IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	resource consent applications and Notices of Requirement by the Bay of Plenty Regional Council to undertake the proposed Kaituna River Re-diversion and Ongatoro / Maketū Estuary Enhancement Project

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STATEMENT OF EVIDENCE OF KEITH DAVID HAMILL

INTRODUCTION

Qualifications and experience

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

2. I hold a Bachelor of Science degree (Geography) from the University of Auckland (1992) and a Master of Science (1st Class Hons) in Ecology and Resource & Environmental Planning from the University of Waikato (1995).

3. I have 20 years' experience in the area of resource management and environmental science. I have previously worked as a Principal Environmental Scientist at Opus International Consultants Limited, in the United Kingdom as a Senior Environmental Scientist for a consultancy called WRc, and as an Environmental Scientist at Southland Regional Council for six years.

4. Examples of projects I have worked on include:

   a) Co-ordinator of expert science panel for developing attributes for brackish lakes and intermittently open lagoons (ICOLLS) for the National Objectives Framework as part of the National Policy Statement for Freshwater (MfE 2014).

   b) Fish passage assessment for lower Kaituna River and Ongatoro/Maketū Estuary (BOPRC 2014).

c) Contributed to the development of ecological guidelines for Waituna Lagoon as a member of Waituna Lagoon Technical Advisory Group (Environment Southland, 2011-2013).

d) Tauranga harbour sediment management review (BOPRC 2011).

e) National Environmental Monitoring and Reporting project (NEMaR). This contributed to the development of a single index for reporting river, lake and recreational water quality and consistent national freshwater monitoring programme for NZ (MfE, 2011 - 2012).

f) Assessment of ecological and water quality impacts of the Whitianga Waste Water Treatment Plant (WWTP) discharge on the Whitianga estuary. This included a Quantitative Microbial Risk Assessment (2009).

g) Assessing and monitoring effects of the Porangahau WWTP on the Porangahau River estuary (2009, 2012).

h) Co-ordinated the European Commission technical secretariat developing guidance for assessing eutrophication for the Water Framework Directive (2004).

Scope of Evidence

5. I have been involved in the Project since 2013. I have been responsible for assessing the current condition of the Maketū estuary and lower Kaituna River and potential effects of the Project on the ecology of those areas. I prepared the report titled Kaituna River Re-diversion Project: Ongatoro/Maketū estuary condition and potential ecological effects (Report).[1] My focus has been on the aquatic environment, and Mr MacGibbon will provide evidence on terrestrial ecology and avifauna, as well as the wetland restoration components of the Project. Mr Tuckey will give evidence on the modelling estuary hydrodynamics, the results of which I have used in my assessments.

6. My evidence will cover:

6.1 The existing environment and impacts of the Project on:

(a) Algae and seaweed in the Maketū estuary;

(b) Shellfish and benthic fauna in the estuary;

(c) Dissolved oxygen in the estuary;

(d) Fish in the estuary and the lower Kaituna River; and

[1] Hamill (2014) Dated June 2014, Application Volume 2, Tab B.

(e) Macroinvertebrate fauna in the lower Kaituna River;

(f) Health risks associated with bathing and shellfish gathering in the estuary; and

6.2 Proposed mitigation measures, where necessary.

7. I will also provide comments on the submissions as they relate to the scope of my evidence. Other witnesses also provide comments on the submissions relevant to their areas of expertise and project involvement.

8. I have read and am familiar with the section 42A report and the proposed set of consent conditions and will refer to these where relevant to my evidence.

9. Lastly, I have read the Code of Conduct for Expert Witnesses in the Updated Environment Court Practice Note (2014) and agree to comply with the Code. This evidence is within my area of expertise, except where relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

EXECUTIVE SUMMARY

10. Ongatoro / Maketū Estuary has important ecological values yet large areas of the estuary are highly degraded. The degradation is due to dense accumulations of benthic algae that occur in the upper estuary, Papahikahawai Lagoon and margins of the mid-estuary and southern estuary. The dense algal accumulations result in anoxic muds and a loss in the abundance and diversity of shellfish and other benthic fauna. In some parts of the upper estuary benthic macrofauna have been completely excluded. The dense algal accumulations also cause very low dissolved oxygen (DO) concentrations. The DO in the main channel of the mid-estuary is sufficiently low to frequently exclude (or kill) most fish species at night. In simple terms, the life-supporting capacity of Ongatoro / Maketū estuary is significantly compromised.

11. The reason for the excessive algal accumulations is because growing conditions are favourable for algae (i.e. sufficient nutrients, shallow water, warm temperatures etc.) and because there is very little flushing from the mid- and upper-estuary. Furthermore, the diurnally low DO limits the extent to which grazing by invertebrates and fish can control algal in parts of the estuary.

12. Changes expected due to the Project that are relevant to ecology include:

12.1 Considerably more flushing of benthic algae and associated muds. This is driven by an increase in both the maximum current speed and residual current speed towards the entrance. Higher current speeds may also improve shellfish feeding.

12.2 Slightly lower salinity in most of the estuary (but a slightly higher mean and range in the upper estuary). This will generally make conditions a little less favourable for the algae *Gracilaria* sp., sea lettuce but a little more favourable for sea grass germination.

12.3 An overall increase in nitrogen (N) and phosphorus (P) concentrations due to a greater river load (ranging from a 4% reduction in the upper estuary to a 25% increase in the lower estuary), but a corresponding decrease in N and P released from anoxic muds associated with algae accumulations. The reduced internal load is unlikely to fully balance the additional load of N from the river but may potentially more than balance the additional load of P from the river. The risk of additional nutrients stimulating faster sea lettuce growth is expected to be small because sea lettuce is already replete in N and P.

13. The Project will increase the salinity in the Kaituna River near the intake and increase the upstream extent of the salt wedge by about 200m. Fish and macroinvertebrates in this section of the Kaituna River have wide salinity tolerances and the overall effect on fish and invertebrates is expected to be small.

14. The lower Kaituna River near the proposed intake is an important area for inanga rearing and spawning. The predicted change in the extent of the saline wedge is small compared to natural variability and there will be negligible impact on potential inanga spawning and rearing sites.

15. Construction of the intake for the proposed re-diversion will result in the loss of about 100m of current wetland margin. The Project more than compensates for this loss by the creation of additional vegetated riparian habitat along the edge of the new channel and Ford's cut.

16. The proposed re-diversion will increase the microbial load from the Kaituna catchment into Ongatoro / Maketū estuary. This will have negligible impact on the suitability of the lower estuary for recreational bathing, but there is a risk of increased microbial contamination of shellfish in the mid and lower estuary. It is likely that increased flushing will reduce the load of microbes from sediment re-suspension, and this may explain the step change reduction in faecal coliform concentrations that followed the initial re-diversion in 1996. High microbial concentrations currently occur in the Maketū estuary following rain events; this will remain the case after the re-diversion. The current and future health risk can be managed by not collecting shellfish within 2 to 5 days of a rain event. This advice is unlikely to change without controlling contaminants from the wider catchment. Other initiatives are being implemented that should reduce catchment microbial loads in the long term.

17. A range of ecological and water quality monitoring is proposed to measure the extent of the benefits and assist with ongoing management of the estuary.

ALGAE AND SEAWEED IN ONGATORO MAKETŪ ESTUARY

Current condition

18. Macroalgae are a natural part of estuary but under conditions of high nutrients and poor flushing the cover and thickness (biomass) of opportunistic macroalgae can foul fishing nets, cause a cause odour, and degrade the ecology. High cover can cause sediment anoxia, contribute to

water column hypoxia, reduce the abundance and diversity of infauna and cause the collapse of sea grass beds by smothering (Sutula et al. 2011, Viaroli et al. 2009).

19. The cover and density of macroalgae in Ongatoro / Maketū estuary was assessed using aerial photographs and field surveys. This found 81 ha of the estuary covered in algae (density > 20% coverage) and reasonably dense algal accumulations (>50% cover) occurred over about 30% (71 ha) of Maketū estuary (Hamill 2014, Park 2014) (see Figure 1). The dominant algae species are *Gracilaria* sp. and to a less extent sea lettuce (predominantly *Ulva pertusa*). *Ulva flexuosa var pilifera* is common in the mid-estuary; *U. clathrata* and *U. intestinalis* are common amongst *Gracilaria* sp. along the margins of the southern estuary.

20. The lower estuary (towards the mouth) generally has sparse algal cover, although patches of sea lettuce occur in the main channel attached to stable substrate such as cockle shells. Dense accumulations of free-floating macroalgae (mostly *Gracilaria* sp., *Ulva pertusa* and *Ulva flexuosa*) are common in the upper-estuary, mid-estuary and along the margins of the southern-estuary (Figure 2). Free-floating sea lettuce and *Gracilaria* sp. accumulate to >0.5m depth in the main channel along the southern margin of the mid-estuary.

21. Large sections of the upper estuary are covered by free-floating *Gracilaria* sp. and *Ulva flexuosa* – with thick accumulations in depressions. Epiphytic diatoms and cyanobacteria are often growing on top of these seaweed accumulations.

22. The western end of the old Papahikahawai Creek is mostly cut off from the rest of the estuary to form a lagoon (referred to as Papahikahawai Lagoon). The lagoon has prolific algal growth dominated by the benthic cyanobacteria *Lyngbya* sp. and *Ulva flexuosa var pilifera*. These form thick floating rafts that cover large sections of the water (Figure 3).

23. Most of the Ongatoro / Maketū estuary has a firm sandy substrate, but anoxic mud overlays this in areas where algae accumulations occur, such as areas of low current velocity, depressions, and channel margins. Organic mud was particularly deep in the upper estuary (about 1-5cm depth), margins of the southern estuary and in the Papahikahawai lagoon (12 to 25cm). Anoxic mud accumulates beneath algal mats and mud was estimated to cover 29% (68 ha) of the estuary to depths of between 1 to 25 cm (Hamill 2014).

Biomass and nutrient pool in algae and sediment

24. I assessed the biomass and nutrient content of algae and underlying sediments in the estuary in order to characterise condition and provide an estimate of the mass of nutrients that can potentially be flushed from the estuary and the relative importance of the internal nutrient flux compared to the external nutrient load. This was done by sampling four transects[2] across the

[2] Transects were perpendicular to algal accumulations.

estuary. The results were combined with the estimates of algal cover and areal extent to calculate the total amount of algae and associated muds in the estuary.

25. The algal accumulations were thick. The biomass along transects in the upper and mid-estuary was 1790 to 6270 g wet wt. /m^2 and 10,000 g wet wt./m^2 in Papahikahawai Lagoon[3]. This is well above thresholds to avoid adverse effects on benthic macrofauna (typically 500 to 1000 g wet wt./m^2), thresholds to avoid surface sediment anoxia (typically 1000 to 2000 g wet wt./m^2), and thresholds to associated with the collapse of sea grass beds.[4]

26. Throughout the estuary the algal biomass was estimated to be 442 tonnes dry weight, and to contain 13.5 tonnes of nitrogen (N) and 1.36 tonnes of phosphorus (P). The unconsolidated surficial muds associated with the algae was estimated to contain about 22.2 tonnes N, and 3.5 tonnes P. In contrast the water in the estuary during high tide was estimated to contain about 0.473 tonnes of N and 0.0417 tonnes of P (see table 2.2 of my Report).

27. It is likely that the macroalgae derives much more nutrients from the diffusion of pore water from underlying anoxic muds than from the overlying water. This is because the surface muds had a much higher concentration of N and P on both a concentration and areal basis.[5]

Changes over time

28. There is little information on algal accumulations in the estuary prior to the 1956 diversion but we do know that sea grass beds (an indication of a healthy estuary) have almost disappeared – reducing from 13.2 ha in 1948, to 2.2 ha in 1961, to 40m^2 in 2011 (Park 2014). There is also evidence to suggest that algal cover and the extent of accumulations have got worse over the last 10 to 35 years. Surveys in 1976 and 1977 suggest that muddy areas were limited to the western end of the estuary (BioResearches 1976). The accumulation of *Gracilaria* has appeared to have increased in the last 10 years; and in the southern estuary *Ulva clathrata* has become much more common in the last five years (Stephen Park, BOPRC, pers. comm. 2014).

[3] This corresponded to 242 to 847 g dry wt./m^2 in the upper and mid-estuary, and 1570 g dry wt./m^2 in Papahikahawai Lagoon.

[4] Scanlan et al. (2007) proposed a threshold of 500-1000 g wet wt./m^2 to avoid threshold effects on benthic macrofauna. McLaughlin et al. (2012) found surface deposit feeders were eliminated when macroalgal biomass was greater than 700-800 g wet wt./m^2. Green et al. (2014) found macroalgal biomass equivalent to 840-930 g wet wt./m^2 caused significant and rapid negative effects on benthic invertebrate abundance (declining by >67%) and species richness (declining by >19%) within two weeks at most sites. Sutula et al. (2014) found near surface sediment anoxia (RPD <1cm) was associated with macroalgae biomass of >1450 g ww/m^2. Huntington and Boyer (2008) found a threshold for decline in sea grass between 325 and 1700 g ww/m^2. Macroalgae density at the upper end of this range reduced eel grass shoot density by 50% after only 3 months.

[5] The median concentration of TN and TP in the sediment pore-water was respectively 43.5 mg/L and 4.1 mg/L compared to an average TN and TP concentration in the estuary water of respectively 0.4 to 0.52 mg/L and 0.035 to 0.053 mg/L (high tide and low tide respectively). On an aerial basis the median TN and TP in the pore-water were respectively 797 mg/m^2 and 85.6 mg/m^2; compared to TN and TP in the overlying water at high tide of 215 mg/m^2 and 19 mg/m^2 respectively.

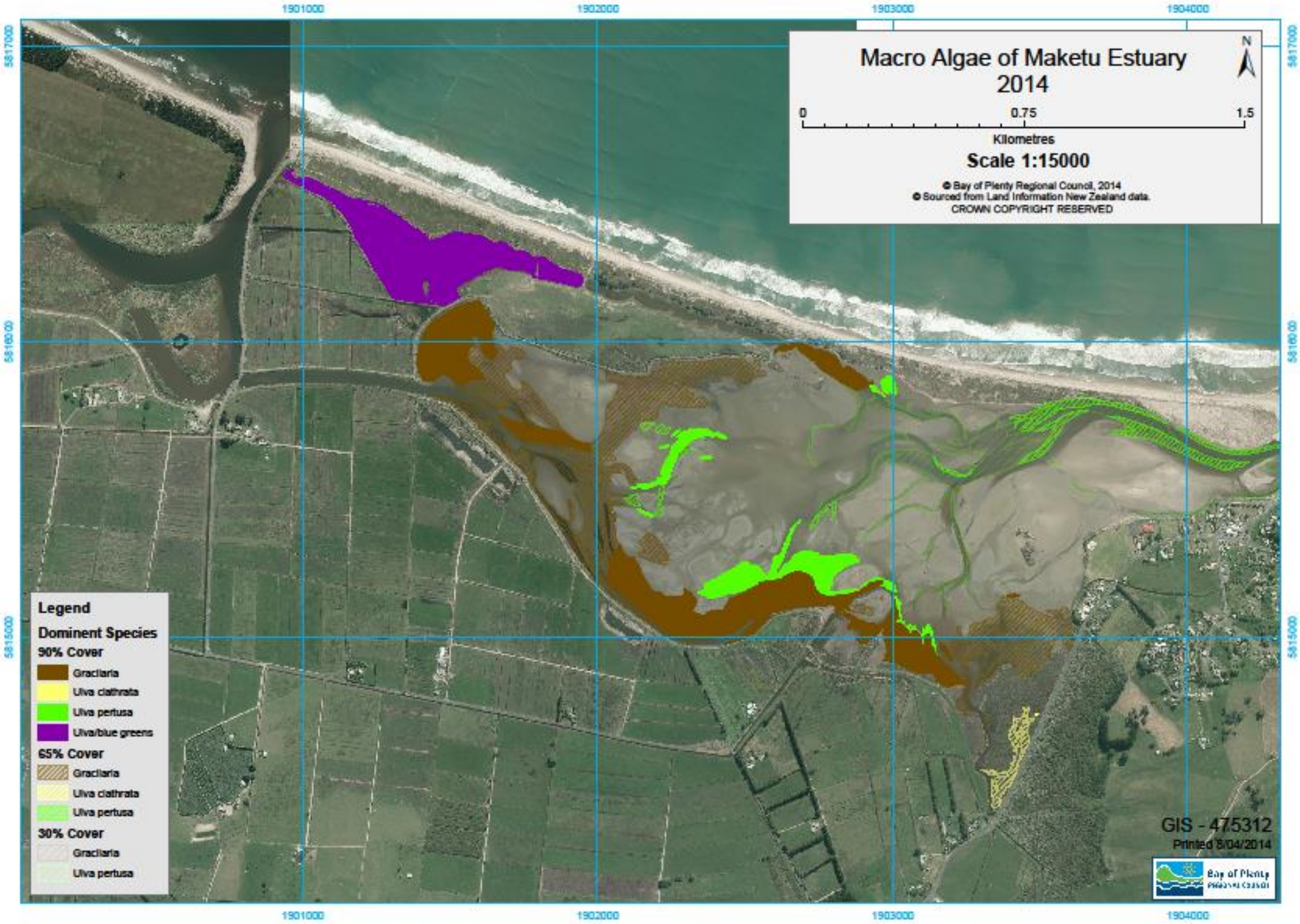

Figure 1: Algal cover in the Ongatoro / Maketū estuary, 2014.

Figure 2: Dense accumulation of *Gracilaria* sp. with epiphytic diatoms and underlying anoxic mud in Ongatoro / Maketū estuary south (March 2014).

Figure 3: Dense accumulations of *Lyngbya* sp. in Papahikahawai lagoon (2014)

Potential effects

29. The cover and biomass of algae (e.g. *Gracilaria* sp, *Ulva* sp. etc) in the Ongatoro / Maketū estuary is determined by algal growth rates (largely driven by nutrient concentrations, light and temperature but also affected by salinity) and loss processes (driven by net flushing and grazing from macrofauna and fish). The Project will result in changes in nutrients and salinity that will potentially impact on algal growth rates, as well as changes in flushing that reduce the susceptibility of the estuary to algal accumulations. In particular the re-diversion will result in:

    a) Faster currents and more tidal outflow resulting in more flushing of algae and associated muds.

    b) Changes in salinity affecting algal growth and sea grass germination.

    c) Changes in nutrient supply from the water and sediments impacting growth rates.

30. There will also be possible positive feedback from increased grazing of fish and invertebrates. These factors are discussed below.

Flushing of algal accumulations and mud

31. Estuaries with more flushing are less susceptible to eutrophication because nutrients move through more quickly and there is less ability for algae to accumulate. The re-diversion will considerably increase the flushing potential of Maketū Estuary. Hydraulic modelling by DHI (2014) found that the re-diversion will cause an increase in current velocity over most of the estuary. Furthermore the net residual current velocity will significantly increase towards the estuary entrance throughout the whole estuary, i.e. there will be more movement of material out to sea (see evidence by Mr Tuckey).

32. The changes in current will mobilise algae, decrease the probability of drifting algae persisting in a location and increase export of algae out of the estuary. Unconsolidated mud and free floating algae are transported when water velocities exceed 0.05 m/s, with the rate of transport substantially greater when velocities exceed 0.1 to 0.2 m/s (Flindt et al. 2007).

33. The greatest increase in current velocity will occur in the upper estuary, south of Papahikahawai Island and in Papahikahawai lagoon. These areas have little current at present and therefore accumulate algae and have poor benthic invertebrate species diversity and abundance. The ecological health is expected to considerably improve as a result of increased flushing. There is little change in maximum current speed in the mid-estuary but a substantial increase in the residual current speed moving material towards the entrance (which will improve flushing of algae out of the estuary). There will remain some areas of low velocity (e.g. in the southern estuary and the western end of what is now Papahikahawai lagoon) where accumulation of algae and mud may continue to persist, but overall there is expected to be a reduction in mud and algal biomass (Figure 4).

34. Gracilaria is sparse in the lower estuary but sea lettuce is often found attached to stable substrate (e.g. cockle shells) in the main channel. It is likely that this will continue to occur but the increased scour will reduce the sea lettuce length and biomass.

35. In the short term there may be a risk that some of the unconsolidated mud mobilised by increased current will redistribute to other parts of the estuary, e.g. some material from Papahikahawai lagoon might redistribute to south east of Papahikahawai Island. This effect will be temporary and material that is not flushed will primarily be deposited in low energy zones. Much of these zones already have accumulations of algae and mud which have degraded the infauna community. In the medium term there will be a net export of fine sediment from the estuary and an improvement in ecology. This is driven by an increase in residual current speeds towards the entrance and is discussed in evidence by Mr Dahm.

Changes in salinity

36. The Project will result in relatively small changes in salinity in most parts of the estuary. The majority of the estuary will have a small decrease in salinity, the upper estuary a small increase, and Papahikahawai lagoon a substantial decrease (from current salinity of 26-28 psu[6] to 10-15 psu) – closer to its natural condition (see Figure 5 below[7]).

37. The growth rate of *Gracilaria* sp. and *Ulva* sp. tends to reduce at salinity below 15 psu, and 18-24 psu respectively (Jenson 2007, McAvoy and Klug 2005). Thus the small decrease in salinity is expected to cause a small reduction in the growth rates of *Ulva* sp. and *Gracilaria* sp. in the mid-estuary. The effect on *Gracilaria* growth of slightly higher salinity in parts of the upper

[6] Psu = practical salinity units and is the same as parts per thousand (ppt).
[7] Also discussed in my Report on pages 18-19.

estuary may be partially balanced by a greater salinity range (i.e. lower minimum salinity) which tends to decrease *Ulva* sp. growth.

38. Papahikahawai Lagoon will have the largest potential improvements in ecological health due to the re-diversion; salinity is predicted to reduce 50% to levels likely to start limiting the growth of *Ulva* sp and *Gracilaria* sp., and the daily fluctuation in salinity will increase. These changes are likely to cause a change in algal species composition and will possibly favour species with a wide salinity tolerance (e.g. *Gracilaria* sp. compared to sea lettuce).

39. The ecological health of Maketū estuary has reduced with the loss of sea grass beds since the 1956 river diversion. A small overall reduction in salinity as a result of the Project will increase the likelihood of sea grass seed germination and potentially open up additional habitat for colonisation or restoration.

Changes in nutrient supply

40. The availability of nutrients for algal growth is a function of the nutrient loads from both external sources (e.g. water from rivers and drains) and internal sources (e.g. release from sediment). Parts of the Maketū estuary with dense algal accumulations are highly eutrophic and are likely to be partially decoupled from external nutrient sources due to high internal loading from anoxic sediments and N-fixing cyanobacteria.

41. There will be an increase in the <u>load</u> of nutrients entering Maketū estuary from the Kaituna River but relatively small changes in <u>concentration</u>, inversely proportional to changes in salinity. The dilution model predicted that the re-diversion will cause a small decrease (about 4% reduction) [8] in N and P concentration the upper estuary because of increased seawater from Te Tumu; a slight (2%) decrease in the southern estuary (because the Kaituna River has lower nutrient concentrations than the Waitipuia Stream), a small (10%) increase in the mid-estuary, and up to a 25% increase[9] in the lower estuary because of increased load relative to seawater from the Maketū mouth (see Figure 6). However, the dilution model only tells part of the story because the increase in external nutrient load to the estuary will be compensated by a decrease in internal nutrient loads - which the model does not account for. Reducing internal nutrient loads by flushing algae and sediments means that the actual increase in nutrient concentrations will be considerably less than these predictions.

42. Estuaries typically have strong benthic-pelagic coupling and considerable nutrient flux from the sediments (e.g. Pratt et al. 2014), i.e. the sediment has a big impact on the water quality. The extent of nutrient flux from sediments dramatically increases when sediments become anoxic. Because of this, the internal nutrient load often becomes more dominant in highly eutrophic

[8] TN of 0.565 mg/L to 0.545 mg/L and TP of 0.050 mg/L to 0.048 mg/L as an average modelled over the spring-neap tidal cycle at sites T1 and T2.

[9] TN of 0.31 mg/L to 0.387 mg/L and TP of 0.028 mg/L to 0.035 mg/L as an average modelled over the spring-neap tidal cycle in the lower estuary at site T5.

systems, resulting in a tipping point where algal biomass is maintained by recycling of internal nutrients and somewhat uncoupled from external loads. Prolific algal growth results in accumulation of organic matter and sediment anoxia. Sediment anoxia releases dissolved nutrients (ammonium, phosphorus and ferrous iron), and this supports further algal growth and further anoxic conditions. Nutrients can also cause a shift towards algal species that grow quickly and have a high demand for nutrients such as cyanobacteria. Nitrogen-fixing cyanobacteria provide another positive feed-back, increasing internal nitrogen loads as the algae fix nitrogen from the atmosphere. This pattern is apparent in the Maketū estuary (Søndergaard et al. 2003, Gao et al 2012).

43. Nutrient fluxes have not been directly measured in Maketū lagoon but the relative importance of nutrient flux from the anoxic sediments in the estuary can be implied by the relative amount of nutrients in surface sediment and pore-water. The parts of the estuary that will experience higher current speeds and flushing as a result of the re-diversion have surface muds[10] containing about 18.2 tonnes of N and 2.79 tonnes of P. I estimated the flux of N and P from these muds to the overlying algae and water is approximately 364 kg N/day and 55.8 kg P/day[11]. In contrast the increase in the total N and P load to the estuary after re-diversion is about 461 kg/day and 29.2 kg/day respectively[12]. Thus the expected flushing of surface muds will substantially reduce the net increase in N load due to the re-diversion and may cause a net reduction in the P load. The actual nutrient concentrations in the lower estuary will also be considerably less than predictions from the dilution model.

44. Nutrient concentrations in the vicinity of algae are more directly relevant to algae growth than the mass flux. The nutrient load released from sediment is directly available to overlying algae, while much of the nutrients entering via the river flow to the ocean without direct contact with benthic algae. On an areal basis the TN and TP concentration in the pore-water of the surface muds below algal accumulations was three to five times higher than that in the overlying water (Hamill 2014). Reducing the nutrient flux from estuarine sediments has a more direct impact on benthic algae growth than an equivalent reduction from a river source because more of the sediment flux is intercepted by overlaying algae.

45. Although a reduction in internal nutrient loads will largely compensate for an increase in external nutrient loads, there is still likely to be a small increase in nitrogen concentrations in the lower estuary. The extent to which higher nutrient concentrations presents a risk of faster algal growth was tested by measuring the cellular nutrient content sea lettuce from the mid- and lower-estuary. Studies in Tauranga harbour have found that the growth of sea lettuce was limited when the cellular N and P was below about 1.5% and 0.1% (of dry weight) respectively.

[10] Based on the top 2.6cm of sediment. These were mostly unconsolidated muds that were easily re-suspended.
[11] Assuming a 2% flux. This is consistent with measured values from Te Waihora (Norton et al. 2014).
[12] External TN load is estimated to change from 359 to 720 kg/day and the external TP load will increase from 12.2 to 41.4 kg/day. The relative increase in nutrient concentration is much less due to dilution from additional sea water entering via Te Tumu cut.

Intracellular N and P above 1.5% - 2% and 0.1 - 0.12 respectively did not result in additional growth (de Winton et al. 1998).

46. Sea lettuce was sampled from the lower and mid-estuary in late January 2015. The intracellular N was 2.2% to 2.8% and the intracellular P was 0.13% to 0.15%. This suggests that the sea lettuce was replete in N and P and growth rates would be limited by factors other than nutrients (Appendix 1). The results are consistent with previous sampling (Hamill 2014) and give some assurance that a small increase in N concentration will have little impact on algal growth rates in the lower estuary. In my opinion sea lettuce biomass is likely to instead decrease due to increased current speeds causing more scour.

Summary

47. Dense algal accumulations occur over 30% (71 ha) of Ongatoro /Maketū estuary and indicate highly eutrophic condition in these areas. The eutrophic conditions appear to have got worse over the years and sea grass (an indicator of good estuarine health) has gradually all but disappeared since the 1956 diversion. The Project is expected to result in an overall decrease in algae cover and improvement in ecological health in the Maketū estuary. Following re-diversion, excessive algae accumulations will still be apparent in places. Over time achieving nutrient reductions in the catchment from other initiatives will build on the positive effects of the Project. Some nutrient reduction initiatives are already incorporated within the Project, e.g. retiring a small amount of farmland and establishing wetlands. Reducing nutrient loads from Waitipuia Stream and nearby drains will be particularly important in order to see significant ecological improvements in the southern part of the Ongatoro /Maketū estuary.

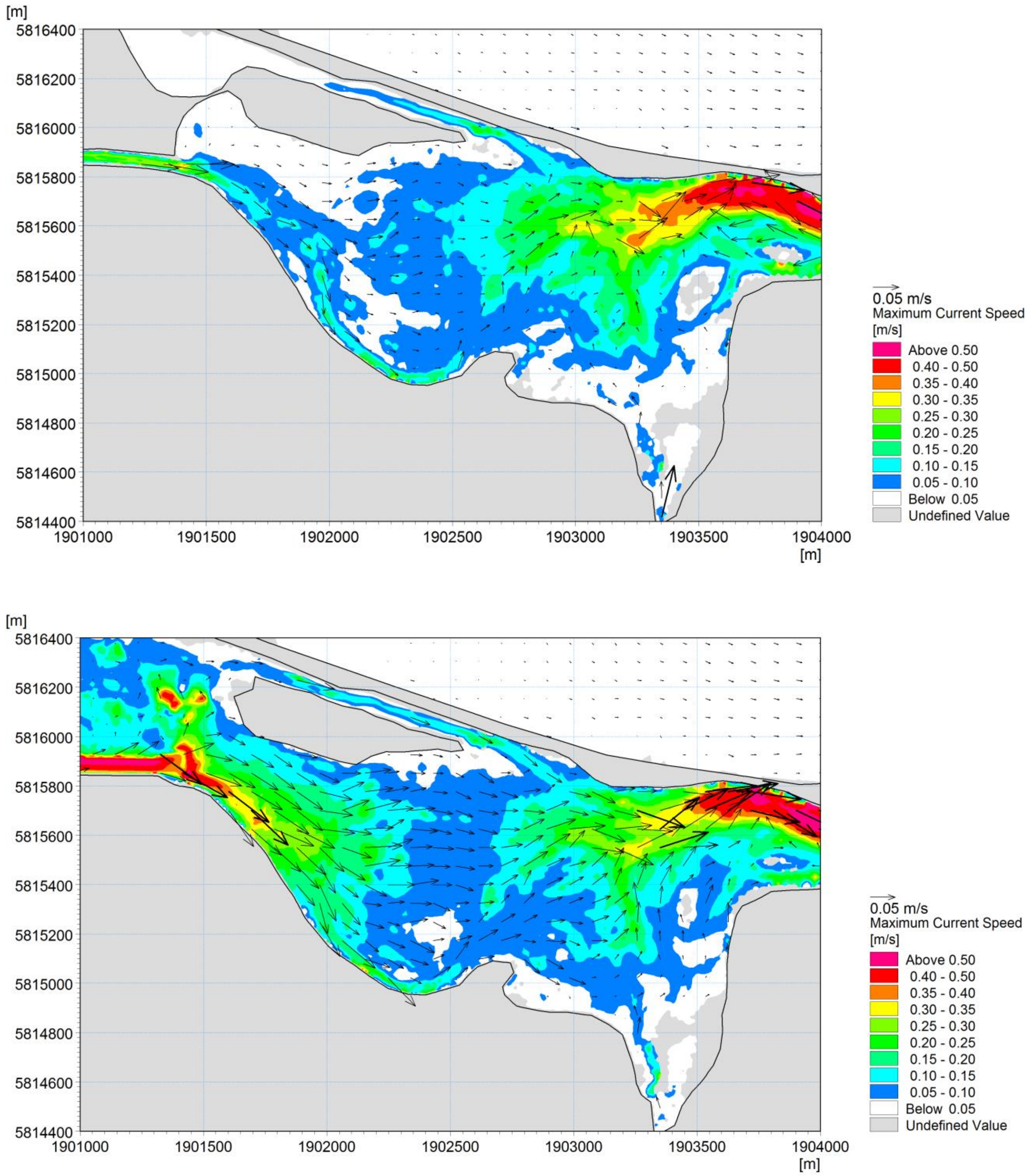

Figure 4: Maximum current speed (colour) and residual current direction and speed (arrows) during a mean River flow and mean tide in the Maketū estuary for the existing (top) and proposed (bottom) scenario (from DHI 2014 model).

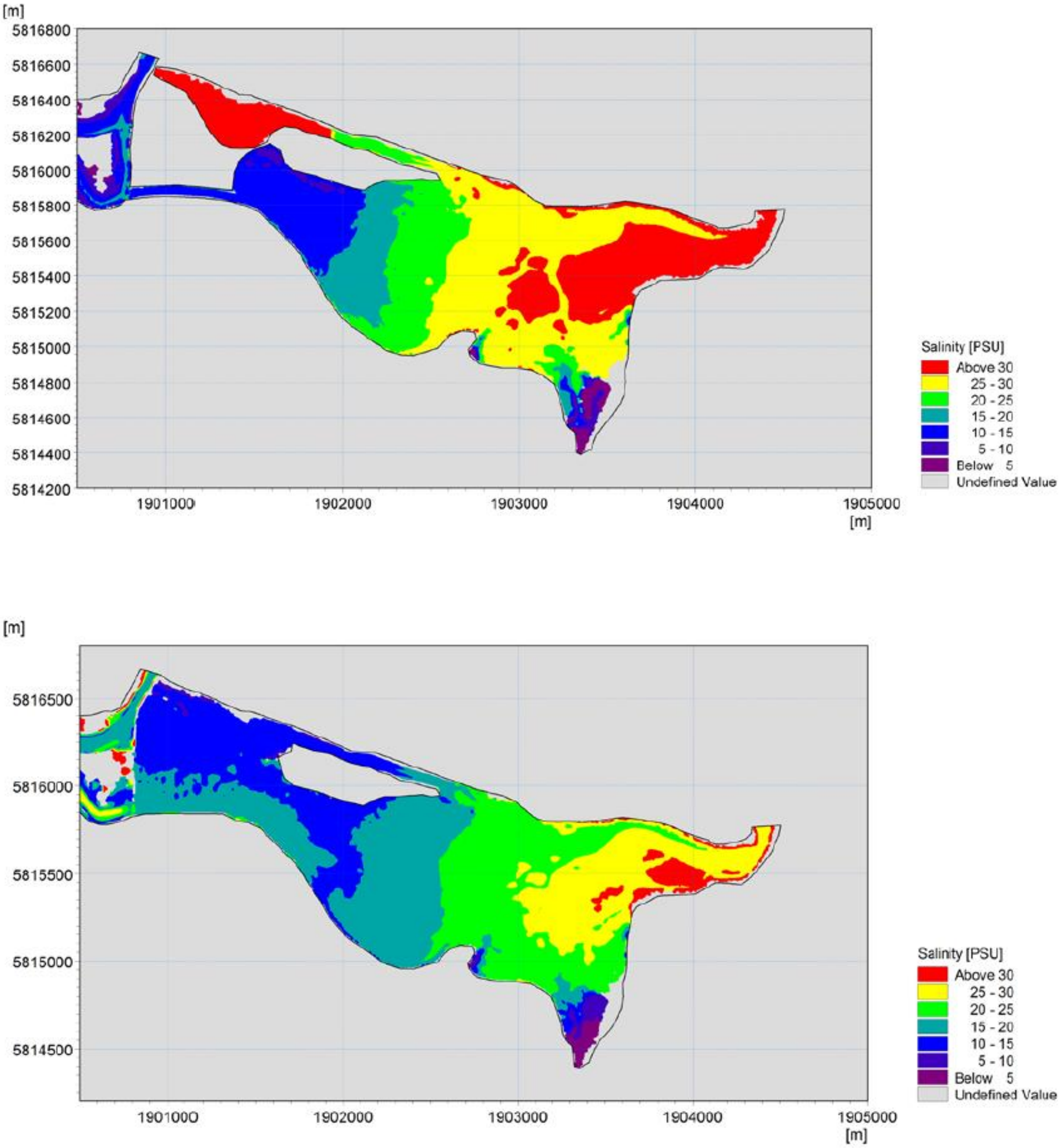

Figure 5: Mean salinity on the estuary bed modelled for the existing (top) and proposed (bottom) scenario for a mean river flow and averaged over a neap spring tidal cycle (DHI 2014). Note that the measured salinity in Papahikahawai lagoon was 26-28 psu rather than the >30 psu assumed in the model of the existing scenario.

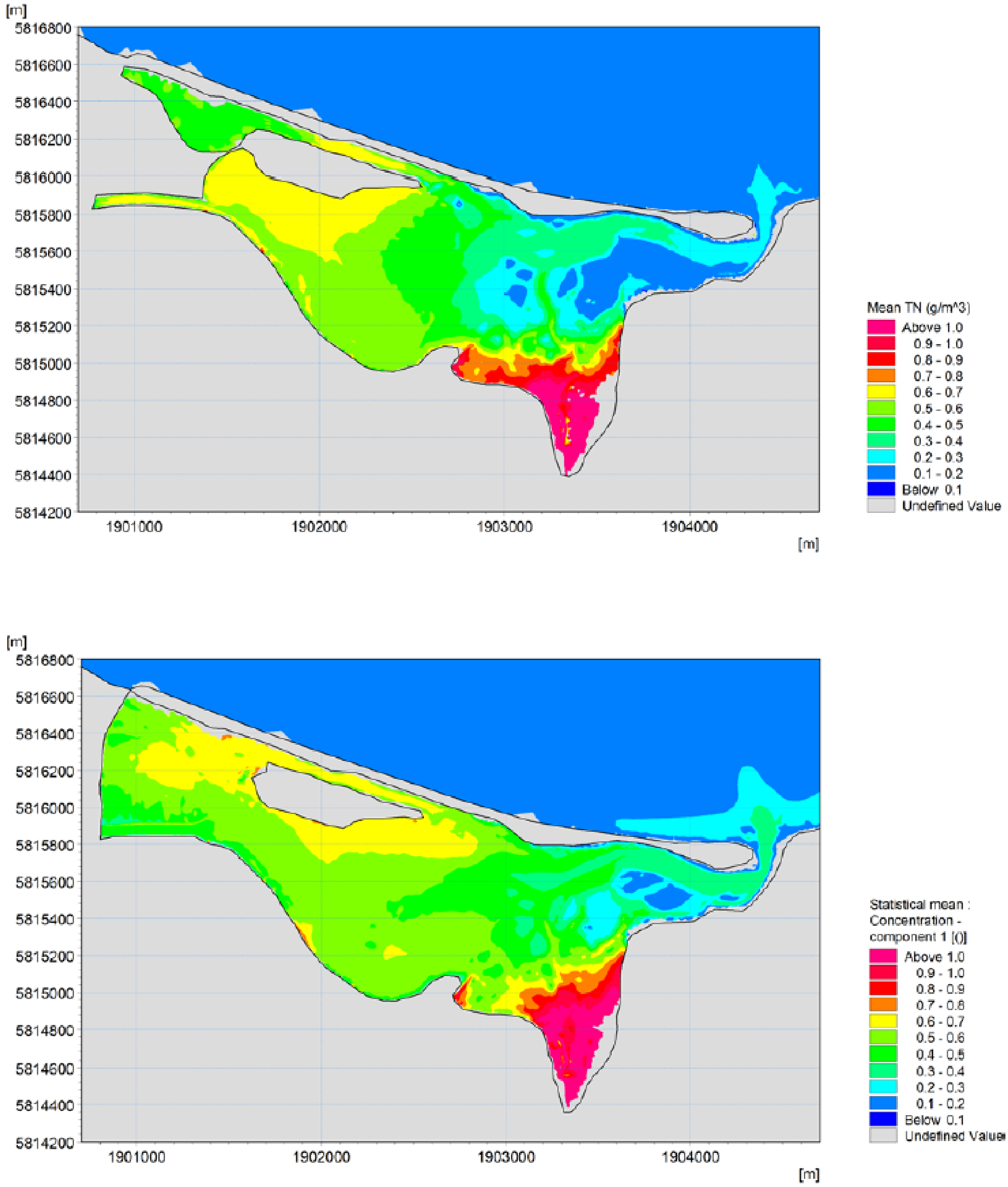

Figure 6: Mean total nitrogen concentration in the Ongatoro / Maketū estuary modelled for the existing (top) and proposed (bottom) scenario for a mean river flow and averaged over a neap spring tidal cycle (DHI 2014). Note that much of the area north of Ford's cut is intended to be planted as wetland.

Proposed monitoring

48. The Project is expected to have net positive benefits in reducing algal accumulations. Monitoring of algae cover and biomass in the estuary will be a key way to assess the benefits of the Project over time. Monitoring has been proposed to assess the areal extent of algal cover. This will be supported by assessing algal and sediment conditions along transects. Water quality and salinity monitoring is proposed at several points in the estuary to provide a basis for assessing whether the actual outcomes generally conform to the predicted outcomes.

SHELLFISH AND BENTHIC FAUNA

Current condition

49. Shellfish and other benthic macrofauna are valued as a fishery and are an important food source for fish and birds. They have a key role in estuary ecology and are useful bioindicators to detect and monitor environmental changes because they integrate water and sediment conditions over time. Benthic fauna have been regularly monitored in Ongatoro / Maketū estuary since about 1993. I complemented this monitoring with a synoptic survey in 2013/14 and sampling of 39 sites across the estuary. The results are discussed below.

50. The lower Ongatoro / Maketū estuary is in reasonable ecological health with a relatively diverse range of macrofauna and dense populations of cockle / tuangi (*Austrovenus stutchburyi*), wedge shell / hanikura (*Tellina liliana*) and pipi (*Paphies australis*). An exception is higher ground on the flood tide delta which had few macrofauna species.

51. Juvenile pipi are abundant on sand flats in the lower estuary (near the boat ramp), and adult pipi are abundant in the main channel of the lower estuary to about 1.5km upstream from the entrance.

52. The mid-estuary, east of Papahikahawai Island, had a relatively diverse range of macrofauna taxa and moderate to high abundance of macrofauna – including cockle and wedge shell (Figure 7). The depth of the anoxic layer in the sediment was generally >3cm down, indicating fair ecological condition. The western part of the mid-estuary generally had low species richness and low shellfish abundance – although horn shell (*Zeacumantus* sp) was often abundant.

53. The southern margin of the estuary had dense accumulations of *Gracilaria* sp. and (to a lesser extent) sea lettuce (*Ulva pertusa*), with several centimetres of black anoxic mud underneath. Shellfish (cockle and wedge shell) were sparse as were most other infauna. This area was in relatively poor ecological condition.

54. The upper estuary was characterised by extensive cover of free-floating algae (mostly *Gracilaria* sp. and sea lettuce), anoxic conditions close to the sediment surface, low diversity and low abundance of benthic macrofauna. Epifauna were generally limited to mud crabs, mud snail

(*Amphibola crenata*), and estuarine snail (*Potamopyrgus estuarinus*). Wedge shell and cockle were absent from many sites in the upper estuary. In some sites no benthic fauna were found – not even mud snails which are tolerant of low oxygen conditions. At these sites the surface sediment was anoxic and dense algal accumulations were common – indicating very poor ecological condition.

55. No benthic macrofauna were found in the Papahikahawai Lagoon. As already mentioned, the lagoon had thick mats of *Ulva flexuosa var pilifera* and the benthic cyanobacteria *Lyngbya* sp., forming floating rafts over large sections of the water. Years of algae decomposition has formed a thick layer (10 to 25cm) of anoxic mud over the surface, again indicating very poor ecological condition.

56. The distribution of infauna and shellfish may be largely explained by the extent to which the sediment was anoxic. Sediments in the upper estuary and southern estuary generally had an anoxic layer within 2cm below the surface (associated with accumulations of *Gracilaria*) and low infauna abundance and diversity. Anoxic condition in the sediment can force shellfish closer to the surface making them more vulnerable to predation. Eventually, continued exposure to low oxygen forces many infaunal species from the sediment and they remain moribund on the sediment surface (Sutula et al. 2011) - this can be observed in parts of the mid-estuary.

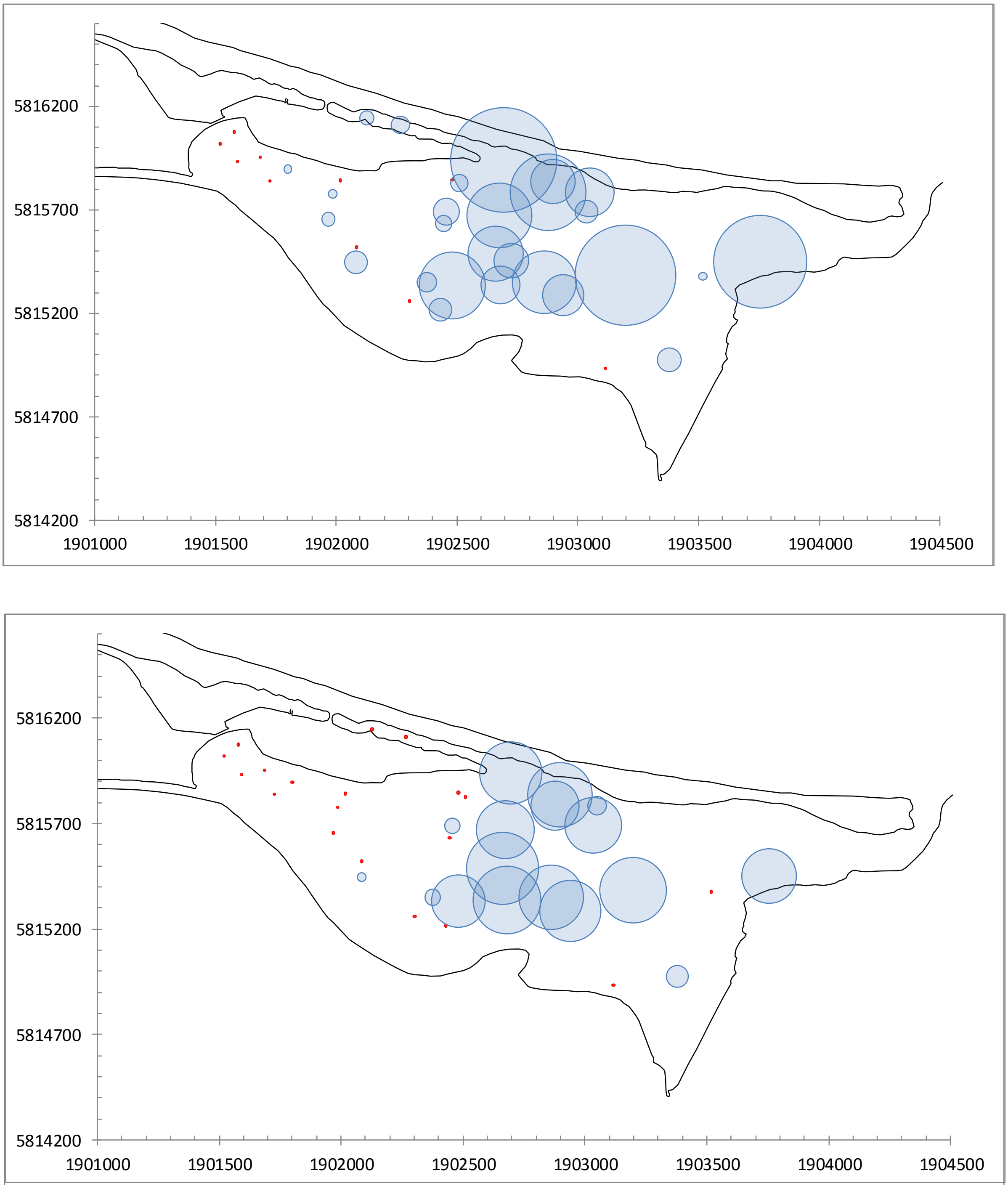

Figure 7: Abundance of cockle (top) and wedge shell (bottom) in the Ongatoro / Maketū estuary. Abundance is indicated by the area of the bubble; red dots = no cockle/wedge shell. In the top graph, the largest bubble = 1648 cockle/m^2, in the bottom graph the largest bubble =603 wedge shell/m^2.

Potential effects

57. Environmental factors that impact on benthic fauna and are likely to change as a result of the Project are discussed below.

58. The flood tide delta is expected to stop expanding and likely erode over time.[13] Expansion of the flood tide delta has tended to reduce shellfish density (Park 2011), and halting its expansion will have a net positive effect.

59. Increasing current velocities is likely to provide more food for filter feeders such as cockle and pipi. Benefits will be most apparent in the upper mid-estuary where cockle are present but current speeds are currently low.

60. An increase in residual outgoing currents will help flush fine mud and free-floating algae towards the entrance and out of the estuary. Reducing dense algal accumulations and associated organic mud will improve oxygen condition in the sediment in many parts of the estuary. This will result in improved abundance and diversity of benthic infauna and shellfish.

61. The changes in salinity due to the Project are expected to have negligible impact on cockle or pipi in the estuary. For parts of the estuary currently occupied by cockle the median salinity in bottom water is predicted to remain above thresholds that impact on feeding rates. Furthermore the food supply for shellfish is likely to increase which mitigates the effects of reduced salinity on cockle growth rates (Marsden 2004).

62. Overall the Project will result in a net increase in benthic macrofauna abundance and diversity. This will be particularly evident in the upper estuary, mid-estuary south of Papahikahawai Island and in what is currently Papahikahawai lagoon. The re-diversion is expected to have little impact on the southern estuary, near Waitipuia Stream input.

Proposed monitoring

63. The Project is expected to have net positive benefits on the abundance and diversity of benthic macrofauna and shellfish in the estuary. Monitoring of macrofauna will be a key way to assess the benefits of the re-diversion. Monitoring conditions are proposed for assessing:[14]

- Shellfish size and abundance; and
- Macrofauna abundance and composition (including algal and sediment conditions).

DISSOLVED OXYGEN

Current condition

64. Oxygen is fundamental for most aquatic organisms and the concentration of dissolved oxygen (DO) is a key aspect of fish habitat quality. DO concentrations change on a diurnal cycle, responding to the photosynthesis and respiration of algae and aquatic plants. In highly

[13] See evidence by Mr Tuckey and Mr Dahm.
[14] Refer to Proposed Conditions 29.5 to 29.8, 30.2 and 32.

productive systems these fluctuations can be sufficiently extreme to result in fish avoidance behaviour or death.

65. DO loggers were deployed in the Maketū estuary to assess the suitability of the current DO regime for fish and to calculate ecosystem metabolism - a measure of how much organic carbon is produced and consumed in an ecosystem.

66. Algal accumulations in the Maketū estuary (middle, upper and south) causes very high rates of gross primary production and ecosystem respiration. This results in large diurnal fluctuations in DO, with daily minimum DO concentrations commonly less than 2 mg/L in the mid estuary and commonly less than 1 mg/L in the upper estuary and in Papahikahawai lagoon (Figure 8).

67. Franklin (2014) established DO criteria for freshwater fish which set an imperative target of 3.5 mg/L as an instantaneous minimum.[15] This was considered the minimum acceptable criteria for minimising the likelihood of significant detrimental effects for the majority of fish species. The low concentration of DO in the main channels of the Maketū estuary (mid and south) is much worse than this imperative target to protect fish and is sufficiently low to stress or exclude many fish species during the early morning when concentrations of DO are lowest. Thus the amount of the estuary suitable for fish will typically vary on a diurnal basis, with much less available at night.

68. The Papahikahawai lagoon had a particularly low minimum DO that is likely to exclude most fish from the lagoon. Even mosquito fish (which is tolerant of degraded water quality) are likely to exhibit avoidance behaviour such as air breathing or aquatic surface respiration during the night.

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[15] A similar instantaneous minimum threshold was derived for juvenile estuarine fish. Sutula et al. (2012) found minimum DO criteria for estuaries in different jurisdiction in California ranged from 2.9 mg/L to 4.3 mg/L.

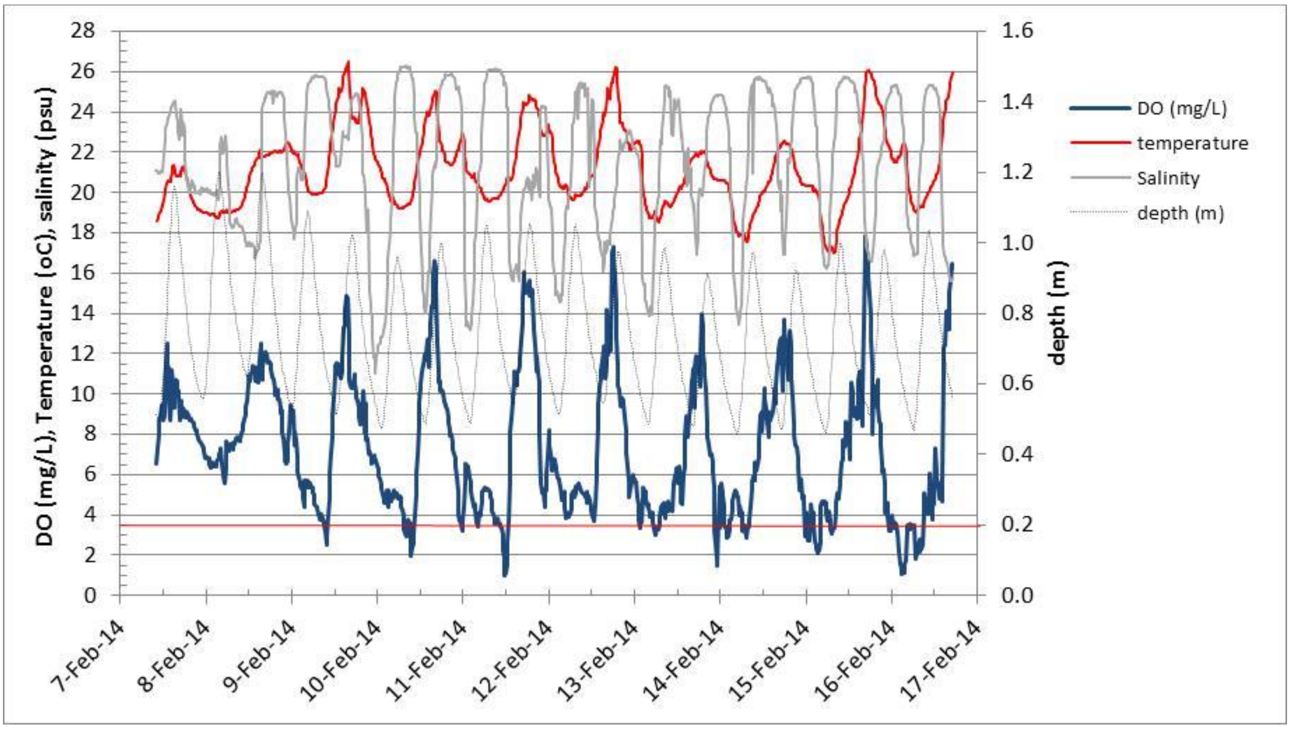

Figure 8: Dissolved oxygen, temperature, salinity and depth at in the main channel of the mid-estuary. DO concentrations below the horizontal red line are likelihood of significant detrimental effects on most fish (Franklin 2014).

Potential effects

69. The Project will improve the dissolved oxygen regime in the estuary, as it will:

a) Substantially increase the inflow of oxygenated water from the river and Te Tumu; and

b) Increase flushing of free-floating macroalgae that currently accumulate in the channels and backwaters of the upper and mid-estuary. This will reduce the primary production and respiration which drives diurnal DO fluctuations and low concentrations. This improvement will be particularly apparent in the upper-estuary and Papahikahawai lagoon.

70. It is likely that an improved DO regime and less dense algal accumulations as a result of the re-diversion will improve habitat conditions for grazers. Grazers known to feed on macroalgae include mullet, sea hare (*Aplysia* sp.), chiton, and various molluscs. Grazing appears to have a substantial influence on the growth and accrual of *Ulva* sp. in Ongatoro / Maketū estuary (see section 2.3 of my Report). Thus reducing algal accumulations and improving the DO regime may contribute to a positive feedback that potentially increases the rate of algal grazing, and further reduce algal accrual.

Summary

71. Many parts of Ongatoro / Maketū estuary currently have a very poor DO regime that will often exclude most fish species during the night. This is caused by respiration from dense algal accumulations. The Project will improve the dissolved oxygen regime in the estuary and increase the extent of estuary habitat suitable for fish.

Proposed monitoring

72. The Project is expected to have net positive benefits by improving the DO regime in the estuary. Repeating the DO monitoring post re-diversion would provide a useful measure by which to assess the success of the Project and would augment monitoring of algal cover. The monitoring should occur during summer when algal accumulations and DO fluctuations are typically highest. I recommend that it occur twice following re-diversion (e.g. years two and five).

FISH IN THE ESTUARY AND LOWER RIVER

Current condition

73. Estuaries are important habitat for fish, providing sheltered habitat and rich food supply – particularly for juveniles which often use estuaries as a rearing habitat. The Ongatoro / Maketū estuary and Kaituna River mouth are commonly fished for kahawai, mullet, flounder and whitebait.

74. Fish surveys have found 24 fish species that either utilise or travel through the estuary or Kaituna River mouth. Fish commonly observed in the main body of Maketū estuary are kahawai, mullet, flounder and parore. Fish common around the estuary margins are shortfin eel, cockabully, common bully, giant bully, inanga and the introduced mosquito fish.

75. Shortfin eel were found to be particularly abundant at the entrance to Waitipuia Stream with 620 caught in the channel below the flapgate and 60 caught in the stream above the flap gate in two day/night trials.

76. The current extent of habitat suitable for fish in the estuary is reduced by low dissolved oxygen concentrations and suitable feeding habitat is indirectly reduced by extensive areas of anoxic sediments (as discussed above).

77. There are a number of important areas of whitebait rearing, and potential spawning habitat along the lower River and tributary streams. These include potential habitat in the Waitipuia Stream and Arawa wetland if fish-friendly flap gates were installed, whitebait rearing habitat in the borrow pits (about 3.8km upstream of the entrance and 500m from the proposed take), and the Kaituna wetland. Shoals of inanga were observed trying to enter Waitipuia Stream (the largest tributary entering the estuary) but were mostly excluded by the flapgate.

78. Inanga spawn in autumn (mostly February to mid-April) amongst dense grasses and vegetation near the top of the saline wedge during a spring high tide. Sampling during January 2014 found the saline wedge to extend to about 2.5 to 3.1 km upstream (adjacent to Kaituna wetland), but the precise location will vary by hundreds of metres according to the river flow and tide heights. In practice inanga have been found to spawn over wide area from about 1.7 to 6.6 km upstream from the entrance.

Potential effects

79. The Project will improve the amount of habitat suitable for fish in the estuary by reducing accumulations of anoxic sediment, improving the abundance of benthic fauna in much of the estuary, and improving the dissolved oxygen regime.

80. The Project will affect the salinity in the lower Kaituna River and the extent of the salt wedge. The modelling shows that the section of river below the proposed intake (1.3 km upstream) will become considerably more saline after the re-diversion, including channels draining the wetland below this point (DHI 2014). The effect is most evident in the surface water (i.e. river margins) rather than on the bed of the main river channel which is already saline. Fish in the lower Kaituna River have wide salinity tolerances and there is a wide diversity of fish in Fords Cut (with similar high salinity) so overall the increased salinity downstream of the proposed intake is not expected to have a significant impact on fish.

81. The DHI model also indicates that the extent of the saline wedge may increase by about 250 metres upstream. This change will have negligible impact on potential inanga spawning sites because the change is negligible in the context of natural variability caused by differences in river flow and variation in spring tide tidal heights.

82. Construction of the intake for the proposed re-diversion will result in the loss of about 100m of current wetland margin. This part of the river has primarily vegetated vertical banks. The Project will compensate for the loss of this potential fish habitat by creating additional, gently sloping edge habitat along the northern edge of the new channel with dense riparian planting; riparian habitat will also be improved along the north side of Ford's Cut – together this will create about 1000m of new or improved riparian habitat. Overall there will be a net gain in potential fish habitat along the wetland edge of the new channel. In addition, the Project involves the creation of a large area of salt marsh wetland adjacent to the estuary east of Fords Road which, if suitably designed, will have potential for whitebait rearing habitat.[16]

[16] Potential effects of the channel on the Titchmarsh wetland and the design approach for the new wetland is discussed in evidence by Mr MacGibbon.

Proposed monitoring

83. The Project is expected to have net positive benefits on fish habitat by improving the DO regime in the estuary and providing additional riparian and wetland habitat. I do not propose monitoring conditions requiring fish surveys because the impact of the Project is more easily and more directly assessed by other monitoring variables that are covered in other conditions.

MACROINVERTEBRATE FAUNA IN THE LOWER RIVER

Current condition

84. The aquatic macroinvertebrate community can provide an indication of river health and the food available for fish. I sampled the lower Kaituna River bed and river margins for aquatic macroinvertebrates in January 2014 to describe their composition and assess the likely changes due to the Project.

85. The survey found low Macroinvertebrate Community Index (MCI) scores at most sites, reflecting the dominance of taxa tolerant of wide changes in salinity. The greatest abundance and species diversity of aquatic macroinvertebrates in the lower Kaituna River tidal zone occurs on the river banks and riparian margins. The river bed had few taxa due to the mobile pumice sands. Pipi are abundant near the mouth (e.g. from 0.7km upstream) where the water is more saline and the substrate more stable.

Potential effects

86. Modelling indicates that the section of Kaituna River below the proposed intake (1.3 km upstream) will become considerably more saline (DHI 2014) after the re-diversion. On the river edge there is likely to be a shift towards more saline tolerant species, but the overall effect is expected to be minor because most species in this section of river are already saline tolerant. The bed of the main river channel is already saline in this section so there will be negligible effect on river bed fauna. However it is possible that the spatial extent of pipi beds in the lower Kaituna River may extend further upstream towards the proposed intake as the section of the river below the proposed intake becomes saline for longer periods of time.

87. Higher species diversity was found on vegetated banks compared to rock rip-rap. The proposal to have a 'soft' vegetated edge along the northern side of the new channel will maximise invertebrate species diversity and interaction with the wetland.

Proposed monitoring

88. The Project will have little impact (positive or negative) on aquatic macroinvertebrates in the lower Kaituna River. The current macroinvertebrate fauna reflects the partially saline conditions

and usual indicators of macroinvertebrate community 'health' are not very applicable to the sections of rivers within the saline wedge. No monitoring has been proposed as a result.

HEALTH RISKS – BATHING AND SHELLFISH GATHERING

Current State [17]

Recreational bathing waters

89. The suitability of the lower Ongatoro / Maketū estuary for recreational bathing was assessed by comparing the microbial water quality in the lower estuary (near the boat ramp) with recreational bathing water guidelines (MfE and MoH 2003). These use a 'traffic light' system with different action proposed for 'surveillance', 'alert' and 'action levels' (see box 1 in Hamill 2014b). In order for a marine site to be graded as 'good' or better it must have a 95 percentile value of <200 enterococci/100mL and a Sanitary Inspection Category of 'moderate'.

90. The microbial water quality in the lower estuary near the boat ramp consistently meets bathing water guidelines. Bimonthly monitoring found 95 percent of samples with less than 74 enterococci/100mL. It was rare for *enterococci* concentrations to increase beyond the 'surveillance' mode, and less than 1% of samples triggered resampling under the 'action' mode (Hamill 2014b).

Suitability for shellfish gathering

91. The suitability of the lower Maketū estuary for shellfish gathering was assessed by comparing the microbial water quality in the lower estuary (opposite the marae) with shellfish gathering guidelines (MfE and MoH 2003) and shellfish flesh criteria (MoH 1995). Guidelines for shellfish waters state that:

"The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL (using a five-tube decimal dilution test)."

92. The Ministry of Health criteria for shellfish flesh allow two out of five samples to have a faecal coliform concentration >230 MPN/100mL, and no sample in a batch to exceed 330 MPN/100 g.

93. Guidelines for shellfish flesh and shellfish waters are solely management tools. They do not relate to a specific risk of infection and they do not guarantee that shellfish grown in water of this quality will be safe (MfE and MoH 2003, Scholes et al. 2009). They are used to assess "*changes in conditions compared with those occurring at the time of a sanitary survey*", and they

[17] In assessing microbial water quality it is helpful to distinguish between predictions made by DHI (2014) using the result of the dilution, predictions made by Hamill (2014b) using the same input data but a different method, and actual results from monitoring. The method used by Hamill (2014b) is more accurate than that applied by DHI (2014) but there is very little difference between results. This explains small inconsistencies in numbers quoted in the Officers Report, PDP reports and the Caucus Document.

are useful for assessing the effect of surface run-off from rain events. "*These factors are used to decide when gathering should be curtailed in commercial shellfish-growing areas … [and] are equally applicable for recreational shellfish-growing waters*".[18]

94. Annual shellfish flesh monitoring has been within microbial criteria most of the time but occasionally exceed maximum criteria, i.e. pipi and cockle had a median FC of 80 FC/100g and 135 FC/100g respectively, and the maximum criteria was exceeded 23% and 26% of the time for pipi and cockle respectively. The results of monitoring shellfish waters gives a similar message i.e. shellfish gathering guidelines are met most of the time but the frequency of high results borderline to exceeding what is allowed under the guidelines.[19]

95. The higher levels of bacteria are mostly associated with rain events. Analysis of bimonthly sampling from the boat ramp found bacteria levels are over three times more likely to exceed the upper shellfish guideline value (of 43 MPN/100mL) during a rain event compared to during dry weather.[20] Targeting sampling to capture rain events demonstrates the impact of rain events more clearly. For the period 2011 – 2013 the median faecal coliform concentration at the boat ramp was 10 MPN/100mL during base flow and 185 MPN/100mL during rain events. The 90 percentile concentration at the boat ramp was 64 MPN/100mL during base flow and 828 MPN/100mL during rain events.[21]

96. It is often recommended that shellfish are not gathered within two to five days following rainfall. Shellfish depurate 90 to 95% of bacteria and viruses within two days. The rate of depuration varies with temperature, salinity and tidal cycle, thus during a large rain event the rate of depuration[22] may be slower and a longer withholding period would be justified (e.g. up to five days) (Ball et al. 2008). Depuration can also be achieved by holding the live shellfish in tanks of clean seawater for one to three days prior to consumption.

97. Microbial contamination of Maketū estuary occurs from multiple sources. The main load of faecal indicator bacteria (e.g. faecal coliforms, *enterococci* bacteria) to the estuary comes via the Kaituna River, Waitipuia Stream, and drains. The impact of these sources was modelled to predict the effects of the re-diversion (DHI 2014, Hamill 2014b). However there are also other sources such as wildfowl, septic tanks and direct stormwater runoff that were not included in the model but can have a significant impact in localised parts of the estuary. I estimated that birds contribute 33% of the current median faecal coliform load to the estuary entering via Fords cut

[18] See section F2 of MfE and MoH (2003).

[19] Annual compliance monitoring of shellfish waters in the lower estuary opposite the marae had a median and 90 percentile faecal coliform concentration of 5 MPN/100mL and 43 MPN/100mL respectively (low, mid and high tide for period 1997-2011). Bimonthly monitoring in the lower estuary near the boat ramp had a median and 90 percentile faecal coliform concentration of 8 MPN/100mL and 75 MPN/100mL respectively (low and high tide for period 1997-2013). FC concentration was >43 MPN/100mL for about 17% of the time.

[20] For period 1996-2013, the trigger of 43 MPN/100mL was exceeded 26/126 times for rain events and 5/126 times when there were no rain events. A rain event was defined as >0.3mm as a three day average.

[21] The 90th percentile concentration at the boat ramp was 64 MPN/100mL during base flow and 828 MPN/100mL during rain events. This is for the period 2011-2013. Baseline sampling n=25, rain event sampling n = 14

[22] Depuration is the purification of shellfish due to the defecation of sediment and any undigested food material in the gut.

(but much more where they congregate). The relative contribution from birds will be about 10% after the Project diverts more water to the estuary (Hamill 2014b).

Potential effects

Suitability for bathing

98. The Project is expected to increase the concentration of faecal indicator bacteria in the lower Maketū estuary. This increase will have negligible impact on the health risk for bathing. It will still be rare for *enterococci* concentrations to increase beyond either the 'surveillance' mode, and only about 1% of samples will trigger resampling under the 'action' mode.

Suitability for shellfish gathering

99. Modelling indicates that after the re-diversion the shellfish gathering guidelines will continue to be met most of the time (i.e. median FC modelled to increase from 5.4 MPN/100mL to 8.8 MPN/100mL). However the 90 percentile guideline of 43 MPN/100mL will be exceeded more frequently - increasing from about 12% exceedance to about 19% exceedance after the re-diversion. This is respectively 2% and 9% more often than the allowable 10% exceedance under the shellfish gathering guidelines. Past monitoring results span a similar range depending on the dataset used.

100. The majority of exceedance will still be associated with rain events, with higher concentrations associated with larger events. In practical terms, the advice regarding shellfish gathering will remain the same, i.e. people should avoid gathering shellfish from the estuary within two to five days of rain.

101. The modelled calculations of microbial contamination at the shellfish water site use conservative assumptions that probably over-estimate the water quality change that will occur as a result of the re-diversion.[23] Although the Kaituna River input does have a significant impact on microbial load to the estuary, the original re-diversion in 1996 resulted in a step change <u>improvement</u> in microbial water quality rather than the expected decline.[24] This is despite higher concentrations of faecal coliform bacteria in the Kaituna River over this period.[25]

102. One reason for the apparent lower faecal coliform concentrations in the estuary despite greater load from the Kaituna River is the additional flushing resulting from this initial re-diversion. A significant fraction of bacteria are associated with estuarine bed sediments, and these bacteria

[23] E.g. use of nigh-time die-off rates.

[24] An equivalence test showed strong evidence of a >20% difference for *enterococci* (t-test *p*-value = 0.013 for log transformed data) when comparing periods 1991-1996 with 1996-2000. Samples spanning this period were collected near high tide.

[25] The median faecal coliform concentration in the Kaituna River at Te Matai was 900 cfu/100mL prior to 2000 and 83 cfu/100mL since 2007. The 90 percentile value was 4840 cfu/100mL prior to 2000 and 225 cfu/100mL since 2007.

have a much longer survival than those free-living in the water[26]. Fine sediments can serve as a reservoir for faecal bacteria in shellfish areas, and high concentrations of faecal bacteria are commonly associated with resuspension of sediments (Pachepsky and Shelton 2011). Fries et al. (2006) found that 38% of microbes in water of the Neuse River Estuary were associated with sediment particles capable of settling and re-suspending. Geo et al. (2013) found that bacteria associated with sediment from the bed of the Severn Estuary were dominant during dry weather, and during wet weather on spring tides. Bacteria from the river were only dominant during wet weather on neap tides.

103. The Project will result in the flushing of more fine sediments from the estuary. This will reduce the potential pool of sediment and bacteria available for re-suspension by the wind and currents. In particular it will reduce the reservoir of microbes that are deposited directly as guano from birds and that enter the estuary during rain events. These effects have not been modelled but they will at least partially mitigate the impact of increased external loads due to the re-diversion.

104. The concentration of faecal indicator bacteria in the lower Kaituna River at Te Matai has significantly declined over the last 10 and 20 years, although at the site below Waiari Stream some of this improving trend appears to have reversed since 2010. I understand that a number of actions are planned by the Regional Council outside of this project that will continue improving microbial water quality in the Kaituna catchment. These include:

104.1 Kaituna River and Ongatoro/Maketū Estuary Strategy – the Implementation Plan has actions around improving water quality.

104.2 Council are working with landowners on developing Biodiversity Management Plans, e.g. with the Papahikahawai Island Trust.

104.3 Kaituna is a priority catchment for implementing the National Policy Statement for Freshwater Management.

104.4 Sufficient funding for a doubling of catchment riparian protection works.

105. An important part of managing public health risk from shellfish gathering is to ensure that the public are informed of risks so they can make informed decisions. In my view, the public could be better informed about how to manage the current health risks from recreational shellfish gathering in Maketū estuary – particularly with regard to avoiding collection within two to five days of rain events and ensuring depuration prior to eating. Improving public awareness in this way would, in my view, also provide mitigation to address the risk of higher microbial concentrations due to the Project.

[26] Numerous studies have found the density of faecal coliforms in sediments to be 10 to 10,000 times higher than that in the overlying water (Pachepsky and Shelton 2011).

106. This assessment has focused on microbial water quality. The overall health risk from shellfish gathering should also consider impacts of biotoxins. The Maketū estuary is often officially closed for shellfish gathering due to the risk of Paralytic Shellfish Poisoning (PSP). The Project will not change the health risk to shellfish gathering due to PSP or other biotoxins.

107. *Lyngbya* sp., the benthic cyanobacteria that currently dominates Papahikahawai Lagoon, contains secondary metabolites and toxins which can cause asthma and dermatitis. The re-diversion will largely remove these cyanobacteria and provide potential public health benefits to uses of the area in addition to the ecological benefits and improvements in the life-supporting capacity of the upper estuary.

Proposed monitoring

108. There is a risk of increased microbial contamination of shellfish as a result of the re-diversion. Monitoring shellfish flesh and shellfish waters will help confirm and manage the microbial risk associated with shellfish gathering. I recommend that consent conditions include monitoring of shellfish flesh and waters during summer months and at sites consistent with past compliance monitoring. This monitoring will help identify the actual effects of the Project and to assist with ongoing advice to the public.

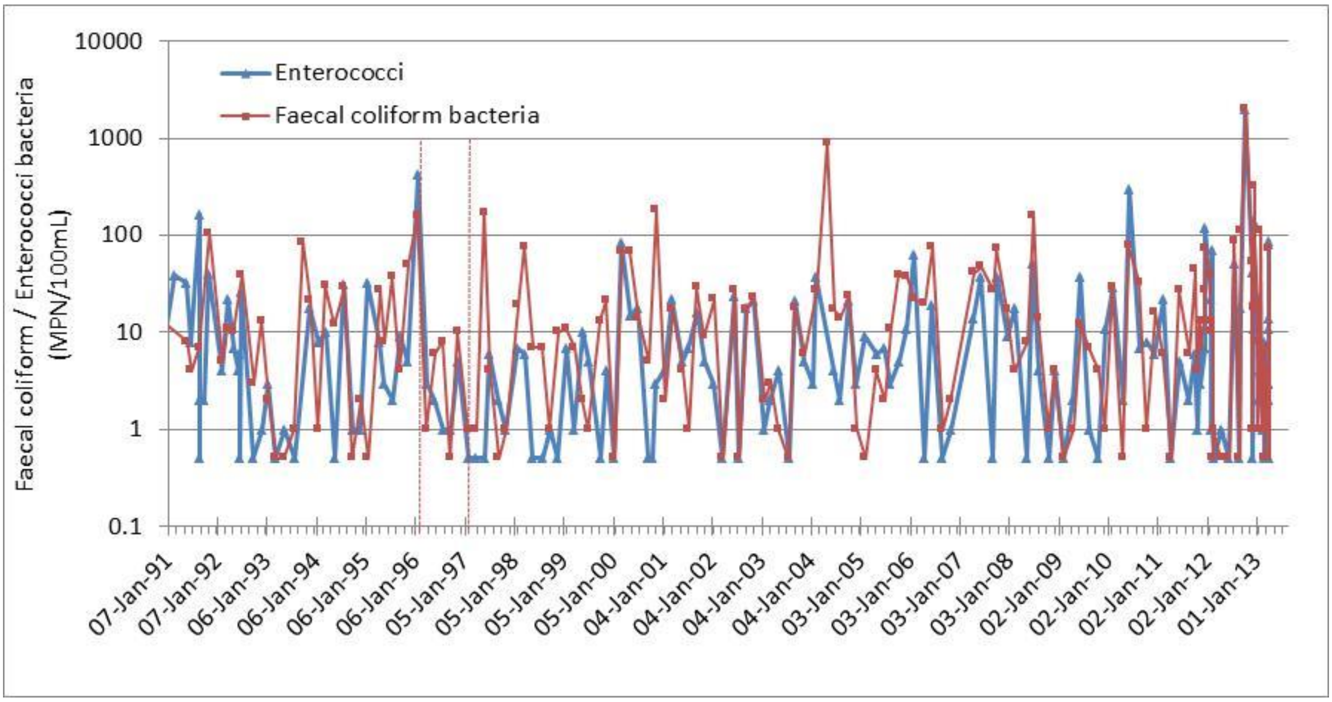

Figure 9: Faecal indicator bacteria in Ongatoro / Maketū estuary at the boat ramp. Bacteria concentrations reduced immediately after the current re-diversion commenced in 1996. In February 1996 the control structure was damaged and gates fully opened, in January 1997 the

gates were closed to 20,000 m^3 per tidal cycle to allow for the staged opening of up to 100,000 m^3 per tidal cycle.

RESPONSE TO SUBMISSIONS

109. I have considered below submissions that have raised issues relating to the scope of my role in the Project.

Submission by E. Harwood

Flushing

110. Mr Harwood disagrees with the model results that there will be higher current speed and additional flushing in Ongatoro / Maketū Estuary as a result of the Project. This view appears to be based on observations that the gates at Fords Cut only open after the tide has already started to flow into the estuary mouth - minimising the water that will flow through the estuary during low or mid-tide.

111. The reduction of algal accumulations and associated muds is an important aspect of the Project's benefits. Mr Tuckey discusses the reliability of the model results in his evidence. I also note that there are several hydrodynamic changes expected as a result of the Project that will help reduce algal accumulations. These include: a) an increase in current speeds, b) an increase in the net outflow of water, and c) halting (and likely reversing) the expansion of the flood tide delta.[27]

Sediment input from river

112. Mr Harwood raised concern that introduction of sediment-loaded water from the Kaituna River may result in an increase in anoxic muds as sediment and algae settle in the estuary. This concern appears to be partially based on observations of a build-up of anoxic mud and a reduction in cockle size in the mid-estuary since 1994. Most anoxic muds found in the estuary are associated with algal accumulations and largely consist of decomposing algae rather than material from the Kaituna River. I have already discussed evidence of algal accumulations increasing in the last 10 years, and the associated muds have probably also increased. Furthermore we know that there has been an expansion of the flood tide delta, and that sand from the flood-tide delta has been redistributed into the upper estuary. There is no indication that these changes were caused by the 1996 re-diversion.

113. Recent results are described in Park (2011) found no adverse impact on cockle densities from the freshwater being re-diverted back into the estuary. Adverse impacts on the cockle bed densities (and possibly size) have occurred at sites nearer the entrance as a result of sand migration into the estuary.

[27] See evidence from Mr Dahm.

114. The effect of the Kaituna River on the deposition of sediment in the estuary is discussed in evidence by Mr Dahm and Mr Tuckey. I also not that my sampling of the Kaituna River during base flow conditions has found that none of the suspended sediment in the Kaituna River settles out under quiescent conditions.

Additional nutrient load from the Kaituna River will stimulate more sea lettuce growth.

115. I have already discussed the effects of the Project on external and internal nutrient loads and the risk of additional nutrients stimulating faster algal growth. The key ecological issue for Ongatoro / Maketū estuary is to reduce the extent of algal accumulations. In my view, the most effective way to do this is to increase net outward current speeds and flushing (as will occur with the re-diversion). Algal accumulations would also be reduced by reducing nutrient inputs sufficiently to limit algae growth. I strongly support catchment nutrient reductions as part of a strategy to improve Ongatoro / Maketū estuary, but to rely on this without increasing flushing rates would require much larger catchment nutrient reductions to achieve the same benefits. In some parts of the estuary (e.g. Papahikahawai Lagoon) it is likely that internal nutrient loads alone are sufficient to support the high algal biomass in the current environment, i.e. we will not see improvements without improving flushing or some other major intervention.

Additional faecal coliform load to the estuary from the Kaituna River.

116. The potential effect of the Project on microbial contamination of shellfish is an important issue which I addressed in detail in my evidence above.

Submission by L Collins

Effects of retiring farmland

117. I agree with the observation that the amount of farmland proposed to be retired is small compared to the size of the catchment and that the contribution of N and P to the estuary from this farmland is small compared to the loads entering from rivers. Nevertheless, it is my view that the retiring of farmland adjacent to the estuary will have a net positive effect on nutrient and microbial water quality (see section 2.4.7 Hamill 2014).

Effects on cockles

118. I do expect improvements in the shellfish community in the mid and upper estuary as a result of the Project. As discussed on page 48 of my Report: "*General increases in current speeds across most of the estuary, and in particular an increase residual current speed towards the ocean, will have overall positive impacts on the benthic invertebrate fauna by improving the rate of food supply for filter feeders such as cockles and by reducing the extent of the estuary that is currently degraded by accumulations of free-floating algae and the associated anoxic mud*."

Sea grass

119. The Project is one action (albeit a very important one) out of many planned into the future to improve the ecological health of Ongatoro / Maketū estuary. In my view it will result in significant ecological benefits, but it will not be the panacea. With respect to restoration of sea grass, reducing salinity in the mid-estuary will help germination, and reducing algal accumulations will help reduce further deterioration. It is possible that these changes alone will not be sufficient to see the restoration of sea grass beds, but they are an important step in the right direction.

Submissions by P Ellery, Maketū Ongatoro Wetland Society, Catalyst High Rise Ltd

120. These submitters raised concerns about the water quality of the Kaituna River entering Ongatoro / Maketū estuary and requested that initiatives be implemented to improve water quality in the Kaituna catchment and/ or drains entering the estuary. In my view, initiatives to improve water quality in the Kaituna River, Waitipuia Stream and drains entering Ongatoro / Maketū estuary will be an important part of improving the ecological condition of Ongatoro / Maketū estuary in the long term. However, I do not consider that these initiatives are necessary as a form of mitigation for effects of the Project. In my view, the Project already incorporates features that minimise, mitigate and compensate for potential adverse effects. There are uncertainties, and monitoring is proposed to understand and manage the outcomes of the Project.

SECTION 42A REPORT

121. The Section 42A report focuses largely on the modelling results when discussing effects on water quality. I would like to highlight that while the modelling provides very valuable information with regard to nutrients that might impact on algal growth; the dilution modelling provides only part of the story. When assessing the likely effects of the Project consideration needs to be given to the combined external and internal nutrient load and how they are likely to impact on algal accumulations. The same point applies to microbial contamination. This was discussed in my Report and in my evidence above.

Shellfish

122. The Section 42A report notes that in response to concern about the risk of increased microbial contamination of shellfish waters "*PDP's technical specialists have recommended that consideration be given to the provision of compensational mitigation in the form of enhancement of a local feature (that is, environmental off-setting)."* (page 35). I have already discussed a number of things that mitigate and compensate for the potential increase in current health risks from microbial contamination. Reduction in the internal load of microbial contamination associated with fine sediments is likely to be important and may have resulted in improvements

in microbial water quality observed after the 1996 re-diversion. However the extent to which this will compensate for the increase in external microbial loads remains uncertain.

123. I note that the Reporting Officer concludes at page 38 that the Project's adverse effects on bacteria levels and shellfish gathering "*are not of a magnitude that require a specific mitigation response based on the information available but, like the other water quality indicators, should be subject to regular on-going monitoring*". I agree with this.

Re-distribution of fine sediment from within the estuary.

124. The section 42A report at page 77 states that "*the Proposal is likely to result in localised deposition of some of the sediments eroded from the Estuary to low energy depositional zones within the Estuary* …". A more complete description of the effects is provided in my evidence above and in the agreed caucusing statement from 25 March 2015. In particular: "*In the short term, there is a risk that some of the muds mobilized by the increased current will redistribute to other parts of the estuary…. The areas most likely to be affected are already low current zones where algae and associated muds already accumulate… and in the long term the net sediment mobilised as a result of the re-diversion will be flushed as the estuary establishes a new state of dynamic equilibrium*." This effect is further discussed in evidence given by Mr Dahm.

Condition 29 (dissolved oxygen)

125. I discuss DO monitoring in paragraph 72 above. The Section 42A report has recommended that this monitoring occur in summer, which I support, but also in winter (refer Condition 29.1 in the Officer's Report). I see little benefit in repeating the monitoring in winter and recommended that this requirement be deleted. In winter algal accumulations are less extensive, DO fluctuations due to photosynthesis and respiration are less extreme, and the water holds more oxygen due to much cooler water temperatures. I also see little rationale in monitoring between stage one and two when the re-diversion is not fully commissioned and flushing benefit only partially realised.

Condition 32: Sediment

126. I consider that Condition 32 should be changed to read "sediment and algae" to better describe what is being measured.

127. The Officer's Report has proposed specifying that sediment core samples be collected as part of the sediment and algae monitoring. I understand that the intention of this is to "*allow for the assessment of the depth of mud/silt and anoxic layer depth*" (page 77 of the Officers Report). I agree with this intent and specifying this information as part of the consent condition. However I do not support requiring core samples as the method to collect this information. Collecting core samples is not necessary for measuring the depth of mud/silt or the depth of the anoxic layer, and there are other methods that are both faster and more accurate for conditions encountered

in Ongatoro / Maketū estuary. I have recommended that the reference to using core samples is removed from this condition and that the detail about the sampling method is left to the monitoring plan.[28]

128. I have also recommended that the condition requiring integration sediment sampling with macrofauna sampling is removed (Condition 32.4), and replaced by a condition under 29.8 (shellfish sampling) and 30.2 (Ecology fauna) stating that: "*At the location of each macrofauna replicate measurements shall also be taken of the following variables using methods consistent with those used for condition 32.3: algal cover and type, percent cover mud/silt, depth mud/silt and anoxic depth*." The reason for this change is that these variables are useful for interpreting macrofauna results but it is not, in my view, appropriate to constrain the location of the transects used for algal and sediment surveys by requiring that they intersect with each shellfish and macrofauna sample location.

Condition 37 Review

129. I support the use of a general review condition as a safe-guard for any unexpected adverse effects of the Project. We know that the Project will result in many changes in the estuary, and most of them are expected to be positive. There may also be localised negative effects balancing positive effects elsewhere, e.g. shifting the influence of Waitipuia Stream further east. In my view, responding to any particular effect needs to consider the wider effects on the whole estuary in the long term. It also needs to account for the considerable spatial heterogeneity and temporal variability that occurs within an estuary. A review clause provides an appropriate mechanism to do this.

CONCLUSION

130. Large areas of Ongatoro / Maketū estuary are highly degraded by dense accumulations of benthic algae. The dense algal accumulations result in anoxic muds, a loss of shellfish and other benthic fauna and severe declines in night-time reduction in dissolved oxygen. This, in my view, significantly compromises the life-supporting capacity of the Maketū estuary.

131. The Project will considerably improve the ecological condition of Ongatoro / Maketū estuary - primarily by creating conditions that flush accumulations of algae and associated muds. Nitrogen concentrations will probably increase in the lower estuary but are unlikely to result in faster sea lettuce growth. Furthermore the increased flushing will make the estuary considerably less sensitive to nutrient inputs.

132. The Project will increase the microbial load from the Kaituna River and may increase the risk of microbial contamination of shellfish – particularly during rain events. The current and future

[28] Note that 'visual assessments' does not mean only surficial assessments as suggested in section 5.1 of PDP memo (dated 30 March 2015) and measuring the anoxic depth from a core would itself be a visual assessment.

public health risk can be managed by ongoing monitoring and providing clear advice around the timing of shellfish gathering.

133. Although the Project will considerably improve the ecological condition of the Maketū estuary, it is not a panacea and attention will also need to be given to improving the wider catchment water quality.

Keith Hamill

17 April 2015

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APPENDIX 1: Cellular nutrient content of sea lettuce in Maketū Estuary and implications for nutrient limitation (April 2015)