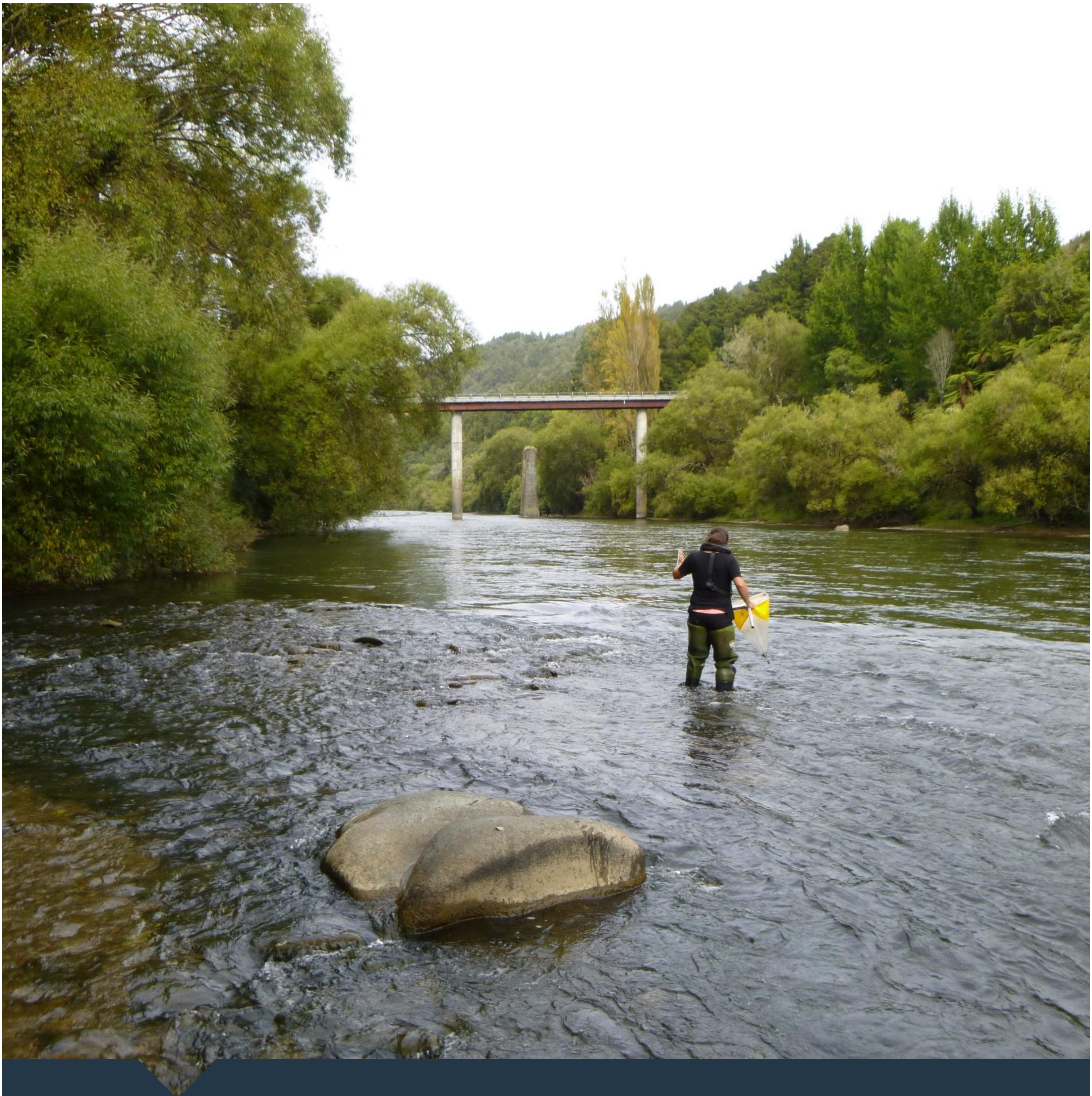

Estuary contaminant load assessment stage 2:

Risk-based approach to assess load reductions for Horizons estuaries

September 2025

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REGIONAL COUNCIL

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Estuary Contaminant Load Assessment Stage 2: Risk-based Approach to Assess Load Reductions for Horizons Estuaries

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GLOSSARY

BBN	Bayesian Belief Network
CPT	Conditional Probability Table
DO	Dissolved Oxygen
DRP	Dissolved reactive phosphorus
ESNZ	Earth Sciences New Zealand (formerly NIWA)
ETI	Estuary Trophic Index
EVA	Ecological Vulnerability Assessment
FWFP	Freshwater Farm Plan
FMU	Freshwater Management Unit
GIS	Geographic Information System
HEC	High Enrichment Conditions
HRC	Horizons Regional Council
LCDB	Land Cover Data Base
MALF	Mean Annual Low Flow
NIWA	National Institute of Water and Atmospheric Research
NBL	National Bottom Line
NPS	Nutrient Policy Scenario
NPS-FM	National Policy Statement for Freshwater Management
SIN	Soluble inorganic nitrogen
SLUI	Sustainable Land Use Initiative
SPS	Sediment Policy Scenario
TN	Total Nitrogen
TP	Total Phosphorus
UPR	Under Protection Risk

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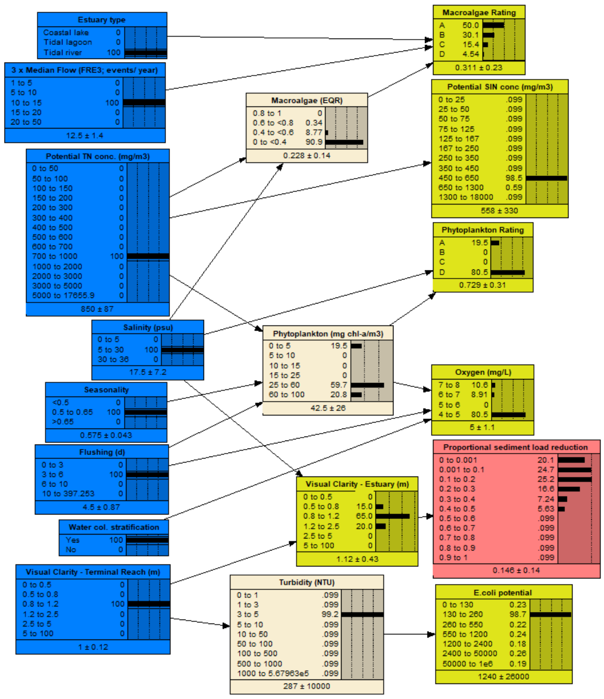
SUMMARY

The Horizons Regional Council (HRC) One Plan includes targets for rivers, lakes, estuaries and marine areas in the Manawatū-Whanganui region, all aimed at maintaining and/or improving waterbody values (e.g., ecosystem health, human health, threatened species, mahinga kai). To support regional freshwater management, the One Plan targets were recently reviewed to align with research and guidance produced since they were originally developed. Further, freshwater contaminant load reductions needed to meet these targets have been calculated for rivers and lakes. However, it remains unclear whether freshwater load reductions will also be sufficient to meet targets set for estuaries.

To address this gap, HRC engaged Salt Ecology to assess whether freshwater contaminant (nutrient and sediment) load reductions would meet estuary health targets across 26 west coast and 15 east coast estuaries, 41 estuaries in total. A two-staged approach was developed to identify estuaries that may need additional load reductions beyond those already applied to freshwater:

- **Stage 1** used an Ecological Vulnerability Assessment (EVA), combining desktop and field data, to evaluate ecological values, susceptibility, pressures, and condition. The EVA identified 25 estuaries that required further evaluation in Stage 2
- **Stage 2** (current report) developed and implemented a Bayesian Belief Network (BBN) risk-based assessment tool to evaluate estuary condition under different load reduction scenarios for sediment and nutrients (see figure to right). The risk assessment tool was used to determine whether freshwater load reductions were sufficient to protect estuary health, or if further reductions or more detailed studies were required.



Results from both Stage 1 and Stage 2 were used to prioritise estuaries for further work, focusing on important systems where load reductions are unlikely to protect estuary health, or where the level of protection remains uncertain. Estuaries were prioritised as follows:

- **Priority 1** estuaries that the EVA (Stage 1) identified as having high ecological values but being in poor condition and deemed either at-risk or with an uncertain level of protection from load reductions (Stage 2).
- **Priority 2** estuaries that the EVA (Stage 1) identified as in poor condition and deemed either at-risk or with an uncertain level of protection from load reductions (Stage 2).
- **Priority 3** estuaries deemed either at-risk or with an uncertain level of protection from load reductions.

Estuaries prioritised based on information in Stage 1 and Stage 2. Indicators that require further investigation are in brackets - nutrients (N), estuary clarity (S) and *E. coli* potential (E).

Priority 1	Priority 2	Priority 3
Rangitikei (N, E)	Kai Iwi (N, E)	Papuka (N, S, E)
Manawatū (N, E)	Mōwhānau (N, S, E)	Ototoka (S)
Ōhau (N)	Turakina (N, S, E)	Okehu (S, E)
Waikawa (N, E)	Kaikokopu (N, E)	Kaitoke (S, E)
Tautāne (N, S)	Hōkio (N, S)	Whangaehu (E)
Wainui (N, S)	Ākitio (N, S)	Koitiata (S)
Waimata (N, S)	Owāhanga (N, S)	Pukepuke (S)
	Whanganui (E)	Wairarawa (E)
		Waiwiri (S)

RECOMMENDATIONS

The BBN provides a transparent means of guiding decision-making but is most useful for assessing relative change under different scenarios. Where estuaries remain vulnerable despite load reductions, or where the level of protection remains uncertain, more comprehensive field and/or modelling investigations are likely required to establish appropriate load reductions. Below is a list of general recommendations and approaches for consideration. Estuary-specific recommendations for Priority 1 and 2 estuaries are presented in the main report.

Modelling

- The Horizons BBN created in this project was based on best available information. To improve its predictive capability, the relationship between node connections can be refined as more data become available. Specifically, the relationship between river and estuary clarity would benefit from refinement, as clarity data to verify this indicator for Horizons estuaries is currently limited or absent. This refinement is considered the main requirement for further exploring load reductions in Priority 3 estuaries vulnerable to sediment-related indicators.
- Basic dilution modelling has been used by other councils to set load reductions (e.g., Plew 2020). However, for tidal river estuaries it is recommended that this method be applied in conjunction with the BBN, as described in the current report, since it better accounts for additional drivers influencing eutrophication (i.e., high flow events). This combined approach proved effective in testing scenarios in most estuaries with nutrient-related issues.
- Hydrodynamic modelling provides a more robust means of assessing nutrient load reductions in estuaries (e.g., the hydrodynamic models prepared for Ōhau and Waikawa; Tuckey 2024). This approach allows for detailed assessment of load reduction scenarios at the site level but requires significant investment, including the collection of field validation data, bathymetry, preparation of the model and scenario testing. Hydrodynamic modelling would be most appropriate for Priority 1 estuaries.

Collection of field data

- Surface water quality data are available for some Horizons' estuaries; however, data gaps limit the ability to: (1) characterise the health of an estuary, (2) assess progress against One Plan targets, and (3) build relationships between driver and indicator nodes in the BBN. In a review of Horizons estuarine water quality programme, Dudley et al. (2018) recommended collecting salinity, suspended sediment and visual clarity data at all estuary sites, in addition to *E. coli* monitoring. The present study further supports those recommendations. To more accurately understand the influence of stratification and bottom water eutrophication, bottom water sampling is also required, particularly to characterise phytoplankton and dissolved oxygen dynamics in estuaries where stratification is likely to occur. Additional field data collection would be most useful for Priority 1 and 2 estuaries to validate any BBN or modelling predictions, particularly where the level of protection was deemed uncertain.
- To improve the outputs of the dilution modelling (Plew 2024) and predictions of the BBN, the desktop-based Coastal Explorer input data used to calculate estuary volume, tidal prism, salinity and flushing time could be strengthened through the collection of field data (e.g., bathymetry, salinity profiles, tide height). This need is also supported by Dudley et al. (2018) and would be most valuable for Priority 1 and 2 estuaries. In particular, where the level of protection was assessed as uncertain for a given estuary, these improvements may be sufficient to test the effects of existing scenarios.
- Improving the linkages between the freshwater programme and the estuary programme would help to improve the relationships between driver nodes and indicators in the BBN. Particularly the inclusion of flow, alongside the general suite of water quality indicators (i.e., temperature, salinity, total nitrogen, soluble inorganic nitrogen, total phosphorus, dissolved reactive phosphorus, chlorophyll-*a*, dissolved oxygen, *E. coli*, pH, suspended sediment concentration, turbidity, visual clarity) at the terminal river reaches for Priority 1 estuaries, in particular.

1. INTRODUCTION

The Horizons Regional Council (HRC) One Plan includes targets for rivers, lakes, estuaries and marine areas in the Manawatū-Whanganui Region, all aimed at maintaining and/or improving waterbody values (e.g., ecosystem health, human health, threatened species, mahinga kai). To implement the National Policy Statement for Freshwater Management (NPS-FM) and review the freshwater provisions of the One Plan, HRC initiated engagement with the community, tangata whenua and other stakeholders on how to manage freshwater across the region. In this process the council also identified seven sub-regions, called freshwater management units (FMUs; Fig. 1).

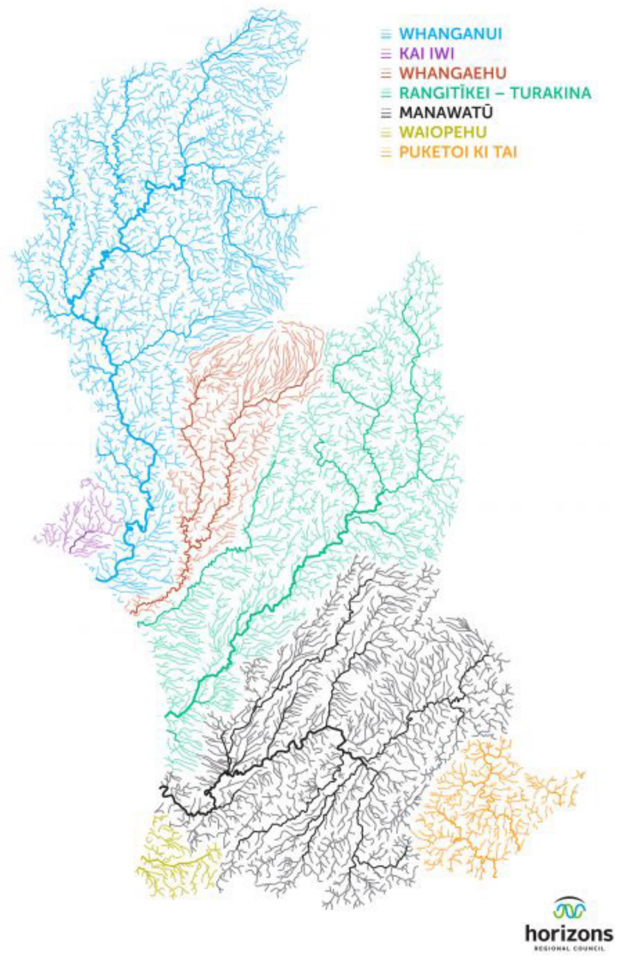


Fig. 1. Horizon Regional Council FMUs. Sourced from freshwater.horizons.govt.nz.

The estuary One Plan targets include water quality parameters (e.g., temperature, nutrients, oxygen), faecal indicator bacteria, water clarity and eutrophic response indicators such as phytoplankton (measured as chlorophyll-*a*) and macroalgae. Table 1 outlines the current estuary One Plan targets (HRC One Plan Schedule 9), along with recommended revisions described in Dudley et al. (2024). Tables 2 and 3 specifically describe the proposed revisions for phytoplankton (chlorophyll-*a*; Table 2) and macroalgae (Table 3).

Reducing catchment loads, including both nutrients and sediment, is critical to achieving One Plan estuary targets, for example:

- Phytoplankton and macroalgae blooms are strongly linked to elevated nutrients, and managing nitrogen loads can reduce their impact (Howarth & Roxanne 2006; Heisler et al. 2008; Robertson et al. 2017; Plew et al. 2018; Stevens et al. 2022).
- Faecal indicator bacteria (*E. coli*) and visual clarity are strongly influenced by sediment loads (Davies-Colley & Smith 2001; Gall et al. 2019; Dudley et al. 2024).

Horizons have modelled nutrient and sediment load reductions based on different land management scenarios and assessed the reductions needed to meet ecological targets in freshwater (Snelder & Fraser 2021; Vale & Smith 2023; Snelder 2024). However, it remains unclear whether these load reductions will be sufficient to meet the estuary targets in Tables 1-3. To address this gap, HRC engaged Salt Ecology to assess whether freshwater contaminant (i.e., nutrient & sediment) load reductions will meet estuary health targets across 41 estuaries in the region (26 west coast, 15 east coast). A two-stage approach was applied:

- **Stage 1** involved an Ecological Vulnerability Assessment (EVA), which combined desktop and field-based information to assess estuary values, susceptibility, pressures, and condition. A synopsis of EVA findings for each of the 41 estuaries is presented in the Stage 1 report (Roberts et al. 2025). That report recommended excluding 16 estuaries from further assessment because they were very small (<0.1ha), had a steep gradient to the beach, and were all freshwater-dominated, hence freshwater targets and associated load reductions are more appropriate. The remaining 25 estuaries (19 west coast and 6 east coast; Figs. 2-3) require further evaluation in Stage 2 to determine load reduction requirements.
- **Stage 2** (the focus of the current report) applied a Bayesian Belief Network (BBN) risk-based assessment to each of the 25 estuaries to evaluate estuary condition under different freshwater load reduction scenarios. The aim was to determine whether current load reductions are sufficient to safeguard estuary health, or if further reductions

may be required. The BBN approach was chosen over other methods as it is most suited for the challenges inherent in the assessment. These challenges arise due to limited water quality and hydrodynamic data, and because tidal river estuaries (the main Horizons estuary type) are complex, physically dynamic systems with environments that vary both spatially (e.g., water column stratification) and temporally (e.g., flushing events; Forrest et al. 2024). This report summarises the findings of the risk assessment, describes the estuaries where further load reductions are unlikely to be needed and provides recommendations for those where they are.

Table 1. Horizons One Plan targets and recommended revisions described in Dudley et al. (2024).

Indicator[1]	Dissolved Oxygen (% sat)	Algal biomass (Chl-*a*; mg/m^3)[2]	Macroalgae (% cover)	Soluble inorganic nitrogen (SIN; g/m^3)[2]	*Escherichia coli* (*E. coli* per 100mL)		Visual clarity (m)
Flow	All flows	All flows	All flows	≤20th %ile[3]	≤50th %ile[3]	≤20th %ile[3]	≤50th %ile[3]
One plan target	>70	<4	<5	Manawatū (0.444) Ōhau (0.110) All other (0.167)	<260[4]	<550[5]	>1.2
Revisions Dudley et al. (2024)	No change	Updated as per Table 2	Updated as per Table 3	No change	Maintain current thresholds, however, remove reference to flow and time of year.		No change[6]

1. Other indicators with One Plan targets including temperature (22-24ºC), dissolved reactive phosphorus (DRP; 0.010-0.015g/m^3), ammoniacal nitrogen (<0.4g/m^3), toxicity (95%), euphotic depth (m; 10% change), and visual clarity (20% change) were not assessed.
2. Annual mean
3. Flow exceedance percentile.
4. 1-November to 30-April 2025.
5. Year-round.
6. Dudley et al. (2024) noted that 1.2m visual clarity is unlikely to be met in estuary turbidity maximum zones (TMZs) where fresh and saltwater meet resulting in naturally high concentrations of suspended sediment.

Table 2. Algal biomass (Chlorophyll-*a*) thresholds proposed for Horizons estuaries. Four bands (A-D) describe progressively worsening states, and thresholds differ across different estuary salinity regimes. The grey shaded column is most closely associated with the original One Plan target of <4mg/m^3 algal biomass.

Chlorophyll-*a* (90th percentile; mg/m^3)	A* Minimal eutrophication	B Moderate eutrophication	C High eutrophication	D Very high eutrophication
Euhaline (>30ppt)	≤ 3	>3 to ≤8	>8 to ≤12	>12
Meso/polyhaline (≥5 to 30ppt)	≤ 5	>5 to ≤10	>10 to ≤16	>16
Oligohaline/ freshwater (<5ppt)	≤ 10	>10 to ≤25	>25 to ≤60	>60

*Dudley et al. (2024) suggested the selection of an appropriate eutrophication target can be made on an estuary-by-estuary basis.

Table 3. Macroalgae bands with corresponding EQR ratings and potential total nitrogen (TN) thresholds. The grey shaded column is most closely associated with the original One Plan target of <5% cover of macroalgae across the available intertidal habitat (i.e., the intertidal area outside of salt marsh).

Macroalgae (OMBT-EQR)	A* Minimal eutrophication	B Moderate eutrophication	C High eutrophication	D Very high eutrophication
EQR	≥0.8	≥0.6 to <0.8	≥0.4 to <0.6	<0.4

*Dudley et al. (2024) suggested the selection of an appropriate eutrophication target can be made on an estuary-by-estuary basis.

Fig. 2. Estuaries on the west coast of the Horizons Region included in Stage 2.

Fig. 3. Estuaries on the east coast of the Horizons Region included in Stage 2.

2. RISK-ASSESSMENT METHOD

2.1 THE BAYESIAN BELIEF NETWORK (BBN)

A BBN is a probabilistic model that represents relationships between variables and how they influence each other (e.g., nutrient loads influence algal growth). BBNs have been used in New Zealand (e.g., Bulmer & Hewitt 2020; Bulmer et al. 2022; Zeldis & Plew 2022) and internationally (e.g., Shenton et al. 2010; Shenton et al. 2014; McDonald et al. 2016) as a management support tool for freshwater and estuaries.

A BBN consists of a series of nodes representing key variables, with unidirectional arrows indicating relationships between them. Each node has a set of states, either numeric or descriptive, and nodes are separated into three types: driver, intermediate or indicator nodes. Driver nodes represent inputs that influence other parts of the network (e.g., estuary type, salinity or water column stratification), intermediate nodes represent calculated values that influence other indicators, while indicator nodes represent the final output variables (e.g., macroalgae, phytoplankton, visual clarity). The dependencies between nodes are quantified by conditional probability tables (CPT) derived from data or expert judgement. The BBN constructed for the current assessment is shown in Fig. 1, with the methodology for deriving the CPTs detailed in Tables 4 and 5 (nutrients) and Table 6 (sediments and *E. coli*). The BBN model was created using the software package Netica (Norsys 2005).

The Horizons model draws on features from the Estuary Trophic Index (ETI) Tool 3, a BBN that describes responses to eutrophication and sediment pressures for three common New Zealand estuary types, i.e., tidal lagoon, coastal lake, and tidal river estuaries (Zeldis & Plew 2022). The current project used the eutrophication component of the ETI Tool 3 BBN, including key driver and indicator nodes for macroalgae, phytoplankton and oxygen. Other features were modified from the ETI Tool 3 BBN as described below.

The potential TN concentration (mg/m^3) range, and subsequent CPTs were updated to account for the higher range of nutrient concentrations in Horizons estuaries compared with the estuaries modelled by ETI Tool 3. An indicator node predicting soluble inorganic nitrogen (SIN) concentration was added, given its inclusion as an estuary One Plan target (Table 1).

In the tidal river estuaries that characterise the Horizons region, high-flow events can supress macroalgae growth through physical scouring (Flindt et al. 1997; Martins et al. 2001). To improve predictions in this situation, an additional driver node was added for macroalgae, specifically the number of freshwater flows equal to and exceeding three times the median flow per year (see Table 4). This addition does not influence other estuary types (i.e., tidal lagoons or coastal lakes) in the BBN.

The ETI Tool 3 assesses sediment pressures using sediment deposition and mud content indicators. However, modelled predictions of sediment deposition are considered less reliable in tidal river systems than tidal lagoons (Plew 2020). Moreover, these indicators are not estuary One Plan targets. Instead, the One Plan target for sediment in estuaries is visual clarity (Table 1). As such, the BBN includes a node based on changes in the visual clarity of the incoming riverine input due to salinity effects.

This approach is simplistic as it does not include other factors that influence visual clarity in estuaries, such as resuspension of mud-dominated substrates driven by wind-driven mixing, stabilisation of sediments and enhanced settling due to the presence of submerged vegetation (e.g., *Ruppia* sp.), freshwater flow magnitude, coloured dissolved organic matter (CDOM), and phytoplankton blooms. Is also excludes the potential for poorer visual clarity to occur in natural turbidity maximum zones. These estuary zones are difficult to include in a simplistic model as they can be highly variable both spatially and temporally, and are influenced by tidal cycles and changes in freshwater flow.

The more simplified approach for visual clarity was taken in the current project for four reasons: (1) sediment indicators such as visual clarity are not routinely monitored in Horizons estuaries; (2) there is an established relationship (from national data) between riverine visual clarity and proportional sediment load reduction (MFE 2022); (3) factors such as CDOM and phytoplankton have a minor effect on clarity; and (4) some factors that influence clarity are highly spatially and temporally variable (e.g., wind-driven mixing), making them difficult to predict.

High turbidity waters at Ākitio Bridge.

In support of the approach taken, several studies have shown total suspended solids as being the primary driver of optical water quality, with coloured dissolved organic matter and phytoplankton generally having a limited influence on estuarine visual clarity (e.g., Vant 1990; Devlin et al. 2009; Gall et al. 2019). Submerged vegetation is also a minor feature of Horizons estuaries, having been recorded in only a few systems (e.g., Tautāne, Waikawa, Turakina; Roberts et al. 2025). While resuspension due to wind-driven mixing can affect estuaries, particularly those with mud-dominated substrates, the lack of detailed information on the frequency and extent of mixing in Horizons estuaries precludes its inclusion.

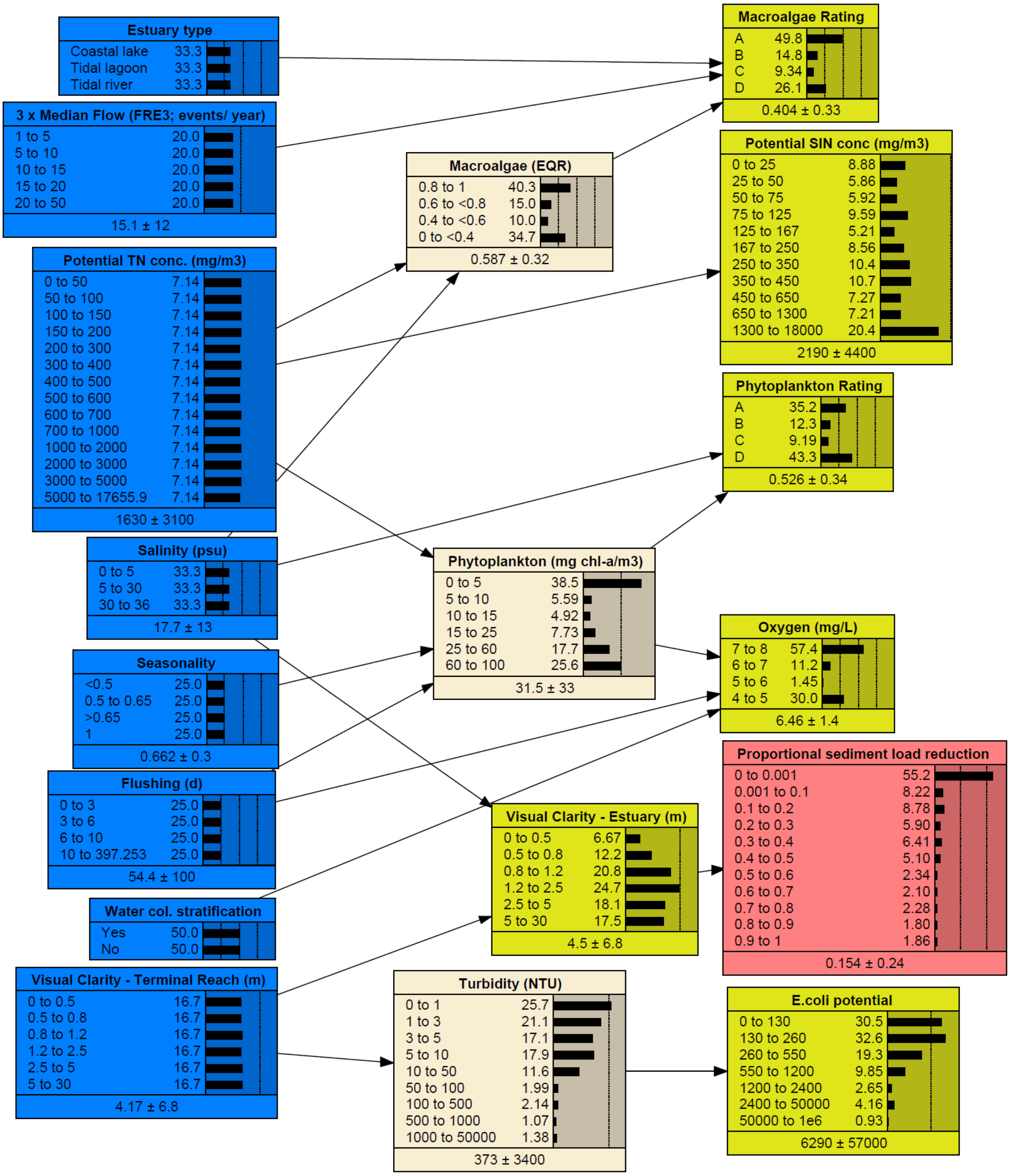


Fig. 4. Structure of the BBN created for Horizons estuaries. Driver nodes (blue) lead to intermediate (cream) and final (yellow) indicator nodes, and the sediment reduction node (red). Tables 4 to 6 outline the basis for deriving dependencies (i.e., CPTs). The value at the bottom of the node box represents the predicted mean value (± predicted standard deviation). See Section 2.2 for an explanation on how to interpret uncertainty.

Fortuitously, *E. coli*, another estuary One Plan target, is closely related to visual clarity and turbidity, and therefore "*E. coli* potential" is included in the BBN. It is considered a "potential" concentration because it does not account for any bacterial die-off in saline waters or dilution with incoming seawater. However, the derivation of the One Plan target recognised that most Horizons estuaries are well flushed, with faecal contamination likely sourced from riverine inputs (Dudley et al. 2024). Schang et al. (2018) showed that *E. coli* can persist in estuarine sediments and increase *E. coli* concentrations in the water column when sediments are resuspended (e.g., by currents or wind-driven mixing). However, resuspension was not included given the reasons provided above. It is important to note that, in this study, median clarity is used as the BBN input data to predict potential *E. coli*, meaning peaks in *E. coli* concentration during high-flow events are unlikely to be captured.

Further, the sediment load reductions required to meet *E. coli* targets are derived from an empirical relationship between river turbidity and *E. coli* (see Table 6). As discussed in Davies-Colley et al. (2018), the strength of this correlation is dependent on the source of faecal contamination. In the Horizons region, there is limited data to determine whether sediment is a significant source of *E. coli*, and further work is needed to establish a direct link between sediment controls and *E. coli* outcomes. As such, the sediment load reductions associated with *E. coli* outcomes in this study provide a useful indication of potential reductions but should be interpreted with caution. Nonetheless, reducing sediment inputs is expected to provide co-benefits for a range of other contaminants.

Eutrophication driver and indicator nodes are presented in Tables 4 and 5, respectively, while Table 6 presents the driver and indicator nodes for sediment and *E. coli*. The tables provide a brief description of the node, along with the data source and/or the basis for deriving dependencies (i.e., CPTs).

The BBN was initially set up using a subset of seven estuaries (Kai Iwi, Whanganui, Rangitikei, Manawatū, Ōhau, Waikawa and Ākitio) for which monthly water quality data were available (Dudley et al. 2024). For these estuaries, the BBN was tested under "baseline" (i.e., present day) nutrient and sediment loads, to determine whether the model could reliably predict baseline state. The outputs were assessed against baseline state as described in Roberts et al. (2025) and Dudley et al. (2024), with refinements made to driver and indicator nodes accordingly.

Subsequently, 19 scenarios (including baseline) were tested across all or most of the 25 estuaries, as described in Section 3. Nutrient scenarios were evaluated under four different flow conditions, whereas sediment-related targets (clarity and *E. coli*) were only tested under mean flow. Input data were sourced and/or calculated as described in Fig. 5, and Tables 4 to 6. The BBN was run for each scenario and flow, using Netica's "Process Cases" function as described in Appendix 2. In total, 688 nutrient BBN runs, and 250 sediment BBN runs were tested across the 25 estuaries.

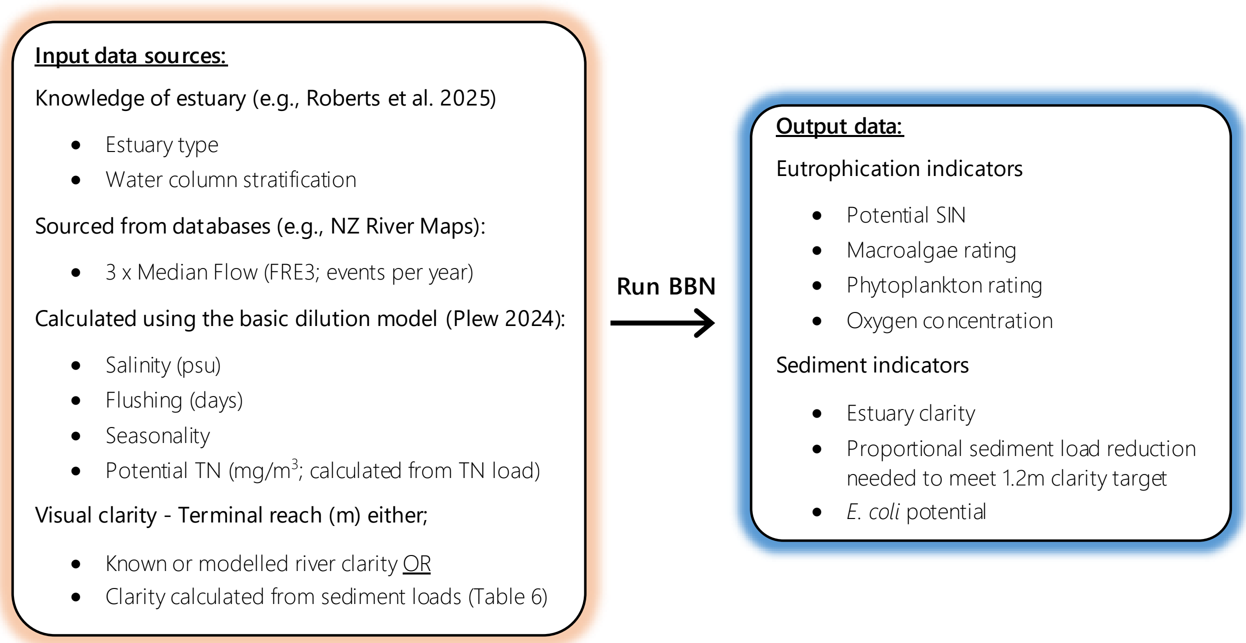


Fig. 5. Description of input data sources used in the BBN and output indicators. See Appendix 1 for further details.

Table 4. Driver nodes for indicators associated with eutrophication.

Indicator node	Description	Data source
Potential Total Nitrogen (TN) concentration (mg/m³)	Potential TN concentrations are defined as those that would occur in the absence of uptake by algae, or losses or gains due to non-conservative processes such as denitrification (Zeldis & Plew 2022). ETI Tool 3 assumes nitrogen is the limiting nutrient for macroalgae and phytoplankton growth.	Potential TN concentration was calculated for each TN load scenario presented in Snelder (2024) using a basic dilution model (Plew 2024) for four different flow scenarios; mean flow, February mean flow, mean annual low flow, and mean annual low flow under closed entrance conditions. February mean flow is most commonly used to assess phytoplankton risk.
Estuary Type Coastal lake Tidal lagoon Tidal river	Based on the ETI estuary types (see Robertson et al. 2016). The estuary type node activates only for tidal rivers, to account for the scouring effect of high freshwater flows. These flows have less impact in coastal lakes and tidal lagoons.	Most estuaries in the Horizons region are classified as Shallow, short residence time, tidal river estuaries (SSRTREs; "Tidal River") with two classified as Intermittently, open, closed lagoons (ICOLL; "Coastal Lake"). See Roberts et al. (2025).
3 x Median flow frequency (FRE3; events/year)	The number of freshwater flows of ≥3 times the median flow is a common high-flow statistic used to assess biological disturbance in rivers (Clausen & Biggs 1997; Henderson & Diettrich 2007; Booker 2013). The frequency of floods of this magnitude have been predictably linked to changes in periphyton and invertebrates in rivers (Henderson & Diettrich 2007 and references therein). Although this relationship does not hold for all periphyton sites in the Horizons region sites upstream of estuaries where monitoring occurs (Rangitikei, Manawatū, Ōhau, and Waikawa) generally show responses within the range of 2 to 5 times median flow (see Table 3-1 in Kilroy et al. 2018). This relationship has not been explicitly tested in estuaries; however, tidal river estuaries are strongly influenced by freshwater flows, and the physical mechanism of periphyton scouring is likely to be similar to that of macroalgae. As such, this high-flow statistic has been used in the BBN as a proxy for physical scouring of macroalgae.	FRE3 values were sourced from NZ River Maps (Whitehead & Booker 2020) for all terminal reaches. However, some reaches are influenced by upstream lake outflows, where high-flow events are likely dampened. Henderson and Diettrich (2007) calculated FRE3 values for several lower catchment river sections in the Horizons region, including the Pukepuke Stream, which drains the Pukepuke Lagoon system. To account for the potential dampening effect of upstream lake/lagoon systems on flows, the proportional difference between the observed and modelled FRE3 was applied to other reaches with upstream lake outflows. For example, Pukepuke Stream had an observed FRE3 of 4.0 events/y compared with a modelled FRE3 of 12.5 events/y, indicating the observed value is 32% of the modelled estimate. This assumption was applied to Kaitoke, Koitiata, Kaikokopu, Three Mile Creek, Hōkio and Waiwiri.
Salinity (psu)	Annual average salinity of the estuary, based on the selected flow scenario. February mean flow is used to calculate salinity when assessing phytoplankton risk.	Basic dilution modelling described in Plew (2024) was used to calculate salinity under four flow scenarios; mean flow, February mean flow, mean annual low flow, and mean annual low flow under closed entrance conditions.
Flushing (days)	Flushing time is the time for the cumulative inflow to equal the volume of freshwater originally in the estuary (i.e., the time it takes for all freshwater in the estuary to be replaced).	As per salinity (psu).
Seasonality	The ratio of summer to annual estuary potential TN concentration. The prevalence of phytoplankton blooms are generally greater in summer, when water column stratification is more likely and water temperatures are higher (Zeldis & Plew 2022). The seasonality factor is applied to calculate the potential TN in summer.	See Plew (2024) and associated spreadsheet calculator.
Water column stratification	Stratification can occur where a change in temperature or salinity creates a density differential within the water column. In estuaries, salinity driven density stratification is most common with fresh surface water overlying denser (heavier) seawater. These deeper layers can become isolated allowing phytoplankton blooms to establish and oxygen to deplete after extended periods.	Based on field observations, desktop information and expert opinion. See Roberts et al. (2025).

Table 5. Indicator nodes for One Plan targets associated with eutrophication.

Indicator node	Description	BBN node dependencies
Potential Soluble Inorganic Nitrogen (SIN) concentration (mg/m^3)	Soluble inorganic nitrogen refers to the sum of nitrate, nitrite and ammoniacal nitrogen. These forms of nitrogen are generally more bioavailable to algae and plants and therefore provide a better representation of eutrophication risk. Potential SIN is likely higher than the measured SIN in the estuary, where consumption and transformation processes occur. As such, relative changes in SIN are more meaningful than assessing absolute concentrations. There is a strong linear relationship between TN and SIN in riverine waters. SIN ranges were approximated from the potential TN ranges using the linear regression between TN and SIN.	To derive a relationship between Potential TN and SIN, and create a CPT for this dependency, terminal reach river water quality data from the Horizons region were used (source: LAWA dataset 2004-2023). These data were used in preference to estuary water quality data to better represent potential SIN, i.e., the concentration prior to uptake, transformation, or loss within the estuary. As terminal reach monitoring is conducted only in a subset of estuaries, it is assumed that the derived relationship is representative of all estuaries tested. SIN = 0.6682(TN) – 17.689 R^2 = 0.8262, n = 23,789, p<0.001
Macroalgae Ecological Quality Rating (EQR) ≥0.8 to 1.0 ≥0.6 to <0.8 ≥0.4 to <0.6 <0.4 to 0.0	Macroalgae (seaweeds) are important primary producers at the base of the food web and provide important habitats for invertebrates, juvenile fish, crabs and other species. However, nuisance blooms of rapidly growing opportunistic species can occur in nutrient-enriched waters when combined with suitable growing conditions. The Opportunistic Macroalgal Blooming Tool (OMBT) is a multi-metric index that includes the measured spatial extent, percent cover, and wet-weight biomass. These metrics are combined to calculate an overall EQR for the estuary (WFD-UKTAG 2014; Stevens et al. 2022).	The network dependencies were directly sourced from ETI Tool 3 (Zeldis & Plew 2022).
Macroalgae rating A: 0.0 to ≤0.25 B: >0.25 to ≤0.5 C: >0.5 to ≤0.75 D: >0.75 to 1.0	The final macroalgae rating combines the EQR score and the frequency of high flow events (FRE3) to calculate a final condition rating (A-D) that aligns with Table 3. The Process Cases output presents the rating numerically (e.g., 0.125 see ratings to left) The final rating incorporates an additional driver node to account for physical scouring (FRE3; Table 1) because Roberts et al. (2025) noted that basic dilution modelling (Plew 2024) tended to overestimate macroalgae state in the Horizons tidal rivers, predicting a poorer state than what was observed.	The network dependencies were directly sourced from ETI Tool 3 (Zeldis & Plew 2022). Additionally, the dependency of the scouring component was derived from expert judgement.
Phytoplankton (mg/m^3)	Phytoplankton are microscopic photosynthetic organisms that play a fundamental role in determining water quality including the regulation of dissolved oxygen, nutrient and carbon cycling, turbidity and total productivity. Excess nutrients can lead to phytoplankton blooms negatively effecting on water quality.	The network dependencies were directly sourced from ETI Tool 3 (Zeldis & Plew 2022).
Phytoplankton rating A: 0.0 to ≤0.25 B: >0.25 to ≤0.5 C: >0.5 to ≤0.75 D: >0.75 to 1.0	Phytoplankton ratings depend on salinity, with different concentration criteria per salinity range (0-5, 5-30, >30 psu; Table 2). Dudley et al. (2024) recommended using the phytoplankton ratings in ETI Tool 2 (Robertson et al. 2016) instead of the current One Plan target of <4mg/m^3, noting that this concentration is equivalent to a condition rating of A.	The network dependencies were directly sourced from ETI Tool 3 (Zeldis & Plew 2022).
Oxygen (mg/L) A: ≥7 B: ≥6.0 to <7.0 C: ≥5.0 to <6.0 D: <5.0	Oxygen is essential for both chemical and biological processes in aquatic environments. Oxygen depletion is common in estuaries, often resulting from high nutrient loads, water column stratification, longer residence times, and the breakdown of organic matter. Low oxygen conditions can have deleterious effects on fish and macroinvertebrates and can also alter nutrient cycling pathways. The One Plan target for dissolved oxygen is 70% oxygen saturation which is ~6mg/L at 20^{o}C.	The network dependencies were directly sourced from ETI Tool 3 (Zeldis & Plew 2022).

Table 6. Driver nodes for One Plan targets associated with sediment and *E. coli*.

Indicator node	Description	Data source
Salinity (psu)	Annual average salinity of the estuary, based on the selected flow scenario. Salinity can promote flocculation of particles and settling, leading to improvements in visual clarity at higher salinities outside of the turbidity maximum zone.	Basic dilution modelling described in Plew (2024) was used to calculate salinity (psu) under four flow scenarios; mean flow, February mean flow, mean annual low flow, and mean annual low flow under closed entrance conditions. February mean flow is used to assess phytoplankton risk.
Visual Clarity – Terminal Reach (m) & Visual Clarity – Estuary (m)	Water clarity refers to how far you can see through the water column using the black disc method. In the presence of suspended sediment particles, and to a lesser extent phytoplankton and dissolved organic matter, light is attenuated (Davies-Colley & Smith 2001). The greater the light attenuation the lower the water clarity. Poor water clarity can reduce light penetration through the water column, limiting primary productivity and plant growth and having flow on effects through the food-web and biodiversity. It has also been correlated with high concentrations of faecal contamination, negatively impacting recreation (Davies-Colley et al. 2018).	Modelled median visual clarity (m) was provided by Horizons for the terminal river reaches. With no clarity data available for Horizons estuaries, the CPT was based on expert opinion informed by river clarity and the Coastal Water Quality dataset for tidal river and intertidally dominated estuaries (Dudley et al. 2017; MfE Data Service). From this dataset, for each salinity range the mean (±standard deviation) estuarine visual clarity was: Salinity 0-5ppt, clarity is 0.83m (±0.25; n=60) Salinity 5-30ppt, clarity is 1.42m (±0.46; n=219) Salinity >30ppt, clarity is 1.94m (±0.56; n=282). It was assumed that at 0 to 5ppt the visual clarity in the river was equal to estuary clarity, and that clarity increases as salinity increases.
Sediment load reduction factor (LRF)	Median visual clarity typically occurs during base flows or well into the recession of storm runoff events (MfE 2022). Therefore, the most effective way to improve median clarity is to mitigate sediment sources active under those conditions. MfE (2022), and references therein, outlines a simplified approach that assumes reductions in suspended sediment loads at erosion sites are proportionally reflected across the hydrograph. When combined with the established relationship between sediment concentration and visual clarity, this approach enables estimation of the mean annual load reduction required to achieve a targeted improvement in median visual clarity.	$LRF = 1 - (Vt_{50}/V_{50})^{1/d}$ Vt_{50} = target median clarity V_{50} = median clarity d = fixed exponent (-0.76 ± 0.13; Hicks et al. 2019). Each clarity range was split into 0.01m increments and the LRF calculated based on the One Plan target of 1.2m. The CPT was based on the proportional LRF for each clarity range.
Turbidity (NTU)	Turbidity is a measure of the 'cloudiness' or light scattering properties of water. Light scattering can be affected by suspended sediment particles, chlorophyll and dissolved organic matter, but typically suspended sediment particles are the dominant influence (Davies-Colley & Smith 2001). A change in the ability of light to penetrate through water can limit photosynthesis, affect the behaviour of visual predators and can negatively affect aesthetics and contact recreation. Turbidity is often used as a proxy for other measures because there is a good relationship with suspended sediments and visual clarity (Davies-Colley & Smith 2001; Ausseil & Clark 2007; Ballantine et al. 2014; Davies-Colley et al. 2014). Here visual clarity and turbidity are used as a proxy for *E. coli* (Davies-Colley et al. 2018).	To derive a relationship between visual clarity and turbidity and clarity, and create a CPT for this dependency, river water quality data from the Horizons region were used (LAWA dataset 2004-2023). These river data were used as no estuary water quality data were available. In addition, river data is considered more appropriate because tidal river estuaries and coastal lakes are strongly influenced by freshwater flows and are generally lower salinity than other estuary types. $\log_{10}(TURB) = -1.105\log_{10}(CLAR) + 0.5911$ $R^2 = 0.7532$, n = 15422, $p<0.001$
E. coli (cfu/100ml)	*Escherichia coli* (*E. coli*) is a faecal indicator bacterium that is commonly used to assess the risk of exposure to faecal contamination from humans and animals (notably livestock), in freshwaters. However, it is also commonly used in estuaries that are heavily influenced by freshwater flows (e.g., tidal rivers). Dudley et al. (2024) endorsed the *E. coli* targets of 260cfu/100ml as an "alert" and 500cfu/100ml as an "action" for swimming. There is good agreement between clarity, turbidity, and *E. coli* measures, dependencies that are used in the BBN.	To derive a relationship between turbidity and *E. coli*, and create a CPT for this dependency, river water quality data from the Horizons region were used (LAWA dataset 2004-2023). These data were used in preference to estuary water quality data to better represent "*E. coli* potential", i.e., the concentration prior to die-off, settling with associated particulate matter, and dilution. $\log_{10}(E.coli) = 0.5558\log_{10}(Turbidity) + 2.005$ $R^2 = 0.2785$, n = 20904, $p<0.001$

2.2 UNCERTAINTY

The probabilistic framework of BBNs captures uncertainty through conditional probability distributions, which define node connections and express the likelihood of different outcomes given specific conditions (e.g., nutrient concentration, stratification, salinity). Rather than single-point predictions, BBNs generate probability distributions over states, allowing both the likelihood of a particular outcome, and confidence around it, to be determined.

An example of the probability distribution of node states for macroalgae, phytoplankton and dissolved oxygen is shown in Fig. 6. This illustrates that multiple states can occur for a specific set of input variables. To simplify interpretation across the 25 estuaries and the 19 scenarios (including baseline) tested, the node state is represented by the "expected value", which is the probability-weighted average of all possible outcomes. For example, if the dissolved oxygen node state had a value of 5 with probability 0.8 and value of 7 with a probability of 0.2, then the "expected value" is: (5 x 0.8) + (7 x 0.2) = 5.4 (norsys.com).

The standard deviation quantifies the uncertainty around the "expected value". Unlike a traditional standard deviation, within the BBN the standard deviation represents the uncertainty across the probability distribution. A small standard deviation indicates probabilities are concentrated around one expected outcome, whereas a large standard deviation indicates a spread across multiple outcomes (i.e., there is more than one predicted node state).

As with any predictive modelling approach, some uncertainty is unavoidable. However, the BBN provides a transparent framework for testing management scenarios and guiding decision-making, particularly where empirical data are limited. Where scenarios suggest a high likelihood that estuary targets will not be met, further work will be required to assess the extent of exceedance. The approach is therefore intended to support decision-making rather than define an absolute state or prescribe fixed load reductions.

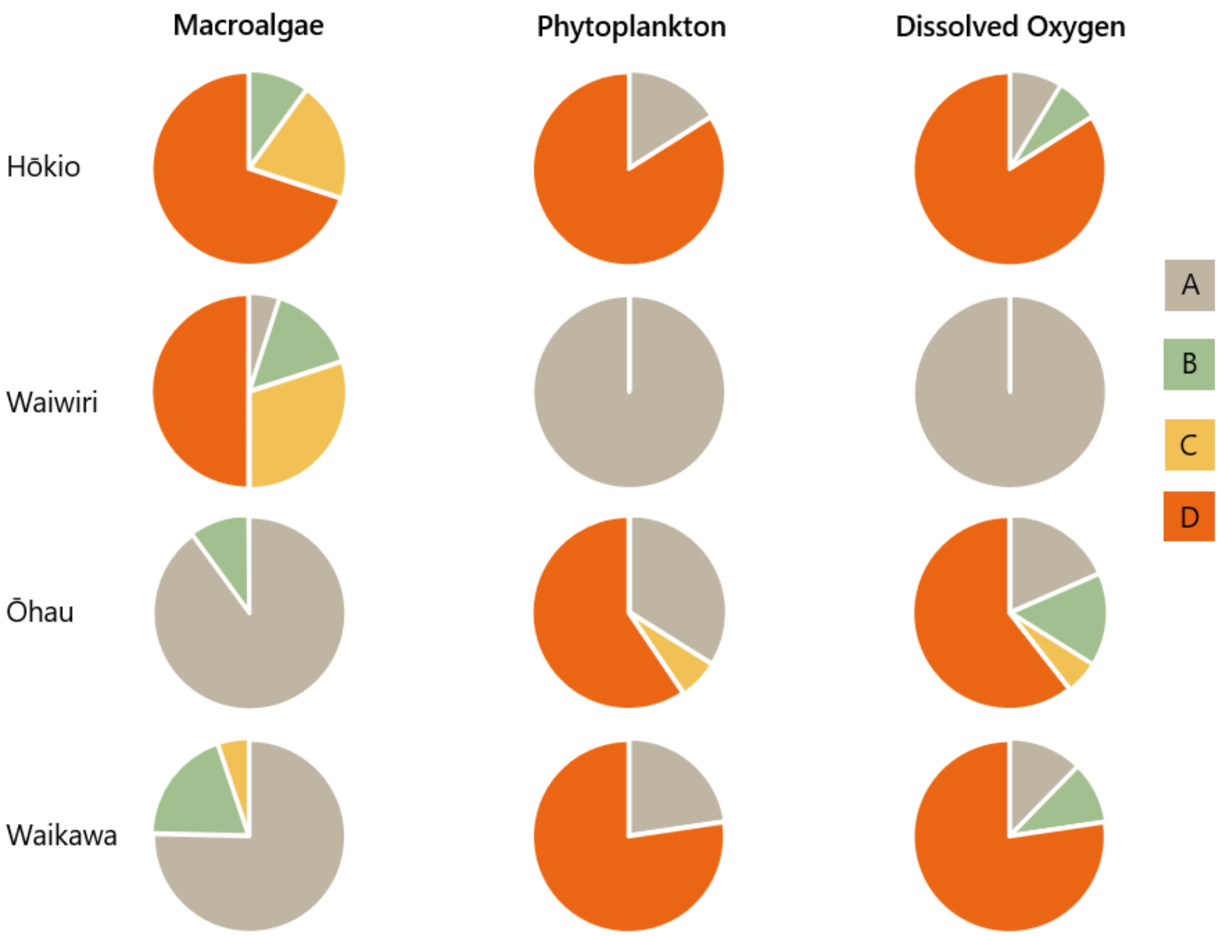


Fig. 6. Probability distribution of node states produced by the BBN for macroalgae, phytoplankton and dissolved oxygen. The pie chart shows the relative likelihood of a particular state (Bands A-D) under baseline conditions.

3. LOAD REDUCTION SCENARIOS

Baseline catchment nutrient and sediment loads for different scenarios have been calculated for Horizons by other providers (Cox et al. 2023; Vale & Smith 2023; Snelder 2024). Below we provide a brief overview of that work, and describe how the modelled load outputs were used to compare against estuary targets. Broadly two approaches to assessing load reductions have been presented:

- Load reductions made by implementing land management scenarios (e.g., farm plans, erosion control programmes, best management practice).
- Load reductions required to meet ecological condition targets in freshwater. For example, load reductions have been calculated to meet ecological targets for periphyton or visual clarity in rivers based on the NPS-FM.

Where the load reductions required to meet ecological targets in freshwater exceed those achieved under land management scenarios, additional regulatory or non-regulatory approaches are likely to be required. The same applies where One Plan targets are not met in estuaries.

3.1 NUTRIENT SCENARIOS

3.1.1 Implementation of land management scenarios for nutrients

Freshwater nutrient loads were modelled for the Horizons region using random forest models fitted to nutrient yields (Fraser 2021; Snelder 2024). These represent total nitrogen loads for baseline (or current) state, with data available for all 25 estuaries considered in the present report (Snelder 2024). As nitrogen is well-recognised as the limiting nutrient in estuarine environments (Howarth & Roxanne 2006), phosphorus was not included in the BBN.

Table 7 outlines a subset of 17 of the 25 estuaries where future load reductions were modelled for four land management scenarios as described in Cox et al. (2023). The scenarios are as follows:

- **Nutrient policy scenario 1** (NPS1) – Pastoral Farm Established Mitigations. Includes specific mitigations such as riparian protection, land retirement, improved management of fertiliser, irrigation water and effluent, and off paddock grazing strategies.
- **Nutrient policy scenario 2** (NPS2) – Pastoral Farm Established and Developing Mitigations. This includes Scenario 1 mitigations plus developing mitigations including edge-of-field mitigation, instream sorbents, controlled drainage, management of critical source areas and retention dams.
- **Nutrient policy scenario 3** (NPS3) – Point Source Mitigations. This scenario relates to the reduction of point source discharges to receiving streams and mitigations include revised consenting, facility closures, facility upgrades, land disposal from facilities that currently have point source discharges.
- **Nutrient policy scenario 4** (NPS4) – Pastoral Farm Mitigations and Point Source Reductions. Combines the mitigations in Scenario 2 and Scenario 3.

Table 8 outlines an additional nutrient policy scenario, **Scenario 5** (NPS5) that includes horticulture mitigations for four estuaries. These scenarios were tested to determine whether commercial vegetable growing areas should or should not be exempt from NPS-FM regulations (Jolly et al. 2023), and are as follows:

- Scenario 5a adopts best management practice and good management practice for commercial vegetable growing in the Hōkio water management subzone.
- Scenario 5b builds on 5a and includes the removal of all other agriculture in the catchment (conversion to native bush).
- Scenario 5c involves removal of commercial vegetable growing and replacement with sheep and beef in the Hōkio water management subzone, with new commercial vegetable growing in the Manawatū and Ōhau water management subzones.
- Scenario 5d involves the use of glass houses and in-field production.
- Scenario 5e involved the removal of the top 25% of nitrate leaching crops.

For each land management scenario, there is an assumption of full implementation of mitigations by 2035. For the present report, the baseline load data, and data for each policy scenario, were provided by Horizons in excel spreadsheets.

The BBN uses potential total nitrogen rather than nitrogen load, this was calculated using the dilution model prepared by Plew (2024) for four different flow conditions (see Fig. 5; Table 4). Relative changes in state were compared to baseline state to determine whether freshwater load reductions would have any effect on estuary state.

Table 7. Modelled baseline total nitrogen (TN) loads (T/y) for the 25 estuaries assessed in this report, and predicted TN loads and percent reduction* by 2035 for 17 estuaries under Nutrient Policy Scenarios (NPS) 1 to 4.

	Baseline	NPS1		NPS2		NPS3		NPS4	
Estuary name	TN load (T/y)	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction
Ototoka	22.2	-	-	-	-	-	-	-	-
Okehu	54.4	46.5	14.5	35.1	35.6	54.4	0.0	35.1	35.6
Kai Iwi	151.5	146.6	3.2	126.2	16.7	151.5	0.0	126.2	16.7
Mōwhānau	25.9	21.8	15.9	16.5	36.4	25.9	0.0	16.5	36.4
Whanganui	5665.8	5356.3	5.5	4457.8	21.3	5665.8	0.0	4457.8	21.3
Kaitoke	35.5	34.4	3.3	26.6	25.3	35.5	0.0	26.6	25.3
Whangaehu	1112.4	1053.7	5.3	875.1	21.3	1112.4	0.0	875.1	21.3
Turakina	750.0	702.1	6.4	581.3	22.5	749.2	0.1	580.4	22.6
Koitiata	36.8	29.6	19.7	18.5	49.8	36.8	0.0	18.5	49.8
Rangitikei	2063.5	1893.7	8.2	1521.2	26.3	2035.3	1.4	1492.9	27.7
Pukepuke	73.2	-	-	-	-	-	-	-	-
Kaikokopu	34.1	-	-	-	-	-	-	-	-
Three Mile Creek	21.0	-	-	-	-	-	-	-	-
Manawatū	5018.1	4452.7	11.3	3633.4	27.6	4511.8	10.1	3127.1	37.7
Wairarawa	11.3	-	-	-	-	-	-	-	-
Hōkio	59.6	51.7	13.3	44.7	24.9	59.6	0.0	44.7	24.9
Waiwiri	12.5	11.6	6.7	10.9	12.6	12.5	0.0	10.9	12.6
Ōhau	153.6	137.7	10.3	112.5	26.7	153.6	0.0	112.5	26.7
Waikawa	62.0	53.6	13.6	43.0	30.7	62.0	0.0	43.0	30.7
Tautāne	18.6	-	-	-	-	-	-	-	-
Wainui	81.1	79.2	2.3	69.0	14.9	81.1	0.0	69.0	14.9
Papuka	5.0	-	-	-	-	-	-	-	-
Waimata	20.6	-	-	-	-	-	-	-	-
Ākitio	465.5	450.4	3.2	387.3	16.8	465.5	0.0	387.3	16.8
Owāhanga	321.8	309.7	3.8	264.2	17.9	321.7	0.0	264.1	17.9

*Percent reduction was sourced from Cox et al. (2023) and applied to the modelled nitrogen loads from Snelder (2024). It was assumed that the proportional load reduction would be the same regardless of the load calculation method. This approach was chosen so that the calculated nitrogen loads were consistent in the current report.

Table 8. Modelled baseline TN loads (T/y) for a subset of 4 estuaries assessed in this report, including predicted TN load and percent reduction* for 2035 under Nutrient Policy Scenarios (NPS) 5a-e.

	Baseline	NPS 5a		NPS 5b		NPS 5c		NPS 5d		NPS 5e	
Estuary	TN load (T/y)	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction	TN load (T/y)	% Reduction
Hōkio	59.6	51.5	13.6	39.7	33.4	53.3	10.6	53.3	10.6	56.2	5.8
Waiwiri	12.5	12.5	0.0	12.5	0.0	12.5	0.0	12.5	0.0	12.5	0.0
Ōhau	153.6	153.6	0.0	153.6	0.0	153.6	0.0	153.6	0.0	153.6	0.0
Waikawa	62.0	62.0	0.0	62.0	0.0	62.0	0.0	62.0	0.0	62.0	0.0

*Percent reduction was sourced from Cox et al. (2023) and applied to the modelled nitrogen load from Snelder (2024). It was assumed that the proportional load reduction would be the same regardless of the load calculation method. This approach was chosen so that the calculated nitrogen loads were consistent in the current report.

3.1.2 Load reductions associated with nutrient ecological targets for freshwater

For nutrients, periphyton was used to determine freshwater nutrient load reductions based on ecological targets (Snelder 2024). For each river reach, target attribute states were based on the analysis in Eveleens et al. (2023) providing for the requirement that the target attribute state must maintain or improve baseline state (i.e., if the target attribute state is lower than baseline state, the baseline state must be maintained; Snelder 2024; Fig. 7). Load reduction scenarios were calculated for three levels of "under protection risk" (UPR), indicating the risk that a location will exceed the periphyton biomass target even when it is compliant with the associated nutrient criteria. Snelder (2024) provided FMU-specific load reductions, shown in Table 9. Estuary-specific load reductions were not calculated hence reductions were applied to estuaries based on their FMU designation.

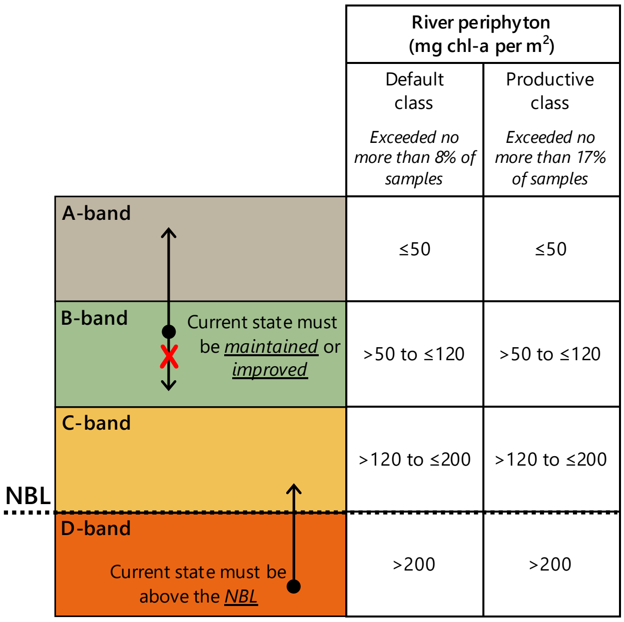
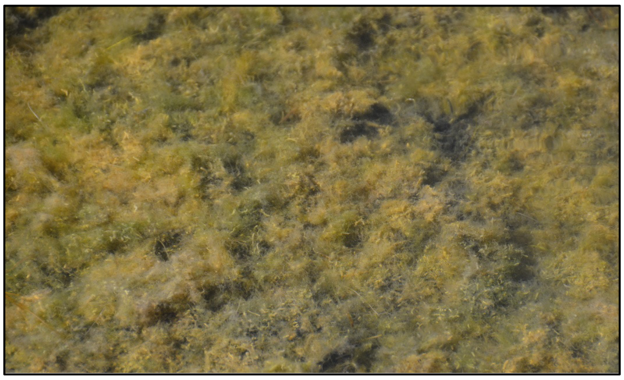


Fig. 7. Periphyton ecological targets sourced from the NPS-FM used to calculate load reductions, including the provision that state must be maintained or improved. NBL = national bottom line.



Likely nutrient related epiphytic growth in Turakina Estuary (2016).

Sparse growths of Ulva spp. in the lower Rangitikei Estuary (2016).

Table 9. Freshwater load reductions required for total nitrogen to meet ecological targets for periphyton in rivers for three levels of "under protection risk" (UPR). The load reductions are expressed as percentages of the current load and the values shown in brackets are the 5th and 95th confidence limits for the reported values (i.e., the range is the 90% confidence interval). Table reproduced from Snelder (2024).

FMU	Estuaries within FMU	20% UPR (% reduction)	25% UPR (% reduction)	30% UPR (% reduction)
Kai Iwi	Ototoka, Okehu, Kai Iwi, Mōwhānau	65 (47 - 79)	53 (31 - 69)	46 (24 - 65)
Whanganui	Whanganui, Kaitoke	46 (11 - 80)	28 (3 - 65)	15 (3 - 34)
Whangaehu	Whangaehu	46 (18 - 72)	35 (12 - 60)	24 (5 - 45)
Rangitīkei-Turakina	Turakina, Koitiata, Rangitikei, Pukepuke, Kaikokopu, Three Mile Creek	58 (44 - 71)	51 (34 - 68)	42 (27 - 56)
Manawatū	Manawatū	83 (56 - 96)	65 (30 - 86)	49 (21 - 82)
Waiopehu	Wairarawa, Hōkio, Waiwiri, Ōhau, Waikawa	74 (60 - 83)	66 (48 - 79)	60 (42 - 76)
Puketoi ki Tai	Tautāne, Wainui, Papuka, Waimata, Ākitio Owāhanga	75 (62 - 87)	59 (40 - 77)	43 (22 - 65)

3.2 SEDIMENT SCENARIOS

3.2.1 Implementation of land management scenarios for sediment

Freshwater sediment loads were modelled for the Horizons region by Vale and Smith (2023) using the SedNetNZ sediment budget model. The model estimates the loss of fine sediment from the land through erosion processes such as shallow landslides, earthflows, gullies, surficial erosion, and streambank erosion. These erosion sources are combined with losses due to floodplain deposition and lake sediment trapping to calculate mean annual sediment loads at the REC2 sub-catchment scale (Vale & Smith 2023).

Tables 10 and 11 show sediment loads for each of the 25 estuaries and three load scenarios as follows:

- **Baseline** state (i.e., 2021).
- **Sediment policy scenario 1** (SPS1; Table 9) which represents the implementation of the Sustainable Land Use Initiative (SLUI) and non-SLUI works (e.g., stock exclusion), including maturity level of erosion control works.
- **Sediment policy scenario 2** (SPS2; Table 10) which represents the accelerated, time-bound implementation of erosion control works identified through Freshwater Farm Plans (FWFPs), stock exclusion regulations, and horticultural mitigations.

For each policy scenario the predicted sediment loads were provided in 5-year increments from 2025 up to 2100, with 2021 being the baseline (or current) sediment load. Data for the present report were provided by Horizons in GIS layers and were extracted for the terminal freshwater river reaches upstream of each estuary. Three time points, 2035, 2050 and 2100, were assessed in the BBN to represent progressively greater reductions over time.

Because the BBN does not include sediment load as a driver node, but rather "Visual Clarity – Terminal Reach" (see Table 6), river clarity for each corresponding sediment load was back-calculated using the approach described in MFE (2022). These data were input into the BBN to assess the outcomes of different sediment load scenarios under mean flow conditions.

High sediment load in Owāhanga Estuary, East Coast.

Table 10. Modelled baseline net sediment loads (kT/y) for the 25 estuaries assessed in this report, including sediment load (Sed. Load), predicted load reduction (%) and river clarity for 2035, 2050 and 2100 under SPS1.

Estuary name	Baseline	2035			2050			2100		
	Sed. load (kT/y)	Sed. Load (kT/y)	% Reduction	Clarity (m)	Sed. Load (kT/y)	% Reduction	Clarity (m)	Sed. Load (kT/y)	% Reduction	Clarity (m)
Ototoka	6.1	6.1	0.5	0.7	6.0	1.2	0.7	4.3	29.8	0.9
Okehu	29.6	27.4	7.5	0.9	25.8	12.8	0.9	18.6	37.0	1.2
Kai Iwi	63.5	58.8	7.3	1.1	55.4	12.7	1.1	41.4	34.8	1.4
Mōwhānau	6.5	6.4	1.6	0.8	6.2	4.1	0.8	4.7	27.5	1.0
Whanganui	2644.8	2480.5	6.2	1.0	2334.0	11.8	1.0	1629.8	38.4	1.4
Kaitoke	0.7	0.6	8.8	0.7	0.6	10.0	0.7	0.5	21.7	0.8
Whangaehu	922.9	829.2	10.2	1.1	729.5	21.0	1.2	374.1	59.5	2.1
Turakina	649.4	600.2	7.6	0.7	532.4	18.0	0.8	262.7	59.5	1.3
Koitiata	0.7	0.4	36.3	0.9	0.4	36.3	0.9	0.4	38.5	0.9
Rangitikei	1169.2	1061.5	9.2	1.1	966.4	17.3	1.2	570.8	51.2	1.7
Pukepuke	0.1	0.0	26.3	0.8	0.0	26.3	0.8	0.0	26.3	0.8
Kaikokopu	0.1	0.0	43.3	1.3	0.0	43.3	1.3	0.0	43.3	1.3
Three Mile Creek	0.0	0.0	49.8	1.3	0.0	49.8	1.3	0.0	49.8	1.3
Manawatū	2297.9	2067.6	10.0	0.8	1894.4	17.6	0.9	1182.7	48.5	1.2
Wairarawa	0.0	0.0	51.0	1.5	0.0	51.0	1.5	0.0	51.0	1.5
Hōkio	0.5	0.5	12.9	0.8	0.5	12.9	0.8	0.5	15.3	0.9
Waiwiri	0.2	0.1	22.5	0.9	0.1	22.5	0.9	0.1	22.5	0.9
Ōhau	39.0	34.4	11.7	1.7	34.0	12.8	1.7	31.8	18.3	1.8
Waikawa	13.2	11.0	16.2	1.3	11.0	16.3	1.3	10.2	22.4	1.4
Tautāne	13.8	12.3	10.9	0.8	10.2	26.0	0.9	3.3	76.0	2.0
Wainui	47.5	42.7	10.3	0.6	37.6	21.0	0.7	18.5	61.2	1.1
Papuka	4.9	4.5	6.6	1.0	3.9	20.6	1.1	1.6	66.9	2.2
Waimata	6.0	5.8	4.6	0.8	5.2	13.0	0.9	4.3	27.9	1.0
Ākitio	216.2	185.8	14.0	0.6	162.7	24.7	0.7	86.9	59.8	1.1
Owāhanga	182.1	159.2	12.6	0.7	142.7	21.7	0.8	79.0	56.6	1.2

Table 11. Modelled baseline net sediment loads (kT/y) for the 25 estuaries assessed in this report, including sediment load (Sed. Load), predicted load reduction (%) and river clarity for 2035, 2050 and 2100 under SPS2.

Estuary name	Baseline	2035			2050			2100		
	Sed. load (kT/y)	Sed. Load (kT/y)	% Reduction	Clarity (m)	Sed. Load (kT/y)	% Reduction	Clarity (m)	Sed. Load (kT/y)	% Reduction	Clarity (m)
Ototoka	6.1	5.5	9.6	0.7	4.4	28.7	0.8	3.4	45.0	1.0
Okehu	29.6	24.3	17.8	1.0	18.0	39.3	1.2	14.8	50.0	1.4
Kai Iwi	63.5	53.3	16.0	1.2	40.2	36.7	1.4	34.9	45.0	1.6
Mōwhānau	6.5	6.0	8.2	0.8	4.9	23.9	1.0	4.2	34.9	1.1
Whanganui	2644.8	2191.3	17.1	1.1	1558.4	41.1	1.4	1279.3	51.6	1.6
Kaitoke	0.67	0.6	9.2	0.7	0.60	10.4	0.7	0.59	11.6	0.7
Whangaehu	922.9	699.1	24.2	1.3	357.5	61.3	2.1	273.4	70.4	2.6
Turakina	649.4	501.0	22.9	0.8	244.6	62.3	1.4	170.1	73.8	1.9
Koitiata	0.66	0.4	36.3	0.9	0.42	36.3	0.9	0.42	36.3	0.9
Rangitikei	1169.2	920.3	21.3	1.2	551.6	52.8	1.8	422.2	63.9	2.2
Pukepuke	0.06	0.0	26.3	0.8	0.05	26.3	0.8	0.05	26.3	0.8
Kaikokopu	0.08	0.0	43.3	1.3	0.04	43.3	1.3	0.04	43.3	1.3
Three Mile Creek	0.04	0.0	49.8	1.3	0.02	49.8	1.3	0.02	49.8	1.3
Manawatū	2297.9	1825.8	20.5	0.9	1185.4	48.4	1.2	946.3	58.8	1.4
Wairarawa	0.04	0.0	51.0	1.5	0.02	51.0	1.5	0.02	51.0	1.5
Hōkio	0.54	0.5	13.9	0.8	0.46	15.8	0.9	0.45	17.5	0.9
Waiwiri	0.18	0.1	22.5	0.9	0.14	22.5	0.9	0.14	22.5	0.9
Ōhau	39.0	33.9	13.1	1.7	32.3	17.1	1.8	31.6	18.9	1.8
Waikawa	13.2	10.8	18.3	1.4	10.2	22.3	1.4	9.8	25.9	1.5
Tautāne	13.8	10.1	26.8	0.9	3.7	73.2	1.9	2.8	79.9	2.3
Wainui	47.5	35.7	24.9	0.7	17.9	62.3	1.2	13.3	72.1	1.5
Papuka	4.9	3.7	23.5	1.2	1.8	62.3	2.0	1.1	77.3	2.9
Waimata	6.0	5.4	10.2	0.8	4.4	26.6	1.0	4.1	31.4	1.0
Ākitio	216.2	159.0	26.4	0.7	87.4	59.6	1.1	65.7	69.6	1.4
Owāhanga	182.1	134.0	26.4	0.8	74.3	59.2	1.3	54.4	70.1	1.6

3.2.2 Load reductions associated with sediment ecological targets for freshwater

For sediment, visual clarity was used, with regional results presented in Vale and Smith (2023). Target attribute states were based on the NPS-FM river clarity rating bands from A to D (Fig. 8) and baseline modelled visual clarity for each terminal river reach supplied by HRC, providing for the requirement that the target attribute state must be maintained or improved (Table 12). To determine the load reduction for each estuary terminal river reach, suspended sediment (SS) class data were sourced from the MfE Data Service (Sediment classes for REC2.4 nzsegments), and NPS-FM visual clarity ratings were applied based on the appropriate suspended sediment class at each location. Reductions for each location were calculated following the method in Vale and Smith (2023) and MFE (2022), and are presented in Table 12. Percent improvements in clarity are proportional to percent reduction in sediment loads. As such, this relationship can be used to assess sediment load reductions required to meet the 1.2m estuary clarity One Plan target (see Table 6; Fig. 3).

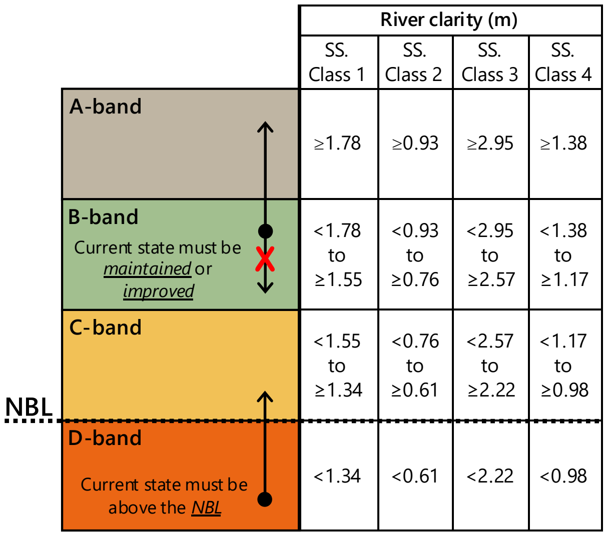


Fig. 8. River clarity targets sourced from the NPS-FM used to calculate sediment load reductions, including the provision that state must be maintained or improved. SS = suspended sediment; NBL = national bottom line.

Table 12. Modelled median clarity (i.e., baseline) for the terminal reach upstream of each estuary, along with predicted river clarity based on the lower target threshold of the clarity NPS-FM bands A to C (Fig. 8). Percent improvement compared to baseline clarity is proportional to the required sediment load reduction (MfE 2022).

		Baseline	NPS-FM river clarity A-band		NPS-FM river clarity B-band		NPS-FM river clarity C-band	
Estuary name	SS class	Median clarity	Clarity (m)	% improvement	Clarity (m)	% improvement	Clarity (m)	% improvement
Ototoka	2	0.66	0.93	36	0.76	17	**0.66***	0
Okehu	2	0.84	0.93	13	**0.84**	0	-	
Kai Iwi	4	1.02	1.38	33	1.17	17	**1.02**	0
Mōwhānau	2	0.79	0.93	19	**0.79**	0	-	
Whanganui	1	**0.94***	1.78	57	1.55	48	1.34	37
Kaitoke	2	0.63	0.93	40	0.76	22	**0.63**	0
Whangaehu	1	**1.03**	1.78	51	1.55	42	1.34	29
Turakina	2	0.68	0.93	34	0.76	14	**0.68**	0
Koitiata	1	**0.62**	1.78	75	1.55	70	1.34	64
Rangitikei	1	**1.00**	1.78	53	1.55	44	1.34	32
Pukepuke	1	**0.65**	1.78	73	1.55	68	1.34	61
Kaikokopu	1	**0.85**	1.78	62	1.55	55	1.34	45
Three Mile Creek	1	**0.78**	1.78	66	1.55	59	1.34	51
Manawatū	3	**0.74**	2.95	84	2.57	81	2.22	76
Wairarawa	1	**0.88**	1.78	60	1.55	53	1.34	42
Hōkio	2	0.75	0.93	25	0.76	2	**0.75**	0
Waiwiri	2	0.74	0.93	26	0.76	3	**0.74**	0
Ōhau	3	**1.57**	2.95	56	2.57	48	2.22	37
Waikawa	3	**1.18**	2.95	70	2.57	64	2.22	56
Tautāne	2	0.69	0.93	32	0.76	12	**0.69**	0
Wainui	2	**0.55**	0.93	50	0.76	35	0.61	13
Papuka	2	0.79	0.93	19	**0.79**	0	-	
Waimata	2	0.77	0.93	22	**0.77**	0	-	
Ākitio	2	**0.56**	0.93	49	0.76	33	0.61	11
Owāhanga	2	0.65	0.93	38	0.76	19	**0.65**	0

Blue bold numbers indicate that predicted median clarity is above the lower threshold of the NPS-FM band, meaning it must be maintained and/or improved. Red bold numbers indicate the predicted median clarity is less than the national bottom line (Fig. 8), meaning it must be improved.

3.3 SUMMARY OF LOAD REDUCTION SCENARIOS

Table 13 presents a summary of the load reduction scenarios tested in this report. Including the input data used in each scenario, and the location of the output data presented either in the main body of the report or Appendices 3 to 6. More detail on the input data can be sourced in Appendix 1.

Example of nutrient related issues expressed as a phytoplankton bloom in Mōwhānau Estuary (2020; Google Earth).

Table 13. List of BBN Scenarios tested, flow conditions, and number of estuaries tested per scenario. The input data was sourced from Tables 7 to 12 and outputs are presented in the main body of the report or in Appendices 3 to 6.

Scenario	Flows tested	# Estuaries	Input	Output
Nutrients				
TN load Baseline	Mean Flow, Summer flow, MALF, MALF closed	25	Table 7	Table 16
Land management scenarios				
TN load NPS1	Mean Flow, Summer flow, MALF, MALF closed	17	Table 7	Appendix 3
TN load NPS2	Mean Flow, Summer flow, MALF, MALF closed	17	Table 7	Appendix 3
TN load NPS3	Mean Flow, Summer flow, MALF, MALF closed	17	Table 7	Appendix 3
TN load NPS4	Mean Flow, Summer flow, MALF, MALF closed	17	Table 7	Table 15
TN load NPS5a-e	Mean Flow, Summer flow, MALF, MALF closed	4	Table 8	Appendix 3
Load reductions based on ecological river targets				
TN load 20 UPR	Mean Flow, Summer flow, MALF, MALF closed	25	Table 9	Table 16
TN load 25 UPR	Mean Flow, Summer flow, MALF, MALF closed	25	Table 9	Appendix 4
TN load 30 UPR	Mean Flow, Summer flow, MALF, MALF closed	25	Table 9	Appendix 4
Sediment				
Sediment load baseline		25	Table 10	Table 17
Land management scenarios				
Sediment load SPS1 - 2035	Mean Flow	25	Table 10	Appendix 5
Sediment load SPS1 - 2050	Mean Flow	25	Table 10	Appendix 5
Sediment load SPS1 - 2100	Mean Flow	25	Table 10	Appendix 5
Sediment load SPS2 - 2035	Mean Flow	25	Table 11	Table 17
Sediment load SPS2 - 2050	Mean Flow	25	Table 11	Table 17
Sediment load SPS2 - 2100	Mean Flow	25	Table 11	Table 17
Load reductions based on ecological river targets				
Sediment load A-band (river clarity)	Mean Flow	25	Table 12	Table 18
Sediment load B-band (river clarity)	Mean Flow	25	Table 12	Appendix 6
Sediment load C-band (river clarity)	Mean Flow	25	Table 12	Appendix 6

4. RISK-ASSESSMENT RESULTS

4.1 TESTING BBN PREDICTION OF BASELINE CONDITIONS AND CURRENT STATE

Table 14 summarises the results of initial testing of BBN efficacy in terms of predicting baseline conditions and current state, which was undertaken for a subset of seven estuaries. As discussed in Section 2.2, the "expected value" presented in Table 14 represents the probability-weighted average of the node state. It is reiterated that BBN outputs are best interpreted as indicative of relative changes in state rather than as accurate predictions. This limitation is illustrated in the initial testing results, as follows:

- The BBN overpredicts SIN because both the TN and SIN inputs represent "potential" concentrations, i.e., concentrations in the absence of uptake by algae, or losses or gains due to non-conservative processes such as denitrification. Hence, relative changes in SIN concentrations, rather than absolute changes, are used to evaluate whether SIN improves with freshwater load reductions. In general, reductions in SIN concentration are proportional to freshwater load reductions.
- For macroalgae the BBN slightly overpredicts state, i.e., it predicts more degraded conditions than generally exist. However, most estuaries were predicted to be in minimal (A) to moderate (B) stages of eutrophication, aligning with observations in the seven estuaries where no significant macroalgal growth is occurring. An exception was Rangitikei, which was predicted to be in a state of high eutrophication (C) under mean flow, owing to less frequent flushing flows (FRE3 <10 events/y) and high potential TN. Macroalgae state improved under lower freshwater flow scenarios, reflecting lower potential TN concentration.
- Phytoplankton and dissolved oxygen were predicted accurately for all seven estuaries, except for Kai Iwi. The BBN underestimated phytoplankton in Kai Iwi, where on occasion blooms have been recorded during low flows or entrance restriction (Roberts et al. 2025). This inaccuracy arises due to the flushing time calculated by Plew (2024) being very short, under which phytoplankton would unlikely be able to establish before being flushed out to sea.
- As visual clarity in estuaries is not monitored by Horizons, a direct comparison between predicted and current state cannot be made.
- *E. coli* concentrations were compared with modelled median *E. coli* concentrations for each terminal river reach (data provided by HRC). In general, there was good agreement between the BBN outputs and the modelled median *E. coli*. However, the BBN underestimated the *E. coli* concentration in Kai Iwi and overestimated it in Ākitio, likely due to the modelled input river clarity being lower than actual.

Despite some limitations, the BBN overall predicted estuary state broadly as expected, with changes in inputs producing corresponding changes in outputs (e.g., phytoplankton under mean flow vs MALF). While it performs reasonably well against observed current state, its greatest value lies in assessing relative changes in state as input conditions are varied. Importantly, where predicted versus current state differ, the BBN is in most cases conservative, in that it predicts a more degraded state than actually occurs.

Kai Iwi in early 2020 with a restricted entrance and appearance of a phytoplankton bloom (top), and in late 2020 with high turbidity (Image source: Google Earth).

Poor visual clarity in Ākitio River Estuary.

Table 14. Predicted baseline state (based on "expected value", see text) from the BBN for seven estuaries under four flow scenarios.

Key: (✓) current state matches predicted baseline state; (↓) predicted baseline state is worse than current state (i.e., the BBN is conservative); (↑) predicted baseline state is better than current state (i.e., the BBN underestimates the extent of degradation); (~) prediction close to baseline state; (nd) no data. See footnote for description of rating colours for predicted state.

Scenario	IDnum	SIN		Macroalgae		Phytoplankton		Oxygen		Clarity[1]		E. coli[1,2]	
Mean Annual Flow	Kai Iwi	1809	↓	B	↓	A	✓	A	✓	<1.2	nd	<260	↑
	Whanganui	394	~	B	↓	A	✓	A	✓	<1.2	nd	<260	✓
	Rangitikei	449	↓	C	↓	A	✓	A	✓	<1.2	nd	<260	✓
	Manawatū[3]	540	✓	B	↓	A	✓	A	✓	<1.2	nd	260	~
	Ōhau[4]	219	✓	A	✓	A	✓	A	✓	>1.2	nd	<260	✓
	Waikawa	386	✓	A	✓	A	✓	A	✓	<1.2	nd	<260	✓
	Ākitio	1208	↓	B	↓	A	✓	A	✓	<1.2	nd	307	↓
Summer Flow	Kai Iwi	998	↓	B	↓	A	✓	A	✓	-		-	
	Whanganui	217	↓	A	✓	A	✓	A	✓	-		-	
	Rangitikei	254	↓	B	↓	A	✓	A	✓	-		-	
	Manawatū[3]	308	✓	B	↓	A	✓	A	✓	-		-	
	Ōhau[4]	129	✓	A	✓	A	✓	A	✓	-		-	
	Waikawa	236	✓	A	✓	A	✓	A	✓	-		-	
	Ākitio	644	↓	B	↓	D	✓	D	✓	-		-	
MALF[5]	Kai Iwi	926	↓	B	↓	A	↑	A	↑	-		-	
	Whanganui	188	↓	A	✓	A	✓	A	✓	-		-	
	Rangitikei	214	↓	B	↓	A	✓	A	✓	-		-	
	Manawatū[3]	278	✓	B	↓	A	✓	A	✓	-		-	
	Ōhau[4]	105	~	A	✓	C	✓	C	✓	-		-	
	Waikawa	197	↑	A	✓	C	✓	C	✓	-		-	
	Ākitio	591	↓	B	↓	D	✓	D	✓	-		-	
MALF[5] Closed	Kai Iwi	1336	↓	B		A	↑	A	↑	-		-	
	Whanganui[6]	-		-		-		-		-		-	
	Rangitikei	364	↓	A		A	✓	A	✓	-		-	
	Manawatū[3]	532	↓	A		D	✓	D	✓	-		-	
	Ōhau[4]	236	✓	A		C	✓	D	✓	-		-	
	Waikawa	436	↑	A		D	✓	D	✓	-		-	
	Ākitio[6]	-		-		-		-		-		-	

[1]Clarity scenarios only tested under mean flow; [2]Terminal reach *E. coli* compared to modelled median *E. coli* concentration supplied by HRC; [3]Manawatū SIN target <444mg/m^3; [4]Ōhau SIN target < 110mg/m^3; [5]Mean annual low flow; [6]Estuaries have modified entrances and therefore cannot close.

Condition rating for macroalgae, phytoplankton and dissolved oxygen outlined in Tables 1 to 3:

A	B	C	D
Minimal eutrophication	*Moderate eutrophication*	*High eutrophication*	*Very high eutrophication*

Condition rating for SIN and visual clarity based on exceedance (Fail) of One Plan target outlined in Table 1:

Pass	Fail

Condition rating for *E. coli* based on exceedance of two *E. coli* thresholds outlined in Table 1:

<260	260-550	>550

4.2 NUTRIENT SCENARIOS

The following section summarises the BBN output for the nutrient scenarios outlined in Section 3.1. BBN outputs for all nutrient scenarios are presented in Appendix 3 (nutrient land management scenarios) and Appendix 4 (load reductions associated with freshwater ecological targets). To illustrate the effect of load reductions on key variables, two nutrient scenarios are presented in more detail here. These are the scenarios that represent the greatest levels of nutrient load reductions for each approach, hence should provide the greatest level of protection for estuaries. They are as follows:

- Implementation of land management scenario NPS4 (i.e., pastoral farm mitigations and point source reductions, which combines mitigations in NPS2 and NPS3) for 17 estuaries.
- Freshwater load reductions that meet freshwater periphyton targets for the 20% "under protection risk" (20UPR) scenario, for 25 estuaries. This scenario allows for a 20% risk that a location will exceed the periphyton biomass target even when it is compliant with the associated nutrient criteria.

4.2.1 Land management scenario NPS4

Nitrogen

As evident from Table 15 and Table 7 above (see Section 3.1), decreases in potential SIN were directly proportional to decreases in the TN load; for example, a 25% reduction in TN load results in a 25% reduction in SIN. Following implementation of NPS4, potential SIN concentrations are predicted to improve (i.e., decrease) by 13-50% across all estuaries and flow conditions tested, with flow-related differences being minimal (Appendix 3). Nonetheless, concentrations are predicted to remain relatively high, and greater load reductions may be required to see any significant improvements in SIN concentration.

Macroalgae

Most estuaries on the Horizons coast are tidal rivers and therefore macroalgae is not the primary eutrophication indicator, with flushing flows and subsequent scouring limiting the establishment and persistence of growths. Because macroalgae can grow year-round, nutrient concentrations under mean flows are the most appropriate conditions to assess macroalgal state. Table 15 shows that under baseline conditions most estuaries

Table 15. Baseline state and predicted state under Nutrient Policy Scenario 4 (NPS4) along with percent improvement (% imp.) in state for SIN (g/m^3), macroalgae, phytoplankton and dissolved oxygen.

	SIN[1]			Macroalgae[1]			Phytoplankton[2]			Dissolved oxygen[2]		
Estuary name	Baseline	NPS4	% Imp.	Baseline	NPS4	% Imp.	Baseline	NPS4	% Imp.	Baseline	NPS4	% Imp.
Okehu	1520	973	36	B	B	7	A	A	0	A	A	0
Kai Iwi	1809	1505	17	B	B	0	A	A	0	A	A	0
Mōwhānau	1656	1049	37	B	B	0	A	A	0	A	A	0
Whanganui	394	307	22	B	B	11	A	A	0	A	A	0
Kaitoke	946	703	26	C	C	0	A	A	0	A	A	0
Whangaehu	431	336	22	B	B	4	A	A	0	A	A	0
Turakina	1347	1040	23	B	B	0	D	D	2	D	D	1
Koitiata	2852	1424	50	D	D	1	A	A	0	A	A	0
Rangitikei	449	321	28	C	B	17	A	A	0	A	A	0
Manawatū	540	332	39	B	B	6	A	A	0	A	A	0
Hōkio	765	572	25	D	D	3	D	C	2	D	D	1
Waiwiri	980	855	13	C	C	0	A	A	0	A	A	0
Ōhau	219	157	28	A	A	8	C	B	25	C	C	8
Waikawa	386	264	32	A	A	18	C	C	5	C	C	3
Wainui	705	598	15	B	B	0	D	D	0	D	D	0
Ākitio	1208	1004	17	B	B	0	D	D	0	D	D	0
Owāhanga	684	560	18	A	A	2	D	D	0	D	D	0

[1]Mean flow; [2]MALF.

are showing (based on the ratings in Table 3) minimal (Band A) to moderate (Band B) levels of eutrophication, expressed as macroalgae. Only five show high (Band C) to very high (Band D) levels of eutrophication - Kaitoke, Koitiata, Rangitikei, Hōkio and Waiwiri. Of these five, implementation of NPS4 would lead to a substantive improvement in Rangitikei (Table 15), but no change in the other estuaries. These four estuaries are small systems with high nutrient concentrations and a low number of flushing events (i.e., FRE3 ~5 events/year), which are conditions that make them susceptible to macroalgae growth. The BBN accurately predicts a eutrophic response in these estuaries, however, high nutrient symptoms often manifest as aquatic weed overgrowth upstream of the estuary, likely utilising excess nutrients and thereby dampening macroalgal growth within the estuaries themselves (see photo to the right from Roberts et al. 2025).

Kaitoke Estuary in 2020 (Google Earth) with a restricted entrance and aquatic weed overgrowth upstream of the estuary.

Phytoplankton

Table 15 shows the predicted phytoplankton condition under MALF conditions, when phytoplankton risk is highest due to longer flushing times. Under baseline conditions phytoplankton state was predicted to be in very good condition for most estuaries; except for Ōhau and Waikawa, (rated as expressing high eutrophication, Band C) and Turakina, Hōkio, Wainui, Ākitio and Owāhanga (rated as expressing very high levels of eutrophication, Band D). Implementation of NPS4 leads to a moderate improvement in Ōhau and minor improvement in Waikawa (Table 15). In Turakina and Hōkio, only a 2% improvement was predicted and no change in state (Table 15). In general, except for Ōhau, implementation of NPS4 had little effect on phytoplankton state.

Dissolved oxygen

Dissolved oxygen follows a similar trend to phytoplankton, with minor improvement predicted for Ōhau and limited improvement in Waikawa (Table 15). In Turakina and Hōkio, only a 1% improvement was predicted and no change in state (Table 15). Wainui and Owāhanga remained in poor condition despite improvements in nutrient loads. This finding is explained by prolonged flushing times (i.e., 9-14 days), which make these systems relatively susceptible to the development of low oxygen conditions. Turakina and Ākitio also remained in a Band D state due to high potential TN and SIN concentrations, stratification, and prolonged flushing times. As expected, with increased flushing under mean-flow conditions, no dissolved oxygen issues were predicted (Appendix 3).

Phytoplankton bloom recorded in Ōhau in January 2020, with clear surface freshwater layer overlying a bloom in deeper saline waters.

4.2.2 Freshwater ecological target nutrient scenario 20UPR

Nitrogen

For the 20% "under protection risk" (20UPR) scenario, the improvement in SIN concentrations is presented in Table 16. Load reductions associated with the 20UPR scenario led to large relative changes (47-85% improvement) in potential SIN concentration across all estuaries. For Kaikokopu, Manawatū, Wairarawa, Ōhau, Waikawa, Wainaui and Owāhanga, reductions led to an improvement in SIN state (Table 16).

Macroalgae

Table 16 shows that under baseline conditions most estuaries are showing minimal (Band A) to moderate (Band B) levels of eutrophication, expressed as macroalgae, with nine estuaries showing high (Band C) to very high (Band D) levels of eutrophication. However, this situation improves with nutrient reductions under the 20UPR scenario, with Kaitoke, Rangitikei, Hōkio, Waiwiri, Tautāne and Waimata showing the greatest improvement. Limited or no improvement was predicted for Pukepuke and Three Mile Creek, with both estuaries maintaining very high levels of eutrophication (i.e., macroalgae; Table 16), which is due to persistently high TN concentrations. The BBN accurately predicts a eutrophic response in these estuaries. However, as noted in the previous section, high nutrient symptoms in these smaller systems often manifests as aquatic weed overgrowth upstream of the estuary, likely utilising excess nutrients and thereby dampening macroalgal growth within the estuaries themselves (Roberts et al. 2025).

Table 16. Baseline state and predicted state under 20% "under protection risk" (20UPR) scenario along with percent improvement (% Imp.) in state for SIN (g/m^3), macroalgae, phytoplankton and dissolved oxygen.

	SIN[1]			Macroalgae[1]			Phytoplankton[2]			Dissolved oxygen[2]		
Estuary name	Baseline	20UPR	% Imp.	Baseline	20UPR	% Imp.	Baseline	20UPR	% Imp.	Baseline	20UPR	% Imp.
Ototoka	1204	414	66	B	B	3	A	A	0	A	A	0
Okehu	1520	520	66	B	A	24	A	A	0	A	A	0
Kai Iwi	1809	623	66	B	B	0	A	A	0	A	A	0
Mōwhānau	1656	571	66	B	B	0	A	A	0	A	A	0
Whanganui	394	207	48	B	A	23	A	A	0	A	A	0
Kaitoke	946	503	47	C	B	37	A	A	0	A	A	0
Whangaehu	431	226	47	B	A	23	A	A	0	A	A	0
Turakina	1347	559	58	B	B	0	D	C	6	D	C	3
Koitiata	2852	1188	58	D	C	32	A	A	0	A	A	0
Rangitikei	449	181	60	C	A	61	A	A	0	A	A	0
Pukepuke	10745	4505	58	D	D	0	A	A	0	A	A	0
Kaikokopu	191	70	63	A	A	1	A	A	0	A	A	0
3 Mile Creek	1240	513	59	D	D	3	A	A	0	A	A	0
Manawatū	540	82	85	B	A	54	A	A	0	A	A	0
Wairarawa	253	53	79	A	A	1	A	A	0	A	A	0
Hōkio	765	191	75	D	B	56	D	C	12	D	C	6
Waiwiri	980	246	75	C	B	57	A	A	0	A	A	0
Ōhau	219	49	78	A	A	16	C	A	61	C	B	22
Waikawa	386	92	76	A	A	34	C	A	67	C	B	31
Tautāne	704	168	76	D	B	70	D	C	17	D	D	0
Wainui	705	167	76	B	A	40	D	C	19	D	D	0
Papuka	735	176	76	B	A	40	C	C	18	A	A	5
Waimata	863	204	76	C	A	79	A	A	0	A	A	0
Ākitio	1208	295	76	B	B	14	D	C	12	D	C	6
Owāhanga	684	164	76	A	A	38	D	C	17	D	D	0

[1]Mean flow; [2]MALF.

Phytoplankton

Table 16 shows the predicted phytoplankton condition under MALF conditions. Compared with the baseline, TN load reductions under the 20UPR scenario led to a significant (>50%) improvement in Ōhau and Waikawa, and a moderate (~15-20%) improvement in Tautāne, Wainui, Papuka and Owāhanga (Table 16). Smaller improvements were recorded in Turakina, Hōkio, and Ākitio. Despite an 18% improvement in Papuka the overall state did not change, remaining at a high (Band C) level of phytoplankton eutrophication. As expected, when flushing improves under mean-flow conditions, no phytoplankton issues were predicted (Appendix 4).

Dissolved oxygen

Dissolved oxygen follows a similar trend to phytoplankton, with ~20-30% improvement in Ōhau and Waikawa, and minor improvement in Turakina, Ākitio and Hōkio (Table 16). However, despite load reductions under 20UPR the BBN predicted persistent low oxygen conditions in Tautāne, Wainui and Owāhanga, owing to prolonged flushing times (i.e., 9-14 days), which make these estuaries more susceptible to low oxygen conditions as noted above. As expected, when flushing improves under mean-flow conditions, no dissolved oxygen issues were predicted to occur (Appendix 4).

Three Mile Creek in 2019 (Google Earth) showing overgrowth of aquatic weeds upstream of the estuary.

4.2.3 Summary of other nutrient scenarios

Appendix 3 outlines all other land management nutrient policy scenarios, for which key findings can be summarised as follows:

- NPS1 had little effect on estuary state (i.e., macroalgae, phytoplankton and dissolved oxygen) or the relative improvement in state.
- NPS2 resulted in similar outcomes to NPS4. This is not unexpected given the only change between the two scenarios was the inclusion in NPS4 of point source mitigations for Turakina, Rangitikei and Manawatū.
- NPS3 (point source mitigations alone) had little to no effect on estuary state or improvements in state, as it only represented small reductions from point sources in Turakina, Rangitikei and Manawatū.
- NPS5a to NPS5e (which included horticulture mitigations) for Hōkio Estuary had very little influence on estuary state or improvements in state. For the other estuaries in this scenario (Table 8), the policy scenario did not result in reductions and therefore no improvements were recorded.

Appendix 4 outlines the other two "under protection risk" levels (i.e., 25UPR and 30UPR) for nutrients. These reflect less stringent reductions than 20UPR, as they allow for a greater risk that a river will exceed the periphyton biomass target even when it is compliant with associated nutrient criteria. Findings can be summarised as follows:

- SIN was proportional to the TN load reductions for each UPR scenario, with high concentrations recorded under 25UPR and 30UPR.
- For both 25UPR and 30UPR, macroalgal state under mean flow was worse in Kaitoke, Koitiata, Tautāne, Wainui, Papuka and worse under 30UPR for Waiwiri, Waimata and Manawatū. While percent improvement varied across scenarios tested, macroalgae state across other estuaries was consistent for the three UPR levels.
- For phytoplankton under MALF, conditions were worse in Waikawa, Tautāne, Wainui and Owāhanga under both 25UPR and 30UPR. While percent improvement varied across scenarios tested, phytoplankton state across other estuaries was consistent for the three UPR levels.
- Despite changes in percent improvement, dissolved oxygen was consistent across all three UPR levels, except in Waikawa and Ākitio where conditions were worse under 25UPR and 30UPR, respectively.

4.3 SEDIMENT SCENARIOS

The following section summarises the BBN output for the sediment scenarios described in Section 3.2, assessed against the estuary One Plan target for clarity of 1.2m (Table 1). BBN outputs for all policy scenario iterations are presented in Appendix 5 (sediment land management scenarios) and Appendix 6 (load reductions associated with freshwater ecological targets). To illustrate the effect of load reductions on key variables, two sediment scenarios are presented in more detail here. These scenarios represent the greatest levels of sediment load reduction for each approach, hence should provide the greatest level of protection for estuaries. They are as follows:

- Implementation of land management scenario SPS2 (i.e., erosion control works, stock exclusion, and horticultural mitigations) for 25 estuaries, for three time periods (2035, 2050, 2100).
- Freshwater sediment load reductions that meet NPS-FM freshwater river clarity targets under the Band A scenario, for 25 estuaries. Note that the terminal river reaches for most estuaries were classified as SS Class 2, for which the Band A clarity target (0.93 m) is lower than the One Plan estuary clarity target (1.2 m).

4.3.1 Land management scenario SPS2

Estuary clarity

In most estuaries, implementation of SPS2 by 2035 is not predicted to markedly improve visual clarity, with 76% showing no improvement and clarity remaining below the One Plan target (Tables 17A). Large improvements were observed in Whangaehu, Kaikokopu, Three Mile Creek, Wairarawa, and Waikawa (Tables 17A). By 2050, the implementation of SPS2 showed improved estuary clarity (i.e., above the One Plan target) in 60% of estuaries, increasing to 68% by 2100 (Table 17A). No significant improvements were predicted for Ototoka, Mōwhānau, Kaitoke, Koitiata, Pukepuke, Hōkio, Waiwiri and Waimata by 2100. To meet the 1.2m estuary target, these estuaries would require further sediment load reductions of approximately 10-20%, except for Kaitoke, which requires a further reduction of almost 40% to achieve the target clarity (Table 17A).

E. coli potential

Implementation of SPS2 by 2035 shows some minor improvements in *E. coli* potential, with the largest shift in state predicted in Turakina, Koitiata, Pukepuke, Manawatū, Tautāne and Owāhanga (Table 17B). By 2100, Kaitoke is the only estuary that does not show any significant improvement in *E. coli* potential. In this estuary, modelled median river clarity is low (0.6m; Table 12) and the estuary is freshwater most of the time (i.e., salinity <5psu). Hence, without any significant gains in river clarity there are no subsequent improvements in *E.coli* potential.

Modelled *E.coli* concentrations for the terminal river reaches indicate that median *E.coli* is predicted to exceed the estuary One Plan target in Ototoka, Okehu, Kai Iwi, Mōwhānau, Kaitoke and Papuka (data provided by HRC). In general, the BBN predicts lower absolute concentrations of *E. coli* for these estuaries, likely because the model is based on median clarity and mean flow. As such, peaks in *E. coli* concentration during high-flow events are unlikely to be captured. In this instance, therefore, relative changes in *E. coli* potential are the most relevant for informing management decisions, rather than absolute concentrations.

Permanent health risk warning in Mōwhānau estuary, with swimming and recreational use not recommended (photo: lawa.org.nz).

Table 17. (A) Baseline and predicted estuary clarity (m) with "% Further load reduction required" to meet the 1.2m estuary target, and (B) baseline and predicted *E. coli* (cfu per 100ml) with "% Improvement" in state under sediment policy scenario 2 (SPS2) for 2035, 2050 and 2100. Estuary clarity estimates are derived from the BBN using terminal reach river clarity (i.e., Table 12) and estuary salinity data (Fig. 4; Table 4).

A. Clarity	Baseline	SPS 2			**% Further load reduction required**		
		2035	2050	2100	2035	2050	2100
Ototoka	1.15	1.15	1.12	1.12	17	15	15
Okehu	1.09	1.09	1.68	1.68	14	0	0
Kai Iwi	1.12	1.12	2.01	2.01	15	0	0
Mōwhānau	1.15	1.12	1.12	1.12	15	15	15
Whanganui	1.12	1.12	2.01	2.01	15	0	0
Kaitoke	0.65	0.65	0.65	0.65	38	38	38
Whangaehu	1.12	2.01	2.01	4.94	0	0	0
Turakina	1.15	1.12	2.01	2.01	15	0	0
Koitiata	0.65	1.09	1.09	1.09	14	14	14
Rangitikei	1.12	1.12	2.01	2.01	15	0	0
Pukupuke	1.15	1.12	1.12	1.12	15	15	15
Kaikokopu	1.09	1.68	1.68	1.68	0	0	0
Three Mile	1.15	2.01	2.01	2.01	0	0	0
Manawatū	1.15	1.12	2.01	2.01	15	0	0
Wairarawa	1.09	1.68	1.68	1.68	0	0	0
Hōkio	1.15	1.12	1.12	1.12	15	15	15
Waiwiri	1.15	1.12	1.12	1.12	15	15	15
Ōhau	2.01	2.01	2.01	2.01	0	0	0
Waikawa	1.12	2.01	2.01	2.01	0	0	0
Tautāne	1.15	1.12	2.01	2.01	15	0	0
Wainui	1.15	1.15	1.12	2.01	17	15	3
Papuka	1.15	1.12	2.01	4.94	15	0	0
Waimata	0.65	1.09	1.09	1.09	14	14	14
Ākitio	1.15	1.15	1.12	2.01	17	15	0
Owāhanga	1.15	1.12	2.01	2.01	15	0	0

B. E. coli	Baseline	SPS 2			**% Improvement**		
		2035	2050	2100	2035	2050	2100
Ototoka	279	267	239	211	5	15	24
Okehu	240	219	190	173	9	21	28
Kai Iwi	213	196	172	161	8	19	24
Mōwhānau	250	240	220	204	4	12	18
Whanganui	224	205	175	159	8	22	29
Kaitoke	286	274	272	270	4	5	6
Whangaehu	211	186	136	120	12	36	43
Turakina	274	243	174	147	11	37	46
Koitiata	289	234	234	234	19	19	19
Rangitikei	216	193	152	134	11	30	38
Pukupuke	281	244	244	244	13	13	13
Kaikokopu	237	182	182	182	23	23	23
Three Mile	252	182	182	182	27	27	27
Manawatū	260	234	191	172	10	27	34
Wairarawa	233	167	167	167	28	28	28
Hōkio	257	239	237	235	7	8	9
Waiwiri	259	230	230	230	11	11	11
Ōhau	164	153	150	148	6	8	9
Waikawa	195	178	173	170	9	11	13
Tautāne	271	235	147	128	14	46	53
Wainui	310	272	197	171	12	37	45
Papuka	249	198	142	112	21	43	55
Waimata	254	240	218	211	5	14	17
Ākitio	307	266	201	176	13	34	43
Owāhanga	281	244	185	160	13	34	43

4.3.2 Freshwater "NPSM river clarity A-band" ecological target sediment scenario

Estuary clarity

Implementation of load reductions to meet the "NPS-FM river clarity A-band", resulted in 56% of estuaries showing an improvement in clarity, and 48% met the One Plan target (Table 18). Under the "NPS-FM river clarity A-band" scenario, the largest improvements in estuary clarity were observed in Kaitoke, Koitiata and Waimata, with a baseline clarity of 0.65m in these estuaries increasing to >1m (Table 18). On the west coast Otokoka, Okehu, Mōwhānau, Kaitoke, Turakina, Hōkio and Waiwiri remained below the One Plan target of 1.2m, and all east coast estuaries remained below the target (Table 18). These estuaries require approximately 15-20% further reductions in sediment loads to achieve the 1.2m estuary clarity target (Table 18).

E. coli potential

Implementation of the "NPS-FM river clarity A-band" scenario shows improvement in all estuaries for *E.coli* potential, ranging from 6 to 57% improvement (Table 18), with 10 estuaries also improving in state.

As discussed earlier in Section 4.3.1, modelled *E.coli* concentrations for the terminal river reaches indicate that, under current baseline conditions, median *E.coli* is predicted to exceed the estuary One Plan target in Ototoka, Okehu, Kai Iwi, Mōwhānau, Kaitoke and Papuka (data provided by HRC). Encouragingly, in these estuaries the BBN predicted improvements from 6 to 21% under the "NPS-FM river clarity A-band" scenario.

Table 18. Baseline and predicted estuary clarity (m) with "% Further load reduction required" to meet the 1.2m One Plan estuary target, and baseline and predicted *E. coli* (cfu per 100ml) potential with "% Improvement" in state under the "NPS-FM river clarity A-band" scenario. Estuary clarity estimates are derived from the BBN using terminal reach river clarity (i.e., Table 12) and estuary salinity data (Fig. 4; Table 4).

	Baseline	"NPS-FM river clarity A-band"		Baseline	"NPS-FM river clarity A-band"	
Estuary name	Estuary clarity (m)	Estuary clarity (m)	% Further load reduction required	E. coli potential	E. coli potential	% Improvement
Ototoka	1.15	1.12	17	279	225	19
Okehu	1.09	1.09	17	240	225	6
Kai Iwi	1.12	2.01	0	213	177	17
Mōwhānau	1.15	1.12	17	250	225	10
Whanganui	1.12	2.01	0	224	151	32
Kaitoke	0.65	1.09	17	286	225	21
Whangaehu	1.12	2.01	0	211	151	28
Turakina	1.15	1.12	17	274	225	18
Koitiata	0.65	1.68	0	289	151	48
Rangitikei	1.12	2.01	0	216	151	30
Pukupuke	1.15	2.01	0	281	151	46
Kaikokopu	1.09	1.68	0	237	151	36
3 Mile Creek	1.15	2.01	0	252	151	40
Manawatū	1.15	4.94	0	260	111	57
Wairarawa	1.09	1.68	0	233	151	35
Hōkio	1.15	1.12	17	257	225	12
Waiwiri	1.15	1.12	17	259	225	13
Ōhau	2.01	4.94	0	164	111	32
Waikawa	1.12	4.94	0	195	111	43
Tautāne	1.15	1.12	17	271	225	17
Wainui	1.15	1.12	17	310	225	27
Papuka	1.15	1.12	17	249	225	10
Waimata	0.65	1.09	17	254	225	11
Ākitio	1.15	1.12	17	307	225	27
Owāhanga	1.15	1.12	17	281	225	20

4.3.3 Summary of other sediment scenarios

Appendix 5 outlines the alternative land management sediment policy scenario (SPS1), for which key findings can be summarised as follow:

- In most estuaries, implementation of SPS1 by 2035 does not markedly improve estuary clarity, with improvement predicted for only 20% of estuaries. This figure increased to 56% by 2100.
- By 2100, no significant improvements in clarity were predicted for Ototoka, Okehu, Mōwhānau, Kaitoke, Pukepuke, Hōkio, Waiwiri, Wainui, Waimata and Ākitio. These estuaries would require further sediment load reductions of approximately 10-20% to meet the One Plan target, except for Kaitoke, which would require a further reduction of almost 40%.
- By 2035 there were minor improvements in *E. coli* potential, with the largest gains observed in Koitiata, Pukepuke, Kaikokopu, Three Mile Creek and Papuka. Ototoka, Kaitoke, Turakina, Wainui, Ākitio and Owāhanga failed to meet the One Plan target.
- By 2100, 80% of estuaries showed >15% improvement in *E. coli* concentration under SPS1.

Appendix 6 outlines the two other less stringent NPS-FM river clarity targets; the "NPS-FM river clarity B-band" scenario and the "NPS-FM river clarity C-band" scenario, for which key findings can be summarised as follows:

- For the "NPSM river clarity B-band" scenario, 44% of estuaries showed an improvement in estuary clarity, and met the One Plan target of 1.2m. Several estuaries require further reductions to meet the target in the range of 10-20%, and up to 40% for Kaitoke and Waimata.
- Implementation of the "NPSM river clarity B-band" scenario shows improvement in 84% of estuaries for *E. coli*, with all estuaries improving in state.
- For the "NPSM river clarity C-band" scenario, 44% of estuaries showed an improvement in estuary clarity, and an improvement in state. Several estuaries require further reductions to meet the 1.2m estuary clarity target in the range of 10-20%, and up to 40% for Kaitoke and Waimata.
- Implementation of the "NPSM river clarity B-band" scenario shows improvement in 52% of estuaries, with seven estuaries – Ototoka, Kaitoke, Turakina, Tautāne, Wainui, Ākitio and Owāhanga – remaining above the 260 *E. coli* per 100ml target (Table 1)

Poor water clarity in Wainui Estuary.

Kai Iwi Estuary looking upstream from the beach.

Waimata Estuary with marginal salt marsh, February 2016.

4.4 SENSITIVITY OF BBN RESULTS TO INPUT DATA

It is important to note that the BBN outputs reflect input conditions. For example, median river clarity is used as the input for sediment variables; therefore, the predictions for estuary clarity and *E. coli* represent median conditions rather than high-flow scenarios, under which *E. coli* concentrations are likely to be higher and clarity lower.

The driver node inputs used to test nutrient scenarios in the BBN were based on estuary parameters gleaned from the dilution model prepared for Horizons by Plew (2024). The dilution modelling approach used updated desktop Coastal Explorer data (i.e., estuary volume and tidal prism) to calculate dilution, salinity and flushing time. Plew (2024) compared Coastal Explorer data for the Ōhau and Waikawa against tidal prism and estuary volumes calculated using the hydrodynamic models prepared by DHI (Tuckey 2024). In both cases the DHI tidal prism and estuary volumes were considerably lower than the Coastal Explorer data. Plew (2024) stated the reasons were twofold: (1) the lower estuary boundary differs, with the hydrodynamic model truncating the seaward boundary, and (2) tidal prism was calculated from the model by comparing the difference in surface area at high and low tide and the tidal range at the coast, treating the estuary as a trapezoidal prism, which can lead to an overestimation of the tidal prism as the tidal range can differ between the coast and within the estuary.

The BBN was run using the input data for both approaches, with results shown in Table 19. DHI potential TN concentrations were slightly higher than those calculated using the Coastal Explorer data, and this is also reflected in the SIN output. The largest difference was in the predicted phytoplankton and dissolved oxygen states. DHI modelling indicated better conditions than the Coastal Explorer inputs, owing to the rapid flushing times calculated for the whole estuary by the hydrodynamic models (i.e., <3.4 days, which is too short for phytoplankton to establish). In this case, Coastal Explorer data likely better reflects the actual condition of these estuaries, as observational studies have recorded phytoplankton and dissolved oxygen stress under stratified low flow conditions (Stevens et al. 2020a; Stevens et al. 2020b).

These results do not diminish the hydrodynamic model outputs presented in Tuckey (2024), as those models were developed and calibrated for a different purpose than how they have been used here (i.e., site-specific state versus estuary-wide state). Instead, this comparison illustrates how input data can influence BBN outputs, and highlights the importance of sense-checking results. For example, Kai Iwi, Mōwhānau and Manawatū have experienced phytoplankton blooms under low-flow conditions (Roberts et al. 2025; HRC Coastal Data), yet this is not reflected in the BBN outputs because the dilution model predicts rapid flushing times in these estuaries. The collection of field data would improve desktop estimates used for Coastal Explorer and would likely improve these predictions.

Table 19. Comparison between Ōhau and Waikawa BBN outputs using different input variables calculated from the DHI hydrodynamic models (Tuckey 2024). Colours described in Appendix 3. NPS = nutrient policy scenario. UPR = under protection risk.

Indicator	Flow	Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4	20UPR	25UPR	30UPR
SIN (mg/m^3)	Mean flow	Ōhau	219	195	157	219	157	49	67	81
		Ōhau_DHI	322	287	232	322	232	72	99	120
		Waikawa	386	332	264	386	264	92	124	148
		Waikawa_DHI	480	413	329	480	329	115	155	184
Macroalgae	Mean flow	Ōhau	A	A	A	A	A	A	A	A
		Ōhau_DHI	A	A	A	A	A	A	A	A
		Waikawa	A	A	A	A	A	A	A	A
		Waikawa_DHI	A	A	A	A	A	A	A	A
Phytoplankton	MALF	Ōhau	C	C	B	C	B	A	A	A
		Ōhau_DHI	A	A	A	A	A	A	A	A
		Waikawa	C	C	C	C	C	A	B	B
		Waikawa_DHI	A	A	A	A	A	A	A	A
Dissolved oxygen (mg/L)	MALF	Ōhau	5.42	5.42	5.86	5.42	5.86	6.63	6.63	6.63
		Ōhau_DHI	7.47	7.47	7.47	7.47	7.47	7.47	7.47	7.47
		Waikawa	5.08	5.21	5.21	5.08	5.21	6.63	5.86	5.86
		Waikawa_DHI	7.47	7.47	7.47	7.47	7.47	7.47	7.47	7.47

5. KEY FINDINGS

To aid in the interpretation of the results, and to assess whether implementation of policy scenarios and/or calculated freshwater load reductions for ecological targets will protect estuary health, each estuary indicator was assigned a confidence rating, as described in Table 20.

Table 20. Confidence ratings applied to each indicator for each estuary.

Rating	Description
High	Reliable prediction of state and general trends.
Medium	Moderate reliability for predicting state, but useful for trends. State should be interpreted cautiously or verified.
Low	Estuary state and trends are predicted with limited reliability and should be interpreted with caution.

Estuaries were further summarised into three categories based on BBN predictions and whether load reductions are likely to protect estuary health (Table 21):

(1) Estuaries are **vulnerable** despite the implementation of management policies and calculated freshwater load reductions.

(2) Estuaries are **protected** based on baseline state and/or improvements with some or all load reductions.

(3) The BBN does not provide a reliable prediction for the estuary and/or indicator; hence the level of protection is **uncertain**.

5.1 NUTRIENT INDICATORS

Under baseline (current) conditions, several of the estuaries meet One Plan targets across all nutrient-related indicators (Table 21). For these systems, load reductions will provide an added layer of protection, and the BBN predictions for these estuaries also support this (Tables 15 and 16). For the remaining estuaries, the 20% "under protection risk" (20UPR) scenario provides the greatest level of protection. In this scenario, required total nitrogen load reductions to meet ecological targets for periphyton in rivers are 46-83% of current loads (see Table 9). Achieving this level of load reduction is predicted to lead to significant improvements in SIN, macroalgae and phytoplankton, and minor improvements in dissolved oxygen for most estuaries. However, several estuaries remain vulnerable to eutrophication despite nutrient load reductions (Table 21). For example, although some improvements were observed, Turakina, Hōkio, Tautāne, Wainui, Papuka, Ākitio and Owāhanga have persistent phytoplankton issues across several scenarios. Ōhau and Waikawa also expressed persistent phytoplankton issues, however these estuaries showed significant improvement under the 20UPR scenario. A similar pattern was observed for dissolved oxygen, which is expected given its linkage to phytoplankton in the BBN.

In addition, five estuaries (Kai Iwi, Mōwhānau, Rangitikei, Kaikokopu, Manawatū,) were rated low confidence and have been highlighted for further investigation, as the BBN did not reliably predict phytoplankton or dissolved oxygen, even under entrance closure (Appendix 4). The lower confidence assigned to these estuaries is in part a byproduct of uncertainties in the input data. As discussed in Section 4.4, for example, these estuaries have experienced phytoplankton blooms under low-flow conditions, despite calculated flushing times being too short (in theory) for blooms to develop.

For macroalgae, many smaller estuaries (e.g., Kaitoke, Koitiata, Pukepuke, Three Mile Creek, Hōkio, Waiwiri) had limited high-flow events (FRE3) and elevated nutrient inputs, which are conditions conducive to macroalgal growth. While the BBN accurately predicted a eutrophic response in these estuaries, *in situ* high nutrient symptoms often manifest as aquatic weed overgrowth upstream of the estuary, likely dampening macroalgal growth within the estuaries themselves. As such, the BBN prediction for these estuaries was rated as medium confidence, because the BBN is predicting a eutrophic response and the relative change in this response may still be useful from a management perspective. In contrast, the BBN accurately predicted that Tautāne and Waimata would express symptoms of macroalgae growth, which is confirmed by field observations, leading to a confidence rating of high (Robertson & Stevens 2016; Table 25).

Other estuaries have expressed macroalgal issues in field studies over the short-term, but were not identified in the BBN, including Turakina, Ākitio and Owāhanga (Roberts et al. 2025 and references therein). Therefore, the BBN prediction has been rated low confidence. Conversely, the BBN predicted Rangitikei was at risk of macroalgal blooms, however no blooms were observed *in situ* on the limited occasions it has been assessed (Stevens 2018).

As discussed, the BBN predicts potential SIN concentration based on potential TN, with reductions in SIN proportional to reductions in TN. Because the BBN uses potential rather than absolute concentrations, a confidence rating was not provided. Furthermore, there are insufficient data to evaluate the BBN's predictive power for SIN, as monitoring data are limited to the seven estuaries presented in Section 4.1.

Table 21. Summary of estuaries, indicators, and protection status under load reduction scenarios for nutrients (NPS4 and 20UPR).

The BBN predicts that an estuary remains vulnerable (×), is protected (✓), or the level of protection is uncertain (�). Estuaries are assigned a confidence rating (CR) as described in Table 20. Where an estuary meets the One Plan target under baseline (BL) conditions (green highlight), load reductions will only lead to further improvements, therefore the BBN results are not summarised here. For estuaries highlighted in yellow, the level of protection remains vulnerable or is uncertain, meaning recommendations for further investigation are considered in the report.

	Phytoplankton					Oxygen					Macroalgae[1]				
	BL	CR	NPS4	20UPR	CR	BL	CR	NPS4	20UPR	CR	BL	CR	NPS4	20UPR	CR
Ototoka	✓	H	-	-	-	✓	H	-	-	-	✓	H	-	-	-
Okehu	✓	H	-	-	-	✓	H	-	-	-	✓	H	-	-	-
Kai Iwi	�	L	�	�	L	�	L	�	�	L	✓	H	-	-	-
Mōwhānau	�	L	�	�	L	�	L	�	�	L	✓	H	-	-	-
Whanganui	✓	H	-	-	-	✓	H	-	-	-	✓	H	-	-	-
Kaitoke	✓	H	-	-	-	✓	H	-	-	-	×[1]	M	×	✓	M
Whangaehu	✓	H	-	-	-	✓	H	-	-	-	✓	H	-	-	-
Turakina	×	M	×	×	M	×	M	×	×	M	�	L	�	�	L
Koitiata	✓	H	-	-	-	✓	H	-	-	-	×[1]	M	×	×	M
Rangitikei	�	L	�	�	L	�	L	�	�	L	×[2]	L	✓	✓	L
Pukupuke	✓	H	-	-	-	✓	H	-	-	-	×[1]	M	nd	×	M
Kaikokopu	�	L	�	�	L	�	L	�	�	L	✓	M	-	-	-
Three Mile Ck	✓	H	-	-	-	✓	H	-	-	-	×[1]	M	×	×	M
Manawatū	�	L	�	�	L	�	L	�	�	L	✓	H	-	-	-
Wairarawa	✓	H	-	-	-	✓	H	-	-	-	✓	M	-	-	-
Hōkio	×	M	×	×	M	×	M	×	×	M	×[1]	M	×	✓	M
Waiwiri	✓	H	-	-	-	✓	H	-	-	-	×[1]	M	×	✓	M
Ōhau	×	H	✓	✓	H	×	H	✓	✓	H	✓	H	-	-	-
Waikawa	×	H	×	✓	H	×	H	×	✓	H	✓	H	-	-	-
Tautāne	×	H	nd	×	H	×	M	×	×	M	×	H	nd	✓	H
Wainui	×	H	×	×	H	×	M	×	×	M	✓	H	-	-	-
Papuka	×	M	nd	×	M	✓	H	-	-	-	✓	M	-	-	-
Waimata	✓	M	-	-	-	✓	H	-	-	-	×	M	nd	✓	H
Ākitio	×	H	×	×	H	×	M	×	×	M	�	L	�	�	L
Owāhanga	×	H	×	✓	H	×	M	×	×	M	�	L	�	�	L

[1] The BBN predicts a eutrophic response in small estuaries; however, this manifests as aquatic weed overgrowth in the upstream reaches rather than macroalgae within the estuary. Hence these estuaries have not been highlighted for further investigation because macroalgae, the One Plan target, is not expressed.

[2] Rangitikei does not express macroalgal symptoms despite the BBN prediction suggesting it is vulnerable to macroalgal growth. Load reductions do lead to improvements in the predicted macroalgal state overall.

5.2 SEDIMENT INDICATORS

Under baseline (current) conditions, only one estuary (Ōhau) meets the One Plan targets across all sediment-related indicators (Table 22), meaning that the efficacy of sediment load reductions must be considered for all other estuaries. The SPS2 scenario provides the greatest improvements for clarity and the "NPS-FM river clarity A-band" scenario provides the greatest improvements for *E. coli* potential. Estuary clarity is not measured in the Horizons estuary water quality monitoring programme, therefore confidence ratings are based on one-off field observations and/or desktop assessments (Roberts et al. 2025 and references therein). To more accurately assess the reliability of the BBN predictions, estuary clarity measurements would be required.

The BBN predicts that most estuaries have poor visual clarity (Table 22). Many smaller estuaries (e.g., Ototoka, Okehu, Mōwhānau, Kaitoke, Koitiata, Pukepuke, Hōkio, Waiwiri, Papuka and Waimata) have small catchments and therefore relatively low sediment loads. However,

Table 22. Summary of estuaries, indicators, and protection status under load reduction scenarios for sediment (SPS2 and NPS-FM A-band). The BBN predicts that an estuary remains vulnerable (×), is protected (✓), or the level of protection is uncertain (�). Estuaries are assigned a confidence rating (CR) as described in Table 20. Where an estuary is protected under baseline or sediment load reduction scenarios it is highlight green. Estuaries highlighted in yellow require further investigation as the level of protection remains vulnerable or is uncertain.

	Clarity					E. coli				
	Baseline	CR	SPS2 2050	NPS-FM A-band	CR	Baseline[1]	CR	SPS2 2050	NPS-FM A-band	CR
Ototoka	×	L	×	×	L	×	M	✓	✓	M
Okehu	×	L	✓	×	L	�	L	✓	✓	L
Kai Iwi	×	M	✓	✓	M	�	L	✓	✓	L
Mōwhānau	×	L	×	×	L	�	L	✓	✓	L
Whanganui	×	H	✓	✓	M	�	L	✓	✓	L
Kaitoke	×	L	×	×	L	×	M	×	✓	M
Whangaehu	×	M	✓	✓	M	�	L	✓	✓	L
Turakina	×	M	✓	×	M	�	L	✓	✓	L
Koitiata	×	L	×	✓	L	×	M	✓	✓	M
Rangitikei	×	M	✓	✓	M	�	L	✓	✓	L
Pukupuke	×	L	×	✓	L	×	M	✓	✓	M
Kaikokopu	×	M	✓	✓	M	�	L	✓	✓	L
Three Mile Ck	×	M	✓	✓	M	✓	M	✓	✓	M
Manawatū	×	H	✓	✓	M	�	L	✓	✓	L
Wairarawa	×	M	✓	✓	M	�	L	✓	✓	L
Hōkio	×	L	×	×	L	✓	M	✓	✓	M
Waiwiri	×	L	×	×	L	✓	M	✓	✓	M
Ōhau	✓	M	✓	✓	M	✓	M	✓	✓	M
Waikawa	×	M	✓	✓	M	�	L	✓	✓	L
Tautāne	×	H	✓	×	H	×	M	✓	✓	M
Wainui	×	H	×	×	H	×	H	✓	✓	H
Papuka	×	L	✓	×	L	�	L	✓	✓	L
Waimata	×	L	×	×	L	✓	M	✓	✓	M
Ākitio	×	H	×	×	H	×	H	✓	✓	H
Owāhanga	×	H	✓	×	H	×	H	✓	✓	H

[1]Estuaries designated as an uncertain level of protection either have modelled median *E. coli* levels above the freshwater One Plan target or the long-term grading for recreational bathing is Poor (i.e., unsuitable for swimming; lawa.org.nz).

the modelled median river clarity remains below 0.85m, meaning the BBN predicts these estuaries will not meet the estuary clarity target of 1.2m. From the limited data available, most of these estuaries appear to have visual clarity close to the estuary clarity target, with some organic colouring but low suspended sediments under baseflow conditions. However, given the limited monitoring data to verify this, the BBN prediction is assigned low confidence, as there is insufficient evidence to confirm the accuracy of the prediction.

High confidence was assigned to many of the larger estuaries (e.g., Whanganui, Manawatū, Ākitio) with known clarity issues (Table 22). For Ōhau and Waikawa, estuary clarity improved under all scenarios, however field studies have shown that estuary clarity is currently on the threshold of the estuary One Plan target and that river clarity is likely lower than the modelled median river clarity, hence these estuaries were rated medium confidence (Stevens et al. 2020a; Stevens et al. 2020b; Roberts et al. 2021).

Estuaries showing significant clarity improvements under SPS2 and the "NPS-FM river clarity A-band" scenario were considered to have adequate protection from current sediment load reductions, despite baseline conditions predicting clarity levels below the One Plan target (highlighted green in Table 22).

Similar to visual clarity, *E. coli* data availability is limited for most estuaries, and many have therefore been rated as medium confidence. For east coast estuaries (i.e., Wainui, Ākitio and Owāhanga), where the BBN predicted poor outcomes for *E. coli*, and limited improvement under the reduction scenarios, these predictions were confirmed using river water quality and/or recreational bathing data sourced from LAWA (lawa.org.nz). In contrast, several estuaries were designated as low confidence and having an "uncertain" level of protection owing to elevated modelled concentration in rivers (data supplied by HRC) and/or "Poor" recreational bathing grades, indicating elevated *E. coli* levels despite the BBN predicting low concentrations (lawa.org.nz). As discussed in Section 4.3, the BBN tends to under predict *E. coli* potential concentration because it does not account for high-flow events when *E. coli* concentrations tend to be high. Despite this, *E. coli* predictions were rated with medium confidence, because although state predictions only have moderate reliability, the BBN remains useful for assessing relative changes in *E. coli* concentration with sediment load reductions (via median river clarity) across different scenarios.

Estuaries showing significant improvements in *E. coli* potential under SPS2 and the "NPS-FM river clarity A-band" scenario were considered to have adequate protection from current sediment load reductions, despite baseline conditions predicting *E. coli* levels above the One Plan target (highlighted green in Table 22). Estuaries with low confidence, uncertain protection, or no improvements from sediment load reductions require further investigation.

6. SYNTHESIS OF KEY FINDINGS FROM STAGE 1 & 2

For estuaries where load reductions do not meet One Plan targets and remain vulnerable, or where outcomes are uncertain, priorities for further investigation and management need to be considered. Determining whether or not, and to what extent, further investigation is necessary or worthwhile can be guided by the outcomes of the Stage 1 Ecology Vulnerability Assessment (EVA; Roberts et al. 2025) together with the findings of the Stage 2 assessment in this report.

6.1 STAGE 1 – ECOLOGY VULNERABILITY ASSESSMENT

A summary of the key findings of the Stage 1 EVA is as follows:

- The highest ecological values were recorded in Rangitikei, Manawatū, Ōhau, Waikawa, Tautāne, Wainui and Waimata estuaries. The ratings were primarily driven by the relatively high percentage of salt marsh habitat, the presence of significant species, and the current level of estuary protection.
- Four of the estuaries with the highest ecological values (Manawatū, Ōhau, Waikawa and Wainui) were also ranked in the poorest condition. Other estuaries in relatively poor condition included Whanganui, Turakina, Ākitio and Owāhanga.
- Whanganui, Manawatū and Waikawa were considered under the highest pressure and had high susceptibility to change. Kaikokopu and Hōkio had moderate pressures scores and a high susceptibility to change.

Whanganui Estuary, 2025.

6.2 STAGE 2 – RISK ASSESSMENT

A summary of the Stage 2 Risk Assessment results from the present report is presented in bullet points below, and in Table 21 and Table 22, with more detail presented in Sections 4 and 5:

- The BBN predicted several estuaries to have persistent eutrophication issues (e.g., phytoplankton, low dissolved oxygen and/or macroalgae) despite nutrient load reductions. At-risk estuaries include Turakina, Hōkio, Ōhau, Waikawa, Tautāne, Wainui, Papuka, Ākitio and Owāhanga. Five estuaries were deemed to have an uncertain level of protection for phytoplankton and dissolved oxygen, - Kai Iwi, Mōwhānau, Rangitikei Kaikokopu and Manawatū. Two estuaries had an uncertain level of protection for macroalgae, Ākitio and Owāhanga.
- Several estuaries showed limited improvement in estuary clarity despite sediment load reductions. West coast estuaries included Ototoka, Okehu, Mōwhānau, Kaitoke, Turakina, Koitiata, Pukepuke, Hōkio and Waiwiri, and all the east coast estuaries.
- All estuaries, except Kaitoke, showed improvement in *E. coli* potential with sediment load reductions. However, twelve estuaries were classified as low confidence with an uncertain level of protection. Field data collected under a range of flow conditions indicates higher levels of *E. coli* in these estuaries than what is predicted under mean flow conditions in the BBN. Without testing more flow scenarios, it remains unclear whether *E. coli* will remain above the One Plan target regardless of load reductions.

6.3 ESTUARIES PRIORITISED FOR FURTHER WORK

From the original list of 41 estuaries assessed in the Stage 1 EVA, 25 required further evaluation in Stage 2 (this report) to assess whether load reduction requirements would protect estuary health. Results from both Stage 1 and Stage 2 have been used to prioritise estuaries for further work, focusing on important systems where load reductions are unlikely to meet One Plan targets for the protection estuary health or human use. Priorities are listed in Table 23 and summarised as follows:

- **Priority 1** estuaries had high ecological values, are currently in poor condition and were deemed either at-risk or had an uncertain level of protection from load reductions.
- **Priority 2** estuaries are currently in poor condition and were deemed either at-risk or had an uncertain level of protection from load reductions.
- **Priority 3** estuaries were deemed either at-risk or had an uncertain level of protection from load reductions.

Most estuaries classified as **Priority 3** estuaries were at-risk of poor estuary clarity and/or elevated *E. coli* potential. Due to the lack of available data on estuary clarity, the findings in this report should be verified before any extensive work is undertaken in these estuaries.

Table 23. Estuaries prioritised based on the information in Stage 1 (Roberts et al. 2025) and Stage 2 (current report). The indicators that require further investigations are highlighted in brackets, including nutrient indicators (N), estuary clarity (S) and *E. coli* potential (E).

Priority 1	Priority 2	Priority 3[1]
Rangitikei (N, E)	Kai Iwi (N, E)[3]	Papuka (N, S, E)
Manawatū (N, E)	Mōwhānau (N, S, E)[3]	Ototoka (S)
Ōhau (N)	Turakina (N, S, E)[2]	Okehu (S, E)
Waikawa (N, E)	Kaikokopu (N, E)[3]	Kaitoke (S, E)
Tautāne (N, S)	Hōkio (N, S)[3]	Whangaehu (E)
Wainui (N, S)	Ākitio (N, S)[2]	Koitiata (S)
Waimata (N, S)	Owāhanga (N, S)[2]	Pukepuke (S)
	Whanganui (E)[2]	Wairarawa (E)
		Waiwiri (S)

[1]Three Mile Creek was protected under all scenarios and indicators; [2]Poor condition recorded in Roberts et al. (2025); [3]Poor condition recorded in Dudley et al. (2024).

7. RECOMMENDATIONS

Recommendations are based on a pragmatic approach that initially focuses on improving the BBN's predictive capability, particularly for estuaries where the level of protection is "uncertain". However, it is reiterated that the BBN is most useful in assessing relative change under different scenarios to guide management decisions, but should not be used to set absolute load reductions. Where estuaries remain vulnerable regardless of load reductions, more comprehensive field and/or modelling investigations are likely required. Below is a list of general recommendations or approaches for consideration, as well as some estuary-specific considerations.

7.1 GENERAL RECOMMENDATIONS

7.1.1 Modelling

- BBNs have been used in New Zealand (e.g., Bulmer & Hewitt 2020; Bulmer et al. 2022; Zeldis & Plew 2022) and internationally (e.g., Shenton et al. 2010; Shenton et al. 2014; McDonald et al. 2016) as a management support tool for freshwater and estuaries. The Horizons BBN created in this project was based on best available information. Where data were limited, expert judgement was used to create the CPTs. To improve the BBN's predictive capability, the relationship between node connections can be refined as more data become available. Specifically, the relationship between river and estuary clarity would benefit from refinement, as clarity data to verify this indicator for Horizons estuaries is currently limited or absent. This is considered the main requirement for further exploring load reductions in Priority 3 estuaries vulnerable to sediment-related indicators.
- Plew (2024) prepared a basic dilution modelling approach to assess an estuary's susceptibility to phytoplankton and macroalgae blooms. In general, the model, based on nutrient potential, tends to over-estimate macroalgae state in tidal river estuaries. This approach has been used by other councils to set load reductions (e.g., Plew 2020). However, for tidal river estuaries it is recommended that either the frequency of high flow events be included in the dilution model or it be applied in conjunction with the BBN (i.e., the dilution model is used to calculate inputs to the BBN; Appendix 1), as the BBN already accommodates for additional drivers that influence a eutrophic response, e.g., the number of high-flow events.
- Tuckey (2024) prepared a detailed hydrodynamic modelling output for Ōhau and Waikawa, projecting indicator state at several locations in each estuary, including bottom waters where phytoplankton and dissolved oxygen issues are most likely to occur. Tuckey (2024) presented the output as a spreadsheet calculator that HRC can adjust to test scenarios. While hydrodynamic modelling provides a robust means of assessing nutrient load reduction scenarios at the site level, it requires significant investment to develop, including the collection of field validation data, bathymetry, model preparation and scenario testing. Hydrodynamic modelling would be most appropriate for Priority 1 estuaries.

7.1.2 Collection of field data

- Surface water quality data are available for some Horizons estuaries; however, data gaps limit the ability to: (1) characterise the health of an estuary, (2) assess progress against One Plan targets, and (3) build relationships between driver and indicator nodes in the BBN. In a review of Horizons' estuarine water quality programme, Dudley et al. (2018) recommended collecting salinity, suspended sediment and visual clarity data at all estuary sites, in addition to *E. coli* monitoring. The present study further supports those recommendations. To more accurately understand the influence of stratification and associated eutrophication, bottom water sampling is also required, particularly to characterise estuary phytoplankton and dissolved oxygen dynamics. Additional field data collection would be most useful for Priority 1 and 2 estuaries to validate any BBN or modelling predictions, particularly where the level of protection was deemed uncertain.
- To improve the outputs of the dilution modelling (Plew 2024) and BBN predictions, the desktop-based Coastal Explorer data used to calculate estuary volume, tidal prism, and flushing time could be improved with the collection of field data (e.g., bathymetry, salinity profiles, depth). This is also supported by Dudley et al. (2018) and would be most useful initially for Priority 1 and 2 estuaries, particularly where the level of protection was assessed as uncertain. These improvements may be sufficient to test the effects of existing scenarios.
- Improving the linkages between the freshwater programme and the estuary programme would help to improve the relationships between driver nodes and indicators in the BBN. Particularly the inclusion of flow, alongside the general suite of water quality indicators (i.e., temperature, salinity, TN, SIN, Total Phosphorus, Dissolved Reactive Phosphorus, Chl-*a*,

DO, *E. coli*, pH, suspended sediment concentration, turbidity, visual clarity) at the terminal river reaches for Priority 1 estuaries, in particular. Noting that the terminal reach site should be far enough upstream from the estuary that it is not affected by tidal changes in flow or water levels.

7.2 ESTUARY-SPECIFIC RECOMMENDATIONS

Specific recommendations for Priority 1 and 2 estuaries are listed below. Lower cost recommendations have been recommended initially; noting that any data collected can support more detailed studies in future if additional confidence in load reductions is required.

7.2.1 Priority 1 estuaries

- **Rangitikei** and **Manawatū** are both estuaries of high ecological value that are currently in poor condition (Roberts et al. 2025). The confidence ratings for the BBN outputs in these estuaries were rated low due to the discrepancy between the BBN predictions and limited field observations, leading to uncertainty about whether freshwater load reductions would meet One Plan targets for the protection of estuary health or human use. To better understand the extent, duration and likelihood of nutrient-related issues, targeted monitoring would be beneficial. This could include synoptic water sampling in mid-to-late summer after a period of low flow, with water quality measurements of salinity, temperature, clarity, nutrients, phytoplankton and dissolved oxygen in both the surface and bottom waters. Sampling could be paired with other types of monitoring, such as habitat mapping. This information can be used to re-assess BBN predictions (and estimates of confidence) and determine whether more comprehensive investigations or modelling approaches are required.
- For **Ōhau** and **Waikawa**, use the hydrodynamic model outputs to further assess nutrient load reductions in those estuaries.
- In **Wainui**, the BBN consistently predicted a poor state for both nutrient related issues and clarity indicating more detailed studies are required for this estuary. For example, basic or complex hydrodynamic modelling or more comprehensive field sampling to assess the estuary's current condition against One Plan targets.
- **Tautāne** and **Waimata** are classified as intermittently closed and/ open lagoons, the only two estuaries of this type in the region. Tautāne is prone to both nutrient and clarity issues, placing high value *Ruppia* spp. at risk (Roberts et al. 2025). Improving Coastal Explorer data, as discussed under general recommendations, would be beneficial in these estuaries. Also, an improved understanding of the duration and frequency of entrance closures and/ or restrictions, conditions under which these estuaries are most vulnerable, would help in assessing the likelihood and persistence of nutrient-related issues. These data can then be used to assess relative changes in state with load reductions under MALF and MALF closed scenarios in the BBN.

7.2.2 Priority 2 estuaries

- **Priority 2** estuaries would initially benefit from the collection of field data on bathymetry, salinity, and depth to improve the Coastal Explorer predictions used in the BBN (i.e., estuary volume, tidal prism, flushing time), as discussed under general recommendations. This would require defining estuary bathymetry and collecting salinity profiles across tidal cycles to improve the physical characteristics used to calculate salinity and flushing time which are key driver nodes in the BBN. These data would improve the BBN's predictive capability. Where these estuaries remain at risk, more detailed work may be required (e.g., hydrodynamic modelling or detailed field studies).

Rangitikei Estuary 2016.

8. REFERENCES

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APPENDIX 1: INPUT DATA SOURCES USED IN THE BBN

Table A1.1. List of input data sources used in the BBN.

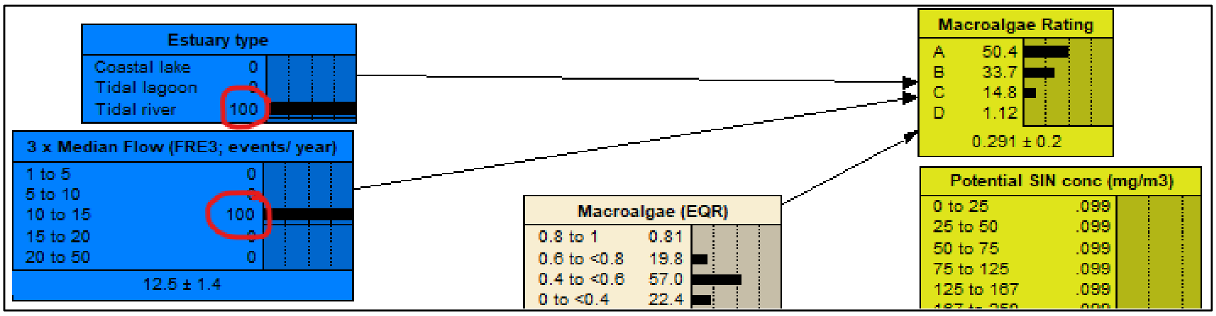
Input	Source
Estuary type	Roberts et al. (2025)
3 x Median Flow (FRE3)	NZ River maps* **For river reaches influenced by upstream lake outflows, where high-flow events are likely dampened. Henderson and Diettrich (2007) calculated FRE3 values for several lower catchment river sections in the Horizons region, including the Pukepuke Stream, which drains the Pukepuke Lagoon system. To account for the potential dampening effect of upstream lake/lagoon systems on flows, the proportional difference between the observed and modelled FRE3 was applied to reaches with upstream lake outflows.*
Potential TN	TN loads sourced from Tables 7 and 8 and input into the dilution model (Plew 2024)
Salinity	Dilution model for each flow scenario (mean flow, summer flow, MALF and MALF closed).
Seasonality	Seasonality was accounted for in the dilution model prepared by Plew (2024). As such, seasonality was set to 1.0 for all scenarios tested in this report. Where the dilution model is not used to calculate flushing time, salinity and Potential TN, the seasonality factor will need to be considered in the BBN.
Flushing	Dilution model for each flow scenario (mean flow, summer flow, MALF and MALF closed).
Water column stratification	Roberts et al. (2025)
Visual clarity – terminal reach	Modelled river clarity supplied by HRC <u>OR</u> River clarity calculated from sediment loads reductions: o Calculate the load reduction factor (LRF) based on the changes in sediment loads over time (e.g., baseline versus 2035 sediment load). Loads sourced from Tables 10 and 11. o Back calculate the clarity (Vt_{50}) for the given sediment load using the rearranged equation in Table 6, and reproduced below: $Vt_{50} = V_{50} (1 – LRF)^d$ Vt_{50} = target median clarity V_{50} = median clarity d = fixed exponent (-0.76 ± 0.13; Hicks et al. 2019). This equation can also be used in reverse to calculate the load reduction factor for a given scenario if the median clarity and target clarity are known.

APPENDIX 2: HOW TO RUN THE HORIZONS BBN

1. Download and install the freely available *Netica* software. Note no administration rights are required, and the **Horizons BBN** can be run using the free *Limited Mode* version of *Netica*.
2. Save the **Horizons_BBN.neta** file to the computer and open in *Netica*. **If prompted do not re-calculate or rebuild equations.*

The BBN can be run in two ways:

1. **Manually run a single estuary:** set the driver nodes (blue boxes) by clicking on the appropriate band. Do this for all driver nodes (see Fig. A2.1 below). The indicator nodes will automatically update with the predicted state under the set driver node inputs.



Fig, A2.1. Example of setting blue driver nodes in the Horizons BBN. By clicking on the appropriate band (i.e., number circled in red) the indicator nodes will automatically update with a predicted state.

2. **Run multiple estuaries simultaneously:** to run several estuaries at once, Netica's case file function can be used. The driver node inputs are uploaded to Netica in a tab delimited text file. To "Process Cases" (i.e., run multiple estuaries at once) two input files are needed:
   - A **"case file"** which describes the output format. The output format is defined using the node name (sourced by right clicking on the node and opening properties) and the summary metric (expval = expected value, stddev = standard deviation, belvec = probability of each node state or band). See example in Fig A2.2. Important! Names must exactly match the name in the node properties, if the name is incorrect the data will not read into Netica and it will assume the value is unknown.
   - An **"input file"** which contains the known inputs for the driver nodes. The estuary ID (i.e., Idnum) will need to be numeric as Netica will not accept full estuary names. See example in Fig. A2.3. Note tab delimited (.txt) files can be prepared in Microsoft Excel and converted to a tab delimited (.txt) file by using the "save as" function and changing the file type to "Text (Tab delimited) (*.txt)".
   - To **RUN,** select the "Cases" menu at the top of the Netica window and then "Process Cases"
     - First upload the **"case file"**
     - Then upload the **"input file"**
     - Then enter the name of the **"output file"** and choose the location where it will be saved. The output file will be in tab delimited format and can be opened in Microsoft Excel.
       - Note! A message stating "out of range" choose to expand will appear when a variable is greater than the designated bandings. If choose to expand is accepted, Netica will expand the last band to accommodate for the higher number and keep the conditional probability table the same.
       - Note! If an error message states that "at least one finding is entered" select "YES" to "retract all findings". This means that variables have been manually altered in the BBN, by selecting "YES" the BBN will reset and use the input data values.

```
IDnum()
expval (PotN)
stddev (PotN)
expval (sal)
stddev (sal)
expval (PotSIN)
stddev (PotSIN)
expval (Macroalgae)
stddev (Macroalgae)
expval (Macro_std)
stddev (Macro_std)
expval (Phyto)
stddev (Phyto)
expval (Phyto_std)
stddev (Phyto_std)
expval (Oxygen)
stddev (Oxygen)
expval (CLAR_V50)
stddev (CLAR_V50)
expval (CLAR_VC_E)
stddev (CLAR_VC_E)
expval (VC_T50)
stddev (VC_T50)
expval (Turb)
stddev (Turb)
expval (ECOLI1)
stddev (ECOLI1)
```

Fig. A2.2. Example of the “casefile” used in this report.

Idnum	EstType	FRE3	PotN	sal	Seasonality	Flushing	Stratification	CLAR_V50
2	SSRTRE	14.800	1083.647142	4.8873	0.6370	0.170	No	0.841
3	SSRTRE	13.800	1471.019461	8.9752	0.6327	0.287	Yes	1.021
4	SSRTRE	14.600	1380.499161	12.1647	0.7550	0.454	No	0.787
5	SSRTRE	13.010	332.9782384	12.6599	0.6228	0.788	Yes	0.941
6	SSRTRE	4.062	1037.15606	6.8189	0.8792	0.205	No	0.629
7	SSRTRE	10.860	390.997053	11.6374	0.6783	0.506	No	1.033
8	SSRTRE	13.520	1115.233884	16.9696	0.6826	1.955	Yes	0.676
9	SSRTRE	3.550	2697.109314	8.0033	0.9264	0.240	No	0.620
10	SSRTRE	9.700	374.3840849	10.6675	0.6313	0.440	No	0.998
14	SSRTRE	12.370	433.8104151	14.9017	0.6407	1.449	Yes	0.736
16	SSRTRE	4.862	730.7892611	16.4508	0.7935	1.314	Yes	0.753
17	SSRTRE	5.405	1030.50197	14.8876	0.8102	0.843	No	0.743
18	SSRTRE	15.700	197.6403037	16.0911	0.6581	1.510	Yes	1.565
19	SSRTRE	16.400	329.3758334	16.2726	0.6617	1.633	Yes	1.177
21	SSRTRE	14.300	648.7490285	14.5826	0.7312	1.180	Yes	0.552
24	SSRTRE	12.900	958.322589	17.2634	0.6174	3.293	Yes	0.562
25	SSRTRE	15.600	567.7545377	18.4529	0.6440	3.658	Yes	0.648

Fig. A2.3. Example of “input file” used in this report for 17 estuaries under nutrient scenario 1 (summer flow).

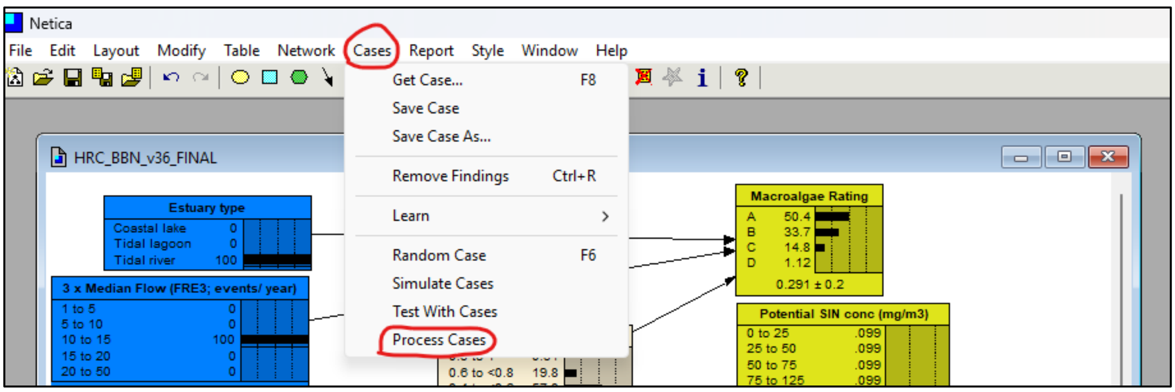


Fig. A2.4. Example of Netica menu used to run multiple estuaries simultaneously.

APPENDIX 3: BBN OUTPUT FOR NUTRIENT POLICY SCENARIOS

Tables A3.1 to A3.4 present the BBN outputs for the four nutrient scenarios described in Section 3.1.1 under four different flow scenarios.

Table A3.5 presents the horticulture scenarios (Scenario 5a-e) for Hōkio Estuary. Other estuaries were not presented as reductions were only recorded for Hōkio.

Sediment targets are not presented as they are not affected by the nutrient load scenarios.

<u>The following ratings were applied to the BBN outputs:</u>

Condition rating for macroalgae, phytoplankton and dissolved oxygen outlined in Tables 2 to 3:

A *Minimal eutrophication*	B *Moderate eutrophication*	C *High eutrophication*	D *Very high eutrophication*

Note: Dissolved oxygen of >70% saturation is ~6mg/L at 20°C (Table 1).

Condition rating for SIN based on exceedance (Fail) of One Plan target outlined in Table 1.

It should be acknowledged that potential SIN concentrations are likely higher than the measured SIN concentrations in the estuary, where consumption and transformation processes occur. Using absolute values in this context may therefore be misleading, and proportional improvements are more appropriate.

Pass	Fail

Table A3.1. BBN output for SIN concentration (mg/m^3; left) and percent improvement from baseline (right), based on baseline nutrient loads and four nutrient policy scenarios across four flow conditions.

Mean flow - SIN (mg/m^3)

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	1520	1296	973	1520	973
Kai Iwi	1809	1750	1505	1809	1505
Mōwhānau	1656	1392	1049	1656	1049
Whanganui	394	372	307	394	307
Kaitoke	946	915	703	946	703
Whangaehu	431	407	336	431	336
Turakina	1347	1260	1041	1345	1040
Koitiata	2852	2286	1424	2852	1424
Rangitikei	449	411	327	443	321
Manawatū	540	478	388	484	332
Hōkio	765	662	572	765	572
Waiwiri	980	914	855	980	855
Ōhau	219	195	157	219	157
Waikawa	386	332	264	386	264
Wainui	705	689	598	705	598
Ākitio	1208	1169	1004	1208	1004
Owāhanga	684	658	560	684	560
Ōhau_DHI	322	287	232	322	232
Waikawa_DHI	480	413	329	480	329

Mean flow - SIN % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	15	36	0	36
Kai Iwi	-	3	17	0	17
Mōwhānau	-	16	37	0	37
Whanganui	-	6	22	0	22
Kaitoke	-	3	26	0	26
Whangaehu	-	5	22	0	22
Turakina	-	6	23	0	23
Koitiata	-	20	50	0	50
Rangitikei	-	8	27	1	28
Manawatū	-	12	28	10	39
Hōkio	-	14	25	0	25
Waiwiri	-	7	13	0	13
Ōhau	-	11	28	0	28
Waikawa	-	14	32	0	32
Wainui	-	2	15	0	15
Ākitio	-	3	17	0	17
Owāhanga	-	4	18	0	18
Ōhau_DHI	-	11	28	0	28
Waikawa_DHI	-	14	32	0	32

Summer (Feb) flow - SIN (mg/m^3)

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	829	706	529	829	529
Kai Iwi	998	965	830	998	830
Mōwhānau	1077	905	681	1077	681
Whanganui	217	205	168	217	168
Kaitoke	699	675	519	699	519
Whangaehu	258	244	200	258	200
Turakina	778	728	601	777	600
Koitiata	2226	1785	1111	2226	1111
Rangitikei	254	232	184	251	181
Manawatū	308	272	220	276	188
Hōkio	544	471	406	544	406
Waiwiri	720	671	628	720	628
Ōhau	129	114	92	129	92
Waikawa	236	202	160	236	160
Wainui	426	416	361	426	361
Ākitio	644	623	534	644	534
Owāhanga	376	362	308	376	307
Ōhau_DHI	183	163	130	183	130
Waikawa_DHI	289	248	197	289	197

Summer (Feb) flow - SIN % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	15	36	0	36
Kai Iwi	-	3	17	0	17
Mōwhānau	-	16	37	0	37
Whanganui	-	6	22	0	22
Kaitoke	-	3	26	0	26
Whangaehu	-	6	22	0	22
Turakina	-	6	23	0	23
Koitiata	-	20	50	0	50
Rangitikei	-	8	27	1	29
Manawatū	-	12	29	10	39
Hōkio	-	13	25	0	25
Waiwiri	-	7	13	0	13
Ōhau	-	11	29	0	29
Waikawa	-	14	32	0	32
Wainui	-	2	15	0	15
Ākitio	-	3	17	0	17
Owāhanga	-	4	18	0	18
Ōhau_DHI	-	11	29	0	29
Waikawa_DHI	-	14	32	0	32

Mean annual low flow (MALF) - SIN (mg/m^3)

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	730	622	466	730	466
Kai Iwi	926	896	770	926	770
Mōwhānau	922	774	583	922	583
Whanganui	188	177	146	188	146
Kaitoke	513	496	381	513	381
Whangaehu	237	224	184	237	184
Turakina	700	655	541	699	540
Koitiata	1977	1585	986	1977	986
Rangitikei	214	195	155	210	152
Manawatū	278	245	198	249	169
Hōkio	473	409	353	473	353
Waiwiri	633	590	552	633	552
Ōhau	105	93	75	105	75
Waikawa	197	169	134	197	134
Wainui	307	299	260	307	260
Ākitio	591	572	491	591	491
Owāhanga	313	301	256	313	256
Ōhau_DHI	139	123	99	139	99
Waikawa_DHI	233	200	158	233	158

MALF - SIN % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	15	36	0	36
Kai Iwi	-	3	17	0	17
Mōwhānau	-	16	37	0	37
Whanganui	-	6	22	0	22
Kaitoke	-	3	26	0	26
Whangaehu	-	6	22	0	22
Turakina	-	6	23	0	23
Koitiata	-	20	50	0	50
Rangitikei	-	9	28	1	29
Manawatū	-	12	29	10	39
Hōkio	-	14	25	0	25
Waiwiri	-	7	13	0	13
Ōhau	-	11	29	0	29
Waikawa	-	14	32	0	32
Wainui	-	2	15	0	15
Ākitio	-	3	17	0	17
Owāhanga	-	4	18	0	18
Ōhau_DHI	-	11	29	0	29
Waikawa_DHI	-	14	32	0	32

MALF CLOSED - SIN (mg/m^3)

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	962	819	613	962	613
Kai Iwi	1336	1292	1111	1336	1111
Mōwhānau	1640	1377	1037	1640	1037
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	865	836	642	865	642
Whangaehu	384	363	298	384	298
Turakina	1491	1395	1152	1489	1150
Koitiata	2874	2304	1434	2874	1434
Rangitikei	364	333	264	359	259
Manawatū	532	470	380	476	325
Hōkio	1016	878	758	1016	758
Waiwiri	1240	1156	1082	1240	1082
Ōhau	236	210	168	236	168
Waikawa	436	375	297	436	297
Wainui	721	704	611	721	611
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	781	751	638	781	638
Ōhau_DHI	236	210	168	236	168
Waikawa_DHI	436	375	297	436	297

MALF CLOSED - SIN % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	15	36	0	36
Kai Iwi	-	3	17	0	17
Mōwhānau	-	16	37	0	37
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	-	3	26	0	26
Whangaehu	-	6	22	0	22
Turakina	-	6	23	0	23
Koitiata	-	20	50	0	50
Rangitikei	-	9	28	1	29
Manawatū	-	12	29	10	39
Hōkio	-	14	25	0	25
Waiwiri	-	7	13	0	13
Ōhau	-	11	29	0	29
Waikawa	-	14	32	0	32
Wainui	-	2	15	0	15
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	-	4	18	0	18
Ōhau_DHI	-	11	29	0	29
Waikawa_DHI	-	14	32	0	32

Table A3.2. BBN output for macroalgae state (left) and percent improvement from baseline (right), based on baseline nutrient loads and four nutrient policy scenarios across four flow conditions.

Mean flow - Macroalgae state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	B	B	B	B	B
Kai Iwi	B	B	B	B	B
Mōwhānau	B	B	B	B	B
Whanganui	B	B	B	B	B
Kaitoke	C	C	C	C	C
Whangaehu	B	B	B	B	B
Turakina	B	B	B	B	B
Koitiata	D	D	D	D	D
Rangitikei	C	C	B	C	B
Manawatū	B	B	B	B	B
Hōkio	D	D	D	D	D
Waiwiri	C	C	C	C	C
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	B	B	B	B	B
Ākitio	B	B	B	B	B
Owāhanga	A	A	A	A	A
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

Mean flow - Macroalgae % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	7	7	0	7
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	4	11	0	11
Kaitoke	-	0	0	0	0
Whangaehu	-	0	4	0	4
Turakina	-	0	0	0	0
Koitiata	-	0	1	0	1
Rangitikei	-	0	17	0	17
Manawatū	-	0	2	0	6
Hōkio	-	0	3	0	3
Waiwiri	-	0	0	0	0
Ōhau	-	0	8	0	8
Waikawa	-	9	18	0	18
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	2	0	2
Ōhau_DHI	-	3	4	0	4
Waikawa_DHI	-	9	18	0	18

Summer (Feb) flow - Macroalgae state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	B	B	A	B	A
Kai Iwi	B	B	B	B	B
Mōwhānau	B	B	B	B	B
Whanganui	A	A	A	A	A
Kaitoke	D	D	D	D	D
Whangaehu	B	A	A	B	A
Turakina	B	B	B	B	B
Koitiata	D	D	D	D	D
Rangitikei	B	B	B	B	A
Manawatū	B	B	A	B	A
Hōkio	D	D	C	D	C
Waiwiri	C	C	C	C	C
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	B	B	B	B	B
Ākitio	B	B	B	B	B
Owāhanga	A	A	A	A	A
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

Summer (Feb) flow - Macroalgae % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	18	0	18
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	19	0	19
Kaitoke	-	0	3	0	3
Whangaehu	-	13	13	0	13
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	22	22	0	42
Manawatū	-	0	13	0	13
Hōkio	-	0	14	0	14
Waiwiri	-	0	3	0	3
Ōhau	-	5	5	0	5
Waikawa	-	0	8	0	8
Wainui	-	0	4	0	4
Ākitio	-	0	0	0	0
Owāhanga	-	0	9	0	9
Ōhau_DHI	-	8	8	0	8
Waikawa_DHI	-	8	8	0	8

Mean annual low flow (MALF) - Macroalgae state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	B	B	B	B	B
Kai Iwi	B	B	B	B	B
Mōwhānau	B	B	B	B	B
Whanganui	A	A	A	A	A
Kaitoke	D	D	C	D	C
Whangaehu	A	A	A	A	A
Turakina	B	B	B	B	B
Koitiata	D	D	D	D	D
Rangitikei	B	B	A	B	A
Manawatū	B	A	A	A	A
Hōkio	D	C	C	D	C
Waiwiri	C	C	C	C	C
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	B	B	B	B	B
Ākitio	B	B	B	B	B
Owāhanga	A	A	A	A	A
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

MALF - Macroalgae % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	19	19	0	19
Kaitoke	-	0	28	0	28
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	26	0	26
Manawatū	-	13	13	13	30
Hōkio	-	14	28	0	28
Waiwiri	-	0	0	0	0
Ōhau	-	0	2	0	2
Waikawa	-	8	8	0	8
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	5	0	5
Waikawa_DHI	-	0	8	0	8

MALF CLOSED - Macroalgae state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	B	B	A	B	A
Kai Iwi	B	B	B	B	B
Mōwhānau	B	B	B	B	B
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	C	C	B	C	B
Whangaehu	A	A	A	A	A
Turakina	B	B	B	B	B
Koitiata	D	D	D	D	D
Rangitikei	A	A	A	A	A
Manawatū	A	A	A	A	A
Hōkio	C	C	C	C	C
Waiwiri	B	B	B	B	B
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	B	B	A	B	A
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	A	A	A	A	A
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

MALF CLOSED - Macroalgae % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	18	0	18
Kai Iwi	-	7	7	0	7
Mōwhānau	-	0	7	0	7
Whanganui	-	0	13	0	13
Kaitoke	-	0	37	0	37
Whangaehu	-	19	30	0	30
Turakina	-	0	7	0	7
Koitiata	-	0	1	0	1
Rangitikei	-	0	17	0	17
Manawatū	-	0	36	0	36
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	5	8	0	8
Wainui	-	0	18	0	18
Ākitio	-	0	0	0	0
Owāhanga	-	0	17	0	17
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	5	8	0	8

Table A3.3. BBN output for phytoplankton state (left) and percent improvement from baseline (right), based on baseline nutrient loads and four nutrient policy scenarios across four flow conditions.

Mean flow - Phytoplankton state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	A	A	A	A	A
Kai Iwi	A	A	A	A	A
Mōwhānau	A	A	A	A	A
Whanganui	A	A	A	A	A
Kaitoke	A	A	A	A	A
Whangaehu	A	A	A	A	A
Turakina	A	A	A	A	A
Koitiata	A	A	A	A	A
Rangitikei	A	A	A	A	A
Manawatū	A	A	A	A	A
Hōkio	A	A	A	A	A
Waiwiri	A	A	A	A	A
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	A	A	A	A	A
Ākitio	A	A	A	A	A
Owāhanga	A	A	A	A	A
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

Mean flow - Phytoplankton % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	0	0	0	0
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

Summer (Feb) flow - Phytoplankton state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	A	A	A	A	A
Kai Iwi	A	A	A	A	A
Mōwhānau	A	A	A	A	A
Whanganui	A	A	A	A	A
Kaitoke	A	A	A	A	A
Whangaehu	A	A	A	A	A
Turakina	A	A	A	A	A
Koitiata	A	A	A	A	A
Rangitikei	A	A	A	A	A
Manawatū	A	A	A	A	A
Hōkio	A	A	A	A	A
Waiwiri	A	A	A	A	A
Ōhau	A	A	A	A	A
Waikawa	A	A	A	A	A
Wainui	A	A	A	A	A
Ākitio	D	D	D	D	D
Owāhanga	C	C	C	C	C
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

Summer (Feb) flow - Phytoplankton % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	0	0	0	0
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	2	0	2
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

Mean annual low flow (MALF) - Phytoplankton state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	A	A	A	A	A
Kai Iwi	A	A	A	A	A
Mōwhānau	A	A	A	A	A
Whanganui	A	A	A	A	A
Kaitoke	A	A	A	A	A
Whangaehu	A	A	A	A	A
Turakina	D	D	D	D	D
Koitiata	A	A	A	A	A
Rangitikei	A	A	A	A	A
Manawatū	A	A	A	A	A
Hōkio	D	C	C	D	C
Waiwiri	A	A	A	A	A
Ōhau	C	C	B	C	B
Waikawa	C	C	C	C	C
Wainui	D	D	D	D	D
Ākitio	D	D	D	D	D
Owāhanga	D	D	D	D	D
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	A	A	A	A	A

MALF - Phytoplankton % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	2	0	2
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	1	2	0	2
Waiwiri	-	0	0	0	0
Ōhau	-	0	25	0	25
Waikawa	-	5	5	0	5
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

MALF CLOSED - Phytoplankton state

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	A	A	A	A	A
Kai Iwi	A	A	A	A	A
Mōwhānau	A	A	A	A	A
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	A	A	A	A	A
Whangaehu	A	A	A	A	A
Turakina	D	D	D	D	D
Koitiata	A	A	A	A	A
Rangitikei	A	A	A	A	A
Manawatū	D	D	C	D	C
Hōkio	D	D	D	D	D
Waiwiri	D	D	D	D	D
Ōhau	C	C	C	C	C
Waikawa	D	D	C	D	C
Wainui	D	D	D	D	D
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	D	D	D	D	D
Ōhau_DHI	A	A	A	A	A
Waikawa_DHI	C	C	C	C	C

MALF CLOSED - Phytoplankton % improvement

Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	11	0	11
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	6	0	6
Waikawa	-	7	29	0	29
Wainui	-	0	0	0	0
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	10	29	0	29

Table A3.4. BBN output for dissolved oxygen (mg/L: left) and percent improvement from baseline (right), based on baseline nutrient loads and four nutrient policy scenarios across four flow conditions.

Mean flow - Dissolved oxygen (mg/L)					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	7.50	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50	7.50
Turakina	7.47	7.47	7.47	7.47	7.47
Koitiata	7.50	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47	7.47
Hōkio	7.47	7.47	7.47	7.47	7.47
Waiwiri	7.50	7.50	7.50	7.50	7.50
Ōhau	7.47	7.47	7.47	7.47	7.47
Waikawa	7.47	7.47	7.47	7.47	7.47
Wainui	7.47	7.47	7.47	7.47	7.47
Ākitio	7.47	7.47	7.47	7.47	7.47
Owāhanga	7.47	7.47	7.47	7.47	7.47
Ōhau_DHI	7.47	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47	7.47

Mean flow - Dissolved oxygen % improvement					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	0	0	0	0
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

Summer (Feb) flow - Dissolved oxygen (mg/L)					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	7.50	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50	7.50
Turakina	7.47	7.47	7.47	7.47	7.47
Koitiata	7.50	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47	7.47
Hōkio	7.47	7.47	7.47	7.47	7.47
Waiwiri	7.50	7.50	7.50	7.50	7.50
Ōhau	7.47	7.47	7.47	7.47	7.47
Waikawa	7.47	7.47	7.47	7.47	7.47
Wainui	7.47	7.47	7.47	7.47	7.47
Ākitio	4.91	4.91	4.91	4.91	4.91
Owāhanga	4.97	4.97	5.01	4.97	5.01
Ōhau_DHI	7.47	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47	7.47

Summer (Feb) flow - Dissolved oxygen % improvement					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	0	0	0	0
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	1	0	1
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

Mean annual low flow (MALF) - Dissolved oxygen (mg/L)					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	7.50	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50	7.50
Turakina	4.86	4.86	4.91	4.86	4.91
Koitiata	7.50	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47	7.47
Hōkio	4.91	4.95	4.97	4.91	4.97
Waiwiri	7.50	7.50	7.50	7.50	7.50
Ōhau	5.42	5.42	5.86	5.42	5.86
Waikawa	5.08	5.21	5.21	5.08	5.21
Wainui	4.50	4.50	4.50	4.50	4.50
Ākitio	4.91	4.91	4.91	4.91	4.91
Owāhanga	4.50	4.50	4.50	4.50	4.50
Ōhau_DHI	7.47	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47	7.47

MALF - Dissolved oxygen % improvement					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	-	0	0	0	0
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	1	0	1
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	0	0	0
Hōkio	-	1	1	0	1
Waiwiri	-	0	0	0	0
Ōhau	-	0	8	0	8
Waikawa	-	3	3	0	3
Wainui	-	0	0	0	0
Ākitio	-	0	0	0	0
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	0	0	0	0

MALF CLOSED - Dissolved oxygen (mg/L)					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	7.50	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50	7.50
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	7.50	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50	7.50
Turakina	4.50	4.50	4.50	4.50	4.50
Koitiata	7.50	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50	7.50
Manawatū	4.91	4.91	4.97	4.91	4.97
Hōkio	4.50	4.50	4.50	4.50	4.50
Waiwiri	6.98	6.98	6.98	6.98	6.98
Ōhau	4.50	4.50	4.50	4.50	4.50
Waikawa	4.50	4.50	4.50	4.50	4.50
Wainui	4.50	4.50	4.50	4.50	4.50
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	4.50	4.50	4.50	4.50	4.50
Ōhau_DHI	7.47	7.47	7.47	7.47	7.47
Waikawa_DHI	4.95	4.97	5.01	4.95	5.01

MALF CLOSED - Dissolved oxygen % improvement					
Estuary name	Baseline	NPS1	NPS2	NPS3	NPS4
Okehu	-	0	0	0	0
Kai Iwi	-	0	0	0	0
Mōwhānau	-	0	0	0	0
Whanganui	*Entrance modified to remain permanently open*				
Kaitoke	-	0	0	0	0
Whangaehu	-	0	0	0	0
Turakina	-	0	0	0	0
Koitiata	-	0	0	0	0
Rangitikei	-	0	0	0	0
Manawatū	-	0	1	0	1
Hōkio	-	0	0	0	0
Waiwiri	-	0	0	0	0
Ōhau	-	0	0	0	0
Waikawa	-	0	0	0	0
Wainui	-	0	0	0	0
Ākitio	*Entrance modified to remain permanently open*				
Owāhanga	-	0	0	0	0
Ōhau_DHI	-	0	0	0	0
Waikawa_DHI	-	1	1	0	1

Table A3.5. Hōkio Estuary BBN output for SIN, macroalgae, phytoplankton and dissolved oxygen state (left) and percent improvement from baseline (right) based on baseline nutrient loads and five horticulture policy scenarios (Scenarios 5a-e) under four different flows. Scenario 5 outputs were not presented for Waiwiri, Ōhau and Waikawa (Table 8) because the reductions were 0% resulting in no change to BBN outputs.

SIN (mg/m^3)

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	765	660	506	683	683	721
Summer (Feb) Flow	544	469	359	486	486	512
MALF	473	407	312	422	422	445
MALF - Closed	1016	875	670	907	907	956

SIN % improvement

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	-	14	34	11	11	6
Summer (Feb) Flow	-	14	34	11	11	6
MALF	-	14	34	11	11	6
MALF - Closed	-	14	34	11	11	6

Macroalgae state

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	D	D	D	D	D	D
Summer (Feb) Flow	D	D	C	D	D	D
MALF	D	C	B	C	C	C
MALF - Closed	C	C	C	C	C	C

Macroalgae % improvement

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	-	0	3	0	0	0
Summer (Feb) Flow	-	0	28	0	0	0
MALF	-	14	41	14	14	14
MALF - Closed	-	0	0	0	0	0

Phytoplankton state

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	A	A	A	A	A	A
Summer (Feb) Flow	A	A	A	A	A	A
MALF	C	C	C	C	C	C
MALF - Closed	D	D	D	D	D	D

Phytoplankton % improvement

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	-	0	0	0	0	0
Summer (Feb) Flow	-	0	0	0	0	0
MALF	-	1	4	1	1	1
MALF - Closed	-	0	0	0	0	0

Dissolved oxygen (mg/L)

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	7.47	7.47	7.47	7.47	7.47	7.47
Summer (Feb) Flow	7.47	7.47	7.47	7.47	7.47	7.47
MALF	4.91	4.95	5.01	4.95	4.95	4.95
MALF - Closed	4.50	4.50	4.50	4.50	4.50	4.50

Dissolved oxygen % improvement

Flow scenario	Baseline	Scenario 5a	Scenario 5b	Scenario 5c	Scenario 5d	Scenario 5e
Mean flow	-	0	0	0	0	0
Summer (Feb) Flow	-	0	0	0	0	0
MALF	-	1	2	1	1	1
MALF - Closed	-	0	0	0	0	0

APPENDIX 4: BBN OUTPUT FOR FRESHWATER NUTRIENT LOAD REDUCTIONS

Tables A4.1 to A4.4 present the BBN outputs for the three nutrient reduction scenarios described in Section 3.1.2 under four different flow scenarios.

Sediment targets are not presented as they are not affected by the nutrient load scenarios.

<u>The following ratings were applied to the BBN outputs:</u>

Condition rating for macroalgae, phytoplankton and dissolved oxygen outlined in Tables 2 to 3:

A	B	C	D
Minimal eutrophication	*Moderate eutrophication*	*High eutrophication*	*Very high eutrophication*

Note: Dissolved oxygen of >70% saturation is ~6mg/L at 20°C (Table 1).

Condition rating for SIN based on exceedance (Fail) of One Plan target outlined in Table 1.

It should be acknowledged that potential SIN concentrations are likely higher than the measured SIN concentrations in the estuary, where consumption and transformation processes occur. Using absolute values in this context may therefore be misleading, and proportional improvements are more appropriate.

Pass	Fail

Table A4.1. BBN output for SIN concentration (mg/m^3; left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean flow - SIN (mg/m^3)				
Estuary name	Baseline	20UPR	25URP	30UPR
Ototoka	1204	414	560	645
Okehu	1520	520	705	812
Kai Iwi	1809	623	842	970
Mōwhānau	1656	571	771	888
Whanganui	394	207	280	333
Kaitoke	946	503	677	802
Whangaehu	431	226	275	324
Turakina	1347	559	654	777
Koitiata	2852	1188	1389	1647
Rangitikei	449	181	213	255
Pukepuke	10745	4505	5258	6226
Kaikokopu	191	70	85	103
3 Mile Creek	1240	513	601	714
Manawatū	540	82	181	270
Wairarawa	253	53	74	90
Hōkio	765	191	253	300
Waiwiri	980	246	325	385
Ōhau	219	49	67	81
Waikawa	386	92	124	148
Tautāne	704	168	282	396
Wainui	705	167	282	397
Papuka	735	176	295	415
Waimata	863	204	345	485
Ākitio	1208	295	490	685
Owāhanga	684	164	275	386
Ōhau_DHI	322	72	99	120
Waikawa_DHI	480	115	155	184

Mean flow - SIN % improvement				
Estuary name	Baseline	20UPR	25URP	30UPR
Ototoka	-	66	54	46
Okehu	-	66	54	47
Kai Iwi	-	66	53	46
Mōwhānau	-	66	53	46
Whanganui	-	48	29	15
Kaitoke	-	47	29	15
Whangaehu	-	47	36	25
Turakina	-	58	51	42
Koitiata	-	58	51	42
Rangitikei	-	60	53	43
Pukepuke	-	58	51	42
Kaikokopu	-	63	56	46
3 Mile Creek	-	59	52	42
Manawatū	-	85	66	50
Wairarawa	-	79	71	64
Hōkio	-	75	67	61
Waiwiri	-	75	67	61
Ōhau	-	78	69	63
Waikawa	-	76	68	62
Tautāne	-	76	60	44
Wainui	-	76	60	44
Papuka	-	76	60	44
Waimata	-	76	60	44
Ākitio	-	76	59	43
Owāhanga	-	76	60	44
Ōhau_DHI	-	78	69	63
Waikawa_DHI	-	76	68	62

Summer (Feb) flow - SIN (mg/m^3)				
Estuary name	Baseline	20UPR	25URP	30UPR
Ototoka	822	281	381	439
Okehu	829	280	381	441
Kai Iwi	998	341	462	533
Mōwhānau	1077	369	500	576
Whanganui	217	112	153	183
Kaitoke	699	371	499	592
Whangaehu	258	134	163	193
Turakina	778	321	376	447
Koitiata	2226	927	1084	1285
Rangitikei	254	100	118	142
Pukepuke	8173	3426	3999	4735
Kaikokopu	159	57	69	85
3 Mile Creek	905	373	437	520
Manawatū	308	44	101	152
Wairarawa	195	38	55	68
Hōkio	544	134	179	212
Waiwiri	720	179	238	282
Ōhau	129	26	37	45
Waikawa	236	54	74	88
Tautāne	443	104	176	248
Wainui	426	99	169	239
Papuka	478	113	191	269
Waimata	493	114	195	276
Ākitio	644	155	259	363
Owāhanga	376	89	150	211
Ōhau_DHI	183	37	53	65
Waikawa_DHI	289	66	90	108

Summer (Feb) flow - SIN % improvement				
Estuary name	Baseline	20UPR	25URP	30UPR
Ototoka	-	66	54	47
Okehu	-	66	54	47
Kai Iwi	-	66	54	47
Mōwhānau	-	66	54	46
Whanganui	-	48	29	16
Kaitoke	-	47	29	15
Whangaehu	-	48	37	25
Turakina	-	59	52	43
Koitiata	-	58	51	42
Rangitikei	-	61	53	44
Pukepuke	-	58	51	42
Kaikokopu	-	64	57	47
3 Mile Creek	-	59	52	43
Manawatū	-	86	67	51
Wairarawa	-	80	72	65
Hōkio	-	75	67	61
Waiwiri	-	75	67	61
Ōhau	-	80	71	65
Waikawa	-	77	69	63
Tautāne	-	77	60	44
Wainui	-	77	60	44
Papuka	-	76	60	44
Waimata	-	77	61	44
Ākitio	-	76	60	44
Owāhanga	-	76	60	44
Ōhau_DHI	-	80	71	65
Waikawa_DHI	-	77	69	62

Table A4.1 continued. BBN output for SIN concentration (mg/m³; left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean annual low flow (MALF) - SIN (mg/m³)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	791	271	367	423
Okehu	730	247	336	388
Kai Iwi	926	316	429	494
Mōwhānau	922	316	428	493
Whanganui	188	97	133	158
Kaitoke	513	272	366	434
Whangaehu	237	123	150	178
Turakina	700	289	339	402
Koitiata	1977	823	962	1141
Rangitikei	214	83	99	119
Pukepuke	8795	3686	4303	5096
Kaikokopu	95	34	41	51
3 Mile Creek	800	330	387	460
Manawatū	278	39	91	137
Wairarawa	115	22	32	40
Hōkio	473	116	155	184
Waiwiri	633	158	209	247
Ōhau	105	21	30	37
Waikawa	197	45	61	74
Tautāne	317	75	127	178
Wainui	307	72	122	172
Papuka	373	88	149	210
Waimata	358	83	142	201
Ākitio	591	142	238	334
Owāhanga	313	74	125	176
Ōhau_DHI	139	28	40	49
Waikawa_DHI	233	53	73	87

MALF - SIN % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	66	54	47
Okehu	-	66	54	47
Kai Iwi	-	66	54	47
Mōwhānau	-	66	54	47
Whanganui	-	49	30	16
Kaitoke	-	47	29	15
Whangaehu	-	48	37	25
Turakina	-	59	52	43
Koitiata	-	58	51	42
Rangitikei	-	61	54	44
Pukepuke	-	58	51	42
Kaikokopu	-	65	57	47
3 Mile Creek	-	59	52	43
Manawatū	-	86	67	51
Wairarawa	-	81	72	65
Hōkio	-	75	67	61
Waiwiri	-	75	67	61
Ōhau	-	80	71	65
Waikawa	-	77	69	63
Tautāne	-	76	60	44
Wainui	-	76	60	44
Papuka	-	76	60	44
Waimata	-	77	60	44
Ākitio	-	76	60	44
Owāhanga	-	76	60	44
Ōhau_DHI	-	80	71	65
Waikawa_DHI	-	77	69	63

MALF CLOSED - SIN (mg/m³)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	1471	503	682	786
Okehu	962	325	443	511
Kai Iwi	1336	456	619	713
Mōwhānau	1640	562	761	877
Whanganui	338	175	239	285
Kaitoke	865	459	618	733
Whangaehu	384	199	243	288
Turakina	1491	616	722	857
Koitiata	2874	1197	1399	1660
Rangitikei	364	143	169	204
Pukepuke	11780	4937	5763	6825
Kaikokopu	159	57	69	85
3 Mile Creek	1431	591	692	823
Manawatū	532	76	175	263
Wairarawa	206	40	58	72
Hōkio	1016	251	334	396
Waiwiri	1240	309	410	486
Ōhau	236	48	69	84
Waikawa	436	100	137	164
Tautāne	774	180	307	434
Wainui	721	167	285	403
Papuka	854	200	340	479
Waimata	672	155	265	376
Ākitio	1251	299	502	705
Owāhanga	781	182	310	437
Ōhau_DHI	236	48	69	84
Waikawa_DHI	436	100	137	164

MALF CLOSED - SIN % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	66	54	47
Okehu	-	66	54	47
Kai Iwi	-	66	54	47
Mōwhānau	-	66	54	46
Whanganui	-	48	29	16
Kaitoke	-	47	29	15
Whangaehu	-	48	37	25
Turakina	-	59	52	42
Koitiata	-	58	51	42
Rangitikei	-	61	53	44
Pukepuke	-	58	51	42
Kaikokopu	-	64	57	47
3 Mile Creek	-	59	52	43
Manawatū	-	86	67	51
Wairarawa	-	80	72	65
Hōkio	-	75	67	61
Waiwiri	-	75	67	61
Ōhau	-	80	71	64
Waikawa	-	77	69	62
Tautāne	-	77	60	44
Wainui	-	77	60	44
Papuka	-	77	60	44
Waimata	-	77	61	44
Ākitio	-	76	60	44
Owāhanga	-	77	60	44
Ōhau_DHI	-	80	71	64
Waikawa_DHI	-	77	69	62

Table A4.2. BBN output for macroalgae state (left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean flow - Macroalgae state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	B	B	B	B
Okehu	B	A	B	B
Kai Iwi	B	B	B	B
Mōwhānau	B	B	B	B
Whanganui	B	A	B	B
Kaitoke	C	B	C	C
Whangaehu	B	A	B	B
Turakina	B	B	B	B
Koitiata	D	C	D	D
Rangitikei	C	A	B	B
Pukepuke	D	D	D	D
Kaikokopu	A	A	A	A
3 Mile Creek	D	D	D	D
Manawatū	B	A	A	B
Wairarawa	A	A	A	A
Hōkio	D	B	B	B
Waiwiri	C	B	B	C
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	D	B	C	C
Wainui	B	A	B	B
Papuka	B	A	B	B
Waimata	C	A	A	B
Ākitio	B	B	B	B
Owāhanga	A	A	A	A
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

Mean flow - Macroalgae % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	3	0	0
Okehu	-	24	7	7
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	23	11	4
Kaitoke	-	37	0	0
Whangaehu	-	23	11	4
Turakina	-	0	0	0
Koitiata	-	32	1	1
Rangitikei	-	61	48	33
Pukepuke	-	0	0	0
Kaikokopu	-	1	1	1
3 Mile Creek	-	3	3	0
Manawatū	-	54	39	13
Wairarawa	-	1	1	1
Hōkio	-	56	43	43
Waiwiri	-	57	31	18
Ōhau	-	16	14	14
Waikawa	-	34	31	31
Tautāne	-	70	43	15
Wainui	-	40	14	3
Papuka	-	40	14	3
Waimata	-	79	71	42
Ākitio	-	14	0	0
Owāhanga	-	38	27	11
Ōhau_DHI	-	4	4	4
Waikawa_DHI	-	40	37	32

Summer (Feb) flow - Macroalgae state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	B	B	B	B
Okehu	B	A	A	A
Kai Iwi	B	B	B	B
Mōwhānau	B	B	B	B
Whanganui	A	A	A	A
Kaitoke	D	C	D	D
Whangaehu	B	A	A	A
Turakina	B	B	B	B
Koitiata	D	D	D	D
Rangitikei	B	A	A	A
Pukepuke	D	D	D	D
Kaikokopu	A	A	A	A
3 Mile Creek	D	C	C	D
Manawatū	B	A	A	A
Wairarawa	A	A	A	A
Hōkio	D	A	A	B
Waiwiri	C	A	B	B
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	C	A	B	B
Wainui	B	A	A	A
Papuka	B	A	A	B
Waimata	D	A	B	C
Ākitio	B	A	B	B
Owāhanga	A	A	A	A
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

Summer flow - Macroalgae % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	14	7	3
Okehu	-	55	48	35
Kai Iwi	-	7	0	0
Mōwhānau	-	7	0	0
Whanganui	-	33	19	0
Kaitoke	-	30	3	3
Whangaehu	-	30	30	13
Turakina	-	7	7	3
Koitiata	-	0	0	0
Rangitikei	-	55	42	42
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	30	17	3
Manawatū	-	50	41	30
Wairarawa	-	0	0	0
Hōkio	-	67	67	55
Waiwiri	-	68	57	45
Ōhau	-	9	9	9
Waikawa	-	14	14	12
Tautāne	-	74	65	49
Wainui	-	48	38	23
Papuka	-	49	25	13
Waimata	-	77	56	41
Ākitio	-	39	13	6
Owāhanga	-	27	23	17
Ōhau_DHI	-	16	14	14
Waikawa_DHI	-	22	20	20

Table A4.2 continued. BBN output for macroalgae state (left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean annual low flow (MALF) - Macroalgae state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	B	B	B	B
Okehu	B	A	B	B
Kai Iwi	B	B	B	B
Mōwhānau	B	B	B	B
Whanganui	A	A	A	A
Kaitoke	D	B	C	C
Whangaehu	A	A	A	A
Turakina	B	B	B	B
Koitiata	D	D	D	D
Rangitikei	B	A	A	A
Pukepuke	D	D	D	D
Kaikokopu	A	A	A	A
3 Mile Creek	D	C	C	D
Manawatū	B	A	A	A
Wairarawa	A	A	A	A
Hōkio	D	A	A	B
Waiwiri	C	A	B	B
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	C	A	B	B
Wainui	B	A	A	A
Papuka	B	A	A	A
Waimata	C	A	B	B
Ākitio	B	A	A	B
Owāhanga	A	A	A	A
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

MALF - Macroalgae % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	14	7	3
Okehu	-	25	7	3
Kai Iwi	-	14	3	0
Mōwhānau	-	14	3	0
Whanganui	-	33	19	19
Kaitoke	-	41	28	14
Whangaehu	-	19	19	19
Turakina	-	14	7	3
Koitiata	-	0	0	0
Rangitikei	-	42	42	26
Pukepuke	-	0	0	0
Kaikokopu	-	24	24	15
3 Mile Creek	-	30	17	3
Manawatū	-	50	41	30
Wairarawa	-	4	4	4
Hōkio	-	67	67	55
Waiwiri	-	67	55	55
Ōhau	-	4	4	4
Waikawa	-	16	14	14
Tautāne	-	74	58	58
Wainui	-	47	30	30
Papuka	-	46	35	20
Waimata	-	69	58	40
Ākitio	-	39	25	6
Owāhanga	-	22	16	16
Ōhau_DHI	-	9	9	9
Waikawa_DHI	-	14	14	12

MALF CLOSED - Macroalgae state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	B	A	B	B
Okehu	B	A	A	A
Kai Iwi	B	A	A	B
Mōwhānau	B	A	B	B
Whanganui	A	A	A	A
Kaitoke	C	B	B	C
Whangaehu	A	A	A	A
Turakina	B	A	B	B
Koitiata	D	C	D	D
Rangitikei	A	A	A	A
Pukepuke	D	D	D	D
Kaikokopu	A	A	A	A
3 Mile Creek	D	B	C	C
Manawatū	A	A	A	A
Wairarawa	A	A	A	A
Hōkio	C	A	A	A
Waiwiri	B	A	A	B
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	C	A	A	B
Wainui	B	A	A	A
Papuka	B	A	A	A
Waimata	C	A	A	A
Ākitio	B	A	A	B
Owāhanga	A	A	A	A
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

MALF CLOSED - Macroalgae % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	24	7	7
Okehu	-	48	35	18
Kai Iwi	-	24	24	7
Mōwhānau	-	24	7	7
Whanganui	-	17	17	13
Kaitoke	-	37	37	0
Whangaehu	-	33	33	30
Turakina	-	24	7	7
Koitiata	-	32	1	1
Rangitikei	-	23	23	22
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	57	32	32
Manawatū	-	47	47	45
Wairarawa	-	0	0	0
Hōkio	-	74	67	55
Waiwiri	-	70	53	38
Ōhau	-	0	0	0
Waikawa	-	9	9	9
Tautāne	-	79	77	59
Wainui	-	57	55	35
Papuka	-	57	48	18
Waimata	-	79	77	71
Ākitio	-	55	18	0
Owāhanga	-	30	29	23
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	9	9	9

Table A4.3. BBN output for phytoplankton state (left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean flow - Phytoplankton state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	A	A	A	A
Okehu	A	A	A	A
Kai Iwi	A	A	A	A
Mōwhānau	A	A	A	A
Whanganui	A	A	A	A
Kaitoke	A	A	A	A
Whangaehu	A	A	A	A
Turakina	A	A	A	A
Koitiata	A	A	A	A
Rangitikei	A	A	A	A
Pukepuke	A	A	A	A
Kaikokopu	A	A	A	A
3 Mile Creek	A	A	A	A
Manawatū	A	A	A	A
Wairarawa	A	A	A	A
Hōkio	A	A	A	A
Waiwiri	A	A	A	A
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	A	A	A	A
Wainui	A	A	A	A
Papuka	A	A	A	A
Waimata	A	A	A	A
Ākitio	A	A	A	A
Owāhanga	A	A	A	A
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

Mean flow - Phytoplankton % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	0	0	0
Waiwiri	-	0	0	0
Ōhau	-	0	0	0
Waikawa	-	0	0	0
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	0	0	0
Waimata	-	0	0	0
Ākitio	-	0	0	0
Owāhanga	-	0	0	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

Summer (Feb) flow - Phytoplankton state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	A	A	A	A
Okehu	A	A	A	A
Kai Iwi	A	A	A	A
Mōwhānau	A	A	A	A
Whanganui	A	A	A	A
Kaitoke	A	A	A	A
Whangaehu	A	A	A	A
Turakina	A	A	A	A
Koitiata	A	A	A	A
Rangitikei	A	A	A	A
Pukepuke	A	A	A	A
Kaikokopu	A	A	A	A
3 Mile Creek	A	A	A	A
Manawatū	A	A	A	A
Wairarawa	A	A	A	A
Hōkio	A	A	A	A
Waiwiri	A	A	A	A
Ōhau	A	A	A	A
Waikawa	A	A	A	A
Tautāne	A	A	A	A
Wainui	A	A	A	A
Papuka	A	A	A	A
Waimata	A	A	A	A
Ākitio	D	C	C	C
Owāhanga	C	C	C	C
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

Summer flow - Phytoplankton % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	0	0	0
Waiwiri	-	0	0	0
Ōhau	-	0	0	0
Waikawa	-	0	0	0
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	0	0	0
Waimata	-	0	0	0
Ākitio	-	12	4	2
Owāhanga	-	18	9	4
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

Table A4.3 continued. BBN output for phytoplankton state (left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean annual low flow (MALF) - Phytoplankton state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	A	A	A	A
Okehu	A	A	A	A
Kai Iwi	A	A	A	A
Mōwhānau	A	A	A	A
Whanganui	A	A	A	A
Kaitoke	A	A	A	A
Whangaehu	A	A	A	A
Turakina	D	C	C	C
Koitiata	A	A	A	A
Rangitikei	A	A	A	A
Pukepuke	A	A	A	A
Kaikokopu	A	A	A	A
3 Mile Creek	A	A	A	A
Manawatū	A	A	A	A
Wairarawa	A	A	A	A
Hōkio	D	C	C	C
Waiwiri	A	A	A	A
Ōhau	C	A	A	A
Waikawa	C	A	B	B
Tautāne	D	C	D	D
Wainui	D	C	D	D
Papuka	C	C	C	C
Waimata	A	A	A	A
Ākitio	D	C	C	C
Owāhanga	D	C	D	D
Ōhau_DHI	A	A	A	A
Waikawa_DHI	A	A	A	A

MALF - Phytoplankton % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	6	4	3
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	12	12	7
Waiwiri	-	0	0	0
Ōhau	-	61	61	61
Waikawa	-	67	36	36
Tautāne	-	17	0	0
Wainui	-	19	1	1
Papuka	-	18	9	4
Waimata	-	0	0	0
Ākitio	-	12	7	2
Owāhanga	-	17	0	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

MALF CLOSED - Phytoplankton state				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	A	A	A	A
Okehu	A	A	A	A
Kai Iwi	A	A	A	A
Mōwhānau	A	A	A	A
Whanganui	A	A	A	A
Kaitoke	A	A	A	A
Whangaehu	A	A	A	A
Turakina	D	D	D	D
Koitiata	A	A	A	A
Rangitikei	A	A	A	A
Pukepuke	A	A	A	A
Kaikokopu	A	A	A	A
3 Mile Creek	A	A	A	A
Manawatū	D	B	B	C
Wairarawa	A	A	A	A
Hōkio	D	C	C	D
Waiwiri	D	C	C	D
Ōhau	C	A	B	B
Waikawa	D	B	B	C
Tautāne	D	C	C	D
Wainui	D	C	C	D
Papuka	D	C	C	D
Waimata	D	B	C	C
Ākitio	D	C	C	D
Owāhanga	D	C	C	D
Ōhau_DHI	A	A	A	A
Waikawa_DHI	C	B	B	B

MALF CLOSED - Phytoplankton % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	65	40	31
Wairarawa	-	0	0	0
Hōkio	-	29	8	0
Waiwiri	-	32	3	2
Ōhau	-	67	40	40
Waikawa	-	57	33	33
Tautāne	-	33	29	0
Wainui	-	33	29	0
Papuka	-	29	7	0
Waimata	-	42	32	12
Ākitio	-	29	0	0
Owāhanga	-	33	29	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	61	40	40

Table A4.4. BBN output for dissolved oxygen (mg/L; left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean flow - Dissolved oxygen (mg/L)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	7.50	7.50	7.50	7.50
Okehu	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50
Turakina	7.47	7.47	7.47	7.47
Koitiata	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50
Pukepuke	7.50	7.50	7.50	7.50
Kaikokopu	7.50	7.50	7.50	7.50
3 Mile Creek	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47
Wairarawa	7.50	7.50	7.50	7.50
Hōkio	7.47	7.47	7.47	7.47
Waiwiri	7.50	7.50	7.50	7.50
Ōhau	7.47	7.47	7.47	7.47
Waikawa	7.47	7.47	7.47	7.47
Tautāne	7.47	7.47	7.47	7.47
Wainui	7.47	7.47	7.47	7.47
Papuka	7.50	7.50	7.50	7.50
Waimata	7.50	7.50	7.50	7.50
Ākitio	7.47	7.47	7.47	7.47
Owāhanga	7.47	7.47	7.47	7.47
Ōhau_DHI	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47

Mean flow - Dissolved oxygen % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	0	0	0
Waiwiri	-	0	0	0
Ōhau	-	0	0	0
Waikawa	-	0	0	0
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	0	0	0
Waimata	-	0	0	0
Ākitio	-	0	0	0
Owāhanga	-	0	0	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

Summer (Feb) flow - Dissolved oxygen (mg/L)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	7.50	7.50	7.50	7.50
Okehu	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50
Turakina	7.47	7.47	7.47	7.47
Koitiata	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50
Pukepuke	7.50	7.50	7.50	7.50
Kaikokopu	7.50	7.50	7.50	7.50
3 Mile Creek	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47
Wairarawa	7.50	7.50	7.50	7.50
Hōkio	7.47	7.47	7.47	7.47
Waiwiri	7.50	7.50	7.50	7.50
Ōhau	7.47	7.47	7.47	7.47
Waikawa	7.47	7.47	7.47	7.47
Tautāne	7.47	7.47	7.47	7.47
Wainui	7.47	7.47	7.47	7.47
Papuka	7.50	7.50	7.50	7.50
Waimata	7.50	7.50	7.50	7.50
Ākitio	4.91	5.65	5.01	4.97
Owāhanga	4.97	6.15	5.21	5.08
Ōhau_DHI	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47

Summer (Feb) flow - Dissolved oxygen % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	0	0	0
Waiwiri	-	0	0	0
Ōhau	-	0	0	0
Waikawa	-	0	0	0
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	0	0	0
Waimata	-	0	0	0
Ākitio	-	15	2	1
Owāhanga	-	24	5	2
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

Table A4.4 continued. BBN output for dissolved oxygen (mg/L; left) and percent improvement (right) based on baseline nutrient loads and three nutrient reduction scenarios across four flows.

Mean annual low flow (MALF) - Dissolved oxygen (mg/L)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	7.50	7.50	7.50	7.50
Okehu	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50
Turakina	4.86	5.01	4.97	4.95
Koitiata	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50
Pukepuke	7.50	7.50	7.50	7.50
Kaikokopu	7.50	7.50	7.50	7.50
3 Mile Creek	7.50	7.50	7.50	7.50
Manawatū	7.47	7.47	7.47	7.47
Wairarawa	7.50	7.50	7.50	7.50
Hōkio	4.91	5.21	5.21	5.08
Waiwiri	7.50	7.50	7.50	7.50
Ōhau	5.42	6.63	6.63	6.63
Waikawa	5.08	6.63	5.86	5.86
Tautāne	4.50	4.50	4.50	4.50
Wainui	4.50	4.50	4.50	4.50
Papuka	7.16	7.50	7.50	7.50
Waimata	7.50	7.50	7.50	7.50
Ākitio	4.91	5.21	5.08	4.97
Owāhanga	4.50	4.50	4.50	4.50
Ōhau_DHI	7.47	7.47	7.47	7.47
Waikawa_DHI	7.47	7.47	7.47	7.47

MALF - Dissolved oxygen % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	3	2	2
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	0	0	0
Wairarawa	-	0	0	0
Hōkio	-	6	6	3
Waiwiri	-	0	0	0
Ōhau	-	22	22	22
Waikawa	-	31	15	15
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	5	5	5
Waimata	-	0	0	0
Ākitio	-	6	3	1
Owāhanga	-	0	0	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	0	0	0

MALF CLOSED - Dissolved oxygen (mg/L)				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	7.50	7.50	7.50	7.50
Okehu	7.50	7.50	7.50	7.50
Kai Iwi	7.47	7.47	7.47	7.47
Mōwhānau	7.50	7.50	7.50	7.50
Whanganui	7.47	7.47	7.47	7.47
Kaitoke	7.50	7.50	7.50	7.50
Whangaehu	7.50	7.50	7.50	7.50
Turakina	4.50	4.50	4.50	4.50
Koitiata	7.50	7.50	7.50	7.50
Rangitikei	7.50	7.50	7.50	7.50
Pukepuke	7.50	7.50	7.50	7.50
Kaikokopu	7.50	7.50	7.50	7.50
3 Mile Creek	7.50	7.50	7.50	7.50
Manawatū	4.91	5.86	5.21	5.01
Wairarawa	7.50	7.50	7.50	7.50
Hōkio	4.50	4.50	4.50	4.50
Waiwiri	6.98	7.50	7.01	7.00
Ōhau	4.50	4.50	4.50	4.50
Waikawa	4.50	4.50	4.50	4.50
Tautāne	4.50	4.50	4.50	4.50
Wainui	4.50	4.50	4.50	4.50
Papuka	6.90	7.50	7.04	6.90
Waimata	6.98	7.50	7.50	7.16
Ākitio	4.50	4.50	4.50	4.50
Owāhanga	4.50	4.50	4.50	4.50
Ōhau_DHI	7.47	7.47	7.47	7.47
Waikawa_DHI	4.95	5.42	5.21	5.21

MALF CLOSED - Dissolved oxygen % improvement				
Estuary name	Baseline	20UPR	25UPR	30UPR
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	0	0	0
Mōwhānau	-	0	0	0
Whanganui	-	0	0	0
Kaitoke	-	0	0	0
Whangaehu	-	0	0	0
Turakina	-	0	0	0
Koitiata	-	0	0	0
Rangitikei	-	0	0	0
Pukepuke	-	0	0	0
Kaikokopu	-	0	0	0
3 Mile Creek	-	0	0	0
Manawatū	-	19	6	2
Wairarawa	-	0	0	0
Hōkio	-	0	0	0
Waiwiri	-	7	0	0
Ōhau	-	0	0	0
Waikawa	-	0	0	0
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	9	2	0
Waimata	-	7	7	3
Ākitio	-	0	0	0
Owāhanga	-	0	0	0
Ōhau_DHI	-	0	0	0
Waikawa_DHI	-	10	5	5

APPENDIX 5: BBN OUTPUT FOR SEDIMENT POLICY SCENARIOS

Tables A5.1 to A5.3 present the BBN outputs for the six sediment scenarios under mean flow as described in Section 3.2.1.

Nutrient targets are not presented as they are not affected by the sediment load scenarios in the BBN.

<u>The following ratings were applied to the BBN outputs:</u>

Condition rating for visual clarity based on exceedance (Fail) of One Plan target outlined in Table 1:

Pass	Fail

Condition rating for E. coli based on exceedance of two E. coli thresholds outlined in Table 1:

<260	260-550	>550

Condition rating for the reduction factor (e.g., 0.25 = 25% reduction). Colours are used to aid interpretation. Band thresholds represent equal quartiles of the potential reduction factor and do not correspond to ecological thresholds.

<0.25	0.25 to <0.5	0.5 to <0.75	≥0.75

Table A5.1. BBN output for estuary clarity (m; left) and percent improvement (right) based on baseline modelled river clarity for two sediment policy scenarios (PS1 and PS2) over three periods 2035, 2050 and 2100.

Mean flow - Estuary visual clarity (m)

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	1.2	1.2	1.2	1.1	1.2	1.1	1.1
Okehu	1.1	1.1	1.1	1.1	1.1	1.7	1.7
Kailwi	1.1	1.1	1.1	2.0	1.1	2.0	2.0
Mōwhānau	1.2	1.2	1.1	1.1	1.1	1.1	1.1
Whanganui	1.1	1.1	1.1	2.0	1.1	2.0	2.0
Kaitoke	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Whangaehu	1.1	1.1	2.0	2.0	2.0	2.0	4.9
Turakina	1.2	1.2	1.2	2.0	1.1	2.0	2.0
Koitiata	0.6	1.1	1.1	1.1	1.1	1.1	1.1
Rangitikei	1.1	1.1	1.1	2.0	1.1	2.0	2.0
Pukupuke	1.2	1.1	1.1	1.1	1.1	1.1	1.1
Kaikokopu	1.1	1.7	1.7	1.7	1.7	1.7	1.7
Three Mile	1.2	2.0	2.0	2.0	2.0	2.0	2.0
Manawatū	1.2	1.2	1.1	2.0	1.1	2.0	2.0
Wairarawa	1.1	1.7	1.7	1.7	1.7	1.7	1.7
Hōkio	1.2	1.1	1.1	1.1	1.1	1.1	1.1
Waiwiri	1.2	1.1	1.1	1.1	1.1	1.1	1.1
Ōhau	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Waikawa	1.1	2.0	2.0	2.0	2.0	2.0	2.0
Tautāne	1.2	1.2	1.1	2.0	1.1	2.0	2.0
Wainui	1.2	1.2	1.2	1.1	1.2	1.1	2.0
Papuka	1.2	1.1	1.1	2.0	1.1	2.0	4.9
Waimata	0.6	1.1	1.1	1.1	1.1	1.1	1.1
Ākitio	1.2	1.2	1.2	1.1	1.2	1.1	2.0
Owāhanga	1.2	1.2	1.2	2.0	1.1	2.0	2.0
Ōhau_DHI	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Waikawa_DHI	1.1	2.0	2.0	2.0	2.0	2.0	2.0

Mean flow - Estuary visual clarity (m) % improvement

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	-	0	0	0	0	0	0
Okehu	-	0	0	0	0	54	54
Kai Iwi	-	0	0	80	0	80	80
Mōwhānau	-	0	0	0	0	0	0
Whanganui	-	0	0	80	0	80	80
Kaitoke	-	0	0	0	0	0	0
Whangaehu	-	0	80	80	80	80	342
Turakina	-	0	0	75	0	75	75
Koitiata	-	69	69	69	69	69	69
Rangitikei	-	0	0	80	0	80	80
Pukupuke	-	0	0	0	0	0	0
Kaikokopu	-	54	54	54	54	54	54
3 Mile Creek	-	75	75	75	75	75	75
Manawatū	-	0	0	75	0	75	75
Wairarawa	-	54	54	54	54	54	54
Hōkio	-	0	0	0	0	0	0
Waiwiri	-	0	0	0	0	0	0
Ōhau	-	0	0	0	0	0	0
Waikawa	-	80	80	80	80	80	80
Tautāne	-	0	0	75	0	75	75
Wainui	-	0	0	0	0	0	75
Papuka	-	0	0	75	0	75	329
Waimata	-	69	69	69	69	69	69
Ākitio	-	0	0	0	0	0	75
Owāhanga	-	0	0	75	0	75	75
Ōhau_DHI	-	0	0	0	0	0	0
Waikawa_DHI	-	80	80	80	80	80	80

Table A5.2. BBN output for *E. coli* (*E. coli* per 100ml; left) and percent improvement (right) based on baseline modelled river clarity two sediment policy scenarios (PS1 and PS2) over three periods 2035, 2050 and 2100.

Mean flow - E. coli (E. coli per 100mL)

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	279	279	278	237	267	239	211
Okehu	240	231	225	193	219	190	173
Kailwi	213	205	200	174	196	172	161
Mōwhānau	250	248	245	215	240	220	204
Whanganui	224	217	211	178	205	175	159
Kaitoke	286	274	273	256	274	272	270
Whangaehu	211	201	189	139	186	136	120
Turakina	274	264	250	180	243	174	147
Koitiata	289	234	234	230	234	234	234
Rangitikei	216	206	197	154	193	152	134
Pukupuke	281	244	244	244	244	244	244
Kaikokopu	237	182	182	182	182	182	182
Three Mile	252	182	182	182	182	182	182
Manawatū	260	248	238	191	234	191	172
Wairarawa	233	167	167	167	167	167	167
Hōkio	257	241	241	237	239	237	235
Waiwiri	259	230	230	230	230	230	230
Ōhau	164	154	154	149	153	150	148
Waikawa	195	180	179	173	178	173	170
Tautāne	271	257	236	139	235	147	128
Wainui	310	295	278	200	272	197	171
Papuka	249	217	201	134	198	142	112
Waimata	254	247	236	216	240	218	211
Ākitio	307	286	269	201	266	201	176
Owāhanga	281	264	251	190	244	185	160
Ōhau_DHI	164	154	154	149	153	150	148
Waikawa_DHI	195	180	179	173	178	173	170

Mean flow - E. coli % improvement

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	-	0	1	15	5	15	24
Okehu	-	4	6	19	9	21	28
Kai Iwi	-	3	6	18	8	19	24
Mōwhānau	-	1	2	14	4	12	18
Whanganui	-	3	6	20	8	22	29
Kaitoke	-	4	5	11	4	5	6
Whangaehu	-	5	10	34	12	36	43
Turakina	-	4	9	34	11	37	46
Koitiata	-	19	19	20	19	19	19
Rangitikei	-	4	9	28	11	30	38
Pukupuke	-	13	13	13	13	13	13
Kaikokopu	-	23	23	23	23	23	23
3 Mile Creek	-	27	27	27	27	27	27
Manawatū	-	5	9	27	10	27	34
Wairarawa	-	28	28	28	28	28	28
Hōkio	-	6	6	7	7	8	9
Waiwiri	-	11	11	11	11	11	11
Ōhau	-	6	6	9	6	8	9
Waikawa	-	8	8	11	9	11	13
Tautāne	-	5	13	49	14	46	53
Wainui	-	5	10	36	12	37	45
Papuka	-	13	19	46	21	43	55
Waimata	-	3	7	15	5	14	17
Ākitio	-	7	12	35	13	34	43
Owāhanga	-	6	11	32	13	34	43
Ōhau_DHI	-	6	6	9	6	8	9
Waikawa_DHI	-	8	8	11	9	11	13

Table A5.3. BBN output for sediment load reduction factors (left) and % sediment reduction factor (right) based on baseline modelled river clarity for two sediment policy scenarios (PS1 and PS2) over three periods 2035, 2050 and 2100. Note 0.06 to 0.07 or 6-7% suggests no reduction required.

Mean flow - Sediment reduction factor

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	0.19	0.19	0.19	0.17	0.19	0.17	0.17
Okehu	0.17	0.17	0.17	0.17	0.17	0.07	0.07
Kailwi	0.17	0.17	0.17	0.06	0.17	0.06	0.06
Mōwhānau	0.19	0.19	0.17	0.17	0.17	0.17	0.17
Whanganui	0.17	0.17	0.17	0.06	0.17	0.06	0.06
Kaitoke	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Whangaehu	0.17	0.17	0.06	0.06	0.06	0.06	0.05
Turakina	0.19	0.19	0.19	0.06	0.17	0.06	0.06
Koitiata	0.39	0.17	0.17	0.17	0.17	0.17	0.17
Rangitikei	0.17	0.17	0.17	0.06	0.17	0.06	0.06
Pukupuke	0.19	0.17	0.17	0.17	0.17	0.17	0.17
Kaikokopu	0.17	0.07	0.07	0.07	0.07	0.07	0.07
Three Mile	0.19	0.06	0.06	0.06	0.06	0.06	0.06
Manawatū	0.19	0.19	0.17	0.06	0.17	0.06	0.06
Wairarawa	0.17	0.07	0.07	0.07	0.07	0.07	0.07
Hōkio	0.19	0.17	0.17	0.17	0.17	0.17	0.17
Waiwiri	0.19	0.17	0.17	0.17	0.17	0.17	0.17
Ōhau	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Waikawa	0.17	0.06	0.06	0.06	0.06	0.06	0.06
Tautāne	0.19	0.19	0.17	0.06	0.17	0.06	0.06
Wainui	0.19	0.19	0.19	0.17	0.19	0.17	0.06
Papuka	0.19	0.17	0.17	0.06	0.17	0.06	0.05
Waimata	0.39	0.17	0.17	0.17	0.17	0.17	0.17
Ākitio	0.19	0.19	0.19	0.17	0.19	0.17	0.06
Owāhanga	0.19	0.19	0.19	0.06	0.17	0.06	0.06
Ōhau_DHI	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Waikawa_DHI	0.17	0.06	0.06	0.06	0.06	0.06	0.06

Mean flow - % sediment reduction factor

Estuary name	Baseline	SPS 1			SPS 2		
		2035	2050	2100	2035	2050	2100
Ototoka	19	19	19	17	19	17	17
Okehu	17	17	17	17	17	7	7
Kai Iwi	17	17	17	6	17	6	6
Mōwhānau	19	19	17	17	17	17	17
Whanganui	17	17	17	6	17	6	6
Kaitoke	39	39	39	39	39	39	39
Whangaehu	17	17	6	6	6	6	5
Turakina	19	19	19	6	17	6	6
Koitiata	39	17	17	17	17	17	17
Rangitikei	17	17	17	6	17	6	6
Pukupuke	19	17	17	17	17	17	17
Kaikokopu	17	7	7	7	7	7	7
3 Mile Creek	19	6	6	6	6	6	6
Manawatū	19	19	17	6	17	6	6
Wairarawa	17	7	7	7	7	7	7
Hōkio	19	17	17	17	17	17	17
Waiwiri	19	17	17	17	17	17	17
Ōhau	6	6	6	6	6	6	6
Waikawa	17	6	6	6	6	6	6
Tautāne	19	19	17	6	17	6	6
Wainui	19	19	19	17	19	17	6
Papuka	19	17	17	6	17	6	5
Waimata	39	17	17	17	17	17	17
Ākitio	19	19	19	17	19	17	6
Owāhanga	19	19	19	6	17	6	6
Ōhau_DHI	7	7	7	7	7	7	7
Waikawa_DHI	17	6	6	6	6	6	6

APPENDIX 6: BBN OUTPUT FRESHWATER SEDIMENT LOAD REDUCTIONS

Tables A6.1 to A6.3 present the BBN outputs for the six sediment scenarios under mean flow as described in Section 3.2.2.

Nutrient targets are not presented as they are not affected by the sediment load scenarios in the BBN.

<u>The following ratings were applied to the BBN outputs:</u>

Condition rating for visual clarity based on exceedance (Fail) of One Plan target outlined in Table 1:

Pass	Fail

Condition rating for E. coli based on exceedance of two E. coli thresholds outlined in Table 1:

<260	260-550	>550

Condition rating for the reduction factor (e.g., 0.25 = 25% reduction). Colours are used to aid interpretation. Band thresholds represent equal quartiles of the potential reduction factor and do not correspond to ecological thresholds.

<0.25	0.25 to <0.5	0.5 to <0.75	≥0.75

Table A6.1. BBN output for estuary clarity (left) and percent improvement (right) based on the river clarity for NPS-FM bands and the appropriate river sediment classes (see Table 12).

Mean flow - Estuary visual clarity (m)				
Estuary name	Baseline	A-band	B-band	C-band
Ototoka	1.15	1.12	1.15	1.15
Okehu	1.09	1.09	1.09	1.09
Kai Iwi	1.12	2.01	1.12	1.12
Mōwhānau	1.15	1.12	1.15	1.15
Whanganui	1.12	2.01	2.01	2.01
Kaitoke	0.65	1.09	0.65	0.65
Whangaehu	1.12	2.01	2.01	2.01
Turakina	1.15	1.12	1.15	1.15
Koitiata	0.65	1.68	1.68	1.68
Rangitikei	1.12	2.01	2.01	2.01
Pukupuke	1.15	2.01	2.01	2.01
Kaikokopu	1.09	1.68	1.68	1.68
3 Mile Creek	1.15	2.01	2.01	2.01
Manawatū	1.15	4.94	4.94	2.01
Wairarawa	1.09	1.68	1.68	1.68
Hōkio	1.15	1.12	1.15	1.15
Waiwiri	1.15	1.12	1.15	1.15
Ōhau	2.01	4.94	4.94	2.01
Waikawa	1.12	4.94	4.94	2.01
Tautāne	1.15	1.12	1.15	1.15
Wainui	1.15	1.12	1.15	1.15
Papuka	1.15	1.12	1.15	1.15
Waimata	0.65	1.09	0.65	0.65
Ākitio	1.15	1.12	1.15	1.15
Owāhanga	1.15	1.12	1.15	1.15
Ōhau_DHI	1.68	4.94	4.94	1.68
Waikawa_DHI	1.12	4.94	4.94	2.01

Mean flow - Estuary visual clarity (m) % improvement				
Estuary name	Baseline	A-band	B-band	C-band
Ototoka	-	0	0	0
Okehu	-	0	0	0
Kai Iwi	-	80	0	0
Mōwhānau	-	0	0	0
Whanganui	-	80	80	80
Kaitoke	-	69	0	0
Whangaehu	-	80	80	80
Turakina	-	0	0	0
Koitiata	-	160	160	160
Rangitikei	-	80	80	80
Pukupuke	-	75	75	75
Kaikokopu	-	54	54	54
3 Mile Creek	-	75	75	75
Manawatū	-	329	329	75
Wairarawa	-	54	54	54
Hōkio	-	0	0	0
Waiwiri	-	0	0	0
Ōhau	-	146	146	0
Waikawa	-	342	342	80
Tautāne	-	0	0	0
Wainui	-	0	0	0
Papuka	-	0	0	0
Waimata	-	69	0	0
Ākitio	-	0	0	0
Owāhanga	-	0	0	0
Ōhau_DHI	-	194	194	0
Waikawa_DHI	-	342	342	80

Table A6.3. BBN output for *E. coli* (*E.coli* per 100ml; left) and percent improvement (right) based on the river clarity for NPS-FM bands and the appropriate river sediment classes (see Table 12).

Mean flow - E. coli (E. coli per 100mL)				
Estuary name	Baseline	A-band	B-band	C-band
Ototoka	279	225	255	278
Okehu	240	225	240	240
Kai Iwi	213	177	196	213
Mōwhānau	250	225	249	249
Whanganui	224	151	165	180
Kaitoke	286	225	255	286
Whangaehu	211	151	165	180
Turakina	274	225	255	273
Koitiata	289	151	165	180
Rangitikei	216	151	165	180
Pukupuke	281	151	165	180
Kaikokopu	237	151	165	180
3 Mile Creek	252	151	165	180
Manawatū	260	111	121	132
Wairarawa	233	151	165	180
Hōkio	257	225	255	257
Waiwiri	259	225	255	259
Ōhau	164	111	121	132
Waikawa	195	111	121	132
Tautāne	271	225	255	271
Wainui	310	225	255	292
Papuka	249	225	249	249
Waimata	254	225	253	253
Ākitio	307	225	255	292
Owāhanga	281	225	255	281
Ōhau_DHI	164	111	121	132
Waikawa_DHI	195	111	121	132

Mean flow - E. coli % improvement				
Estuary name	Baseline	20UPR	25URP	30UPR
Ototoka	-	19	9	0
Okehu	-	6	0	0
Kai Iwi	-	17	8	0
Mōwhānau	-	10	0	0
Whanganui	-	32	26	19
Kaitoke	-	21	11	0
Whangaehu	-	28	22	15
Turakina	-	18	7	0
Koitiata	-	48	43	38
Rangitikei	-	30	24	17
Pukupuke	-	46	41	36
Kaikokopu	-	36	31	24
3 Mile Creek	-	40	35	28
Manawatū	-	57	54	49
Wairarawa	-	35	29	23
Hōkio	-	12	1	0
Waiwiri	-	13	1	0
Ōhau	-	32	26	19
Waikawa	-	43	38	32
Tautāne	-	17	6	0
Wainui	-	27	18	6
Papuka	-	10	0	0
Waimata	-	11	0	0
Ākitio	-	27	17	5
Owāhanga	-	20	9	0
Ōhau_DHI	-	32	26	19
Waikawa_DHI	-	43	38	32

Table A6.2. BBN output for sediment load reduction factor (left) and percent sediment reduction factor (right) based on the river clarity for NPS-FM bands and the appropriate river sediment classes (see Table 12). Note 0.05-0.07 or 5-7% suggests no reduction required.

Mean flow - Sediment reduction factor				
Estuary name	**Baseline**	**A-band**	**B-band**	**C-band**
Ototoka	0.19	0.17	0.19	0.19
Okehu	0.17	0.17	0.17	0.17
Kai Iwi	0.17	0.06	0.17	0.17
Mōwhānau	0.19	0.17	0.19	0.19
Whanganui	0.17	0.06	0.06	0.06
Kaitoke	0.39	0.17	0.39	0.39
Whangaehu	0.17	0.06	0.06	0.06
Turakina	0.19	0.17	0.19	0.19
Koitiata	0.39	0.07	0.07	0.07
Rangitikei	0.17	0.06	0.06	0.06
Pukupuke	0.19	0.06	0.06	0.06
Kaikokopu	0.17	0.07	0.07	0.07
3 Mile Creek	0.19	0.06	0.06	0.06
Manawatū	0.19	0.05	0.05	0.06
Wairarawa	0.17	0.07	0.07	0.07
Hōkio	0.19	0.17	0.19	0.19
Waiwiri	0.19	0.17	0.19	0.19
Ōhau	0.06	0.05	0.05	0.06
Waikawa	0.17	0.05	0.05	0.06
Tautāne	0.19	0.17	0.19	0.19
Wainui	0.19	0.17	0.19	0.19
Papuka	0.19	0.17	0.19	0.19
Waimata	0.39	0.17	0.39	0.39
Ākitio	0.19	0.17	0.19	0.19
Owāhanga	0.19	0.17	0.19	0.19
Ōhau_DHI	0.07	0.05	0.05	0.07
Waikawa_DHI	0.17	0.05	0.05	0.06

Mean flow - % sediment reduction factor				
Estuary name	**Baseline**	**A-band**	**B-band**	**C-band**
Ototoka	19	17	19	19
Okehu	17	17	17	17
Kai Iwi	17	6	17	17
Mōwhānau	19	17	19	19
Whanganui	17	6	6	6
Kaitoke	39	17	39	39
Whangaehu	17	6	6	6
Turakina	19	17	19	19
Koitiata	39	7	7	7
Rangitikei	17	6	6	6
Pukupuke	19	6	6	6
Kaikokopu	17	7	7	7
3 Mile Creek	19	6	6	6
Manawatū	19	5	5	6
Wairarawa	17	7	7	7
Hōkio	19	17	19	19
Waiwiri	19	17	19	19
Ōhau	6	5	5	6
Waikawa	17	5	5	6
Tautāne	19	17	19	19
Wainui	19	17	19	19
Papuka	19	17	19	19
Waimata	39	17	39	39
Ākitio	19	17	19	19
Owāhanga	19	17	19	19
Ōhau_DHI	7	5	5	7
Waikawa_DHI	17	5	5	6

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