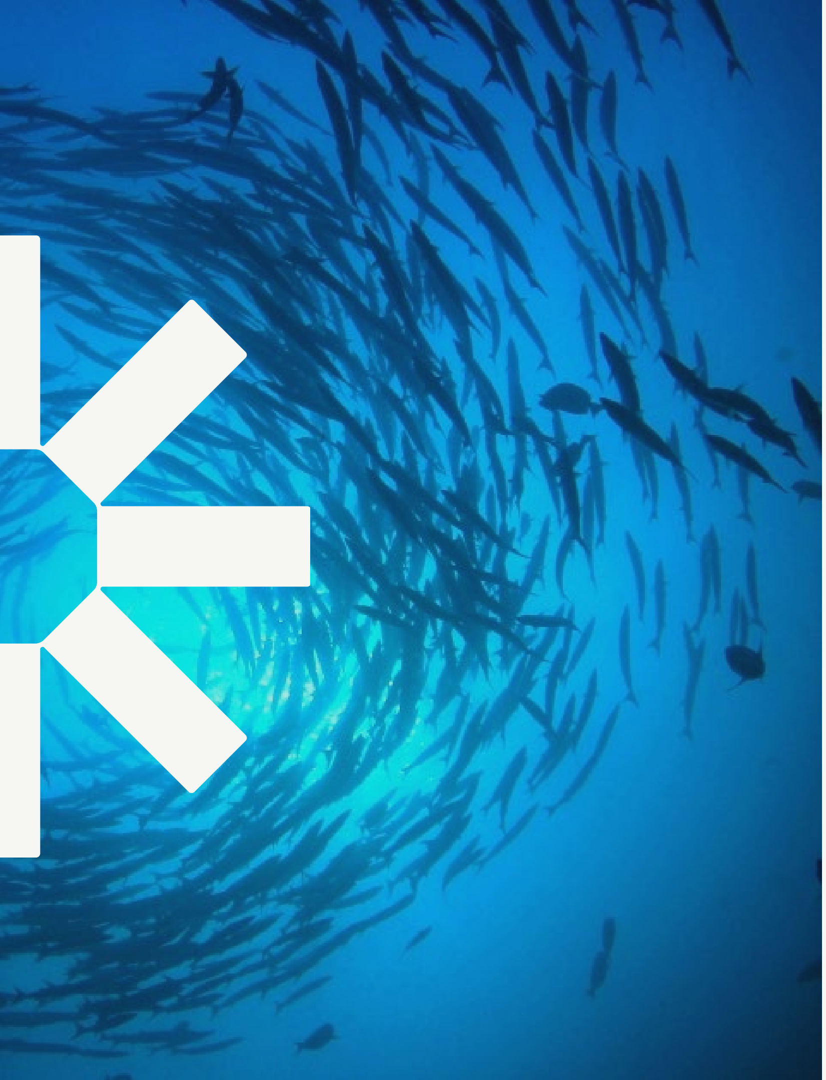

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March 2026

Hananui Aquaculture Project

Hydrodynamic and Water Quality Modelling and Assessment

OCEANUM CALYPSO SCIENCE SLR

Hananui Project

Hydrodynamical model setup and validation

Context for defining the modelling scope

A peer review by John Oldman of the previous hydrodynamical modelling efforts by MetOcean Solutions identified three key shortcomings:

1) The hydrodynamical hindcast was only a short duration.

   We have run 10 years.

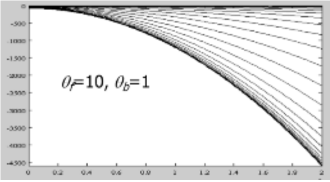
2) The overall performance of the hydrodynamic model to predict the currents in the area was relatively low and the ability of the model to reproduce near-bed and surface currents was not quantified.

   We have compared the measured and modeled current profile and performed a validation on three distinct layers. No model is perfect, but the governing dynamics are now being well replicated in our model.

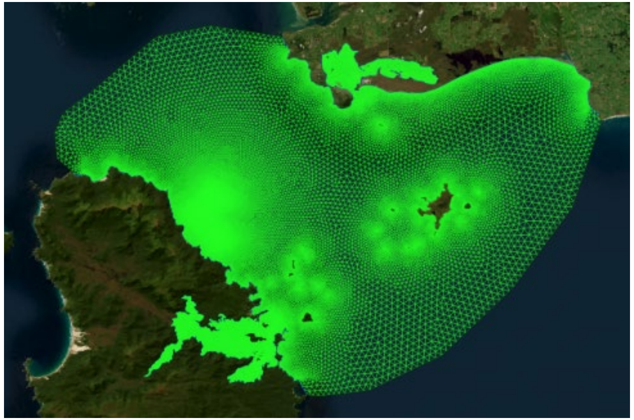
3) There is no quantification of the errors in the near-bed currents so the errors relating to how far particulate material may move cannot be determined.

   Accuracy metrics are now reported for three layers in the water column.

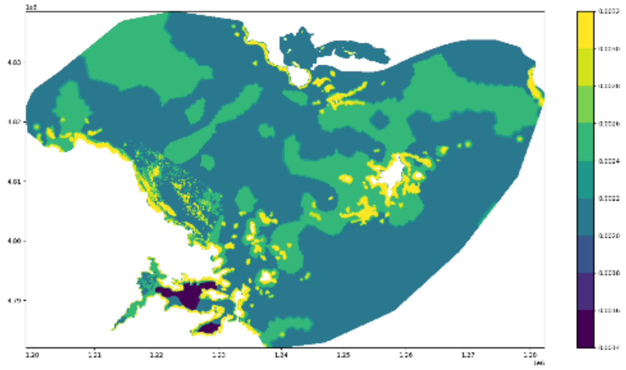
Model methods - setup



Mode	3D Barotropic
Layers	20 sigma layers, high res top and bottom
Hydrodynamic dt [s]	100 s
Minimum water depth [m]	0.1 m
Friction	Drag coefficient varying
Boundary condition	3D NZ SCHISM domain (tide+residual)
Wind forcing	ERA5 winds
Resolution at farm	26 m



High-resolution triangular model mesh



Variable friction scheme

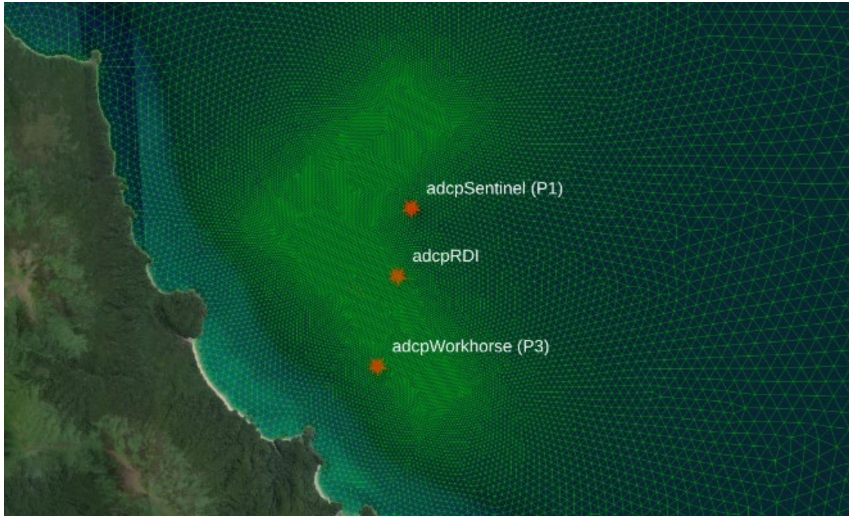
Model validation

Model validation performed against the following model layers:

- Surface (4-8 m bss)
- Mid water (11-18 m bss)
- Nearbed (2-3 m asb)
- Depth-averaged at P3 was 8-33 m bss and at P1 was 4-22 m bss

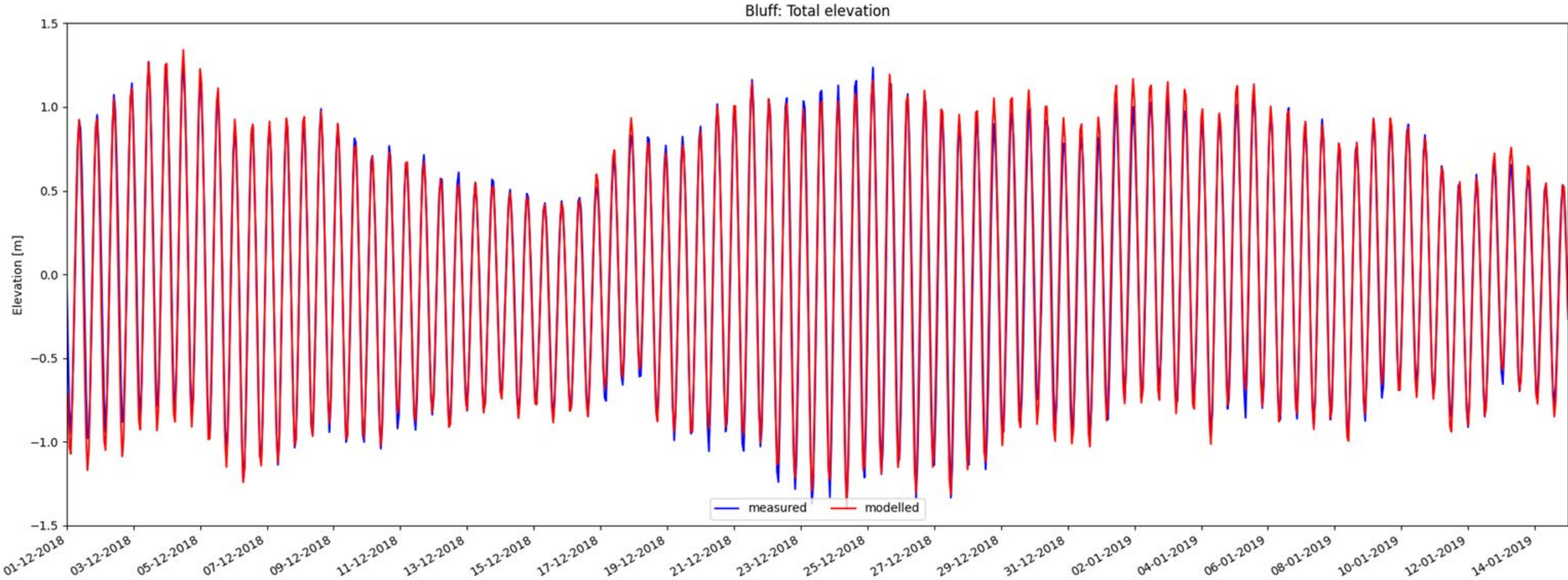
The non-tidal residuals were calculated by:

- Detiding
- Resampling to an hourly time series
- Bandpass filtering from 16 h to 40 days



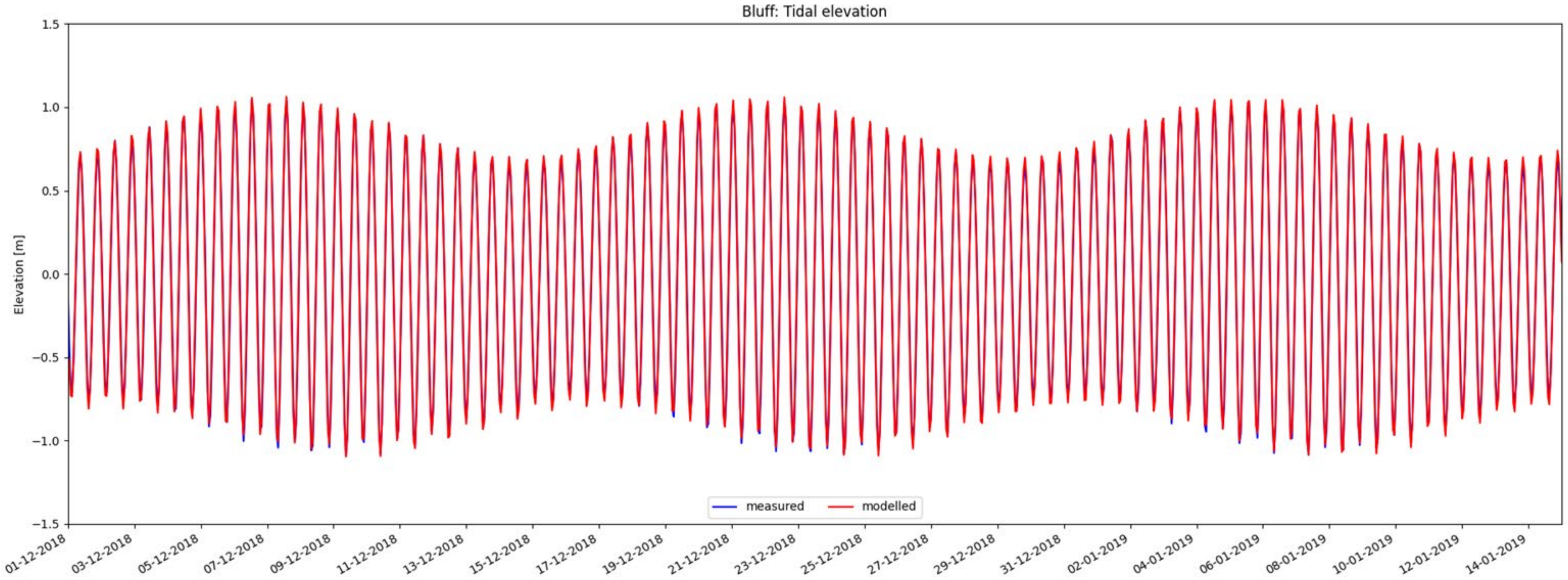
Sites for validation against observations

Model validation results



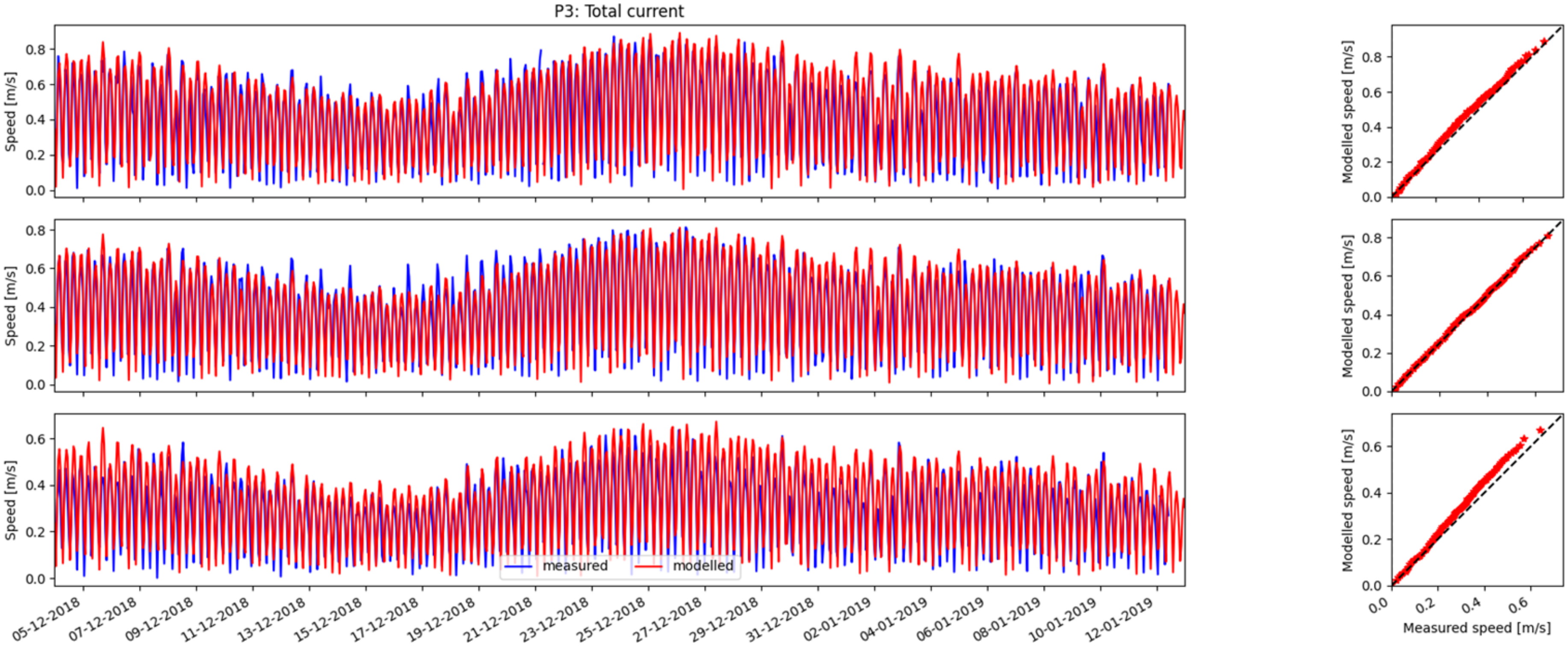
Total water level - Bluff Harbour

Model validation results



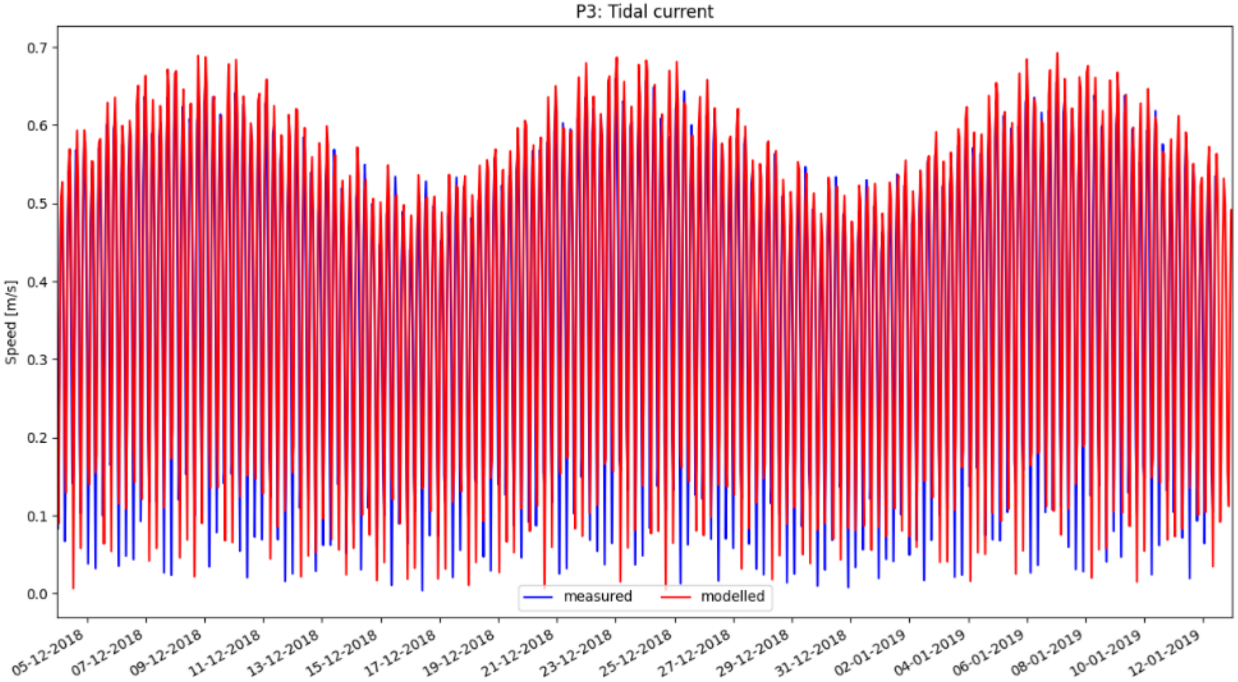
Tidal water level - Bluff Harbour

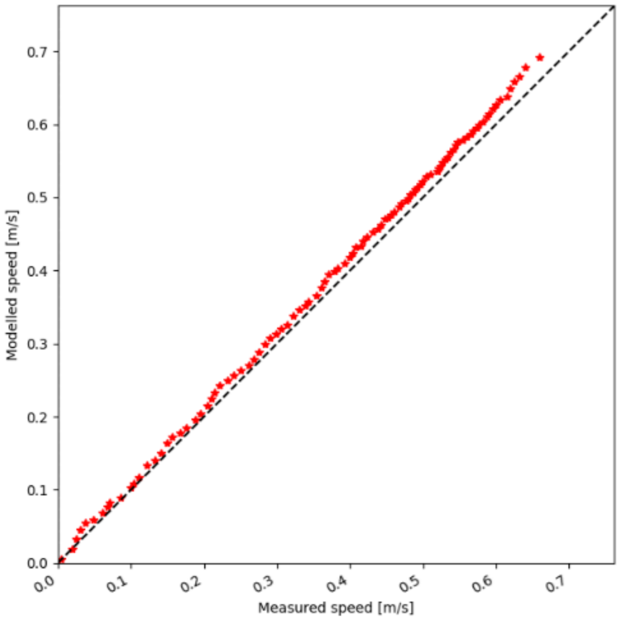
Model validation results



Site 3 total currents

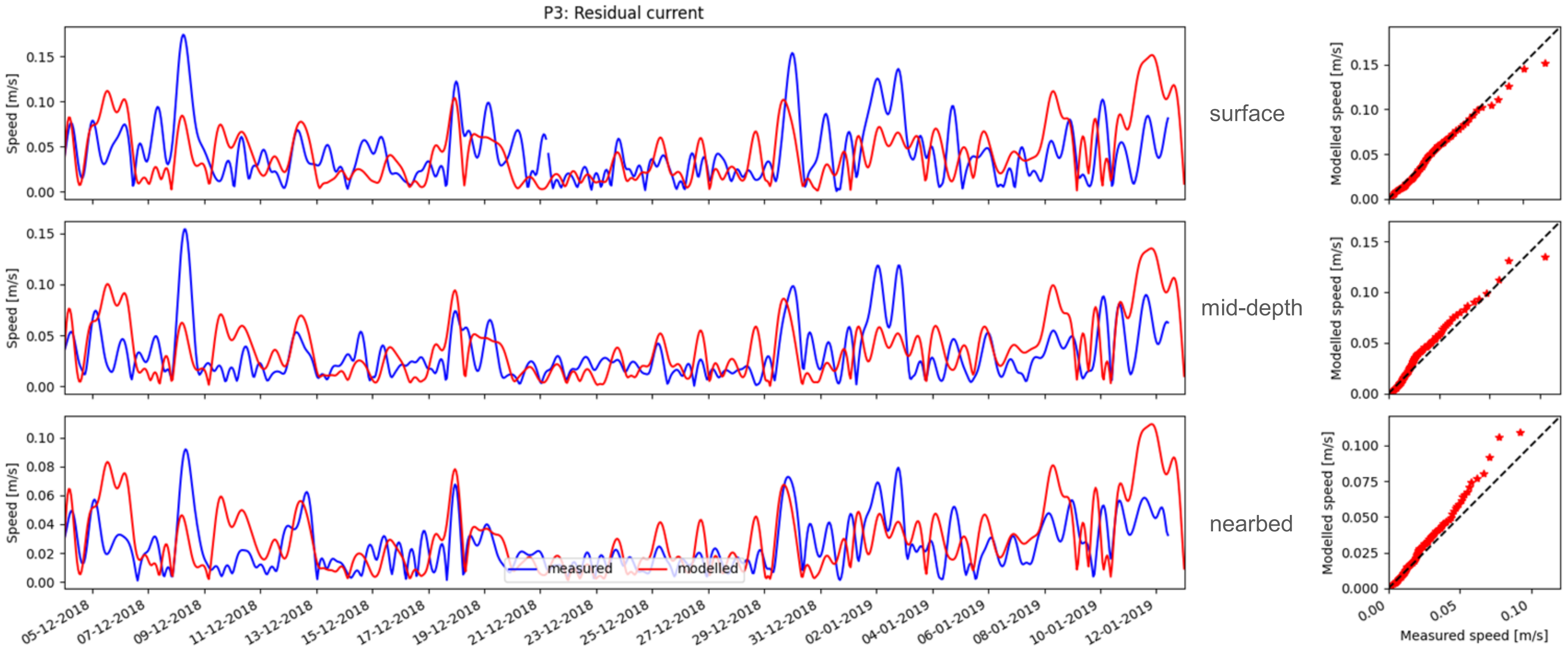
Model validation results





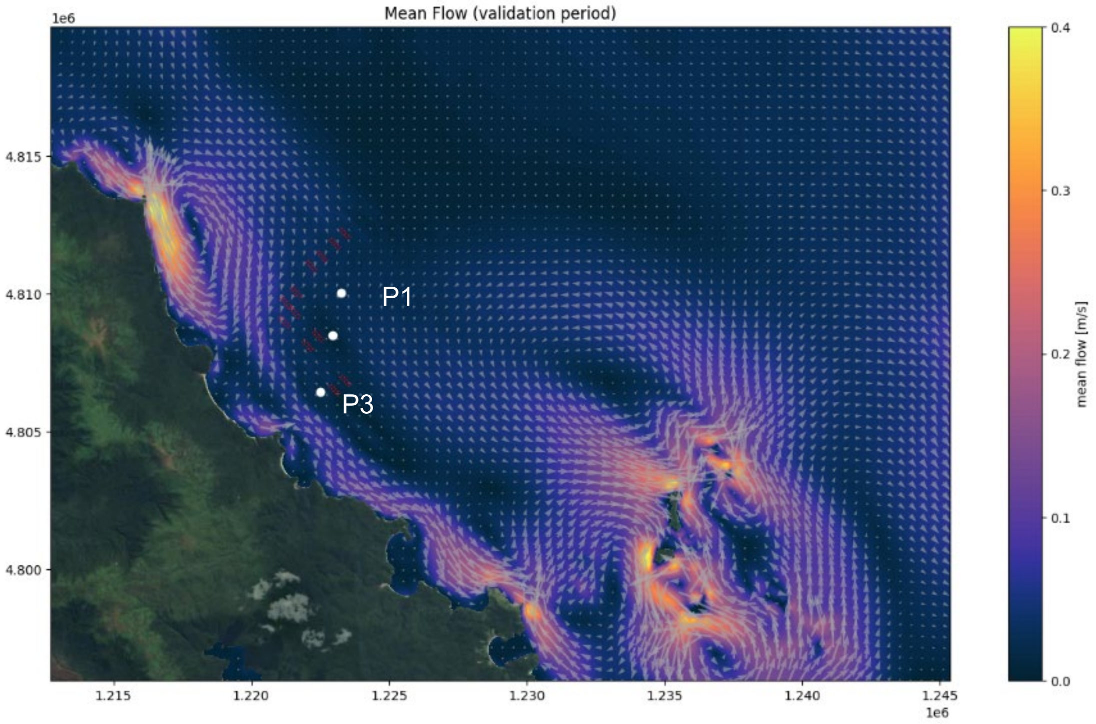
Site 3 tidal currents

Model validation results



Site 3 non-tidal currents

Model validation results

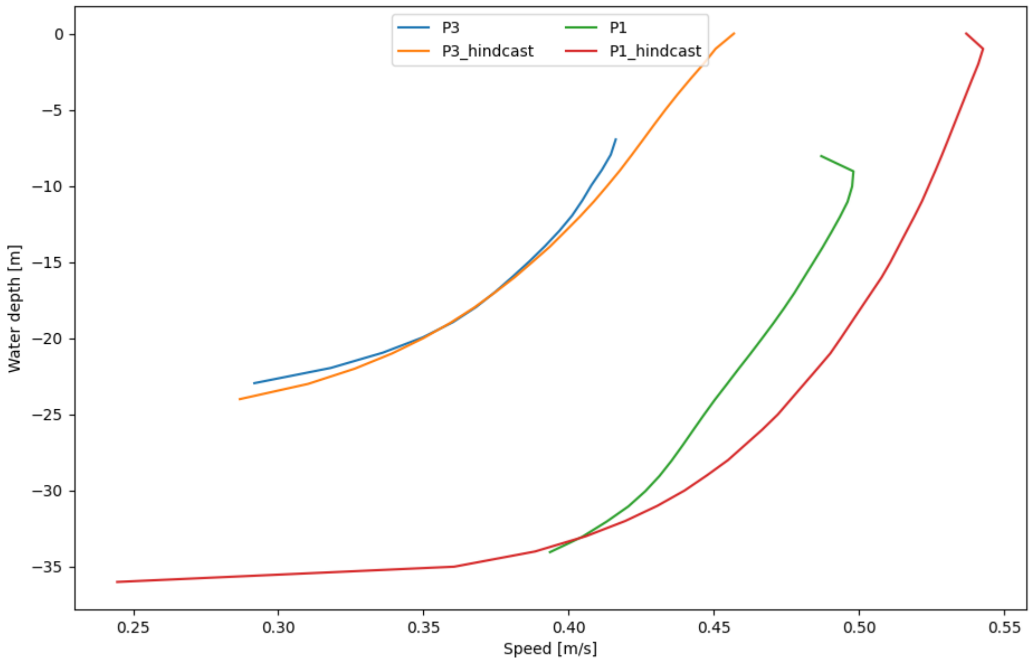


Residual flows are due to a combination of tidal asymmetries, local wind forcing and regional water level gradients derived from mesoscale weather.

In the farm area, the direction of net flow to the south was consistent spatially, but the magnitude varied.

The ADCPs were positioned in a zone of low residual flows, with adjacent gradients in residual speed.

Model validation results



Plot showing depth vs the mean speed for measured and modeled data.

The model nicely replicates the mean P3 profile. At P1, the model shows slightly stronger mean flows (by about 0.03 m/s), and a similar profile slope.

We speculate the movement of the P1 ADCP into deeper water may be having an effect on this type of comparison.

Summary of results

- Quantitative validation for tidal elevation and speed shows adequate agreement, noting that harmonic analysis of the measured tide suffers from a short duration to resolve constituents. However, this is supported by the finding that the predicted elevations at Bluff (total and tidal) are excellent.
- The total flows at both P1 and P3 are being well replicated by the model, with no suggestion of systematic under- or over-prediction of speed.
- The mean modeled profiles are tolerably similar to the mean measured profiles.
- The QQ plots confirm the distribution of residual speed is very similar.
- The Foveaux Strait has complex and rapidly changing hydrodynamics. The SCHISM model we have established is not perfect, however this validation exercise against quality observations suggests that the governing dynamics are being well replicated. This gives confidence that a decadal hindcast will provide fit-for-purpose spatial and temporal outputs.

Hananui Project

Water Quality Modelling Methods

Context for defining the modelling scope

A realistic time series representation of the farm and its development stages was required, covering annual and interannual variability. Key parameters: Total Nitrogen (TN), Resuspended Nitrogen (RN) and Dissolved Oxygen (DO).

TN methodology:

- 10-year run for Stage 2 and 1-year run for Stage 1
- Time-varying loads of TN applied evenly to all pen cells (from surface to 16 m depth).
- Load for Stage 2 varies from 7.31 to 74.37 kg/day, TN concentration varies from 0.0024 to 0.024 mg/m³/s.
- Assuming slack water of 30 minutes, the maximum TN concentration is between 4 and 43 mg/m³.
- At the end of each run the maximum concentration throughout the water column is extracted and reported.

RN methodology:

- 25 day run for Stage 2, covering one spring tide and one neap tide.
- Time series of gridded nitrogen deposition fields (g/m²) provided by Cawthron.
- 1% of deposited nitrogen is transferred to the water column as inorganic nitrogen effluent.
- At the end of each run the maximum concentration throughout the water column is extracted and reported.

DO methodology:

- A 1-year run for Stage 1 and Stage 2.

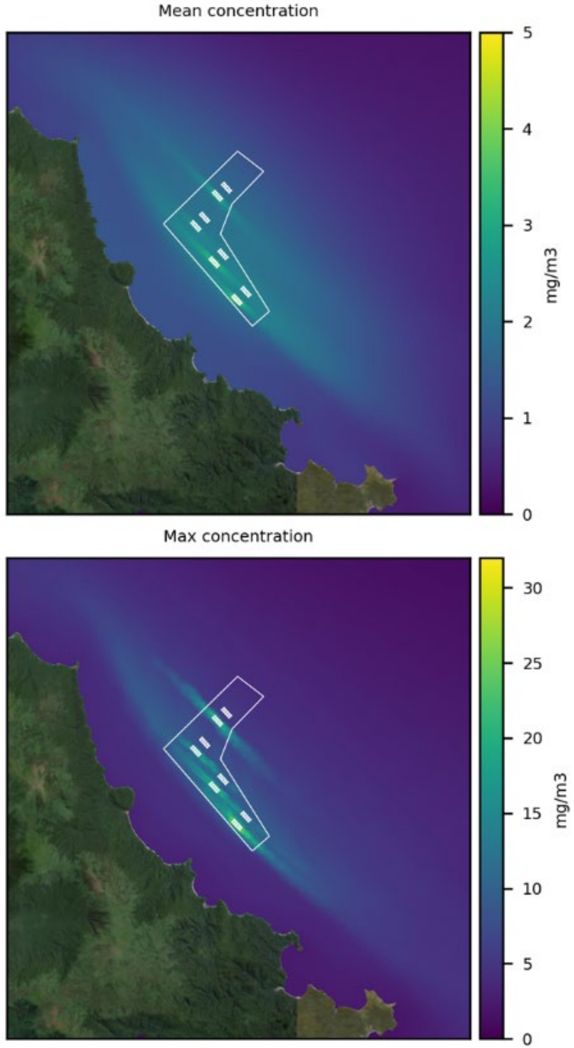
The WQ model results are a function of the site dilution properties

The contours of minimum dilution from all the farms

Water Column Assessment

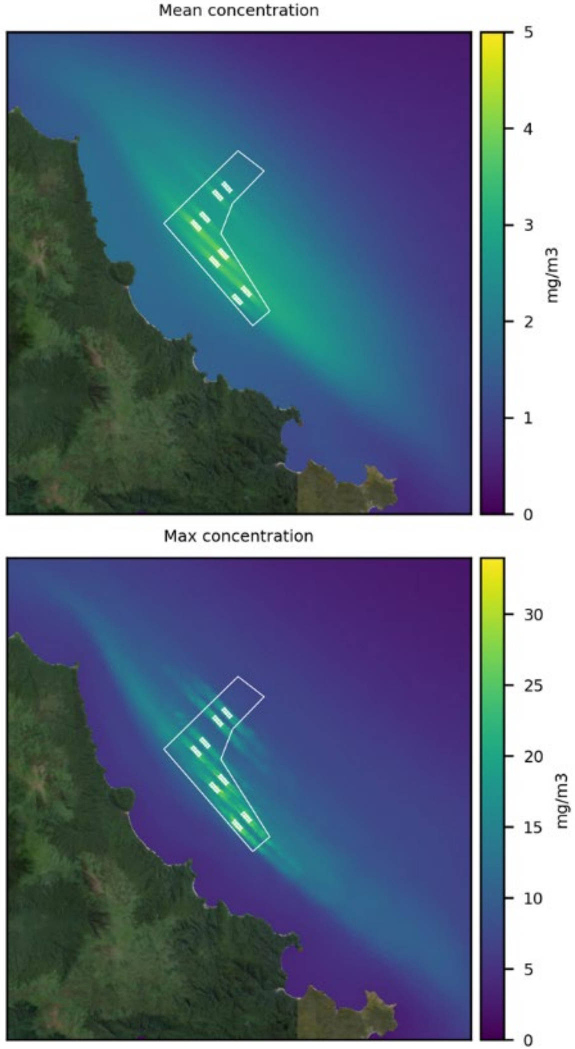
TN – Stage 1

- For context, baseline measurements in 2018/19 and 2025 ranged from 190 to 700 µg/L
- Low predicted changes in TN in context of mean background TN concentration of 405   µg/L in 2025 and 115 µg/L in 2018/19
- Mean concentration increase within 100m of the pens predicted to be 8.6 µg/L (2% increase from 2025 background and 7% increase from 2018/19 background)
- Short-lived maximums near the pens up to 31.9µg/L (limited to slack tide)
- Mean concentrations in the plumes extending up to 4km away from the farming area <3µg/L
- Negligible effects outside of this



TN – Stage 2

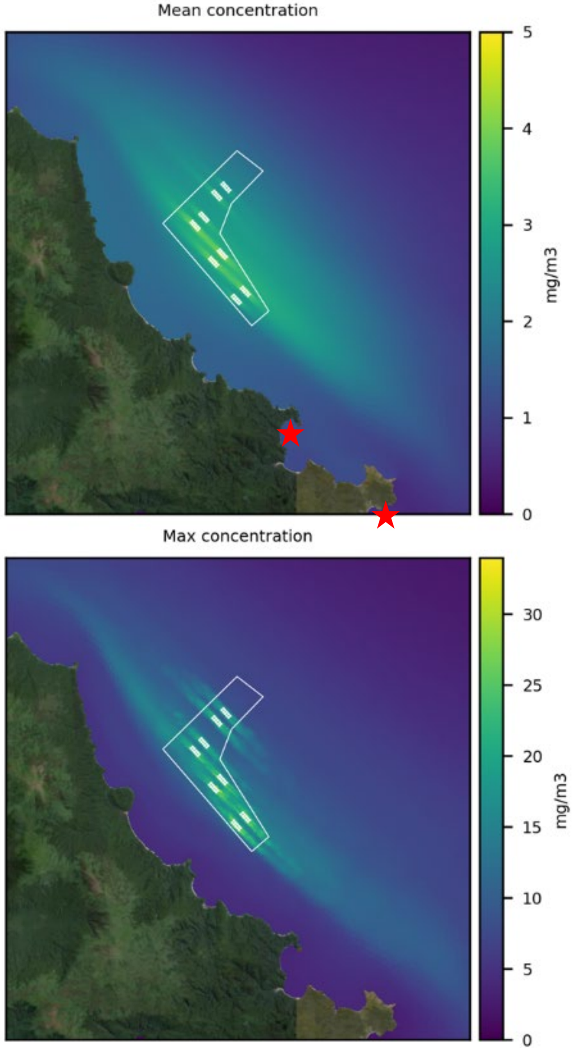
- Scales the same as Stage 1. Primarily slightly higher concentrations within the farming area, and little difference outside of this
- Mean concentration increase within 100m of the pens predicted to be 9.2 µg/L (2.3% increase from 2025 background and 8% from 2018/19)
- Short-lived maximums near the pens up to 28.6µg/L – note less than Stage 1 due to lower stocking density
- Mean concentrations in the plumes extending up to 4km away from the farming area <4µg/L
- Negligible effects outside of this



TN – Sheltered Areas

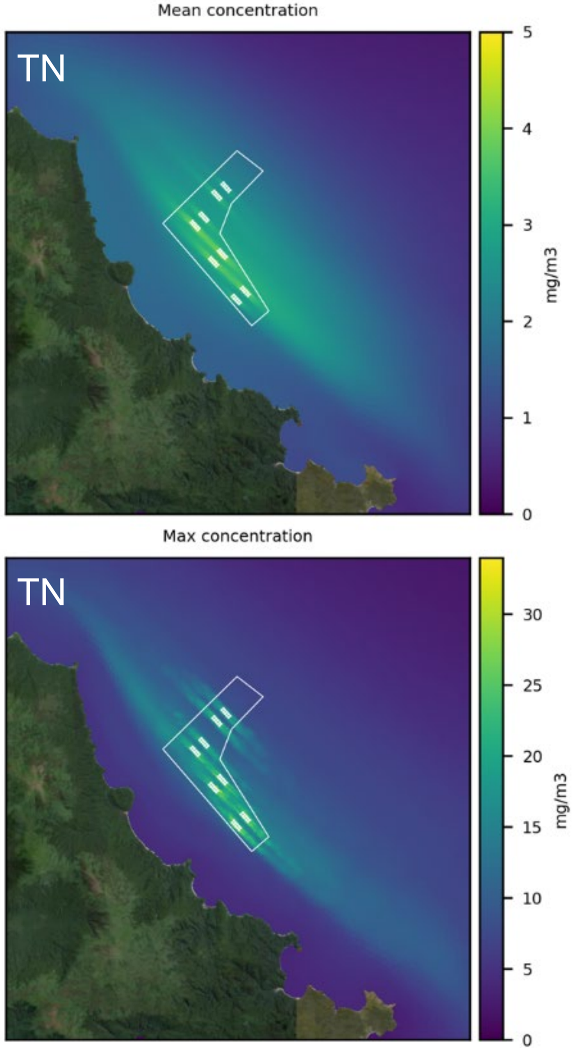
- Mean concentration increases in nearby sheltered areas predicted to be <0.8µg/L for Stage 1 and <1.0µg/L for Stage 2.
- Negligible changes at the mouth of Patterson Inlet and the wider environment

Location/Area	Mean (SD)	Median	95th %ile	Maximum
Stage 1				
Pen (within 100 m)	8.6	7	18.6	31.9
Farm area (excluding near pen)	7.7	6.7	15.4	28.3
Port William	0.8	0.8	1.8	2.3
Halfmoon Bay	0.3	0.3	0.8	0.9
Patterson Inlet	0.1	0	0.5	1.4
Stage 2				
Pen (within 100 m)	9.2	7.9	17.9	28.6
Farm area (excluding near pen)	8.2	7.5	15.3	26.7
Port William	1	0.9	2	2.4
Halfmoon Bay	0.4	0.3	0.8	0.9
Patterson Inlet	0.1	0.2	0.5	1.5



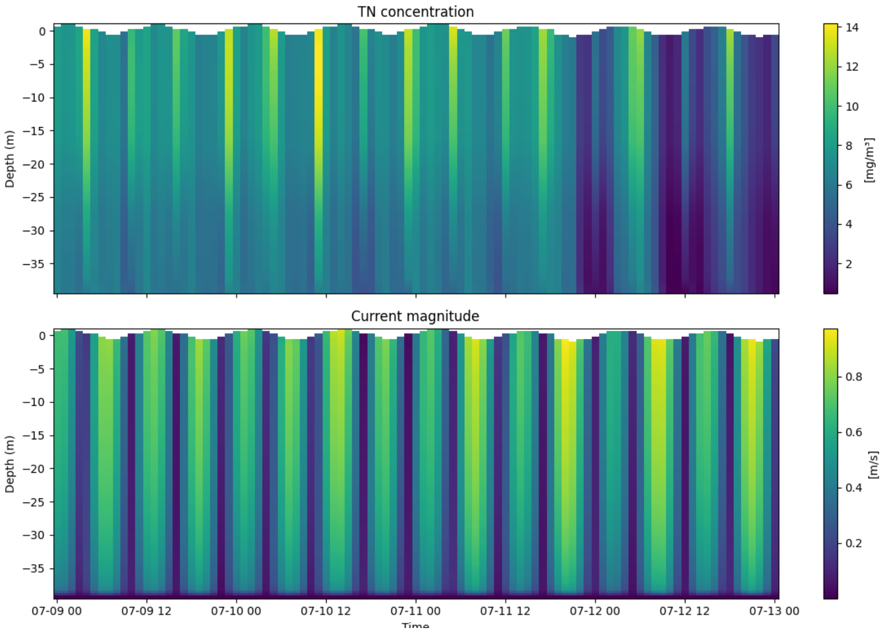
Phytoplankton

- An increase in nitrogen concentration has the potential to stimulate phytoplankton growth
- Blooms unlikely to occur in the proposed farming area due to high flow/short residence time, well mixed water column
- Nearby embayments may be more susceptible (and they have occurred previously)
- However, the <1µg/L TN increase predicted in these embayments is unlikely to result in notable increases in phytoplankton biomass



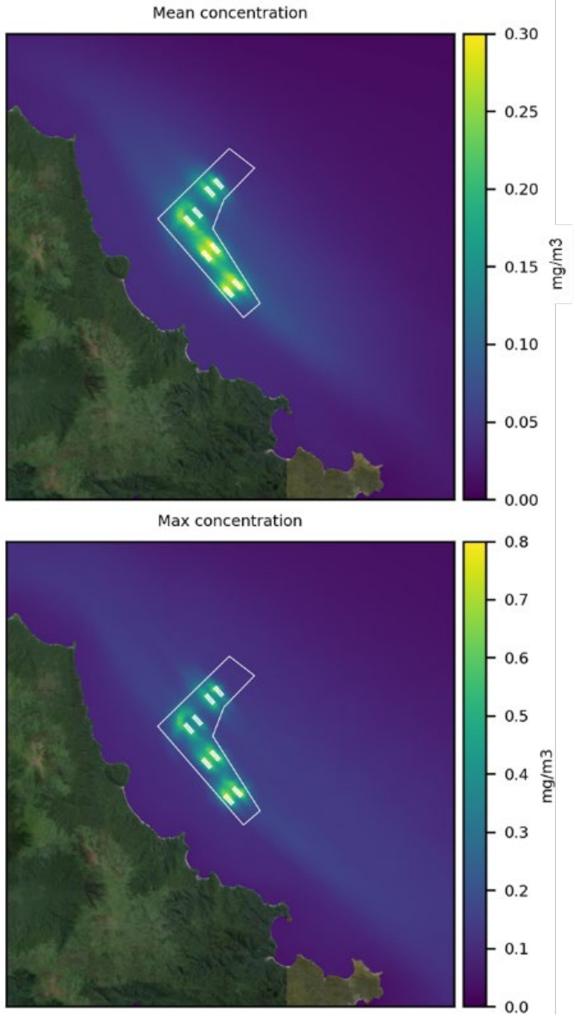
Changes Through Water Column and Time

- Fish pens occupy upper ~16m of water column
- Predicted increases in TN largely localised to upper 20m of the water column
- Maximum increases in TN occur following a slack tide (approx. 1 hour)
- Spring tides (on the right of the plot) also result in lower predicted increases due to higher flushing



Remineralisation

- The degradation of deposited organic matter could result in nitrogen being released back into the overlying water column
- Modelled using the outputs of Cawthron’s benthic modelling
- Predicted contribution <0.8µg/L constrained to the lower water column localized to the farm’s benthic footprint
- Effects considered negligible

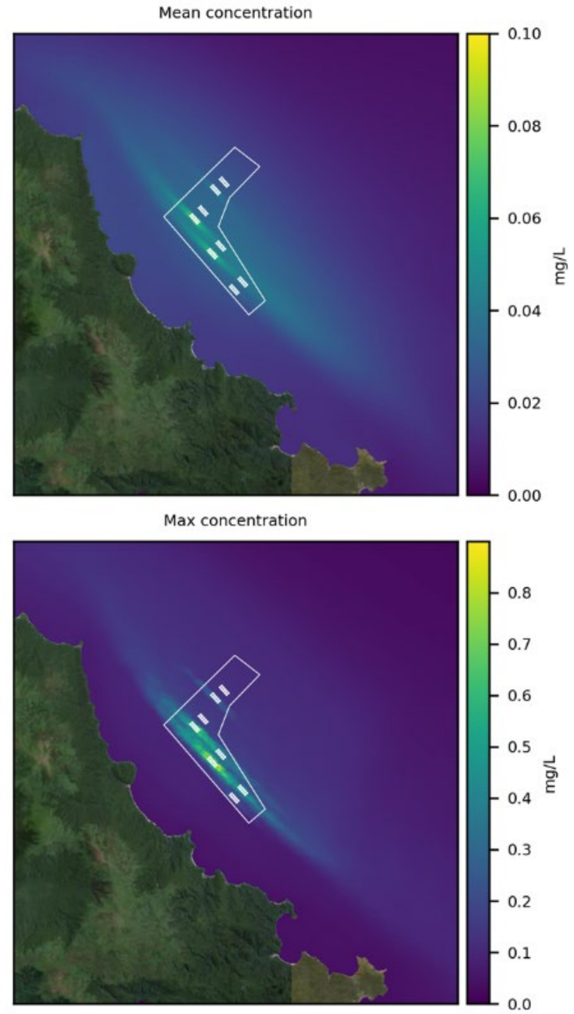


Nutrient Enrichment Summary

- Effects of the proposed farming activity on nutrient concentrations in the water column will be low and localized to the pens, farming area, and to a lesser extent up to 4km downcurrent from the farm boundary
- Within 100 m of the pens, mean increases in TN are predicted to be less than 10 µg/L, with short-lived maximum concentrations of up to approximately 30 µg/L occurring approx. 1 hour follow slack tides
- Within the broader farming area, mean increases of <8.5 µg/L predicted to occur (2% increase from 2025 background, 7% from 2018/19 background)
- Mean increases up to 4km downcurrent of the farming area <4µg/L and negligible outside of that
- Such small change not considered sufficient to alter the tropic state
- Effects on nutrient enrichment assessed to be low within the Hananui boundary and negligible outside of the boundary.

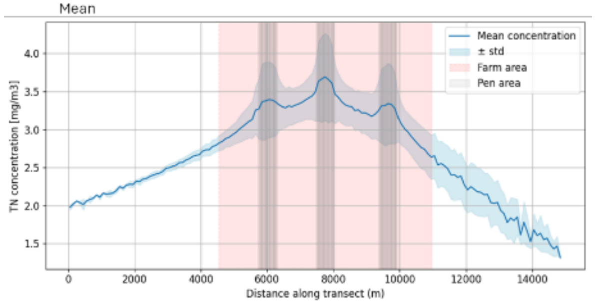
Oxygen Depletion

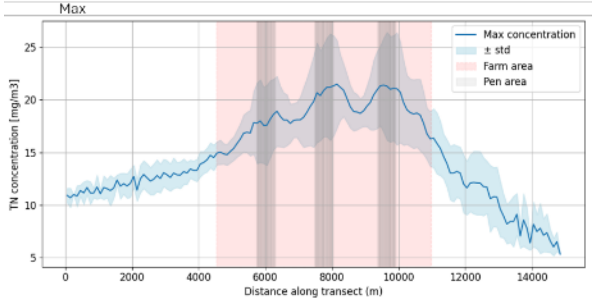
- Fish respiration has the potential to reduce dissolved oxygen concentrations
- To a lesser extent, microbial degradation of organic matter (but this hasn't been modelled)
- DO reductions with 100m of the pen predicted to be <0.2 mg/L under Stage 1 and <0.18 mg/L under Stage 2
- Very small changes relative to background and DO concentrations would remain above 7.8 mg/L based on mean background concentrations
- Far exceeds threshold of 5 mg/L where adverse effects on fish have been observed (sublethal effects)
- Effects are localised and assessed to be low near the pens and negligible in the surrounding environment
- Bottom water DO depletion unlikely without substantial adverse benthic effects so considered unlikely and negligible



Mixing

- Strong currents running along a northwest - southeast axis
- TN concentrations extracted from a transect through and extending either end of the proposed farming area plus 500 m either side
- Decrease in TN fairly consistent with distance from the pens
- Slightly higher decrease within 200 m of the pens.
- Elevated concentrations up to 4km away, however, likely very difficult to differentiate from natural variability
- Mixing is complex, and considered that best approach is to identify specific compliance distance/locations for each parameter, rather than defining a mixing zone.





Do you have any questions?