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Rees River Bridge

Options Assessment

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150 YEARS IN AOTEAROA

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Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for Queenstown Lakes District Council ('**Client**') in relation to developing an Options Report for the Rees River Bridge ('**Purpose**') and in accordance with the Consultancy Services Order dated 17 February 2023. The findings in this Report are based on and are subject to the assumptions specified in the Report and the WSP Offer of Service dated 21 December 2022. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

1 Introduction and Background

The Rees River Bridge is a 207 m long 15-span single lane structure across the Rees River. The bridge is located along the Glenorchy-Paradise Road, approximately 8 km north of the Glenorchy township and is owned by the Queenstown Lakes District Council (QLDC). An aerial view of the site is shown in Figure 1 with a typical elevation shown in Figure 2.

Figure 1. Aerial view of Rees River Bridge

Figure 2. Typical elevation of Rees River Bridge

In 2022, the Otago Regional Council (ORC) commissioned a study into the Dart and Rees floodplains, which identified potential risks to the Rees River Bridge from continued bed aggradation and the potential for the Rees River to avulse upstream of the bridge. This has followed recent observation of bed aggradation in the Rees River, as shown in Figure 3, which has resulted in QLDC extracting gravel from the riverbed. While the extracted gravel has previously been used to raise neighbouring Kinloch Road, there is concern that current reactive measures may be unsustainable given the rate of bed level rise observed and potential funding limitations.

Figure 3. Rees Riverbed circa 2021

To assess and develop longer term options at this site, QLDC has engaged WSP to undertake a structural options assessment to help provide direction and guidance towards a long-term asset management strategy for this structure.

2 Existing Bridge Structure

2.1 Structural Configuration

On site markings indicate the bridge was built in 1958 to the design loading H20-S16-44. The superstructure comprises of three simply supported steel beams seated on concrete wall piers. Each of the 15 spans are nominally 13.7 m (45'). From drawings supplied by QLDC, the beams are believed to be designed to act compositely with the concrete deck nominally 180 mm thick (7") with a clear width of 3.7 m (12') between kerb upstands. Each pier is founded on five driven steel piles of an unknown founding depth. Existing drawings indicate that supplied piles are nominally 6 m (20') long and embedded approximately 1 m into the base of the pier. This indicates that the piles are founded at approximately 5 m below the base of the pier or approximately 7.9 m from the beam soffit level. A cross section of the structure is shown in Figure 4.

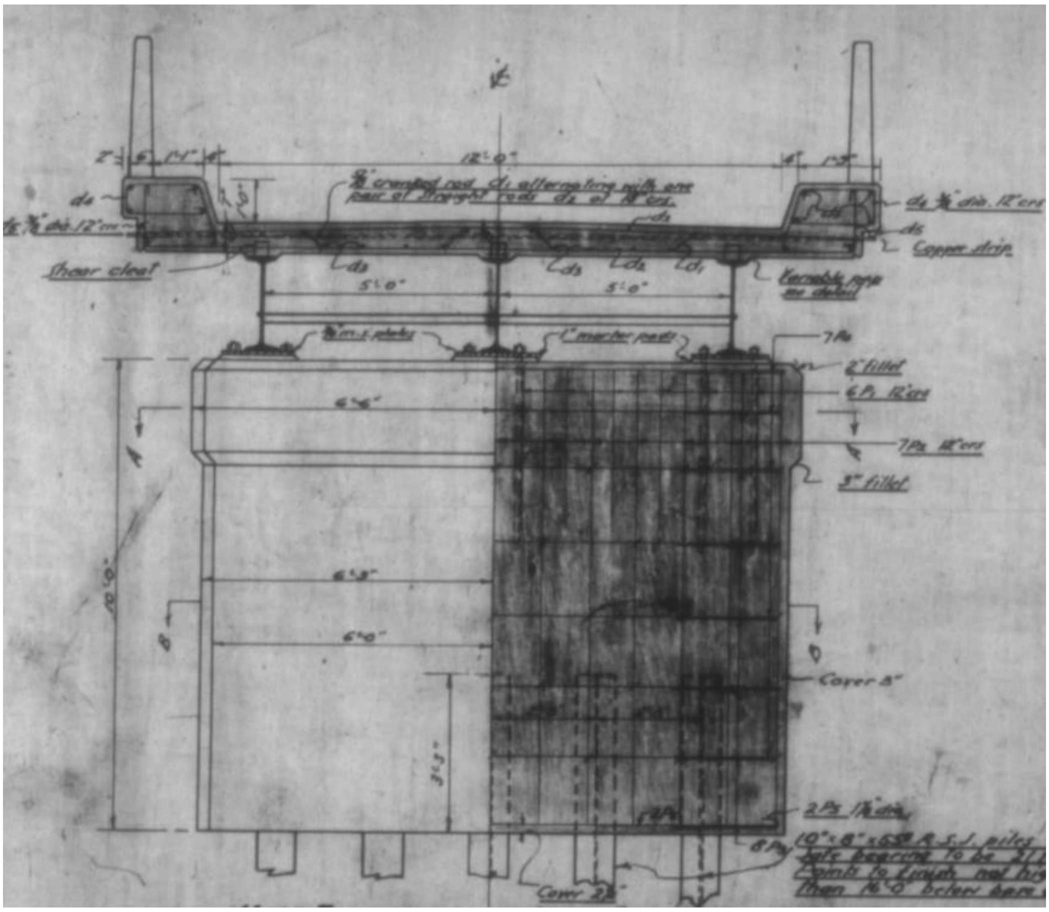

Figure 4. Cross section of existing bridge

2.2 Condition

A general inspection of the Rees River Bridge was undertaken by WSP in 2021, which identified minor defects on the structure. These are summarised in Table 2-1 below.

Table 2-1 : Summary of maintenance items at Rees River Bridge

Defect	Photo
Bitumen in joints expanding and protruding above deck level causing a hazard. Timeframe: 1 Year ROC $15,000	

<table>
<tr><td>Rutting in pavement on True Right approach.

Timeframe:

5 Years

ROC

$5,000</td><td></td></tr>
<tr><td>Minor damage to handrails and concrete posts

Timeframe:

5 Years

ROC

$1,000</td><td>
</td></tr>
</table>

Some minor spalling on the concrete piers and debris build up were also noted but these are relatively minor and did not warrant remediation at the time of inspection. Based on the noted defects, it can be concluded that the bridge is in a good condition with an expected remaining life in the order of 40 years based on structural condition.

2.3 Historical Maintenance

To address observations of aggradation in the riverbed, QLDC currently spends approximately $220,000 on a biannual basis to extract gravel from the Rees River. Of the 15,000 m^3 of gravel extracted from the bed, most of the material is transported and stockpiled at the nearby Reid Earthworks Pit, where it is screened and reused for ongoing road maintenance. However, there is concern that this level of extraction is unlikely to significantly manage the aggradation risk given the volume of bed material that is deposited at the bridge site.

In 2019, QLDC undertook a programme of refurbishment on the steel beam coatings. This has resulted in a renewed life for the beams, which remain in a good condition.

3 Current Levels of Service

3.1 Number of Lanes

The bridge has an estimated AADT of 1147 (Mobile Road) and is classified as a secondary collector due to the high tourist value of the route. Based on this AADT value, it is anticipated that the level of service provided by the structure is at the upper end of what would be considered appropriate for a single lane structure and may be restrictive to traffic in periods of high tourist traffic and the likelihood of increasing tourist traffic within the region. However, this is expected to be seasonal, and it is likely that traffic volumes outside of the peak tourist season would be significantly lower than the estimated figure. There is no currently known issues around traffic delays at this site and it is likely that a single lane structure would remain serviceable for the foreseeable future. It is noted that the existing bridge has no passing bays despite its considerable length.

3.2 Road geometrics

The bridge is situated after a slight horizontal curve on the northern approach, which reduces the available sight distance of road users approaching from this direction. The southern approach to the bridge is straight with good forward intervisibility of the northern approach, which has the right of way. There are no significant concerns with the current geometry of the site.

3.3 Bridge Width

The bridge has a width between kerbs of 3.7 m, which satisfies the minimum width for a single lane bridge in accordance with Appendix D of the NZ Bridge Manual.

3.4 Rideability

There are no rideability issues currently noted. Remediation to the pavement and expansion joints identified in Section 2.2 is required to maintain the adequacy of rideability across the structure.

3.5 Pedestrian and cyclist access

The bridge does not have a dedicated shoulder or walkway for pedestrian and cyclist use. The demand for pedestrian access is anticipated to be low given the rural location of the structure.

3.6 Safety Barriers

The bridge currently has steel handrails supported on intermittent concrete posts. Nominally 15-20 m of TL-3 guardrail has been installed on the bridge approaches. The bridge is not considered a high-risk area for crashes by QLDC although several minor incidents have been noted. Retrofitting the existing barrier with guardrail could be considered if there becomes concern about side protection across the structure.

3.7 Live Load Capacity

Having been designed to H20-S16-44, there is no current deficiency in the bridge's load carrying capacity, including HPMV and 50 MAX vehicles.

3.8 Seismic and Flood Performance

No specific seismic assessment has been undertaken for this structure. However, there are no apparent vulnerabilities from the detailing observed. Existing steel piles are founded nominally 5 m below the base of the existing piers, which may cause long term concerns around the scour potential should the bed degrade.

It is understood that flooding at this site is a concern with instances of road closures noted following flood events. This is explored further in Section 4.

4 Hydraulic Assessment

4.1 Hydrology

Dr Magdy Mohssen from the Otago Regional Council (ORC) has developed the input hydrology for this study, using rainfall runoff modelling techniques and HEC-RAS software (Mohssen M, 2021). A detailed analysis of the study can be found in Appendix C of the ORC report "Dart and Rees Rivers Flood Hazard Modelling" (2022). The summary of the adopted flows for this modelling study is presented in Table 4-1. However, it is worth noting that the 5-year ARI event in Table 4-1 has been scaled down from the input hydrology data of ORC (2020) report using the Regional Flood Frequency Method.

Table 4-1 : Adopted inflow boundary condition.

Event	Rees @ Bridge (m^3/s
100-year ARI	941
February 2020	642
5-year ARI	386

There is a gauged site upstream of the bridge at the confluence with Invincible Creek, however, the record for this site is too short to be used for any statistical assessment of likely flood flows.

For comparison, the Regional Flood Frequency Method (NIWA) yields a lower 100 yr ARI flood flow of 637.09 m^3/s. However, the 5 year ARI flood flow derived from the Regional Flood Frequency Method (351 m^3/s) is much closer to our scaled value.

4.2 Hydraulic Model

A 2D steady state hydraulic model was developed for the Rees River using HEC-RAS 6.3 software and LiDAR information to determine flood parameters. The model was used to evaluate the behaviour of the river during different flood events, including the key design event, which was a 100-year Annual Recurrence Interval (ARI) flood event. It is worth noting that the analysis did not include any allowances for climate change, and therefore the results should be interpreted accordingly. Also, using a steady state model is likely to be more conservative in nature than an

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unsteady model. However, unsteady analysis was beyond the scope of this assessment at this stage.

In addition to the 100-year ARI flood event, a 5-year ARI event was also modelled to assess the freeboard during a more frequent flood event and to validate the ORC hydrology. The modelling of this event allowed for the determination of the minimum freeboard required to prevent overtopping of the bridge during more frequent flood events.

Table 4-2 : Hydraulic model parameters

Parameter	Existing conditions
Geometry	1 m DEM LiDAR survey raster data (2019)
Manning's roughness value (n)	• 0.1 for broadleaved indigenous hardwoods • 0.1 for built-up area • 0.125 for deciduous hardwoods • 0.15 for exotic forest • 0.125 for gorse and broom • 0.04 for gravel or rock • 0.05 for high producing exotic grassland • 0.02 for lake or pond • 0.09 for low producing grassland • 0.05 for orchard and vineyard • 0.1 for short-rotation cropland • 0.033 for parkland or open space • 0.035 for river
Upstream boundary condition	• 100-year ARI peak flow excluding the effects of climate change from ORC (2020) report. • 5-year ARI peak flow excluding the effects of climate change from ORC (2020) report.
Downstream boundary condition	• Normal flow

The flood depth and velocity maps for the 100-year ARI event and 5-year ARI event are shown in Figure 5 and Figure 6, respectively. The maximum flood depth near the bridge is below 2.4 m and the maximum velocity is below 2.0 m/s, during the 100-year ARI event. For the 5-year ARI event, the maximum flood depth is below 2.1 m, and the maximum velocity is below 1.5 m/s. Table 2-1 summarizes these findings.

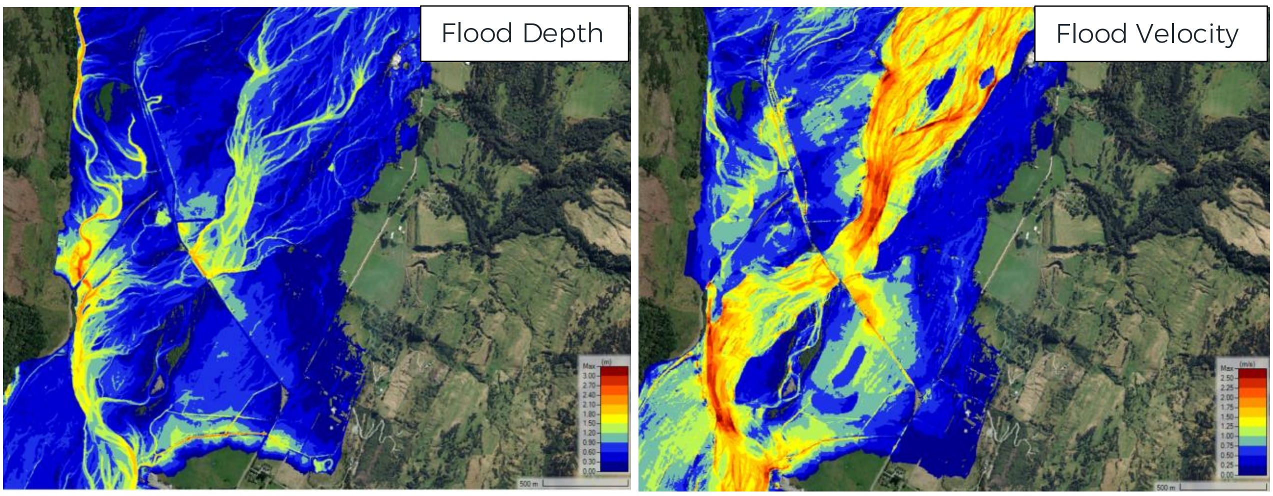

Figure 5. 100-year ARI flood depth and velocity

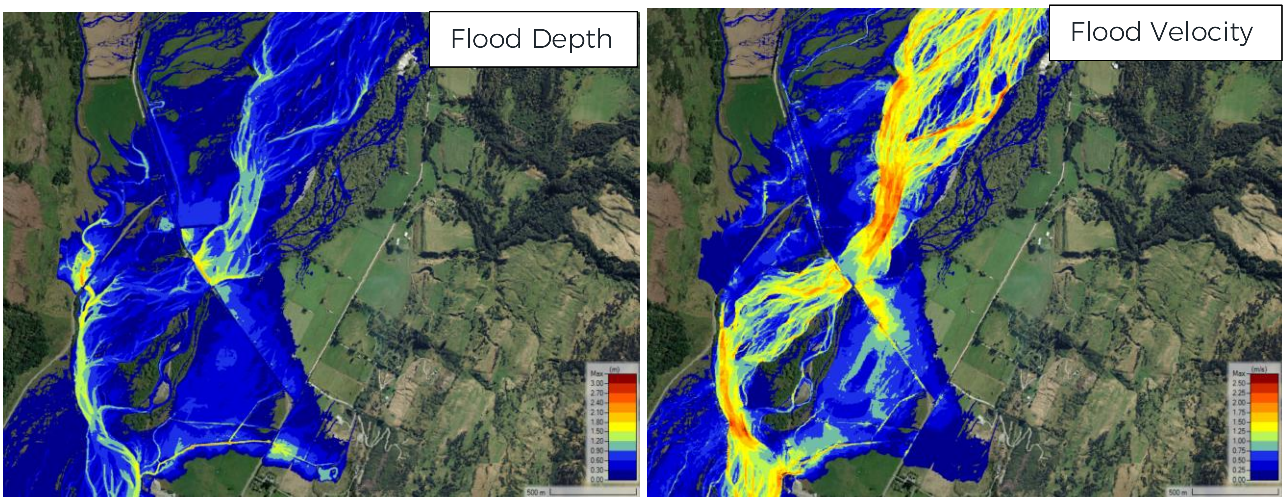

Figure 6. 5-year ARI flood velocity

Table 4-3 : Flood model results

Underside of Bridge Deck Level (m RL)	Road Embankment Level (m RL)	100yr ARI Flood Level at Bridge Cross-section (m RL)	100-year ARI Freeboard (m)	5yr ARI Flood Level at Bridge Cross-section (m RL)	5-year ARI Freeboard (m)
334.82	335.66	335.3	0.0	335.05	0.0

The modelling does not indicate that the bridge deck is overtopped but does indicate that the water level exceeds the level of the bridge soffit resulting in no freeboard during either flood events. Anecdotally, the bridge has never been overtopped, but it is understood that the true left approach has been flooded several times in recent years (and likely the true right as well). This aligns with our modelling results of the 5 year ARI flood event.

It should be noted that while there is conservatism in the modelling approach undertaken, there is also a heightened level of uncertainty with the flood flows derived for this site given the limited data available to estimate projected flows. The results do however broadly align with the observations of flooding on the road approaches. Once more data is available for the Rees flow gauge upstream more accurate estimation of the flood flows will be possible that would enable the model to be refined.

4.3 Scour Assessment

The scour evaluation methodology used in this project is based on two sources. The first is the internationally recognised document "HEC-18 Evaluation Scour at Bridges" by the United States Federal Highways Administration (FHWA). The second is the New Zealand specific Melville and Coleman book, "Bridge Scour," which is referenced by the NZTA bridge manual.

The scour assessment focuses on the following key components:

- General scour including contraction scour
- Pier scour
- Abutment scour

4.3.1 General Scour

The main form of general scour expected in the Rees River is contraction scour, which is primarily caused by constriction of the flood plain and by pressure scour resulting from the submergence of the Rees River Bridge soffit during flood events. However, calculations based on the HEC-18 method suggest that this is unlikely to be significant at this site. This is likely due to the approach road being overtopped and the bridge outflanked reducing the effective constriction.

4.3.2 Pier Scour

To assess the potential for pier scour, two methods were used: HEC-18 and Melville and Coleman. The scour depth calculations obtained from both methods were found to be similar, with a predicted maximum depth of 4.8 m.

4.3.3 Abutment Scour

The abutment scour was evaluated using three different methods, namely NCHRP, HIRE, and Melville and Coleman. Table 4-4 presents the results of all three methods. On comparison of the different results, it was found that the Melville and Coleman method provided the most reliable and consistent results in terms of the average scour. Therefore, for this assessment, the abutment scour is calculated using the Melville and Coleman method.

Table 4-4 : Abutments scour depths

Methods	Left Abutment Scour Depth (m)	Right Abutment Scour Depth (m)
Melville and Coleman	2.4	2.4
HIRE	3.84	3.68
NCHRP	0.61	0.5

4.3.1 Total Scour

Given that the predicted contraction scour is negligible at this site, the abutment and pier scour depths are considered to be total scour depths. Figure 7 presents the plot of the total predicted scour depth based on the existing ground levels at the abutment and pier locations. Note that as local scour is dominates the total scour, it is anticipated that any scour occurring will be concentrated at pier/abutment locations and not uniform across the width of the channel. It is important to note that the persistent aggradation in the river can lead to less total scour depth than calculated in this assessment. Based on the currently assumed minimum founding depths, there is not an immediate undermining risk at this bridge. However, this will need to be considered if longer term measures have the potential to increase local scour effects.

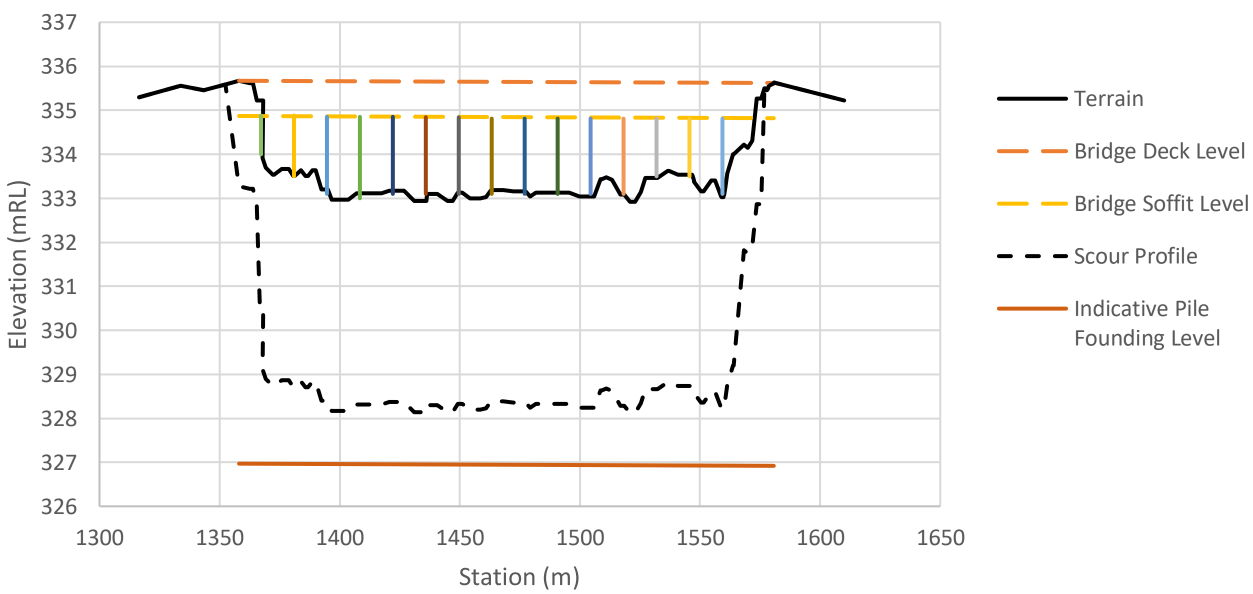

Figure 7. Total scour plot

4.4 Morphological Issues and Options

To understand wider geomorphological behaviours that may be influencing the Rees River, an assessment of the geospatial data including Google Earth, terrain data (incl. 2019 LiDAR), and imagery sourced from LINZ and RetroLens was undertaken. A summary of the observations and findings are summarised below:

4.4.1 Morphological Setting

- The contemporary braidplain of the Rees River lies along the left margin of an alluvial fan (Figure 8).
  - The apex of the fan is approximately 7 km upstream of the bridge.
  - The central axis of the fan is aligned from the apex roughly toward the summit of Mt. Alfred.
- The contemporary Rees River appears committed to the left-half of its fan (Figure 8,).
  - The erosion scarp north of the airstrip is the probable boundary of the Holocene floodplain, suggesting that the Rees has flowed across a swath to the vicinity of Lake Reid in the recent geologic past.
  - Review of LiDAR indicates much of right-hand portion of the floodplain area is at least 1-2 m lower than the contemporary braidplain.
  - The portion of the fan to river-right (north) of Camp Hill is assumed to be older (likely late-Pleistocene) and result from deposition associated with ancestral alignments of the Rees River that would have flowed into/toward Diamond Lake and/or Lake Reid.

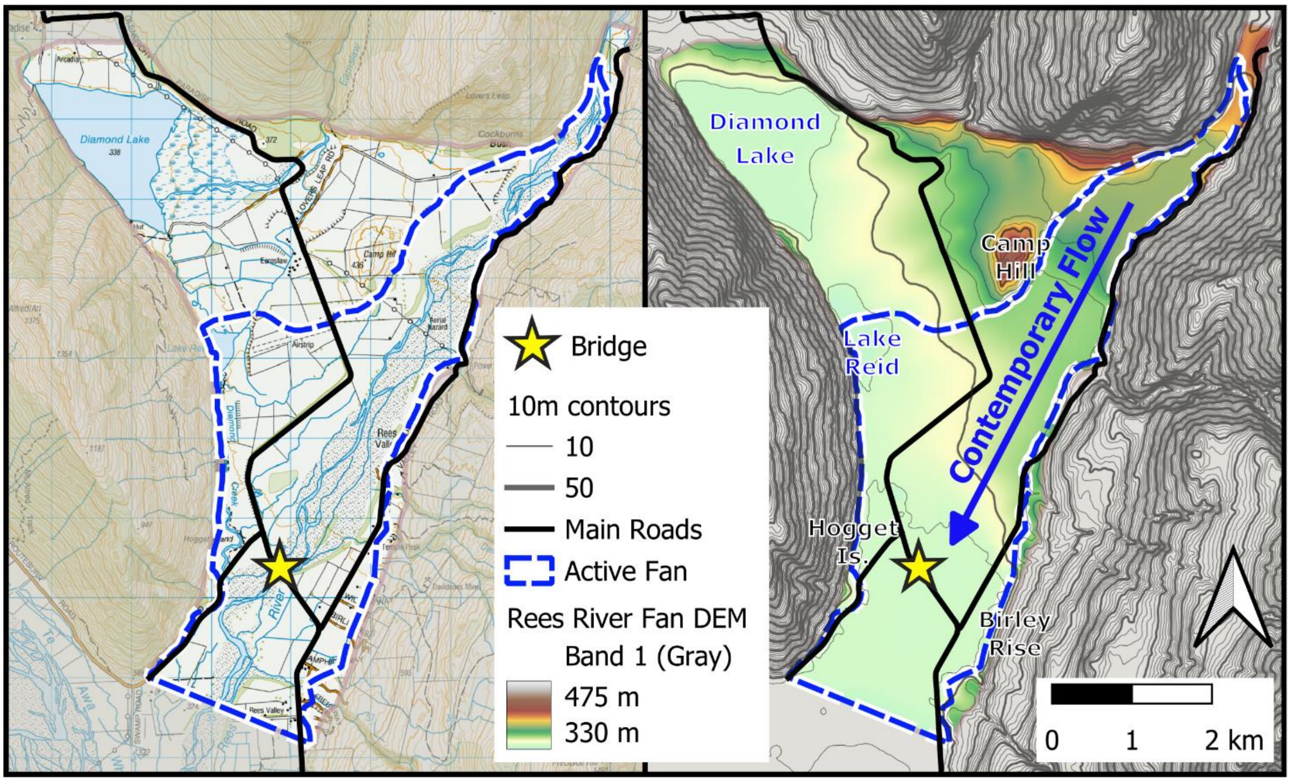

Figure 8. Overview of the Rees River alluvial fan with LINZ Topo50 (left) and 8m DEM (right) as base imagery.

- The bridge location:
  - Occurs at one of the narrowest points of the active braidplain (Figure 9, lower-left).
  - The left (Birley Rise vicinity) and right (Hogget Is.) valley margins are 1-2 m lower than the contemporary braidplain.
- The widest portion of the active braidplain occurs approximately 1.5 km upstream of the bridge (Figure 9, lower-left).
- The most active braidplain wandering since the 1960s appears in a zone from approximately 0.4-2.2 km upstream of the bridge. Notably, the following have been observed at the true left and true right margins:
  - The true left margin:
    - Appears to have been more laterally active from the 1960s into the 1980s (Figure 9, right).
    - Is now well-vegetated and not particularly active (Figure 9, lower-left), though still hydraulically-connected (Figure 5, Figure 6).
  - The true right margin:
    - Was more laterally active since at least 2011, though there is evidence of movement on this margin since the 1966-1984 epoch (Figure 9, right)
    - The road to Paradise (right floodplain upstream of the bridge) was relocated approximately 500 m north and west between 1966 and 1984.
    - By 1984, the right margin of the active braidplain was 100 m inland of the old road alignment with two large break-out scars up to about 250 m inland of the old alignment.
    - The 2019 imagery indicates the maximum zone of migration along the right margin of the braidplain was in the same vicinity as the ~1984 break-outs and approximately 160-180 m inland of the old road alignment
    - Seepage features to the right-side of the braidplain suggest a groundwater head directed toward Diamond Creek originating from the Rees River (proximity of a 90-degree bend in a stopbank). Comparatively fresh fluvial scarring in the same vicinity suggests this as a location for a recent and/or future break-out location, though could possibly date to the mid-1980s.

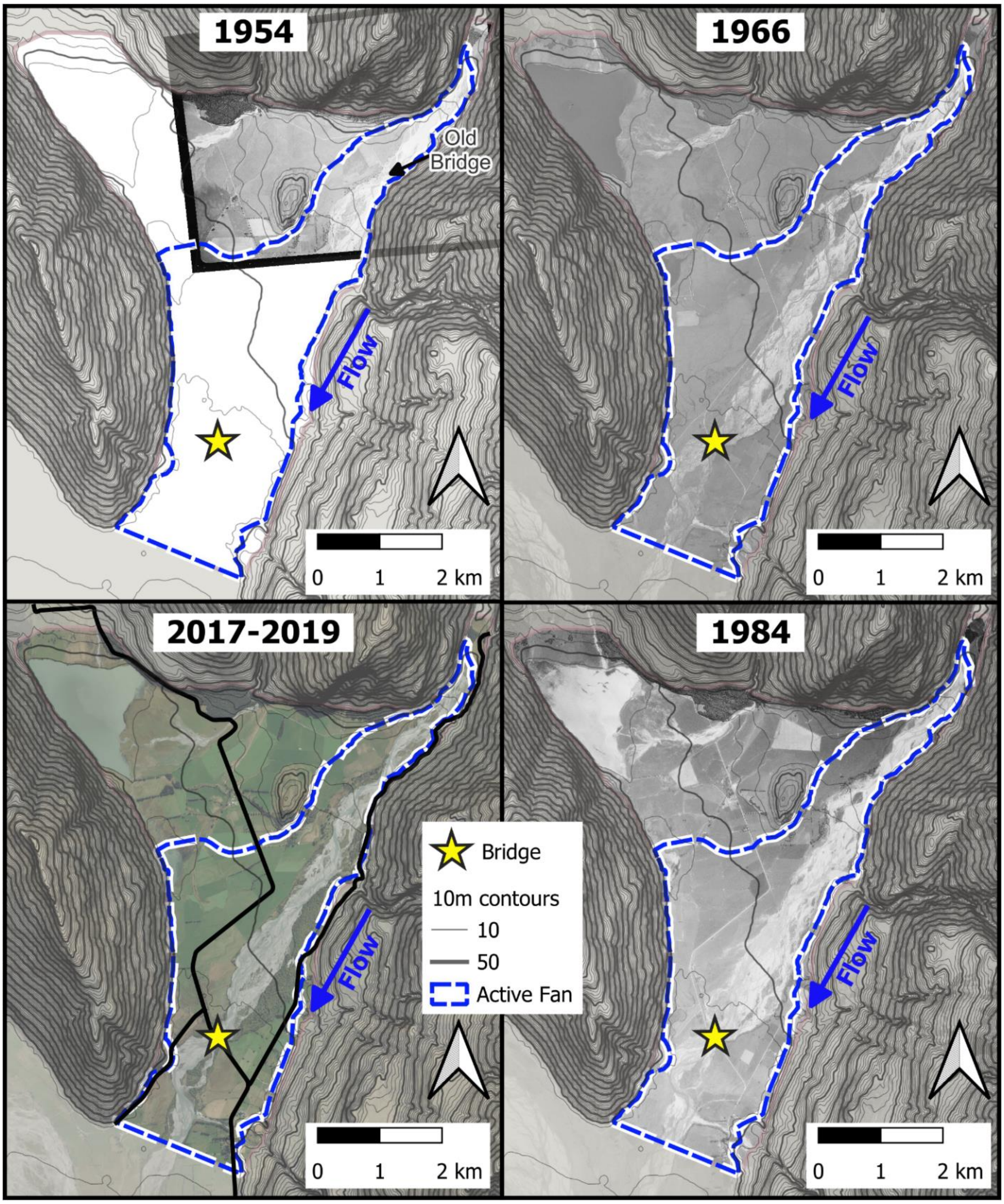

Figure 9. Aerial photo time-series of the Rees River alluvial fan and project site, advancing in time clockwise from the upper-left.

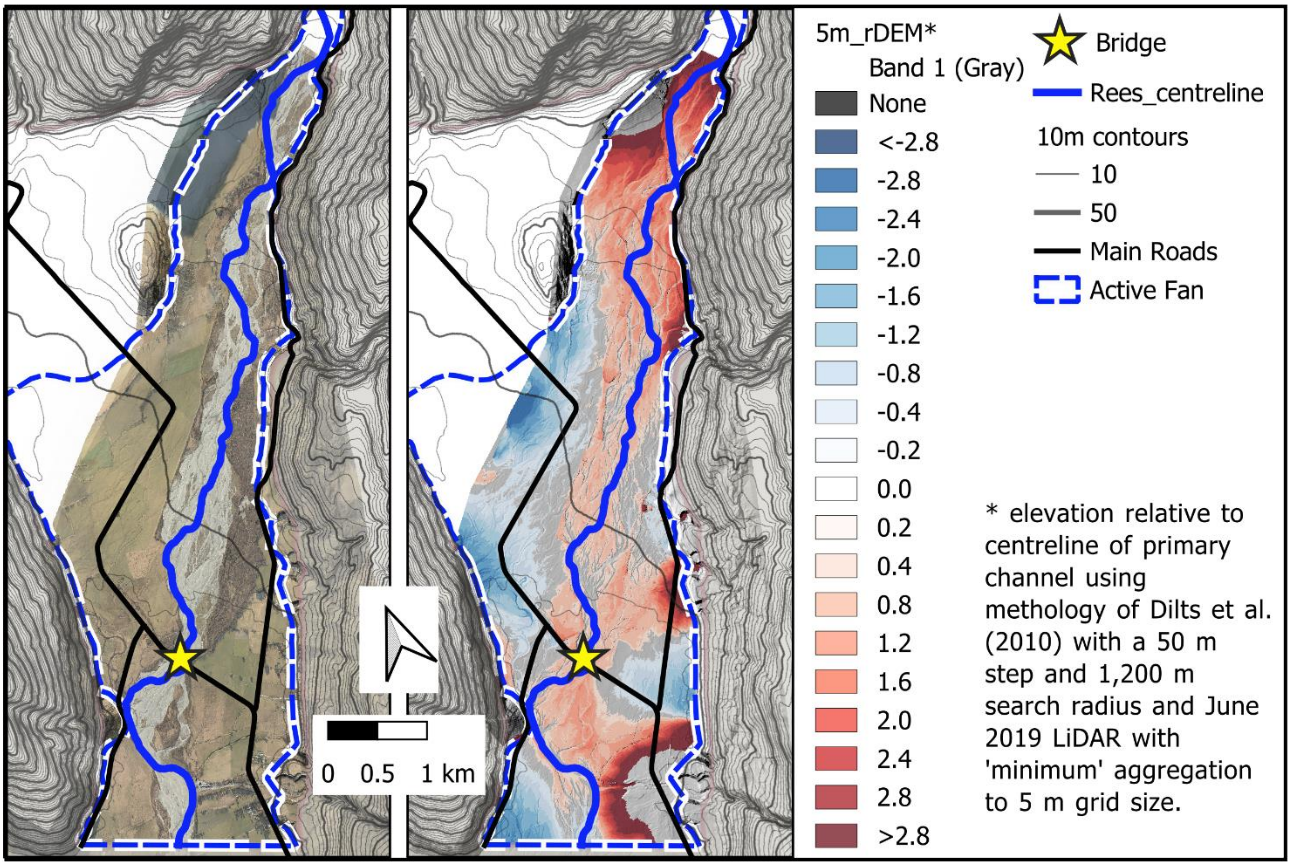

Figure 10. 2019 Aerial orthoimage (left) and relative elevation DEM based on June 2019 LiDAR. The "centreline" represents the location of the primary channel's centreline.

4.4.2 Findings

- The bridge is sited within a general area expected to naturally accumulate sediment and rise in elevation over time. Such behaviours are expected to produce lateral shifts in the horizontal location of the braidplain that are difficult to predict at a point in time but can generally be expected to occupy much of the active fan zone, potentially over the next couple of decades.
- Upstream of the bridge, the contemporary braidplain:
  - Seems likely to continue flanking/migrating along the right margin in the near-term.
  - Has sufficient topographic advantage to avulse (realign) at several locations of the right floodplain, with Diamond Creek a preferred alignment/outlet.
- The bridge section is also one of the narrowest portions of the braidplain. It appears under-sized based on backwatering indicated by the hydraulic model results (Figure 5, Figure 6). Some key observations of the upstream and downstream reaches are:
  - The sub-reach ~125-150 m upstream of the bridge Is backwater-influenced during the 5-year and 100-year ARIs. Hence, it is inferred that backwatering inhibits local sediment transport capacity.
  - The sub-reach ~150-700 m upstream of the bridge exhibits flow contraction and very high velocities at the 5- and 100-year ARIs. This zone of higher velocities is inferred to mobilise and transport a greater quantity (and larger calibre) of bed materials per unit of stream flow.

  - The differential in sediment transport capacity of the two sub-reaches immediately upstream enhance the natural tendency for sediment deposition (and bed aggradation) as the river transits its alluvial fan. This is because the contraction sub-reach can recruit and transport more sediment than can be passed through the backwater sub-reach. This will tend to reduce channel stability and hydraulic capacity at and immediately above the bridge section.
  - Flow expansion downstream of the bridge appears to promote downstream deposition and likely contributes to bed aggradation and lateral channel activity.
- The reach from ~700 to 2200 m upstream of the bridge is one of the most active across the alluvial fan (Figure 9) and is actively flanking to the right (and has been for several decades).
  - It is unclear to what degree effects observed closer to the bridge section (i.e., increased sedimentation over the long-term associated with backwatering) may affect tail-water control for this reach.
  - Widening and active flanking of this reach could result from autogenic (self-governed) alluvial fan processes with or without amplification by the bridge.
- Other contributors to activity in this reach could include enriched sediment supply, reduced water flow (e.g., downstream of an abstraction diversion), and/or change in morphological boundary conditions. Widening (lengthening) the bridge section can be expected to increase hydraulic capacity (and reduce backwatering) associated with lateral constriction, but carries risks that have not been fully explored:
  - There is a risk of encouraging sedimentation within the section that could increase lateral hydraulic forcing (and potentially, abutment scour).
  - The likely width needed for a 50 or 100-year design life (i.e., doubling the span, or more) will be costly.
  - Even if widening the bridge addressed local sediment transport issues and tailwater control, it would not address autogenic morphological behaviour.
  - The river could avulse toward either valley margin at the bridge site with or without bridge widening, mostly likely the right. Increasing flow conveyance at the bridge could be explored for reducing left-margin avulsion risk.
- Given the observations to date and the assessment of current river behaviour, it is likely that aggradation remains an ongoing risk at this site. Several potential mechanisms could also increase sediment load in the future:
  - Seismic activity with Modified Mercalli VII or greater shaking is highly likely, including potential Alpine Fault rupture. Such an event would result in a significant increase in available sediment for transport.
  - Glacial retreat increasing exposure/availability of fresh sediments for recruitment and transport.
  - More intense precipitation events with potentially greater unit runoff to recruit and deliver catchment-derived sediments.

4.4.3 Strategies for Management

Based on the assessment completed, the following measures are recommended to manage that aggradation risk at this site.

- Data and information for on-going monitoring:

- Frequent (annual or better) high-resolution (1 m or better) topographic and bathymetric surveys (e.g., LiDAR) for the active portion of the fan (Figure 8) from at least the Precipice Creek confluence to upstream of the fan apex (approximately McDougall's Creek confluence).
- High-resolution surveys should be compulsory associated with earthworks within the river and/floodplain. This will inform action-effectiveness and provide an evidentiary basis for future business cases. Surveys should occur:
  - Immediately preceding all earthwork.
  - Immediately following all earthwork (i.e., as built).
  - At high temporal frequency (e.g., 1, 2, 3, 6, and 12 months) following a selected subset of earthworks.
  - Extend into untreated areas by at least half the length of the works upstream and downstream, respectively.
- Modelling of sediment transport:
  - Through the fan (inclusive of bridge section) to include the zone of probable aggradation downstream of the bridge where transport capacity drops.
  - At a minimum, modelling should assess transport continuity along the profile.
  - Explicit characterisation/prediction of quantities and morphologic forms is secondary.
  - Should be used to inform/optimise geometry and methodology for in-channel works (including gravel extraction).

- Sediment Management:
  - Designing bridge approaches/embankments to deliberately breach could potentially avoid larger river movements across the valley.
  - Stopbank geometry along the right margin upstream of the bridge is not likely suited for the long-term and will continue to be threatened in the absence of an alignment change and/or supplemental treatments (see below).
  - There may be scope to narrow the channel in the location of the bridge to increase flood velocity and sediment transport. This would be expected to provide a short-term benefit in the range of 5 – 10 years. Whilst the benefit would only be limited, it does provide some time to source additional survey so that more comprehensive assessment is feasible in the near future. This will need to be carefully considered as increasing flood velocities would likely increase local scour effects, which would need to be managed based on existing pile founding depths.
  - Realignments of individual channels should not straighten them. In the absence of data to the contrary, it is unlikely straightening at the scale being practiced is effective at reducing aggradation. There is potential it may promote sedimentation and lateral movement.
  - Extraction in proximity of the bridge should extend downstream of the bridge, not just upstream. Any bedforms (e.g., bars) should not be removed outright without consideration of (potentially undesired) morphological effects. At a minimum, bar heads (i.e., the upstream end of bars) should be preserved. As a rule, channel

excavations (including gravel extractions) should preserve/stockpile surface armour stone (i.e., the coarser surface materials), remove finer subgrade material only, then re-place the armour layer.

- There may be potential to shift the channel form from braided to more of an island-braided morphology upstream and immediately downstream of the bridge. This would create a generally more efficient sediment transport reach upstream of the bridge with increased certainty of channel locations at any given point in time. It also facilitates defining the zone of efficiency away from braidplain margins, versus the traditional stopbank/ groyne approach that encourages channel occupation along margins. Large wood jams have been used to promote island formation/persistence in numerous applications overseas for 20+ years, though have yet to be implemented in NZ. Further investigation and modelling around the feasibility of this option within the Rees River would need to be explored as there is no certainty this reach of the Rees could be converted as such and it is likely that this option will carry a significant cost.
- Actions such as bed/bar ripping, bed armour removal, and/or flow concentration upstream of the bridge should be performed with full awareness and consideration they could increase downstream sediment delivery and contributing to sedimentation at the bridge. In particular, such actions should not be conducted in the high-velocity, contracting sub-reach (~150-700 m upstream of bridge) without addressing the (lack-of) sediment transport in the backwatered sub-reach immediately upstream of the bridge.

- For the longer term, a parallel planning exercise is recommended to address the future management of the Rees River and the risks associated with continued aggradation and avulsion towards the true right portion of the floodplain (i.e., toward Diamond Creek). This should be undertaken as a collaborative effort between ORC and QLDC.

5 Structural Options Considered

In addition to the hydraulic assessment completed, options to raise the existing and/or replace the Rees River Bridge have been explored. These are discussed below:

5.1 Raising Existing Bridge

This option involves raising of the Rees River Bridge and approaches to provide freeboard during flood events. Based on current flood estimates, a raising in the order of 1 m would be required, however, this does not consider the likelihood of further aggradation at this site which would reduce the available waterway capacity.

There is also concern that raising the existing bridge (and approaches) could result in unintentional hydraulic behaviours that have not been accounted for in the modelling undertaken. This is because the current modelling results suggest that flood conveyance at this site is reliant on overland flows. Raising the bridge and approach embankments could disrupt this behaviour which may force flood flows to converge at the bridge location and consequently cause damage.

Raising of the bridge is also likely to be complex given the amount of raising required and the length of the bridge, which would make staging of the works difficult. This would involve installing jacking brackets to the piers and having a coordinated approach to lifting spans to avoid unintentional damage of the spans. An operation of this scale will likely require a period of closure on this route, which will have implications on through traffic to areas beyond the bridge including to Kinloch given that there is no alternative bridge crossing across the Rees River.

Given that it is unlikely that raising the bridge would adequately address the wider aggradation issues and the substantial cost and complexity involved, this option has currently been discounted as a potential strategy at this site. Further assessment of the implications of raised approach embankments to the hydraulics of the site is required. A raised bridge would also require further assessment to determine an appropriate allowance for future aggradation at this site, which would have an impact on the structural assessment of the existing structure and foundations.

5.2 Replacing Existing Bridge

A replacement bridge at this site will likely be single laned as there are no current wider level of service or safety issues that are apparent. Undertaking a replacement bridge enables construction to occur offline of the existing alignment, which would eliminate the need for any prolonged closures and disruption to the route during construction.

Further assessment of preferred alignments and any level of service improvements would be required if this option was to be progressed. This includes further hydraulic modelling and assessment to confirm a suitable length of structure noting that a longer bridge at this site would increase the hydraulic capacity at this site.

It should be noted that replacing the structure would not necessarily resolve the underlying aggradation and hydraulic risks at this site and consideration of the implications of raising the road embankments on overland flows would still be required along with the potential risks of having a bridge of longer length. As the current structure is in an adequate condition with a remaining life of around 40 years, further economic assessment would be required to justify the benefits of early replacement. This will likely require QLDC to undertake a business case given the scale and complexity of the works.

An indicative cost for a single lane replacement bridge of a similar length at this site is $10 M.

6 Preliminary Planning Assessment

A statutory planning scoping assessment has been completed for the Rees River bridge site and includes the riverbed immediately up / downstream of the bridge. This preliminary assessment has identified the following relevant existing regional consents, land-use resource consents, and approvals for works within the riverbed and on DOC lands located within the flowpath of the Rees River.

This preliminary assessment has not considered the proposed activities so that relevant consenting triggers are identified. It is recommended that a preliminary assessment is undertaken once a preferred option (or short-list of options) has evolved to the equivalent of concept design level. It is also recommended that pre-application meetings with council and DOC are undertaken, and possibly the resource consent and concession processes formally started, prior to the developed design phase kicking-off.

These are summarised in Table 6-1 and outlined below.

Table 6-1 : Otago Regional Council Consents (ORC Consents Database)

Consent No.	Consent Holder	Type of Consent	Location	Expiry
RM 18.194.01	Rees River Supplies Ltd	Land Use – To disturb the bed of Rees River for the purpose of extracting gravel	• Rees River, between approximately 3.8 to 4 km north northwest of the intersection of Glenorchy-Paradise Road and Rees Valley Road, Glenorchy	Due to expire (28/11/2023)

RM 18.194.02	Queenstown Hardfill Management Company Ltd	Land Use Consent -Gravel Extraction– to disturb the bed of Rees River for the purpose of extracting gravel	• No information online	Due to expire (14/11/2023)
RM 19.083.01	Queenstown Hardfill Management Company Ltd	Land Use – to disturb the bed of Rees River for the purpose of gravel extraction	• Various locations across the Rees Riverbed approx. 2.3km northeast and 2 km southwest of Glenorchy Paradise Road Bridge. (see • Copy of Consent weblink: Consent Document RM19.224.01 (orc.govt.nz)	08/11/2031
RM 20.205.01	Queenstown Lakes District Council	Land Use Consent – To disturb the bed of the Rees River including the remobilisation (discharge) and redeposition (deposit) of bed materials for the purpose of removing alluvium and debris around the Rees River Bridge.	• Approximately 480 metres south southeast of the intersection of Glenorchy Paradise Road and Priory Road • Copy of Consent weblink: ConsentMain_ALTID_AFS_SWL (orc.govt.nz)	13/05/2046
RM 19.224.01	Queenstown Hardfill Management Company Ltd	Land Use Consent – To disturb the bed of the Rees River for the purpose of gravel extraction	• Approximately 2.5 km northeast of the intersection of Glenorchy Paradise Road and Rees Valley Road • Copy of Consent weblink Consent Document RM19.224.01 (orc.govt.nz)	19/03/2025
RM 12.399.02	Glenorchy Gravel Ltd	Water Permit – To discharge contaminants, namely sediment to the Rees River and the Precipice Creek for the purpose of operating river bed crossings during gravel extraction	• Expired consent	Expired consent
RM 12.399.03	Glenorchy Gravel Ltd	Land Use Consent – Gravel Extraction – to disturb the bed of the Rees River for the purpose of extracting up to 8,000 cubic metres of gravel per year and for operating river	• Expired consent	Expired consent

		bed crossings during extraction		

The Queenstown Lakes District Council hold a land-use consent from the Otago Regional Council (RM 20.205.01) to disturb the bed for purpose of remobilisation and redeposition of bed materials for the purpose of removing alluvium and debris around Rees River bridge. The consent authorises the removal of alluvium and debris within a 50 metre radius of the Rees River bridge as shown in Figure 11 below. The conditions of this consent place limits on the amount of gravel extraction of 20,000 m^3 per event & once per calendar year within the gravel extraction zone. In addition, the conditions specify the methodology and timing of works and include conditions on the notification of affected parties, on-going monitoring and reporting requirements.

Figure 11. RM 20.205.01 Access point to Rees River (A & B) and extraction area (red shaded area)

The Queenstown Hardfill Management Company Ltd (RM RM19.224.01 & RM 19.083.01) hold two ORC land-use consents to undertake gravel extraction within the riverbed up / downstream of the bridge site. RM 19.224.01 (expires 19/05/2025) allows the gravel extraction within the area of riverbed upstream of the Rees River Bridge shown in Figure 12 below. The consent limits the amount of gravel extraction to 20,000 m^3 per year and must be undertaken in accordance with the conditions set out in the consent which specify methodology, timing of works, notification of affected parties, monitoring and annual reporting.

Figure 12. RM 19.224.01 Gravel Extraction Area near Rees River Bridge

Queenstown Hardfill Management Company Ltd also hold a land-use consent (RM 19.083.01) to disturb the bed of the Rees River for gravel extraction within an area of 2,260m upstream and 1990m downstream of the Rees River bridge shown in Figure 13 below. This resource consent (expires 8/11/2031) limits gravel extraction to 25,000 m^3 per year. The conditions of this consent specify the methodology and timing of works, notification of affected parties' requirements, monitoring and reporting requirements.

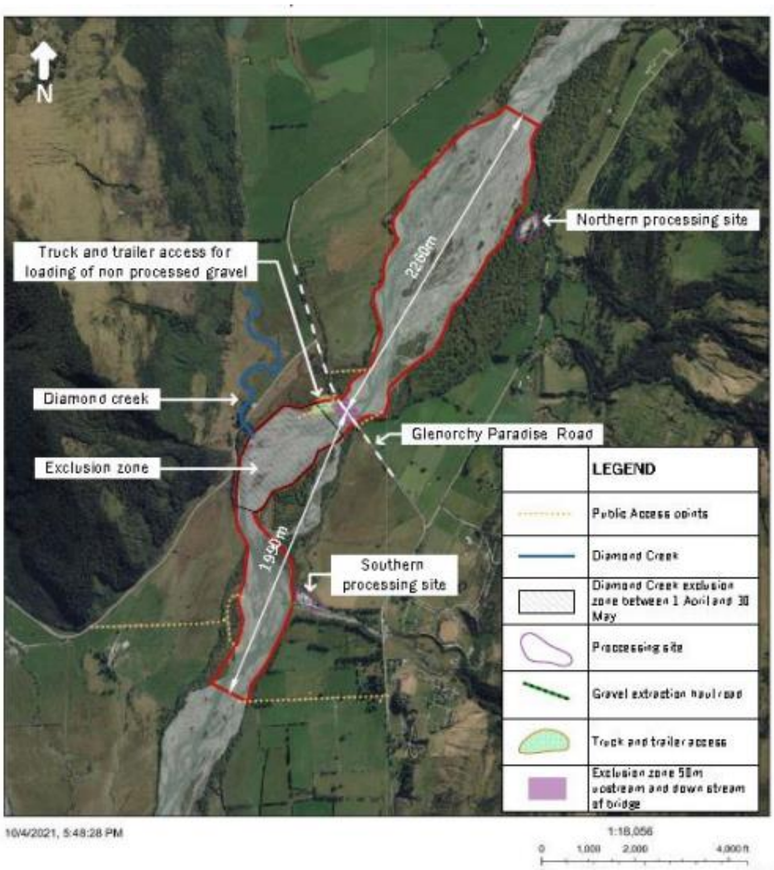

Figure 13. RM 19.083.01 Gravel Extraction Area.

Note: there is overlap in gravel extraction areas between the Queenstown Hardfill Management Company Ltd consents and the consent held by the Queenstown Lakes District Council.

In addition, one DOC Concession is active and held by Queenstown Hardfill Management Company Ltd (NO. 81314-OTH) for gravel extraction and access to Dart and Rees Rivers. A DOC Concession (No. 36143-OTH) is currently held by Glenorchy Gravel Ltd but is due to expire on 30 June 2023.

With respect to the options addressed in this report, any proposed works that are not authorised by the existing resource consent held by Queenstown Lakes District Council (RM 20.205.01) will need to be assessed against the provisions of the Proposed Queenstown Lakes District Plan, Water for Otago – Regional Plan, National Environmental Standards for Freshwater and Proposed National Policy Statement for Indigenous Biodiversity to determine what consents or approvals are required. In addition, any works on Conservation lands will need to be discussed with DOC to determine whether a Concession is required. It is recommended that preliminary consenting assessment be prepared once a preferred option is determined for this bridge site.

7 Conclusions

This report encompasses a hydraulic and scour assessment of the Rees River Bridge conducted using HEC-RAS software and LiDAR information, and a high-level review of the geomorphology at this site. The key design event assessed was the 100-year ARI flood event, and the 5-year ARI event was also modelled to assess the freeboard during a more frequent flood event and to verify the hydrology.

The key outcomes of this assessment are summarised below:

- No freeboard is available during the 5-year and 100-year ARI events. This may result in additional lateral forces being applied to the superstructure of the bridge during flood events. There is a high level of uncertainty over the hydrology due to limited observational flow data for the catchment. However, the values adopted from ORC do not appear unreasonable given we know the true left approach is flooded every few years. A longer record of flow for the Rees River and better observation information on flood events would allow more accurate assessment in the future e.g. 10 years from now.
- The maximum scour depth predicted is 4.8 m at the piers and 2.4 m at the abutments. Based on available drawings, the minimum founding depths of the existing piles are below the predicted scour depths. However, the scour assessment has indicated that the scour depths could be sufficient to expose a large portion of the piles during a flood event, especially with debris accumulation at the pier. The level of risk is hard to quantify as the exact depth of the piles is unknown and is currently based off a minimum pile level assumed from available drawings. Given the alluvial nature of the site, it is expected that the piles rely on end bearing primarily. Hence the predicted scour should not compromise their load carrying abilities provided that they are able to resist hydraulic pressures acting on them.
- There is no simple solution to the sediment transport issue, and it is expected to continue to aggrade, and potentially worsen under certain future scenarios (such as a major earthquake effecting the catchment).
- There is potential for the Rees River to avulse into the true right flood plain upstream of the bridge and plans for such an event should be considered and planned for (emergency planning). Direct linkage to the bridge section is unclear based on present analysis.
- There is potential for the Rees River to avulse toward the left margin immediately upstream of the bridge section. Backwatering evident in the hydraulic modelling results suggests the bridge may increase the risk of this occurring.

- The juxtaposition of the high-velocity, contracting sub-reach (~150-700 m upstream of bridge) discharging to the low-velocity, backwatered sub-reach (within 150 m upstream of the bridge) proliferates local aggradation and channel instability.
- Due to predicted and observed outflanking of the bridge, there is also potential for the approaches to be damaged or washed away. However, this is preferable to a bridge pier being damaged. The approaches (and hence the bridge) should not be raised in the absence of lengthening the total span as this would potentially increase the risk and extent of scour at the bridge itself by forcing more flow through the bridge.
- Lengthening the bridge will not necessarily help the situation. It can be fairly expected to increase hydraulic capacity, reduce backwater, and diminish left-margin avulsion risk. However, there is a non-zero potential for adverse bed and channel effects that would necessitate consideration of sediment transport and morphological dynamics. Narrowing (e.g. an inset channel for high-frequency events) could be explored for short-term improvement allowing additional time to collect data and undertake more comprehensive assessment. However, this will need to be considered against the potential to increase local scour effects at the piers.

It is evident that the aggradation risk at the Rees River Bridge is reliant on wider geomorphological behaviours and the hydraulic characteristics of the wider floodplain. While structural options such as raising the existing bridge and early bridge replacement were considered, the feasibility of both options remain subject to further assessment and not considered to be of priority. The bridge raising option is also likely to be cost prohibitive and unlikely to be favoured particularly given the potential closure that would be required given that alternative crossings are not available. A full bridge replacement also carries a significant cost and is unlikely to be favoured given the considerable remaining life (~40 years) of the structure.

8 Recommendations

8.1 Hydrology

ORC should continue to collect flow data for the Rees River to allow more robust estimation of flood flows for the site in the longer term (>10 years).

QLDC or ORC should collect data on any flooding that occurs in the vicinity of the bridge to allow better validation of flood flow estimates and flood modelling at the bridge. This could include aerial observation (e.g. photography from a helicopter or drone), marking of flood extents for survey pick up and / or survey of wrack marks. This would allow inference of the flood elevation at the bridge relative to the soffit.

8.2 Monitoring of Braidplain

At least annually, undertake LiDAR survey of the area, including channel bathymetry to provide a better understanding of the changes occurring.

8.3 River Management

In addition to ongoing monitoring and data collection, the following are considered appropriate short-, medium- and longer-term measures to manage the aggradation risk and help inform longer term plans for the bridge:

- In the short term, managing ongoing aggradation through continued gravel extraction measures appear most appropriate to minimise the rate of gravel build up. As a rule,

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channel excavations (including gravel extractions) should preserve/stockpile surface armour stone (i.e., the coarser surface materials), remove finer subgrade material only, then re-place the armour layer. Realignments of individual braids should not straighten them and not remove bedforms outright. A methodology to optimise the efficacy of the gravel extraction (both in terms of geometry and location) should be developed as part of a wider implementation plan for managing the aggradation risk in the Rees River.

- In the short to medium term, narrowing the channel (e.g. groynes) in the location of the bridge to increase flood velocity and sediment transport should be considered. This would be expected to provide a short-term benefit in the range of 5 – 10 years, providing time to source additional survey so that more comprehensive assessment is feasible in the near future. Implementation of this option will require additional hydraulic modelling to iteratively determine the optimal configuration and to also 1) ensure that it does not adversely result in increased local scour at the pier locations and 2) evaluate backwatering compared to existing condition and inform potential for increased gravel extraction.
- Longer term options at this site are highly dependent on the river management strategy for the Rees River as there is potential for the Rees River to avulse into the true right flood plain upstream of the bridge and plans for such an event should be considered and planned for (emergency planning). A river management plan for the Rees River is recommended and requires collaboration between QLDC and ORC, noting that works in the vicinity of the bridge (upstream/downstream) to control the Rees River would require assessment of the implications to the bridge.

9 References

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