss assessment, unless the PIC was clearly above the High threshold and detailed output was not required for a risk assessment."*	While the PIC is above High, we consider that it is useful to understand PAR and PLL based on a more refined level of assessment than is currently available. It is very important to recognise that a comprehensive level of assessment requires understanding of PAR and PLL for reasons other than determining PIC as above.
9	2.3 Process for Intermediate and Comprehensive Assessments	7	***"Estimate the number of people at risk and the potential for loss of life (taking into consideration permanent and itinerant populations, any warning that may be possible, and the ability of people to evacuate the affected area)."***	Indicates that thorough understanding of PLL and PAR is required as part of a comprehensive assessment.
10	Figure 2.1 Overview of the Dam-Break Flood Hazard and Consequence Assessment Process	8	*"Comprehensive Assessment* • *Undertake comprehensive dam break analysis* • *Carry out detailed flood inundation mapping* • *Accurately assess PAR and damages and losses"*	Indicates that thorough understanding of PLL and PAR is required as part of a comprehensive assessment.

Item	Section	Page number	Guidance	Comment
11	Table 2.1: Information Required for a Dam-Break Flood Hazard and Consequence Assessment	9 & 10	*"Locations and sizes of downstream centres of population* *Capability of emergency response resources and use of exercises and education to prepare personnel and downstream population* *Ease or difficulty of providing and disseminating a warning* *Ease or difficulty of evacuation* ***Temporal patterns of population (itinerants)*** *Locations and types of community facilities (schools, hospitals, other institutions, commercial and retail areas, camping areas)* *Potentially affected infrastructure (bridges, airports, railway lines, water, power and communication systems)* *Land use and development types"*	Indicates that thorough understanding of PLL and PAR is required.
12	2.7.2 Purpose	12	*"The effects of greatest interest are the population at risk (the PAR), the Potential Loss of Life, and the damage to property and the environment."*	Indicates that thorough understanding of PLL and PAR is required.
13	2.8.1 Population at Risk	17	*"PAR estimates should include both permanent populations and temporary populations (e.g. recreational users of tracks and waterways, campers, passengers in vehicles on highways and bridges, school populations, and people in commercial and retail areas)."* *"It is important that all affected people are identified"*	Indicates that thorough understanding of PLL and PAR is required.
14	2.8.1 Population at Risk	18	*"temporary populations:* • A temporary population in a fixed location daily or weekly • **A temporary population in a fixed location seasonally** • A temporary population on a designated route on a daily or weekly basis"	Indicates that consideration of itinerants is necessary.

Tonkin+Taylor

Proposed Klondyke Dam Depth Velocity or DV



Depth velocity (DV) – South east breach

- Depth velocity is flow depth (m) multiplied by velocity (m/s) at a particular location.
- DV of approximately 5 m^2/s corresponds to a 1 in 10 fatality rate.
- Yellow – DV estimate is 1.5 to 5 m^2/s.
- Orange areas DV estimate exceed 5 m^2/s.
- Hard to reconcile with specific locations on the ground.
- Figure from Appendix A of evidence dated 28 March 2018 prepared by N Fletcher.

Depth velocity (DV) – West breach

- Depth velocity is flow depth (m) multiplied by velocity (m/s) at a particular location.
- DV of approximately 5 m^2/s corresponds to a 1 in 10 fatality rate.
- Yellow – DV estimate is 1.5 to 5 m^2/s.
- Orange areas DV estimate exceed 5 m^2/s.
- Hard to reconcile with specific locations on the ground.
- Figure from Appendix A of evidence dated 28 March 2018 prepared by N Fletcher.