Auckland Design Manual

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Freshwater Management Tool

Healthy Waters & Flood Resilience

23/08/2024

Version 1

Auckland Design Manual

Freshwater Management Tool

Contents

1.1 Introduction

Auckland Council's Healthy Waters and Flood Resilience department is developing an innovative stormwater quality accounting and management programme to enable effective, transparent and integrated management decisions for waterways.

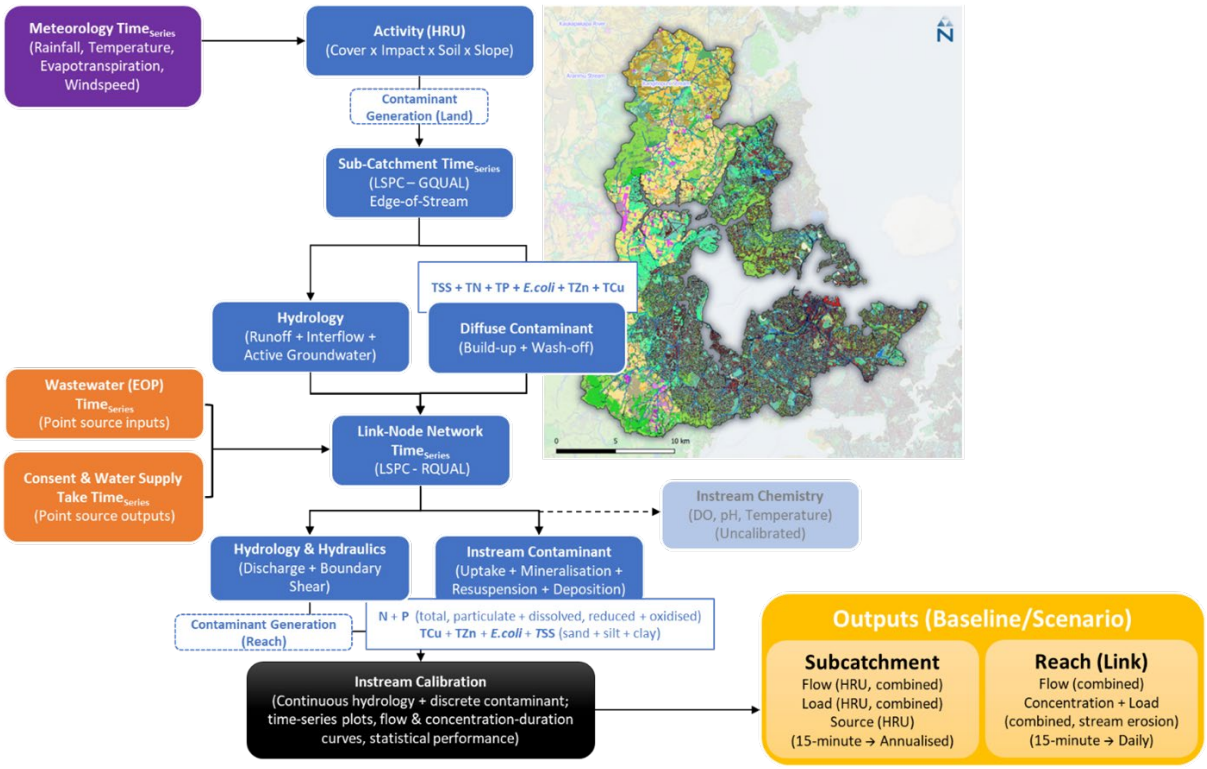
Healthy Waters monitors rainfall, river levels, overland flow paths and the performance of stormwater management and treatment devices. Data is fed into modelling programmes to inform reporting and decision-making on how to manage waterways for weather events, changing climate, development and land use.

A tailor-made stormwater catchment contaminant model, the Freshwater Management Tool (FWMT), is core to the new accounting programme – combining local data and knowledge with open-source models developed by the United States Environmental Protection Agency.
The FWMT will be integral to Auckland Council's implementation of NDC requirements and investing in improving water quality outcomes, in rural and urban catchments, for freshwater and coastal waterways – by predicting:

- time series of stormwater contaminant generation and runoff
- time series of in-stream concentrations and loads for operationally relevant contaminants – contaminants relevant to catchment management responsibilities specified in the regional stormwater network discharge consent (NDC)
- sources of contaminants.

The FWMT information allows Healthy Waters to inform:

- design of Healthy Waters asset management plans (AMP) for environmental outcome
- operational network management decisions and compliance reporting by Healthy Waters for performance targets and conditions set out in the NDC
- design of integrated management plans and allocation of funding for environmental outcome (Water Quality Targeted Rate) – including both freshwater and coastal water quality targets downstream from Auckland's rural and urban catchments.



Freshwater Management Tool model schema for baseline and scenario application.

1.2 Programme

The FWMT is part of a digital ecosystem of data, tools and services designed to deliver on core planning and management requirements of the NDC, targeted rate investment and Healthy Waters responsibilities to deliver catchment remediation ("management tool" programme).

The management tool programme includes generation of:

- Datasets – for land use (surface or land cover and use), risk (contaminant generation, connectivity), soils (hydrologic soil groups), streams (erosional risk, vegetation status), contaminants (activity and sub-catchment yields, loads to and delivered through reaches, concentration time-series, grading)
- Typologies – classification systems for rural and urban land, highly erodible land classification and stream classification systems (erosional risk, shading)
- Models – intervention lifecycle cost models (rural, urban), intervention greenhouse gas lifecycle models (rural, urban), intervention opportunity models

(feasible footprints, drainage areas), accounting framework (FWMT, Tātaki Wai*) and NDC application tool (C3 water footprint calculator)

- Technical documentation – including programme technical papers and reports on core and supporting modelling.

** Tātaki Wai is a FWMT-variant delivered for the Kaipara Moana Remediation group, a partnership between mana whenua (Kaipara Uri – Ngā Maunga Whakahī o Kaipara, Te Rūnanga o Ngāti Whātua, Te Uri o Hau), Auckland Council and Northland Regional Council for informing decision-making on strategic and adaptive management of investment on-farm to remediate the Kaipara moana (harbour).*

Management Tool partners and supporters involved in modelling programme.

1.3 Principles

The management tool programme ("programme") has adopted principles throughout, of:

1. **Trust and transparency** – decision-making on model inputs, configuration, outputs and broader information is publicly available, including clarity of modelling scope and fit for purpose.
2. **Best practice (environmental modelling)** – programme adheres to USEPA (2009) and MfE (2023) environmental modelling practices.
3. **Continual improvement** – inviting independent peer review, stakeholder review and versioning as review and validation data becomes available.
4. **Fit for operational purpose** – information, model design and applications are fit for purpose in managing water quality outcomes.
5. **Robustness** – model performance meets benchmarks for accuracy, certainty and sensitivity.

1.4 Purpose

The overall management tool programme is **operational** and designed to generate information to manage on a wide array of pollutants, catchment conditions, climate patterns and management scenarios – purposely for managing water quality.

The FWMT is of use in decision-making about development, integrated catchment management, climate resilience and catchment remediation impacts on operational contaminants (sediment, nutrients, metals, faecal bacteria).

The FWMT has been designed for:

- NDC decision-making and reporting requirements of Auckland Council (Healthy Waters, Regulatory Services, network applicants)
- asset management planning forecasting and decision-making requirements of Healthy Waters
- water quality remediation decision-making requirements of Auckland Council (Healthy Waters, mana whenua partnerships, primary sector partnerships, network operator partnerships, developer partnerships).

All other FWMT applications require careful consideration (contact: fwmt@aucklandcouncil.govt.nz).

1.5 Staging

Auckland Council is the first government agency to adopt a "management tool" approach in New Zealand – combining continuous, process-based and intervention-optimisable models to underpin baseline, scenario and managed scenario choices for water quality outcome.

The Healthy Waters management tool programme is staged – undertaking internal review, independent peer review and stakeholder extension to identify limitations and prioritising continuous improvement.

Core and supporting models for FWMT Stage 1 are nearing completion.

Development is now commencing to operationalise the management tool programme, via:

a. Communications framework – providing operational services and tools for applying the FWMT to NDC, asset-management and catchment remediation decisions

b. C3 water footprint calculator – NDC applicant contaminant generation and treatment calculator based on FWMT outputs.

1.6 Validation

Staging allows for ongoing validation, including of intervention, network and waterway changes.

The Healthy Waters management tool programme is developing targeted observational sampling and intervention monitoring programmes – purposely for model validation including targeted at "critical conditions".

Critical conditions are specific places, times and broader climate conditions associated with management outcomes – process-based, continuous and mountains to sea

modelling in the FWMT is ideal for identifying the critical conditions to target sampling and underpin validation with.

2 Fresh Water Management Tool (FWMT)

2.1 Design Outcomes

2.1.1 Model scope

The FWMT is designed to help Healthy Waters optimise its capital and operational investments to deliver the greatest value-for-money water management outcomes for Auckland ratepayers.

The FWMT will allow Healthy Waters to model the movement of water and operationally-relevant contaminants through rural and urban catchments, identify critical contaminant sources, estimate the loads and concentrations of contaminants in receiving environments, infer their likely impacts on ecosystem health, simulate the effectiveness of different management options for mitigating those impacts, estimate the cost of achieving desired management outcomes, and determine where those costs fall.
This information will guide Healthy Waters as it develops action plans for achieving water quality targets in Auckland's rural and urban catchments and in linking operational, asset management, and investment decisions for the NDC.

2.1.2 Operationally relevant contaminants

The primary purpose of the FWMT is to aid stormwater management and so must simulate behaviour of contaminants that are "operationally relevant" to integrated catchment management, and specified in the regional stormwater NDC.

Operationally relevant contaminants:

- have a direct and measurable effect on water quality, causing changes in processes and/or contaminants underpinning waterway health (e.g., discharged by activity, concentrated through activity effects on flow regime, altered by changes in stream form and condition).

- have a direct and measurable response to management actions (e.g., contaminant form, mass, flow, instream physiochemistry).

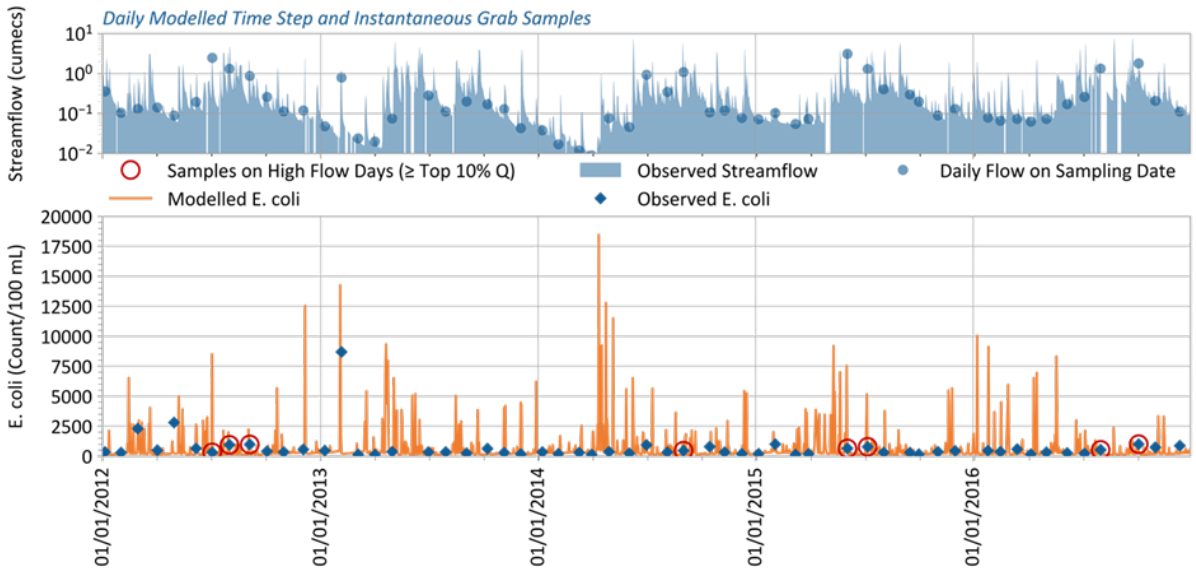
- are supported by reliable observed datasets and well understood theory of pressure-response (e.g., guiding process-based configuration).

- have national or regional guidance underpinning state assessment (e.g., National Objective Framework, Australia and New Zealand Standards, AUP Standards, Taumata Arowai guidance).

The operationally relevant contaminants modelled by FWMT Stage 1 span:

a. Instream – Nitrogen (total nitrogen, total oxidised nitrogen, total ammoniacal nitrogen, dissolved inorganic nitrogen), Phosphorus (total phosphorus, dissolved reactive phosphorus), Copper (total), Zinc (total), Sediment (total suspended solids, sand, silt and clay proportion), and Faecal Indicator Bacteria (E.coli).

b. In-lake (by water column depth) – Nitrogen (total nitrogen, dissolved inorganic nitrogen, nitrate-nitrogen, ammoniacal-nitrogen), Phosphorus (total phosphorus, phosphate-phosphorus), Dissolved Oxygen (DO), Chlorophyll-a (Chl-a) and Secchi-depth (SD) including amalgamation to Trophic Level Index (TLI) 3 and 4 score.



FWMT Stage 1 produces hydrology [top panel] and contaminant concentration [bottom panel] time-series over a baseline period [2013-17] in 5,465 sub-catchments and across various operationally relevant contaminants. Example is total suspended solids concentration. Modelled output [Version 1.2] in orange and monthly State of Environment sampling in blue diamonds.

2.1.3 Core models

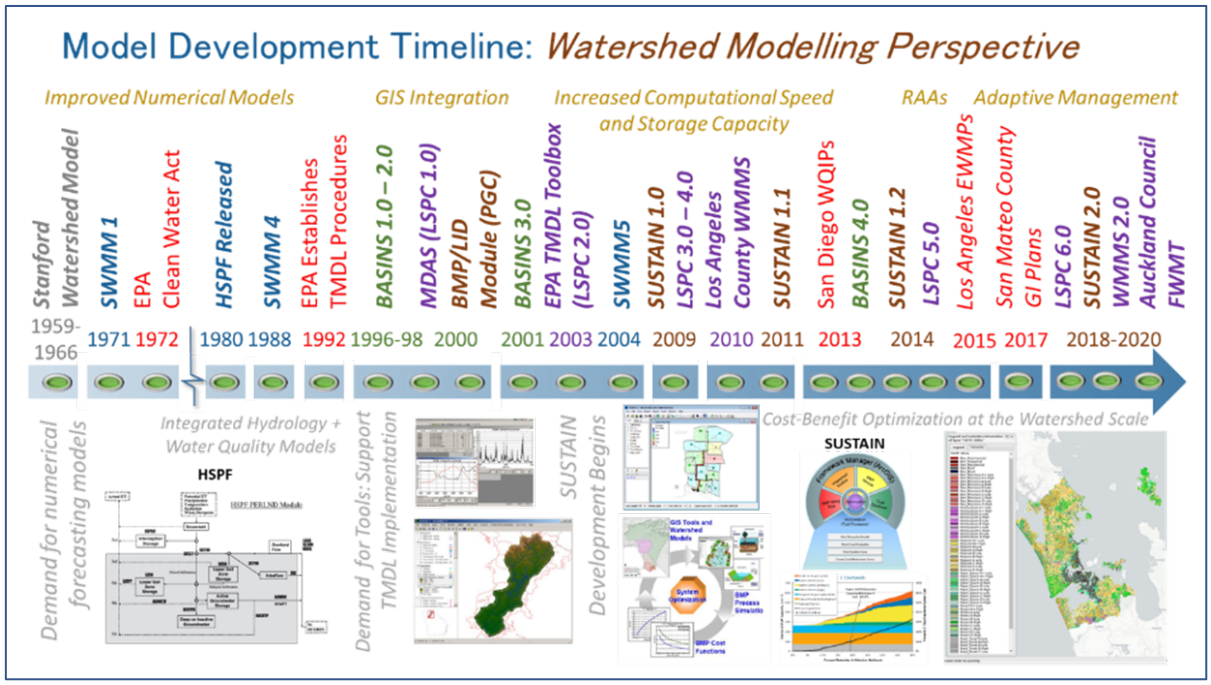
The accounting framework (FWMT) comprises two linked process-based, continuous-simulation open-source models, developed by the US-EPA:

- Loading Simulation Programme in C++ (LSPC), which is used to simulate hydrology, sediment erosion and transport, and water quality processes at a sub-catchment scale, and

- System for Stormwater Treatment and Analysis (SUSTAIN), which is used to predict outcomes under a range of stormwater management/intervention scenarios and estimate the costs and benefits of different management options to identify the optimal mix of actions for achieving specified contaminant objectives (including nature based solutions).

LSPC represents watersheds via a link-node stream network that integrates sub-catchments of varying HRU extent, topography and climate conditions. LSPC simulates land and stream dynamics. LSPC has been coupled to ensemble lake biophysical process models in the Lake Management Tool (LMT – in development).

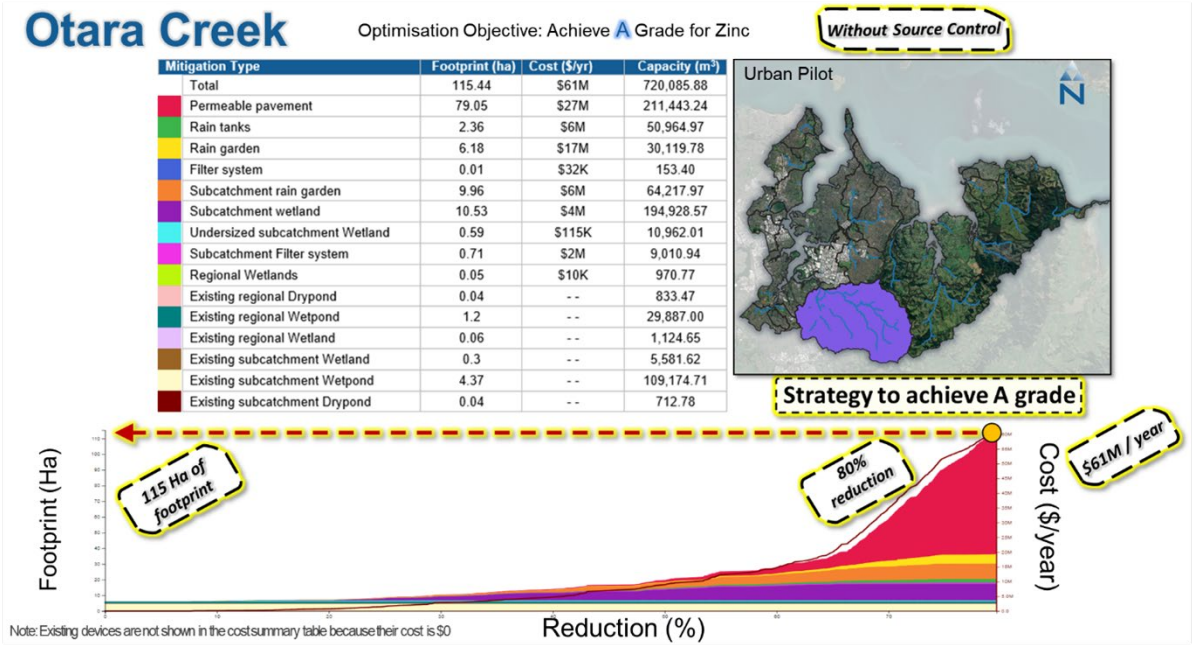
SUSTAIN optimises intervention choices for contaminant impact and cost. SUSTAIN can simulate millions of alternative intervention choices on a sub-catchment basis (type, extent, mix) for cost and reduction in HRU yields to identify “best” solutions for design storm conditions (least cost, greatest reduction in contaminant yield). SUSTAIN is able to then generate longer-term continuous outputs for any mix of “best” solutions (over multiple years and broader climatic conditions).



FWMT core models (LSPC, SUSTAIN) have evolved from a multidecadal investment programme in open sourced modelling by the US-EPA.

FWMT Stage 1 operates LSPC and SUSTAIN on 15-minute time-steps across 5,465 sub-catchments spanning ~490,000 Ha of the Auckland region and inclusive of 106 activity types (urban and rural HRUs) and 100+ uniquely designed and costed management interventions – simulating all operationally relevant contaminant responses.

FWMT Stage 1 is "regionalised" with all HRU, reach and intervention processes consistent across the Auckland region. Note outputs are not then identical in sub-catchments; differing HRU extents and types, stream types and intervention choices generate diverse outputs across sub-catchments.



Mitigation Type	Footprint (ha)	Cost ($/yr)	Capacity (m³)
Total	115.44	$61M	720,085.88
Permeable pavement	79.05	$27M	211,443.24
Rain tanks	2.36	$6M	50,964.97
Rain garden	6.18	$17M	30,119.78
Filter system	0.01	$32K	153.40
Subcatchment rain garden	9.96	$6M	64,217.97
Subcatchment wetland	10.53	$4M	194,928.57
Undersized subcatchment Wetland	0.59	$115K	10,962.01
Subcatchment Filter system	0.71	$2M	9,010.94
Regional Wetlands	0.05	$10K	970.77
Existing regional Drypond	0.04	--	833.47
Existing regional Wetpond	1.2	--	29,887.00
Existing regional Wetland	0.06	--	1,124.65
Existing subcatchment Wetland	0.3	--	5,581.62
Existing subcatchment Wetpond	4.37	--	109,174.71
Existing subcatchment Drypond	0.04	--	712.78

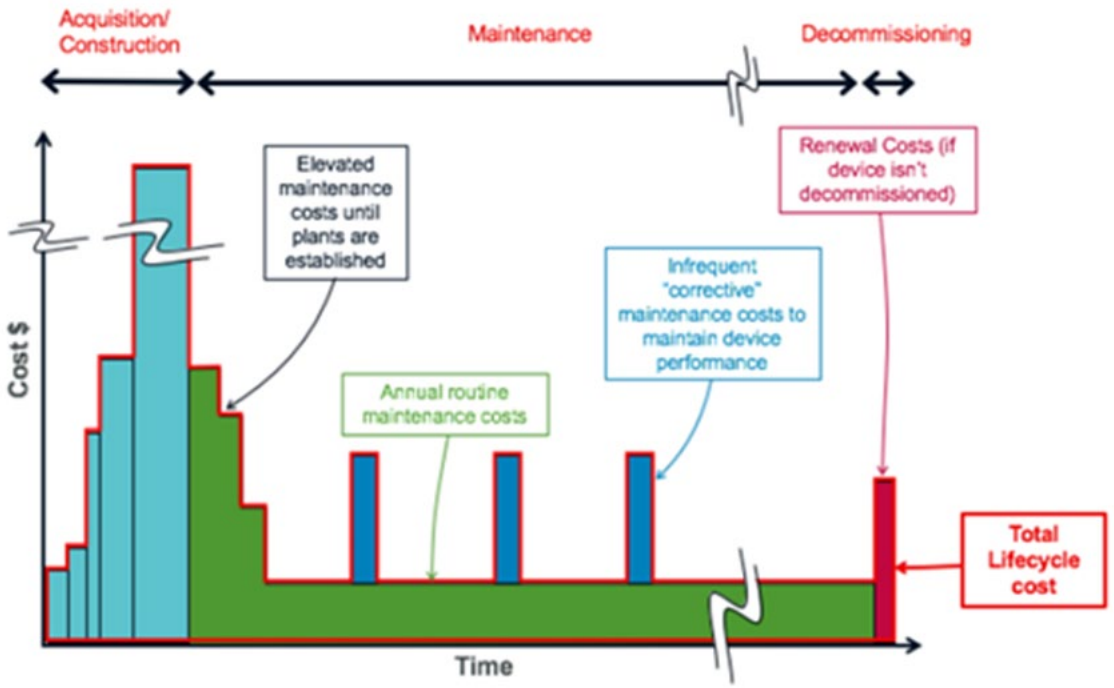
FWMT Stage 1 simulates millions of alternative feasible interventions at sub-catchment scale, identifying the best combinations for improved water quality at least costs [on lifecycle basis and over varying climatic conditions].

2.1.4 Supporting models

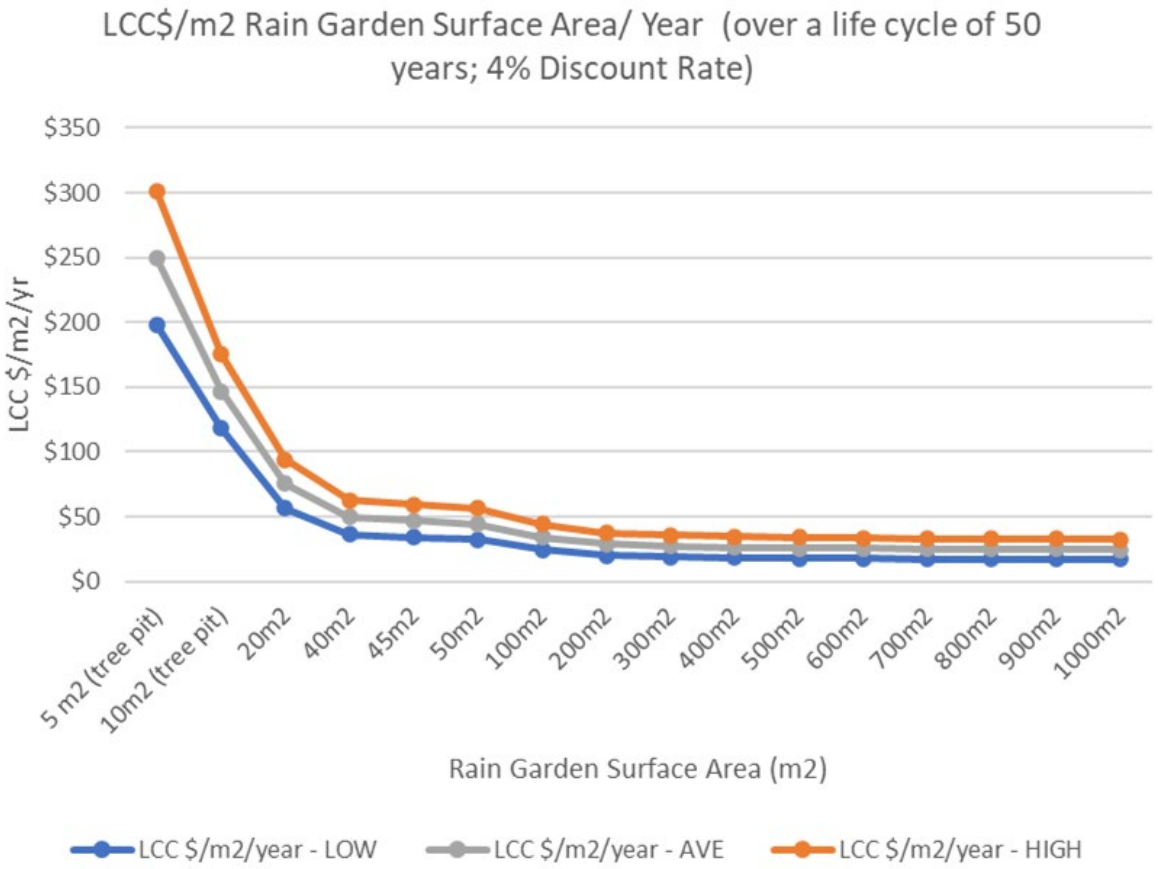
The FWMT requires additional supporting models to operate, including:

- Lifecycle cost models for all urban and rural interventions – spanning both devices () and underlying source controls (green streets, road sweeping, management practices) for a variety of design-specifications and discount rate (50-year)
- Greenhouse gas emission lifecycle models for all urban and rural interventions – as above for CO2eq emissions profiles of interventions (50-year)
- Geospatial feasibility (opportunity) models for limited urban and rural interventions – FME models for determining feasible footprint (treatment) area and upstream drainage (treated) of interventions (including existing stormwater network devices)

All supporting models are intellectual property of Auckland Council (see "Resources"). Requests to modify or adopt models for other purposes are encouraged and can be supported by the Healthy Waters department (fwmt@aucklandcouncil.govt.nz).



Intervention lifecycle models for urban and rural interventions are used in the FWMT Stage 1 to optimise for 50-year discounted (2-6%) and standardised devices (size, design) and source controls.



Intervention lifecycle models have been developed for urban and rural interventions of varying design (low, medium, high cost components) and standardised size, demonstrating efficiencies simply in ensuring minimum device sizes are set sufficiently high.

2.1.5 Model applications

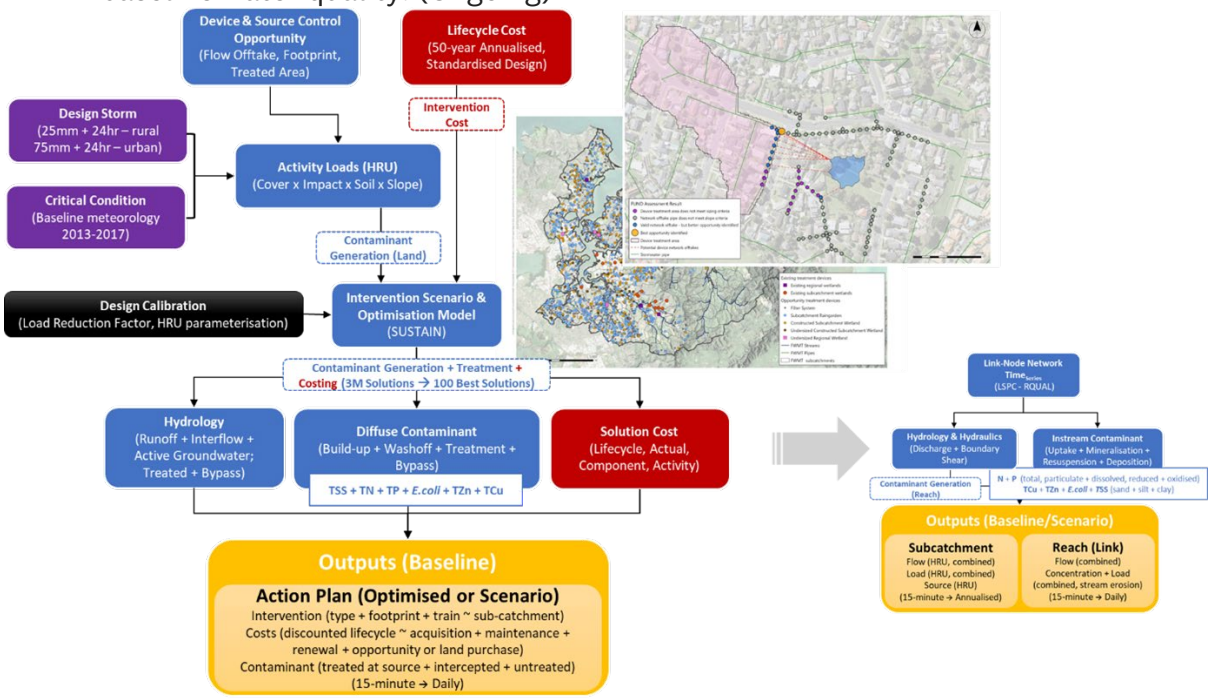
The management tool programme is operational and purposely for asset/network/catchment management decision-making. Application to regulatory decisions is not in-scope for FWMT Stage 1.

The programme offers regionwide transparent, objective data on water quality for decision-making and reporting of:

- Baseline water quality – variation in hydrology and contaminant regimes, regionwide over the 2003-2017 period in all sub-catchments; (Completed)

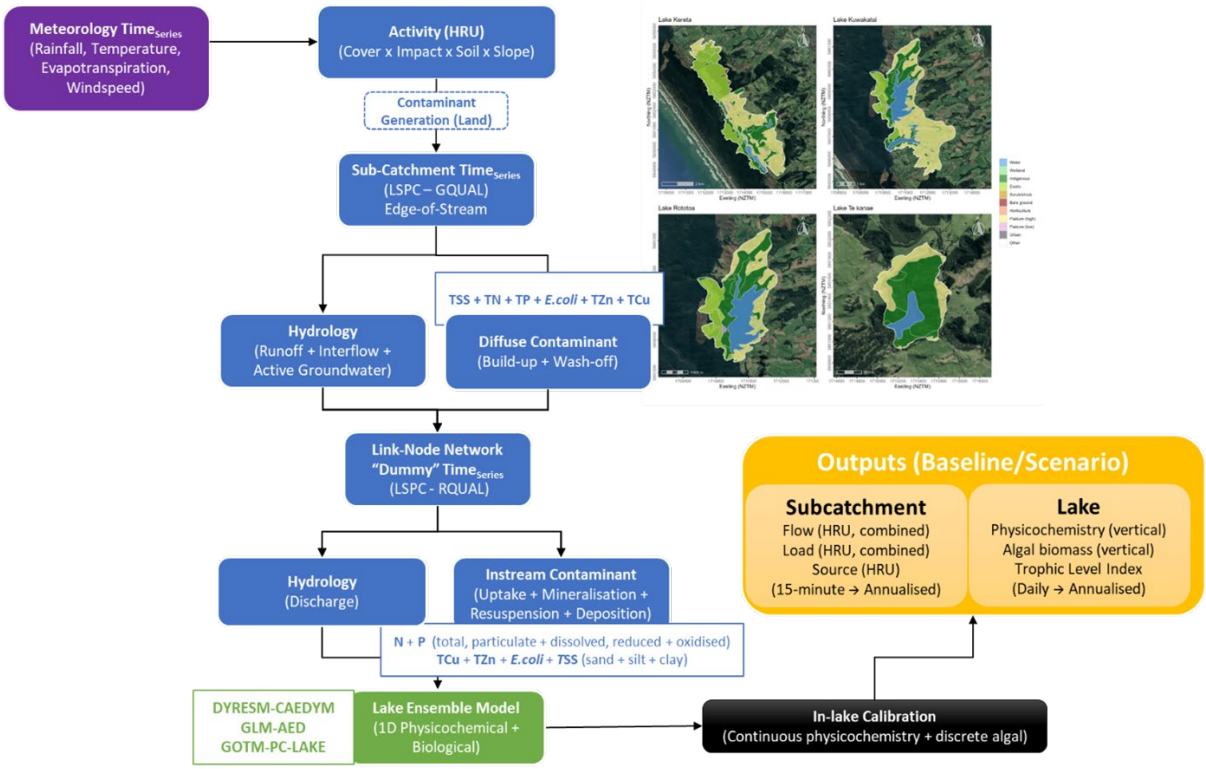
- Scenario water quality – forecast outcomes for development (maximum permitted development as circa 2050) and climate change (ensemble regional climate model [RCM] downscaled forecasts of shared socioeconomic pathways [SSP]); (Ongoing)

- Action plans for water quality – testing and identifying optimal, feasible interventions to improve operational contaminant effects on water quality (from mountains to sea, integrated). FWMT Stage 1 is limited to action plans for baseline water quality. (Ongoing)



Freshwater Management Tool model schema for optimised baseline (action plan) application.

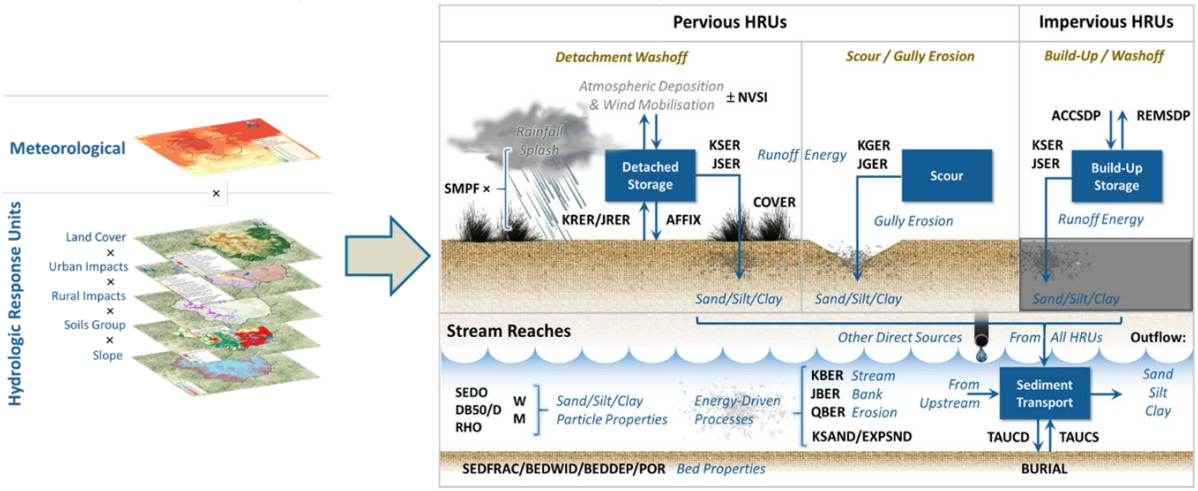
Note: FWMT is also undergoing development to couple directly with ensemble lake process-models (Lake Management Tool) including DY-CD, GLM-AED and GOTM-PCLake, and with instream macroinvertebrate extirpation models (SSDM) to expand applications.



Lake Management Tool model schema for baseline and scenario applications – utilising FWMT for catchment modelling.

2.1.6 Process configuration

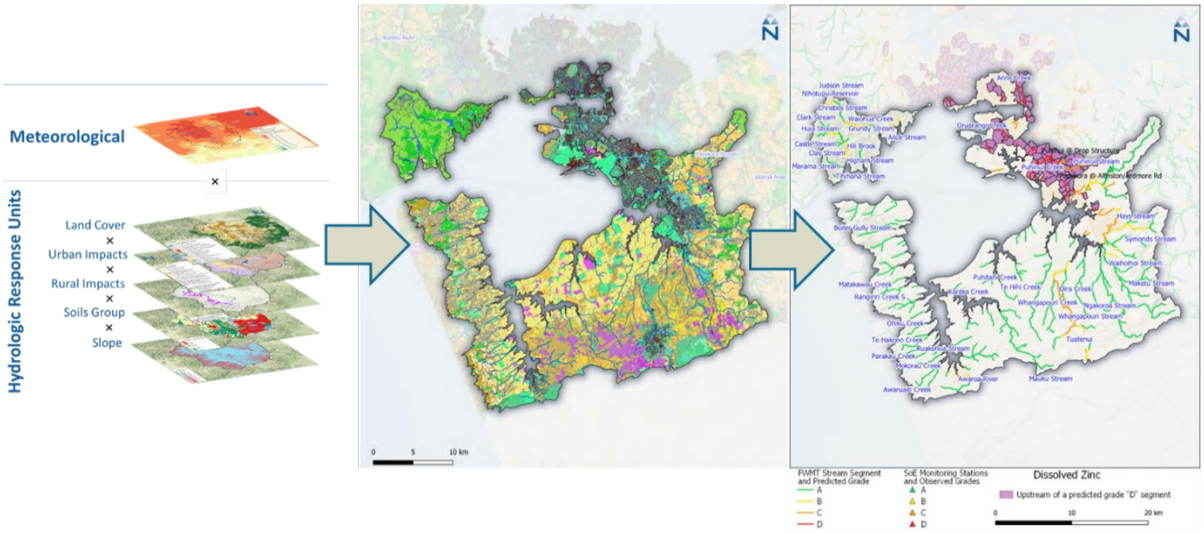
Activities (land use, wastewater network discharges) are represented as Hydrological Response Units (HRU) or point-source discharges (wastewater). HRU's have regionalised process parameters for hydrological flow (runoff, interflow, active groundwater) and contaminants (build-up, detachment, wash-off, soil loss). HRU's span differences of soil, slope, land cover and use (impact).



Hydrologic response units (HRU) are regionally parameterised in FWMT Stage 1 for hydrological and contaminant processes, with regionwide mapping for baseline and scenario applications.

Waterways are simulated using regionalised parameters for contaminant fractionation (from total to dissolved, reduced and particulate), sediment dynamics (deposition, resuspension, scour/bank erosion) and broader physicochemical processes including nutrient uptake.

FWMT Stage 1 uses a static HRU and waterway configuration for sub-catchments over baseline, scenario and intervention applications. Meteorological conditions vary on 15-minute basis at sub-catchment level. Combined, simulating dynamic steady state outputs to sub-catchment with underlying activity yields, loads and intervention impacts (cost, load reduction).



Hydrologic response units (HRU) once mapped and parameterised generate instream water quality time-series to grade state.

2.1.7 Model Outputs

FWMT Stage 1 outputs include geospatial, time-series and integrated summary information on HRU contaminant yields and loads to water, instream flow , intervention opportunity, treatment and lifecycle costs for contaminant objective:

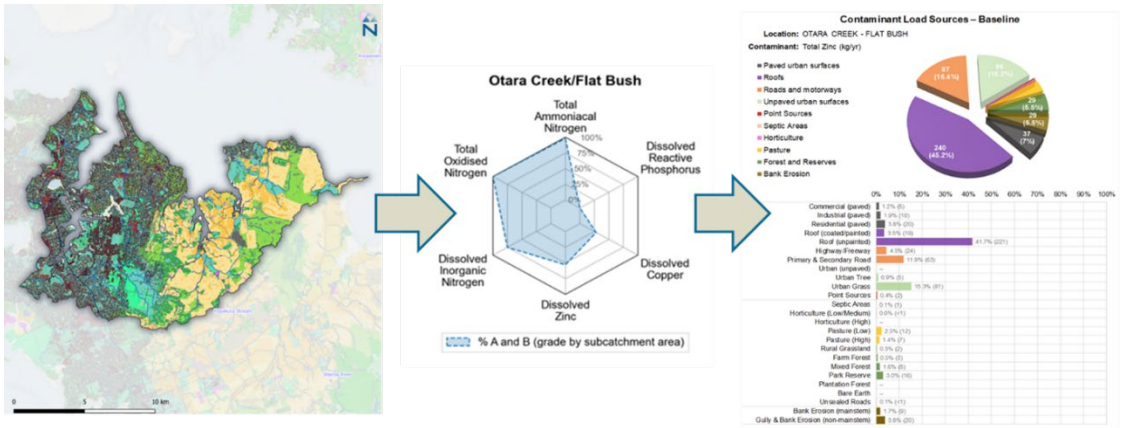
- Baseline and scenario outputs – activity contaminant yield and load, instream concentration and load including from instream erosion (continuous and annualised);

- Intervention optimisation – intervention opportunities (location, footprint, drainage area) and best solutions including the optimal interventions to deliver water quality improvements.

Action plans are produced by the FWMT Stage 1 using intervention optimisation for baseline state (v1.2). Each resolves the least cost mixes of feasible, scaled and integrated actions necessary to change water quality for some critical freshwater objective.

Action plans are limited to what is currently feasible to both implement and model robustly, resolved in each of 5,465 sub-catchments, for all operationally relevant contaminants and of the least-cost (optimal) improvement in freshwater state (95th% numeric attribute).

Combined, over 110 interventions, across 106 activities under 5-years of baseline weather and returned as 100 incrementally better solutions in 5,465 sub-catchments for each of the graded forms of nutrient, metal, sediment and E.coli modelled by FWMT Stage 1 – with corresponding spatial information on uptake, cost, treatment and efficiency.



Water quality information is available regionwide to sub-catchment including contaminant source information resolved to hydrological response units.

Figure 3-18. Example identification of qualifying pipe offtakes for flow diversions.

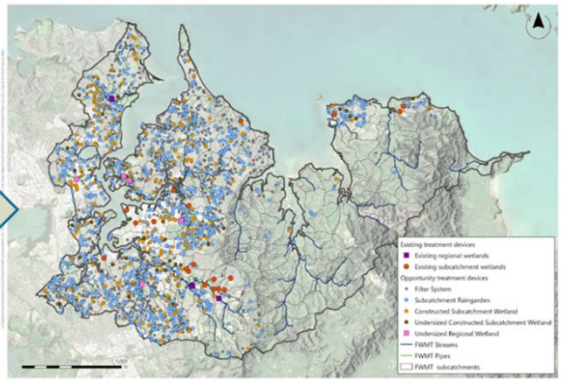
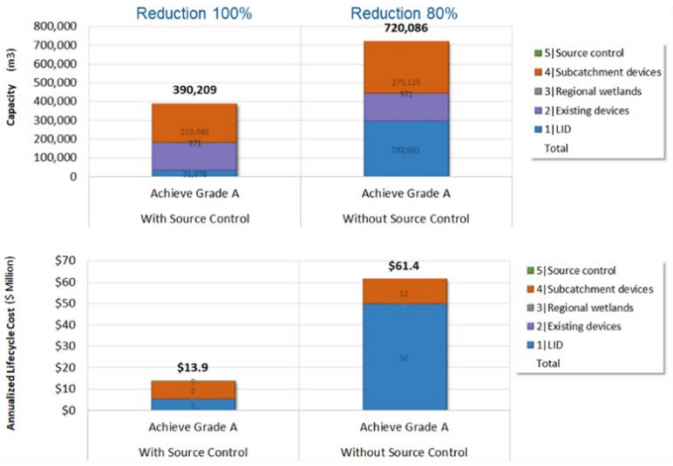
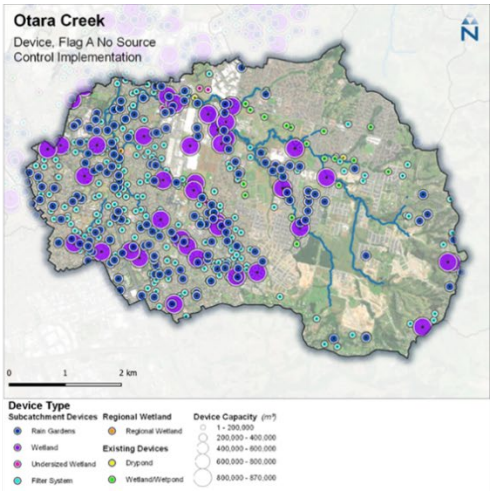


Figure 3-16. Overview of mapped structural device opportunities for the Tāmaki Urban Pilot (excluding existing devices) identified via the FUND tool.

Intervention modelling is supported by detailed feasibility mapping and local information on footprint area, offtake and treated area.





Optimised intervention modelling determines best solutions from feasible options in millions of alternative action plans. All action plans produced include geospatial and time-series data to aid implementation. Best solutions cost less for outcome.

3 Resources

3.1 Design Outcomes

3.1.1 Trust and Transparency

The management tool programme is building a digital ecosystem of data, tools and services designed to deliver on core planning and management decision-making requirements of the NDC, targeted rate investment and catchment remediation.

To ensure the principle of “trust and transparency” is practised by the programme, development and outputs are regularly reviewed, internally and externally by leading national and international experts.

This page shares the resources developed by the programme from outputs, including the findings of the peer review committee on core modelling.

Management Tool partners and supporters involved in modelling programme.

3.1.2 Peer Review Committee

Core modelling is subject to independent peer review, to identify limitations and recommendations for continuous improvement (accounting framework).

All supporting modelling is available to the peer review committee but subject to external (contractor) and internal (Healthy Waters) review prior to publication.

The FWMT Stage 1 peer review committee includes:

- Professor David Hamilton (david.p.hamilton@griffith.edu.au) – Director, Australian Rivers Institute (Griffith University)
- Dr. Kit Rutherford (kit.rutherford@niwa.co.nz) – Emeritus Principal Scientist, National Institute for Water and Atmospheric research (NIWA)
- Dr. Clint Rissmann (clint@landwatersci.net) – Director, Land and Water Science (LWS)*

** Replaces Nic Conland from "baseline" core modelling review committee (Nic Conland is now an independent project manager for Tātaki Wai – the Kaipara Moana Remediation programme's variant of the FWMT for Kaipara Uri, AC and NRC).*

3.1.3 Technical reports

Technical reports document in detail management tool development and application. Technical reports are subject to supporting agency, Auckland Council and independent peer review.

Core model development is reported in:

- Baseline Inputs (v 1.0) – reports sources and treatment of input data to FWMT Stage 1 baseline modelling (AC)

- Baseline Configuration and Performance (v 1.0) – reports configuration decisions and limited performance information for hydrology and contaminant time-series (AC)
- Baseline State Assessment (Rivers) (v 1.0) – reports graded water quality state using national and regional guidance for waterways across the baseline period (AC)
- Baseline Peer Review (v 1.0) – reports peer review committee findings on programme development for baseline modelling (PRC)

Supporting model development is reported in:

Hydrometric Network – Regional Flow Assessment (Civix)

Total economic valuation approach (Part 1 Urban device costs) – Lifecycle cost models for urban stormwater devices (Koru)

Total economic valuation approach (Part 2 Urban source control costs) – Lifecycle cost models for urban stormwater devices (Koru)

Literature review of primary sector responses to water quality – desktop review of primary sector water quality intervention (state of knowledge) (Perrin Ag)

Riparian area management scenarios – desktop review of diversity, efficacy and lifecycle cost of alternative pastoral and horticultural riparian interventions (Perrin Ag)

Lifecycle costs and benefits for rural mitigations – finalised lifecycle models, estimates and assumptions for rural water quality interventions (Perrin Ag, Koru)

Addendum (Lifecycle costs and benefits for rural mitigations) – expanding rural mitigation lifecycle and benefits assessment for additional riparian and wetland interventions (Perrin Ag)

Recommendations for improving rural mitigation modelling – primary sectoral research and policy body review and recommendations of rural interventions (Perrin Ag)

Post-processing carbon footprint for rural and urban actions – lifecycle CO2eq modelling for rural and urban water quality interventions (Perrin Ag, Koru, Motts Macdonald)

Freshwater Management Tool Instream Monitoring Recommendations – review of State of Environment monitoring and recommendation for new targeted validation monitoring (Aqualinc, Puhoi-Stour)

Metal Partitioning Investigation to Improve Modelling – review of zinc and copper dissolved-to-total ratio variation to inform FWMT configuration (NIWA)

Metals in Rural Streams – synoptic survey of zinc and copper metal concentration and toxicity in rural Auckland to inform FWMT configuration (NIWA)

Metal Toxicity Modifying Factors – relevance of toxicity modifying factors for varying dissolved metal concentration effect in FWMT (NIWA)

Prospects for Ecological Response Modelling – review and development of prototype instream ecological models to couple with FWMT (NIWA)
Development of Macroinvertebrate Response Models – review and development of novel bio-extirpation models of macroinvertebrate taxa and stacked community models to couple with FWMT (NIWA)
Plantation Forestry: Review of baseline performance, source control and device options – desktop review and sectoral recommendations on representing plantation forestry (Perrin Ag)
Freshwater Management Tool – Coastal Receiving Environment Scenario Tool (CREST): Inner and Outer Waitemata Pilot (DHI)
Okura Wēiti Marine Receiving Environment Modelling – Technical Summary (DHI)
Okura Wēiti Marine Receiving Environment Modelling – Calibration Report (DHI)
Okura Wēiti Marine Receiving Environment Modelling – Data Report (DHI)
Okura Wēiti Marine Receiving Environment Modelling – Scenario Report (DHI)
Horticulture Typology Modelling for the FWMT (Perrin Ag)
Relating suspended sediment concentration to visual clarity for rivers in Auckland Region (NIWA)

3.1.4 Conference papers

Stormwater (WaterNZ)

2019

Current and future state of Auckland's watersheds: Stage 1 Freshwater Management Tool

2020

Water quality in Auckland – FWMT Current State and Process Modelling Advances
Future State of Auckland's Watersheds – Inputs to FWMT Future Scenario Modelling
A Total Economic Valuation Approach to the Assessment of Water Quality Intervention Options within the Auckland Region

2021

FWMT Advances in Water Quality Management: Future and Optimised Scenario Modelling
Auckland Council's Freshwater Management Tool: Lifecycle Costing Model

2022

Radical Advances in Stormwater Management: Freshwater Management Tool
Advances of Integrated Management from Sea-to-Mountain

2023

Freshwater Management Tool – Outcomes and Lessons from Trading Cost for Complexity

New Zealand Association of Resource Management

2022

Freshwater Accounting: Boring or key to unlocking value in Freshwater Farm Planning

2023

Partnership for wetland restoration: A Freshwater Management Tool Case Study

Farmed Landscapes Research Centre

2023

Accounting for change: A pioneering approach to optimised catchment action planning using the Freshwater Management Tool (FWMT)
Improved understanding of grower systems within the Pukekohe area to inform the Freshwater Management Tool (FWMT)

Australasian Agricultural and Resource Economics Society

2022

Informing freshwater management for the Auckland region
Modelling horticulture in the Auckland region (Freshwater Management Tool)

New Zealand Coastal Society

2023

Coastal Receiving Environment Scenario Tool (CREST)

New Zealand Freshwater Sciences Society

2020

Freshwater Management Tool – A next generation decision-support tool for science, policy and catchment management in New Zealand

3.1.5

For any questions or feedback, please contact us through our email address: fwmt@aucklandcouncil.govt.nz

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