RADICAL ADVANCES IN WATER QUALITY MODELLING – AUCKLAND'S FRESHWATER MANAGEMENT TOOL

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ABSTRACT

The Freshwater Management Tool (FWMT) is an open-sourced, continuous and process-based variant of US-EPA software (Shen et al., 2004; Shoemaker et al., 2009) modified for regulatory and non-regulatory water decision-making by Auckland Council (e.g., Resource Management Act 1991, Local Government Act 2003, Water Quality Targeted Rate, Jobs for Nature).

The FWMT simulates hydrological and contaminant processes affecting concentration and load of ecosystem and human health stressors, accounting for contaminant losses from 100+ activities under varying weather (e.g., acute and chronic conditions). Contaminants simulated by the FWMT include nutrients, metals, sediment and faecal indicator bacteria (*E.coli*) on land, throughout 3,085 km of freshwater and to all coastal receiving bodies.

The FWMT also simulates dynamic intervention and life-cycle cost optimization – modelling changes in water quality within opportunity constraints, 50-year (life cycle) cost and effects of interventions, to determine least-cost actions to maintain and improve water quality under existing or altered boundary conditions.

The FWMT radically advances understandings of current state, future state and management strategies to maintain or improve water quality across the Auckland region. The FWMT approach of combining continuous, process-based and dynamic, cost-optimised intervention models is of broader national relevance; FWMT-variants are now being developed for decision-making by the Kaipara Moana Remediation entity ($200M Jobs for Nature targeted investment programme) and Tauranga City Council.

Our presentation will highlight completion of baseline FWMT modelling, availability of innovative datasets to guide decision-making, before revealing novel outputs of optimised, dynamic intervention modelling – the very first demonstration in New Zealand.

FWMT APPROACH – BASELINE EXAMPLAR

FWMT baseline modelling is complete, including formal peer review. The independent peer review team[1] offered strong support for the FWMT approach:

"It [the baseline FWMT] *will also be looked upon as an exemplar for assisting catchment-level decision making by regional councils in New Zealand"* (Hamilton et al., 2021:7).

[1]FWMT baseline peer review team included Prof. David Hamilton (Griffith University), Dr. Kit Rutherford (NIWA) and Mr. Nic Conland (Taiao Natural Resource Management).

FWMT reports are available on Knowledge Auckland and baseline datasets are available directly from Healthy Waters (fwmt@aucklandcouncil.govt.nz) and Geomaps.

Previously, Auckland Council was reliant on steady-state, statistical and generally load-based models of current state, lacking resolution of event-based changes to instream concentration (Contaminant Load Model [CLM] – ARC, 2010; Catchment Land Use for Environmental Sustainability Model – Semadeni-Davies et al., 2016). Auckland Council also currently relies on limited use of steady-state, non-continuous models or non-optimised intervention models (CLM; CLUES; Model for Urban Stormwater Improvement Conceptualisation [MUSIC] – Melbourne Water, 2018).

Now, hydrological and contaminant time-series are available for 5,465 sub-catchments covering 490,000 Ha of urban and rural land, continuously over a 15-year baseline period (e.g., daily average flow and concentration derived from 15-minute computation for 2003-17, on: dissolved and total nitrogen and phosphorus; total copper and zinc; total suspended sediment including clay, silt and sand fraction; *E.coli*) – see Figure 1. Accompanying estimates of contaminant yield to freshwater and coastal receiving environments are also now available, by sub-catchment for up to 107 sources including wastewater (Type 1 & 2 events at 448 engineered overflow points in six major networks) – see Figure 2.

To support continuous improvement, FWMT baseline peer review recommendations are also now being implemented:

- Healthy Waters and NIWA are exploring coupled FWMT-ecological modelling (macroinvertebrates, fish, algae)
- Healthy Waters and DHI are exploring integrated freshwater-coastal modelling (see *Stormwater Conference 2022 presentation by Kpodonu et al.*)
- Healthy Waters and University of Waikato are exploring coupled FWMT-lake process modelling
- Healthy Waters, NIWA and University of Otago are exploring improvement to metal simulation and toxicity reporting
- Healthy Waters, NIWA and HAL are developing novel climate time-series for representative concentration pathways to be scenario modelled
- Healthy Waters, Puhoi Stour and Aquanet are developing a novel model-targeted monitoring programme

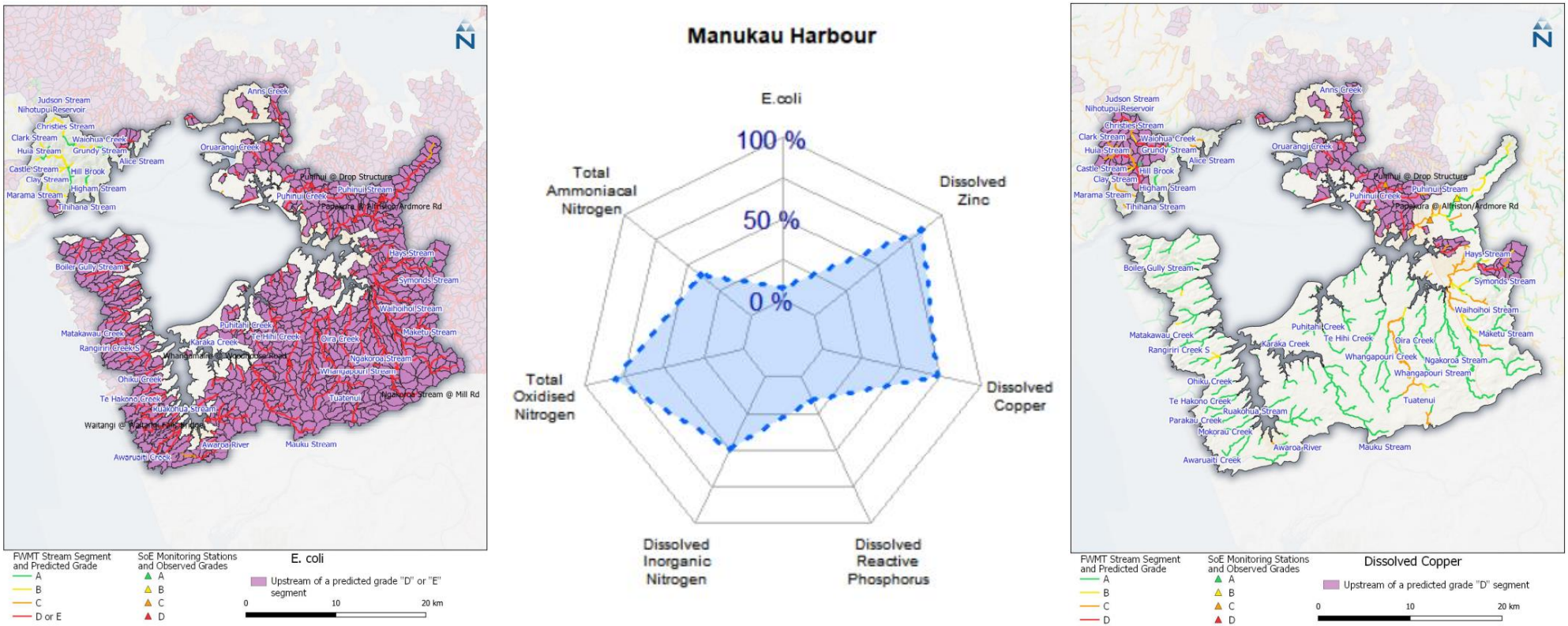

Figure 1. FWMT baseline instream water quality for Manukau Harbour watershed (2013-2017). Images left to right: *E.coli* overall grading; proportion of modelled streams in A and B grade; dissolved copper overall grading. Sub-catchments discharging to streams failing national target (*E.coli*) or >5% community affected by toxicity (dissolved copper) shaded. **Notes**: (1) daily concentration graded for acute and chronic degradation using national and regional guidance (median, 95th%...); (2) worst (overall) of numeric attribute states presented.

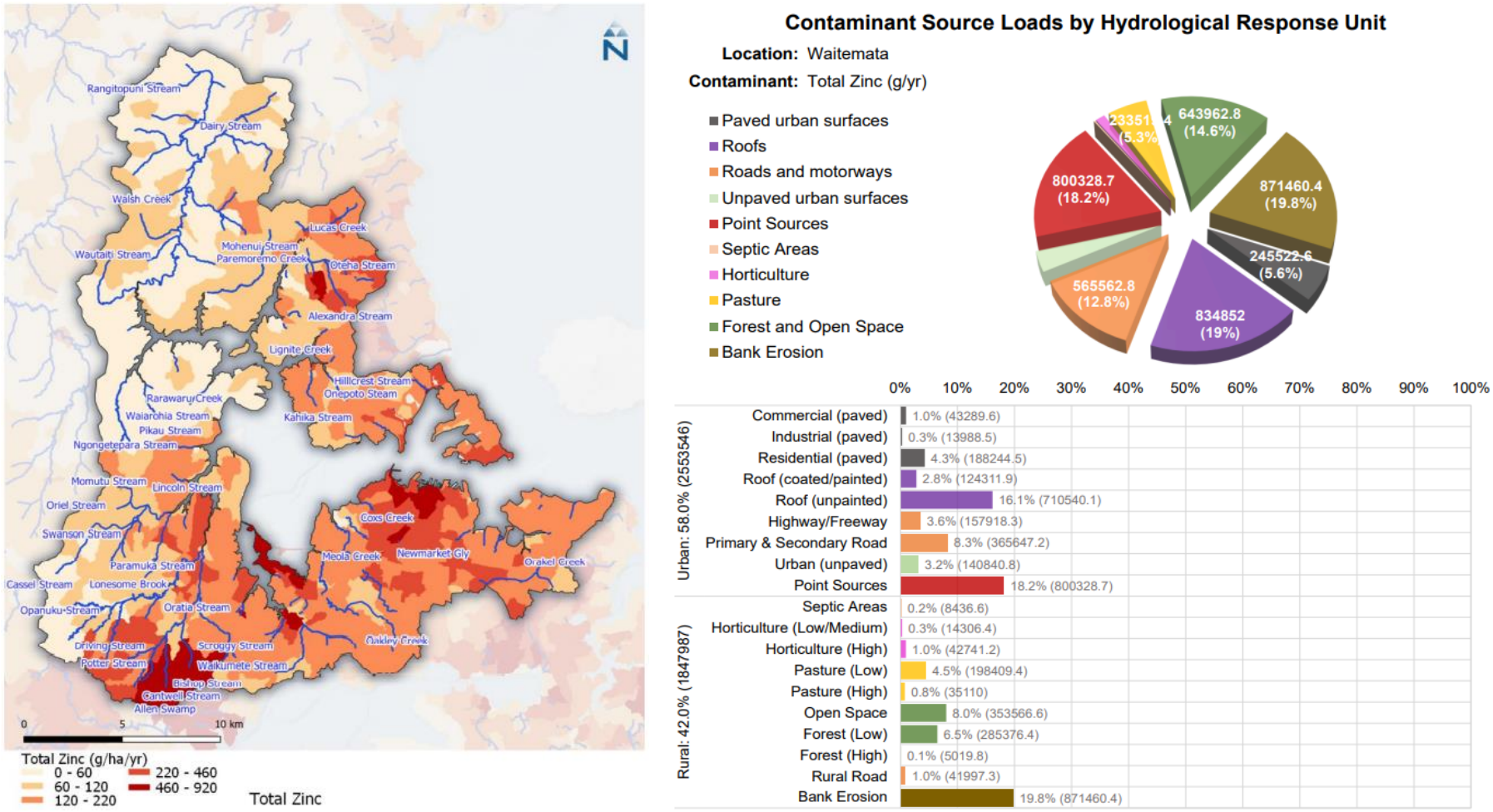

Figure 2. FWMT baseline annualized yields (left) and sources (right) of total zinc to receiving environment in Waitematā watershed (modelled stream or direct to coast) (2003-2017). Sources reported as hydrological response unit groups – larger parent groupings of the 107 activity types continuously simulated for contaminant generation and transport by FWMT.

FWMT APPROACH – ADVANCING OPTIMISED INTERVENTION MODELING

The FWMT approach enables optimised, dynamic water quality modelling: continuous simulation of devices and source controls for hydrology and contaminant effect; and determination of least-cost interventions for water quality objective(s).

A core purpose of the FWMT is decision-making about "action plans". Specifically, how best to target interventions to improve already degraded or maintain water quality under future growth, differing primary production and/or climate change.

Preliminary FWMT modelling inputs were presented by Judd et al (2021) and Ira et al (2021) for a maximum permitted development (MPD) scenario across the Auckland region. Considerable progress has since been made creating datasets and tools (available from fwmt@aucklandcouncil.govt.nz):

- Future land use – geospatial layer mapping anticipated changes in development as defined within the Auckland Plan 2050
- Intervention workbooks and cost-functions – expanded mitigation options now spanning rural devices and source controls, accompanied by life-cycle cost functions from Ira et al (2021), design criteria and efficiencies (wetlands, raingardens, tree pits, swales, green rooves, filtration systems, rain tanks…)
- Primary Flow Network - geometric network delineating hydrological flows paths between surface, permanent stream networks and urban stormwater networks
- Intervention opportunity layers & tool – geospatial datasets identifying explicit locations suited to urban and rural devices (for device-based interventions). Geospatial tool developed to rapidly automate delineation of upstream areas to devices

FWMT trials on pilot rural and urban stormwater catchments are now complete. The FWMT can now successfully identify least cost interventions from upstream rural and urban device and source control opportunities, to achieve objectives for nutrients, metals, sediment and faecal indicator bacteria (see Figures 3 & 4). Regionwide MPD scenario modelling has commenced.

Optimisation routines for "critical conditions", "assessment points" and "limiting contaminants" have been defined in an NPS-FM compliant approach. Critical conditions are periods of excessive contamination. For instance, a target for 95% species protection from NH4N toxicity might be set in a regional plan (B-grade), making the critical condition those flows and times of NH4N concentrations >0.24 mg/L. It is more complex for NPS-FM optimization, where a grade is associated with multiple conditions (e.g., median and 95th concentrations). Assessment points are locations requiring optimisation, which are numerous and integrated for freshwater management in New Zealand; NPS-FM requirements are unclear (e.g., one or more representative location[s] of a freshwater management unit – FWMT offers 5,465 potential assessment points). Limiting contaminants are those driving the cost of intervention (i.e., C-grade for *E.coli* could be more costly to treat than B-grade for NH4N).

The FWMT approach is flexible enough to optimize for treatment at critical conditions in locations for multiple objectives.

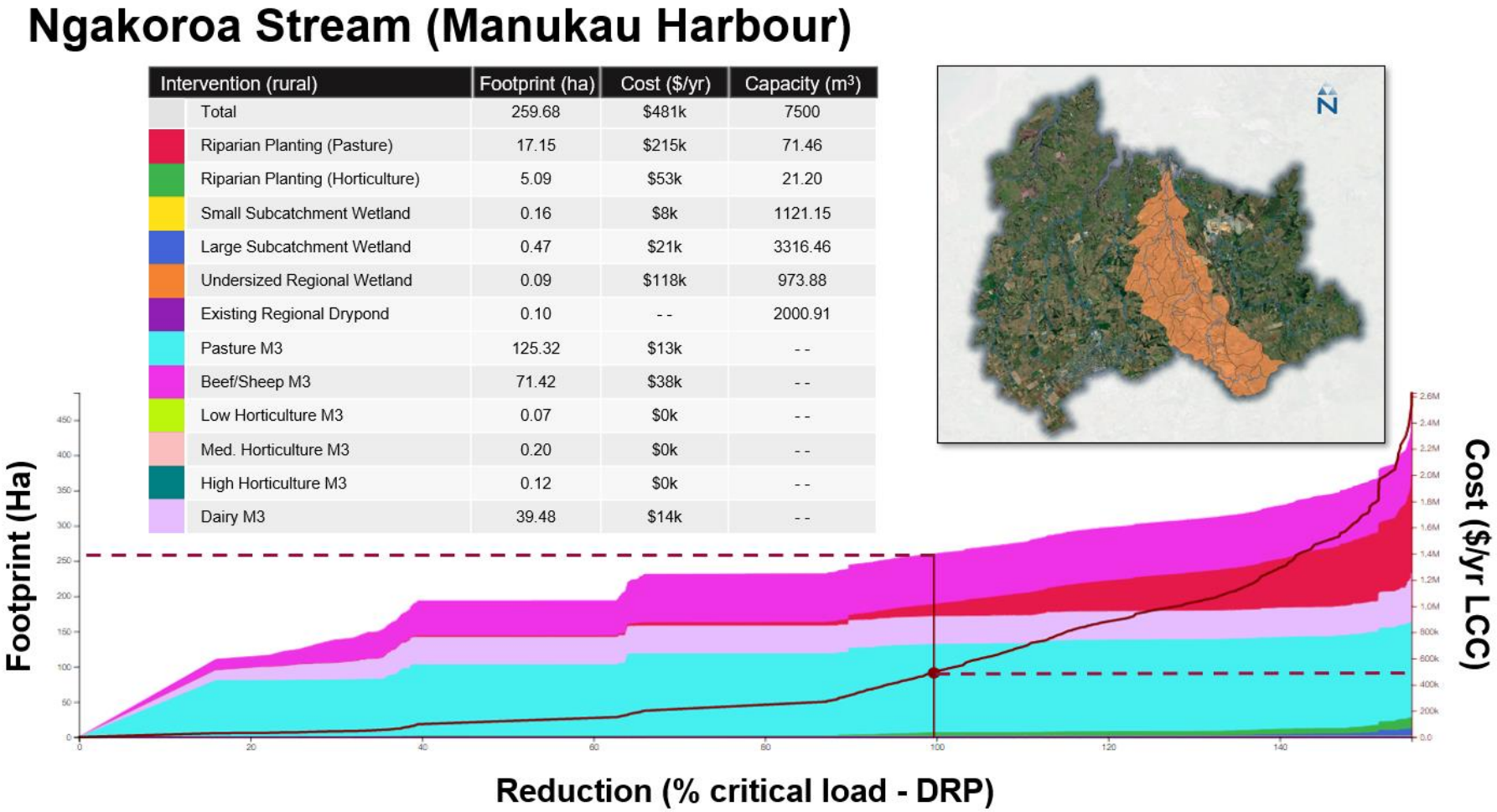

Figure 3. Optimisation curve for Ngakoroa Stream in Manukau watershed and critical condition of instream A-grade on Dissolved Reactive Phosphorus (DRP). Solid red line is lifecycle cost (right y-axis) and compound curve is split of intervention footprint (left y-axis). Costs to remediate Ngakaroa Stream to A-grade for DRP (100% critical load treated) would be ~NPV$480,000/year (lifecycle – annualized for 50-years at 4% discount rate) for intervening on ~260Ha of land. **Note**: footprint ≠ cost per unit area.

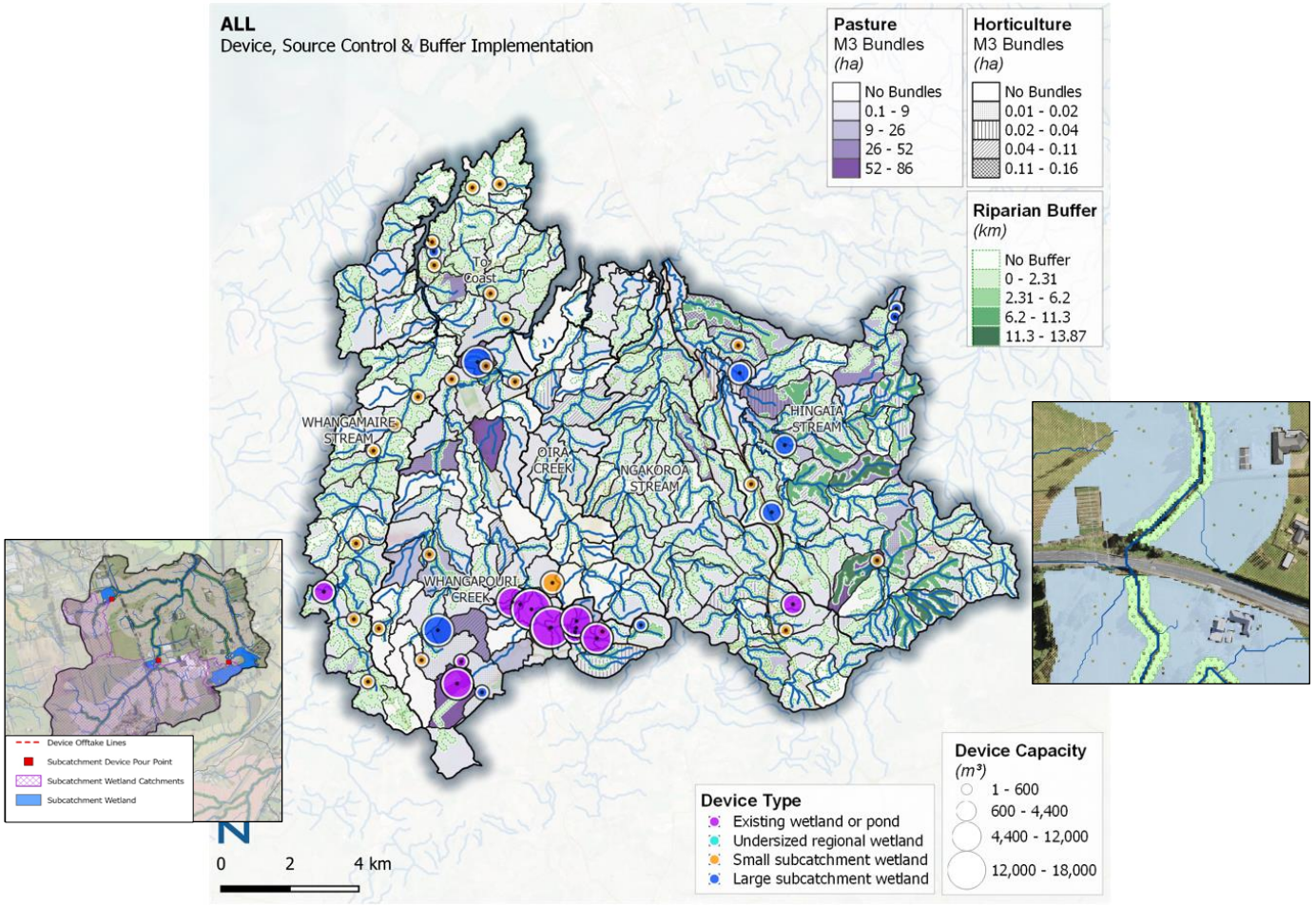

Figure 4. Geospatial information from optimisation curve for stormwater catchments in Manukau watershed. Critical condition of instream A-grade for Dissolved Reactive Phosphorus (DRP) (100% treatment point on Figure 3 for Ngakoroa and four other catchments combined). **Notes**: (1) all points in FWMT optimisation curve contain geospatial information on associated location and type of intervention, optimal to achieving corresponding reduction in critical load (water quality objective); (2) insets demonstrate explicit opportunity layers for "devices" used in optimisation modelling and enabling explicit guidance from FWMT to stormwater and farm plans; (3) M3 are practice-based changes in farming.

FWMT – NEARING COMPLETION

Auckland's FWMT is an innovative new decision-support tool to report on water quality and guide regulatory and non-regulatory decision-making. Pilot applications of the FWMT are now complete for rural and urban management to achieve freshwater quality objectives. Optimised, dynamic intervention modelling will soon be available regionwide for Auckland.

The FWMT approach offers advances over previous and ongoing modelling in Auckland and much of New Zealand:

1. Causative (process-based), event-scale (continuous) time-series of hydrology and contaminants integrated through 5,465 sub-catchments draining to freshwater and coastal receiving environments (including source information for a diverse library of 100+ urban and rural activities)
2. Scenario modelling of marked change to boundary conditions (climate change, development, management)
3. Optimised, dynamic intervention modelling to determine feasible, least-cost actions to improve and maintain water quality

FWMT baseline development and external peer completed, reported and datasets are available for external use (fwmt@aucklandcouncil.govt.nz).

KEYWORDS

water quality, Auckland, baseline state, optimization, dynamic intervention, Freshwater Management Tool