DAMWATCH
ENGINEERING BEYOND THE SURFACE

28 November 2019

Rebecca Jackson
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Dunedin 9054

Dear Rebecca

Technical Review of Supporting Documentation for Notice of Requirement of an Alteration to a Designation and Resource Consent Applications for Proposed New Bridge on Clutha River at Beaumont

We have reviewed the relevant technical reports supporting the New Zealand Transport Agency's (NZTA) Notice of Requirement and Application for Resource Consents for the construction of a new State Highway 8 Bridge on the Clutha River at Beaumont. These reports are incorporated in the WSP Opus document entitled "*New Beaumont Bridge – Notice of Requirement of an Alternation to a Designation and Resource Consent Applications*" (dated October 2019).

Our technical review has covered specific engineering and natural hazards aspects of the proposed new bridge as detailed in your email of 14 November 2018.

In general, the design concept for the new bridge is an appropriate solution to replace the existing bridge. However, there are a number of matters pertaining to the effects of the new bridge on the existing environment which the main report and the supporting technical reports do not address.

The key findings of our technical review are:

- We have identified a number of issues with the downstream boundary applied to the 1-d HEC-RAS model of the Clutha River. This is significant because the model is used to set design flood levels for the new bridge. The issues of concern are discussed in detail in Item 2(b)(ii) below.
- The estimated freeboard for the SLS flood at the critical location on the soffit of the new bridge (on the downstream side of the deck at the left abutment) appears to be less than the minimum freeboard allowance of 1.2 m recommended in the NZTA Bridge Manual where there is a possibility of large trees being conveyed down the waterway by flood flows. There is no indication in the supporting technical reports that the bridge designer has sought a departure from the design freeboard standard from NZTA and that this non-compliance is acceptable. Refer further to Items 2(g)-(i) below.
- The estimated flood level for the ULS flood is estimated to be approximately 1 m above the critical soffit level on the new bridge. This means floodwaters in the ULS flood will be surcharged on the bridge deck which will impose a significant hydrodynamic load on the

whole of the bridge structure. The applicant needs to confirm that the new bridge will remain stable under these loading conditions. Refer further to Item 2(t) below.

- The Appendix 5C hydraulic assessment report is focussed on providing input to the development of the design concept for the new bridge. However the report does not provide any discussion on whether or not any bank overtopping occurs in either the existing situation or the situation with the new bridge in place. From an RMA perspective, it is important to understand this and, if bank overtopping does occur, the extent of overbank flows and the effects of those flows. Refer further to Items 2(l)-(o) below.
- There is no comment in either the main report or any of the supporting technical reports on the effects of the new bridge on the river morphology. Refer further to Item 3 below.
- There is no comment in either the main report or any of the supporting technical reports on the potential effects on the waterway of the proposed temporary work platforms used facilitate construction of the new bridge, or of other construction activities. Refer further to Items 4(a)-(c) below.

We recommend that the applicant is requested to provide further information on these and other matters as set out in detail in the following technical review.

Yours sincerely,

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Principal Hydraulic Engineer	**Senior Civil Engineer**
Damwatch Engineering Limited	Damwatch Engineering Limited

Attachments: Technical Review

TECHNICAL REVIEW OF ENGINEERING AND NATURAL HAZARD ASPECTS OF NEW BEAUMONT BRIDGE

1. Future Management of Existing Bridge

Section 2.2 of the main report indicates that the existing Beaumont Bridge (first opened in 1887) shows signs of deterioration such that NZTA is unable to retain confidence as to its long-term serviceability. It is understood that the existing Beaumont Bridge is to be retained for pedestrian and cyclist use once the new Beaumont Bridge is in operation. However, in our view, the existing bridge will remain vulnerable to future seismic and flood hazards (including debris raft formation in flood events). Collapse of the existing bridge could endanger the new bridge with debris from the collapsed bridge either impacting directly on the new bridge piers or forming a flow constriction in the waterway.

We note that Section 14 of the main report states "*repair works to the existing bridge… are matters that the Transport Agency, as asset owner, will undertake outside of this RMA process*". However, we recommend that the consenting authority seek clarification from NZTA on future management arrangements for the existing bridge to ensure the potentially adverse effects of a bridge collapse on public safety, the waterway and the new bridge structure are appropriately mitigated.

2. Flood Hazards

<u>Flood Estimates</u>

a. The hydrological assessment provided in Appendix 5D was undertaken prior to a large flood in November 2018 on the Clutha River. This flood was estimated to be the largest event since the very large flood in November 1999 and is one of the five largest flood events 0n the Clutha River since records began in 1954. We do not anticipate that the November 2018 flood will significantly affect the flood discharge estimates presented in the application and no further information is required on this matter. However, we recommend that the applicant updates the flood frequency analysis to account for this recent flood event during the detailed design stage for the new bridge in order to confirm the design flood level used for setting the minimum bridge soffit level.

<u>Flood Levels</u>

b. Predicted flood levels at the new bridge for the design flood events[1] are stated in Section 8.12 of the main report. They are based on the results of a hydraulic assessment provided in Appendix 5C. The hydraulic assessment used a one-dimensional (1-d) steady state computational hydraulic model to estimate flood levels. This model was based on surveyed Clutha River cross-sections which extended approximately 900 m upstream and 600 m downstream of the new bridge. We make the following comments on the fitness for purpose of the hydraulic model used to estimate the design flood levels:

    i. A 1-d computational hydraulic modelling approach is reasonable in this context for the estimation of flood levels for the new and existing bridge as long as it is suitably calibrated against measured flood flow and level data. The choice of HEC-RAS software for the model is appropriate.

[1] The design floods adopted in the application are the 1 in 100 Annual Exceedance Probability (AEP) flood for Serviceability Limit State (SLS) design and the 1 in 1,000 AEP flood for Ultimate Limit State (ULS) design. The flow estimates for both the 1 in 100 and 1 in 1000 AEP design floods have been adjusted to account for the possible effects of future climate change to 2120.

ii. The estimated flood levels predicted by the 1-d model are likely to be sensitive to the “average energy slope” of 0.13% and river cross-section used to derive the stage / discharge rating curve at the downstream boundary. The assumed average energy slope value seems unusually low for a relatively steep river such as the Clutha. The selected downstream boundary for the model is located at a cross-section (C27 - see Figure 3-1 in Appendix 5C report) which is wider than other typical river cross-sections immediately downstream. The channel size downstream of cross-section C27 could well influence the backwater profile for different floods past the new and existing bridges.

We note that there appears to be a hydraulic control in the river located about 4 km downstream of the new bridge as marked in Figure 1 below. This could also potentially affect backwater profiles upstream past the new and existing bridges.

We recommend that the 1-d hydraulic model is extended a few kilometres further downstream using additional river cross-sections available from Otago Regional Council to ensure that the backwater profiles past the new and existing bridges are not influenced by the downstream boundary condition assumptions (i.e. the river cross-section and the energy slope).

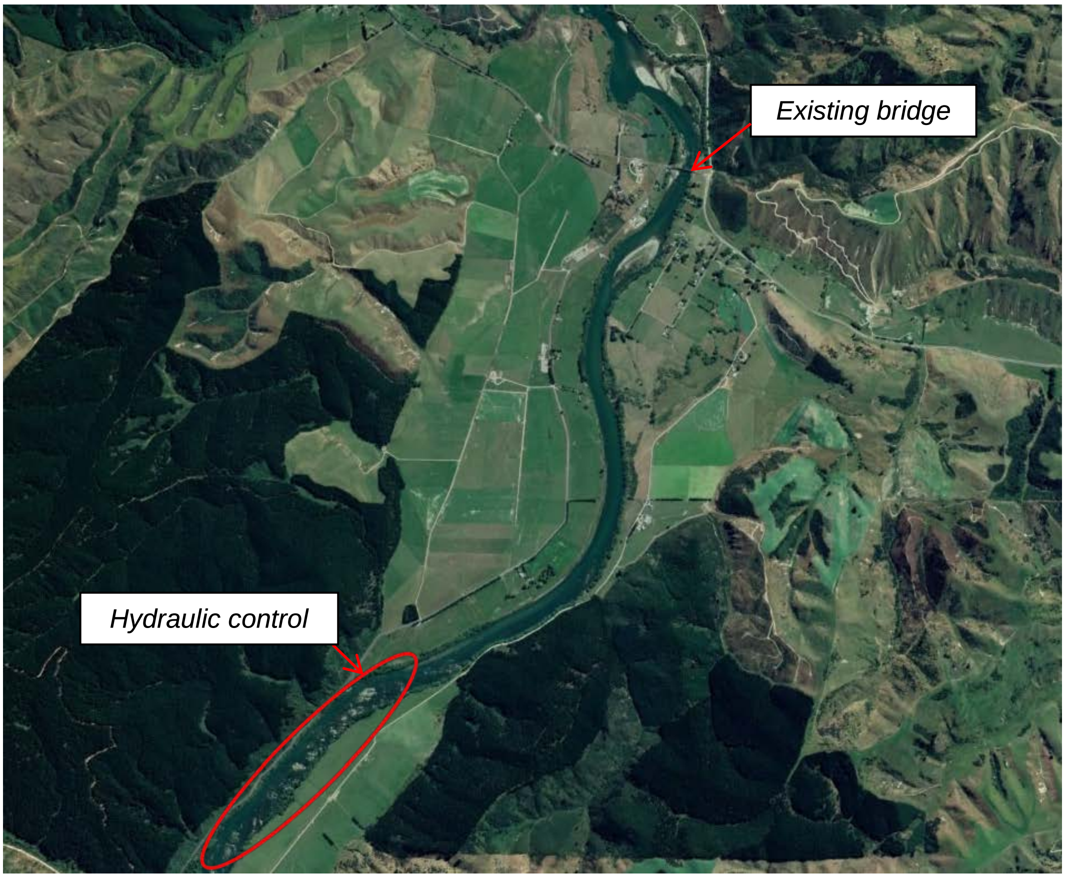

Figure 1: Hydraulic control in Clutha River downstream of existing Beaumont Bridge

iii. The model was calibrated against measured flood level and discharge values for two flood events in January 1994 and December 1995 (2,700 and 3,250 m^3/s respectively). These are not as large as the largest recorded flood in November 1999 but we understand there is a paucity of measured flood levels for this event.

The historic flood of 1878 was even larger than these recorded floods. We are aware of a measured flood level at the Beaumont Bridge site. This level and an estimate of the flood magnitude are given in a 2000 report on the flood history of the Clutha River prepared by Opus International Consultants (the predecessor of WSP Opus) for Contact Energy. It would be helpful to ask Contact Energy to provide access to this data so that it can be used to further inform the calibration of the 1-d HEC-RAS computational hydraulic model and provide greater confidence in the design flood level estimates for the new bridge[2].

iv. The banks of the Clutha River are heavily lined with willow trees for which the hanging branches drag in the water as flood levels rise. The additional drag induced by the hanging branches will potentially increase the channel 'roughness' and thereby cause elevated flood levels as the flood discharge increases above the discharge for the highest calibration event. We would recommend that the sensitivity of the backwater profile predictions of the HEC-RAS model for the SLS and ULS floods be tested by increasing the Manning's n channel roughness calibration value by up to 0.005.

v. We note that both the existing and new bridges are sited on a slight bend in the Clutha River (just downstream of a sharper bend). The 1-d computational hydraulic model predicts flood levels along the channel centreline. In practice flood levels are affected by flow super-elevation around a bend (with higher flood levels on the outside of the bend and lower levels on the inside of the bend). There is no discussion of super-elevation effects on flood levels in the Appendix 5C report.

Super-elevation of flood levels will be significant for the proposed new bridge because the bridge deck is cambered and also grades up from the left (east) abutment to the right (west) abutment. The critical location for freeboard on the bridge soffit is at the left abutment on the downstream side of the bridge. The applicant needs to clarify whether the design flood levels given in the main report and in the Appendix 5C report are affected by flow super-elevation and, if so, by how much.

<u>Backwater Profiles and Bridge Afflux Effects</u>

c. For the Resource Consent Hearing Panel to fully understand the backwater effect of the new bridge and the cumulative backwater effect of both the new and existing bridges, it would be helpful if the Appendix 5C report included a figure showing backwater profiles for both the SLS and ULS floods (adjusted for the possible effects of future climate change) with and without the new bridge. The backwater profiles should extend from the downstream boundary of the 1-d computational hydraulic model to the upstream boundary.

d. The piers on both the existing and new bridges act to reduce the effective channel width and thereby cause an afflux effect[3] which is superimposed on each backwater profile. There is no discussion in the Appendix 5C report of this afflux effect. We do not

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[2] The bed profile in this reach of the Clutha River appears to be controlled by rock outcropping so that the geomorphological form of the river channel is unlikely to have changed very much since the 1878 flood. It would therefore be reasonable to use the measured peak flood level from the 1878 flood and the estimated flood discharge to inform the calibration of the HEC-RAS model of the river channel.

[3] This is a localised elevation of flood levels due to the additional channel constriction caused by the bridge piers.

expect it to be significant due to the wide spacing of the piers on both bridges but nonetheless it is an important effect to be considered and assessed.

e. As noted 2(b)(iv) above, the Clutha River is heavily lined with willow trees. This is likely to give rise to a large woody debris load conveyed by the river under flood conditions. The potential for debris raft formation on the piers of both the existing and new bridges is therefore fairly high. While the bridge afflux due to the piers alone may not be significant, the afflux due to debris raft formation on each bridge pier is potentially very significant. This effect needs further consideration and assessment.

f. We note that the piers on the new bridge are proposed to be circular in shape. This shape is the best shape for minimising the size of debris rafts that may form under flood conditions.

Freeboard (including debris raft formation)

g. The NZTA Bridge Manual (3rd Edition, 2018) indicates (refer Section 2, Table 2.4) that, where there is a possibility of large trees being carried down the waterway, then a free-board[4] allowance of 1.2 m should be applied to the estimated flood level for the SLS flood. Given the willow-lined nature of the Clutha River, we consider this to be an appropriate design standard for the new bridge. There is no discussion in the Appendix 5C report about the expected freeboard on the new bridge for the SLS flood although these is some discussion of this matter in relation to the existing bridge.

h. The soffit level of the bridge at the critical location on the downstream side of the left abutment is estimated to be about RL 48.93 m. This estimate is based on a centreline deck level of RL 51.12 m, a deck cross-fall to the outside bridge girder of 0.24 m and a girder depth of 1.95 m. The estimated soffit level at the critical location implies a freeboard of 1.0 m for the SLS flood (including the possible effects of future climate change to 2120).

i. The estimated freeboard value at the critical location on the bridge soffit is less than the recommended NZTA design standard although the standard would be met at the bridge centreline. The bridge designer needs to clarify whether a departure from the design freeboard standard has been sought from NZTA as the applicant and if this non-compliance with the design standard is acceptable. Further discussion of this matter needs to be provided.

j. We note that a permanent maintenance / inspection platform has been constructed on the underside of the deck on the existing bridge (refer to Figure 21 and 28 in Appendix 5E). It is also not clear in the Appendix 5C report whether the freeboard value for the SLS flood given in Section 3.5 is to the soffit of the actual bridge deck or to the soffit of the maintenance / inspection platform. If the freeboard value given is to the actual bridge, then the risk of debris raft formation on the maintenance / inspection platform and the potential for adverse effects on the new bridge need to be clarified as per Paragraph 1 above.

Floodplain Effects

k. The Appendix 5C report is focussed on providing input to the development of the design concept for the new bridge. The 1-d computational hydraulic model assumes vertical 'walls' along the river banks. From an RMA perspective, it is important to

[4] Freeboard is an allowance added to model-predicted water levels to account for such factors as model uncertainty, channel bed level changes, surface waves, minor debris build-up in the channel and other unforeseen effects.

understand whether the river banks confine the flood flows upstream of the new and existing bridges or whether the flood flows spill over the top of the banks onto the floodplains. It would be helpful if the applicant could extend the figure illustrating the backwater profiles for the SLS and ULS floods (Paragraph 2c) to show the line of the top of the bank on each side of the river. This would help illustrate whether bank overtopping occurs in these floods. Some discussion of this matter needs to be provided.

l. If bank overtopping is predicted to occur, the extent of overbank flows and their likely flow path need to be identified for the SLS and ULS floods with and without the new bridge. The applicant needs to make a statement on whether the new bridge exacerbates the extent of overbank flows.

m. The approach embankments to the new bridge are proposed to be constructed up to 3.87 m above natural ground level (refer Drawing 6-CT012.00-C03B in Appendix 1 to the main report). The potential effects of the proposed approach embankments on any overbank flows resulting from the SLS and ULS floods needs to be clarified.

n. If the approach abutments to the new bridge are likely to be overtopped by overbank flow resulting from the SLS and ULS floods, the applicant needs to indicate whether or not any erosion protection measures are proposed for the approach embankments.

Turbulent Wake from Piers on Existing Bridge

o. The new bridge is proposed to be located immediately downstream of the existing bridge. The existing bridge piers generate wake vortices which could impact on the new bridge piers if the piers on both bridges are approximately aligned. In some situations, interference between wake vortices shed off adjacent piers on an upstream bridge may exacerbate scour under flood conditions around the piers on a downstream bridge. The applicant needs to provide appropriate comment on the potential for wake vortices shed off the piers on the existing bridge to impact on the new bridge piers and exacerbate the scour risk to them.

Scour and Erosion Protection

p. As noted in the previous paragraph, the applicant proposes that the piers on the new bridge will be socketed sufficiently deeply into rock outcrops across the bed of the river such that scour will not be a risk to the pier foundations. The erosion resistance of the rock foundations needs to be confirmed by ground investigations during the detailed design phase for the new bridge.

q. The abutments to the new bridge are proposed to be constructed from fill material as spill-through type abutments. The abutment fill material is erodible and erosion protection in the form of a rock riprap cover layer with an underlying granular protection layer and geotextile filter is proposed. The toe of the riprap cover layer will be keyed into rock outcrops on each abutment. This protection concept is an appropriate erosion mitigation measure for the abutments.

r. As referred to in Paragraphs 2m and 2n above, we recommend that the applicant clarifies whether overtopping of the bridge approach embankments by overbank flows is likely in the design SLS and ULS floods and, if it is, whether any erosion protection measures are proposed.

Bridge Stability in Flood Events

s. The formation of debris rafts round the piers on the new bridge will increase the lateral hydrodynamic load on the bridge structure. We do not expect this to be a dominant load for the bridge structure. However, the applicant needs to provide a statement that it has been considered and that the structure is stable under a ULS flood with a debris raft on each pier in accordance with the requirements of Section 3.4.8 of the NZTA Bridge Manual (3rd edition, 2018).

t. We note that the estimated flood level for the ULS flood of RL 49.91 m is approximately 1 m above the critical soffit level on the new bridge. It would be appropriate for the applicant to provide comment on this and on whether the stability of the new bridge under the hydrodynamic loads imposed on the bridge by floodwaters and debris raft formation at this level is affected.

3. Effects on River Morphology

There is no discussion in the technical documentation on how the proposed new bridge will impact on the morphology of the river. The applicant needs to provide an appropriate statement on this matter. We note that the bed profile in this river reach appears to be controlled by rock outcropping with selected outcrops used to provide pier foundations for the new bridge.

4. Construction Issues

a. To facilitate bridge construction, the applicant refers to the use of temporary steel trestle type work platforms and gravel bund work platforms (causeways) pushed out from each bank. There is no discussion in the technical documentation supporting the Notice of Requirement and Resource Consent applications regarding the effects of these work platforms on flood flows in the river. For the purposes of an RMA assessment, further information needs to be provided as set out below:

   i. The applicant needs to confirm the effect of any temporary work platforms on the flood capacity of the waterway and the upstream backwater influence of these platforms.

   ii. The applicant needs to describe how the temporary work platforms will be founded on the river bed.

   iii. For the gravel bund work platforms, the applicant needs to confirm the proposed source of the gravel material for their construction, the methodology of extraction and the approximate quantity of material required.

   iv. The applicant needs to confirm the potential impact on the downstream river channel in the event that the temporary gravel work platforms are washed away in a flood event.

   v. Flood transported woody debris conveyed by the Clutha River has the potential to be snagged on any temporary steel trestle type work platforms. The applicant needs to confirm how this risk is to be managed during construction.

b. The applicant needs to make a statement about how the safety of the construction site is proposed to be managed with respect to the flood risk. Due to the likely presence of construction personnel and equipment within the river bed during construction, a suitable flood warning system and evacuation procedures will need to be developed as part of a construction management plan.

c. The applicant needs to make a statement about how fine sediment plumes which could be released by construction activities (e.g. from gravel bund temporary work platform construction) into the Clutha River are proposed to be managed and mitigated. This matter also needs to be covered by a construction management plan.