ADVANCES OF INTEGRATED MODELLING FROM SEA-TO-MOUNTAIN

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ABSTRACT

New Zealand is facing ongoing pressure from historic and continuing decline of water quality (PCE, 2013; Larned et al., 2016). New Zealanders are engaged and concerned by water quality issues. This has led to the development of national policies for freshwater management and a coastal policy (MfE, 2020). Whereas the national policy for freshwater has a national objective framework outlining the attributes of freshwater and the various states that could be attained as a consequence of management, the coastal national policy statement lacks the same. However, a universal acknowledgment that freshwater must be managed for ki uta ki tai (integrated management) to give effect to Te Mana o te Wai. The NPS-FM requires regional councils set limits on resource use that must have regard to the foreseeable impacts of climate change (Clause 3.14) and utilise information from freshwater accounting systems (Clause 3.29).

Auckland Council (Healthy Waters) has developed the Freshwater Management Tool (FWMT), a process-based and continuous model to account for water quality regionwide, integrated from mountains-to-sea. The FWMT services a broad range of growing regulatory and non-regulatory requirements for robust, objective evidence of water quality in the Auckland region – for existing (baseline), future (maximum permitted development, climate change) and intervention or managed futures (optimised).

The FWMT is the region's most advanced freshwater accounting system, able to support numerous requirements of the NPS-FM (e.g., baseline state assessment, objective and limit setting, integrated catchment action-planning, efficiency analysis and future state assessments). The FWMT implements continuous, process modelling for nutrients (nitrogen, phosphorus), metals (copper, zinc), sediment (total suspended solid) and *E.coli*. An integrated understanding of water quality and the distribution of contaminants from freshwater to coast requires process-based modelling. Only process-based models allow transport of contaminants to be traced back to land or stream sources and forecast the effects of marked changes to boundary conditions (e.g., climate change, farming intensification, development, management interventions). Continuous, process-based models also offer detailed information on acute and chronic effects instream through to event-scale and long-term coastal loading.

Stephens et al (2022) are presenting at *Stormwater Conference 2022* on considerable advances in FWMT development. FWMT baseline modelling has been completed, independently reviewed and now reported on Knowledge Auckland (https://www.knowledgeauckland.org.nz/). Continuous, process-based datasets on hydrological and contaminant responses of activities in 5,465 sub-catchments are now available for the 2003-2017 baseline period (fwmt@aucklandcouncil.govt.nz).

FWMT – COASTAL CHALLENGE

Coastal receiving environments are heavily affected by load-driven effects. The greater residence times and access to internal reservoirs, makes coastal health much more strongly governed by load received than periodic concentration of discharge received [Zeldis et al., 2017; Plew et al., 2018]. Freshwater and coastal critical conditions differ, meaning action plans for freshwater objectives may not protect coastal water quality. For instance, critical conditions instream might correspond to periodic high concentration under low flow, resulting in minimal coastal loading or effect.

The Auckland region is dominated by the marine environment consisting of two oceans, three major harbours and estuaries with coastline totalling about 2400 km. The differences in sensitivity and critical condition of coastal and freshwater environments, presents an important challenge to FWMT use for integrated (freshwater and coastal) action-plan development. Whereas observational records provide information on the state of Auckland's harbours, process-based models will add to the understanding of key processes that lead to degradation and therefore lead to the determination of ideal interventions.

A combined set of challenges have emerged for Auckland Council from development of the FWMT:

1. Understanding of coastal water quality state – similar high-resolution and causative knowledge of the effects of land and resource use on water quality
2. Understanding of coastal critical conditions – knowledge of the targets for contaminant loading to coast to ensure action plans are integrated for freshwater and coastal water quality

INTEGRATED MODELLING

To help address both coastal challenges above, Healthy Waters requested DHI to couple the FWMT to DHI's numerical coastal model for the Waitematā Harbour to evaluate the transport and fate of Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), Total Copper (TCu) and Total Zinc (TZn) in the harbour. The coupled FWMT-coastal receiving model is a proof-of-concept to simulate baseline coastal water quality and identify "load targets" for improved coastal health – with capability to resolve event and long-term contaminant mass effects.

The FWMT-coastal receiving model is process-based, with wave and tide hydrodynamic processes coupled to deposition and resuspension processes for sediment. Conservative or decaying tracers for total nutrients in suspension and metals in deposition were also used, combined with the hydrodynamic processes affecting flow and concentration.

The coastal model received daily time-step inputs from the FWMT at 334 terminal freshwater nodes, that were aggregated to 89 coastal inputs. The coastal model disaggregated daily inputs to operate at a 5-minute timestep over an annual period. The annual period of inputs was 2015 (chosen as a representative contaminant year) whilst the annual period of wave/tidal configuration was 2018; differing boundary input periods reflect data availability. Results are therefore indicative of coastal water quality for a mix of recent and short-term (annual) but varying boundary conditions.

The integrated FWMT- coastal model simulates the fate of freshwater-derived contaminant inputs from all land draining to the Waitematā Harbour. A connectivity matrix was developed between FWMT inflows and sub-estuaries within the model domain (Figures 1 and 2). With this approach the contribution of freshwater-derived contaminants to the estuarine receiving environment could be estimated at 86 sub-estuaries within the inner and outer Waitematā Harbour.

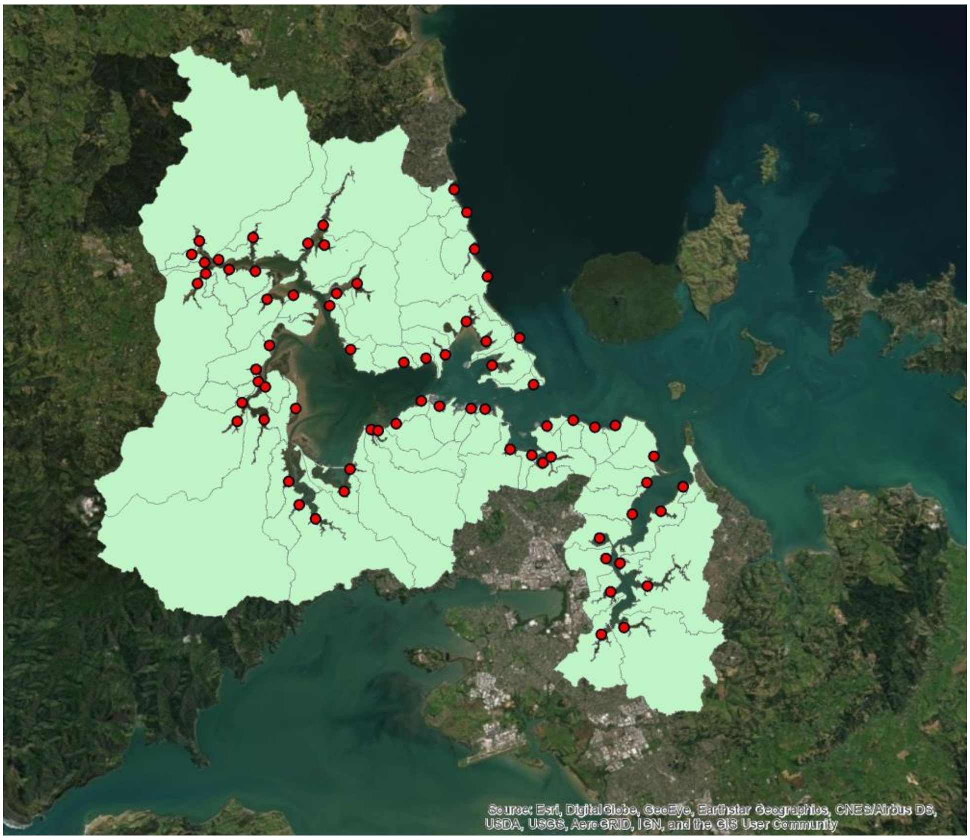

Figure 1. FWMT discharge nodes and associated catchments, draining to Waitematā Harbour. Note continuous (daily) time-series of contaminant discharge to the coast are now available from the FWMT baseline (2003-2017; nutrients, sediment, metals, *E.coli*).

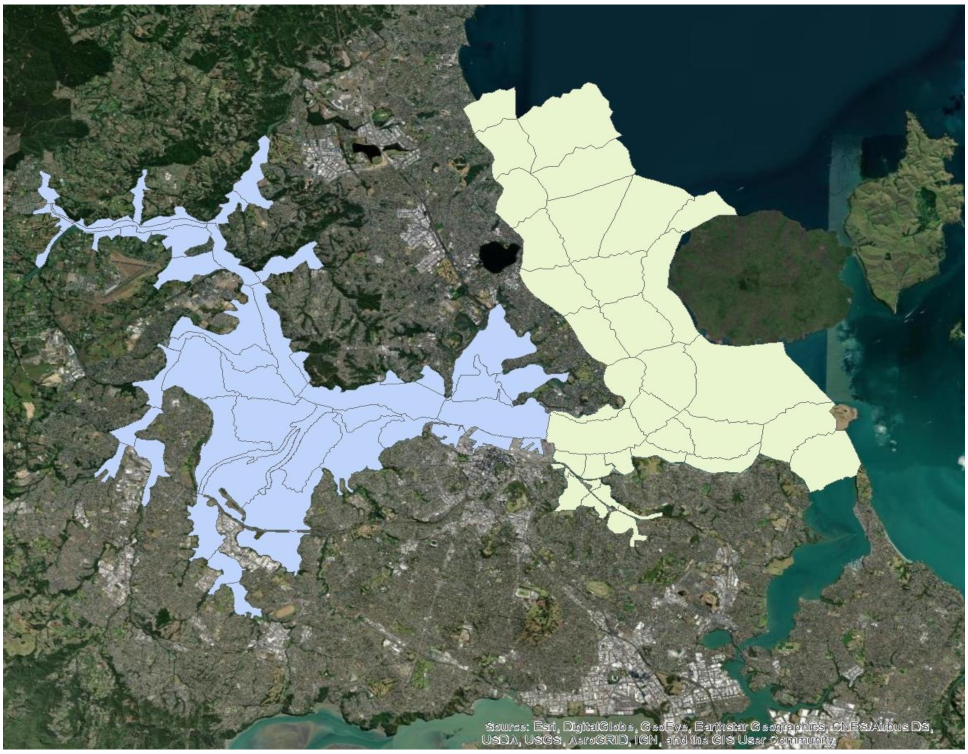

Figure 2. Sub-estuary polygons for FWMT-coastal model. Inner Waitematā (blue) and Outer Waitematā (yellow).

FWMT-coastal model development is ongoing. 2D hydrodynamic model calibration for depth averaged currents and water level are generally good (minor under-prediction of peak current speeds). Wave height and peak period are also generally well calibrated, albeit outside of the Waitemata Harbour with observed wave datasets scarce. Contaminant decay tracers were manually tuned until reasonable agreement with observed sedimentation rate, %mud, deposited metal concentration (total copper, total zinc) and dissolved nutrient concentration (total nitrogen, total phosphorus).

Preliminary FWMT-coastal outputs are shown in Figures 3 to 5 to demonstrate the potential to address Challenges 1 and 2 (e.g., identify land use effects on the state of Waitematā Harbour; utilise baseline state and loading understandings to inform optimisation targets for freshwater loading).

Key FWMT-coastal pilot learnings include:

- Translating outputs to risk-based narratives akin to freshwater grading – the absence of nationally agreed and statutory guidance for coastal contaminants, results in inconsistent grading to freshwater (i.e., differing number of bands, varying thresholds in risks for banding)
- Matching observed sedimentation rates in central Waitematā – FWMT baseline TSS loading predictions closely match instream observations. However, inputs of TSS loads from the FWMT are unable to approximate sedimentation rates observed in the harbour, (i.e., a legacy and/or marine source is likely to dominate sedimentary effects)

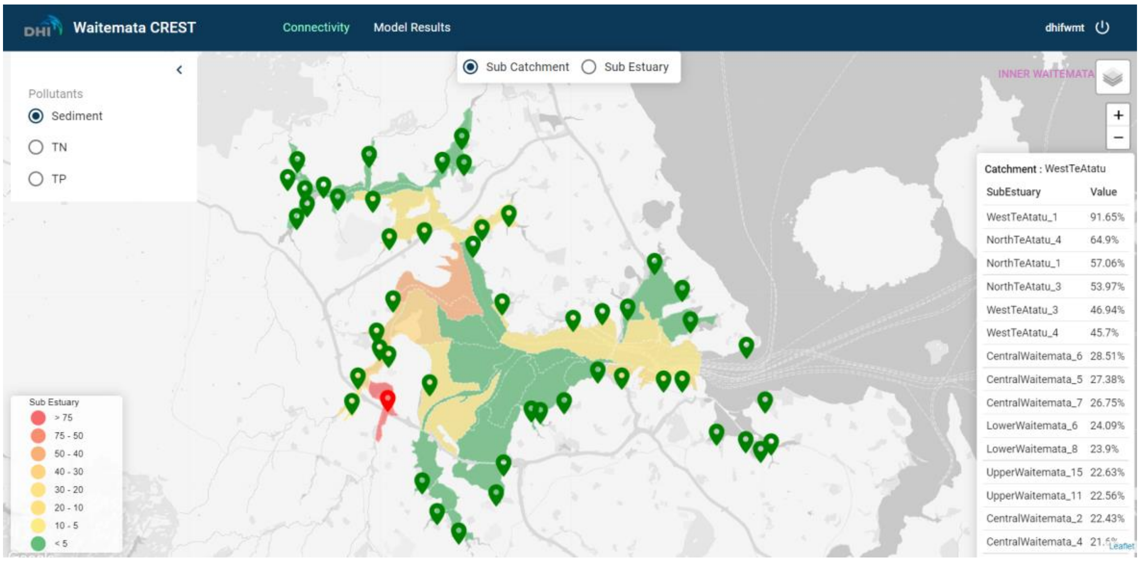

Figure 3. Connectivity outputs showing proportion of FWMT terrestrial sediment load dispersed from selected (red balloon) to 86 sub-estuaries.

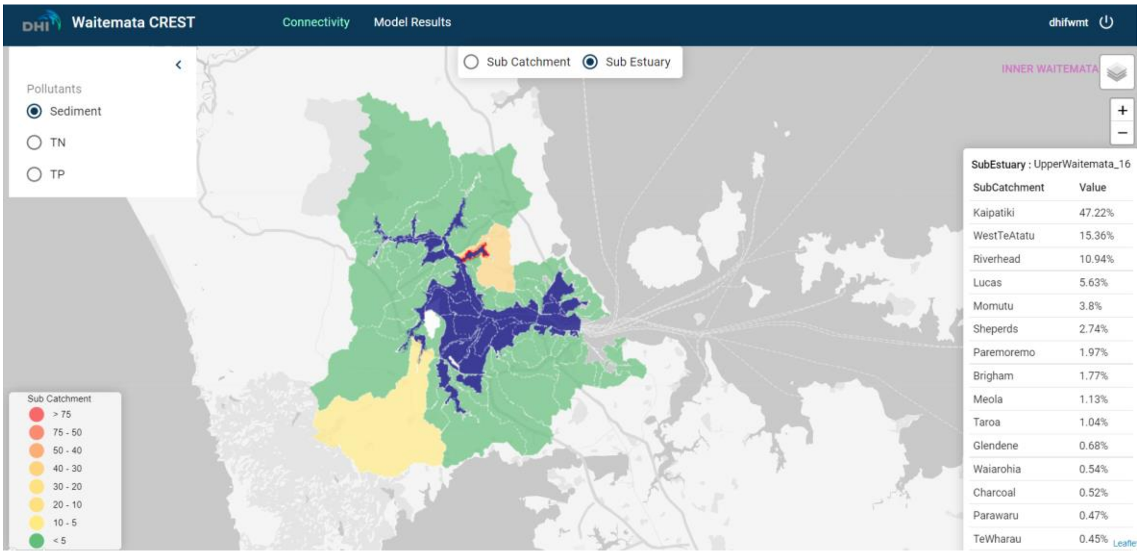

Figure 4. Connectivity outputs showing origin of selected (red outline) sub-estuary sediments from all FWMT catchments.

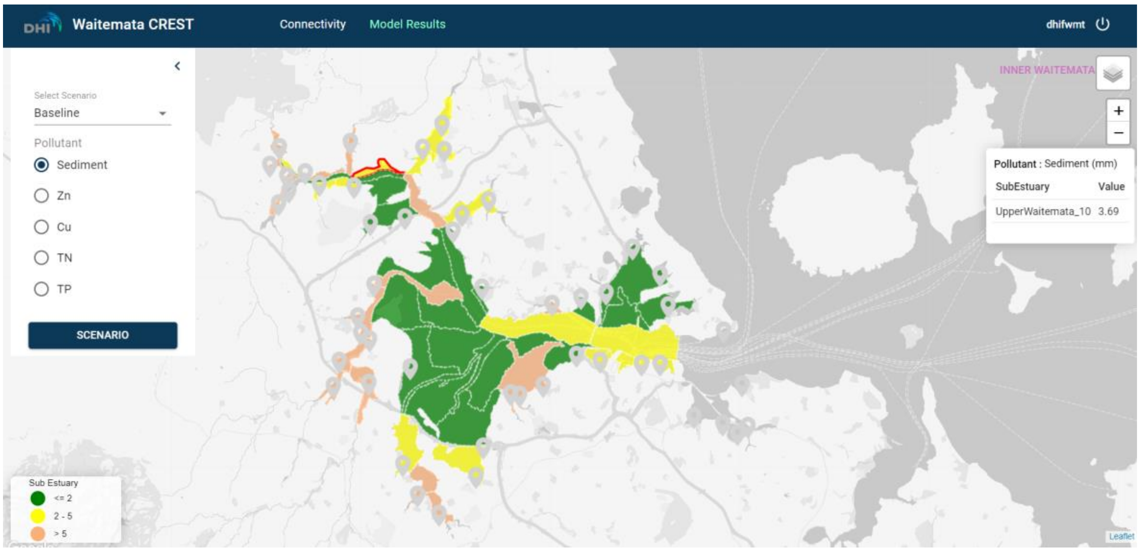

Figure 5. Coastal state of Waitemata Harbour for sedimentation (degradational) effects associated with erosion from land and streams (using FWMT baseline results for 2015). **Note**: provisional grading guidance based on Townsend and Lohrer (2015).

FWMT-COASTAL

FWMT-coastal pilot modelling has integrated FWMT and hydrodynamic models for the first time throughout the Waitemata Harbour.

The FWMT-coastal approach adopted can be expanded to other harbours of Auckland, to identify and manage contaminant loading to the harbours in an integrated manner.

The FWMT-coastal approach can be modified to include greater process-driven rather decay-based simulation, to

- Identify specific catchments contributing the most load to coast
- Identify the sub-estuaries most impacted by catchment processes

- Optimise catchment management for coastal and freshwater outcomes

KEYWORDS

water quality, coupled-modelling, hydrodynamic, estuary, national policy statement for freshwater management, Freshwater Management Tool