Memo

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To	Waimakariri Water Zone Committee
CC	
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Assessment of nitrate-N impacts in Te Aka Aka

1. Summary

Elevated nitrogen concentrations can cause excessive growth of fast-growing macroalgae species in estuaries. Macroalgae trap fine sediment, making the sediments muddier, can reduce dissolved oxygen levels in water and cause anoxic conditions in estuarine sediment. The abundance and diversity of estuarine species may decline in response to these effects.

Field investigations undertaken by Environment Canterbury suggest that Te Aka Aka is somewhere between slightly and highly impacted by excessive macroalgae growth, i.e. in the range of moderate to high eutrophication. However, there is significant spatial variability on impacts within the estuary. There is also likely to be year-to-year variability, as nitrogen loads discharging to the estuary vary with weather and climate cycles.

Modelling results suggest that successful implementation of GMP could reduce the nitrate-N concentration in the estuary, but that the benefits of this are likely to be counteracted if land users within the catchment make full use of the proposed Plan Change 5 Permitted Activity (PA) rules, which allow for additional winter grazing and irrigation. The net effect of GMP and 50% uptake of the proposed PA rules is expected to be neutral – i.e. nitrate-N concentrations will remain similar to present. A major nitrogen load reduction would be required in the Te Aka Aka catchment in order to reduce the eutrophication susceptibly of the estuary.

2. Introduction

Nitrogen is typically the limiting nutrient for the growth of phytoplankton and algae in coastal and estuarine water. When there is plenty of nitrogen, and other growing conditions are right (such as water temperature and sunlight), these plants grow prolifically.

Prolific growth of macroalgae can cover intertidal sediments and cause the sediments to become anoxic. This means there is no oxygen to support the worms and other animals that live within the sediment and keep the sediment healthy. Anoxic sediment is black and emits a sulphurous odour.

Macroalgae smothers and eliminates seagrass and traps fine sediment particles such that the estuary could become muddier over time. The respiration of abundant macroalgae can lower/deplete the water of oxygen at night, when there is no oxygen production through photosynthesis. Depleted oxygen levels can result in the death of the animals that live in the water, such as fish.

When macroalgae die they can dislodge and either be carried out of the estuary or deposited on the shore or in backwaters. The breakdown of the algae in these locations by microorganisms can deplete the water of oxygen which in turn can result in the death of the animals that live in the water, such as fish. The decaying macroalgae emits a strong odour.

Field surveys have shown that within Te Aka Aka there are large areas of the fast-growing macroalgae species *Ulva* spp. (Figure 1) and *Gracilaria chilensis* (Figure 2). Flushing of the estuary within a tidal cycle limits the potential for excessive phytoplankton growth in the estuary. There is no seagrass in Te Aka Aka.

The presence of macroalgae within an estuary is not entirely negative. *Ulva* spp. and *Gracilaria* provide habitat for a range of estuarine species such as topshells, hoppers and worms (Bressington, 2003). In turn this is food for the birds and fish that feed on these species. We have seen many birds including godwits, oyster catchers and spoonbills feeding in and around the edges of a dense bed of *Ulva* sp. within Te Aka Aka. But excessive growth of macroalgae over large areas of an estuary do cause ecological issues. The process of nutrient enrichment and excessive growth of plants and algae associated with this is called eutrophication.

Figure 1: *Ulva* sp. Within Te Aka Aka. 100% cover and a thick layer

Figure 2: *Gracilaria chilensis* within Te Aka Aka

3. Current state

A set of tools for assessment of the trophic index of NZ estuaries was released for use in 2016 (Robertson *et al,* 2016a, 2016b). The tools include:

- Determination of the eutrophication susceptibility using physical and nutrient load data, and
- use of monitoring indicators to assess the actual eutrophication band.

The tools define four eutrophication bands, as shown in Table 1.

Table 1 Description of the four eutrophication categories

A Minimal Eutrophication	B Moderate Eutrophication	C High Eutrophication	D Very High Eutrophication
Ecological communities are healthy and resilient. *Primary Producers: dominated by seagrasses and microalgae. **Primary Producers: dominated by phytoplankton (diverse, low biomass). Water Column: high clarity, well-oxygenated. Sediment: well oxygenated, low organic matter, low sulphides and ammonia, diverse macrofaunal community with low abundance of enrichment tolerant species.	Ecological communities are slightly impacted by additional algal growth arising from nutrient levels that are elevated. *Primary Producers: seagrass/ microalgae still present but increasing biomass opportunistic macroalgae. **Primary Producers: dominated by phytoplankton (moderate diversity and biomass). Water Column: moderate clarity, mod-poor DO esp at depth. Sediment: moderate oxygenation, organic matter, and sulphides, diverse macrofaunal community with increasing abundance of enrichment tolerant species.	*Ecological communities are highly impacted by macroalgal or phytoplankton biomass elevated well above natural conditions. Reduced water clarity likely to affect habitat available for native macrophytes. **Ecological communities are highly impacted by phytoplankton biomass elevated well above natural conditions. Reduced water clarity may affect deep seagrass beds. *Primary Producers: opportunistic macroalgal biomass high, seagrass cover low. Increasing phytoplankton where residence time long e.g. ICOLLs. **Primary Producers: dominated by phytoplankton (low diversity and high biomass). Water Column: low-moderate clarity, low DO, esp at depth. Sediment: poor oxygenation, high organic matter, and sulphides, macrofauna dominated by high abundance of enrichment tolerant species.	*Excessive algal growth making ecological communities at high risk of undergoing a regime shift to a persistent, degraded state without macrophyte/seagrass cover. **Excessive algal growth making ecological communities at high risk of undergoing a regime shift to a nuisance algal bloom situation (often toxic). *Primary Producers: opportunistic macroalgal biomass very high or high/low cycles in response to toxicity, no seagrass. At very high nutrient loads, cyanobacterial mats may be present. Phytoplankton only high where residence time is long. **Primary Producers: dominated by nuisance phytoplankton (e.g cyanobacteria, picoplankton). Water Column: low clarity, deoxygenated at depth. Sediment: anoxic, very high organic matter, and sulphides, subsurface macrofauna very limited or absent. Eventually the sediments are devoid of macrofauna and are covered in mats of sulfur-oxidizing bacteria (i.e. *Beggiatoa*).

We have used monitoring indicators ((Robertson *et al,* 2016b) to assess the current eutrophication state of Te Aka Aka. This has involved mapping the extent of macroalgae within the estuary (2014 and 2018) as well as measuring several sediment parameters (2016/2017). The macroalgae mapping results (which evaluated the area of the estuary covered by macroalgae) indicate that Te Aka Aka is within band B. However, the sediment parameters results show that, depending on the sediment parameter and the location within the estuary, the band does vary (Figure 3).

The macroalgae distribution and sediment parameter results overall suggest that:

- Saltwater Creek nutrients are causing macroalgae growth and effects on some sediment parameters along the margins of this creek;
- the small drains flowing into the western margin of the estuary are a source of nutrients causing macroalgae growth in the small channels in this area; and
- The Ashley River/Rakahuri is the likely source of nutrients causing macroalgae growth and effects on some sediment parameters in the southern part of the estuary. However, there may be some influence of Taranaki Creek water on these indicators here.

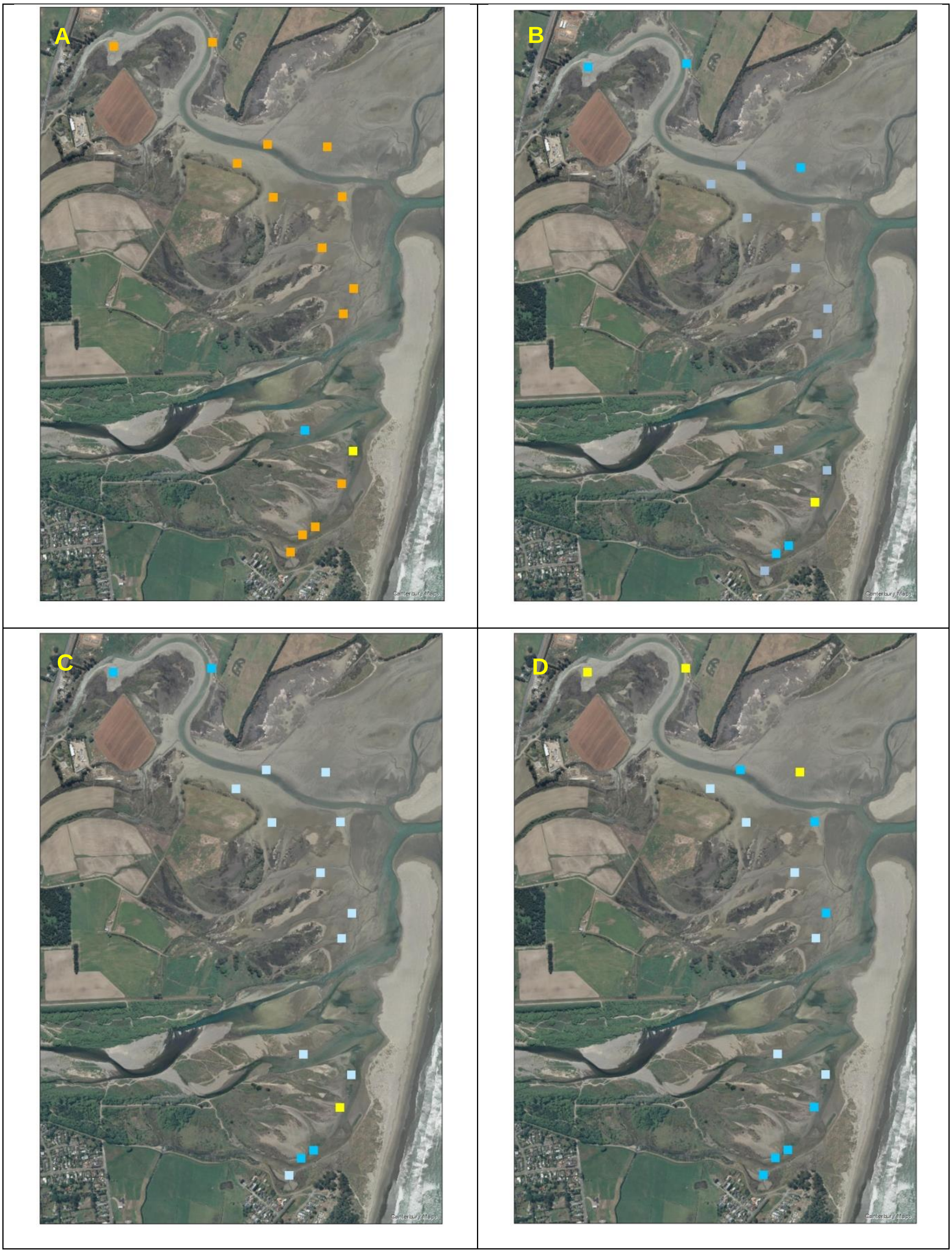

Figure 3: Sediment parameter assessment 2016/2017 A: Percent mud B: Total nitrogen C: Total organic carbon D: Redox

Symbols: Light Blue - ETI Band A, dark blue - ETI Band B, yellow - ETI Band C, Orange – ETI Band

4. Modelling method and scenarios

Nitrogen (nitrate-N) load modelling was undertaken using a calibrated, peer-reviewed groundwater model together with an N load layer optimised to measured N loads at the Ashley Gorge site and subjected to uncertainty analysis by a panel of experts from industry, research and Environment Canterbury. Modelling scenarios are summarised below.

Table 2 Model scenarios

Scenario name	Description	Purpose
CMP	Current Management Practice	Estimates nitrate-N concentrations/loads at steady state, when water quality equilibrates with current land use
GMP	Good Management Practice	Assess the benefits of implementation of industry-agreed good management practices on nitrate-N discharges
PC5PA	Proposed Plan Change 5 Permitted Activity Rules for winter grazing & irrigation	Assess the additional nitrogen losses associated with additional winter grazing and irrigation permitted under the proposed PC5. Assumes full uptake of both allowances.
Current Pathways	Assumes 50% of the PA winter grazing and irrigation is implemented on the ground	Full uptake of the winter grazing and irrigation area on every property in the Ashley catchment is very unlikely. This scenario represents a more reasonable estimate of the possible ultimate outcome of the current management regime.

5. Nutrient susceptibility modelling

Environment Canterbury contracted NIWA staff to evaluate the eutrophication susceptibility of Te Aka Aka using physical and nutrient load data and the CLUES (Catchment Land Use Environmental Sustainability) model for the model scenarios above. The nutrient load data were provided by Environment Canterbury and included nutrient loads for the model scenarios in Table 2.

Modelling results (Table 3) are presented as nitrogen (N) loads and the eutrophication susceptibility bands (Dudley and Plew, 2018). Results are presented for both the ETI tool 1 band and for the Clues-Estuary tool assessment band. Results are presented for 5th and 95th percentile estimates of nitrogen loads based on the results of the expert panel uncertainty assessment.

The CMP results, which should reflect the current worst year N load, fall within band D under the ETI tool 1 assessment for both the 5th and 95th percentile N loads, and band C and D respectively for the assessment based on the CLUES estuary tool.

As noted above, field measurements and observations are consistent with classification of the estuary as band B with some evidence of band C conditions in certain areas. Model results represent the worst year nitrogen load (since nitrogen controls should aim to maintain acceptable Nitrogen levels in all years, not just in average or below average N load years). On this basis the model results are not necessarily inconsistent with field observations.

Because the 5th percentile CLUES estuary tool assessment correlates the closest with observation data, we have assumed that these results provide the most useful indication of the outcome of each modelling scenario. Other modelling results are therefore greyed-out in Table 3. All discussion of modelling results from here on relates to the 5th percentile CLUES estuary tool assessment results.

Table 3 Summary of the potential eutrophication bands (susceptibility) of Te Aka

Scenario	Modelled N load		ETI tool 1 eutrophication susceptibility		CLUES Estuary tool eutrophication susceptibility	
	5th percentile	95th percentile	5th percentile	95th percentile	5th percentile	95th percentile
CMP	293	598	D	D	C	D
GMP	264	538	D	D	C	D
PC5PA	389	795	D	D	D	D
Current pathways	284	639	D	D	C	D

Modelling results indicate that introduction of GMP will not be sufficient to reduce N loads in the estuary to within the band B classification in the highest N load years, but would likely help to maintain the estuary within band B for more of the time and therefore maintain and possibly improve estuarine health.

Full uptake of the PC5PA winter grazing and extra irrigation allowance could potentially degrade the estuary to band D in the worst (highest N load) years, but the more realistic 50% uptake scenario results (Current Pathways) suggest that the N load discharging to the estuary is likely to be marginally lower than current loads. On this basis no significant degradation (or improvement) of the eutrophication state of the estuary is anticipated under the current management regime.

In the future the ideal outcome is that the eutrophication state of the estuary is maintained within band B and does not reach band C, even in high N load years. Analysis of the N load reductions required to achieve each the ETI band under the four modelling scenarios (

Table 4) indicates that major load reductions (e.g. 65% under Current Pathways) may be required to achieve this.

Table 4 Annual loads required to meet ETI band

Scenario	Band and N load (t/year)			
	A	B	C	D
	<42 t/year	42-100 t/year	100 – 320 t/year	>320 t/year
	N load reduction required to achieve band			
CMP	86%	66%	N/A	N/A
GMP	84%	62%	N/A	N/A
PC5PA	89%	74%	18%	N/A
Current pathways	85%	65%	N/A	N/A

Nitrogen management options for the estuary are presented in the Environment Canterbury document entitled *Setting and Achieving Flow, Allocation and Nitrate Limits in the Ashley/Rakahuri Catchment*.

6. Future research and recommended monitoring

Further investigations could be undertaken in the future to:

- understand the variability in eutrophication susceptibility between average and high N load years.
- understand the relative impacts of N loads from different freshwater sources within the estuary catchment on eutrophication susceptibility.

We recommend long-term annual monitoring to assess the eutrophication band of Te Aka Aka. This should include:

- mapping of the macroalgae within Te Aka Aka – distribution, % cover
- sampling sediments and macroalgae at ~ 20 sites within Te Aka Aka to assess the ETI parameter values – Redox, sediment total nitrogen, sediment total reactive phosphorus, sediment grain size, algae biomass.

References

Bressington, M. 2003. The effects of macroalgal mats on the marine benthic fauna in the Avon-Heathcote Estuary. University of Canterbury M.Sc, thesis.

Dudley, B and Plew, D. 2018. Te Akaaka eutrophication susceptibility assessment. NIWA Client Report for Environment Canterbury. 2017041CH.

Robertson, B.M, Stevens, L., Robertson, B., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T., Oliver, M. 2016a. NZ Estuary Trophic Index Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420. 47p.

Robertson, B.M, Stevens, L., Robertson, B., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Oliver, M. 2016b. NZ Estuary Trophic Index Screening Tool 2.

Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420. 68p.