IN THE ENVIRONMENT COURT OF NEW ZEALAND
WELLINGTON REGISTRY

I MUA I TE KŌTI TAIAO O AOTEAROA
TE WHANGANUI-Ā-TARA ROHE

ENV-2020-WLG-00014

UNDER	the Resource Management Act 1991
IN THE MATTER OF	a notice of motion under section 87G of the Act seeking the grant of resource consents to Waka Kotahi NZ Transport Agency for Te Ahu a Turanga: Manawatū-Tararua Highway

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STATEMENT OF EVIDENCE OF KEITH DAVID HAMILL ON BEHALF OF WAKA KOTAHI NZ TRANSPORT AGENCY

WATER QUALITY

12 June 2020

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INTRODUCTION

1. My full name is **Keith David Hamill**.

2. I am an Environmental Scientist and Director at River Lake Limited. River Lake Limited is a consultancy company that provides research and environmental science advice for understanding and managing rivers, lakes and estuaries. My technical speciality is in water quality and aquatic ecology.

3. I prepared Technical Assessment C Water Quality ("**Technical Assessment C**") as part of Volume IV of the Assessment of Environmental Effects ("**AEE**"), which accompanied the application for resource consents lodged with Manawatū-Whanganui Regional Council ("**Horizons**") on 11 March 2020 in respect of Te Ahu a Turanga: Manawatū Tararua Highway Project (the "**Project**").

4. My qualifications and experience are set out in paragraph 2 of Technical Assessment C.

5. In preparing Technical Assessment C and my evidence I have:

    (a) provided advice on water quality matters related to the Project to Te Ahu a Turanga Alliance ("**Alliance**"), and ultimately Waka Kotahi NZ Transport Agency ("**Transport Agency**"), since September 2019;

    (b) participated in natural character workshops and discussions with other members of the natural character team as described in the evidence of **Mr Boyden Evans**;[1]

    (c) visited the site with iwi representatives (on 30 September 2020);

    (d) reviewed other technical assessments and management plans provided in the AEE with respect to water quality issues;

    (e) responded to parts of the section 92 request for further information that relate to water quality, and participated in a teleconference meeting on 20 April 2020 with representatives of Horizons (including Logan Brown, Mark St Clair and Kerry Pearce) to discuss the section 92 request; and

    (f) met with representatives of Horizons (Logan Brown, Mark St Clair and Kerry Pearce) on 2 June 2020 to discuss issues raised in the section 87F report.

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[1] This includes updating my assessment of water quality attributes (together with Dr Alex James) for crossing points 4D, 5B and catchments 4 and 5; and agreeing the overall rating for these crossing points / catchments now that it is proposed to remove some of the stream diversions and riparian planting from within Te Āpiti Wind Farm. Dr James and I concluded that the removal of these features would not have sufficient effect to change the ratings for the water quality attribute.

Code of conduct

6. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2014. This evidence has been prepared in compliance with that Code. In particular, unless I state otherwise, this evidence is within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

Purpose and scope of the evidence

7. Technical Assessment C assesses the potential effects of the Project on water quality and recommends measures to address those effects.

8. My evidence does not repeat in detail the technical matters set out in Technical Assessment C. Rather, in this evidence I:

    (a) present the key findings of Technical Assessment C, updated to take into account information received more recently, in an executive summary;

    (b) comment on issues raised in submissions received in respect of the Project; and

    (c) comment on the section 87F report prepared by Horizons.

EXECUTIVE SUMMARY

9. As noted above, in this section of my evidence I summarise the key matters addressed in my Technical Assessment C and response to Horizons' section 92 request for further information.

10. The Project consists of approximately 11.5km of new state highway connecting Ashhurst and Woodville via a route over the Ruahine Ranges. I have undertaken an assessment of the Project’s construction and operational effects on water quality.

Existing environment

11. The Project is within the main catchments of the Pohangina River and the Manawatū River and directly affects nine smaller catchments (referred to as "**C1 to C9**"), which all drain to the Manawatū River except C9. Most of the catchments are steep with the exception of C1, C8 and parts of C2 and C4.

12. Water quality across the catchments is varied; in general, the streams are characterised by:

(a) relatively low water clarity (well below the applicable One Plan target) and high turbidity – particularly during rain events;

(b) generally high cover of deposited sediment in all catchments except the middle reaches of catchment 7 and lower reaches of catchment 6;

(c) high concentrations of nitrate in C1, C2, C7 and C8;

(d) high concentrations of dissolved phosphorus in C5, C6 and C7;

(e) occasionally high or very high concentrations of *E. coli* bacteria in all catchments, with the possible exception of C6 and upper C7; and

(f) concentrations of copper (Cu) and/or zinc (Zn) elevated above Australian and New Zealand Guidelines for Fresh and Marine Water Quality ("**ANZG**") Default Guideline Values ("**DGV**") in C4, C5, C6 and C7. The potential toxicity of Zn and Cu on aquatic life is reduced by all catchments having moderate to high water hardness. Water hardness was particularly high in C7.

13. Turbidity loggers installed in C2 and C7 since September 2019 frequently record high turbidity (>100 NTU[2]); these records are often, but not always, associated with rain events.

Potential effects on water quality

14. The key activities considered in assessing the potential effects of the Project on water quality were:

(a) sedimentation effects from earthworks and potential effects of flocculants in erosion and sediment control devices;

(b) vegetation clearance and mulching that potentially affects water quality;

(c) use of concrete which potentially affects water quality; and

(d) stormwater discharges from the long-term operation of the road.

15. My assessment of the effects of sediment released during the construction phase of the Project was informed by sediment yield calculations from Technical Assessment A by **Mr Campbell Stewart**. The bulk earthworks during construction will increase sediment loss and reduce water clarity. This

[2] NTU stands for Nephelometric Turbidity Unit. It is a measure of light scattering and is usually strongly correlated with water clarity and the concentration of total suspended sediments.

will be more apparent during high flow events and in smaller sub-catchments. In some locations, discharges during rain events may cause the water clarity to temporarily reduce by more than the 30% reduction set as a target in the One Plan.

16. Aquatic life is generally more sensitive to deposition of sediment on the stream bed than short term changes in water clarity or suspended sediment. The risk of sedimentation from discharges from treatment devices is reduced because appropriately designed treatment devices like sediment retention ponds ("**SRPs**") with chemical treatment are particularly effective at removing the fraction of sediment most prone to settling. However, it is appropriate to have a monitoring and response framework to address potential effects of any sediment discharges and I support the instream routine monitoring and event-based monitoring of deposited sediment and aquatic macroinvertebrates described in the Freshwater Ecology Management and Monitoring Plan that forms part of the overall Ecology Management Plan ("**EMP**").

17. Overall, the bulk earthworks during construction will increase sediment loss during rain-events. The effects on downstream water quality will be mitigated through actions undertaken in accordance with the Project's Erosion and Sediment Control Plan ("**ESCP**"), Site-Specific Erosion and Sediment Control Plans ("**SSESCPs**"), and the monitoring-response framework described in the EMP.

18. Vegetation clearance and the associated wood chip can pose a risk to stream water quality, however those effects can be avoided by following good practice. The EMP describes procedures to minimise the amount of wood that is mulched and to minimise the risk of any wood chip residue entering waterways. These procedures will result in a negligible to small risk of wood chip residue having an adverse effect on water quality.

19. Concrete pouring can also pose a risk to water quality, but the effects can easily be avoided and minimised by following good practice. The Hazardous Substances Procedure (**Appendix 7 of the ESCP, Volume VII of the AEE**) describes the processes to be implemented to minimise potential risks to aquatic life; these are minimising water on the works area, capturing any residual water associated with the concrete curing and either using the residual water for dust control (i.e. disposing it to land) or treating it separately prior to any discharge. Implementing these practices for concrete

pouring will, in my view, result in a negligible to low risk of adverse effects on aquatic life.

20. Road stormwater run-off during long-term operation can contain a range of contaminants that can affect stream water quality if not adequately treated. To inform my assessment of effects of long-term stormwater discharges from the Project I applied the Contaminant Load Model ("**CLM**") to each catchment for scenarios before and after the Project.

21. The Project provides for long-term stormwater treatment from all road runoff. This is in contrast to the current situation where there is no specific stormwater treatment on either the Saddle Road or the old Manawatū Gorge route. Consequently, the Project will result in improved water quality in the Manawatū River, the Pohangina River and catchments C1, C2, C4 and C9. No stormwater from the road will enter C5 and C6, so there will be no resulting stormwater effects in these catchments. There is potential for treated stormwater discharges to cause a decline in water quality in sub-catchment C2E and in C3, C7 and C8. However, for these catchments the effects will likely be small because:

    (a) stormwater discharges will be intermittent in nature;

    (b) the quality of the stormwater will be within relevant guidelines; and

    (c) for total suspended solids ("**TSS**"), the stormwater will have similar concentrations to that currently found in the streams during flood events.

COMMENTS ON SUBMISSIONS

Submission from QEII Trust (submission 16)

22. The submission made on behalf of the Queen Elizabeth the Second National Trust ("**QEII Trust**") states in paragraph 4(b) that "*Sedimentation effects will be high and have been underestimated because of the "overall" approach to effects assessment."*

23. The rationale for this conclusion is not clear to me; conversely, in my view, the assessment of effects from sediment loads has been conservative. **Mr Stewart** describes in Technical Report A and in his evidence that the modelled estimate of sediment yields is likely to be an over-estimate. This in turn makes the calculation of water quality changes during rain-event discharges a conservative estimate. This submission point is also discussed in evidence by **Ms Justine Quinn**.

Submission from Mr John Bent (submission 18)

24. The submission by Mr Bent raised concerns about the treatment of stormwater from the road and potential for contamination of the receiving environments.

25. I assessed the potential effects of road stormwater from the road in Technical Assessment C. This report describes how the Project provides a high level of stormwater treatment. In contrast to the current Saddle Road and the old Manawatū Gorge route, which have no specific stormwater treatment, all of the stormwater from the new road will be treated and as a result the Project will result in an overall improvement in water quality in the Manawatū River in this regard.

COMMENTS ON SECTION 87F REPORT

26. Mr Brown raises a number of issues in his contribution to Horizons' section 87F report. I have addressed below the key issues raised with respect to water quality.

TSS discharge standard

27. Mr Brown has used estimates for TSS from paragraph 98 of my Technical Assessment C as the basis for a proposed standard at the point of discharge (in Horizons' proposed condition ES2(f)). This is not an appropriate application of the estimates for several reasons.

28. The numbers proposed by Mr Brown were calculated by me to apply as instream concentrations after full mixing; their application as end-of-pipe standards is inappropriate, in my view. This confusion is likely attributable to a typographical error in paragraph 98 of Technical Assessment C. The sentence that reads: "*Assuming this is representative and given the predicted increase in sediment loads from earthwork sites, the median TSS discharge from sediment treatment devices would be approximately 63 mg/L in C2, 32 mg/L in C4 and 40 mg/L in C7*" should read "*Assuming this is representative and given the predicted increase in sediment loads <u>in the stream</u>, the median TSS discharge <u>in the streams downstream</u> from sediment treatment devices would be approximately 63 mg/L in C2, 32 mg/L in C4 and 40 mg/L in C7*".

29. At paragraph 95 of Technical Assessment C I estimated the TSS concentration that might occur end-of-pipe; however, in my view it is not appropriate to use either the end-of-pipe estimate (paragraph 95) or the

instream estimate (paragraph 98) as a consent compliance limit. This is because of the following:

(a) These concentrations are derived by multiplying fractional increases in sediment load by the median TSS concentration during rain events and are approximate estimates based on a very small number of samples in the monitoring dataset. They are therefore helpful for understanding a magnitude of change that might typically occur, but are not appropriate for setting a compliance limit.

(b) The estimates apply to median values over multiple rain events. Assuming the measurements are representative, then half of the rain events will have TSS values higher than estimated, thus the estimate cannot be applied as a compliance limit for a single rain-event.

(c) All the wet weather measurements were collected during small rain events (i.e. the daily rainfall prior to sampling ranged from ca. 2.5mm to 14mm). This provides an indication of what commonly occurs because small rain events are frequent, but the results are not representative of large rain events which correspond with higher sediment concentrations and higher sediment loads.

(d) The monitoring data was a single grab sample during a rain event. It is not known how representative the data are of any single rain event. The data almost certainly missed the peak TSS/turbidity and probably reflect TSS at some point on the falling limb of the hydrograph.

30. There is high variability within rain events and between rain events, and this can make it challenging to accurately characterise and estimate TSS concentrations and loads. The USLE model expresses its outputs as an annual load (e.g. tonnes per year); to convert this to a concentration (e.g. g/m^3) requires either having a large amount of knowledge about the relationship between flow and concentration in a particular stream or making assumptions about the flow conditions. In the case of my estimates, I assumed that the measurements were representative of flow weighted values for representative (i.e. median) rain events. This was helpful for describing typical effects, but I do not consider it is appropriate to derive a consent limit from this information.

31. Data from turbidity loggers are available for catchment 2 and catchment 7, which provides a much more comprehensive characterisation of stream

turbidity than grab sampling. Catchment 2 has higher baseflow turbidity than catchment 7, but both sites have very high turbidity for (usually) short durations during rain events (i.e. regularly over 100 NTU and sometimes over 1000 NTU). This turbidity data was provided in the response to the section 92 request.

32. I have used the turbidity data from catchment 2 and catchment 7 to model TSS in the streams under baseline conditions and if construction had been occurring in these catchments (see **Appendix KH.A** to my evidence). The model shows that during the construction phase, TSS in catchment 7 will be elevated during rainfall events, but there is little change in TSS during baseflow conditions and outside of rain events. Average TSS concentration over the modelled period was 22.4 mg/L and 30.7 mg/L for the baseline and construction phase respectively, but there was no change in the median TSS, which was 1.6 mg/L for both the baseline and construction phase.

33. Sediments (both suspended and deposited) have a strong influence on ecological communities but modelling these linkages can be complex. Mr Brown acknowledges this at paragraph 129 of his report, where he states that there have been *"issues developing models to establish sediment reductions required to meet deposited sediment thresholds"*. These issues include, in particular, accounting for the impact of short-term events (Franklin et al. 2019). This does not mean that short-term sediment events are unimportant – they certainly can be – but it highlights the challenges in establishing meaningful thresholds for short-duration events.

34. Setting meaningful limits for TSS / turbidity from sediment retention devices is challenging because of the high temporal variability, strong skewed correlation between rain events and flow rates, and the often complex link with ecological effects. Given the comprehensive approach to managing erosion and sediment control proposed for this Project, in my view it is more practical and ecologically meaningful to focus triggers and actions more directly on ecological effects, such as instream deposited sediment and aquatic macroinvertebrates.

Condition ES2(g) proposed by Horizons

35. Horizons' section 87F report proposes condition ES2(g), which states:

> "*The discharge of sediment from the sediment retention devices must not cause:*

i. An increase in the median visual sediment coverage of 20% or more, relative to the highest baseline visual estimates for that site, for the season that the comparison is being made against; or

ii. An increase in the median re-suspendable sediment of 20% or more, relative to the highest baseline visual estimates for that site, for the season that the comparison is being made against; or

iii. A 20% or greater decrease in mean QMCI relative to the lowest score from baseline monitoring for the season that the comparison is being made against; or

iv. A decline in median percent (%) EPT taxa richness of 20% or more compared to baseline monitoring scores for the season that the comparison is being made against."

36. It may be difficult for the Project to comply with this condition as currently written because there may be increases in deposited sediment in some areas for short periods of time during the construction phase. In my view, the monitoring and response framework described in evidence by **Ms Quinn** (and at Attachment JQ.5 to her evidence) is a more appropriate and flexible response. It recognises that there may be short term adverse effects and includes responses to mitigate effects that might occur in both the short-term and if they persisted over the long-term.

Current state in relation to One Plan targets

37. Mr Brown raises concerns that because many of the streams show signs of degradation and do not meet all the One Plan targets, this is being used as justification for further degradation (refer, for example, to Mr Brown's paragraphs 26 and 100). He proposes (in paragraph 94 and 100) that streams that do not meet all the One Plan targets (e.g. for deposited sediment and clarity) have no capacity to assimilate further sediment inputs.

38. I agree with Mr Brown that *"the fact that [water quality is] already compromised is not a sufficient or good reason to allow for further degradation"* (paragraph 26). I have not suggested otherwise in Technical Assessment C. However, current water quality has been used to estimate sediment concentrations that may occur as a result of the discharge, and has

been considered in order to understand the potential effects of a discharge on the relevant streams.

39. **Mr Damien McGahan** explains the relevance to the Project of the One Plan water quality targets not currently being met, from a planning perspective. I can confirm that the proposed discharges from bulk earthworks during the construction phase will increase sediment loads to receiving water during rain and flood events. I can also confirm that many of these waterways appear to not currently meet One Plan targets for clarity or deposited sediment.

40. In my view the concept of *"assimilative capacity"* is not readily applicable to sediment discharges. *"Assimilative capacity"* is a pseudo-technical term that can be appropriate when used in a narrow sense for comparing with a target or limit of some variables. However, in my view *"assimilative capacity"* is generally inappropriate for assessing the ecological effects of contaminants such as sediment.

41. The concept implies that there is a tipping-point, below which effects are minor and above which effects are significant. In fact, it is more common for natural systems to show a continuum of effects which are often non-linear. In the case of sediment, ecological communities with small amounts of deposited sediment (e.g. clean gravel substrate) tend to be more sensitive to additional sediment deposition than those with large amount of deposited sediment (e.g. soft-bottom streams) (see Figure 3). Focusing on *“assimilative capacity”* potentially has the perverse outcome of incentivising discharges to

streams with less sediment deposition and cleaner gravel where the incremental ecological effects of additional sediment will be greatest.

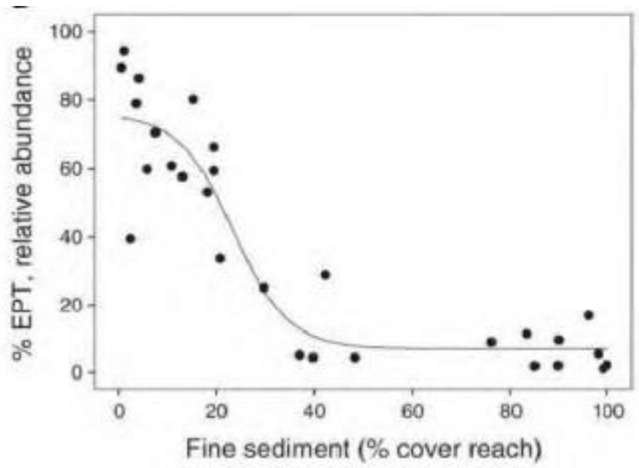

Figure 3: Response of sensitive macroinvertebrates (%EPT[3]) to fine sediment cover (from Burton et al. 2017 in Franklin et al. 2019).

42. In summary, existing water quality is relevant to assessing what the effects of an activity will be, but it has not been applied to 'allow' further degradation – rather, my assessment has assessed the expected effects of the works on water quality, taking into account the current condition.

Phosphorus connected with sediment

43. Mr Brown makes the point that phosphorus is often associated with sediment and that this can be released from sediment and utilized by periphyton (paragraph 112). This is correct and is another reason to manage sediment discharges to rivers. Both the surface-bound organic-P and inorganic-P are readily taken up by algae that are in contact with sediment. Stream bed sediments are also known to release a small fraction (about 2%) of particulate phosphorus into the river water as dissolved reactive phosphorus by mineralisation, desorption and/or reducing conditions (Hedley 1978 in Parfitt et al. 2007). Periphyton can also 'mine' particulate phosphorus trapped within their mats by creating conditions of either low dissolved oxygen or high pH (Gainswin et al. 2006, Wood et al. 2015, Hamill 2014). Although this process releases only a small percentage of the particulate phosphorus in a

[3] EPT refers to sensitive macroinvertebrates of the order Ephemeroptera, Plecoptera, Tricoptera).

dissolved form, it has potential to provide periphyton with a substantial amount of their phosphorus growth requirements.

44. In the case of sediment derived from earthwork sites we can expect a lower concentration of phosphorus per weight of sediment and less ability for periphyton to mine this sediment compared to sediment derived from farm runoff. Phosphorus in sediment derived from subsoil and stream bank material releases less in a dissolved form available to periphyton than phosphorus in sediment from farm runoff (McDowell and Wilcock 2007, Hedley 1978). This is in part because freshly sorped[4] phosphates (e.g. associated with recent enrichment from land use practices) are more readily desorped from soil colloids (Afsar et al. 2012).

Operational stormwater *E.coli* bacteria and dissolved nutrients

45. At paragraph 121 of his report, Mr Brown expresses concerns regarding the effects of stock truck effluent on the receiving environment. Mr Brown considers that there is some uncertainty around the effectiveness of the stormwater treatment proposed to treat dissolved nutrients and *E. coli* bacteria. He recommends the monitoring of at least one treatment wetland for dissolved phosphorus, dissolved nitrogen, suspended solids and *E.coli* bacteria, with faecal source tracing undertaken if *E.coli* bacteria concentrations exceed 240 cfu/100mL (e.g. paragraph 125 and in Horizons' proposed condition SW2).

46. I addressed a number of these concerns in the response to the section 92 request and I explain these in more detail in **Appendix KH.B**. In summary, the key points are as follows:

(a) Rural road runoff typically has low concentrations of microbiological contamination.

(b) Treatment wetlands are effective at treating stormwater with high bacteria loads but they often have a background bacterial load from wildlife living in the wetlands.

(c) Treatment wetlands are effective at treating both total and dissolved nutrients (i.e. nitrogen and phosphorus) but the processes can be complex and dynamic. Some wetlands can be a net source of

[4] Sorption (and adsorption) is the process by which a substance is bound to the surface of a particle. Desorption is the opposite process of release.

phosphorus but this is very unlikely to occur over the long-term for the Project wetlands because of their design and management.

(d) Saddle Road currently provides no treatment of stormwater in contrast to all sections on the proposed new route which will have stormwater treatment.

(e) The Project will reduce the existing bacterial load to streams by reducing stock access to waterways, this is likely to contribute to an overall improvement in water quality.

(f) The stormwater monitoring proposed by Mr Brown is, in my view, unnecessary and is likely to provide low quality and potentially inaccurate or misleading information.

CONCLUSION

47. Overall, once operational, the Project will result in improved water quality in the Manawatū River and the Pohangina River. Some catchments will receive additional road stormwater but this will be well treated and any effects will be small.

48. During construction, the bulk earthworks will increase sediment loss and reduce water clarity during rain events. In my view, the potential adverse effects during the construction phase will be appropriately minimised and mitigated with the Project's ESC Management Plan, SSESCPs, and ESC Monitoring Plan.

49. I have read the appendices to the section 87F report prepared by Mr Brown, and the amendments to conditions recommended by Horizons. My key areas of concern are:

(a) the proposal to impose discharge limits on sediment retention devices and other standards (in Horizons' proposed conditions ES2(f) and (g)); and

(b) the proposal to impose monitoring on stormwater treatment devices (in Horizons' proposed condition SW2).

50. The TSS limits proposed by Horizons are inappropriate, in my view. Setting meaningful limits for TSS / turbidity from sediment retention devices is challenging because of the high temporal variability, strong skewed correlation between rain events and flow rates, and the often complex link

with ecological effects. In my view it is more practical and ecologically meaningful to focus triggers and actions directly on instream ecological effects, such as instream deposited sediment and aquatic macroinvertebrates.

51. I broadly support the comprehensive and responsive approach to erosion and sediment control described in evidence by **Mr Stewart** and the responsive and routine monitoring approach set out in the Freshwater Ecology Management and Monitoring Plan within the EMP as described in evidence by **Ms Quinn**.

52. The treatment proposed for operational stormwater is, in my view, comprehensive and appropriate.

Keith Hamill

12 June 2020

APPENDIX KH.A: MODELLING OF TOTAL SUSPENDED SOLIDS

1. Loggers have measured turbidity and flow in Mangamanaia Stream (catchment 2) and Raukawa Stream (catchment 7) at five-minute intervals since September 2019. I used the turbidity data to calculate an equivalent TSS using the equation TSS=TURB/0.61 (discussed in the response to the section 92 request, question 5).

2. I estimated the TSS during the construction phase by assuming the construction sediment control devices will only discharge when the 4-hour cumulative rainfall is 1.5mm or greater. The TSS concentration during the construction phase was calculated by multiplying the baseline TSS by a constant. This constant was calculated iteratively so as to ensure that the total increase in TSS load over the record period was equal to the increase in load predicted by the USLE model, i.e. a 53% increase in catchment sediment load above baseline for Raukawa Stream (catchment 7), and 7.1% increase for catchment 2 (see Table C.14 of Technical Assessment C). Extra weight was given to heavy rainfall by using a higher constant that was 2 times higher than the standard multiplier when the 4-hour rainfall was >8mm. This is a simplified approximation to assist with visualising the nature of TSS variability. In reality there is likely to be more of a continuum of higher turbidity / TSS with heavier rainfall. Instantaneous spikes in the turbidity data has been smoothed by graphing the 15-minute median values.

3. This model assumes that the 9-month record period is representative of the long term annual average load assumed in the USLE model.

4. Figure KH.1 shows that during the construction phase, TSS / turbidity in catchment 7 will be elevated during rainfall events, but there was little or no change in TSS / turbidity during baseflow conditions and outside of rain events. Average TSS concentration over the modelled period was 22.4 mg/L and 30.7 mg/L for the baseline and construction phase respectively (a 37% increase), but there was no change in the median TSS, which was 1.6 mg/L for both the baseline and construction phase. If sediments were to

accumulate on the streambed then TSS / turbidity may also become elevated during low flows.

5. Note that the current range in TSS is very large and that there are many occasions when turbidity / TSS is elevated at times when there has been no rain or increase in flow. The effect of construction on TSS in catchment 2 is difficult to see in Figure KH.2 because the increase in catchment load was only 7.1%.

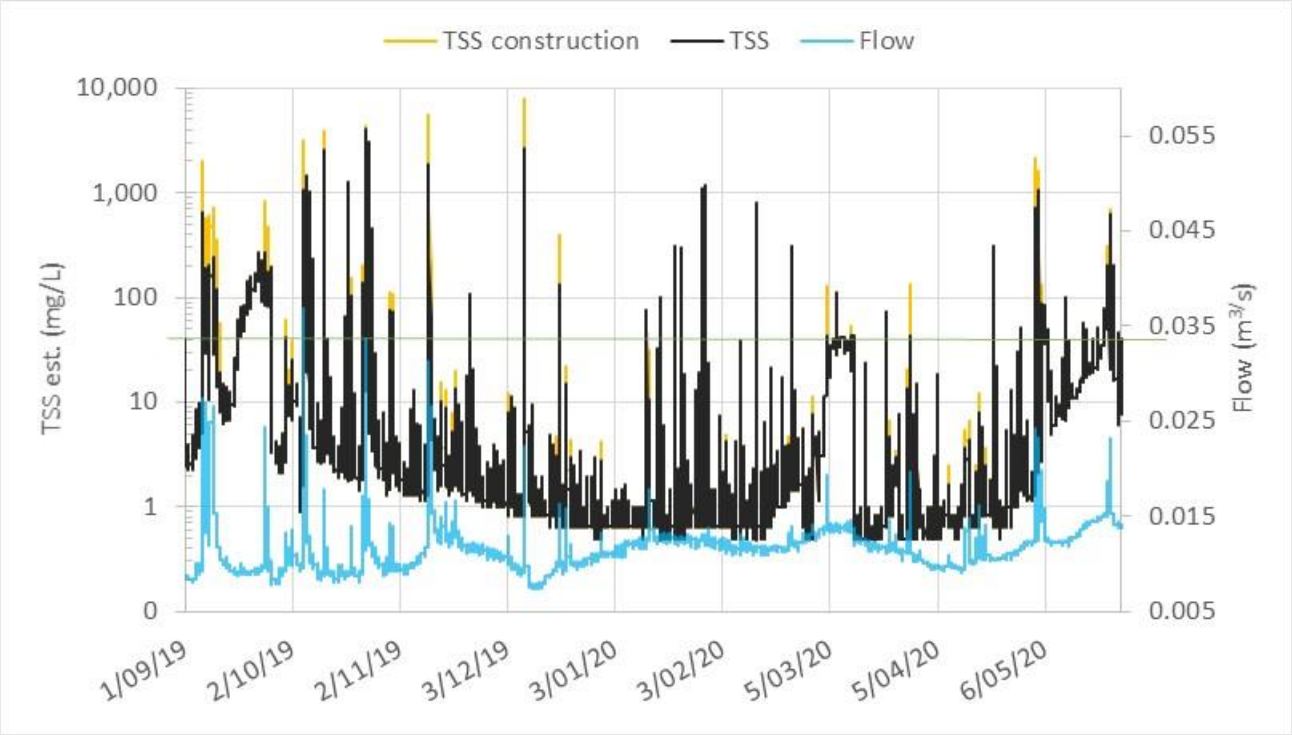

Figure KH.1: Estimated TSS in Raukawa Stream (catchment 7) currently (black line) and modelled during the construction phase (orange line) assuming a 53% increase in catchment sediment load. The horizontal green line is 40 mg/L, which is the discharge consent limit proposed in the section 87F report.

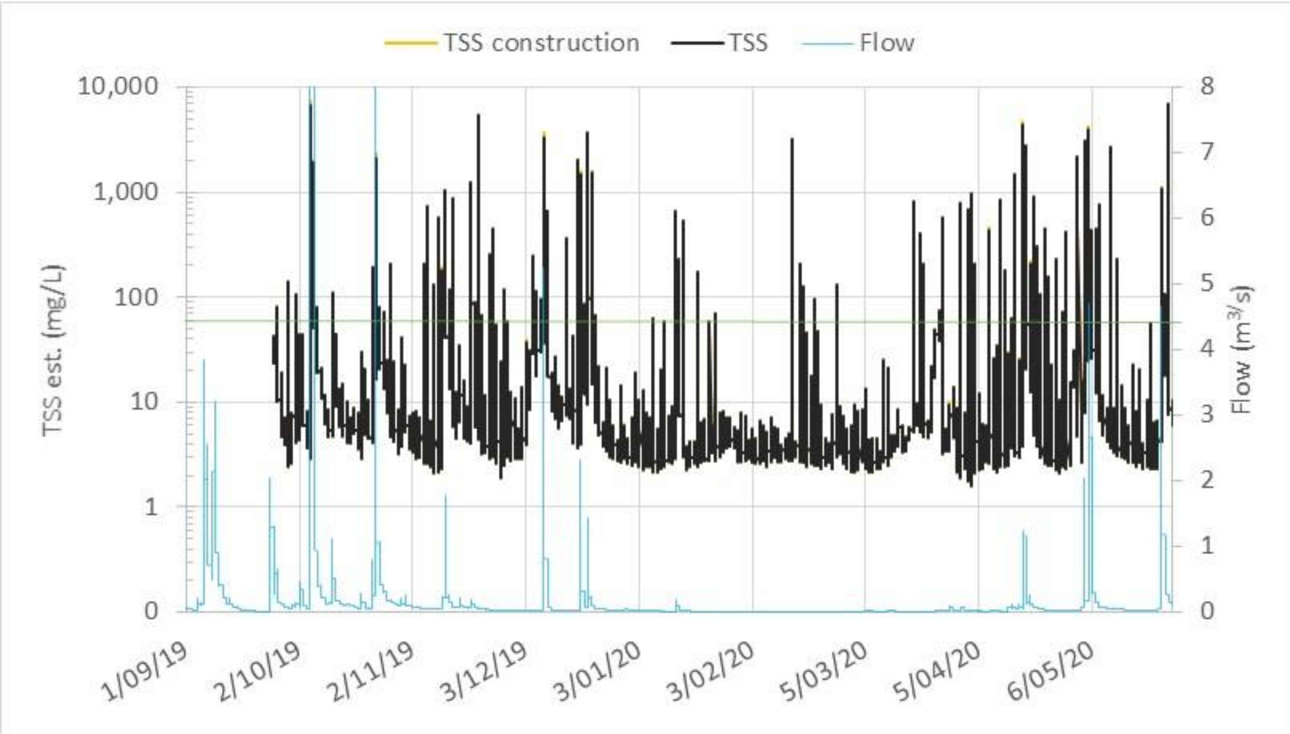

Figure KH.2: Estimated TSS in Mangamanaia Stream (catchment 2) currently (black line) and modelled during the construction phase (orange line) assuming a 7.1% increase in catchment sediment load. The horizontal green line is 63 mg/L, which is the discharge consent limit proposed in the section 87F report.

APPENDIX KH.B: OPERATIONAL STORMWATER BACTERIA AND DISSOLVED NUTRIENTS

1. At paragraph 121 of his report, Mr Brown expresses concerns regarding the effects of stock truck effluent on the receiving environment. He expressed uncertainty around the effectiveness of the stormwater treatment proposed to treat dissolved nutrients and *E. coli* bacteria. I addressed a number of these concerns in the response to the section 92 request and I explain these in more detail below.

Rural road runoff characteristic

2. Rural road runoff (as compared to urban stormwater) typically has low concentrations of microbiological contamination due to low loading and bacteria die-off between rain events. This was discussed in paragraph 117 of Water Quality - Technical Assessment C.

3. Auckland Regional Council (2003) records contaminant loading for various land uses. The loading of faecal coliforms from roads was estimated to be 1.8 $x10^8$ cfu/ha/year which is considerably lower than pasture (1.6 $x10^{10}$ cfu/ha/year) or bush (4 $x10^9$ cfu/ha/year). The bacterial contamination from New Zealand rural roads is likely to have improved since these estimates were made with implementation of the stock effluent code of practice in 2003.

Treatment wetlands are effective are removing elevated bacteria

4. All stormwater runoff from the new road will be treated by either a wetland, wetland swale or swales, and often with additional pre-treatment from catch pits or grassed channels. Most (91%) of the road stormwater will be treated by either a wetland or a wetland swale. In contrast the current Saddle Road has no stormwater treatment devices.

5. Treatment wetlands are effective at treating stormwater with high bacteria loads but they often have a background bacterial load from wildlife living in the wetlands and the background load can be quite variable between wetlands. Kadlec and Wallace (2009) found that wetlands were at least as effective as other natural treatment technologies and especially when inflow concentrations are high. However, they have a natural background level of bacteria so that wetlands receiving disinfected inflows typically had faecal indicator bacteria concentrations in the outlet in the range of 10 to 1000 cfu/100mL with a median of 60 cfu/100mL. Similarly, Hathaway et al. (2011) reported faecal coliform removal rates from constructed stormwater wetlands

ranging from 56% to 98% with better removal rates when influent concentrations were higher during storm events. However, there remained a baseline concentration of faecal coliform bacteria. Removal mechanisms include sorption to sediment, sedimentation, predation and solar deactivation.

Treatment wetlands are effective are removing nutrients

6. Treatment wetlands are effective at removing both total and dissolved nutrients (i.e. nitrogen and phosphorus) but the processes can be complex and dynamic. Kadlec and Wallace (2009) compiled a large dataset of treatment wetlands and found the median nitrogen reduction by urban stormwater wetlands was 45% for nitrate, 31% for ammonium, and 30% for total nitrogen. The median removal rate for total phosphorus was 40%. Although it should be noted that the percent removal rate is highly dependent on the hydraulic loading and inflow concentrations.

7. Treatment wetlands provide both short term and sustainable long-term storage of phosphorus. Treatment mechanisms include uptake by bacteria, algae and plants, sorption to substrate, chemical precipitation, accretion, particulate settling and burial. The ability to store phosphorus can reduce over time, but this can be managed by wetland maintenance and rejuvenation.

8. Some wetlands can be a net source of phosphorus. This would typically occur when the soils used to construct the wetland are rich in phosphorus and the incoming phosphorus concentrations are low. In some cases there can also be short-term release of phosphorus if wetland waters become anoxic (Kadlec 2005). The risk of net phosphorus release from stormwater treatment wetlands proposed for the Project is, in my view, low because of their design and management.

Monitoring of stormwater treatment wetlands

9. Mr Brown recommended the monitoring of at least one treatment wetland for dissolved phosphorus, dissolved nitrogen, suspended solids and *E.coli* bacteria, with faecal source tracing undertaken if *E.coli* bacteria concentrations exceed 240 cfu/100mL (e.g. paragraph 125). This proposed monitoring is, in my view, unnecessary and is likely to provide low quality and potentially misleading information.

10. Stormwater treatment wetlands are event driven and consequently their treatment effectiveness is more variable than continuous-flow wetlands.

Small pulses are very well treated but percent removal rates reduce at higher flows. In contrast, the mass load removal rate increases with increasing flow. The removal rates can be highly variable during an event due to changing flows, inflow concentrations and time lags between the inlet and outlet. To accurately characterise wetland treatment performance requires a large number of samples through rain events, spanning multiple rain events and seasons. It also requires flow monitoring in order to calculate mass load removal. Spot measurements are generally insufficient for characterising the effectiveness of stormwater wetlands and can provide misleading results if insufficiently frequent to characterize temporal dynamics and time lags. Kadlec and Wallace (2009) (page 558) note that: "*Because the outlet concentrations depend on event size, wetland storage, and interevent spacing, there is no obvious simple correspondence between outflow concentrations and inflow concentrations and flow rates. Dynamic mass balance modelling is required to analyze this complex set of interactions*."

APPENDIX KH.C: REFERENCES

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