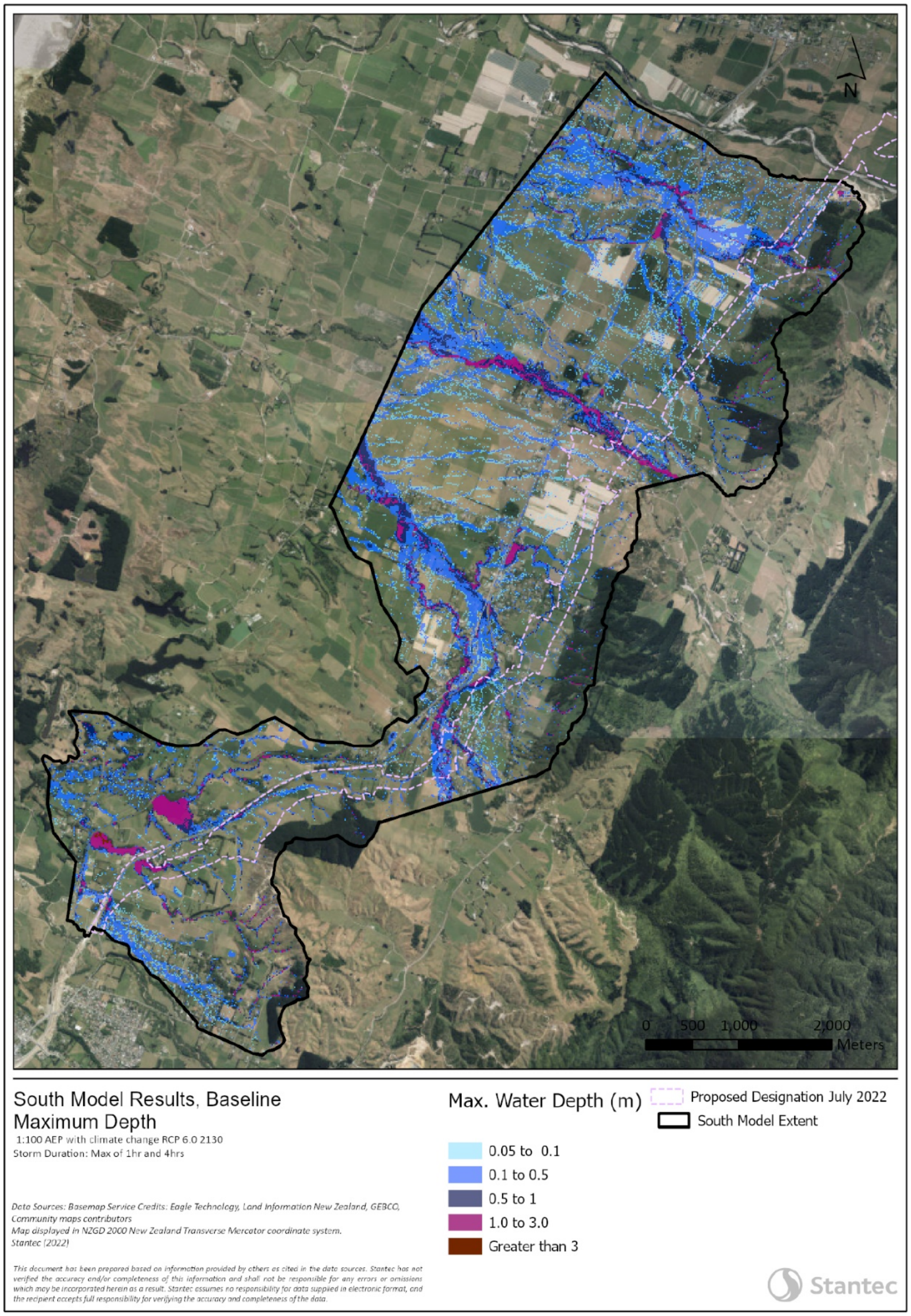

Figure F.11: Baseline (without Project) maximum modelled depths 1:100 AEP RCP6.0 2130 (South)

Ō2NL PROJECT SHAPING AND AVOIDING AND MINIMISING EFFECTS

109. My early integration into the Ō2NL Project design team has allowed me to contribute to the design to avoid or minimise potential adverse hydrological effects.

110. General principles of the hydraulic design philosophy were developed to be consistent with the Ō2NL Project Cultural and Environmental Design Framework ("**CEDF**"), included as Appendix 3 to Volume II, the principles of which will continue to guide the detailed design.

111. Examples of key principles that will help to avoid and minimise effects on hydrology and flooding include:

(a) Maintaining existing natural flow paths downstream as far as reasonably practicable, during low and flood flows. This will be achieved through suitable number, size and placement of bridges and culverts and managing intervening overland flows via small clean open diversion channels.

(b) Minimising the encroachment of proposed works into streams and their floodplains where practicable, to minimise loss of flood conveyance or storage, high value ecological habitat and disturbance of natural fluvial processes. This is achieved through the proposed bridging of the major rivers / streams and avoiding or minimising placement of other project features in floodplains where practicable.

(c) Avoiding or minimising exacerbating the existing flood hazard.

(d) Culverts on permanent streams with existing or potential fish habitat will be designed consistent with the Resource Management (National Environmental Standards for Freshwater Regulations 202 ("**NES Freshwater**") Regulation 70.

112. Additional information on the design philosophy is provided in the DCR (Appendix 4 to Volume II).

ASSESSMENT OF EFFECTS

Potential effects to be assessed

113. Potential hydrology and flooding effects from a new highway, if unmitigated, could include the following:

(a) Increase in peak flood levels, depths and durations, either upstream or downstream, which could cause damage to buildings or crops.

(b) Increase in peak velocities on account of changes in infiltration, and/or modification of flow pathways.

(c) Increase in flood hazard (a function of depth and velocity) which could pose risk to people or livestock.

(d) Increase in scour potential (a function of velocity, material composition, sinuosity, depth and other hydraulic parameters) which could result in localised erosion.

Adopted assessment criteria

114. The main design event referenced in this assessment is the 1:100 AEP event, including the potential effects of climate change (RCP 6.0 scenario to 2130). All model results refer to this event, unless stated otherwise.

115. The thresholds I have applied when considering the actual and potential effects of the Ō2NL Project on hydrology and flooding are influenced by the following factors:

(a) Land-use and receptor type, which is predominantly rural apart from Levin and Manakau. The settlement at Ohau is on a ridge that is not sensitive to any hydrological changes within the proposed designations. Any existing building in an area potentially affected by the Ō2NL Project was given careful analysis.

(b) Topography, which is dominated by moderate gradients in which upstream backwater effects are short and the downstream redistribution of any changes in flow occurs over a short distance.

(c) Flooding, which is typically of short duration because of the short catchment response times and relatively steep topography. Most plant species are not expected to be sensitive to minor changes in the depth of inundation over such short durations, given the extreme nature of the selected design event.

(d) Extent or spatial scale of potentially impacted areas.

(e) Considering the project core principles, which include Kaitiakitanga and to 'Tread Lightly, with the whenua'.

(f) Accuracy of modelling used to assess potential effects, which is reasonable for the scale and stage of the Project.

(g) Other factors of pre-existing and ongoing change in the area, such as natural sediment mobility, which can change the course of rivers or the elevations of their beds and banks over time, including their hydraulic roughness and velocities. This process varies over time, particularly after earthquakes and/or heavy rain which can trigger injections of debris into stream systems.

116. These factors provide context to the dynamic environment in which the potential effects of the Ō2NL Project are evaluated.

117. Therefore, it is difficult to assign a single set of effects thresholds uniformly to all areas and some expert judgement is required. The criteria in **Table F.4** have been used as a guide for the assessment of effects in the context of the Ō2NL Project.

Table F.4: Less than minor effects screening criteria (project specific context)

Location of impact	1:10 AEP current climate	1:100 AEP RCP 6.0 2130
Upstream 50m beyond proposed designation, provided no buildings impacted (confirmed by model)[7]	<0.1m	<0.1m
Upstream at proposed designation, provided no buildings impacted (confirmed by model)	<0.2m	<0.5m
Within proposed designation upstream of bridges[8]	<0.5m	<1m
Within proposed designation upstream of culverts[9]	<1m	<1.5m
Downstream at proposed designation[10]	<0.2m	<0.2m
Downstream 100m beyond proposed designation[11]	<0.05m	<0.05m

118. The change criteria in each box does not imply that exceeding the threshold is necessarily unacceptable or that mitigation is required. Rather, the aim is

[7] These upstream criteria are only applicable in a rural environment with no buildings impacted. Modelling has confirmed that no buildings upstream of the designation are impacted by the Project, therefore there is no need for an additional category for impacted buildings. Distances upstream or downstream of designation can be measured as a distance buffer rather than following a particular watercourse.
[8] This threshold is a guide, and consideration is also given to site-specific velocity. For this assessment, all buildings within the proposed designations are ignored (assumed to be acquired and either demolished or later sold with an updated flood risk profile where applicable).
[9] P46 references a maximum of 2m surcharge above soffit (soffit typically being higher than the pre-project flood level), but 2m surcharge causes high culvert velocities that are not conducive to substrate stability requirements for fish passage. For this assessment, all buildings within the designation are ignored (assumed to be acquired and either demolished or later sold with an updated flood risk profile where applicable).
[10] Small lateral differences that re-distribute a short distance downstream may be tolerable in the rural context.
[11] It is important to avoid cumulative effects passing a significant distance downstream of the Project, to avoid increasing flood risk to dwellings downstream. Greater distances for lateral redistribution may be tolerable on a site-specific basis.

to identify potential increases above this threshold for consideration, even where there the effects on the receptor or receptors may be acceptable.

119. The minimum threshold of 0.05m change in water level is informed by the considerations discussed above, and the modelling tolerance when comparing simulations. It does not imply that the models are an accurate representation of actual flood levels to within 0.05m at all locations within the model domain. The model allows detection of likely relative change arising consequent of the Ō2NL Project concept design.

120. Changes within the footprint of the modelled concept design can appear to produce large changes in peak water level because of the applied changes in topography (i.e., earthworks) and can therefore be ignored. These are not discussed unless there are consequential effects such as high velocities requiring scour protection, or effects extend outside of the proposed designations.

121. Changes in velocity are assessed on a site-by-site basis, including by comparison with baseline velocity in upstream and downstream reaches.

122. Changes in maximum water level and velocity outside the proposed designations are both less than minor, and do not extend into built-up areas, therefore hazard (which is a function of depth and velocity) is less than minor and is not discussed.

123. Full maps of modelled peak water level difference (on account of the concept design) are presented in Appendix F.2. Site specific comments are provided below.

Ohau River bridge and floodplain relief bridge

124. The Ohau River bridge and floodplain relief bridge function together to pass flood flows and are therefore considered together.

125. The Ohau River has a bank full channel width of approximately 70m in the vicinity of the proposed crossing (refer to **Figure F.12**). The floodplain width varies from 300m-500m; formed by past meandering and braiding of the river along with the deposition of alluvium.

Figure F.12: Ohau River near proposed crossing (looking upstream)

126. The Ohau River bridge concept design would result in an increase of water levels in the main channel of 0.5m-0.6m relative to baseline. This is within the 1m criterion for change within the proposed designation. The increase is caused by the attenuating effect of northern embankment and associated backwater. This reduces some of the flow leaving the main channel toward the north, near and upstream of the bridge. Along the upstream proposed designation boundary, the maximum increase remains below 0.4m (ie within the 0.5m criterion). This decreases to <0.1m within approximately 70m upstream of the designation boundary, without posing risk to any buildings. The distribution of increased water levels for the main design event is shown in **Figure F.13**. The slight change in flow distribution between the main channel and floodplain returns to its original flow pattern (<0.05m change) approximately 115m downstream of the proposed designation, over undeveloped land. This effect is considered less than minor.

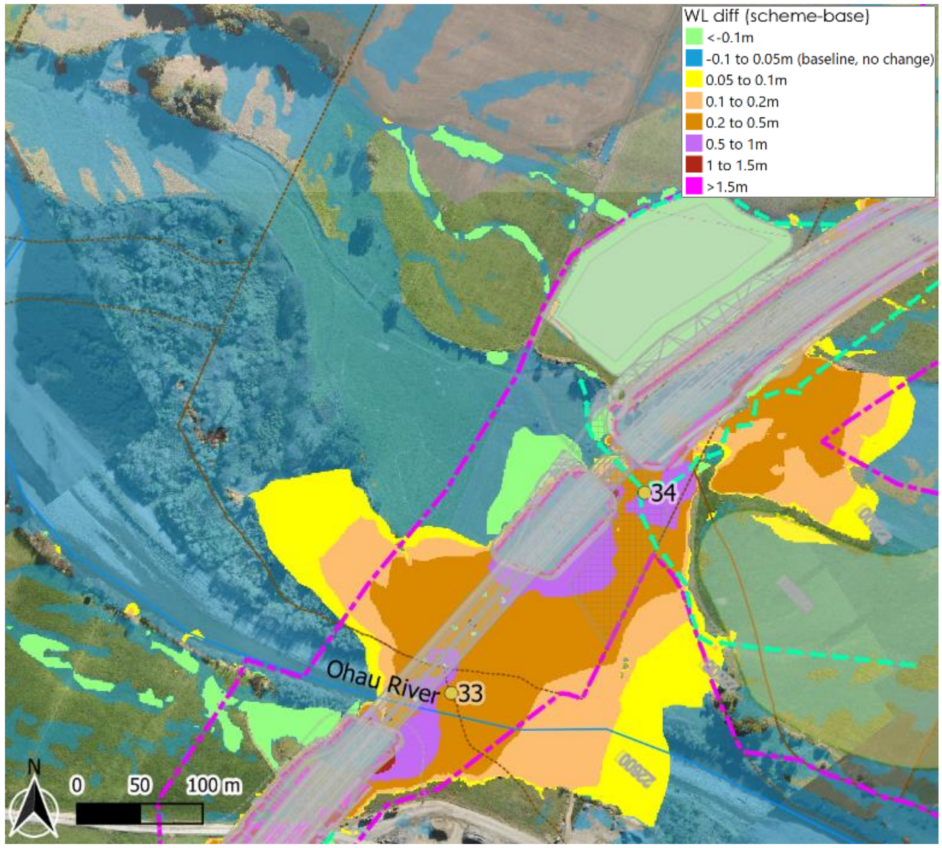

Figure F.13: Peak water level differences Ohau River and floodplain in a 1:100 AEP flood event with climate change

127. In the 1:10 AEP baseline event, there are areas of shallow flow over the northern floodplain. The small change in in-bank levels on account of the Project causes these shallow overland flows to increase slightly. The slightly modified flows (which are small in the context of the Ohau River) propagate along the floodplain for approximately 500m until the flow path re-joins and fully mixes with the main channel, as shown in Figure F.14. Given the landscape context and absence of sensitive receptors within the areas showing change, these effects are considered acceptable. It is also likely that improvements to the detailed design of the southern bridge abutment position (for the quarry access track), and refinements to the modelling of the piers and scour protection, will demonstrate lessened effects for the final design.

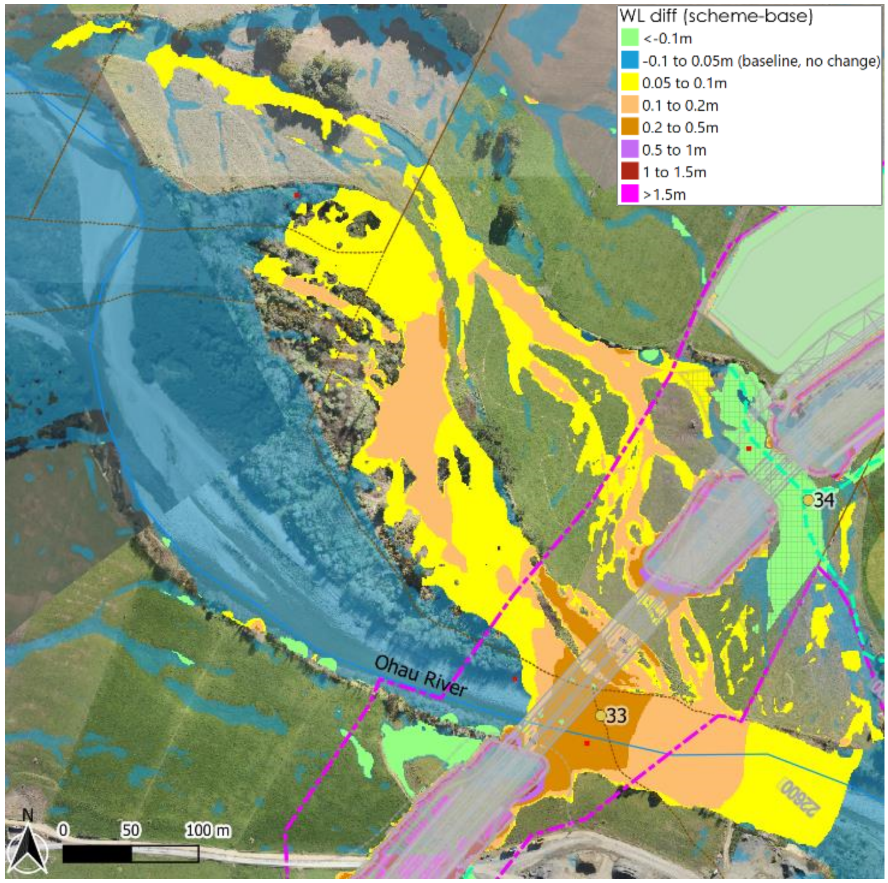

Figure F.14: Peak water level differences Ohau River and floodplain in a 1:10 AEP flood event

128. At the location where the river crosses the upstream designation, the change in water level between baseline and with-scheme (ie With Project) is illustrated by the water level hydrographs below.

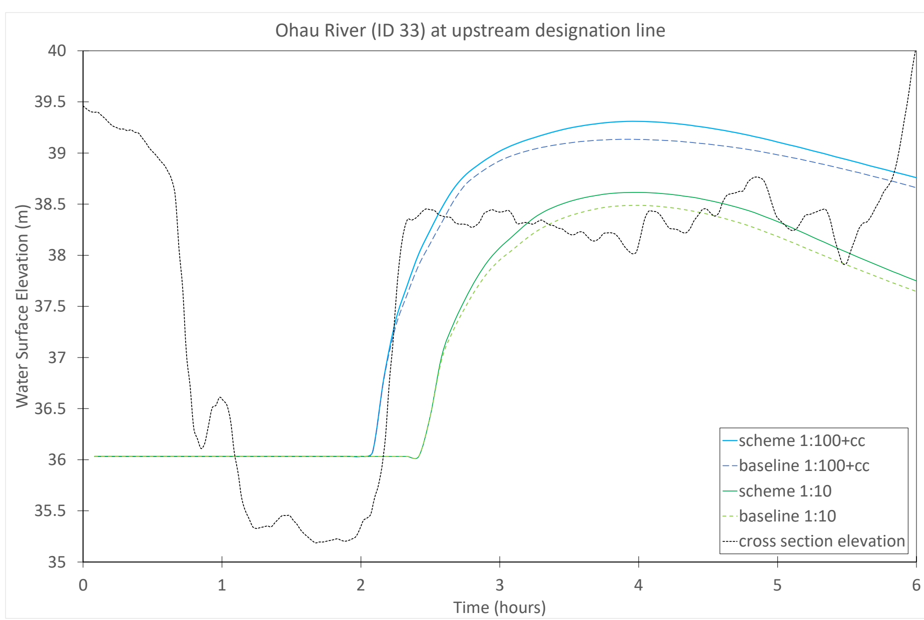

Figure F.15: Water level hydrographs on the Ohau River at the upstream designation

129. Despite the increases in peak water levels, the effect of the Ō2NL Project is considered less than minor for the following reasons:

(a) The changes within the proposed designation meet the screening criteria.

(b) The rural land-use and landscape features are not sensitive to the small, short duration of peak water level change during the extreme design event.

(c) Once the slight changes in flow distribution between the main channel and floodplain returns to the original flow pattern downstream, there are no cumulative effects passed further downstream and no existing buildings with discernible increases in flood risk.

(d) Because of the land-use and topographic contexts, effects of this magnitude are considered less than minor.

130. The indicative bridge piers (four sets of two piers) have been included in the model. There is a localised reduction in velocities around the piers (**Figure F.16**). Because the piers and the northern floodplain embankment both slightly impede the flow, the velocities are slightly increased in the spans between the piers, particularly on the northern / right bank floodplain (**Figure F.17**).

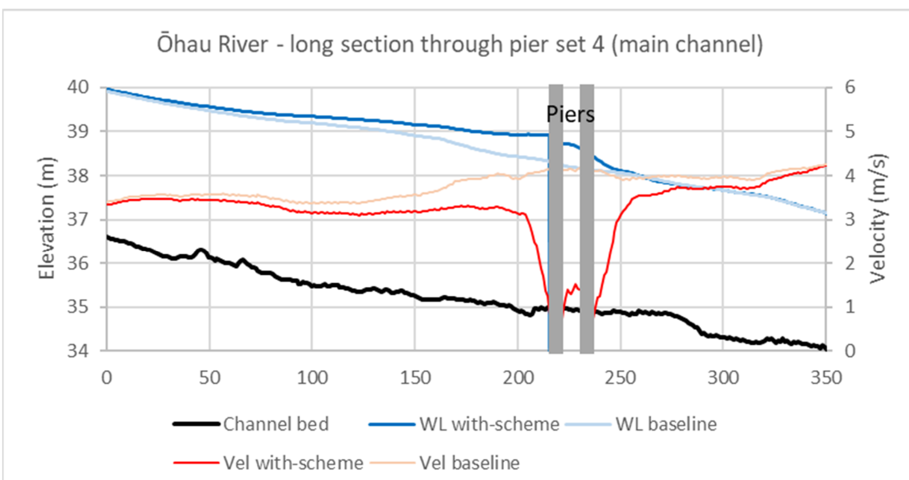

Figure F.16: Ohau River long section through pier set in a 1:100 AEP flood event

131. On the downstream true left (southern) bank of the Ohau River, the in-bank water levels closely mimic baseline behaviour. When the detailed design is progressed, including bank scour protection and provision of an access track to the quarry, the elevation of this bank can be refined to maintain the existing flood behaviour downstream.

132. The true right (northern) floodplain slopes northwards away from the Ohau River at this crossing location. A significant proportion of the total design flow is conveyed across this floodplain, including some flow that breaks out of bank much further upstream (east of Muhunoa East Road). To cater for this combined flow, the proposed flood relief bridge on the northern floodplain (flow path ID 34) has a 35m long top span, which reduces to 31m at floodplain level (because of the abutments). A wide shallow ‘scrape’ is applied in the concept design to improve flow capacity on the floodplain approaching and through the throat of the flood relief bridge. This feature does not influence how much flow exits the Ohau River onto the floodplain. The net result of the concept design is approximately 0.5m increase in peak levels at the bridge, relative to baseline, dissipating to <0.1m within 50m upstream of the proposed designation. Because of the land-use and topographic contexts, an effect of this magnitude is considered less than minor.

133. Velocities in the centre of the main Ohau River channel exceed 4m/s under the existing environment and the concept design scenarios. The exact locations of these peak velocities change over time because of sediment movement. This occurs independently of the Project.

134. Velocities in the throat of the flood relief bridge reach approximately 3m/s, and scour protection is proposed through this bridge. During the 1:10 AEP event, the floodplain flow is shallower, and the velocity is less than 1m/s through this bridge.

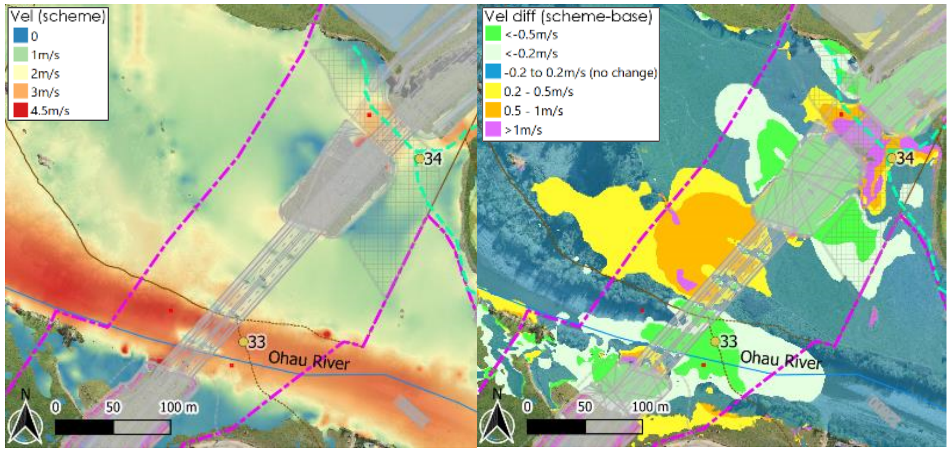

Figure F.17: Ohau River with-scheme velocity, and velocity change from baseline in a 1:100 AEP flood event with climate change

135. The presence of the combined bridges will not impede the passage of sediment and provides reasonable space for the river to migrate naturally within its floodplain.

136. Given the above findings, the overall effects on hydrology and flooding in this area are considered less than minor.

Kuku Stream bridge

137. Kuku Stream at the proposed crossing is currently traversed by a farm track with an existing pipe culvert (estimated DN1050) that appears to be partly embedded (**Figure F.18**). vThis culvert is significantly under capacity and would be outflanked and overtopped during large events. It is also at risk from blockage.

138. This undersized culvert will be replaced with a new bridge that can pass the design event with >0.6m clearance to the soffit. This freeboard allows for the passage of floating debris.

Figure F.18: Kuku Stream near proposed crossing (us/ds respectively)

139. The indicative Kuku Stream bridge has a clear width at floodplain level of approximately 17m. The modelled bridge causes an increase in flood levels relative to baseline of less than 0.5m, which is commensurate with the size of the stream (**Figure F.19**).

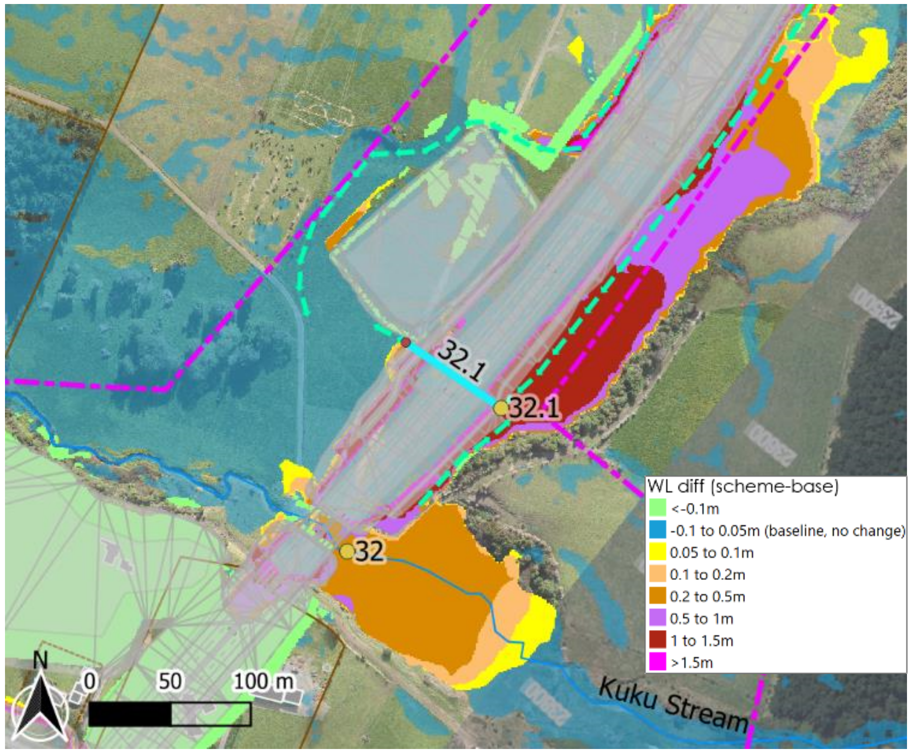

Figure F.19: Peak level differences Kuku Stream in a 1:100 AEP flood event with climate change

140. There is an existing flood berm / stop bank on the right (northern) bank upstream of the existing culvert. Historic aerial images indicate that this was built around 2017, along with some local channel straightening. This stop bank overtops during the baseline event, flowing onto the right / northern floodplain which is lower than the stream itself. This flow path is reduced by the presence of the proposed highway embankment. However, the distribution of flows rebalances quickly downstream, well within the proposed designation, to mimic the original pattern. There is no discernible change in peak water levels further downstream.

141. As indicated in **Figure F.19**, culvert ID 32.1 increases the flood level upstream by up to 1.3m along the designation boundary. It then decreases to <0.1m approximately 50m from the proposed designation, although the footprint of impacted area runs along the proposed designation for a longer distance. Given the rural land use and extreme nature of the design event, and the fact that there are no increases beyond the proposed designation for the 1:10 AEP event, these effects are considered acceptable. The extent of increased modelled water levels for the 1:10 AEP current climate event is shown in **Figure F.20** below.

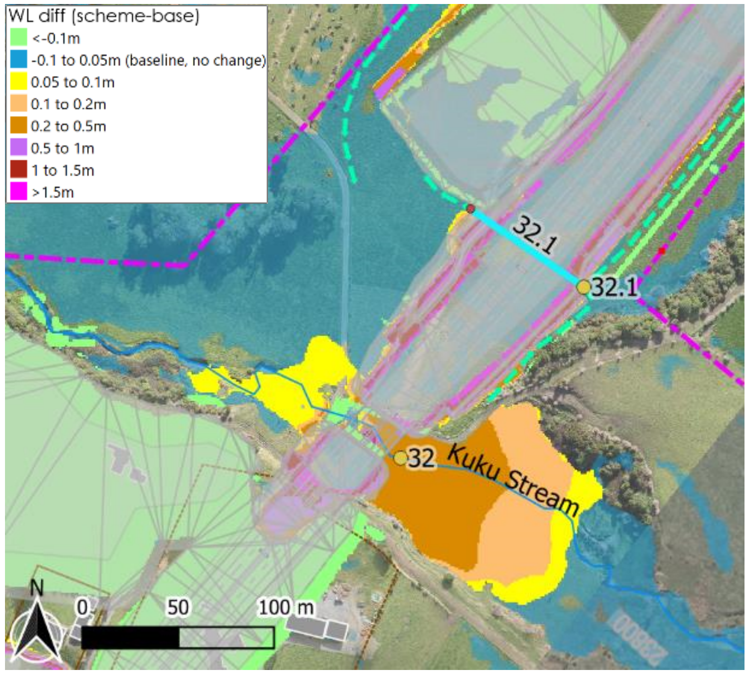

Figure F.20: Peak level differences Kuku Stream in a 1:10 AEP flood event

142. Velocities in the throat of the Kuku Stream bridge reach almost 3m/s during the design event, compared to approximately 2m/s in the baseline. Therefore, scour protection may be necessary to retain a stable channel.

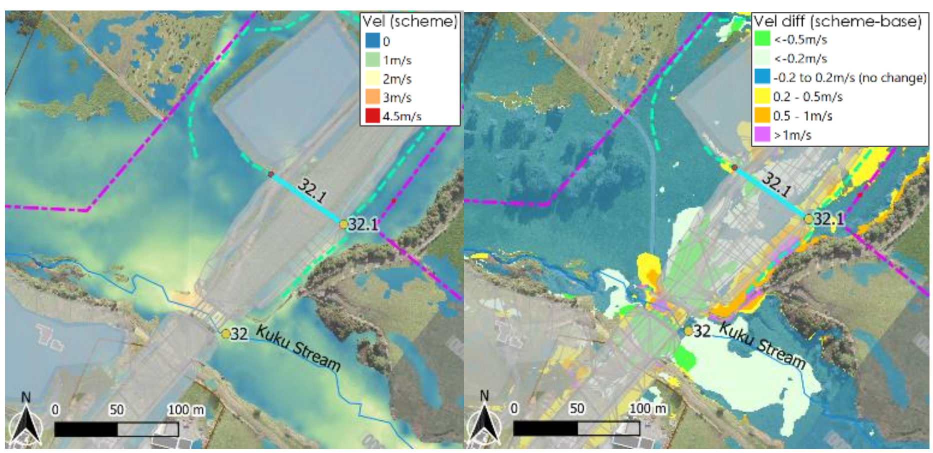

Figure F.21: Peak velocity, and velocity differences Kuku Stream in a 1:100 AEP flood event with climate change

143. The effects of Kuku Stream bridge on hydrology and flooding meet the proposed criteria for less than minor. The new bridge will be substantially more resilient than the existing SH1 bridge which floods frequently and results in closure of the State Highway.

Waikawa Stream bridge and floodplain culvert

144. The Waikawa Stream (ID 27) is an actively mobile stream with a terraced floodplain (**Figure F.22**). The main bankfull channel near the proposed crossing is approximately 25m wide, although the width varies considerably. Historical aerial photography shows that the location of the stream centreline moved approximately 45m northwards between 2005 and 2017, a period of just 12 years. The piers and abutments will be designed to allow and withstand lateral movement.

Figure F.22: Waikawa Stream photographs near proposed crossing site

145. The total width of the floodplain is around 400m. The contemporary floodplain, inundated in the 1:10 AEP design event is around 110m wide. The proposed location of the main Waikawa bridge span and abutment will avoid encroaching on this part of the floodplain. The Waikawa Stream concept bridge modelled has a 140m long total top span. The effective width reduces at floodplain level because of the spill-through abutments and the three pier sets. The resulting upstream increase in water levels compared to baseline is less than 0.3m in the main channel. There is no perceptible difference in peak water level in the main channel, either upstream or downstream of the proposed designation boundaries. It is considered that effects of this magnitude are less than minor.

146. The Waikawa tributary (ID 27.1) has a catchment area of 2km^2 but at the location of the proposed crossing also carries some excess flow from the Waikawa Stream's right bank (northern) floodplain. As a result, it has been modelled with a large culvert, with a 10m total waterway width (split into a triple box culvert). This culvert results in a relatively large increase in water levels upstream (approximately 1.2m). The difference is just over 0.5m at the upstream proposed designation boundary but dissipates rapidly to <0.1m over an additional 30m upstream.

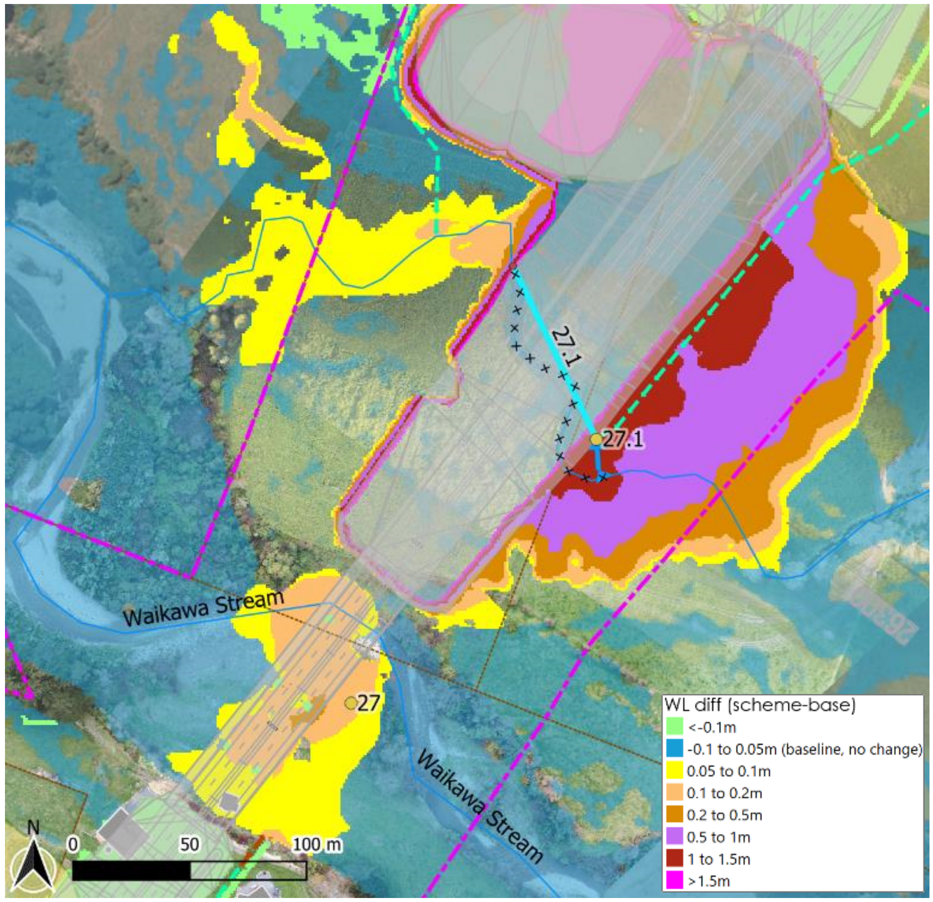

Figure F.23: Peak level differences Waikawa Stream and tributary in a 1:100 AEP flood event with climate change

147. During the 1:10 AEP current climate event, the effects on the main channel remain well within the proposed designation. On the floodplain, the upstream impacts dissipate approximately at the proposed designation. There are shallow overland flow paths on the floodplain that show a mix of reduction and increase of approximately 0.1m extending downstream of the proposed designation. These differences dissipate to original pattern (<0.05m) approximately 50m downstream of the proposed designation where the tributary joins the main Waikawa Stream floodplain. Given the land use context effects of this magnitude are considered less than minor.

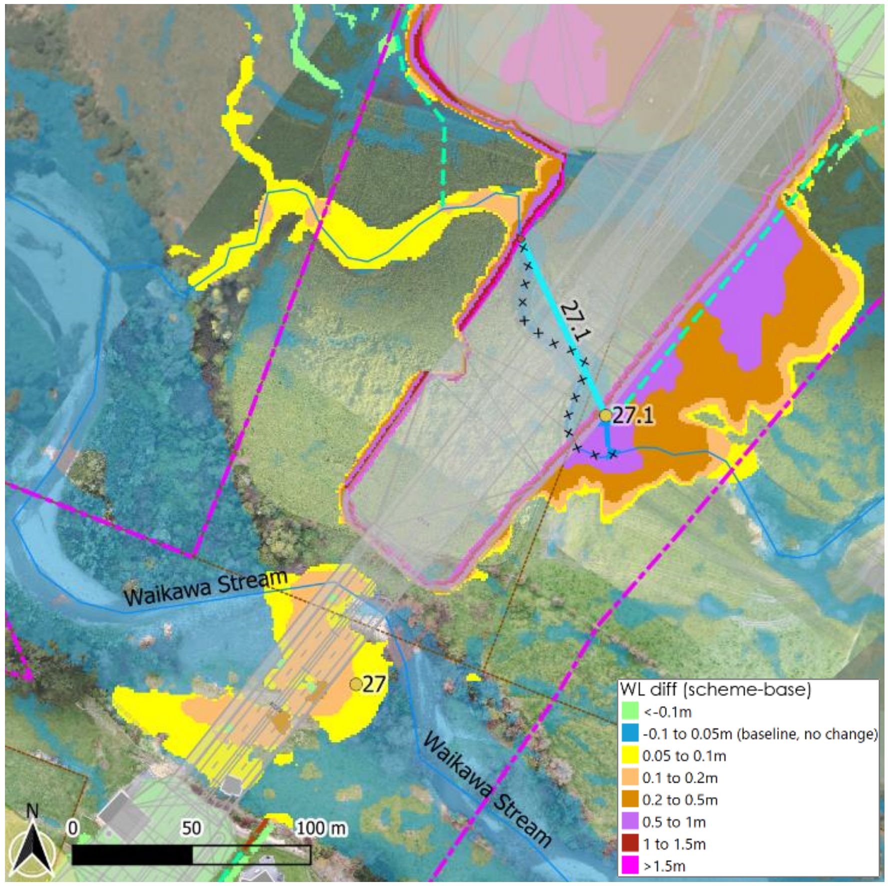

Figure F.24: Peak level differences Waikawa Stream and tributary in a 1:10 AEP flood event

148. At the location where the tributary crosses the upstream designation, the change in water level between baseline and with-scheme is illustrated by the water level hydrographs below.

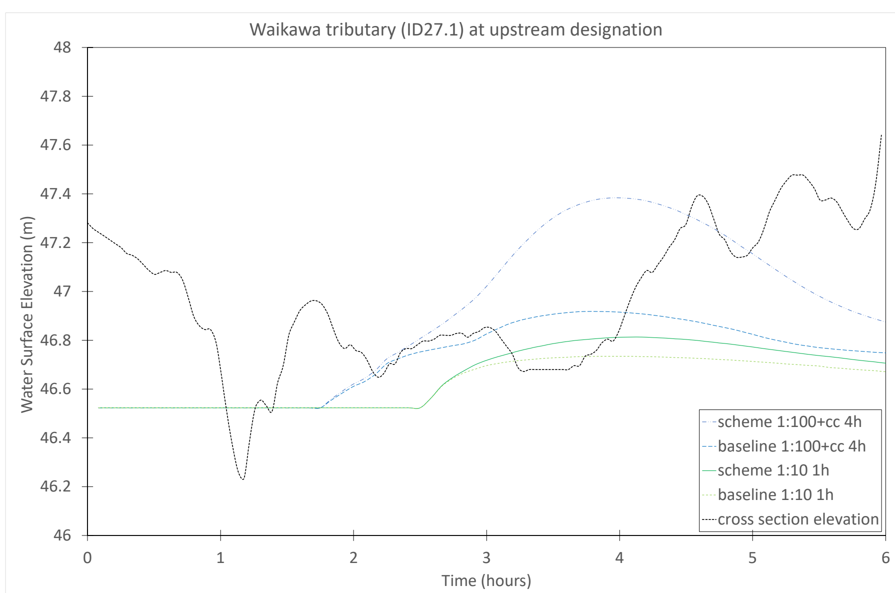

Figure F.25: Water level hydrographs on the Waikawa tributary at the upstream designation

149. At the main Waikawa Stream bridge, three sets of double piers have been included in the model. There is a slight reduction in velocities around and downstream of the piers. In the free spans between the pier sets there is a slight localised increase in velocity, but this is mainly a shift in where the peak velocities occur across the section (**Figure F.26**). Peak velocities in both the Ō2NL Project and baseline models are approximately 3m/s. Velocities on the northern floodplain are reduced as they approach culvert ID 27.1, because of the embankment. Patches of slightly increased velocity occur downstream on the floodplain, associated with small changes in shallow depth and therefore less than minor in effect.

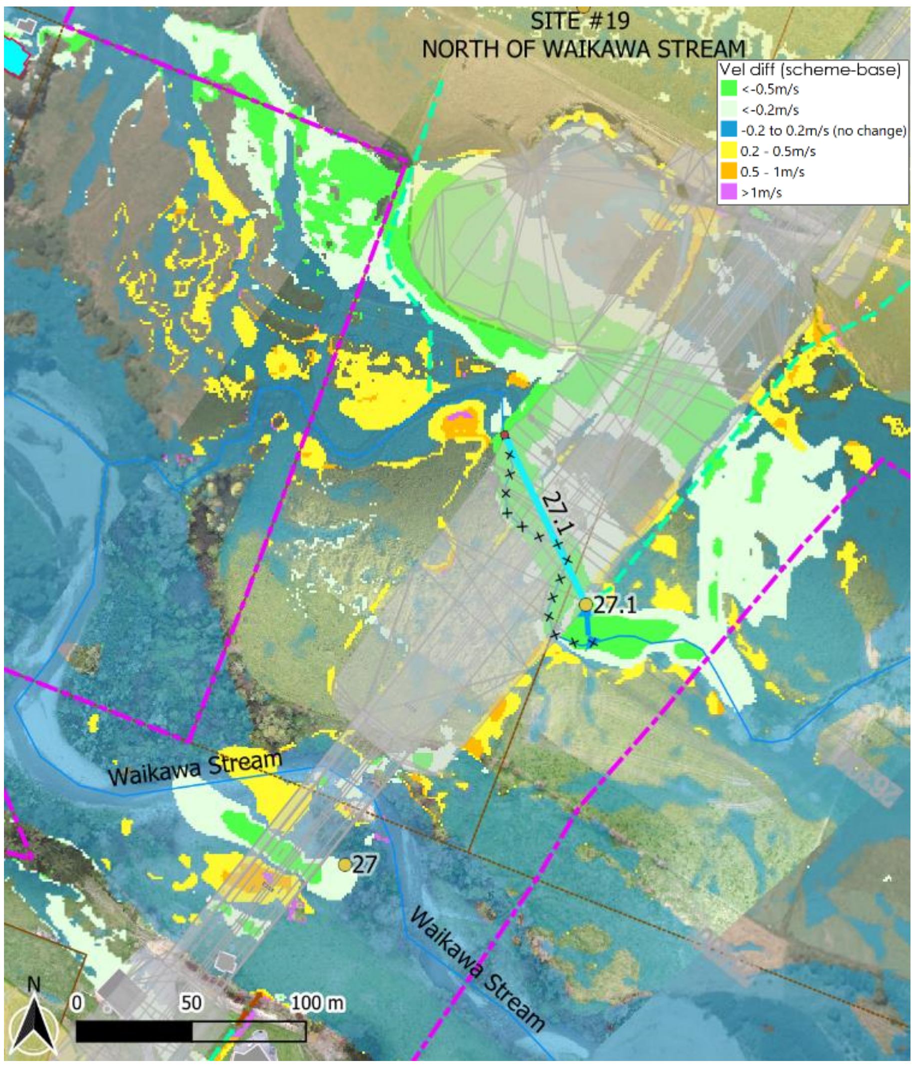

Figure F.26: Peak velocity differences Waikawa Stream and tributary in a 1:100 AEP flood event with climate change

150. Given the above, any effects of the Ō2NL Project on hydrology and flooding can be considered less than minor.

151. The Ō2NL Project offers the benefit of being much more resilient than the existing SH1 bridge.

Waiauti & Manakau stream bridges

152. Manakau Stream (ID 15) is a small meandering stream, although the floodplain is not particularly wide or well defined near the proposed crossing. Manakau Stream is currently constrained by South Manakau Road and the existing bridge (to be retained) immediately downstream of the proposed crossing (**Figure F.27**).

153. The existing bridge is 9m wide, and the opening is partly filled with gravel on the right-hand (eastern) side. The existing channel upstream varies in width but is typically around 5m wide.

Figure F.27: Manakau Stream existing bridge downstream of proposed crossing

154. The indicative concept bridge will span both the watercourse (modelled as 13m of 28m) and the existing South Manakau Road (15m of 28m for road and SUP).

155. Assuming this design, peak water levels increase by 0.3-0.4m approaching the embankment (**Figure F.28**). There is a slight reduction in levels through the throat because of the necessary realignment of one meander loop under the design modelled. A small amount of spill over South Manakau Road