Freshwater Management Tool

August 2021 FWMT Report 2021/1

Report 1
Baseline Data Inputs

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Freshwater Management Tool: Report 1. Baseline Data Inputs

August 2021

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Freshwater Management Tool: Baseline Input Report Overview

Freshwater Management Tool

- FWMT is a freshwater accounting and decision-making tool for water quality, integrating all catchments from mountain to sea (rural and urban) throughout the Auckland region.
- FWMT utilises open-sourced, peer-reviewed US-EPA tools for continuous and process-modelling.

Baseline reporting

- This report is 1 of 5 documenting baseline (2013-17) water quality for freshwater receiving environments in the Auckland region.
- This report should be read alongside [FWMT Baseline Configuration and Performance] to understand how climate, land use and network discharges are represented in the FWMT Stage 1.

Report scope

- This report documents all sources of data used directly or transformed to drive hydrological and contaminant processes in the FWMT Stage 1.
- Data covers climate, land and stream domains. Data sources include observed and modelled, regional and national datasets. Transformations to datasets included spatial aggregation, temporal disaggregation and amendment of multiple time-series spanning the baseline period.

Report messages

- FWMT Stage 1 baseline modelling is conducted in the Load Simulation Programme in C++ (LSPC). LSPC is a continuous, process-based model simulating rainfall-runoff, throughflow and active groundwater responses for land types (hydrological response units – HRUs).
- Hydrological responses are linked to contaminant processes for the build-up/wash off and transport of contaminants from HRUs to modelled freshwater streams.
- The FWMT Stage 1 uses an HRU library developed to span a range of soil, slope, land cover and activity or impact factors, with up to 106 unique HRUs able to be represented for their effects on a range of water quality parameters and processes, regionwide within the FWMT Stage 1.

- HRU datasets span urban and rural information, using best available sources as of the commencement of model development in 2017-18. Best information was determined on basis of data quality, coverage, resolution and representativity of baseline period (2013-17).
- Reticulated wastewater network models were also used to generate information on Type 1 and 2 discharge events at 15-minute resolution for 448 engineered overflow points. Reticulated wastewater discharges represent a 107th contaminant source (HRU) in the FWMT.
- For all climate, land and stream datasets multiple sources have been used, with the report documenting the hierarchy and coverage of datasets.

Quality assurance

- FWMT Stage 1 baseline modelling has been externally peer reviewed by Prof. David Hamilton [Griffith University], Dr. Kit Rutherford [NIWA] and Nic Conland [Taiao Consulting]. Findings of the external peer review are contained in [FWMT Baseline Peer Review].

Continuous improvement

- FWMT Stage 1 is the first generation of a paradigm shift in water quality accounting for Auckland – an advance on simpler, empirical and non-continuous modelling (CLM, C-CALM).
- Ongoing changes to the FWMT Stage 1 are expected in light of external peer review and end-user needs. Please contact the FWMT team to request data and updates to the FWMT.

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Executive summary

The Freshwater Management Tool (FWMT) is a continuous and process-based water quality accounting framework for the Auckland region. In its first iteration (Stage 1) contaminants simulated include total suspended solids (TSS), total and dissolved forms of nutrients (TN, DIN, TON, TAM, TP, DRP), total forms of heavy metals (TCu, TZn) and faecal indicator bacteria (*E. coli*). The FWMT Stage 1 simulates the generation, transport and fate of contaminants in multiple flow paths across and through land, and ultimately along instream freshwater environments.

This report documents the inputs (sources of information) used in the configuration of the FWMT Stage 1. The report identifies sources of information including hierarchies (where multiple datasets overlap) and regional coverage. A mix of observed and modelled sources of best available information were utilised as inputs to the FWMT Stage 1, including geospatial information derived from regional and national datasets.

The choice of input data varied with coverage, resolution, quality and consistency of spatial and temporal information over the baseline period (2013-17) and as of model development (commencing in 2017-18).

Data inputs span a range of model sub-routines, including:

- Sub-catchments (derived using regional LiDAR topography and overland flowpath information)
- Stream network (inclusive of >500mm stormwater networks)
- Climate (inclusive of gauged and virtual climate station networks)
- Wastewater network and discharge (inclusive of six major reticulated networks [Watercare] and onsite wastewater)
- Impoundments (inclusive of ponds, dams and reservoirs)
- Hydrological response units (inclusive of soil, slope activity and impact factors spanning 106 unique contaminant and hydrological responses)
- Reach groups (inclusive of nutrient and erosion types)

Combined, input datasets derived for the FWMT offer baseline information on climate, biophysical, land activity and stream characteristics spanning the full region and resolved to 5465 sub-catchments of <40-100 ha.

This report should be read with the *FWMT Baseline C and P Report* to determine how input datasets were configured prior to simulation of baseline hydrology and contaminant state throughout freshwater streams in the Auckland region.

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Glossary of key terms

Term	Abbreviation	Definition
Aquifer		An underground layer of water-bearing rock or sand from which groundwater can be extracted.
Attenuation		The storage of excess stormwater during the peak of a storm, followed by controlled release of the stored water.
Attribute		A measurable characteristic of fresh water, including physical, chemical and biological properties, which supports particular values.
Attribute measure		One of several statistics for an attribute, each of which is graded and from which overall grade is determined as the least of measures (e.g., median, 95th%).
Attribute state		The level to which an attribute is to be managed for those attributes specified in Appendix 2 of the National Policy Statement for Freshwater Management (2014).
Auckland Unitary Plan	AUP	The Auckland Unitary Plan Operative in part providing the land use zonation for Auckland region.
Bank Height		The average vertical distance between the stream bed and the top of the bank (immediate bank associated with the watercourse) measured in metres.
Best Management Practices	BMPs	BMPs are structural, vegetative or managerial practices used to treat, prevent or reduce water pollution.
Brownfield		Previously developed land that may be available or have potential for redevelopment, often for more intensive or different land use.
Catchment Land Use for Environmental Sustainability	CLUES	CLUES is a GIS based modelling system which assesses the effects of land use change on water quality and socio-economic indicators. It was developed by NIWA and is an amalgamation of existing modelling and mapping procedures.
Coastal Receiving Environment	CRE	The marine area where freshwaters discharge to.
Combined Sewer Overflow	CSO	Overflows from combined sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. These overflows contain not only storm water but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern.
Contaminant		Chemicals and particles within a water sample that degrade the water quality
Contaminant Load Model	CLM	The Contaminant Load Model (CLM) is an annual stormwater contaminant load spreadsheet model developed for the Auckland region of New Zealand. It was first developed by Auckland Council's predecessor in 2006 to enable estimation of stormwater contaminant loads on an annual basis.
Contributing Catchment Area	Asset_Ac	Area of contributing catchment to the treatment device measured in meters squared.
Dam		Built to store stormwater to control flooding, water for drinking supply, power generation, or irrigation.
Digital Elevation Model	DEM	The digital representation of the land surface elevation with respect to any reference datum.
Directly Connected Impervious Area	DCIA	The portion of impervious with a direct hydraulic connection to a waterbody or drainage network

Term	Abbreviation	Definition
Distributed Structural Device		Structural Device installed in private property or at the inlet to the public stormwater network or otherwise with inflows from a small catchment.
Drainage Catchment		An area of land where stormwater runoff flows to a discharge point at a watercourse, treatment device or the coast.
Drainage Class	DRAIN_CLAS	Drainage class values (1-5) are based on New Zealand Soil Classification's hydromorphic classes (1993). They are assigned predominantly on the depth to the seasonally high-water table within the soil profile, which describes the available volume of the soil for retention of water at saturation.
Existing forestry operation		All parcels classified as 'forestry' in Agribase.
Floodplain		The land bordering a stream, built up of sediments from stream overflow and subject to inundation when the stream floods.
Fluvial deposits		All sediments, past and present, deposited by flowing water.
Fractured Basalt Aquifer		Basalt is a finely granulated igneous rock, which is usually black or gray in color. These rocks are formed due to lava flow. Basaltic rocks are the most productive aquifers in volcanic rocks as they are highly porous and permeable. In Auckland, the basalt aquifers are used to dispose stormwater via drilled soak holes, serve as groundwater supply in the Onehunga aquifer and disperse industrial and commercial sites across the city, and feed important springs in Western Springs and Onehunga.
Future Urban Zone	FUZ	Development area for township expansion in the AUP to be included into the urban area.
Grade		The lesser of any attribute measure's grades under the National Objective Framework (NOF) or any regional objective framework. Interchangeable with attribute state for purposes of report.
Greenfield		Land that has not been previously developed and therefore has little to no existing infrastructure.
Gross Pollutant Trap	GPT	Device used for water quality control that removes solids typically greater than five millimetres conveyed by stormwater runoff. GPTs can operate in isolation to reduce pollutant effects within immediate downstream receiving waters, or as part of a more comprehensive treatment train system to prevent overload of downstream infrastructure or treatment devices
Groundwater		Water in the zone of saturation where all open spaces in sediment and rock are filled with water.
Groundwater recharge		Water added to the aquifer through the unsaturated zone after infiltration and percolation following any storm rainfall event.
Gully Erosion		Erosional process occurring when sediment is mobilised from an HRU through scouring due to overland flow.
Hydrological Response Unit	HRU	A watershed area assumed to be homogeneous in hydrologic response due to similar land use and soil characteristics and used in the LSPC model.
Hydrologic Soil Group	HSG	Soils grouped by their runoff-producing characteristics. Soils are assigned to five groups in the FWMT: group A+ - D where A+-HSGs have a high infiltration rate and low runoff potential through to D-HSGs that have a low infiltration rate and high runoff potential. HSGs are determined by drainage, permeability,

Term	Abbreviation	Definition
Impoundment		A body of water confined within an enclosure, as a reservoir.
Interflow		Shallow subsurface flow that contributes to streamflow through the upper soil layer as opposed to recharging aquifers.
Intervention		A measure put in place through either capital investment operational activity, regulation, education
Land Cover		The material covering the earth, being vegetation, water, asphalt etc.
Local Government Act	LGA	The Local Government Act 2002 is an act of Parliament that defines local government in the New Zealand.
Land Information New Zealand	LINZ	land titles, geodetic and cadastral survey systems, topographic information, hydrographic information, managing Crown property and supporting government decision making around foreign ownership
Land Use		Activity undertaken on the land, usually grouped into classes
Livestock Units	LSU	The standard unit to compare the feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given farm or area of grazing land. The reference unit used for the calculation of livestock units (=1 LSU) is used to express the annual feed requirement of a "standard" 55 kg breeding ewe rearing a single lamb (dry sheep equivalent).
Load reduction factor	LRF	Treatment or control efficiency
Loading Simulation Program in C++	LSPC	The watershed modelling system used to characterise the state (concentrations and loads) of freshwater quality and recharge rates of shallow aquifers across the Auckland region. LSPC is an open-source, process-based watershed modelling system developed by the U.S. EPA for simulating watershed hydrology, sediment erosion and transport, and water quality processes from both upland contributing areas and receiving streams
Manning's N		A coefficient which represents the roughness or friction applied to the flow by the channel.
Mapped Impervious Area	MIA	The spatial representation of area identified as impervious from available information
Mean High Water Springs 10	MHWS10	Mean high water spring (MHWS) describes the highest level that spring tides reach, on average, over a long timescale. MHWS10 is the mean high-water spring tide exceeded 10 percent of the time.
Node		A sub-catchment outlet point that represents the reporting node of the FWMT. Otherwise known as [Pour Point]
Northern Allochthon		The Northern Allochthon is characterised by weak, highly sheared mudstones, siltstones, sandstones and limestones. Permeability is typically very low, with northern allochthon rocks forming an aquitard in most areas.
On-Site Wastewater Treatment	OSWW	Onsite wastewater treatment systems are decentralised systems that are used to treat wastewater from a home or business and return treated wastewater back into the receiving environment.
Overland flow		Stormwater that flows overland until it enters the formal stormwater network, stream or the sea.
Overland flow path	OLFP	The route followed by stormwater which runs over the surface of the ground (overland flow) when it becomes concentrated as it makes its way downhill following the path of least resistance towards streams and watercourses, or the sea.

Term	Abbreviation	Definition
Overseer		Overseer is New Zealand software that enables farmers and growers to improve nutrient use on farms, delivering better environmental outcomes and better farm profitability. Also used by some councils to manage nutrient loadings on the environment.
Pastoral		Land use for keeping and grazing livestock.
Peat soils		Soils with high levels of organic material as a result of decaying vegetation.
Permeability	PERMEABILI	Permeability is based on grain size and porosity, which describes the soil's ability to transmit flow. The permeability of a soil profile is related to potential rooting depth, depth to a slowly permeable horizon and internal soil drainage.
Pervious		Natural ground surfaces including trees, shrubs, grass and soil which allow water to pass through and soak into the ground, reducing the volume of runoff flowing over the ground.
Potency factor		Potency reflects the behavior of pollutants, such as phosphorus, which are assumed to be sorbed to soil. The potency factory of a pollutant indicates to quantity of pollutant per quantity of soil (i.e. mg/kg).
Pour point	PP	A sub-catchment outlet point that represents the reporting node of the FWMT. Otherwise known as [Node]
Regional Retrofit		Structural Device installed on the stormwater network to treat a larger area by take-off or inlet from the live network
Resource Management Act	RMA	The Resource Management Act 1991 promotes the sustainable management of natural and physical resources such as land, air and water in New Zealand.
Riparian		Relating to, or situated on, the bank of a river or other water body.
Runoff		Water flows which result from rainwater which is not absorbed by permeable surfaces or that which falls on impermeable surfaces
Rural		Outside of the defined urban area under the Auckland Unitary Plan HRUs with land uses classified as forest, horticulture, pasture or open space
Rural Urban Boundary	RUB	Zoned extent of the urban area and associated rules under the AUP
Sewage Fungus		Sewage fungi consists of filamentous bacteria, associated with fungi and protozoa. It is the slimy growth found in sewage and sewage polluted water.
Soak holes		Belowground pit to collect runoff and allow it to soak naturally into the soil. An alternative drainage method for rainwater and is similar to a Retention tank or Detention tank.
Source Control Strategy		Non -structural intervention either rural or urban usually targeted at avoiding an impact on the hydrological cycle by more closely matching a hydrological process to the natural baseline.
Special Housing Area	SHA	To address Auckland's housing crisis, areas established across the city where fast-track development of housing, including affordable housing is undertaken
Stormwater Catchment		The authoritative stormwater catchment extents as defined by Auckland Council datasets dated August 2014.
Stormwater network		The pipes, associated assets and watercourses associated with the treatment and conveyance of stormwater.
Structural Device		Generic term to cover a wide range of devices to remove contaminants from runoff. A physical asset installed in the

Term	Abbreviation	Definition
		stormwater network to provide a quality or quantity function Sometimes referred to as a BMP or Stormwater Treatment Device.
Sub-catchment		Area of land in which rainfall drains toward a common stream, river, lake, or estuary. Sub-catchments in the FWMT function as spatial accounting units for the model and are nested within Auckland Council's 233 Stormwater Catchments.
Surface Water Takes		Water take involves abstracting water from a stream, lake or river for land use activities. A water permit is needed to take water unless it is for human consumption or stock water.
System for Urban Stormwater Treatment and Analysis IntegratioN	SUSTAIN	SUSTAIN is a decision support system that assists stormwater management professionals with developing and implementing plans for flow and pollution control measures to protect source waters and meet water quality goals. SUSTAIN allows watershed and stormwater practitioners to develop, evaluate, and select optimal best management practice (BMP) combinations at various watershed scales based on cost and effectiveness.
The National Policy Statement for Freshwater Management	NPS-FM	Policy providing direction about how local authorities should carry out their responsibilities under the Resource Management Act 1991 for managing fresh water. It’s particularly important for regional councils, as it directs them to consider specific matters and to meet certain requirements when they are developing regional plans for fresh water. The NPS-FM came into effect on 1 August 2014.
Topography		Description of the geographical surface features of a region.
Treatment performance	Asset_treatment	A measure of the effectiveness of the asset with respect to its ability to remove stormwater pollutants; TSS, Zinc, and Copper.
Urban area		HRUs with land uses classified as residential, commercial, industrial, or otherwise developed
Vehicles Per Day	VPD	Land use impact measure calculated by average annual daily traffic (AADT) count
Wastewater	WW	Water that has been used in the home, in a business, or as part of an industrial process. Also known as sewage.
Waterbody		Distinct and significant volume of water. For example, for surface water: a lake, a reservoir, a river or part of a river, a stream or part of a stream.
Watershed		Planning units that refer to the area from which surface water drains into a common lake or river system or directly into the ocean; also referred to as a drainage basin or catchment basin. Stormwater management across Auckland is organised into 10 major watersheds.

1.0 Introduction

The Auckland region includes an estimated 16,650 km of permanent streams and rivers, and an additional 4,480 km of intermittent stream (Storey and Wadhwa, 2009). The nature of these rivers and their water quality is influenced by a variety of factors including geology, land use, impervious surface type, canopy cover, climate, and soil type. Anthropogenic influences, particularly land use and activities in watersheds, can strongly affect water quality in New Zealand (Larned et al., 2016; PMCSA, 2017). While Auckland has extensive networks of high-quality streams, water quality degradation has been documented in both urban and rural areas (Larned et al., 2016).

New Zealand is facing ongoing pressure from historic and continuing decline of water quality. New Zealanders are engaged and concerned by water quality issues. In 2019, Stats NZ revealed that freshwater quality concerned 80% of New Zealanders, building on prior surveys by a range of agencies highlighting water quality as of high or highest environmental concern (e.g. Hughey et al., 2016; PMSCA, 2017; WaterNZ, 2017; Fish and Game, 2019; Stats NZ, 2019). Concerns are likely to grow as pressures on freshwater increase from development, food security, climate change resilience, social mobility. and remediation of historic degradation) (PMSCA, 2017).

In 2011, the Government signaled freshwater quality improvement was needed throughout New Zealand and in 2014 introduced the National Policy Statement for Freshwater Management (NPS-FM) – revised in 2017 and currently undergoing further revision. The latest NPS-FM 2020 version is operative but awaiting detail on several clauses.

Management of freshwater has become a matter of national significance requiring notification and/or operative plans implementing the NPS-FM by 31 December 2024, in all regions of New Zealand (RMA Subpart 4, Section 80A). Underpinning the NPS-FM is an acknowledgment of a freshwater pollution crisis in New Zealand, requiring change, improved management and more robust evidence underpinning all water quality decision-making.

To meet this challenge, the Healthy Waters Department of Auckland Council, in partnership with the wider Auckland Council family and stakeholders, are developing the Freshwater Management Tool (FWMT).

The FWMT is a regional scale, process based, continuous simulation water quality and hydrology modelling system with ability to represent baseline and optimised intervention scenarios, utilising US EPA Modelling Software programmes LSPC and SUSTAIN. The FWMT requires a large volume of input data that is configured to the model framework. This report sets out the background and approach for the data inputs preparation for the freshwater management tool, centred around the Data inventory contained in Appendix A. The report describes data sources and preparation, compilation and geoprocessing methodologies used to derive FWMT parameter data. This report should be read in conjunction with its companion Report the FWMT Baseline C and P Report for further details around model parameterisation and framework development.

1.1 NPS-FM, Water Quality Accounting and FWMT

The NPS-FM directs all regional councils and unitary authorities, to follow a consistent approach in managing water quality. Notably, to consult with their communities and identify: (1) the values for fresh waterways; (2) objectives to underpin maintaining or improving such values; and (3) attributes for objectives on which any assessment must be objectively and consistently made to demonstrate maintenance or improvement of water quality. This is the National Objective Framework (NOF; MfE, 2017a). The NOF requires supplementation by regional attributes for broader community-held values.

To support both the needs for integrated and efficient water management, the NPS-FM also requires Auckland Council develop a freshwater accounting system (Clause 3.29).

Freshwater accounting refers to the collection of information about pressures on resources within Freshwater Management Units (FMUs), the spatial scale set by regional councils for freshwater management.

The NPS-FM (2020: Clause 3.29, 5) defines the requirements of freshwater quality accounting systems to "*record, aggregate and keep regularly update information on the measured, modelled or estimated:*

- *Loads and/or concentration of relevant contaminants; and*
- *Where a desired contaminant load has been set as part of a limit on resource use, or identified as necessary to achieve a target attribute state, the proportion of the contaminant load that has been allocated; and*
- *Sources of relevant contaminants; and*
- *Amount of each contaminant attributable to each source*".

Freshwater accounting systems must therefore account for the type and amount of relevant contaminants affecting freshwater quality, including pathway for contaminants, from natural, diffuse and point sources.

Prior guidance for the NPS-FM (MfE, 2017:82) noted that freshwater accounting systems, are intended to:

- "*Inform decisions on setting freshwater objectives and limits (providing information on sources and amounts of contaminants; testing economic and social impacts of various scenarios);*

- *Inform decisions on managing within limits (determine most equitable and cost-effective methods to achieve objectives);*
- *Report on progress to meeting freshwater objectives*".

The NPS-FM (2020: Clause 3.29, 2) clarifies this further, stating the purpose for accounting systems is "*to provide the baseline information required:*

- *For setting target attribute states, environmental flows and levels, and limits; and*
- *To assess whether an FMU is, or is expected to be, over-allocated; and*
- *To track over time the cumulative effects of activities (such as increases in discharges and changes in land use)*".

Any regional freshwater accounting system therefore needs to be resolved to sufficient detail for objective setting, determining management actions and reporting on implementation (e.g. "commensurate with the significance of the water quality or quantity issues applicable to each FMU or part of an FMU" [NPS-FM, 2020 Clause 3.29, 3]). Equally regional accounting systems must be flexible enough to support varying scales of accounting resolution from sub-catchment to FMU. MfE (2015:12) recommend that nine high-level principles of freshwater accounting become standard practice for councils implementing the NPS-FM, to assure the quality of baseline information used in decision-making.

Freshwater accounting systems are not explicitly recognised by the NPS-FM as either modelling or monitoring-based. However, accompanying guidance by the Ministry for the Environment (MfE, 2015) notes that for the sake of practicality, it is unfeasible to monitor everything, everywhere, at all times and that monitoring costs are often disproportionate to catchment modelling for equivalent or lesser information. For the purpose of NPS-FM freshwater accounting, modelling is a likely and supported approach to set freshwater objectives and limits (MfE, 2015, 2017b, 2020).

In developing a freshwater quality accounting framework, it is important to note the progress and investment that Auckland has already made to improved water management, including its prior quantity and quality accounting systems. Figure 1-1 outlines some of the important milestones in Auckland's Water management history, representing the journey to the FWMT since 1990.

Targeted and State of the Environment (SoE) monitoring by Auckland Council has created a body of freshwater knowledge including:

- SoE Monitoring with continuous flow and several physicochemical indicators (e.g. pH, turbidity, dissolved oxygen) coupled with grab sampling for most water quality indicators.
- Edge of field and end of pipe studies to contribute to contaminant load and concentration understanding.

- Consent compliance data and metering of takes and discharge quantity/quality.

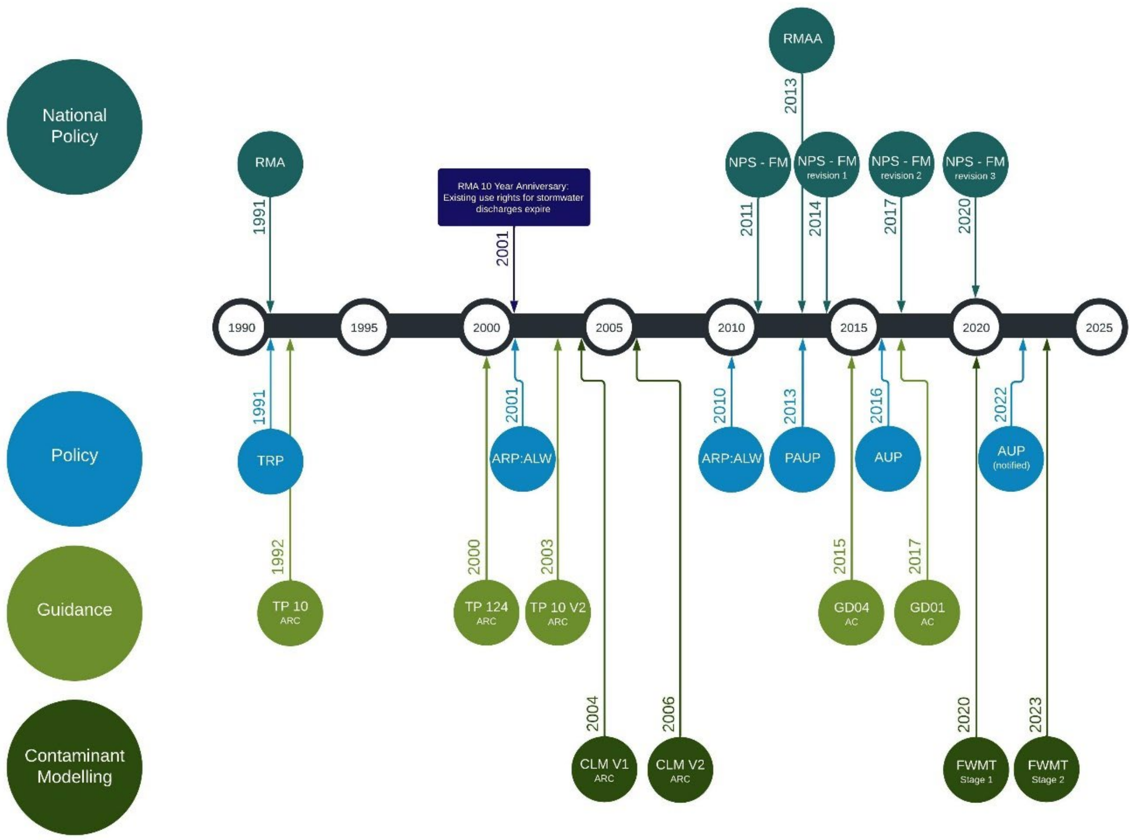


Figure 1-1. Timeline of policy, guidance and contaminant modelling in Auckland from 1990 - 2025

The Contaminant Load Model (CLM; TR 2010/003 and 004) was developed to by the legacy Auckland Regional Council (ARC) in 2006 as part of the Stormwater Action Plan (SWAP). The CLM is an excel-based spreadsheet model developed to estimate stormwater contaminant loads on an annual basis, based on edge of stream yields derived from monitoring studies applied to a set of standardised land cover types. The period between 2006 and 2010 resulted in significant use of the CLM to support stormwater infrastructure planning across Auckland urban areas, including a new variant with static, steady-state intervention capability. The CLM was modified in 2013/14 for broader use in New Zealand urban environments and published by NIWA as C-CALM (Semadeni-Davies and Wadhwa, 2014).

Both CLM and C-CALM remain simple tools to resolve annual load from surface only (i.e. unable to simulate variation in yield and/or concentration discharged by time and/or by flowpath or ultimately, instream). Whilst marking progression for decision support tools to understand contaminant loading in stormwater management, neither meets ongoing NPS-FM requirements for water quality effects assessment; neither

CLM and C-CALM resolve acute or chronic conditions, instream from contaminant discharge and hydrological modification.

The FWMT continues earlier accounting framework development, to support improved rules and implementation programs for water quality outcomes but purposely in alignment with the NPS-FM. Combined, sources of freshwater quality accounting data available to Auckland Council, for the NPS-FM include:

- 'Observed' data from the State of the Environment (SoE) river water quality network managed by Auckland Council's Research and Evaluation Unit. The SoE river water quality monitoring network includes 36 stations across Auckland's 10 major watersheds. A key purpose for the SoE river water quality monitoring network is trend analysis (e.g. changes in contamination over time) with lesser purposes for loading analysis since a lack of direct monitoring of tracers for source assessment limits calibration. The objective of this network is to help characterise the quality of the region's freshwater resources including changes therein, and to adaptively evaluate the efficacy of council's policy initiatives and management approaches under the Resource Management Act 1991.
- Various past targeted monitoring exercises into contaminant concentration, loading and sources, which have effectively become incorporated into the FWMT via configuration and performance assessment (e.g. FWMT Configuration and Performance report Healthy Waters, 2020).
- 'Predicted' outputs from the Freshwater Management Tool (FWMT), which is a continuous and integrated accounting framework (rural and urban, spanning all freshwater management units in the Auckland region) for hydrological and contaminant processes resulting from the use and development of land upon freshwater and coastal receiving environments. To simulate water quality in monitored and unmonitored watersheds, the FWMT uses the Loading Simulation Program in C++ (LSPC) (Shen et al., 2004). LSPC was developed by the U.S. Environmental Protection Agency and is built on an open-source platform to simulate watershed hydrology, sediment erosion and transport, as well as water quality processes from both upland contributing areas and receiving streams (the code for LSPC can be downloaded here: LSPC Code). The FWMT accounts for approximately 490,000 ha of land, 3,085 km of permanent streams, and 2,761 sub-catchment outlets or "nodes" (~18% of the regional permanent and intermittent stream network).

1.2 FWMT Scope and Brief

The FWMT serves dual purposes for the NPS-FM and WQTR outlined in Section 1.3. Specifically, to fulfil freshwater accounting system requirements, decision-making and implementation requirements for Auckland Council as a unitary authority (i.e. regional and district government functions of the Resource Management Act 1991 and Local Government Act 2002). The FWMT is therefore required to support both policy development and infrastructure planning.

The FWMT scope includes both current (2013-2017) and future state freshwater accounting, region-wide at sub-catchment scale via continuous process-based modelling (i.e. to reasonably foresee the effects of targeted investment, development and climate change on freshwater quality, integrated across the Auckland region).

The FWMT scope is supported by an iterative build programme to accommodate revisions to national policy statements, improved regional evidence (including monitoring datasets) and community engagement in decision-making. For Stage 1, the FWMT scope is limited to accounting for six contaminants in varying forms (dissolved, total): N, P, Cu, Zn, TSS and *E. coli*.

The Stage 1 FWMT is also limited in scope to *direct* accounting from land to stream, lake and coast environments, *direct* accounting instream (e.g. contaminants continuously transformed for instream processes), and *indirect* accounting for in-lake via optimised-Vollenweider equations (i.e. FWMT predicted external nutrient loads transformed to steady-state in-lake TN, TP, Chl-a and SD, graded by NOF guidance).

***Note**: the above and following introductory sections are adapted from the FWMT baseline reports to ensure consistency of context and purpose for the FWMT is clear to readers of inputs, configuration and performance, and outputs.*

1.2.1 FWMT Staging – Iterative approach to development

Accommodating the FWMT's ambitious scope for a process-based and comprehensive (continuous, region-wide, sub-catchment resolved) freshwater contaminant accounting model, is not feasible within a short timeframe and single modelling stage. Instead, a prioritised and iterative approach underpins the FWMT development, of both baseline and scenario capability (e.g. for concentration and/or load grading and optimisation).

An iterative approach enables the FWMT to better accommodate (ongoing) changes to the NPS-FM, inform a targeted monitoring programme for greater understanding of freshwater contaminant processes, incorporate such data in revised configuration (for improved performance) and provide an increasingly strengthened evidence base for freshwater objective-setting, limit-setting and implementation decisions.

Development of Stage 1 FWMT commenced in November 2017 using data collected up to 30th June 2017, with a multi-year and incremental programme for Baseline and

Scenario Modelling. Stage 1 FWMT baseline state is anticipated for delivery by early 2020 and scenario state including optimisation capability, by late 2021[1] (Figure 1-2).

Design and development of Stage 2 FWMT will occur in response to delivery, engagement, policy, regional planning and operational planning uptake of Stage 1 output. Scenario and sensitivity testing using Stage 1 FWMT will proceed only after development is complete.

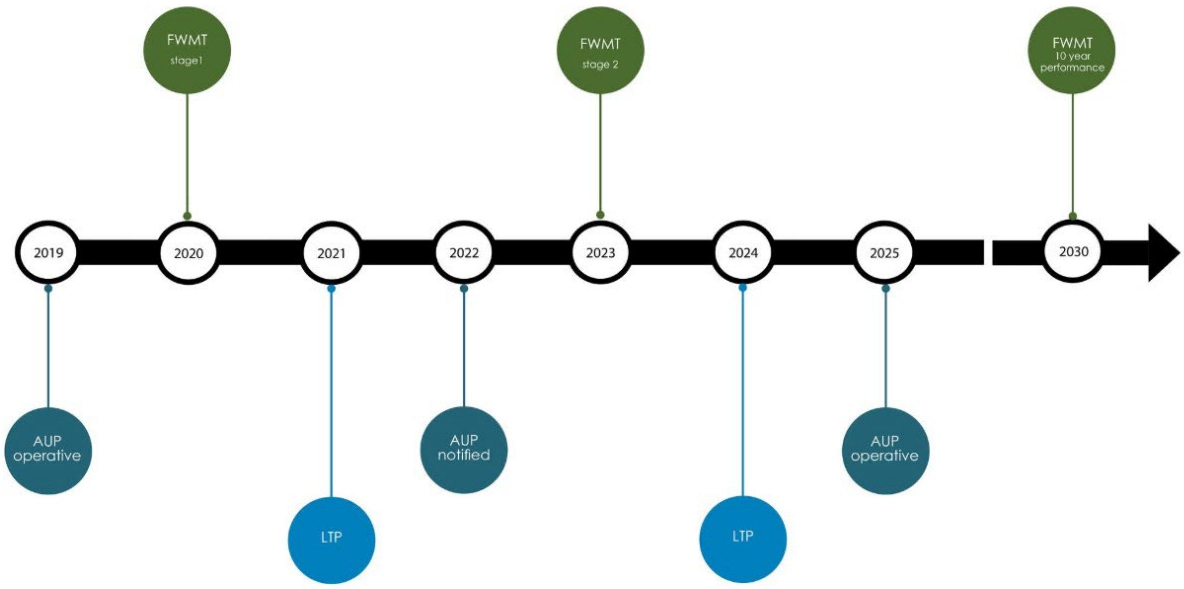


Figure 1-2. Delivery timeline of the FWMT through three iterative stages, with consistent scope between to deliver both baseline and scenario evidence on freshwater quality attribute states under existing and alternate management actions

1.2.2 Baseline Modelling

Catchment modelling of baseline freshwater quality typically aims to establish the baseline state of hydrological and contaminant distributions, across a catchment and either as generalised or continuous state. Baseline modelling is acknowledged in NPS-FM supporting guidance (MfE, 2015) as necessary to ensure variation in contaminant concentration or loading, is understood: throughout an FMU/watershed, across acute and chronic conditions, for variation in natural and anthropogenic drivers (soil, land cover, intensity of use, climate).

The objectives for baseline modelling can include:

[1] Development timeframes have adjusted since completion of this report and delayed publication by Auckland Council internal engagement processes.

- Simulation of a historical period matching the best flow and contaminant concentration records available to allow calibration against monitored data.
- Simulation of un-monitored conditions, across time and space, to allow improved understanding of baseline conditions across the regional gradients in driving factors.
- Establish a suitable tool with an appropriate level of confidence for use in scenario modelling.

In practice, catchment modelling requires a range of existing datasets, of varying quality and resolution, nested in a hierarchy reflecting modelling objectives. Where synthesis of data is required, a focus on transparency, repeatability and producing useful data assets for wider business processes is essential.

Baseline modelling can be expected to result in the identification of deficiencies of existing datasets (i.e. in response to testing model performance and/or understanding the spread of likely conditions in contrast to any existing monitoring network). The iterative development of the FWMT is intended to enable continuous improvement of baseline accounting performance, by identifying any dataset deficiencies.

The primary unit for FWMT accounting varies by focus, including for:

- Contaminant, by load and/or concentration (from land and instream) – for rivers and to-lake, available continuously from-land as load and/or concentration. For rivers only, also available as transformed instream concentration and load throughout modelled stream network (inclusive of cumulative and continuous transformation process);
- Space, by sub-catchment through to watershed – for river and lake alike;
- Time, continuously from 15-minute through to multi-year period – for river and to-lake alike whereas in-lake accounting is limited to steady-state only (i.e. not continuously transformed in-lake).

The FWMT thereby generates a mix of continuous time-series from land and instream, as well as steady state in-lake, resolved to sub-catchment and stream network. Both continuous time-series and steady-state output are suitable to account for a range of grading concentration metrics (e.g. median, 95^{th}%) and for *E. coli*, additional grading metrics (e.g. %>260 MPN/100ml; % >540 MPN/100ml).

Baseline state for FWMT Stage 1 is the period 2013 to 2017, representing a near-recent period of sufficient length to determine a range of acute and chronic responses to resource use but with sufficient high-quality data for robustness of freshwater quality accounting. During this period the underlying landscape is static whilst overlying climate is varied alongside point-sourced discharge from reticulated wastewater networks.

1.2.3 Scenario Modelling

Scenario catchment modelling adapt baseline conditions, including representation of a range of interventions, to represent future conditions driving water quality. Scenario capability is required of the NPS-FM to avoid further impairment and/or improve water quality for the reasonably foreseeable growth and development of Auckland.

Configuration of scenarios will likely undergo change in response to FWMT findings (i.e. including or excluding options for contaminant loss reduction or updating costs associated with different land uses). Optimised scenario modelling in the FWMT will also require an a-priori understanding of limiting contaminant(s), targets and attainment points to deliver on NPS-FM objectives.

Much like baseline modelling, scenario modelling capability can be therefore expected to require improvement as datasets, planning instruments and attainment objectives are varied. Equally, sensitivity testing of scenarios can be expected to identify further modelling needs, especially for optimised future scenarios (i.e. where intervention types, effects, costs and opportunities can each alter optimal management strategies).

1.3 FWMT Objectives

The FWMT has a set of objectives relating to its role as Auckland Council's freshwater quality accounting framework. These integrate the principles of freshwater accounting as provided for in the Guide to Freshwater Accounting under the National Policy Statement for Freshwater Management 2014 (MfE 2015).

Figure 1-3. below reflects the FWMT value chain of purposes and objectives. The FWMT supports four linked purposes, each with a range of objectives listed beneath. The objectives relevant to this report are those highlighted in Figure 1-3. and expanded on in Sections 1.3.1 to 1.3.4.

The current SoE freshwater monitoring network guides configuration of the FWMT Stage 1. The SoE network records the state of freshwater at many monitored sites across the region, for stream hydrology and quality. However, the SoE monitoring network lacks continuous data on quality and offers limited regional coverage or resolution. To support continuous modelling improvement, future FWMT iterations will be supported by both SoE and dedicated monitoring programmes.

Figure 1-3. FWMT value chain of purposes and objectives. The FWMT supports four linked purposes, each with a range of objectives listed beneath

1.3.1 Adaptable Hydrology

The process-based routines used by the FWMT are applied at a 15-minute time step, continuously across a multi-year period to produce flow and contaminant concentration time-series throughout a modelled stream network spanning the entire Auckland region. FWMT time-series output support a range of analyses, including water quality load and concentration reporting. The key features of this hydrology framework for the FWMT are the methods of continuous simulation and process simulation described below.

Continuous simulation uses time-series of boundary conditions to represent the variability of climate at high-resolution (spatially and temporally), including rainfall intensity, rainfall duration and antecedent period. Thereby able to better simulate first-flush behaviour and acute contaminant events. Continuous simulation with a high resolution of actual or virtual climate enables both improved understanding of state and variable sizing of interventions for optimal benefit in scenarios. Equally, time-series output enables rapid accounting should guidance change (i.e. NOF and regional attribute guidance focusses largely on median and 95^{th}% contaminant concentration, but could in future shift to other percentiles; the FWMT can be used to generate information on any contaminant concentration percentile);

Process-simulation uses equations and parameters to simulate hydrological and contaminant processes (on land and instream for the FWMT). Process-simulation enables accounting to represent the hydraulic routing and physicochemical performance of devices under the influence of important variables such as friction, gradient, volume, residence time, settling velocity, infiltration rates and erosion. Process-simulation also contrasts with statistical or stochastic modelling techniques that apply observed distributions generalised against governing factors (e.g. CLUES, eSource). Process-simulations thereby enable greater understanding of the causes for and behaviour of contaminants, with greater capability to demonstrate how and why interventions will deliver water quality outcomes.

1.3.2 Robust contaminant sources

Diverse natural, point and diffuse contaminant sources are accounted for by the FWMT. All contaminant sources are tiered into a typology of 106 unique Hydrological Response Units (HRU) derived from combinations of soil, slope, land cover and intensity classes. All contaminants are accounted by HRU to edge-of-field (prior to instream processing) but subject to overland or through-soil processes, as well as to downstream receiving environments (following instream processing). Major reticulated wastewater networks operated by Watercare Services Ltd. (Watercare) in the Auckland region and major stormwater networks operated by Auckland Council are separately configured within the FWMT. Natural geological sources of contaminants are not directly accounted for with information on geology not incorporated into the HRU typology. Deep or old groundwater processes are also not directly accounted for; only active groundwater is simulated within the Stage 1 FWMT.

1.3.3 Practical performance

Freshwater quality accounting performance of the FWMT has been assessed through calibration and validation to State of Environment monitoring stations (e.g. 46 continuous flow and 36 discrete [monthly] contaminant stations). Both calibration and validation has been undertaken only at instream locations, albeit for a lengthy period (up to 15 years, 2003-2017) and in numerous reporting envelopes for conditions (e.g. lower through to greater flow and seasons). In both calibration and validation, numerous measures are also utilised for the varied reporting envelopes (e.g. r2, Nash-Sutcliffe Efficiency, bias). Collectively, the mix of varying envelopes and measures of performance have been identified as necessary to support the use of the continuous simulation capability of the FWMT. For instance, as continuous time-series are produced by the FWMT, these can be queried for changes to contaminant contribution by source, under varying conditions of flow and time. Meaning information on model performance is needed across such gradients to ensure appropriate use of FWMT accounting.

Output from the FWMT is modelled but informed by measured data through performance assessment (e.g. in calibration and validation). Doing so ensures region-wide spatial coverage (of all sub-catchments and watersheds), continuous temporal coverage (of all events) and provenance of contaminants (to relevant sources). All three outcomes are otherwise impossible within the limitations of Auckland Council's State of the Environment monitoring network (i.e. monthly grab-samples for most contaminants, limited to 36 locations only). Importantly, freshwater accounting for the NPS-FM does not require use of measured or modelled data, with both combined being best practice (MfE, 2015).

1.3.4 Leverage Stakeholder Inputs

The FWMT development is intended to lead through iterative phases including direct engagement of stakeholders, iwi and community to leverage stakeholder inputs of targeted information to improve freshwater quality accounting. Engagement is essential to utilising input data from a wide range of sources and testing assumptions.

1.4 FWMT Reporting Approach

Reporting is an integral requirement of freshwater quality accounting under the NPS-FM (Policy 2, 14 and 15 – especially Clauses 3.2 to implement Te Mana o te Wai, 3.7 to follow the NOF process transparently, 3.10 to identify baseline attribute states using best available information, 3.15 to prepare and share action plans for achieving environmental outcomes and 3.29 to operate, maintain and publish information on freshwater accounting systems regularly). Reporting is required both to inform decision-makers and for engagement with community in implementation of objective- and limit-setting decisions. For both outcomes, engagement will depend on clarity about the purpose, scope and objectives of the FWMT as well as the model development process and accounting outcomes (e.g. inputs, configuration, performance, outputs under both baseline and scenario conditions).

The reporting framework for the Stage1 FWMT is indicated in Table 1-1. This framework has been developed to allow the model development processes to remain transparent and flexible.

Table 1-1. FWMT Reporting Framework

Report #	Report	Purpose
1	**Integration**	Defines the context, purpose, objectives, development and reporting approach for the FWMT. Included is discussion of how to integrate the FWMT with wider Auckland Council planning and operational functions (e.g. wider national policy statements, local government functions).
2	**Baseline Data Inventory**	References and documents all pre-existing datasets used in baseline modelling. Describes how all other modified or new datasets were generated, describes limitations Includes – meteorology, topography, stream network and geometry, soil, land cover and use, impervious surfaces, on-site wastewater, reticulated wastewater, stormwater, pre-existing devices.
3	**Baseline Configuration and Performance**	Describes the configuration of LSPC to represent baseline. Describes which processes are accounted for and how these are generalised. Acknowledges limitations of configuration. Document calibration performance against a range of metrics.
4	**Baseline State (rivers)**	Describes output of baseline accounting. Assesses spread of predicted hydrology, distribution of yields and instream loads – describing that by watershed, source and pathway, for 5-year baseline state interval (2013-17). Assesses instream gradings by contaminant over full 5-year interval (2013-17) and subsets of (wet vs. dry years; storm vs. base flow) – linking back to calibration findings on robustness of such output for FWMT purposes and objectives.
5	**Baseline State (lakes)**	Describes output of LSPC and post process assessment on baseline lake conditions utilising optimised Vollenweider equations for predicting steady-state in-lake TN, TP, Chl-a and SD from continuous external TN and TP inputs.
6	**Scenario Data Inventory**	References and documents all pre-existing datasets used. Describes how all other modified or new datasets were generated. Describes limitations thereof. Includes – future climate, future land use, structural device menu and maximum opportunity, source control menu, future wastewater network performance, rural interventions, intervention cost and benefit.
7	**Scenario Configuration and Optimisation**	Describes configuration of LSPC to represent future state or scenarios (e.g. AUP, development, climate change). Describes configuration of SUSTAIN to represent mitigation strategies, costs and effects as well as optimisation process (e.g. for nodes instream or downstream, for which limiting contaminant or hydrology).

Report #	Report	Purpose
8	**Scenario Outcomes**	Frames changes in contaminant outcomes (loads, grading) resulting from climate change, development, and interventions including regulation, non-regulatory policy, infrastructure delivery and lifecycle management. Limited as per baseline state – Rivers and Lakes reports, to relevant contaminants, sources and interventions.

2.0 FWMT Data Inputs Approach

The FWMT was built using the process-based model Loading Simulation Programme in C^{++} (LSPC) (USEPA, 2004; USEPA 2009). FWMT is a numerical model driven by meteorology, landcover and land use, hydrological soil characteristics, topography and biogeochemical processes on land and instream. The LSPC was built for and used to account for freshwater quality in several states in the United States. To adapt LSPC to Auckland, data for the region was assembled from various sources and processed to fit the requirements of the FWMT. To ensure best available input data was used the following approach was adopted:

- **Data Hierarchy.** A hierarchical approach was used for data quality evaluation. Where multiple data sources exist, data were prioritised according to their positional and temporal accuracy, completeness (in coverage and attribution), thematic accuracy (the correctness of feature classification) and usability. Where hierarchy order is listed throughout this Report, lower numbers are used in preference to higher.
- **Traceability with Data Flagging.** Where gaps in data existed, data of lower quality was used. Data flags were used to identify the data quality
- **Efficient Model Update Processes**. Where data was combined, transformed or modified to suit FWMT purposes, methods are scalable and repeatable to readily utilise evolving data.
- **Model iterations.** A data inventory has been developed, enabling comparison to any future model input data on an iterative basis. The FWMT programme is staged with later versions intended to improve on Stage 1.

The Data Inputs Approach is presented in Figure 2-1. Appendix A provides more detailed information on FWMT data inputs including limitations and opportunities for improvement. Note limited data modification as part of model configuration is explored in [FWMT Baseline C and P Report]. Appendix B Limitations and Recommendations Register records limitations of data inputs modified for the FWMT

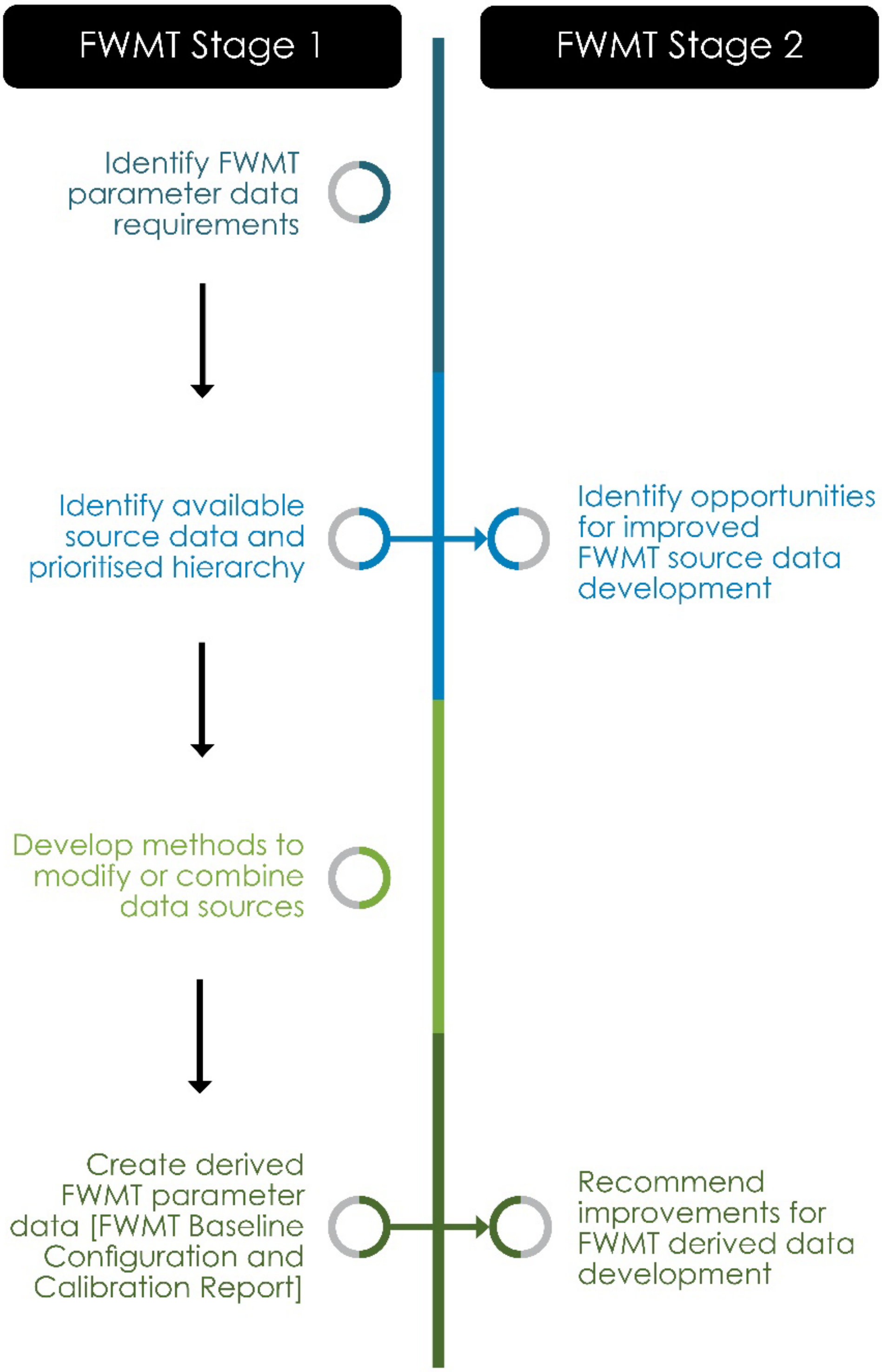


Figure 2-1. A diagrammatic representation of the quality control and assurance methods used for the data warehousing for the FWMT

3.0 Sub-catchments

The Freshwater Management Tool (FWMT) requires the Auckland region to be divided into a series of Sub-catchments which function as the spatial reporting units in the FWMT and represent the hydrological connectivity of source to receiving environment. The FWMT sub-catchments are nested within Auckland Council's 233 stormwater catchments which in turn are nested within 10 Consolidated Receiving Environment (CRE) watersheds. The following sections describe the process to prepare a sub-catchment layer for the FWMT. Information on the model configuration implications of the sub-catchments is contained in [FWMT Baseline C and P Report Sections 3.2 and 3.3].

3.1 Delineation

The process of sub-catchment delineation is indicated in Figure 3-1.

The pre-existing Auckland Council Healthy Waters Stormwater Catchments layer divides the region into 233 catchments for the management of stormwater. Whilst useful for large catchment delineation, these catchments are too large to form the sub-catchment accounting units for the FWMT. Stormwater catchments are also delineated as part of flood modelling exercises by the Auckland Council Healthy Waters Department for extreme flood connectivity which often differs from pipe flow direction. FWMT sub-catchments were delineated based on the regional DEM (2012; see Section 3.1) and adjusted utilising the Auckland Council stormwater network.

The regional DEM was based on spatially variant LiDAR data created as a 2m grid from 2005/2006, 2007, 2008, and updated LiDAR tiles from 2010. The various datasets were combined into a single DEM created as a 2m grid in 2012. The DEM was hydrologically corrected and used to prepare the Overland Flow Path (OLFP) Layer by Auckland Council. The OLFP Layer was created by the Stormwater Hydraulic Modelling Team (2013) and covers the whole extent of the Auckland region. A separate DEM was provided for Great Barrier Island (Appendix A, 3.3). The latter was modified to redirect a single flow path for the Claris Stream. Several sub-catchments along the southern boundary of the Auckland region were transferred from the Waikato region during the formation of the Auckland Unified Authority.

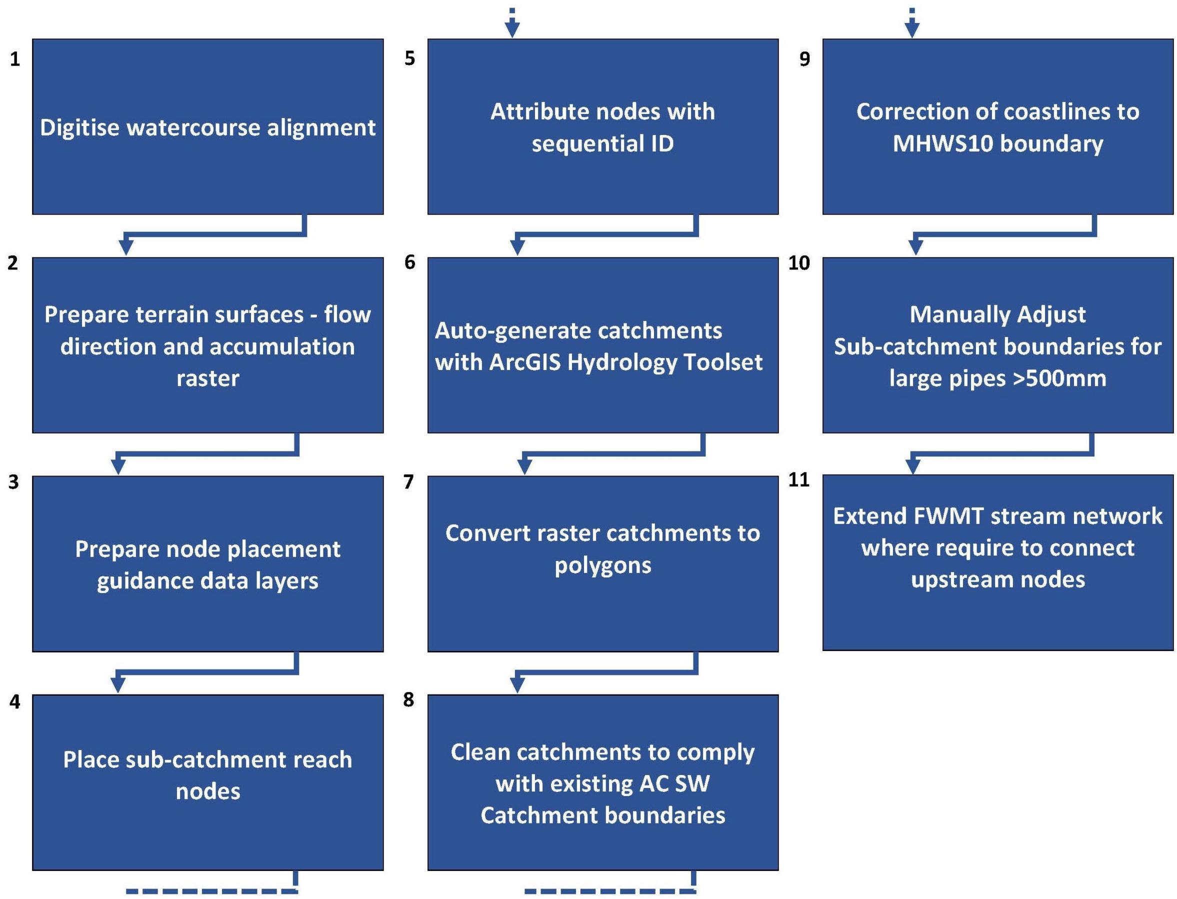


Figure 3-1. FWMT Catchment Delineation Process

Sub-catchment outlets were defined by manual placement of nodes along the river network. A one-to-one relationship exists between the nodes and sub-catchments. Nodes were created from downstream to upstream based on a hierarchy of sources as follows:

1. The coastal terminus of a stream or OLFP with greater catchment area than 100ha.
2. Locations of State of the Environment (SOE) monitoring sites, and other sites with observed records for water quality and flow monitoring.
3. Upstream locations where catchment area reduces by 100ha. This generates an average of 100ha catchment area which is considered optimum for SUSTAIN optimised intervention modelling and development of sub-catchment intervention strategies. This also resulted in a majority of second order reaches and greater to be represented within the explicitly modelled routing network.
4. Node guidance layers were used to guide, where possible, node placement at logical locations representing key hydraulic elements, e.g. culvert inlets or

outlets, water body outlets (e.g. lakes and constructed treatment facilities) or key land use changes (boundary of land uses, local boards or ecological zones).

5. Where possible, confluences of two streams each with multiple upstream sub-catchments were aligned with the sub-catchment boundaries, i.e. one downstream and two upstream catchments. Where this approach would result in undersized catchments, two channels were preserved within the confluence catchment.
6. The large remainder of small catchments draining directly to the coast were further subdivided by creating outlet nodes for sub-catchments with >40ha of catchment area.
7. The remaining coastal land with catchment areas <40ha, and therefore without nodes, were amalgamated as a single “balance catchment” draining directly to the coast for each of the 233 Stormwater catchments with coastline.

To ensure legitimate sub-catchments were formed, each pour point was permitted to search for the zone of greatest accumulation within a 5m radius of where it had been manually placed. Sub-catchments were initially created as raster datasets using the ARC GIS Watershed tool before being converted to polygons for use in the FWMT. Examples of delineated sub-catchments, and their associated pour points, are shown in Figure 3-2.

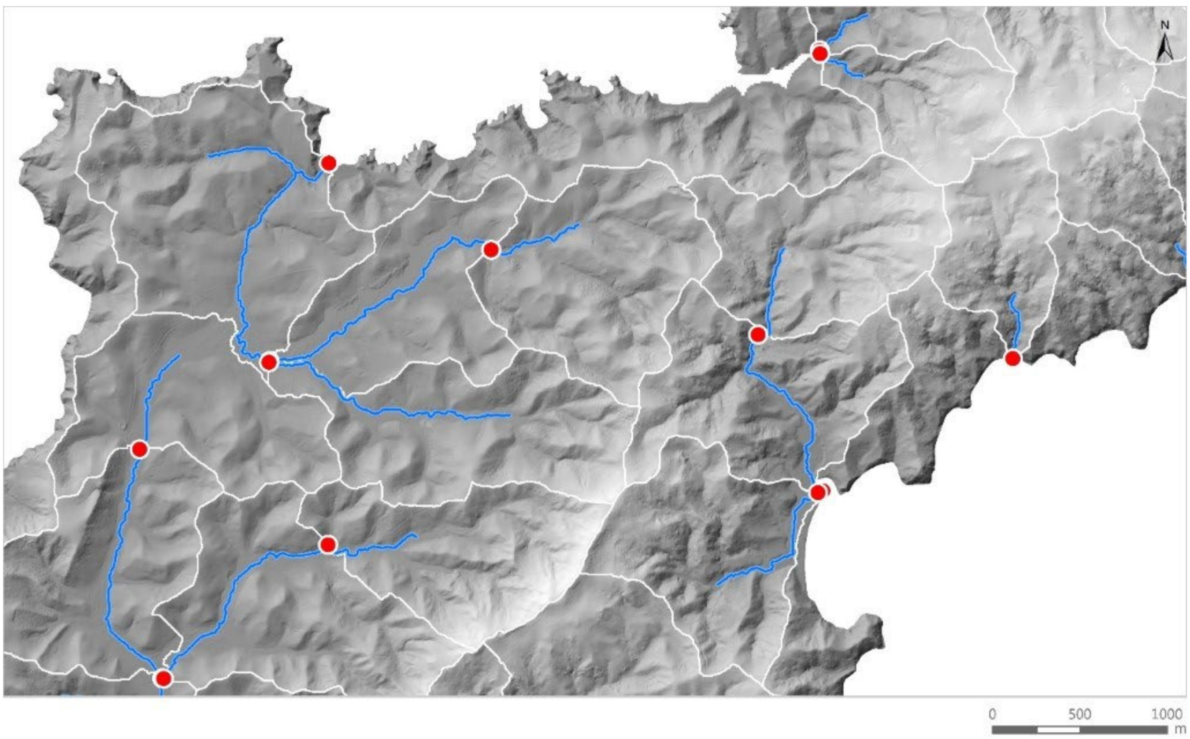


Figure 3-2. Outlet nodes and corresponding sub-catchments

Three broad classes of sub-catchment were produced:

1. Those which discharge into another sub-catchment (area generally 1-2 km^2). These require downstream routing network (see section 4.0)
2. Those which discharge directly to the coast (area 0.4km^2 – 1km^2) represented by a terminal node with a hydrograph loaded to the coast. These do not require downstream routing.
3. Remaining coastal areas (slivers) grouped to one per AC Stormwater Catchment (233 in total) for which no discrete sub-catchment is ≥40ha. These do not require downstream routing.

Sub-catchments that discharged into downstream sub-catchments required a delineated stream (or pipe) reach to be generated as a routing network (as described in Section 4.0). The pour point rules resulted in approximately 18% of the Auckland permanent stream network, a total of 3,3085km being delineated (Storey and Wadhwa, 2000).

The remaining balance of coastal land where catchments are less than the 0.4 km^2 threshold, were merged within one of the 233 stormwater catchments and given a generic ID of 999 to distinguish them from sub-catchments which drain to an outlet node. Examples of each type of sub-catchment are shown in Figure 3-3.

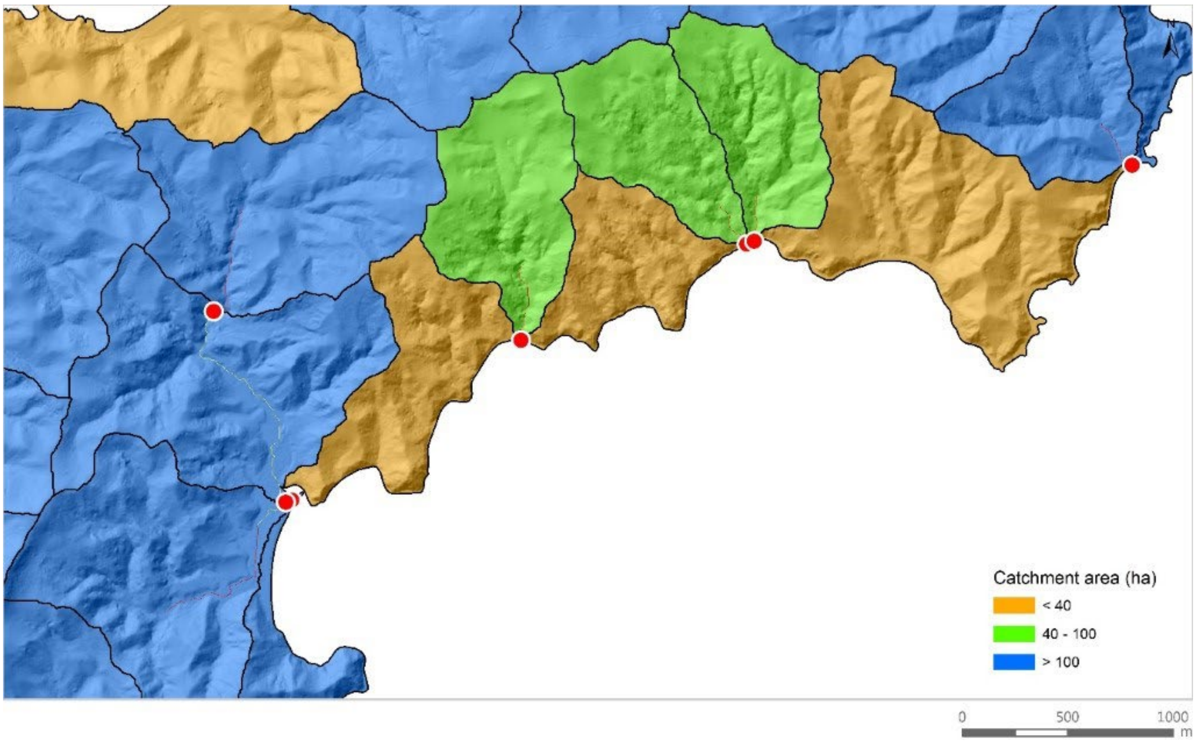


Figure 3-3. Delineation of sub-catchments based on size. NB 1. Blue catchments draining to Modelled Network, 2. Green catchments draining to coastal node, 3. Yellow un-noded "balance" catchments, one per AC SW Catchment

The polygon sub-catchments were required to match the spatial extent of the parent stormwater catchment as the primary hydrology management unit for Auckland Council. To clean up the auto-generated catchments to comply with the AC Stormwater Catchment boundaries, sub-catchments were clipped to the latter parent boundary. Any gaps between the two datasets were merged into an adjacent sub-catchment. The summed area of all sub-catchments within a particular stormwater catchment therefore equals the area of the parent stormwater catchment. The relationship between the delineated sub-catchments, parent stormwater catchment, and master CRE watershed is shown in Figure 3-4.

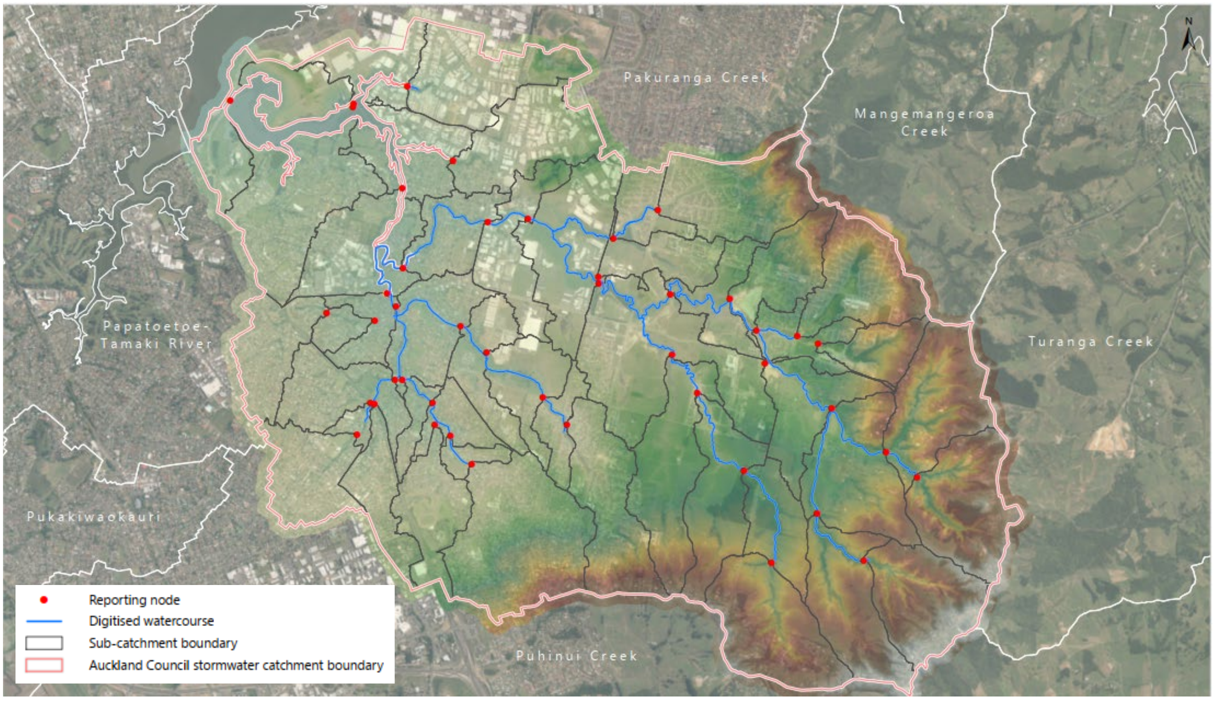


Figure 3-4. The positions of delineated FWMT sub-catchments in relation to AC stormwater catchments

3.2 Sub-catchment Boundary Piped Network Adjustments

Sub-catchment boundaries were adjusted to account for stormwater diversion effects on contaminant and flow routing.

Stormwater pipes greater than 500mm in diameter were identified from the AC Corporate SW Network layer (Appendix A, 3.5; Appendix A, 3.2) as representative of diversions from significant areas averaging >10 Ha. Pipes that crossed the boundary of sub-catchments were manually corrected.

The final FWMT sub-catchment layer includes 5465 polygons and accounts for 48000km^2 of the Auckland region.

3.3 Coastline Adjustments

The coastal extent of FWMT sub-catchments were defined using the Mean High-Water Springs 10% exceedance water level (MHWS10) (Appendix A, 3.4). Sub-catchment boundaries from 3.1 were adjusted to terminate at the MHWS10 level.

4.0 Stream Network

The stream network in the FWMT allows for a single routing reach per sub-catchment to represent lag, transformation, erosion and deposition processes instream (i.e., max of a single modelled reach per sub-catchment).

This section describes how input data on stream alignment and physical attributes were developed. For information on configuration of the model reach representation please refer to [FWMT Baseline C and P Report Section 3.3]. Modelled stream reaches begin downstream of Headwater Catchments (Section 3.0). Digitisation of the trunk stream network resulted in 3,085 km of streams in the routing network of the FWMT, which represents approximately 18% of the 16,650 km of permanent streams in the region (Storey and Wadhwa, 2000).

The FWMT routing network was built using the method and base data detailed in the Open Watercourse Geometry Assessment and Methodology Report (Rieger, 2016). The Rieger (2016) method incorporates a variety of data sources for delineation of watercourses and was trained on 23 pilot stormwater catchments.

Several data sources informed FWMT stream reach geometry. The data and sources were ranked based on accuracy. Data with higher accuracy were used preferentially. Table 4-1 details the stream geometry informing data sources prioritised for development of the FWMT stream network. Figure 4-1 indicates the spatial coverage of network from the various data sources.

Table 4-1. FWMT Routing Network digitisation data sources

Preference	Data source	Description	Extent	% Utilised	Reference	Accuracy*
1	Auckland Council Underground Services	Piped streams	Urban Auckland	3.0	Appendix A, 5.2	Very High
2	Auckland Council Underground Services	Watercourse and Channel layers: high geometric accuracy	Urban Auckland	0.3	Appendix A, 5.2	High
3	Ecoline (Watercourse Assessment Reports)	Field collected data	Selected Auckland Catchments	2.7	Appendix A, 5.3	High

Preference	Data source	Description	Extent	% Utilised	Reference	Accuracy*
4	Aerials	Used for Validation and correction of OLFP in ponding areas	Auckland	39.9	Appendix A, 5.8	Med
5	Auckland Council Viewer OLFP	Most extensive approximation of surface water flow	Auckland	53.6	Appendix A, 5.1	Med
6	Topo NZ River Centrelines	Only used where no other source coverage for ex Waikato areas	New Zealand	0.2	Appendix A, 5.5	Low

*If a dataset is assigned a low accuracy, it was produced by a model and not corrected. If a dataset is assigned a medium accuracy, it was produced by detailed remote sensing information and partially updated using surveyed data. If the dataset was assessed as has high accuracy it was collected by field observation.

FWMT stream network geometry was largely based on OLFP data (Appendix A, 5.1) which gives the greatest coverage of Auckland regional extent, augmented with Underground Services, Watercourse, Channel and Pipe data (Appendix A, 5.2), Ecoline Watercourse Assessment Report data (Appendix A, 5.3), Drainage Scheme channel works (Appendix A, 5.6) and NZ River Centrelines (Appendix A, 5.5). Where culverts or piped sections along the routing network occur, the Auckland Council Underground Services pipe layer (Appendix A; 5.2) was utilised for spatial alignment as well as channel geometry information (Section 4.1).

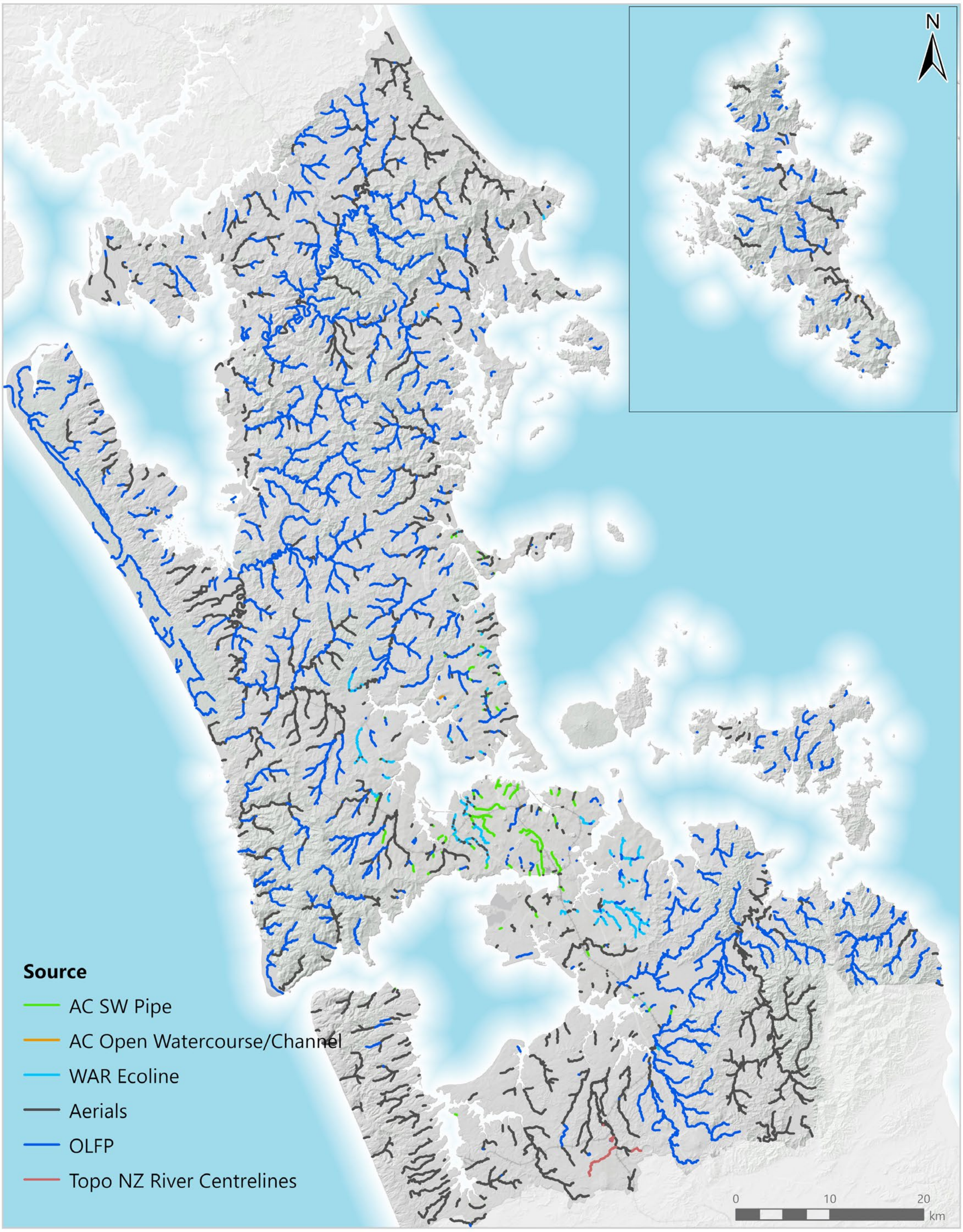


Figure 4-1. FWMT stream geometry coverage by data source

The FWMT network includes both reaches (natural channels) and pipes to form a contiguous flow path to coast. The pipe feature class was used to inform where open watercourses have been piped. Piped reaches less than 30m length were considered to represent culverts and were therefore ignored in favour of the open channel reach. Pipe sections >30m were preserved in the routing network as piped reaches.

Where OLFPs did not accurately define the main FWMT reach in a sub-catchment, the earlier sources (Appendix A, 5.1-5.6) were used to verify and substitute geometry. Where no other sources existed, aerial photography (Appendix A, 5.7) was used to align the FWMT reaches with the watercourses if OLFP alignment clearly departed from channels centrelines (e.g., in floodplain ponding areas).

The FWMT stream reach configuration generally results in one reach per sub-catchment. Multiple reaches were sometimes preserved from sub-catchment delineation to ensure contiguous routing (see Figure 4-2). In those instances, both reach segment characteristics were weighted by length and applied to the main stem for instream processing.

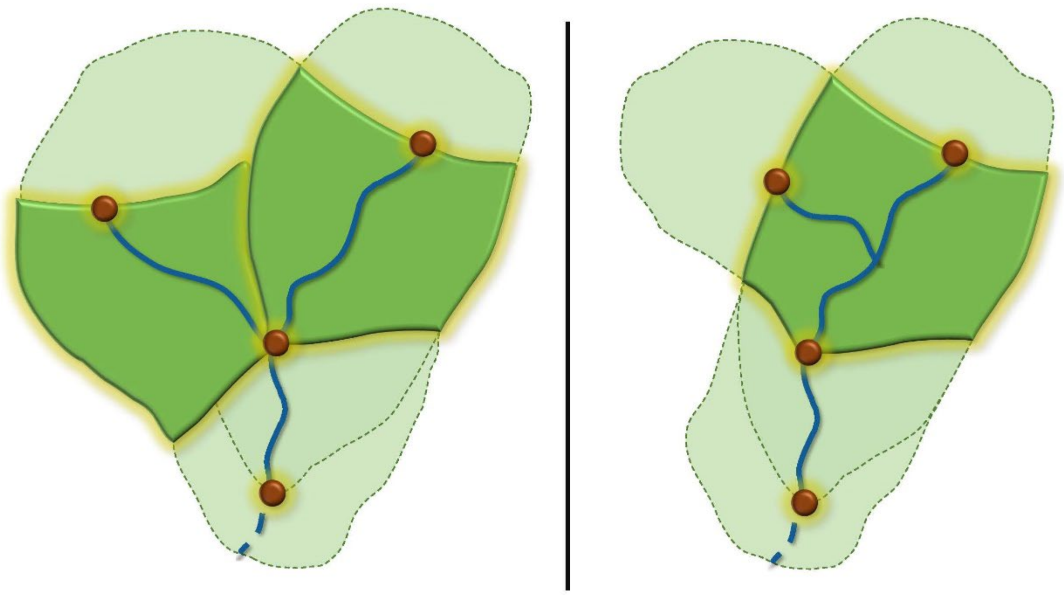


Figure 4-2. FWMT stream confluence examples at sub-catchment node (left) and within a sub-catchment (right)

4.1 Channel Geometry

Each of the FWMT routing reaches require parameters to allow hydraulic routing and for contaminant process simulations that consider velocity, depth and lag. The stream routing configuration detail is provided in [FWMT Baseline C and P Report, Section 3.3]. Key input parameters required for LSPC and their sources are indicated in Table 4-2 and Table 4-3. Where possible, a primary data source was utilised and where not available, a secondary data source was utilised. Note Manning's-n is not adapted for sinuosity.

All parameters were determined for the finest resolution of the input data source, for example a single pipe length <100m long from the AC Underground Services

(Appendix A, 5.2, 5.3) or WAR Ecoline typically <100m long (Appendix A, 5.4), and then amalgamated into longer FWMT reaches as a length weighted average. If a FWMT reach was piped more than 50% of its length, the pipe parameters were adopted for the reach.

Table 4-2. Channel parameter sources

Code	Description	Primary Source and Method	Secondary Source and Method
WID _ m	Top of bank width in metres	Calculated from WAR Ave Wet Width, Bank Angles and Bank Heights True Right Bank (TRB) and True Left Bank (TLB) or stormwater pipe diameter for piped reaches	Applied derived relationship from WAR-assessed reaches for WID-m to catchment size for Rural and Urban or measured from aerial and lidar for catchment >300km^2
Dep	Bank full depth in metres	Average of WAR Bank Height TRB and TLB plus Average Dep	Applied derived Average Bank Height from measured WAR reaches for Rural (1.0m) and urban (1.1m)
R1	Ratio of bottom width to top width	Calculated from WAR Ave Wet Width divided by WID_m	Calculated from WID, Dep and derived average bank angles from completed reaches of Rural (60°) and Urban (50°)
W1	Ratio of floodplain width to top of bank width	Regional Floodplain polygons (Appendix A, 5.5) clipped by reach to 60m max width (removing tributaries). Area divided by length divided by WID	Nil
R2	Angle of floodplain edge	Taken from DEM (Appendix A, 3.1) as average slope within buffer from Regional Floodplain	Nil
LEN_m	Longitudinal length	Spatially calculated from delineated watercourse reach intersected by FWMT sub-catchments	Nil

Code	Description	Primary Source and Method	Secondary Source and Method
Slope	Percentage slope m / 100m	Calculated as overall slope end to end of the stream segment from the unconditioned DEM (Appendix A, 3.1)	Nil
n-main	Main channel Manning's-n roughness	Typical Manning's-n assigned by WAR data on bed material weighted % composition (See Table 4-3 for applied Manning's values adopted from Te Chow [1959])	Applied average from slope bands: Urban streams slope < 3° n = 0.031 slope 3°-5° n = 0.032 slope > 5° n = 0.033 Rural Streams slope < 3° n = 0.030 slope 3°-5° n = 0.031 slope > 5° n = 0.034
n-flood	Floodplain Manning's-n roughness	Non-Ground DEM used to assess proportion of floodplain in paving, grass and vegetation. Manning's weighted by area. (See Table 4-3 for applied Manning's values.)	Nil

Table 4-3. Adopted Manning's values used to length-weight FWMT reaches

Channel Type	Channel Substrate	Manning's *n*
Natural	Sand/Silt/Clay	0.030
	Gravel	0.035
	Cobbles	0.040
	Boulders	0.050
	Bedrock	0.035
Modified	Artificial	0.020
	Piped	0.013

Channel Type	Channel Substrate	Manning's *n*
	Farm Drains	0.027
Floodplains	Grasses (<0.5m)	0.030
	Vegetation (>0.5m)	0.075
	Impervious Surfaces	0.016

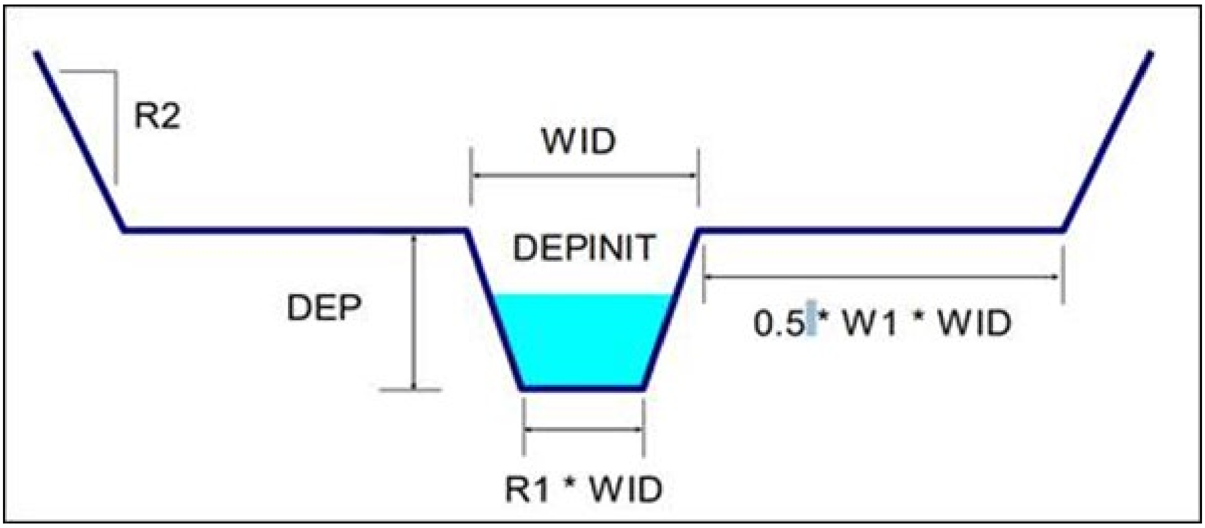


Figure 4-3. Channel geometry input parameter summary

5.0 Climate

To model hydrologic processes, LSPC requires input of precipitation, air temperature, and potential evapotranspiration. In addition, several other parameters including solar radiation, cloud cover, dew point temperature, and wind speed are required for specialised water quality processes modules within the model (e.g. shading, water temperature). Those climate data provided the key boundary conditions to drive hydrology and water quality modules in the FWMT.

5.1 Data Sources

Data were collected from several sources including Auckland Council, the National Institute of Water and Atmospheric Research (NIWA), and Watercare to allow hydrological simulation of a 15-year period 1 January 2002 to 31 December 2017. The following data sources were evaluated:

- Auckland Council's Hydstra database (Appendix A, 4.1)
- NIWA National Climate Database (CliFlo) (Appendix A, 4.2)
- NIWA Virtual Climate Station Network (VCSN) (Appendix A, 4.3)
- Watercare Precipitation Data (Appendix A, 4.4)

Note CliFlo data was not used in the FWMT Stage 1 as regional coverage was achieved with Hydstra and VCSN. Watercare precipitation data was combined with Hydstra and quality codes used to augment Watercare time-series.

Table 5-1 summarises the availability of each climate parameter from each of the four data sources evaluated above.

Table 5-1. Summary of the climate parameters evaluated during the initial inventory

Parameter	Number of Available Stations by Source			
	Auckland Council	NIWA CliFlo	NIWA VCSN	Watercare
Precipitation	●	●	●	●
Potential Evapotranspiration	--	●	●	--
Air Temperature	●	●	●	--
Dew Point Temperature	--	--	●	--
Solar Radiation	--	●	●	--
Wind Speed	●	●	●	--

Auckland Council uses and operates HYDSTRA, a water quality and quantity system database containing time series data including those recorded by precipitation, temperature, and wind speed and direction across the Auckland region. All available stations with associated precipitation and air temperature data in Hydstra were identified. A second set of queries was sent for each station in this list to obtain available metadata and time series data for climate parameters were collected for all stations.

NIWA maintains and updates a VCSN dataset consisting of spatially interpolated estimates of daily rainfall, potential evapotranspiration, air and vapour pressure, maximum and minimum air temperature, soil temperature, relative humidity, solar radiation, wind speed and soil moisture. These estimates are produced at points organised on a 5x5 km regular grid covering the whole of New Zealand. The VCSN estimates are updated daily through based on spatial interpolation of observed data made at climate stations around the country. The observed climate stations include those maintained by both NIWA and regional councils. The VCSN dataset includes over 11,000 grid points throughout New Zealand (NIWA, 2018). In the Auckland region, 188 VCSN grid points fall within Auckland Council watersheds.

Watercare provided high-resolution (5-minute) precipitation data at select locations available between January 1, 1990 and March 14, 2017. Prior to July 1, 2012, the data were collected and quality controlled by Watercare. After July 1, 2012, these data were augmented and quality controlled by Auckland Council (Shaw, 2018). All Watercare datasets were aggregated from 5 to 12-minute intervals.

5.2 Gauge Selection

Based on review of the NIWA VCSN data product and previous modelling experience with similar gridded data products (e.g. PRISM, NLDAS, DAYMET), the VCSN dataset was selected as the foundational climate data input for the FWMT. The VCSN dataset promotes consistency of spatial and temporal climate data inputs, takes advantage of the existing quality control and spatial normalisation of those values, and enhances the ability to easily maintain and update the system over time.

Out of 383 gages inventoried between Auckland Council and Watercare, 28 Auckland Council (i.e., Hydstra) and 11 Watercare gauges were used in conjunction with the VCSN data set to represent 15-minute rainfall from 1990 through 2017. The full record period for each gauge was used to cover the 1990 through 2017 modelling period. In some cases where selected gauges did not extend back to 1990, the nearest Watercare gauge was used to represent the missing period. The selection of these gauges was primarily based on the following:

- Representation across the calibration/validation period (2012-2016),
- Availability of hourly or finer time step continuity of data,
- Spatial coverage across the region, and

- Guidance from AC on which gauges have generally high-quality coding according to National Environmental Monitoring Standards (NEMS) (Milne, 2019).

5.3 Climate Pairing to Sub-catchment

Climate time-series were paired to sub-catchments. For all sub-catchments, a 'primary' precipitation gauge was identified as the closest amongst available gauges. Once this mapping of primary precipitation gauges, sub-catchments were assigned either VCSN or primary precipitation time-series based on the shortest distance between any primary precipitation gauge, VCSN node and sub-catchment centroid. Where the nearest gauge was greater than 5km from the sub-catchment centroid, rainfall from the nearest VCSN grid point was used in lieu of the observed gauge. Except, in the Waitemata watershed where no VCSN grid points were used due to the high density of observed gauges.

The schematic presented in Figure 5-1 presents the process of assigning precipitation gauges, and corresponding VCSN grid points, to each model sub-catchment.

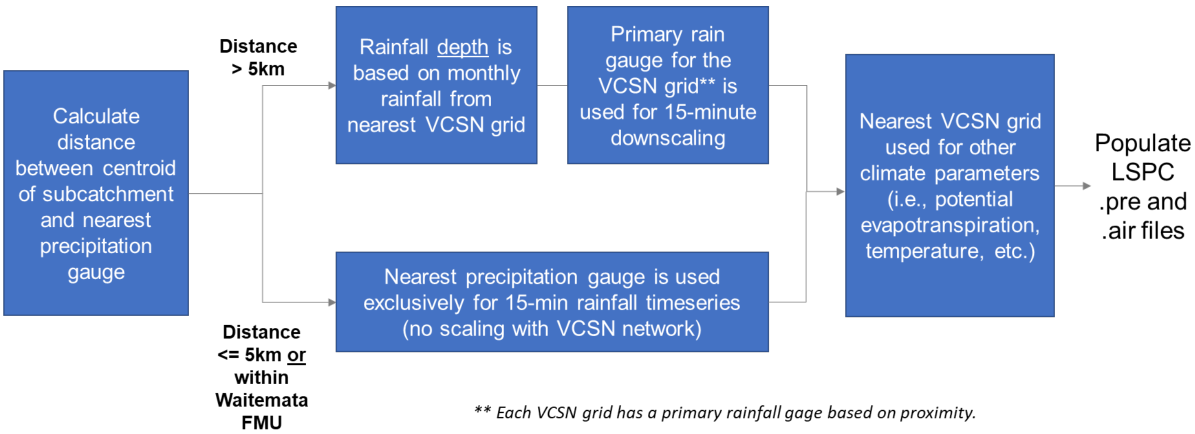


Figure 5-1. Methodology for assigning climate time series to model sub-catchments

5.4 Temporal Down-scaling

Primary precipitation gauges were assigned to all sub-catchments to facilitate disaggregation of VCSN monthly rainfall depths for all catchments >5km radius from a gauge and exclusive of the Waitemata watershed.

In the FWMT a 15-minute simulation time step was modelled. Consequently, daily VCSN data was "downscaled" to 15-minute increments. For rainfall, VCSN disaggregation involved:

- Aggregating the daily VCSN rainfall data into monthly rainfall totals,

- Scaling each of the assigned 15-minute primary gauge rainfall time series (**Section 6.3**) to proportion of month,
- Applying 15-minute primary gauged proportions to VCSN monthly totals.

Other climate inputs to LSPC include potential evapotranspiration, solar radiation, and min/max air temperature. Each was estimated with daily VCSN data disaggregated to a 15-minute time step. For both potential evapotranspiration (PET) and solar radiation, disaggregation procedures were based on the procedures of Hamon (1961) and (Hamon et al, 1954), respectively, both of which are presented in the BASINS User's manual (EPA, 2019).

6.0 Wastewater Network and Discharge

LSPC accounts for point source wastewater contributions to water quality and stormwater flows. For the FWMT, data on the location, type and volume of Auckland's wastewater network discharges or overflows was required. There are three sources of water to separated sewer networks:

1. Dry Weather Flow (DWF) – Domestic, Commercial, Schools and Tradeflows, etc. Dry weather flow refers to the wastewater flow in a sewer system during periods of dry weather with minimum infiltration.
2. Rainfall Derived Inflow and Infiltration (RDII) is the inflow of extraneous stormwater and groundwater to the wastewater network.
3. Ground Water Infiltration (GWI) is groundwater that enters the wastewater systems through cracks and/or leaks in the wastewater pipes.

Whilst a wastewater network typically has ample capacity to convey DWF to a wastewater treatment plant, in times of wet weather, this capacity can be exceeded, resulting in intermittent discharges of untreated dilute wastewater to the environment from designated relief points (Engineered Overflow Points, or EOPs) or at uncontrolled locations such as manholes and gully traps. Identifying wastewater contaminant loads to the environment from overflows requires an estimate of the wet weather overflow volumes and contribution of DWF within each overflow event.

6.1 Engineered Overflow Points

6.1.1 Overflow Type

Overflows from Watercare's wastewater network are characterised into three types as below:

- Type 1: Engineered Overflow Points (EOPs) associated with a wastewater pump station or storage facility
- Type 2: EOPs that provide a relief point on the network, including combined sewer overflows (CSOs)
- Type 3: Uncontrolled overflow points that usually discharge from a manhole, or in some cases gully traps, as the result of surcharging during wet weather.

Discharges from Type 1 and 2 EOPs are typically directed directly to watercourses, sometimes via the stormwater network, whilst in comparison, overflows from Type 3 locations usually discharge to land. These Type 3 overflows will occur onto impervious or permeable surfaces from where the spill may be collected by the stormwater system and conveyed to a nearby watercourse or to the coast. However, in many other cases the uncontrolled spills would be contained on the surface.

Additionally, in some cases, the modelled Type 3 overflows represent catchment overflows which occur upstream of the modelled network extents that may or may not actually occur or may have generally low confidence associated with the performance. For the above reasons there is high uncertainty associated with these outputs and therefore Type 3 overflows were recommended by HAL to be omitted from the LSPC model.

6.1.2 Overflow Quantity

Overflows used in configuring the FWMT were predicted using six of Watercare's strategic wastewater hydraulic models, operated by HAL (Appendix D). The six strategic models include:

- Warkworth (MIKE URBAN) – Strategic Management Area (SMA)
- Waiuku (ICM) – Satellite Township
- Army Bay (MIKE URBAN) – Strategic Management Area (SMA)
- Rosedale (MIKE URBAN) – Strategic Management Area (SMA)
- Pukekohe (ICM) – Strategic Management Area (SMA)
- Mangere (ICM) – Strategic Management Area (SMA)

The predicted wastewater overflow (WWOF) time-series outputs from these models provide the best source of data on type and quantity of overflows from the wastewater network. The six Watercare strategic models have varying build dates, model architecture and population dates, but span 60,174 ha of reticulated catchment and 440 EOPs in their representation of baseline wastewater discharges to freshwater receiving environments.

The six Watercare wastewater network models were run for simulated continuous Long-Term Series (LTS) from the 1st of July 2002 to 30th of June 2017. Results for all Type 1 and 2 Wastewater and Combined Sewer overflows were saved at 15-minute intervals and extracted to provide discharge and volume time series of overflow events (HAL, 2019). The input rainfall data is taken from the 11 State of the Environment (SoE) monitoring sites from the 01/07/2002 to the 30/06/2017 and this is a portion of the same hydrological data set that was used for LSPC. Evaporation data (PET) from the 01/07/2002 to the 30/06/2017 is taken from five SoE sites. Some of this environmental data was pre-processed into the required formats as outlined in the memos supporting each model (Appendix D).

6.1.3 Overflow Quality

LSPC utilises an estimate of untreated DWF overflowing from the wastewater network and entering the environment[2]. The proportion of DWF is dependent upon a number of factors and accordingly varies in each overflow event at each EOP.

To account for the amount of DWF in each wastewater overflow, a contaminant tracer associated with the DWF portion was included within the network models. This tracer was applied on a Population Equivalent (PE) basis. The models were set up so that each PE within the wastewater network generates an arbitrary tracer load into the wastewater network and the simulated output of that tracer for each overflow event exported at a 15-minute interval for subsequent post-processing and input into the LSPC. For the future (MPD) scenario, a simplified approach was used, where the amount of DWF in each overflow at a given timestep was estimated based upon the calculated dilution factor of the incoming flow and this dilution factor assumed to be consistent in the overflow volume to allow the DWF load to be estimated (Figure 6-1).

$$Q_{spill\_dwf} = Q_{dwf} \times \left(\frac{Q_{spill}}{Q_{in}}\right)$$

Q_{spill_dwf} = Residential Wastewater Discharge in Overflow
Q_{dwf} = Residential Wastewater Discharge
Q_{spill} = Wastewater Overflow Discharge
Q_{in} = Wastewater Total Discharge incoming to Overflow Structure

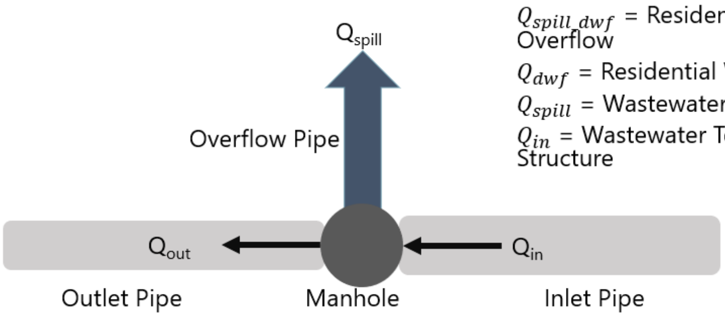


Figure 6-1. Schematic for calculation of discharge-ratio for DWF contaminant mass and discharged volume for EOP events in future wastewater time-series

6.2 Surface Water Takes

LSPC can account for effects of water abstraction from rivers, lakes and dams, generally known as water takes. Surface water takes in the Auckland region are either consented or permitted, depending on volumes and location. Detail on the LSPC configuration of data inputs available for surface water can be found in [FWMT Baseline C and P Report, Section 3.6.2].

[2] These estimates are limited to overflows due to capacity constraints, with overflows caused by operational issues such as blockages or power failures being inherently unpredictable and therefore not included in this analysis; these would also typically be minor in comparison.

6.2.1 Permitted Takes

Permitted takes are defined as either less than 5 or 20 cubic meters per day, depending on the aquifer or catchment (Auckland Council, 2016). For takes greater than these rates, resource consent is required.

Auckland Council has limited data available about permitted takes (e.g., volume, location, rate and timing). The presumption is that permitted takes are modest and predominantly rural (e.g., for domestic, livestock use and minor irrigation). Without further robust information, the assumption is made in the FWMT Stage 1 that permitted takes are negligible on-stream hydrology.

Further investigation over later FWMT stages is recommended to test this assumption.

6.2.2 Consented Takes

Data inputs available for consented takes are presented in Table 6-1. Auckland Council provided a consented water takes database as well as timeseries of meter readings for a portion of consented takes (Bradbury, 2018). The consented take database includes both current and past consented takes and usage is updated quarterly by consent holders through Auckland Council's Water Use Data Management System (WUDMS). Annual takes (June 1-May 31) greater than 40,000m^3 from rivers and 60,000m^3 from dams were extracted from the WUDMS as time-series. The latter represented 13% of the number of takes with issued consent for the region. However inclusion of additional takes smaller than 40,000m^3 had negligible impact on stream hydrology due to limited volume. Further stages of the FWMT may provide an opportunity to test this assumption or include more takes.

Table 6-1. Consented takes data inputs

FWMT Surface Water Takes					
Name	**Data Type**	**Source**	**Date Created**	**Year Represented**	**Percentage Utilised**
Consented Water Takes	Point and table	Auckland Council	2018	1950 - 2017	13*
Metered Takes Readings	Time series	Auckland Council	2018	2006 - 2017	100
Watercare Water Takes and Releases	Time series	Watercare	2018	2001 - 2017	100

*Percentage of issued status consents as at 2018

Auckland Council’s consent data was compiled from resource consenting information and monitoring data. Issued takes from the period July 2002 to July 2017 are included. The water takes data included municipal supplies, large irrigation, stock watering and industrial requirements. Whilst the data provided by Auckland Council included consented bores, only dam, river and lake takes were used in the LSPC build [FWMT Baseline C and P Report, Section 3.6].

Metered take and release data spanning a period from 1 July 2001 to 30 June 2017 were supplied by Watercare for municipal takes from the following dams: Cosseys Dam, Wairoa Dam, Upper Huia Dam, Upper Niho Dam, Lower Huia Dam, Lower Niho Dam, Waitakere Dam, Hays Creek Dam, Mangakura Dam 1 and Mangakura Dam (Utting 2018).

Figure 6-2 presents the coverage of consented water take utilised from Auckland Council and Watercare consented take data.

For consented takes without time-series, available information was insufficient to warrant inclusion with little change in uncertainty (e.g., actual vs consented withdrawal rate, seasonality and timing of take varied).

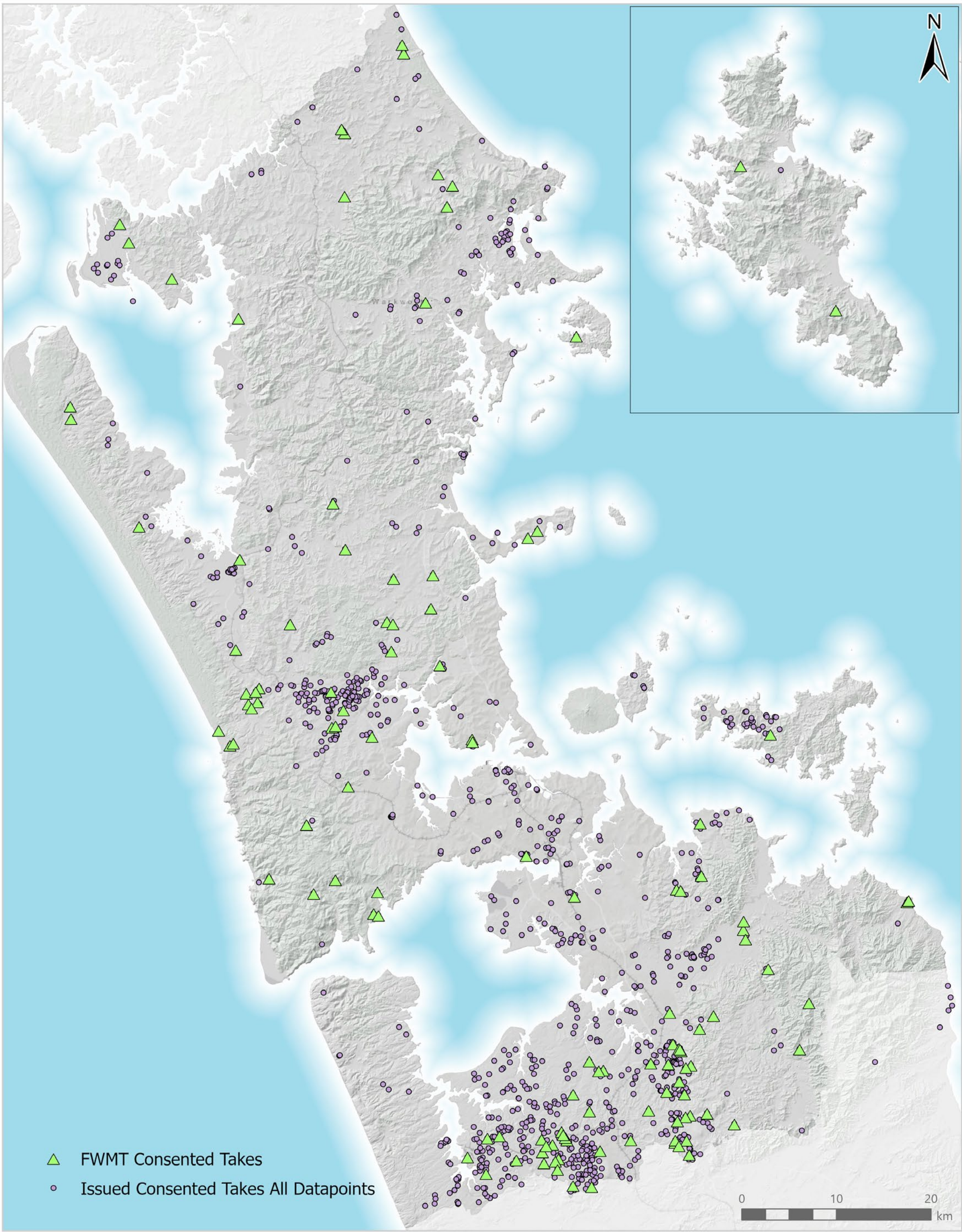


Figure 6-2. FWMT water takes and coverage of all issued consented takes

7.0 Impoundments

7.1 Surface Ponds

LSPC can represent the impact of artificial ponds and wetlands by adjustment of HRU runoff parameters. Typically, SUSTAIN is used to model the impact of structural devices explicitly where runoff is routed through devices, and contaminant processes are modelled. In the Stage 1 development of the FWMT, limited data was available for structural devices and therefore these were not modelled in the baseline LSPC configuration. Ponds and constructed wetlands were drawn from the Research and Evaluation Unit Auckland Wetlands Layer (AC, 2018;Appendix A, 8.18). Configuration and parameterisation of LSPC for pond representation is detailed in [FWMT Baseline C and P Report, Section 3.8.7].

A total of 602 Ponds and Wetlands and 1,994 farm ponds were incorporated from Auckland Council's Research and Evaluation Unit's Auckland Wetland Layer (AWL). Figure 7-1 presents the data coverage in the Auckland region.

Auckland Council's Stormwater Treatment Facilities layer (Appendix A, 7.1), extracted in 2017, included 757 water quality and detention facility footprints. Limited attribute information on drainage catchment, capacity, dimensions, condition, status, and treatment efficiencies was available and so attribution was not incorporated in the LSPC input dataset. These stormwater treatment facilities will be incorporated in explicit representation through scenario modelling.

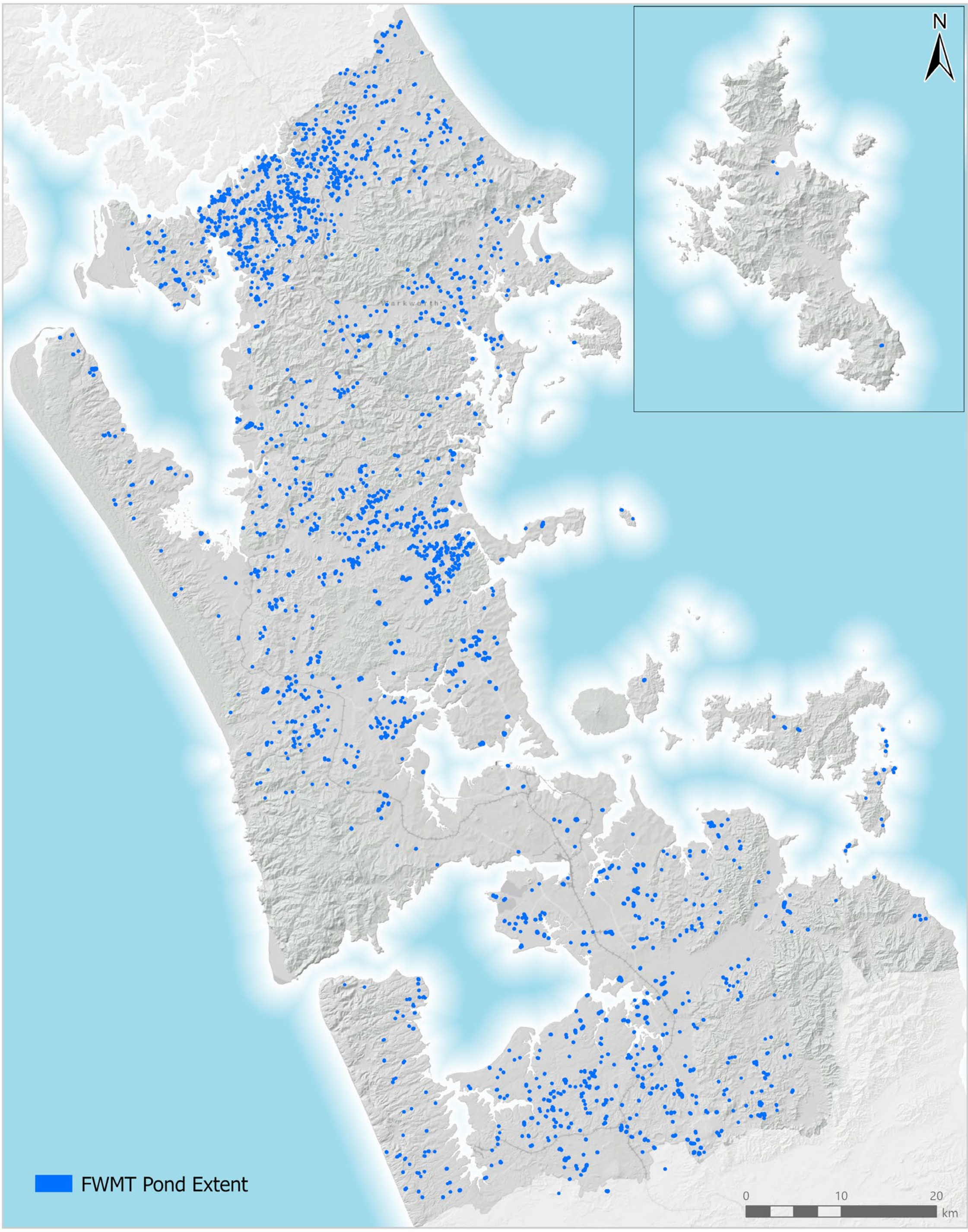


Figure 7-1. FWMT Pond locations

7.2 Reservoirs and Lakes

Data for ten public water supply reservoirs (dams) were extracted from Auckland Council Wetland Layer (Appendix A; 7.3). Lake footprints were represented by seven (7) boundary features provided by Auckland Council (2003/2004). Data sources utilised are listed in Table 7-1. Coverage of reservoirs and lakes is presented in Figure 7-2. Configuration of water quality simulation for impoundments within LSPC is found in [FWMT Baseline C and P report, Section 3.7.1].

Note, an additional FWMT Lakes Module was developed to assess steady state outcomes across 16 dune lakes and reported separately in [FWMT Baseline State Lakes Report].

Table 7-1. Reservoirs and Dams Lakes data inputs

FWMT Reservoirs and Dams				
Name	**Data Type**	**Source**	**Date Created**	**Year Represented**
Auckland Wetland Layer	Polygon	Research and Evaluation Unit, Auckland Council	2016	2010/2011
Major Lakes	Polygon	Auckland Council	2003/2004	2003/2004

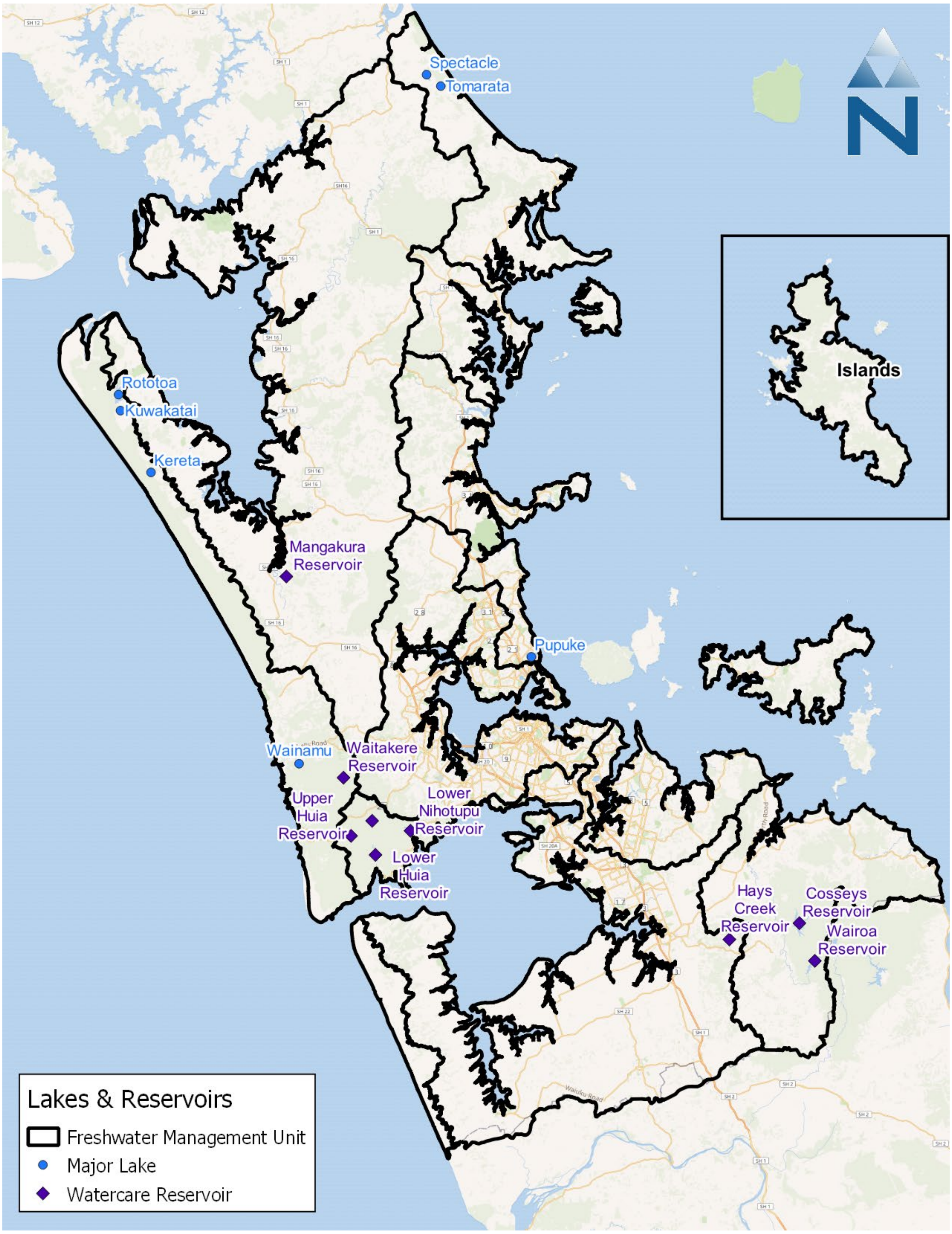


Figure 7-2. Map of major lakes and reservoirs across the Auckland region

8.0 Hydrological Response Units

The core hydrologic modelling unit within LSPC is the Hydrologic Response Unit (HRU). HRUs are a unique representation of factors influencing the generation of runoff/interflow/active groundwater and contaminants from land surfaces. HRU factors include slope, hydrologic soil group, land cover and impact (intensity of land use). Numerous source data were compiled and synthesised to derive the HRU inputs required to configure a regionwide raster with a resolution of 2x2m. Configuration of the HRU raster is described in the [FWMT Baseline C and P Report, Section 3.8].

8.1 Slope

Slope classes were assigned to the HRU raster from Auckland Council's digital elevation model (DEM) (Appendix A; 8.1). Slope was created using ArcMap's Slope tool (Spatial Analyst) on the DEM, which creates a slope raster in 2x2m resolution. Reclassification of slope for HRU rasterization is detailed in [FWMT Baseline C and P Report, Section 3.8.2].

8.2 Hydrologic Soil Groups

Hydrological Soil Groups (HSGs) are an important factor governing hydrological responses of HRUs to varying climate within the LSPC manual. The U.S. Natural Resource Conservation Service National Engineering Handbook (NRCS, 1997) classifies HSGs into four soil classes (A to D) based on infiltration characteristics as presented in Table 8-1. A fifth HSG of A+ was classified for the FWMT to account for volcanic geology in the region.

HSGs represent the influence of soil infiltration characteristics on the water balance, building on prior application in Auckland Regional Council TP108 (Auckland Council, 1999). TP108 utilises HSGs along with land cover, soil treatment, rainfall and antecedent weather in determining extreme event runoff across the Auckland region.

Table 8-1. Hydrologic soil group typologies

HSG	Drainage description	Infiltration Rate (mm/hr)*	Soil Type	Description
A+	Very high infiltration	12.7 – 25.3	Volcanic Geology, medium to high classes soakage areas	Deep, excessively drained sands or gravels with a high rate of water transmission.
A	High infiltration	7.6 – 12.7	Sand, Loamy Sand, or Sandy Loam	Deep, well to excessively drained sands or gravels with a high rate of water transmission.

HSG	Drainage description	Infiltration Rate (mm/hr)*	Soil Type	Description
B	Moderate infiltration	3.8 – 7.6	Silt, Silt Loam or Loam	Moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures
C	Low infiltration	1.3 – 3.8	Sandy Clay Loam	Soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Very low infiltration	0.0 – 1.3	Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay, or Clay	Clay soils with a high swelling potential, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

* Estimated infiltration rate bands informed by the ARC TP108 (Auckland Council, 1999).

HSGs were assigned throughout the Auckland region based on a range of sources and attributes outlined in Table 8-2. Regional coverage of the various sources is presented in Figure 8-1. Assumptions used to classify HSGs are detailed in following sections by preferential order (dominant sources of HSG information first). A finalised, regional HSG layer was configured as a 2x2m HSG raster for the Auckland region as detailed in [FWMT Baseline Configuration and Performance Report, 3.8.6].

Table 8-2. Hydrological Soil Group data inputs for the FWMT HSG layer. Note lower priority numbers are used over higher where two or more datasets overlap

Hierarchy	Name	Description	Source	Date Created	Year Represented	HSG
1	Soakage Areas	Medium to high classed soakage areas	Auckland Council	Not provided	2013	A+
2	Volcanic Aquifers	Boundaries of aquifers classified as volcanic for the Auckland region. Queried for Mt Wellington, Western Springs, Auckland Isthmus, Wiri, Onehunga, Mt Richmond, and Franklin	GNS Science	Not provided	Unknown	A+
3	GNS Geology	Allochthonous rocks north of Auckland	GNS Science	2013	1909 - 2013	D
4	Northern Allochthon	Allochthonous rocks north of Auckland identified based on a desktop survey.	Tonkin and Taylor	2004	Unknown	D

Hierarchy	Name	Description	Source	Date Created	Year Represented	HSG
5	Fundamental Soils Layer (FSL)	A combination of the New Zealand Land Resource Inventory (NZLRI) and National Soils Database (NSD). FSL queried for 'Urban Areas'	Landcare Research	2014	1959 - 2000	C
6	Soil Drainage Characteristics	Based on the NZ Fundamental Soils Layer (NZLRI), the layer depicts Auckland region's soil types, grouped according to available information about their drainage properties.	Landcare Research, modified by Auckland Council	2014	1960 - 2000	Appendix C
7	Soil-Map Database (S-Map): Hingaia Stream Catchment	This layer represents the NZSC soil order for S-map attributed with HSG from S-Map Fact Sheets for Hingaia soils	Landcare Research	Not provided	2018	Appendix C

* Soil series dependent. Appendix C provides the HSG mapping tables for specific soil series.

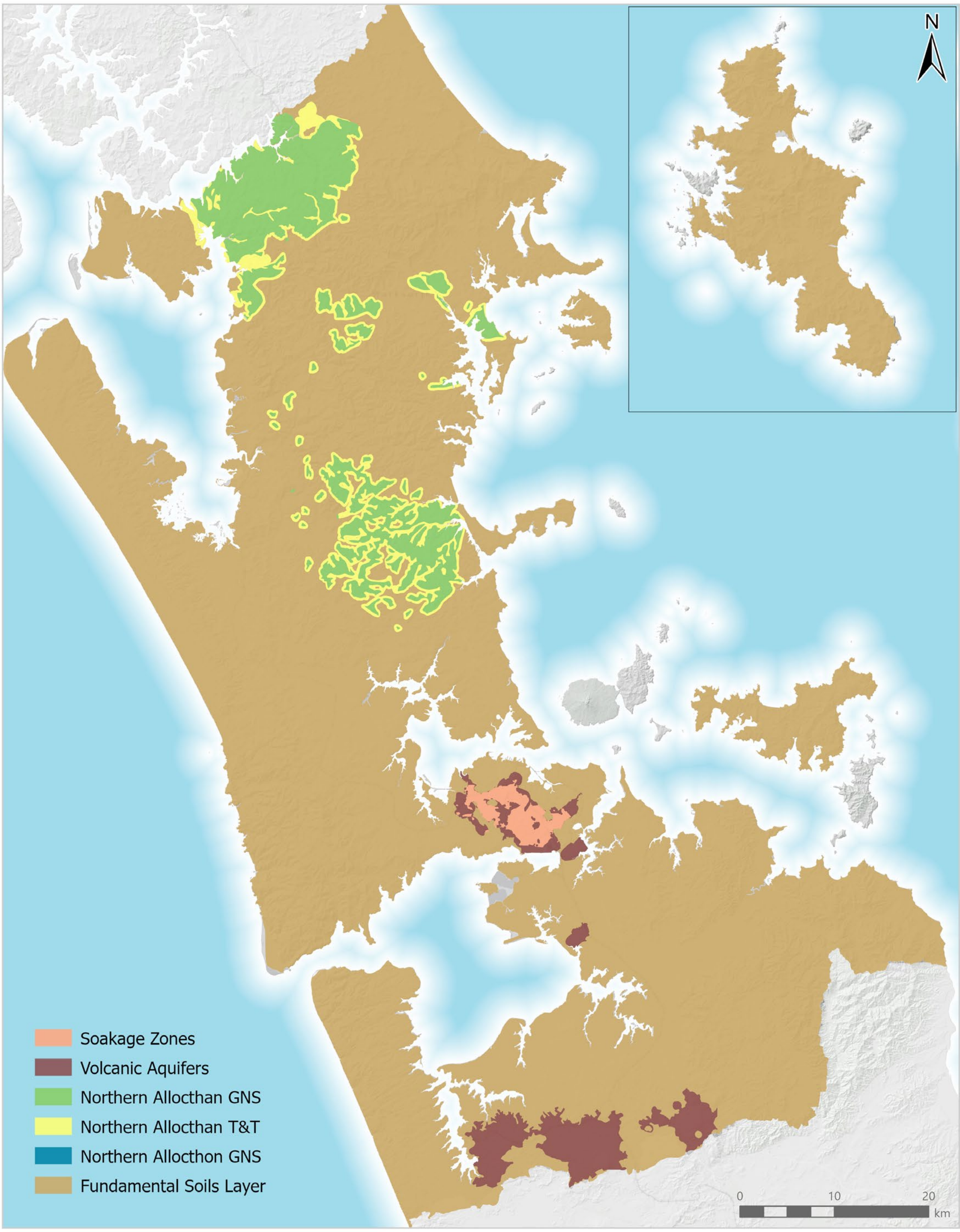


Figure 8-1. Data inputs used to derive the FWMT HSG layer

8.2.1 Volcanic Aquifers and Soakage Zones

Data representing volcanic aquifers and soakage zones are spatially well-defined with well-known physical properties. The Auckland isthmus is characterised by several fractured basalt terranes, which were mapped as part of the GNS study of the area's volcanic aquifers (Edbrooke, 2001). Some basalt areas in Auckland are also used to accommodate soakage, the disposal of stormwater to underlying aquifer, due to their infiltrative capacity. Soakage areas are mapped by AC TR2013/040 (Appendix A, 8.4). The following aquifer zones have been assigned a hydrologic soil group of A+ to account for the rapidly draining volcanic soils in these areas;

- Mt Wellington Volcanic Aquifer
- Western Springs Volcanic Aquifer
- Auckland Isthmus Volcanic Aquifer
- Wiri Volcanic Aquifer
- Onehunga Volcanic Aquifer
- Mt Richmond Volcanic Aquifer
- Franklin Volcanic Aquifer
- Other Areas shown with Moderate to Good Soakage

8.2.2 Northern Allochthon

Data from GNS (Appendix A, 8.5) and Tonkin and Taylor (Appendix A, 8.6) were incorporated to identify areas underlain by the Northern Allochthon. The Northern Allochthon rocks are characterised as weak, highly sheared mudstones, siltstones, sandstones and limestones with low permeability with northern allochthon rocks forming an aquitard in most areas (Balance and Spörli, 1979). All areas underlain by the Northern Allochthon were therefore classified HSG-D.

8.2.3 Fundamental Soils Layer

Remaining areas required additional analysis to assign HSGs using the Fundamental Soils Layer (Appendix A, 8.2). The FSL is a single spatial layer with national coverage, supplemented with soil survey layers of local coverage.

Areas characterised as ‘Urban’ in FSL data did not have any physical characteristics assigned. Factors that influence urban soils capacity to mitigate stormwater run-off include reduction in soil water storage, permeability, and topsoil infiltration rate bought about by soil compaction or construction disturbances. HSG-C was applied to urban areas as recommended by TR2009/073 (Simcock, 2009).

For remaining areas, Auckland Council’s *Soil Drainage Characteristics* layer (Appendix A, 8.2) was assessed. This was developed from the FSL and assigned drainage characteristics using the four FSL factors below to place soil series in one of ten drainage categories (1a – 4b), as presented in Table 8-3.

1. Permeability class of topsoil and subsoil (extreme to high, moderate, slow to very slow),
2. Depth to regolith or bedrock (shallow, intermediate, deep),

3. Position of water table (rises to topsoil or surface, rises into subsoil, stays in regolith or bedrock),
4. Interface with underlying regolith or bedrock (porous, fissured, impervious but fractured, impervious and massive).

NRCS (1997) bases HSGs on the principle that soils can be expected to display similar runoff characteristics if they are similar in depth to a restrictive layer or water table, intake and transmission of water, texture, structure, and degree of swelling (NCRS, 1997). A comparative assessment was performed to best match the available soil drainage characteristics (1a – 4b) descriptions to HSGs, with an emphasis on characteristics that would impact water infiltration and transmission. Table 8-4 presents the HSG assigned by drainage and soil type. Some soil series within 2d, 4a and 4b drainage types were modified based on expert judgement. Complete HSG mapping to each soil series is presented in Appendix C.

Table 8-3. Drainage characteristics of soils on different rock types in the Auckland region from Soil Drainage Characteristics layer (Auckland Council, 2018) and mapped HSGs

Soil Type	Drainage code	Drainage Description	HSG
Sand soils	1a	Free to slow-draining	A
	1b	With imperfect to impeded drainage	B
Volcanic soils	2a	Free to slow-draining, on basaltic ash or basalt	A+
	2b	Free to slow-draining, on water laid basaltic or rhyolitic ash	B
	2c	Free to slow-draining, on thin basaltic or rhyolitic ash, over other rocks	B
	2d	With imperfect to impeded drainage, weathered from basalt, dolerite or andesite	B/C*
Clays and silts weathered from sedimentary rocks	3a	Free to slow-draining	B
	3b	With imperfect to impeded drainage	C
Alluvial clays, silts and peats	4a	Free to slow-draining	B/C*
	4b	With imperfect to impeded drainage	D/C*

8.2.4 S-Map

S-Map is an online soil database and informatics system that delivers soil maps and factsheets based on soil descriptions from the New Zealand Soil description handbook (Milne et al., 1995) and the New Zealand soil classification (Hewitt, 2010; Webb and Lilburne, 2011).

S-Map determines HSGs by utilising information based on soil texture, permeability, depth class and drainage. S-Map data covers ~20% of the Auckland regional extent. Only Karaka and Patumahoe related soils in parts of the Hangaia catchment have locally sourced descriptions in the fact sheets; S-Map HSG classifications for these soil types were used as a validation test of corresponding soil series information in the FSL.

8.3 Land Cover and Use

HRUs incorporate land cover and use information to discriminate hydrologic and contaminant responses.

The Auckland region was divided into impervious (roof, road, paved surfaces) and pervious (forest, farm, grassland) surfaces. Data (2008-2018) of national, regional and local extent refined the land cover raster.

Land use types were assigned through the application of impact factors, a classification of the intensity of human operation on land. The development of HRU land impact factors is detailed in [FWMT Baseline Calibration and Performance Report, Section 3.8.5]. Stage 1 LSPC land cover and use types vary in resolution and age of supporting data.

The FWMT baseline land cover and use layer is a continuous layer. Due to the discrepancies in resolution of datasets, land cover and use was depicted at parcel-scale resolution for rural areas and sub-parcel scale for urban areas (e.g., where more resolved information was available).

The FWMT baseline urban extent includes all areas within the Auckland Rural/Urban Boundary (RUB) (Appendix A, 8.8) but excluding Future Urban Zones (FUZ). Analysis of aerial imagery (Appendix A, 8.9) suggested the FUZ was predominantly of rural character and omitted from the FWMT baseline urban extent. The FWMT baseline rural extent includes FUZ and all areas not classified in the RUB.

Table 8-4 presents a summary of the sources of land use and land cover data used to develop the classes within the HRU raster layer for the Stage 1 FWMT.

Table 8-4. Summary of input datasets describing land use and land cover for the FWMT

Type	Data	Description	Data Source	Data type	Date represented
Cover	Developed Impervious	Impervious surfaces mapped for urban areas, expansion areas and some rural catchments draining to urban	Auckland Regional Council (ARC)	Polygon feature class	2007/2008
Cover	Building Outlines	Roof outline of buildings	Land Information New Zealand: LINZ Data Service	Polygon feature class	2008/10
Cover	Parcel boundaries	Primary Parcel boundaries	LINZ	Polygon feature class	2017
Cover	Roads	Road centerlines (rural) and road corridor (urban)	LINZ	Polyline feature class	2017
Cover	Land cover database (LCBD4)	Classification of land cover	Landcare Research	Polygon feature class	2012/13
Cover	Vegetation Height	Regional Li2006/10 LiDAR	Auckland Council (AC)	Raster	2006-2010
Impact	Auckland Unitary Plan Base Zones	Zoning information	AC	Polygon feature class	2016
Impact	Agribase	Land use	Agribase	Polygon feature class	2015/16
		Animal counts			2015/16
Impact	District Valuation Roll (DVR)	Construction material of roofs	AC	CSV	2018
Impact	Traffic Data	Annual average daily traffic	RAMM Software Ltd (RAMM)	Polyline feature class	2017

8.3.1 Impervious Surfaces

The FWMT impervious surface extent assigns each 2x2m in the region a surface type which distinguishes building outlines, roads and paved surfaces, and a land use which distinguishes roof material, road intensity, paved zone type. Figure 8-2 presents an example sub-catchment with sub-parcel resolution for impervious cover.

Figure 8-2. Example of impervious land cover and impact classifications for the FWMT

Landcare Research mapped impervious surface cover for the urban areas (the Auckland metropolitan urban limit [MUL], urban expansion areas, and associated catchments including Territorial Local Authority boundaries) and some rural areas within the Auckland region for Auckland Regional Council (ARC) in 2007/2008 (Appendix A, 8.10) (Pairman et al., 2009).

The ARC (2007/2008) impervious surface layer was used as the base impervious layer for the FWMT and was classified into impervious land cover and impact (intensity) types as summarised in Table 8-5. Data sources used to develop the FWMT Baseline impervious layer was exclusive (i.e., did not overlap between urban cover types).

Table 8-5. FWMT impervious HRU land cover, impact (intensity) classes and related data sources

Impervious Land Cover	Land Cover Data Source	Impervious Impact	Impact Data Source
Road	Urban: Impervious surface layer (Auckland Regional Council, 2008) Primary Parcel boundaries (LINZ 2017) Rural: Road centerlines (LINZ, 2017)	1: Vehicles Per Day ≤ 1,000	Annual average daily traffic [AADT] (RAMM Software Ltd, 2017)
		2: Vehicles per Day ≤ 5,000	
		3: Vehicles per Day ≤ 20,000	
		4: Vehicles per Day ≤ 50,000	
		5: Vehicles per Day ≤ 100,000	
		6: Vehicles per Day > 100,000	
Roof	Building Outlines (LINZ, 2008/10)	1: Concrete/Tile/Iron, Painted	District Valuation Roll (DVR) roof material (Auckland Council, 2018) Roof runoff study (Kingett Mitchell Ltd., 2003)
		2: Iron, Zn-Al alloy coated	
		3: Iron, Unpainted	
Paved	Impervious surface layer (Auckland Regional Council, 2008)	Commercial	Auckland Unitary Plan Base Zones (Auckland Council, 2016) Hauraki Gulf Island District Plan (Auckland Council, 2013)
		Industrial	
		Residential	
Lakes/Reservoirs/Ponds	Auckland Wetland Layer (Auckland Council, 2016), Stormwater Treatment Facilities (Auckland Council, 2017), Auckland Unitary Plan Base Zones (Auckland Council, 2016)	*No impact assigned*	

8.3.1.1 Road

The extent of FWMT urban road were determined from the national LINZ primary parcels layer (2017; 8.10). Where the road corridor is identified, the width extent includes all area between opposite property boundaries, including berms (footpaths and pervious land cover). The impervious surface layer (Appendix A; 8.10) was used to delineate impervious from pervious area within the road corridor.

The impervious dataset is largely incomplete for rural areas. To represent rural roads, LINZ's national road centreline layer (Appendix A, 8.12) was used to provide the most spatially accurate polyline data for rural roads. To determine impervious extent for rural areas, selected road segment samples with varying lane counts were measured against aerial imagery. The rural road centrelines were buffered to give a total road width according to the number of lanes attributed by LINZ, as presented in Table 8-6.

Since gravel roads experience some hydrological runoff processes from surface water inputs, all road segments that were classified as unsealed were assigned to pervious HRUs.

Table 8-6. Lane numbers and associated total road width for rural roads

Lane Count	Total road width (m)
1	6
2	8
3	15
4, 5, 6	20

Transportation facilities have the potential to contribute a significant contaminant loading. As previously adopted in New Zealand contaminant load modelling (C-Calm), heavily trafficked roads typically produce higher contaminant loads compared with low trafficked roads. FWMT road impact was accordingly grounded in daily traffic counts, (vehicles per day [VPD]) measured as annual daily averages. Annual Average Daily Traffic (AADT) data (Appendix A, 8.14) provided a coarse polyline dataset of daily traffic counts calculated as total volume of vehicle traffic of a road segment for a year divided by 365 days. Traffic counts were attributed to the 'road' impervious delineated for rural and urban. Road intersection configurations were assigned a total VPD equal to the highest plus the lowest of the approaching roads as rationalised through GIS trials. Additional information on impact factors for FWMT roads can be found within [FWMT Baseline C and P report, Section 3.8.5.2].

8.3.1.2 Roof

The extent of roofs for the development of the FWMT was determined from LINZ data (Appendix A, 8.15) and assumed to correspond to building outlines, 2D representations of relatively permanent walled and roof construction[3].

LINZ building outlines classification was done in 2009 using 2007/2008 orthophotography supplemented by 2008/2009 and 2006 aerial imagery. LINZ data was updated in 2012 to include building outlines for North Shore City using 2010/2011 aerial imagery (Golubiewski, Lawrence and Fredrickson, 2019). The LINZ' building outline data covers 14% of urban Auckland with little information for rural Auckland.

Roof material classifications were assigned using District Valuation Roll (DVR) (Appendix A, 8.16) which assigns properties with a dominant construction material (Table 8-7). The DVR table was georeferenced using addresses and lot numbers spatially joined to NZ primary parcel polygons (Appendix A, 8.10). Material was allocated to FWMT roof geometries through intersection with building outlines. Multiple roofs on the same property were assigned the same construction material; a single roofing material is assigned per property title within the DVR.

Table 8-7. District Valuation Roll roof material code and description

DVR Roof Type Code	Roof material description
A	Aluminium, including aluminium-coated timber
B	Brick, including clay and concrete bricks
C	Concrete, including reinforced block and precast slab
F	Fibrous cement or asbestos, including flat or corrugated sheets and sidings
G	Glass
I	Iron, including steel and corrugated long-run
M	All forms of fabric, bitumen, and butyl rubber
P	Plastic
R	Roughcast, including stucco and all modern texture coat finishes
S	Stone
T	Tiles, including all materials with a tile profile
W	Wood in all forms, including treated plywood and compressed wood products
X	Mixture of materials without a predominant material, or a material not included above

The DVR roof types were aggregated into 3 categories for the FWMT build and their spatial distribution is presented in Table 8-8. Additional information on impact factors for roofs can be found within [FWMT Baseline C and P report, Section 3.8.5.1].

[3] Not to be synonymous with building footprints, which represent where a building touches the ground,

Table 8-8. Material splits and region coverage percent

Material	Data Code	%
Iron	I	47
Tile/Other	T, X, F, M, C, S, G, W, B	53

8.3.1.3 Paved

The FWMT paved surface extent was derived by eliminating FWMT roofs and road geometries from the Auckland Council impervious surface layer (Appendix A, 8.9).

The CLM was configured to vary paved surface yields by land use (ARC, 2010a). The same approach is adopted in the FWMT where impact of paved surfaces varied by land use type: residential, commercial or industrial, using Auckland Council's Unitary Base Zone (AUP) layer and the Hauraki Gulf Island District Plan (HGI DP). The FWMT paved surface zoning resolution is presented in Table 8-9.

AUP and HGI DP zones were aggregated to enable a simplified set of contaminants loading assumptions to paved surfaces, guided by Auckland Council's own grouping within the AUP and aerial imagery (Appendix A, 8.13). Paved surfaces within Future Urban Zones were assigned residential impact for baseline modelling.

Table 8-9. Paved surface zoning class aggregation from Auckland Unitary Plan Base Zone and Hauraki Gulf Island District Plan land use mapping

FWMT Aggregated Zone	AUP and HGI DP Zone
Commercial	Business - Business Park Zone
	Business - City Centre Zone
	Business - General Business Zone
	Business - Local Centre Zone
	Business - Metropolitan Centre Zone
	Business - Mixed Use Zone
	Business - Neighbourhood Centre Zone
	Business - Town Centre Zone
	Coastal - Ferry Terminal Zone
	Open Space - Civic Spaces Zone
	Open Space - Community Zone
	Special Purpose - Healthcare Facility and Hospital Zone
	Special Purpose - Major Recreation Facility Zone
	Special Purpose - Maori Purpose Zone
	Special Purpose - School Zone
	Special Purpose - Tertiary Education Zone
Industrial	Business - Heavy Industry Zone
	Business - Light Industry Zone
	Coastal - Defense Zone
	Coastal - Minor Port Zone
	HGI Inner: Industrial

FWMT Aggregated Zone	AUP and HGI DP Zone
	Special Purpose - Airports and Airfields Zone
	Special Purpose - Quarry Zone
Residential	Coastal - Coastal Transition Zone
	Coastal - General Coastal Marine Zone
	Coastal - Marina Zone
	Coastal - Mooring Zone
	Green Infrastructure Corridor
	HGI: alluvial flats
	HGI: bush residential
	HGI: coastal cliffs
	HGI: conservation
	HGI: dune systems and sand flats
	HGI: ecology and landscape
	HGI: forest and bush areas
	HGI: gateway
	HGI: landscape amenity
	HGI: productive land
	HGI: rakino amenity
	HGI: rangihoua park
	HGI: regenerating slopes
	HGI: rotoroa
	HGI: western landscape
	HGI: wetland systems
	HGI: wharf
	HGI: quarry
	Open Space - Conservation Zone
	Open Space - Informal Recreation Zone
	Open Space - Sport and Active Recreation Zone
	Rural - Rural Coastal Zone
	Rural - Rural Conservation Zone
	Rural - Rural Production Zone
	Rural - Waitakere Foothills Zone
	Rural - Waitakere Ranges Zone
	Special Purpose - Cemetery Zone
	Strategic Transport Corridor Zone
	Water
	Future Urban Zone
	HGI: local shops
	HGI: marae
	HGI: oneroa village
	HGI: ostend village
	HGI: recreation and community facilities
	HGI: traditional residential

FWMT Aggregated Zone	AUP and HGI DP Zone
	HGI: visitor facilities
	Residential - Large Lot Zone
	Residential - Mixed Housing Suburban Zone
	Residential - Mixed Housing Urban Zone
	Residential - Rural and Coastal Settlement Zone
	Residential - Single House Zone
	Residential - Terrace Housing and Apartment Building Zone
	Rural - Countryside Living Zone
	Rural - Mixed Rural Zone

8.3.1.4 Water

Auckland Council's Auckland Wetland Layer (AWL) (Appendix A, 8.18) was used as a base layer for water classification in the FWMT. The AWL is regional in extent. Only wetlands with inland waterbody (or open water wetland) typology were represented as FWMT waterbody. AWL wetland features classified as riverine, lacustrine, palustrine or estuarine were not classified as FWMT waterbodies to ensure their modification of hydrological runoff processes within the FWMT.

The AC Stormwater Treatment Facilities Layer (Appendix A, 8.19) features of "In Service Wetlands" and "Wet Detention Ponds", and "Water" areas in the AUP Zoning Layer (Appendix A, 8.9) were merged with the AWL for the FWMT.

8.3.2 Pervious

Pervious land cover extent for the FWMT was defined as the land cover that remained after FWMT development areas (Roofs, Roads, Paved Surfaces and Waterbody) were derived. All pervious land within the urban extent was classified as "open space". Open space had a single set of parameters not differentiated by impact factors.

The FWMT vegetation layer (Morphum, 2018;Appendix A, 8.20) was developed to further refine pervious areas into classes of vegetation height. The layer was derived by extracting the non-ground LiDAR (2006-2010) and trimming out building outlines. Both rural and urban pervious areas were defined by height: >50 cm, <50 cm or non-vegetated using the FWMT vegetation layer 2x2m overlay. Assumptions used to incorporate vegetation height into the HRU raster configuration are detailed in [FWMT Baseline C and P Report, Section 3.8.3]. Table 8-10 presents how the land use and vegetation data were reclassified into more general HRU categories. As an example: if idle/unclassified land had an associated vegetation layer that was >50 cm, it was reclassified to forest. Table 8-10 includes the land use base layer categories, whose development is discussed below.

Three land classification datasets (Figure 8-3) were used to derive rural pervious land cover extent and the baselayer categories. These datasets were: Agribase (2016; Appendix A, 8.21); Land Cover Data Base (LCBD) version 4.1 (Landcare Research, 2014; Appendix A, 8.22); and LINZ Topographic forestry dataset (Appendix A, 8.23). Within AgriBase, the Department of Conservation (DOC) owns the largest proportion of land, dispersed over Auckland region. Visual inspection of aerial imagery demonstrated DOC polygons to be frequently misclassified as sheep and beef farming. To mitigate this misclassification, the LINZ Topographic forestry dataset (Appendix A, 8.23) was intersected with DOC owned Agribase features, replacing Agribase pastoral information and land cover updated to exotic or native forest (e.g., using LINZ class).

Agribase (2016) data was prioritised over LCDB4.1 for assigning rural pervious HRUs in the FWMT, offering quantitative information on livestock variety and density with a resolution loosely based on aggregated 2016 property parcel geometry. Where Agribase (2016) data was missing, rural HRUs were then assigned with LCBD4.1, offering complete regional coverage in four pervious land cover types: pasture, horticulture, forestry and open space. Appendix E presents impact assignments based on land use type. These assignments were used when no overlapping Agribase data was available and are represented under category 2 in Table 8-11. When Agribase data was available, that information took precedence, represented as categories 1 and 3 in Table 8-11.

AgriBase (2016) provides two land use components that were utilised to derive FWMT pervious impact for rural areas.

1. **Rural land use sector metrics** – reported area of farm activity per parcel such as grazing, arable, annual and perennial crop land etc.
2. **Animal metrics** – quantitative information on livestock variety and density – numbers of animals by stock class e.g. numbers of sheep, beef, deer, chickens etc. used to categorise grazing intensity on a per hectare basis. A variety of species per property may exist.

These data were used to classify levels of contaminant load impact and further refine HRUs. Development of HRU impact factors is detailed in [FWMT Baseline C and P Report, Section 3.8.5].

A supplementary dairy herd record (Auckland Council, 2018; Appendix A, 8.24) maintained by Auckland Council was used to refine herd numbers in Agribase (2016). Approximate herd sizes with corresponding consent addresses were supplied in 2018 and these data were checked against AgriBase (2016) animal counts for the same farm (Appendix A, 8.24). The greater stocking rate of either Agribase (2016) or AC (2018) was used to estimate pastoral stocking rates where the two shared addresses (applying to all Agribase parcels listed against the address). It was found that some Agribase parcels were multipart polygons, whereby spatially discrete features were attributed with the same farm data, and total pastural livestock densities and grazing, forestry and horticulture hectares – effectively double counting numbers. To resolve this, all multi-part properties were split and resulting single-part parcels received a proportion of land use ha and/or animal numbers based on parcel size as presented in Figure 8-4.

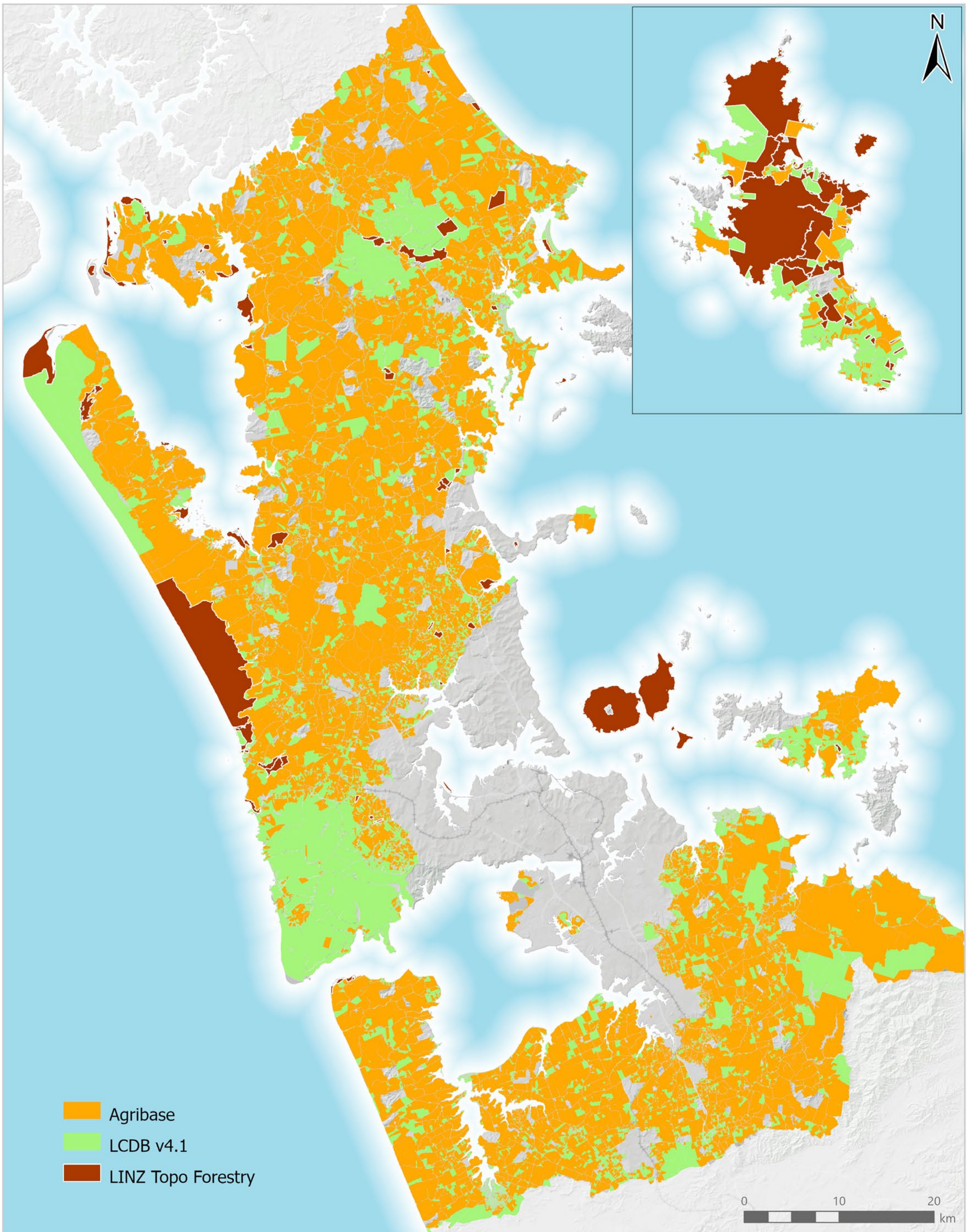


Figure 8-3. FWMT rural land cover data input coverage

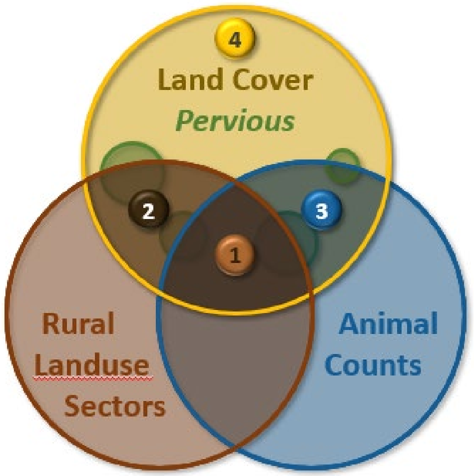
Table 8-10. Reclassification of Agribase/LCBD/Vegetation information into the HRU land use categories

Agribase	LCDB4	Proposed Land Use Type Name	Vegetation Height (> 50cm, < 50cm)	HRU Re-classification
Estuary, Mangrove	River, Lake or Pond, Estuarine Open Water, Mangrove, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation	Estuary and marine	All	Forest
	Built-up Area (settlement), Transport Infrastructure	Pervious	> 50 cm	Forest
Tourism (ie camping ground, motel)		Tourism areas	> 50 cm	Forest
Not farmed (ie idle land or non-farm use), New record - unconfirmed farm type		Idle/unclassed	> 50 cm	Forest
Forestry	Deciduous Hardwoods Forest - Harvested Exotic Forest	Exotic forest/plantations	> 50 cm	Forest
Native bush	Broadleaved Indigenous Hardwoods Manuka and/or Kanuka Indigenous Forest	Native forest	All	Forest
	Built-up Area (settlement), Transport Infrastructure	Pervious	< 50 cm	Open Space
Fodder		Ungrazed high producing exotic pasture	All	Open Space
	Flaxland	Native grassland and conservation	All	Open Space
	Mixed Exotic Shrubland, Gorse and/or Broom, Urban Parkland/Open Space, High Producing Exotic Grassland, Low	Exotic Grassland	All	Open Space

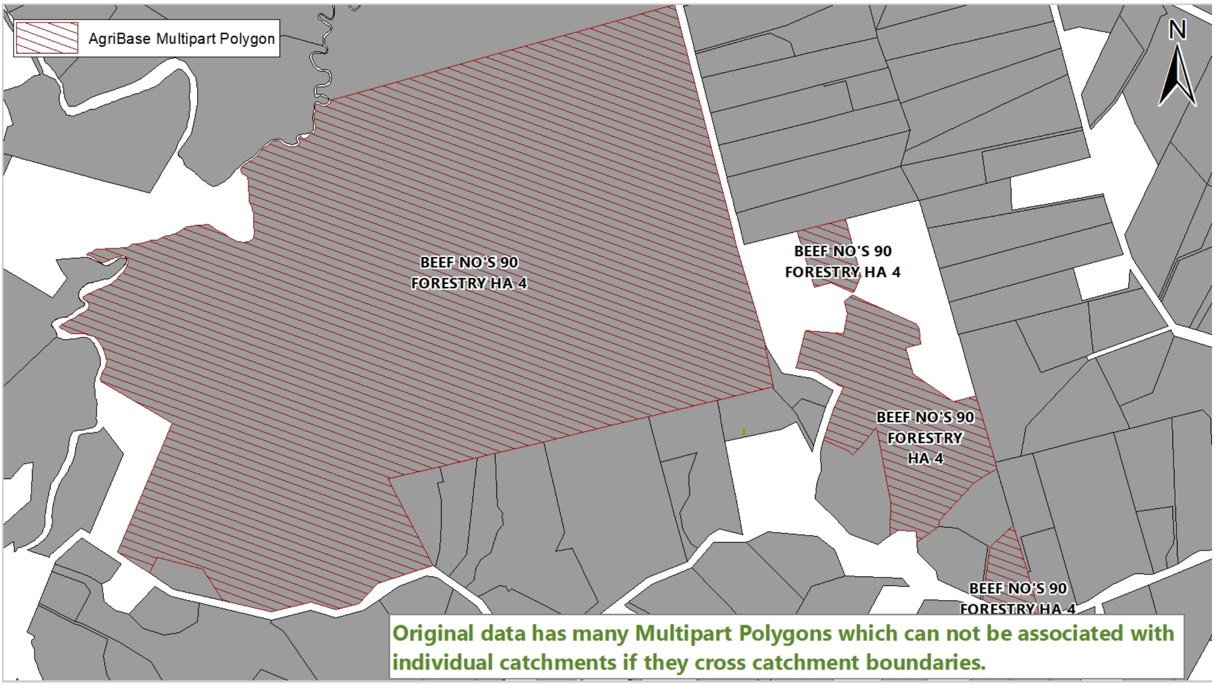
Agribase	LCDB4	Proposed Land Use Type Name	Vegetation Height (> 50cm, < 50cm)	HRU Re-classification
	Producing Grassland			
Tourism (ie camping ground, motel)		Tourism areas	< 50 cm	Open Space
Not farmed (ie idle land or non-farm use), New record - unconfirmed farm type		Idle/unclassed	< 50 cm	Open Space
Forestry	Deciduous Hardwoods Forest - Harvested Exotic Forest	Exotic forest/plantations	< 50 cm	Open Space
Arable cropping or seed production	Short-rotation Cropland	Cereal Crops	All	Horticulture
	Vegetable growing	Vegetables	All	Horticulture
Fruit growing Other planted types (not covered by other types) Viticulture, grape growing and wine	Orchard, Vineyard or Other Perennial Crop	Orchards	All	Horticulture
Flowers, Plant nurseries		Green houses, flowers and nurseries	All	Horticulture
Beef cattle farming, Sheep farming, Deer farming, Grazing other people’s stock, Mixed Sheep and beef farming, Other livestock (not covered by other types)		Sheep, beef and deer	All	Pasture
Dairy cattle farming, Dairy dry stock		Dairy - Irrigated and dry land pasture	All	Pasture
Zoological gardens, Goat farming, Alpaca and/or Llama breeding, Deer farming, Dogs, Emu bird farming, Goat farming, Grazing other		Pigs, poultry and other	All	Pasture

Agribase	LCDB4	Proposed Land Use Type Name	Vegetation Height (> 50cm, < 50cm)	HRU Re-classification
people's stock, Horse farming and breeding, Ostrich bird farming, Pig farming, Poultry farming				
Lifestyle block		Lifestyle blocks	All	Pasture
	Surface Mine or Dump, Sand or Gravel	Mine and bare ground	All	Mine Barren

Table 8-11. Refinement of pervious land. Assumption 1 corresponds to aligned Agribase and LCDB, 2 to LCDB only, 3 to Agribase only and 4 to "open space" due to lack of Agribase or LCDB land activity information but that was also not classified as impervious



Rural Land Use	Impact	Area (km^2)	Area Distribution Assumption			
			1	2	3	4
Forest	Low	1,080	-	-	-	100%
	High	155	73%	27%	-	-
Horticulture	Low	18	-	-	-	100%
	Medium	31	72%	28%	-	-
	High	68	34%	18%	-	48%
Pasture	Low	869	7%	6%	44%	43%
	High	1,548	7%	9%	64%	20%
Open Space	Low	708	13%	2%	-	84%
Total	Percent	100%	10%	5%	25%	60%
	km^2	4,477	442	234	1,129	2,672



Using Python scripts, the data is converted to Singlepart polygons and all values are distributed by the percentage of polygon areas.

FARM_ID	RD01428
FARM_TYPE	Sheep farming
BEEF_NOS	90
FORESTRY_HA	4
NATIVEBUSH_HA	20
SHEEP_NOS	2500
Shape_Area	1,811,735.80

FARM_ID	RD01428	RD01428	RD01428	RD01428
FARM_TYPE	Sheep farming	Sheep farming	Sheep farming	Sheep farming
BEEF_NOS	81	7	1	1
FORESTRY_HA	3.58	0.33	0.05	0.04
NATIVEBUSH_HA	17.89	1.66	0.23	0.22
SHEEP_NOS	2237	207	28	28
Shape_Area	1,620,828.74	150,144.10	20,428.07	20,334.89
Percentage	89.46	8.29	1.13	1.12

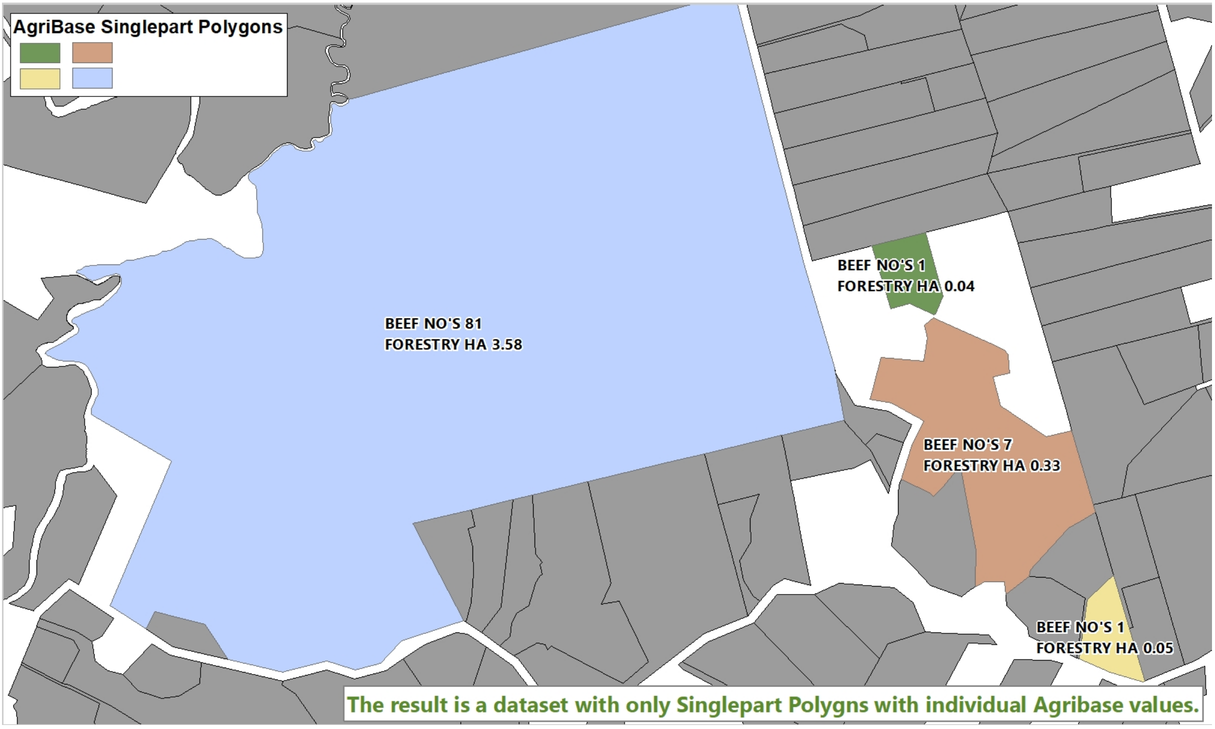


Figure 8-4. Method to proportion livestock number and land type areas for multipart polygons in Agribase data

8.3.2.1 Onsite Wastewater Systems

A separate onsite wastewater disposal systems (OSWW) HRU, a subset of 'open space' was delineated in the FWMT land use layer. There was no single dataset available to spatially represent existing OSWW systems. To represent the OSWW area the FWMT, property titles with potential OSWW facilities were isolated using the Wastewater (WW) connection layer (Appendix A, 8.25) which distinguishes between wastewater reticulated (areas that are serviced for wastewater) and non-reticulated properties (areas that outside of wastewater network serviced catchments). OSWW on lot impact areas were derived using building outline areas (rooftops) as identified in the FWMT land use layer, assumed to be coincident with OSWW. Configuration of the OSWW impact area is detailed in [FWMT Baseline C and P Report, Section 3.8.5.6].

To support the development of OSWW HRU impact factors, The Regional OSWW GIS Risk Assessment Tool (Appendix A, 8.26) was used develop OSWW HRU impact factors. The tool was developed in alignment with TP58 (Auckland Council, 2004) to estimate an elevated likelihood of adverse effects to human health due to on-site wastewater disposal to ground. It applies a combined source risk to 20m x 20m cells based on lot density, soil type, slope, and building age factors. Risk was classified from none to low, low to medium, medium to high and high to very high using the categories included in the Risk Assessment Tool (Figure 8-5). OSWW impact was assessed by first calculating an area weighted average risk for each sub-catchment using the numerical equivalents of each classification (0-3), areas without risk data were assumed to be 0. The values were then normalised by dividing by 3. The resulting number was treated as equivalent to a percentage, ranging from 0.0 to 1.0, which was in turn multiplied by the area of rooftop within the respective sub-catchment to calculate an area that was assumed to be at risk of mobilising OSWW waste. An equivalent amount of open space HRUs within each respective sub-catchment was then flagged as impacted by OSWW. A sub-catchment may have high risk, but no rooftop area, and therefore no impact assigned to it, while another sub-catchment may have moderate risk, but a large amount of rooftop area, and therefore a substantial portion of HRUs assigned to the OSWW Impact factor. Additional details can be found in [FWMT Baseline C and P Report, Section 3.8.5.6].

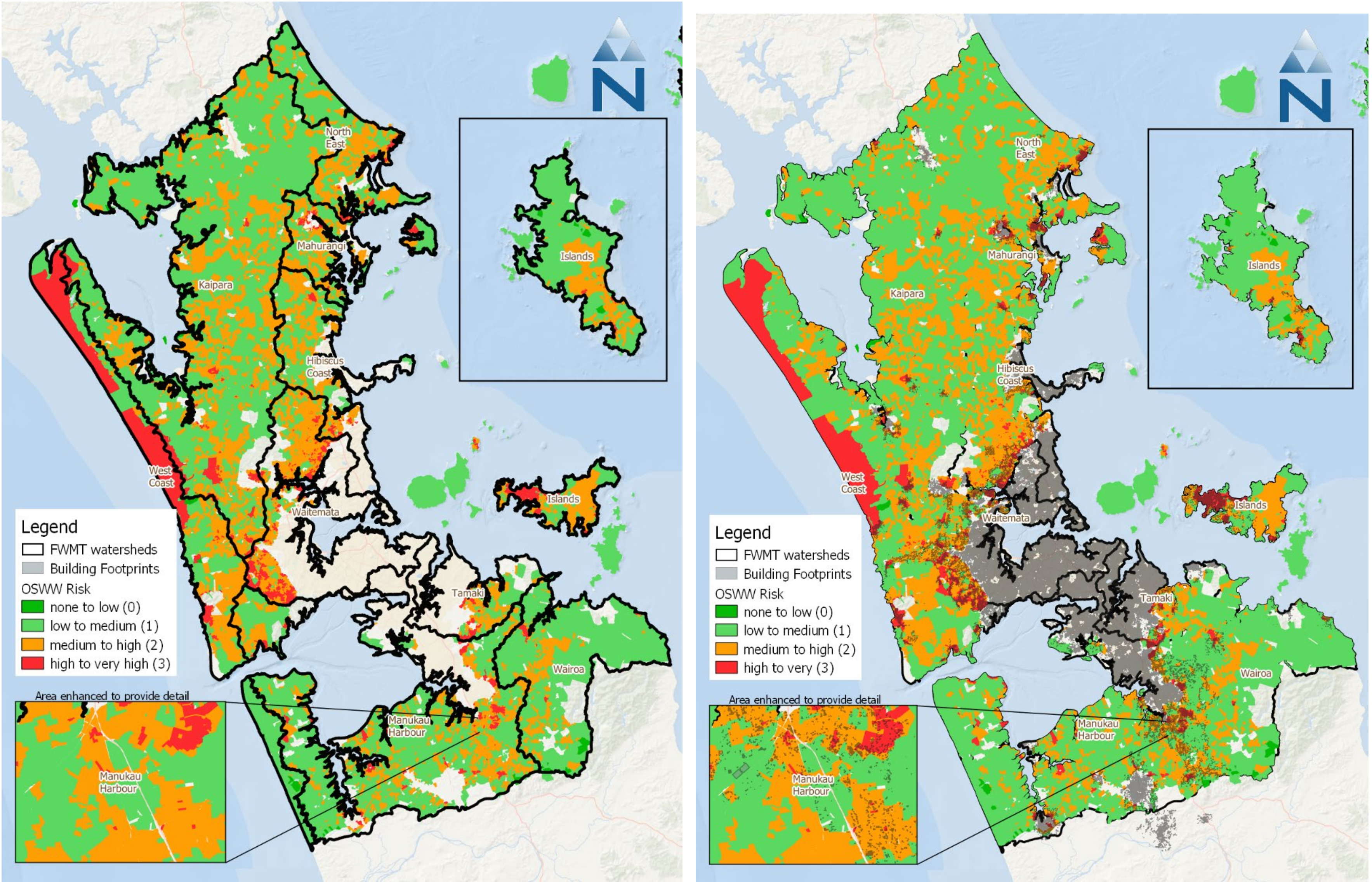


Figure 8-5. Datasets used to calculate OSWW Impact (reticulated areas not shown)

9.0 Reach Groups

The FWMT Sediment, temperature, GQUAL and RQUAL modules simulate instream processes impacting sediment, metals, *E. coli* and nutrients. The GQUAL module simulates zinc, copper and *E. coli* processes while the RQUAL module simulates nitrogen and phosphorus processes.

Process parameterisation of RQUAL and GQUAL modules was regionalised and simplified further, by classifying reaches for the purpose of assigning these parameters efficiently and consistently to over 3,000km of stream network represented in the FWMT. Physical characteristics of modelled reaches were used to develop three process-based reach groupings, with up to five classes within each of: riparian shade; dissolved nutrients; and erosion groups.

As with HRU impact classes, reach group classes were used to simplify variability among instream process parameters. Model reaches were assigned reach groups using several data inputs. Information on assignment and parameterisation of reach groups and their role in activating the LSPC modules is found in [FWMT Baseline C and P Report, Section 3.9]. A summary of the reach groups and key classes and factors controlling model reach classification are presented in Table 9-1.

The following sections describe the data inputs to reach groups.

Table 9-1. FWMT reach groups for shade, erosion and dissolved nutrient processes within LSPC and RQUAL (FWMT Stage 1)

Reach Group	Classes	Factors
Shade	Low (<10%), Low-Medium (10-30%), Medium (30-50%), Medium-High (50-70%), High (>70%)	Overhead Cover (percent vegetation cover)
Nutrients	Low, Medium, High	Overhead Cover (percent vegetation cover) Upstream pastoral and horticultural (percent vegetation cover)
Erosion	Low, Medium, High	Bank Material (dominant of lined, hard, soft bottom) Shade (percent of water surface shaded) Slope (longitudinal slope) Stream Order

9.1 Shade

Riparian vegetation cover (%) was used to assign FWMT reaches into shade groups. Grouping modelled reach segments into channel shade classes (>70%, 50%-70%, 30%-50%. 10%-30%, and <10%) was based on vegetative cover (Table 9-2). A simple hierarchy of data sources was applied. Data was summarised at the sub-catchment scale and used to length-weight the associated FWMT reach. Where available, WAR data records of overhead cover (%) were used to assign shade class membership to FWMT reaches (Appendix A, 9.1 and 9.2). The records of WAR field assessments enable proportion of reach segments that are shaded to varying degrees by riparian vegetation to be estimated. Otherwise, for all modelled reaches that lie outside of the WAR extent, the FENZ (Leathwick, 2010) predicted riparian shading was used to assign shade class membership to all remaining FWMT reaches. Table 9-2 presents a summary of sources used to classify reaches for shade. Approximately 15% of sub-catchments had a non-zero % based on WAR data while 77% of sub-catchments had a non-zero % of shade based on FENZ data. Approximately 8% of sub-catchments were assigned 0% shade, the 0% shade may be derived from the data sources or assigned due to a lack of coverage. Note that these percentages are for the full set of FWMT sub-catchments, only those with respective stream reaches had the shading values transferred to the reach segments.

Table 9-2. Shade group factors for FWMT reaches data sources

Factor	Category	Data Source	Data Intellectual Property Owner	Description Attribute Utilised	Date Represented
Vegetative cover	>70% (High) 50%-70% (Medium-High) 30%-50% (Medium) 10%-30% (Low-Medium) <10% (Low)	Watercourse Assessment Report (WAR) GIS data amalgamated	Auckland Council	Overhead cover (%)	Dates from collected data range from 2002 to 2014
		Freshwater Ecosystem of New Zealand (FENZ)	NZ Dept. of Conservation	Predicted Riparian Shading (SegRipShade)	2010

Table 9-3 presents a summary of model reach lengths by shade group. The spatial extent of the WAR and FENZ data is presented in Figure 9-1. Note that for each reach group, there is 21 km of modelled streams that are not assigned reach groups. These streams represent piped segments in the urbanised sub-catchments of Waitemata and Tamaki.

Table 9-3. Model reach lengths by shade group

Shade group	Length (km)	% of regional total
Low	71	2.29%
Low-Medium	486	15.74%
Medium	1,101	35.70%
Medium-High	858	27.82%
High	548	17.76%
Unassigned	21	0.69%
Total (region)	3,085	100.00%

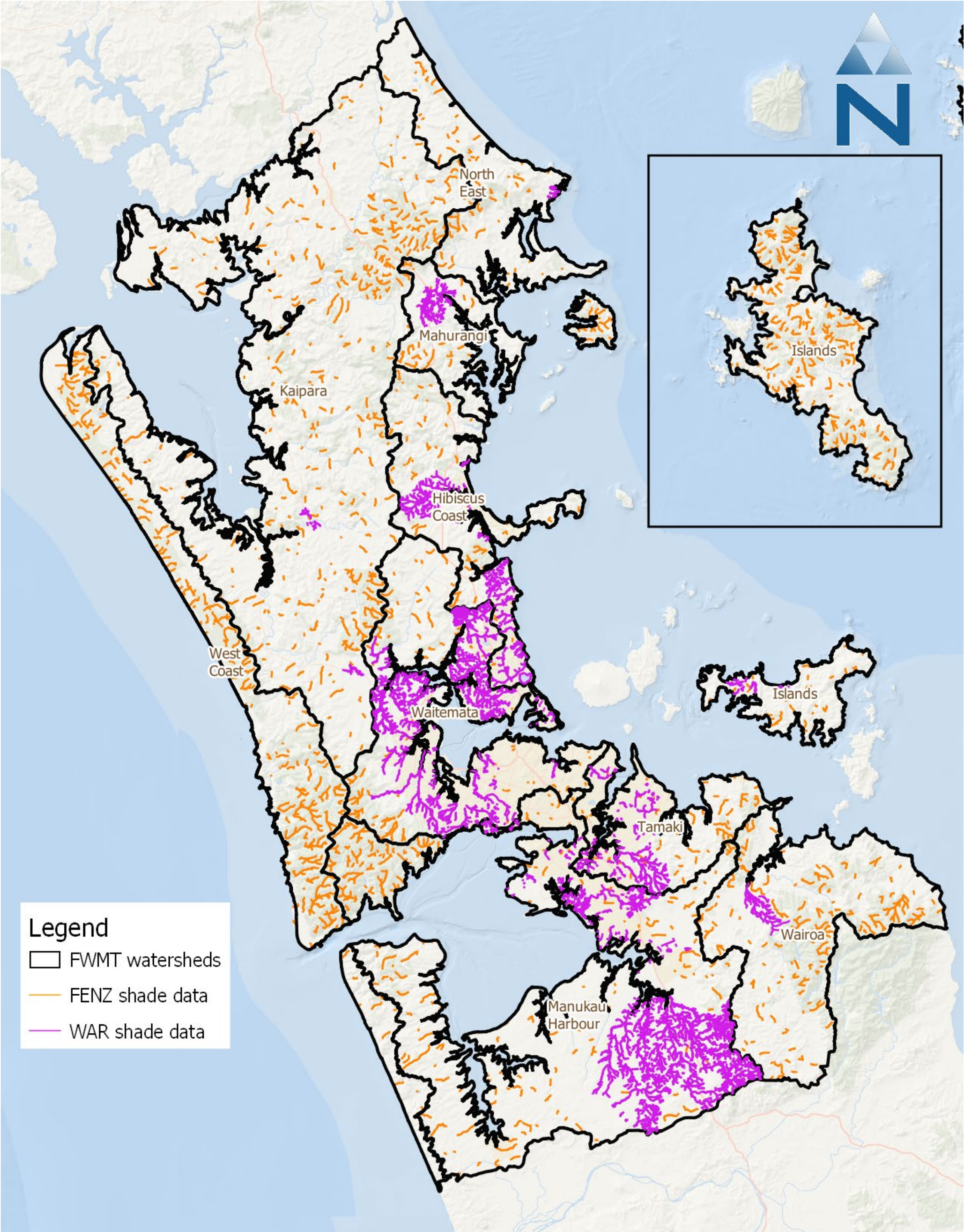


Figure 9-1. Spatial extent of FENZ and WAR shade data

9.2 Nutrients

Nutrient reach groups were classified using two factors assigned to all FWMT reaches: (1) riparian vegetative cover (Table 9-4); and (2) the proportion of the contributing watershed in pastoral and horticultural cover.

The percentage of upstream land use percent was estimated using the FWMT land cover (HRU) layer (Section 8.3) and each FWMT representative reaches then were assigned into one of five upstream land cover use classes: >70%, 50%-70%, 30%-50%. 10%-30%, and <10%. Table 9-4 presents a summary of sources used to classify modelled reaches for nutrients. Best professional judgement was used to assign the 25 combinations of riparian cover and upstream agricultural area into three impact factor classifications (Table 9-5). While three classifications were possible, only two classifications, low and medium, occurred in sub-catchments with modelled reaches. Table 9-6 presents a summary of model reach lengths by nutrient group.

Table 9-4. Nutrient reach group factors for FWMT reaches data sources

Factor	Category (Group)	Data Source	Intellectual Property Data Owner	Attribute utilised	Date Represented
Riparian vegetative cover	>70% 50%-70% 30%-50% 10%-30% <10%	Watercourse Assessment Report (WAR) GIS data amalgamated	Auckland Council	Overhead cover (%)	Dates from collected data range from 2002 to 2014
		Freshwater Ecosystem of New Zealand (FENZ)	NZ Dept. of Conservation	Riparian shading (%)	2010
Upstream land use	>70% 50%-70% 30%-50% 10%-30% <10%	FWMT Land Cover Use Layer (LCDB4 in rural)	Auckland Council	Agricultural and horticultural land use cover types (% upstream area)	2012

Table 9-5. Nutrient reach group classifications

Shade	U/S Ag/Hort	Nutrient Group
<10%	50%-70%	High
<10%	>70%	High
10%-30%	>70%	High
<10%	10%-30%	Medium
<10%	30%-50%	Medium
10%-30%	30%-50%	Medium
10%-30%	50%-70%	Medium
30%-50%	50%-70%	Medium
30%-50%	>70%	Medium
50%-70%	>70%	Medium
50%-70%	50%-70%	Medium
>70%	50%-70%	Medium
>70%	>70%	Medium
<10%	<10%	Low
10%-30%	<10%	Low
10%-30%	10%-30%	Low
30%-50%	<10%	Low
30%-50%	10%-30%	Low
30%-50%	30%-50%	Low
50%-70%	<10%	Low
50%-70%	10%-30%	Low
50%-70%	30%-50%	Low
>70%	<10%	Low
>70%	10%-30%	Low
>70%	30%-50%	Low

Table 9-6. Model reach lengths by nutrient group

Nutrient Group	Length (km)	% of regional total
Low	3,040	98.52%
Medium	24	0.79%
Unassigned	21	0.69%
Total	3,085	100.00%

9.3 Erosion

Erosion FWMT reach groups were classified using factors for describing bank material, vegetation cover, slope and stream order (Table 9-7). Classification of the four factors into the three erosion reach group classes (high, medium, low) is presented in [FWMT Baseline C and P Report, Section 3.9.3.4] and Table 9-8. Table 9-9 presents a summary of modelled reach lengths by erosion group.

Table 9-7. Erosion reach group data factors for FWMT reaches

Factors	Categories	Data	Description	Reference
Bank/bed Material	Soft, Intermediate, Hard/Lined	Watercourse Assessment Report (WAR) Erosion Hotspot and Ecoline	Stream substrate material	Appendix A, 9.1 and 9.2
		SW Stormwater Watercourse/Channel layer	Streams recorded as artificially lined	Appendix A, 9.3
		Freshwater of New Zealand (FENZ) geodatabase	Stream substrate material	Appendix A, 9.4
		NZLRI Lithology	Dominant Rock	Appendix A, 9.5
		GNS Geology	Dominant Rock	Appendix A, 9.6
Bank Cover	<30%; 30-70%; >70%	FWMT Vegetation layer	Percent cover of vegetation >1.5m in height	Appendix A, 9.7
Slope	<2%; 2%-4%; >4%	FWMT modelled stream reaches	Reach slope	FWMT [9.3.3]
Stream Order	1 and 2, 3 and 4, >5	River Environment Classification (REC) database	Stream order	Appendix A, 9.8

Table 9-8. Bank Material Classification

Material	Cover	Slope	Stream Order	Erosion Group Classification
Intermediate	<30%	High (>0.04)	Low (1 and 2)	High
Soft	<30%	Med (0.02 - 0.04)	Low (1 and 2)	High
Soft	<30%	High (>0.04)	Low (1 and 2)	High
Soft	<30%	High (>0.04)	Middle (3 and 4)	High
Soft	30-70%	High (>0.04)	Low (1 and 2)	High
Intermediate	<30%	Med (0.02 - 0.04)	Low (1 and 2)	Medium
Intermediate	<30%	Med (0.02 - 0.04)	Middle (3 and 4)	Medium
Intermediate	<30%	High (>0.04)	Middle (3 and 4)	Medium
Intermediate	<30%	High (>0.04)	High (>= 5)	Medium
Intermediate	30-70%	Med (0.02 - 0.04)	Low (1 and 2)	Medium
Intermediate	30-70%	Med (0.02 - 0.04)	Middle (3 and 4)	Medium
Intermediate	30-70%	High (>0.04)	Low (1 and 2)	Medium
Intermediate	30-70%	High (>0.04)	Middle (3 and 4)	Medium
Soft	<30%	Low (<0.02)	Low (1 and 2)	Medium
Soft	<30%	Med (0.02 - 0.04)	Middle (3 and 4)	Medium
Soft	<30%	Med (0.02 - 0.04)	High (>= 5)	Medium
Soft	<30%	High (>0.04)	High (>= 5)	Medium
Soft	30-70%	Med (0.02 - 0.04)	Low (1 and 2)	Medium
Soft	30-70%	Med (0.02 - 0.04)	Middle (3 and 4)	Medium

Material	Cover	Slope	Stream Order	Erosion Group Classification
Soft	30-70%	High (>0.04)	Middle (3 and 4)	Medium
Soft	30-70%	High (>0.04)	High (>= 5)	Medium
Soft	>70%	High (>0.04)	Low (1 and 2)	Medium
Hard/Lined	<30%	Low (<0.02)	Low (1 and 2)	Low
Hard/Lined	<30%	Low (<0.02)	Middle (3 and 4)	Low
Hard/Lined	<30%	Low (<0.02)	High (>= 5)	Low
Hard/Lined	<30%	Med (0.02 - 0.04)	Low (1 and 2)	Low
Hard/Lined	<30%	Med (0.02 - 0.04)	Middle (3 and 4)	Low
Hard/Lined	<30%	Med (0.02 - 0.04)	High (>= 5)	Low
Hard/Lined	<30%	High (>0.04)	Low (1 and 2)	Low
Hard/Lined	<30%	High (>0.04)	Middle (3 and 4)	Low
Hard/Lined	<30%	High (>0.04)	High (>= 5)	Low
Hard/Lined	30-70%	Low (<0.02)	Low (1 and 2)	Low
Hard/Lined	30-70%	Low (<0.02)	Middle (3 and 4)	Low
Hard/Lined	30-70%	Low (<0.02)	High (>= 5)	Low
Hard/Lined	30-70%	Med (0.02 - 0.04)	Low (1 and 2)	Low
Hard/Lined	30-70%	Med (0.02 - 0.04)	Middle (3 and 4)	Low
Hard/Lined	30-70%	Med (0.02 - 0.04)	High (>= 5)	Low
Hard/Lined	30-70%	High (>0.04)	Low (1 and 2)	Low
Hard/Lined	30-70%	High (>0.04)	Middle (3 and 4)	Low
Hard/Lined	30-70%	High (>0.04)	High (>= 5)	Low
Hard/Lined	>70%	Low (<0.02)	Low (1 and 2)	Low
Hard/Lined	>70%	Low (<0.02)	Middle (3 and 4)	Low
Hard/Lined	>70%	Low (<0.02)	High (>= 5)	Low
Hard/Lined	>70%	Med (0.02 - 0.04)	Low (1 and 2)	Low
Hard/Lined	>70%	Med (0.02 - 0.04)	Middle (3 and 4)	Low
Hard/Lined	>70%	Med (0.02 - 0.04)	High (>= 5)	Low
Hard/Lined	>70%	High (>0.04)	Low (1 and 2)	Low
Hard/Lined	>70%	High (>0.04)	Middle (3 and 4)	Low
Hard/Lined	>70%	High (>0.04)	High (>= 5)	Low
Intermediate	<30%	Low (<0.02)	Low (1 and 2)	Low
Intermediate	<30%	Low (<0.02)	Middle (3 and 4)	Low
Intermediate	<30%	Low (<0.02)	High (>= 5)	Low
Intermediate	<30%	Med (0.02 - 0.04)	High (>= 5)	Low
Intermediate	30-70%	Low (<0.02)	Low (1 and 2)	Low
Intermediate	30-70%	Low (<0.02)	Middle (3 and 4)	Low
Intermediate	30-70%	Low (<0.02)	High (>= 5)	Low
Intermediate	30-70%	Med (0.02 - 0.04)	High (>= 5)	Low
Intermediate	30-70%	High (>0.04)	High (>= 5)	Low
Intermediate	>70%	Low (<0.02)	Low (1 and 2)	Low
Intermediate	>70%	Low (<0.02)	Middle (3 and 4)	Low
Intermediate	>70%	Low (<0.02)	High (>= 5)	Low
Intermediate	>70%	Med (0.02 - 0.04)	Low (1 and 2)	Low
Intermediate	>70%	Med (0.02 - 0.04)	Middle (3 and 4)	Low
Intermediate	>70%	Med (0.02 - 0.04)	High (>= 5)	Low

Material	Cover	Slope	Stream Order	Erosion Group Classification
Intermediate	>70%	High (>0.04)	Low (1 and 2)	Low
Intermediate	>70%	High (>0.04)	Middle (3 and 4)	Low
Intermediate	>70%	High (>0.04)	High (>= 5)	Low
Soft	<30%	Low (<0.02)	Middle (3 and 4)	Low
Soft	<30%	Low (<0.02)	High (>= 5)	Low
Soft	30-70%	Low (<0.02)	Low (1 and 2)	Low
Soft	30-70%	Low (<0.02)	Middle (3 and 4)	Low
Soft	30-70%	Low (<0.02)	High (>= 5)	Low
Soft	30-70%	Med (0.02 - 0.04)	High (>= 5)	Low
Soft	>70%	Low (<0.02)	Low (1 and 2)	Low
Soft	>70%	Low (<0.02)	Middle (3 and 4)	Low
Soft	>70%	Low (<0.02)	High (>= 5)	Low
Soft	>70%	Med (0.02 - 0.04)	Low (1 and 2)	Low
Soft	>70%	Med (0.02 - 0.04)	Middle (3 and 4)	Low
Soft	>70%	Med (0.02 - 0.04)	High (>= 5)	Low
Soft	>70%	High (>0.04)	Middle (3 and 4)	Low
Soft	>70%	High (>0.04)	High (>= 5)	Low

Table 9-9. Model reach lengths by erosion group

Erosion group	Length (km)	% of regional total
Low	2,225	72.13%
Medium	787	25.49%
High	52	1.69%
Unassigned	21	0.69%
Total (region)	3,085	100.00%

9.3.1 Bank/bed material

Bank and bed material classification was split into categories of high, medium, and low erosion impact categories. Bank material classification of modelled reaches was developed using a hierarchy of data sources and attributes (Table 9-10, Figure 9-2).

The original datasets for WAR, AC Stormwater Watercourse Channel data, and FENZ were polyline GIS files representing Auckland streams. The NZLRI lithology and GNS Science – NZ geology layers existed as polygons, so they were intersected with the FWMT model reach layers. The result was 6 stream layers representing the dendritic stream networks in Auckland, the spatial extent of each was dependent on the extent of the original dataset. Each stream layer was converted to a raster with classifications of “low”, “medium”, and “high” bed material. Bed material layers were then overlaid to create a single composite raster dataset. When cells from different layers overlapped, the preference order (Table 9-10) dictated the value of overlapping cells. As an example, if a WAR ecoline raster cell was classified as intermediate (medium), but it was overlain by a WAR erosion hotspot raster cell, the final cell was classified as soft (high).

Each sub-catchment was assigned an overall bed material class from the mode of cell counts for soft, intermediate, and hard classes (e.g., each FWMT reach has a single dominant bed material class).

Table 9-10. Bank Material Classification. Note data of lower numeric value was used in preference

Preference order	Data	Field	Attribution	Classification
1	WAR data – Erosion Hotspot	N/A	N/A	Soft
2	WAR data - Ecoline	Dominant Substrate	Artificial, Bedrock, Boulder	Hard
		Substrate Gravel and Cobble	> = 50 %	Intermediate
		Substrate Silt/Sand	> 50 %	Soft
		Dominant Substrate	Silt/Mud/Sand	Soft
3	AC SW Watercourse/Channel	Asset Type	Lined Channel	Hard
		Base Material	Concrete, Rock or Stone, Galvanised Iron or Steel, Reno Mattress	Hard
		Base Material	Natural State / Clay / Earth	Soft
3	FENZ	Reach Sediment	> 4.5 (bedrock, boulder, cobble)	Hard
		Reach Sediment	3-4.5 (fine gravel, coarse gravel)	Intermediate
4	NZLRI	Dominant Rock	Igneous	Hard
		Dominant Rock	Sedimentary (Indurated) - Greywacke and Argillite	Intermediate
5	GNS	Dominant Rock	Limestone, vitric tuff, volcanic sandstone, volcanic breccia, volcanic conglomerate	Intermediate
6	All other modelled reaches	N/A	N/A	Soft

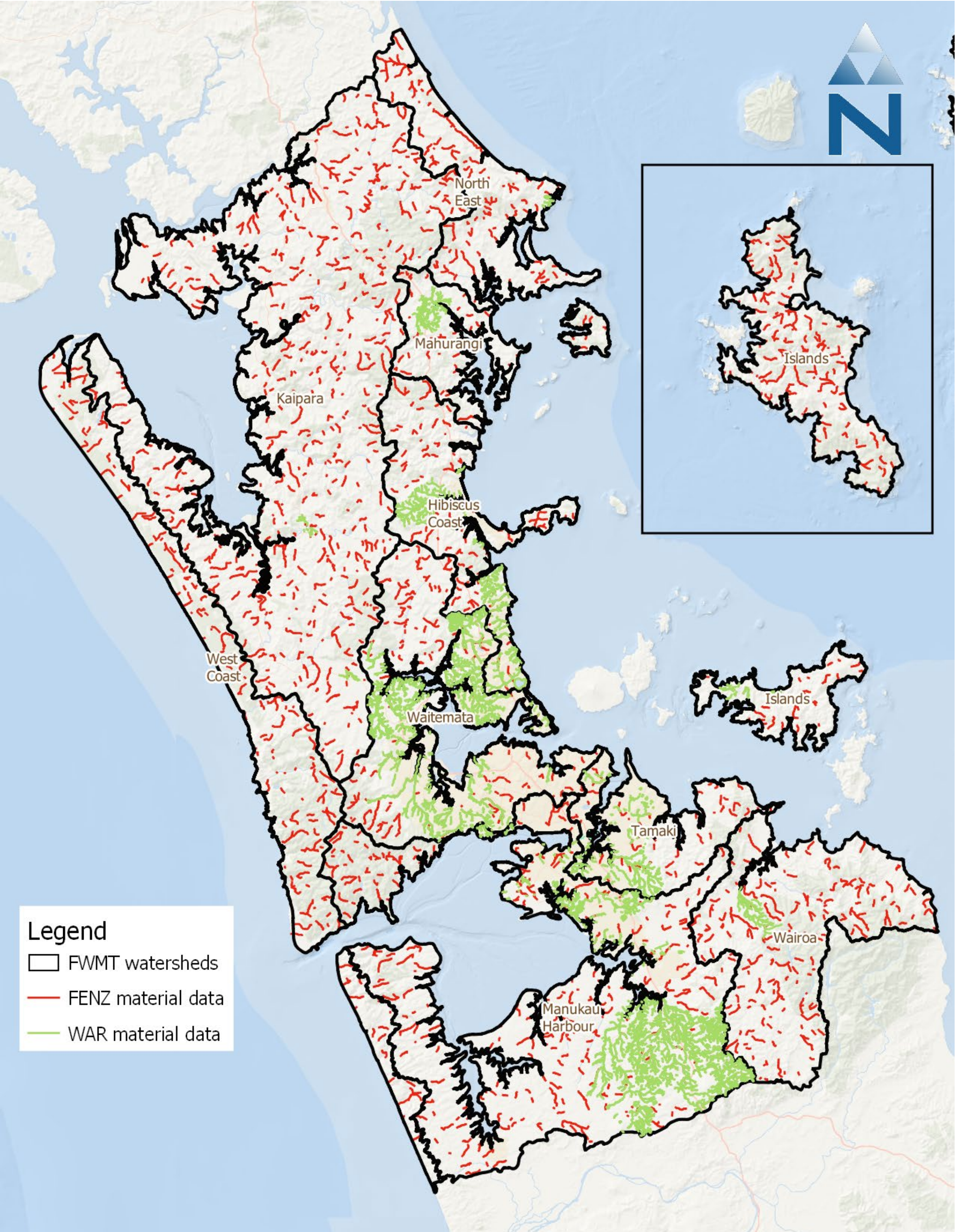


Figure 9-2. Spatial extent of FENZ and WAR bank/bed material data

WAR field assessment recording of erosion hotspots and the relative proportion of substrate class was used to classify associated raster cells as: **hard** where the reach was lined and/or the dominant substrate was recorded as Artificial, Bedrock or

Boulder; as **intermediate** where Gravel and/or Cobble substrate was recorded as greater than 50% of bed cover; and as **soft** where the >50% domain substrate was Silt, Mud or Sand, the Silt or Sand substrate was greater than 50% and/or the reach had an identified erosion hotspot. Erosion hotspots extents were identified by WAR where severe, active erosion was observed within and/or on the banks of the stream channel.

The AC Stormwater Watercourse Channel layer (extracted 2018) data was used to classify associated raster cells as either **hard** or **soft**. If the stream type was lined channels with hard substrate (e.g., base material categorised as Concrete, Rock or Stone, Galvanised Iron or Steel, or Reno Mattress) the associated cells were classified as **hard**. If the classification was unlined channels (base material categorised as Natural State, Clay or Earth), the associated raster cells were classified as **soft**.

For FENZ data (Leathwick, 2010), streams were classified as **hard** or **intermediate**. Streams with dominant bed substrates of bedrock, boulder, or cobble had their associated raster cells classified as **hard**, while streams with dominant bed substrates of coarse or fine gravel had their associated raster cells classified as **intermediate**. If FENZ data indicated another substrate type other than hard or intermediate, NZLRI data was assessed as described below.

For FWMT sub-catchments which lacked WAR, SW or FENZ data coverage, but contained NZLRI lithology, associated reaches were classified as **hard** or **intermediate**. NZLRI delineates areas (polygons) of surface rock-type from stereo aerial imagery, field verification and measurement (Appendix A, 9.5). Once the FWMT stream layer was attributed with the underlying the NZLRI data, streams categorised as igneous rock had their associated raster cells classified as **hard** while those categorised as sedimentary had their associated raster cells classified as **intermediate**.

FWMT stream reaches attributed with GNS Science – NZ geology layer data were classified as **intermediate.** The GNS Science Geology Science layer (Appendix A, 9.6) represents the most current geological mapping of New Zealand but at a coarser spatial accuracy (250m) than the NZLRI dataset. Finally, if a FWMT stream reach did not have underlying NZLRI or GNS Science data the associated raster cells were assumed to be **soft**. Rocks break down to soil through physical and chemical weathering, with most common rock forming minerals changing to clay. The depth of soil varies regionally and is influenced by climate and geology (Balance, 2017). Therefore, where streams are located within the weathered soil layer, but have not down cut to bedrock, the fine soil material breaks down and the stream will be soft bottomed.

9.3.2 Bank cover

A raster vegetation cover layer derived and filtered from 2006/10 LiDAR (Appendix A, 9.7) was categorised into categories of vegetated (elevation heights >1.5 m) and unvegetated (elevation heights < 1.5 m). FWMT streams reaches were buffered by 40m (20m on either side of centreline channel) and the buffer was intersected with the FWMT vegetation category layer. For each sub-catchment, raster cells were summarised within the respective stream buffers. Depending on the ratio of vegetated to unvegetated cells, FWMT reaches were then grouped into three categories of bank cover (<30%, 30-70% and >70%).

9.3.3 Slope

FWMT reach slopes were used to assigned from the streams layer to inform erosion reach groups categories. Channel slope methodology is detailed in Section 8.1 and [FWMT Baseline C and P report, Section 3.4].

9.3.4 Stream Order

The location of the modelled reach in the network, or stream order, was attributed to modelled reaches using the REC database stream order classification (1-5). The River Environment Classification (REC1) layer (Appendix A, 9.8) is a representative watercourse feature class which maps information about the physical characteristics of New Zealand’s rivers, including stream order. Stream order was transferred by intersecting 100m FWMT stream segment buffer with the REC1 layer. Where multiple REC1 segments could transfer differing stream order information, the stream order that makes up the longest REC1 reach was transferred. If the REC1 reach was outside the 100m buffer, the stream order was not transferred.

The REC1 dataset is based on a 30m DEM and considers watercourses greater than 20 ha so quite low spatial accuracy in comparison to the FWMT Streams.

10.0 Summary

The inputs for the baseline modelling for the Freshwater Management Tool (FWMT) have been developed utilising the approach detailed in this report in order to suit the stated purposes and objectives of the Freshwater Management Tool. Data inputs meet the objectives to support the FWMT purpose as follows:

Freshwater Quality Accounting Framework

- **Adaptable hydrology. –** To support the development of process-based simulation in the FWMT and to represent the key variability in hydrological processes for the Auckland region the relevant source and derived input data had to be of suitable resolution. The sub-catchment delineation and stream routing network was developed to represent the connection of land to water through almost 5500 sub-catchments covering the Auckland region, and 3300km of stream network were digitised and parameterised using the best available information. The meteorological inputs compiled were of high resolution to support the model's continuous simulation processes over the modelled time period. Source data used to derive the reach groups and surface water take accounts, was assessed thoroughly for spatial and temporal appropriateness for informing scale and parameterisation of hydrological and contaminant processes on land and instream to determine water balance and therefore dilution, erosion and transport processes affecting contaminant concentrations for grading purposes.
- **Robust contaminant sources. –** The FWMT must account for a variety of contaminant sources that impact baseline water quality (2013-2017). Key baseline input data are non-point source data – those that inform 106 unique HRU typologies, slope, soil, land cover, land use and on-site wastewater, and point-source discharge data. These data were derived from sources that were assessed for relevancy for intended use, as well as accuracy, completeness, timeliness and consistency with cross referenced data sources. Time series data were sought for the most significant discharges with a large effort mobilised to define wastewater overflow volume and strength. The Stage 1 baseline input HRU and point-source data accordingly supply LSPC with suitable spatial and timeseries data to account for contaminants to edge-of-field and downstream receiving environments for contaminant source configuration.
- **Practical performance. –** In order to meet the data input intentions for the FWMT, it was fundamental to create and sustain good data quality by means of a considered data pipeline. A combination of data sourcing, validation, geoprocessing and data synthesis specific to the status of the available existing data was undertaken. To meet practical performance objectives, the

effort required varied depending on the balance between the quality of data available and the complexity and/or novelty of the geoprocessing method undertaken to synthesise derived FWMT data against the programmed timeline and budget. In compiling or synthesising each FWMT derived data input, the data approach aimed for the best quality return for investment of effort. Some derived data were given more emphasis during the geoprocessing stage to ensure higher data quality. This was the case for FWMT sub-catchment delineation, whereby FWMT sub-catchments were clipped for MHWS10 and extensively quality controlled for stormwater pipe diversions, as well as FWMT land cover and use classifications in rural areas, whereby more involved geoprocessing methods were required to supply LSPC with pasture, horticulture and forestry metrics in order to configure impact factors. Where higher quality source datasets became available during the geoprocessing period, the decision was made whether to refurbish methods with the new data or store it for FWMT Stage 2 and document in the FWMT Recommendations Register (Appendix B). In the former situation, geoprocessing methods to develop the FWMT hydrological soils layer were refurbished when the Soils Drainage Layer (Auckland Council, 2015) became available. In the latter situation, it was determined that the FWMT Land Use/Cover Layer would not be updated with new building outlines (LINZ, 2019) due to the effort required to reconfigure the HRUs at that time.

Effective Communication

- **Leverage stakeholder inputs. –** Compilation of FWMT source data required direct engagement with industry stakeholders, across Auckland Council, Watercare, NIWA, HAL etc. as well as community stakeholders, specifically the Rural Advisory Group (RAG), to ensure all the available data had been considered. Outcome workshops were organised with stakeholders to ensure communication channels were kept open, and all relevant stakeholders were informed of the source data utilised for input into LSPC.

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Appendix A Data inventory

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
	FWMT Sub-catchments											
3.1	Auckland Digital Elevation Model (DEM)	Digital elevation model for determination of catchment and stream slope.	Raster	Digital Elevation Model (DEM) created as a 2m grid from various LiDAR data	Auckland Council	2012	2006 - 2012	Nil	High	AC DEM resampled to 2m	Missing Great Barrier Island coverage and parts of the region on the southern boundary	Update data with new regionwide LiDAR (2016), augment to include Great Barrier Island and sub-catchments on the Southern boundary
3.2	DEM conditioned for Overland Flow Path (OLFP)	Digital elevation model for determination of catchment and stream slope.	Raster	2m DEM of Ground Points from 2006-2012 with culverts burnt and ARC Hydro infill tool run. DEM had been hydrologically corrected by AC to prepare the operative overland flowpath layer.	Auckland Council	2012	2006 - 2012	Nil	High	AC DEM conditioned to add culverts/pipes	The OLFP geometry is often limited by its positional accuracy, especially in flatter areas.	Update data with new regionwide LiDAR (2016)
3.3	Great Barrier Island DEM	Digital elevation model for determination of catchment and stream slope.	Raster	Digital elevation model for determination of catchment and stream slope. Date unknown.	Auckland Council	Not provided	Unknown	One modification made to the surface to redirect a single flow path which was known to differ from that described by the DEM	High	Nil	No metadata accuracy or date provided	Update data with new regionwide LiDAR (2016)
3.4	Mean High-Water Springs 10% exceedance water level (MHWS10) boundary	The coastal boundary sub-catchment adjustments	Polyline	The Coast Boundary MHWS10 provides a representation of the level of mean high water springs (MHWS) where 10% of predicted tides would exceed the defined level	Auckland Council	2013	Unknown	Nil	High	The Coast Boundary MHWS10 provides a representation of the level of mean high water springs (MHWS) where 10% of predicted tides would exceed the defined level. The MHWS line provides a practical measure of the natural land – sea boundary. This line was developed by taking output from tidal exceedance curves from across the region and projecting the heights of MHWS10 onto the regional LiDAR dataset in order to provide an indication of the MHWS10 position in a consistent manner along the entire coastline. Note the MHWS10 line takes into account local and regional variability of tide levels based on best available information, including differences between east and west coasts on a regional scale, and estuaries to open coasts on a local scale. Minor manual corrections have been made to the modelled MHWS10 line to improve its representation on aerial photography in some places along the coast.	Uncertainty of MHWS10 around estuaries	Opportunity to confirm true MHWS10 water level in estuaries and adjust as necessary.
3.5	Stormwater Pipe Network	Stormwater pipe geometry used to guide catchment adjustments where water is diverted through the pipe network	Polyline	AC Corporate Pipe network, a spatial layer from Auckland Council public underground services	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	High	Nil	Attributes are not well populated, especially Upstream/Downstream Invert, diameter and install dates. Flow direction is not present. Often sections of pipes are not connected and end up as small independent branches.	Updates to relevant attributes would greatly enhance the value and enable better modelling. Creating a Geometric network which enables flow would be very useful, especially as it would allow gaps between branches to be closed where they are currently missing.
3.6	Major Lakes	Sub-catchment boundaries were revised around seven major monitored lakes	Polygon	Major Lake outlines for Auckland	Auckland Council	2003/2004	2003/2004	Nil	High	Nil	Nil	Nil
	FWMT Meteorological Data											
4.1	Hydstra database	Rain gauge point geometry and associated precipitation data	Point and Time Series	Water quality and quantity system database containing time series data including those recorded by precipitation, temperature, and wind stations across the Auckland region	Auckland Council	2017	2012 - 2017	Nil	High	Nil		
4.2	National Climate Database (CliFlo)	Provide the boundary conditions for LSPC: primary climate data used in the model	Point and Time Series	NIWA's climate database providing raw data from climate stations around New Zealand. Outputs include ten	NIWA	2017	2012 - 2017	Nil	High	Nil		

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
		configuration are precipitation, potential evapotranspiration, air temperature, and solar radiation.		minute, hourly and daily frequencies for a range of parameters.								
4.3	Virtual Climate Station Network (VCSN)	Provide the boundary conditions for LSPC: primary climate data used in the model configuration are precipitation, potential evapotranspiration, air temperature, and solar radiation.	Point and Time Series	Estimates of daily rainfall and other parameters (~5km) grid covering the whole of New Zealand. The estimates are produced every day, based on the spatial interpolation of actual data observations made at climate stations located around the country.	NIWA	2017	2012 - 2017	Nil	High	Nil		
4.4	Precipitation Data	Rain gauge time series	Point and Time Series	High-resolution (5-minute) precipitation data at select locations	Watercare	2017	1990 - 2017	Nil	High	Nil		
	FWMT Stream and Pipe Routing Network											
5.1	Overland Flow Paths (OLFP)	Overland Flow Paths used to delineate main reach in each FWMT sub-catchment	Polyline	Auckland Council Corporate OLFP Layer	Auckland Council	2006	2006	Nil	Moderate	Nil	Source Raster is 2m DEM. The OLFP geometry is often limited by its accuracy, especially in the flatter areas.	Higher spatial resolution source data will help increase the accuracy of OLFPs.
5.2	Underground Services: Stormwater Pipe Network	Stormwater pipe geometry used where main FWMT network reach is piped	Polyline	AC Corporate Pipe network	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	High	Nil	Attributes are not well populated, especially Upstream/Downstream Invert, diameter and install dates. Flow direction is not present. Often sections of pipes are not connected and end up as small independent branches.	Updates to relevant attributes would greatly enhance the value and enable better modelling. Creating a Geometric network which enables flow would be very useful, especially as it would allow gaps between branches to be closed where they are currently missing.
5.3	Underground Services: Watercourse/Channels	Reach centrelines used to delineate main reach in each FWMT sub-catchment	Polyline	AC Corporate Watercourse and Channel network, a spatial layer from Auckland Council public underground services	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	High	Nil	Dataset does not provide the extent for all watercourses in the Auckland region	Creating a Geometric network which enables flow would be very useful, especially as it would allow gaps between branches to be closed where they are currently missing.
5.4	WAR Data Amalgamated: Ecoline	WAR parameters defining FWMT channel width, depth, height, angle and substrate material were used to determine channel geometry and roughness. WAR Ecoline geometries used to determine man FWMT stream reach per catchment for the catchments that the data covers.	Polyline	Field collected data of stream lengths. Stream reach data updated from various sources for Geometry (slope, width, depth) and hydraulic function Manning's "n"	Auckland Council	2014	2002 - 2014	WAR data converted to FWMT parameters. Non-WAR reaches assigned WAR parameters based on simple catchment area relationships.	High	WAR data collected by Morphum and other consultants until 2014	Limited data coverage over the Auckland region. Watercourse attributes derived from WAR data has limited accuracy in terms of bank height. There is no correlation in bank height to catchment area. Average bank height has been used for rural and urban areas.	Opportunity for further investigation in any relationship with underlying channel geometry and channel geometry to improve the parameters. Prospects for more stream survey through lidar remote sensing or by developing regression for catchment area, imperviousness, soils, vegetation etc
5.5	Floodplains	Floodplain widths were used to determine FWMT channel geometry and Manning's "n"	Polygon	Auckland Council Corporate Floodplain Layer produced from hydraulic modelling.	Auckland Council	2013	2013	Clipped to a maximum of 60m from the stream centrelines	Moderate	Indicates areas predicted to be covered by flood water as result of a rainstorm event of a scale that occurs on average once every hundred years. These areas have been produced from hydraulic modelling. The floodplain contains the most up to date information for each of the 23 Stormwater Catchments in the Auckland region. Summary data for each catchment is attributed against each floodplain. Created by the Stormwater Hydraulic Modelling Team Updated July 2013. Provided by Council 18/04/17, current at this date		Data could be updated with newer and more accurate models.
5.6	Topo NZ River Centrelines	Reach centrelines used to delineate main reach in each FWMT sub-catchment	Polyline	Auckland Council Corporate OLFP Layer	Auckland Council	2006	2006	Nil	Moderate	Nil	Source Raster is 2m DEM	Higher spatial resolution source data will help increase the accuracy of OLFPs. Override data source with Auckland Councils Permanent

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
												Streams made available in 2018
5.7	Drainage Schemes	Channel works data used to delineate main reach in each FWMT sub-catchment	Polyline	The feature classes provide the location of existing flood schemes in certain rural areas in the Auckland region. Depicting the locations of all the causeways, channel works, stopbanks and road embankments	Morphum	2014	2014	Nil	High	Nil	The channel works line dataset has limited coverage in the Auckland region, however, in the rural Franklin and Rodney areas it provides good accuracy.	N/A
5.8	Aerial Photography	Verification and delineation of stream features	Raster	NZ raster imagery using latest available data for each region. Auckland updated in 2017.	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	High	Nil	Aerial photos provide can locations of open watercourses, however, are often limited by their age (as watercourses may be modified following the capture of the aerials) and the location of overhead objects (i.e. trees can obstruct the view of the ground).	Update high-res aerial imagery for urban and rural areas
	FWMT Point Sources											
6.1	Wastewater Discharge Model Outputs	To account for point source contaminant contributions in LSPC	Time series and Point	Timing and volume of spills from the combined and separate sewer systems, locations of EOPs for six reticulated wastewater networks: Warkworth, Rosedale, Army Bay, Mangere, Pukekohe and Waiuku	Watercare models operated by HAL	2019	2002 - 2017	Nil	Moderate	Watercare models developed with data a from 2006 to 2015. 6 models in total, one for each network and treatment plant. Three MIKE URBAN models and three ICM models. All run on same weather data as LPSC. Models: Mangere, Warkworth, Rosedale, Army Bay, Pukekohe and Waiuku. Each model provides network type 1, 2 and 3 spill points.	MIKE URBAN model Water Quality simulation does seem to have some numerical dispersion, dependent on the adopted simulation time step, this dispersion produces an error in the estimate of wastewater load. Models are based on old data (most pre-2010)	Models should be updated with new input data after Central and Northern interceptors are active.
	FWMT Surface Water Takes											
6.2	Consented Water Takes	To account for abstractions: location and attributes of consented water takes in the region	Point and table	AC Consent Data	Auckland Council	2018	1950 - 2017	Nil	Moderate	NA	Only consented takes provided (surface and bore), permitted takes are omitted.	Update consented takes dataset, combine with other sources to create a full database containing abstractions for Auckland region
6.3	Metered Takes Readings	To account for volumes of surface water takes	Time series	Time series of surface water takes where available as reported on Auckland Council's Water Use Data Management System (WUDMS)	Auckland Council	2018	2006 - 2017	Nil	Low	NA	The reporting system requires users to submit readings, which is inconsistently adhered to. System does not take into account meter replacements. Some duplicate and null readings. Does not give timeseries for all consented surface water takes (Auckland Council, 2018)	
6.4	Watercare Water Takes and Releases	To account for abstraction and discharge volumes from dams	Time series	Time series for Watercare takes and releases from main water supply dams in m^3/day	Watercare	2018	2001 - 2017	Nil	Moderate	NA	Some missing volume information for some dams across the time period provided	Update this record
	FWMT Structural Devices - Ponds											
7.1	Stormwater Treatment Facilities	Delineation of ponds layer	Polygon	Treatment facilities layer as a part of the AC Corporate Underground Services dataset	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	Moderate	Using as built sent to the stormwater team from development engineers and/or internal projects, the geometry of stormwater assets are captured using standard ArcGIS editing functionality (updating the SAPGEO feature class) and its attributes are populated within SAP (updating the SAPGEO table). Whilst due care has been taken to capture the assets as accurately as possible, the data is indicative and cannot be considered to align to any particular boundaries or features including cadastral.	Most stormwater facility features do not have any attribution so are missing performance, footprint dimensions and catchment areas	The corporate underground services data set is readily updated. Opportunity to integrate an updated dataset which may have better attribution completeness.
7.2	Auckland Wetland Layer	Delineation of ponds layer	Polygon	Spatial data for wetlands: estuarine, lacustrine, palustrine, riverine and inland	Research and Evaluation Unit, Auckland Council	2016	2010/2011	Query for 'inland water bodies' and then 'settling ponds', 'stormwater ponds',	High	This layer captures the current (2011) extent of wetlands in the Auckland region. The near complete re-digitisation of wetland extents and the mapping of previously un-	Only wetlands detectable in the aerial imagery are included in this inventory. Small wetlands less than 0.01ha in	Updated dataset required for V2.0 using most recent aerials

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
				water bodies for the Auckland region.				'stormwater wetlands', 'man-made impoundments'		mapped wetlands has resulted in a single dataset for the Auckland region that has a consistent mapping scale, mapping resolution, delineation method and classification methodology, a first for the Auckland region. This layer is the latest version as of 16/08/2016. Quality control processes and writing up our methods in a technical report to accompany the layer are currently being finalised. Layer is going to be uploaded onto the SDE by Research and Evaluation Unit.	size were not included and some wetlands difficult to detect on the images may have been missed. There is inevitably error in the data, particularly where the boundaries of wetlands are cryptic or obscured by other features in the imagery. The dataset is dated, a snapshot in time from 2010/11 aerials	
	FWMT Reservoirs and Dams											
7.3	Auckland Wetland Layer	Representation of dams and reservoir footprints	Polygon	Spatial data for waterbody and wetland types in the Auckland region.	Research and Evaluation Unit, Auckland Council	2016	2010/2011	Query for dams and reservoir "use"	High	This layer captures the current (2011) extent of wetlands in the Auckland region. The near complete re-digitisation of wetland extents and the mapping of previously un-mapped wetlands has resulted in a single dataset for the Auckland region that has a consistent mapping scale, mapping resolution, delineation method and classification methodology, a first for the Auckland region. This layer is the latest version as of 16/08/2016. Quality control processes and writing up our methods in a technical report to accompany the layer are currently being finalised. Layer is going to be uploaded onto the SDE by Research and Evaluation Unit.	Only wetlands detectable in the aerial imagery are included in this inventory. Small wetlands less than 0.01ha in size were not included and some wetlands difficult to detect on the images may have been missed. There is inevitably error in the data, particularly where the boundaries of wetlands are cryptic or obscured by other features in the imagery. The dataset is dated, a snapshot in time from 2010/11 aerials	Updated dataset required for V2.0 using most recent aerials
7.4	Major Lakes	Representation of lakes footprints	Polygon	Major Lake outlines for Auckland	Auckland Council	2003/2004	2003/2004	Nil	High	Nil	Nil	Nil
7.5	Watercare Water Takes and Releases	To account for abstraction and discharge volumes from dams	Time series	Time series for Watercare takes and releases from main water supply dams in m^3/day	Watercare	2018	2001 - 2017	Nil	Moderate	NA	Some missing volume information for some dams across the time period provided	Update this record
	FWMT Slope											
8.1	Auckland Digital Elevation Model (DEM)	Digital elevation model for determination of land slope.	Raster	2m DEM of Ground Points from 2006-2012	Auckland Council	2012	2006 - 2012	Nil	High	AC DEM resampled to 2m		Update data with new regionwide LiDAR (2016)
	FWMT Hydrological Soil Groups											
8.2	The New Zealand Fundamental Soil Layer (FSL) data	Primary source for classifying soils for HRUs	Polygon	The soil fundamental data layers (FDLs) a combination of the New Zealand Land Resource Inventory (NZLRI) and National Soils Database (NSD).	Landcare Research	2014	1960 - 2000	Auckland Council modified the FSL by including drainage groupings in 2015	High	The soil fundamental data layers (FDLs) contain spatial information for 16 key attributes, each of which is measurable (i.e. is given a numeric value rather than being assigned to a descriptive class or category) and is recorded in appropriate units of measure. Since attributes have measurable values, FDLs are particularly useful in computer modelling and have enabled researchers and resource management decision-makers to make the most of rapid developments in GIS technology. Key soil attributes were selected through a consultation process with stakeholders, and generally fall into three groups: soil fertility/toxicity, soil physical properties (particularly those related to soil moisture), and topography/climate (T). Parameters include slope, potential rooting depth, topsoil gravel content, proportion of rock outcrop, pH, salinity, cation exchange capacity, total carbon, phosphorus retention, flood interval, soil temperature, total profile available water, profile readily available water, drainage, and macropores (shallow and deep).	Some key attribution missing, such as soil series with null information.	FSL predates and is being replaced by S-map, which is considered better quality and more reliable data. Upgrade analysis using S-Map input data when full coverage becomes available.

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
8.3	Soil-Map Database (S-Map) offered by Landcare Research	Secondary source for classifying soils for HRUs	Polygon	This layer is a "dissolved" representation of the NZSC soil order for S-Map previously available as a lookup table. Refer to document S-Map Data Dictionary Dissolved Layers.pdf	Landcare Research	Not provided	2018	Nil	High	S-Map data is polygon-based (soils are represented as discrete areas on a map shown by a line). For dominantly flat to rolling lowland areas soil mapping uses conventional methods, based on air-photo interpretation and free survey techniques. In dominantly hilly and mountainous terrain soil mapping uses soil-landscape modelling based on digital elevation models and other spatial information.	Limited coverage of S-Map data for the Auckland region	Broaden HSG coverage with extended S-Map data
8.4	Soakage Areas	HSG Modifier layer for A+ soils	Polygon	There are 2 soakage layers in the supplied GDB that have been used: Soakage_Ratepoly_Dec16 and Volcanics_GAS_Dec16	Auckland Council	Not provided	2013	Nil	Moderate	Nil	Nil	Nil
8.5	GNS Geology	HSG Modifier layer for D soils	Polygon	1:1 000 000 geological units data for New Zealand. The dataset comprises polygons with each polygon having attributes describing the type of geological unit, its content, name and age. Polygon layer depicting allochthonous rocks north of Auckland	GNS Science	2013	1909 - 2013	Nil	Moderate	https://data.gns.cri.nz/geology/	Nil	Nil
8.6	Northern Allochthon	HSG Modifier layer for D soils	Polygon	Polygon layer depicting allochthonous rocks north of Auckland identified on this map based on a desktop survey.	Tonkin and Taylor	2004	Unknown	A buffer (±250m) has been placed around the regions containing these soils to allow for uncertainties due to the scale of the survey data.	Moderate	Northland Allochthon is a geological formation widely known for its potential instability on even gentle slopes. Northland Allochthon is comprised of a number of geologic soil types: allochthon Waitemata, motatau complex, puriri mudstone, mahurangi limestone, mangakahia complex, hukerenui mudstone, whangai formation, and tangihua complex	Developed by desktop exercise, possible that sites within the buffer are not underlain by the Northern Allochthon	Nil
8.7	Volcanic Aquifers	HSG Modifier layer for A+ soils	Polygon	Boundaries of aquifers classified as volcanic for the Auckland region	GNS Science	Not provided	Unknown	Nil	Moderate	Nil	Aquifer extent details, source and methodology of creation unknown	Opportunity to improve attribution and metadata
	FWMT Existing Land Cover and Use											
8.8	Rural/Urban Boundary (RUB)	Delineate urban extent	Polygon	The RUB is a boundary line representing the outer edge of Auckland's urban core and expected future urban	Auckland Council	2016	2016	Modified to exclude Future Urban Zones (UPBaseZone, 2016)	High	Nil	Potentially dated boundary with updates to FUZ zones occurring since	
8.9	Unitary Plan Zoning	Classification of general land use and paved surfaces	Polygon	Auckland's combined regional policy statement, regional plan and district plan is made up of 40 land type zonings which have been mapped for the entire Auckland region	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Aggregated Base Zone classification to FWMT aggregated zoning	High	Nil	Unitary Plan Zoning: risk of temporal inaccuracy and is potentially outdated Unitary Plan zoning may not accurately represent all aspects of existing Land-Use	Opportunity to update any Unitary Plan areas that are out-dated. Opportunity to investigate additional Remote Sensing/Machine Learning techniques to deliver improved/higher resolution Land-Use information.
8.10	Impervious Surface	Delineate impervious surface cover	Polygon	Impervious surface mapping covering the Auckland metropolitan urban limit [MUL], urban expansion areas, and associated catchments including Territorial Local Authority boundaries	Landcare Research for Auckland Regional Council	2008/2010	2007/2008	Building Footprints and Road dataset polygons removed and remainder characterised as 'paved surfaces'.	High	Impervious areas mostly digitised from aerial imagery, some areas through analysis	Impervious extent dated. Incomplete impervious data coverage outside of the RUB. Does not satisfy completeness for current land cover, especially within the rural space. Road surfaces may be underestimated where overhanging vegetation exists.	Machine learning imagery analysis to delineate current impervious surface.
8.11	NZ Primary Parcels	Existing Property Boundaries	Polygon	National coverage of legal property boundaries	LINZ Data Services	2018	2017	Nil	High	Downloaded from LINZ NZ Primary Parcels on 18/02/18	Nil	Nil
8.12	NZ Road Centre Line	Identification of rural road area.	Polyline	This layer is a component of the Topo50 map series. The Topo50 map series provides topographic mapping for the New Zealand mainland, Chatham and New Zealand's offshore islands, at 1:50,000 scale.	LINZ Data Services	2018	2017	Nil	Moderate	Nil	Road centrelines do not provide precise geometry of roads in Rural Areas. Consequently, Rural Road area coverage may not be of a high accuracy.	Opportunity to use impervious layer once updated to represent the whole Auckland region. Opportunity to investigate additional Remote Sensing/Machine Learning techniques to deliver Road information in rural areas.
8.13	Aerial Photography	Verification of land cover features	Raster	NZ raster imagery using latest available data for each	ESRI	Ongoing, the dataset	2017	Nil	High	Nil	Aerial photos provide can locations of land cover/use	Update high-res aerial imagery for urban and rural areas

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
				region. Auckland updated in 2017.		is live and updated on an ongoing basis.					features, however, the dataset is limited by age (as land cover may be modified following the capture of the aerials) and the location of overhead objects (i.e. trees can obstruct the view of the ground).	
8.14	Annual Average Daily Traffic (AADT)	Land impact: Road vehicle intensity	Polyline	Polyline data describing traffic levels for the length of a road network	RAMM database	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Nil	High	Nil	Positional inaccuracy whereby the polyline data does not intersected the FWMT road data very well	Opportunity for RAMM to attribute AADT to road corridor polygon geometries instead of polyline. Research additional resolution of traffic volume information (e.g. using sensor data gathered from e.g. Google)
8.15	Building Outlines	Geometry for rooftops	Polygon	Auckland Council's default building outline dataset.	Landcare Research for Auckland Regional Council	2009/2012	2008/2011	Attributed with primary parcel addresses and lot numbers	Moderate	Building outlines defining the extent of permanent building or structures, captured from high resolution aerial photography. Data was originally captured from 2008 photography and in some areas (e.g. North Shore) updates have been made to match 2010 imagery. In some areas (e.g. Rodney) there have been updates made from building consent plans	Data is dated. No metadata is available, so unclear what regions are updated or not. Building roof outlines observed in aerial imagery larger than or equal to 10 square meters are captured in this dataset, and may include structures such as elevated decks, water tanks and patios which do not have roofs. Extensive QA of the data from Auckland Council found many false negatives and positives (Auckland Council, 2017).	A new building outline dataset (LINZ, 2019) is now available in high quality.
8.16	District Valuation Roll (DVR)	Roof impact: roof material typology	Table	Extract from Auckland Council's valuation roll, maintained by AC's Valuation Department.	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Pre-processed addresses and lot numbers for georeferencing	High	Nil	The DVR only provides one roof material per address data so multiple roofs on the same property could only be assigned one construction material. The DVR categorises roofs by address and unit ID, which is not always in the same text format as that in NZ Primary Parcels and can't be always assigned correctly to the building footprints.	Further investigation into differences on a site scale could be considered in future improvements. Updates to the DVR to record differing roof types on the same property.
8.17	Hauraki Gulf Island District Plan Zones	Classification of general land use and paved surfaces	Polygon	District plan as maintained by AKC under local government planning regulations.	Auckland Council	2013	2011	Nil	Moderate	Shows extents of land unit classifications defined in Auckland City Council's Proposed Hauraki Gulf District Plan. Shows areas of land separated into land units based on common features of the physical and natural landscape for the purpose of resource management.	The Proposed Auckland City Hauraki Gulf Islands District Plan land units were classified in 2013 and became operative in 2018. Potentially temporally inaccurate	Opportunity to update land unit information if chances were implemented since 2013.
8.18	Auckland Wetland Layer	Delineation of water HRU	Polygon	Spatial data for wetlands: estuarine, lacustrine, palustrine, riverine and inland water bodies for the Auckland region.	Research and Evaluation Unit, Auckland Council	2016	2010/2011	Query for inland water bodies		This layer captures the current (2011) extent of wetlands in the Auckland region. The near complete re-digitisation of wetland extents and the mapping of previously un-mapped wetlands has resulted in a single dataset for the Auckland region that has a consistent mapping scale, mapping resolution, delineation method and classification methodology, a first for the Auckland region. This layer is the latest version as of 16/08/2016. Quality control processes and writing up our methods in a technical report to accompany the layer are currently being finalised. Layer is going to be uploaded onto the SDE by Research and Evaluation Unit.	Only wetlands detectable in the aerial imagery are included in this inventory. Small wetlands less than 0.01ha in size were not included and some wetlands difficult to detect on the images may have been missed. There is inevitably error in the data, particularly where the boundaries of wetlands are cryptic or obscured by other features in the imagery. The dataset is dated, a snapshot in time from 2010/11 aerials	Updated dataset required for V2.0 using most recent aerials
8.19	Stormwater Treatment Facilities	Delineation of water HRU	Polygon	Treatment facilities layer as a part of the AC Corporate Underground Services dataset	Auckland Council	Ongoing, the dataset is live and updated on an ongoing basis.	2017	Queried for Status = In Service and Asset Type not equal to Dry Detention Ponds	Moderate	Lineage - Through the OnePlus project, all seven legacy systems were migrated to the new GIS-SAP environment where the creation of new assets and maintenance of existing assets are now being undertaken. Using as built sent to the stormwater team from development engineers and/or internal	Many stormwater facility features do not have an identified asset type and/or status. These were included for conservations sake; however it is possible that some of these features are dry	The corporate underground services data set is readily updated. Opportunity to integrate an updated dataset which may have better attribution completeness.

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
										projects, the geometry of stormwater assets are captured using standard ArcGIS editing functionality (updating the SAPGEO feature class) and its attributes are populated within SAP (updating the SAPGEO table). Whilst due care has been taken to capture the assets as accurately as possible, the data is indicative and cannot be considered to align to any particular boundaries or features including cadastral.	detention ponds or dry wetlands, and should not be effectively impervious in the FWMT	
8.20	Vegetation	Refine pervious HRUs	Polygon	Non ground LiDAR extent polygons trimmed for building footprints	Morphum Environmental Ltd	2018	2006-2010	Converted raster to polygons and dissolved by <0.5m and >0.5m	High	Data generated from LiDAR delimitting non-ground features	Dated base data	An updated dataset in higher resolution (additional height bands within the data) would enable more detailed analysis and higher confidence in the output.
8.21	Agribase	Location and type of agricultural activity in the region	Polygon	Agribase is a voluntary database that provides spatial data for over 18,000 rural property typologies in Auckland including farm information that dates from 2003-2016.	Agribase 2016, Landcover Basemap, LINZ Topo Dataset	2016	2003-2016	Multipart polygons for large scale ownership of land in Agribase processed	Low	Purpose: The AgriBase™ database holds information on all types of rural properties such as farms, vineyards, orchards, forests, and small holdings and includes contact details for the individuals that own and manage them. AgriBase™ is a voluntary system and AsureQuality is continually in touch with rural properties in order to collect and update information. In the event of a rural, regional or national emergency AgriBase™ can be quickly populated with any additional data necessary to control and manage the situation. Because AgriBase™ is fully linked with geospatial systems, real-time analysis and problem solving can be easily and expertly handled.	Land use groupings either too broad or too narrow, providing potential disharmony with stakeholders/agribusiness. Agribase is incomplete and has data across multipart polygons.	AC to review and develop an improved understanding of the rural land use through mapping and stakeholder engagement processes. Opportunity to update currency, completeness and content of Agribase.
8.22	Land Care Data Base (v4.1)	Identification of rural land cover types	Polygon	The New Zealand Land Cover Database (LCDB) is a multi-temporal, thematic classification of New Zealand's land cover.	LandCare Research	2012	1996 - 2012	Nil	High	https://lris.scinfo.org.nz/layer/48423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/metadata/	Dated data	Update with newer imagery, possibly use machine learning
8.23	Consented livestock density	Verification of Agribase livestock number	Table	A record of the dairy herd in the region within dairy discharge consents.	Auckland Council	2018	Unknown	Nil	Low	Nil	Incomplete dataset with no date information. Property addresses were brief and some unknown.	Update dataset to have complete attribution
8.24	Topo Vegetation	Delineate forest areas to refine Agribase land cover	Polygon	This layer is a component of the Topo50 map series. The Topo50 map series provides topographic mapping for the New Zealand mainland, Chatham and New Zealand's offshore islands, at 1:50,000 scale.	LINZ Data Services	2013	2013	Nil	Medium	Nil	Nil	Nil
8.25	Network Connection	Non-reticulated network identification for on-site wastewater HRU determination	Point	Point dataset intersecting with primary parcels showing water and wastewater reticulation	Watercare	Not provided	Unknown	Query for non-reticulated parcels	High	Nil	Nil	Nil
8.26	Septic Tank Risk	Risk of discharge of contaminants from on-site wastewater	Raster	Onsite Wastewater Risk Assessment	Tonkin and Taylor	2017	Unknown	Summarised risk by sub-catchment	Moderate	This layer gives the combined wastewater risk per property and FWMT sub-catchment.	Limited confidence in septic tank condition. Risk does not equal overflow.	
	FWMT Reach Group											
9.1	WAR Data: Erosion Hotspot	Reach groups: erosion - bank material	Polyline	Field data indicating severe erosion located within the channel and/or lower or upper banks	Auckland Council	2014	2002 - 2014	Nil	Moderate	WAR data collected by Morphum and other consultants until 2014	Limited coverage for the Auckland region	Incorporate WAR data from recent years
9.2	WAR Data Amalgamated: Ecoline	Reach groups: erosion - bank material and shade	Polyline	Reach based stream survey geometry and attribution including assessments on riparian vegetation, bank and channel material and modifications and stream bed substrate	Auckland Council	2014	2002 - 2014	Nil	Moderate	WAR data collected by Morphum and other consultants until 2014	Limited coverage for the Auckland region	Incorporate WAR data from recent years
9.3	Underground Services: Watercourse/Channels	Reach centrelines used to delineate main	Polyline	AC Corporate Watercourse and Channel network, a spatial layer from Auckland	Auckland Council	Ongoing, the dataset is live and	2017	Nil	High	Nil	Dataset does not provide the extent for all watercourses in the Auckland region	Creating a Geometric network which enables flow would be very useful, especially as it

ID	Name	Model Purpose	Data Type	Description	Source	Date Created	Year Represented	Modifications	Confidence	Metadata Summary	Data Deficiencies	Data Opportunities
		reach in each FWMT sub-catchment		Council public underground services		updated on an ongoing basis.						would allow gaps between branches to be closed where they are currently missing.
9.4	Freshwater Ecology NZ (FENZ)	Reach groups: shade	Polyline	Supporting information on New Zealand's rivers including descriptions of the physical environment and biological character and classifications that group together rivers and streams	Department of Conservation (DOC)	2010	2005-2008	Nil	Moderate	This set of river and stream attribute data was mostly created during the research that led (i) to the development of the Freshwater Environments of NZ classification, and (ii) to the modelling of freshwater fish and macro-invertebrate distributions by NIWA staff for all NZ rivers and streams over the period from 2005-2008. It also includes a small number of predictors that were developed as part of the original REC classification. In developing these attributes, strong emphasis was placed on the need for functionally relevant predictors of the distributions of species and/or ecosystems, while working within the limitations imposed by having to work with existing input data at national scales.	Different geometry to the FWMT streams may result in incorrect transfer of shade factors. FENZ data was created from a mix of GIS analysis, interpolation using statistical procedures, and/or field measurement. Errors are inherent in all of these procedures, and because of the large number of river segments only partial checking could be carried out.	Possible FENZ classification update with any new information collected
9.5	NZLRI Lithology	Reach groups: erosion - bank material	Polygon	Polygon layer delineating physiographic areas of relatively homogenous surface and near-surface lithology (rock type). This expression is segregated to identify the principal surface lithology and the principal underlying lithology.	NZ Land Resources Inventory	2008	Unknown	Query for igneous and sedimentary (indurated) dominant rock	Moderate	https://lris.scinfo.org.nz/layer/48066-nzlri-soil/	Nil	Nil
9.6	GNS Geology	Reach groups: erosion - bank material	Polygon	1:1 000 000 geological units data for New Zealand. The dataset comprises polygons with each polygon having attributes describing the type of geological unit, its content, name and age.	GNS Science	2013	1909 - 2013	Query for limestone, vitric tuff, volcanic sandstone, volcanic breccia, volcanic conglomerate	Moderate	https://data.gns.cri.nz/geology/	Coarse spatial accuracy (250m).	Nil
9.7	Vegetation	Reach groups: erosion - bank material and shade	Polygon	Non ground LiDAR extent polygons trimmed for building footprints	Morphum Environmental Ltd	2018	2006-2010	Converted raster to polygons and dissolved by <0.5m and >0.5m	High	Data generated from LiDAR delimiting non-ground features	Dated base data	An updated dataset in higher resolution (additional height bands within the data) would enable more detailed analysis and higher confidence in the output.
9.8	River Environment Classification (REC)	Reach groups: erosion - stream order	Polyline	REC is a system that classifies New Zealand's rivers at a range of spatial scales. It organises and maps information about the physical characteristics of New Zealand's rivers, including catchment climate, topography, geology and land cover.	The Ministry for the Environment (MfE) and various regional councils	2010	Unknown	Nil	Moderate	https://data.mfe.govt.nz/layer/51845-river-environment-classification-new-zealand-2010/	Differing geometry to the FWMT streams may result in incorrect transfer of stream order	Override data source with Auckland Councils Permanent Streams (2018) if stream order is attributed

Appendix B Limitations and recommendations register

Section Number:	Item:	Stage 1 Limitation	Stage 2 Recommendation	Priority	Scale of Effort
2.1: Sub-catchments	DEM	Sub-catchments polygons rather than DEM clipped to MWSH10	DEM would be improved by cropping to MHWS10 coastline instead of SW catchments coastline, thereby reinstating some initially excluded areas.	Low	Low
3.3 Sub-catchments	Sub-catchment delineation	Sub-catchments were manually adjusted for pipe diversions in urban areas. Only sub-catchments that had diversion pipes greater than 500mm were adjusted. Manual adjustments were subjective resulting in potential subjective error.	Development of a geometric network of all pipes and open channels for the Auckland region to automatically delineate sub-catchments with higher accuracy. A geometric network is a geospatial dataset that represents the stormwater drainage of catchments comprising of both the piped network and open watercourse network.	High	High
3.3 Sub-catchments	Sub-catchment delineation	Sub-catchments were manually adjusted for pipe diversions in urban areas. Only sub-catchments that had diversion pipes greater than 500mm were adjusted. Manual adjustments were subjective resulting in potential subjective error.	Develop and incorporate of a stream and pipe network conditioned DEM to automatically delineate sub-catchments with higher accuracy. This involves 'burning' in stream and pipe network to recondition the DEM to drain elevations towards streams and pipes. This will allow assignment of flow direction and accumulations to each grid according to elevation as well as will adjust the flow to account for infrastructure influences.	High	Medium
4.4: Existing devices	Accounting for Treatment	No existing treatment explicitly modelled due to lack of available information on performance and device design	Improve the corporate database of Treatment Facilities: source and compile best available Treatment Measure data including past Morphum projects on Auckland's stormwater assets.	High	Medium
4.4: Existing devices	Accounting for Treatment	No existing treatment explicitly modelled due to lack of available information on device catchments	WSP Opus has completed a Pond Capacity Design Standard Assessment (Taylor, 2019) which delineates device catchments and calculates water quality and extended detention runoff volumes of devices. Recommend incorporating data outputs from this study to better represent existing devices.	High	Low
4.5: Point source	Watercare's EOP models for the various treatment plants	Watercare's models have known issues and outdated networks and population data (some from 2006).	With many Watercare systems under construction (Central and Northern interceptors, Warkworth changes and recent developments), recommend updating the models with current input data for v2.0	Medium	High
4.5: Surface Water Takes	Centralised, current and complete Regional Water Takes and Discharges database.	Abstractions data is varied, missing and temporally inconsistent	Create a regional Water Takes database that is centralised and maintained by the respective custodians (AC, Watercare).	Medium	High

Section Number:	Item:	Stage 1 Limitation	Stage 2 Recommendation	Priority	Scale of Effort
4.7: Rural	Rural land cover and use base data set upgrade	Whilst Agribase and LCDB databases may suit defined purposes, neither contains adequate information on its own to accurately inform current rural land use at a level suitable for assessing contaminant loads, watercourse impacts and the effect of land use changes.	Development of an in-depth, spatially accurate and industry socialised rural land use layer	High	High
5.2 Channel Geometry	Channel Width, Depth and Bank Angles	Reaches without WAR survey information were parameterised with regional averages by land use, slope or catchment area.	Refined methods for average cross section extraction developed as part of pilot erosion susceptibility assessments can be utilised to estimate channel geometry	Medium	Medium
8.2: Soils	Soil seasonal response	Due to HRUs being a snapshot in time, the soils are classified as one hydrological soil group for the whole model run. Many soils have different responses at different times of the year i.e. Subsurface throughflow when dry and surface runoff (after cracks and pores saturate in winter and spring).	Configure soils to change HSG accordingly seasonally.	Medium	Medium
8.2: Soils	Urban soils	Blanket assumption given for all soils in urban areas. This method may work for some soils - such as for housing suburbs where a high percentage of section area is lawn or shrubbery with somewhat disturbed soil beneath. But for industrial areas and the CBD where small pervious areas are highly compacted, D might be appropriate.	Update soils layer to better reflect variability in urban soils. This could be tied to a policy intervention to promote preservation of soil during land development.	Low	Low
8.3: Land cover	Land cover	Land cover data incorporated from several data sources across time.	Explore machine learning/remote sensing technologies to create a homogenous land cover layer that is current and includes required land cover classes for the FWMT	High	High

Section Number:	Item:	Stage 1 Limitation	Stage 2 Recommendation	Priority	Scale of Effort
8.3: Rural	Splitting of AgriBase multipart polygons	Agribase has multipart polygons, particularly prevalent for large scale ownership of land. The separation of these multipart polygons and proportional sharing of the fields of animal numbers and land use results in parcels being allocated some animal attribute, but possibly not having any animals. The net effect is likely only slight under or over representation of animals in some sub-catchments.	AgriBase must distinguish farm type and animal counts per parcel, not per owner, to allow for better spatial identification of land use intensity.	Medium	Medium
8.3: Rural	Impervious extent on the urban fringe	The impervious surface extent (2008) is deficient for properties on the urban fringe.	If the impervious layer does not get updated in time for v2.0, there is an opportunity to estimate impervious land use composition based on average composition of similar developments for which there is adequate spatial data.	High	Medium
9.3: Erosion Reach groups	Bank material	Bank material classified as soft, moderate or hard using several data sources of varying accuracy.	Using a Neural Network Modelling approach to better identify stream bank material and erosion susceptibility. Neural networks use an iterative learning approach to identify the relationship between regionally mapped variables and a training dataset.	Low	Medium

Appendix C HSG mapping tables

Table 2. Hydrologic Soil Group based on Drainage Characteristics of Soils		
SERIES	**Drainage**	**HSG**
AAA	4b	D
AAB	4b	D
AB	4b	C
ACA	4a	C
ACB	4a	C
ACC	4b	C
AHA	2b	B
AHB	2b	B
AJ	2a	A+
Akeake	4b	D
AO	4b	C
Aponga	3b	C
Arapohue	3b	C
Ararimu	2c	B
Ardmore	4b	C
Atuanui	3a	B
Awana	4b	D
Awapuku	2d	B
Bald Hill	2d	B
BCB	4a	C
BD	3a	B
BE	3b	C
BG	3b	C
BHA	2b	B
BHB	2b	B
BJ	2a	A+
Bombay	2d	B
Bream	2d	C
Brookby	3b	C
BXE	3a	B
C1 complex	2b	B
C1A complex	2b	B
C4 complex	2b	B
CE	3b	C
CG	3b	C
CHB	2b	B
Clevedon	4b	C
Cornwallis	2d	C

Table 2. Hydrologic Soil Group based on Drainage Characteristics of Soils		
CX	3b	C
CXE	3b	C
DE	3b	C
DG	3b	C
DJ	2a	A+
Dome Valley	2d	C
DX	3b	C
DXE	3b	C
DXG	3a	B
EG	3a	B
EXG	3a	B
Hamilton	2a	A+
Horea	1b	B
Houhora	1a	A
Huia	2d	B
Hukerenui	3b	C
Hunua	2c	B
Kaipara	4b	C
Kairanga	4b	C
Kaitoke	4b	C
Kapu	2d	B
Kara	4b	C
Karaka	2b	B
Kiripaka	2a	A+
Konoti	3a	B
Mahurangi	3b	C
Manawatu	4a	B
Mangakahia	2b	B
Mangatawhiri	3b	C
Mangonui	2d	C
Marsden	1a	A
Marua	3a	B
Matakawau	2c	B
Maungaturoto	3b	C
Mercer	4b	D
Miranda	4b	D
Motatau	3b	C
Mount Rex	3b	C
Okaka	3a	B
Omaiko	3b	C
Omu	3b	C

Table 2. Hydrologic Soil Group based on Drainage Characteristics of Soils		
One Tree Point	4b	C
Opaheke	3b	C
Opita	2c	B
Orere	2b	B
Otao	2b	B
Otonga	4b	C
Papakauri	2a	A+
Parau	2d	B
Parore	4b	D
Patumahoe	2a	A+
Petekuku	1a	A
Pinaki	1a	A
Piroa	3b	C
Pollock	1b	B
Pongakawa	4b	C
Puhoi	3b	C
Pukekaroro	3a	B
Pukekohe	2d	B
Pukenamu	3b	C
Rangiora	3b	C
Rangitoto	2a	A+
Rangiuru	2d	C
Red Hill	1a	A
Rimutaka	3a	B
Rockvale	3b	C
Ruakaka	4b	C
Takahiwai	4b	D
Tangatara	3a	B
Tangitiki	1b	B
Tawharanui	4b	D
Tawharenui	4b	C
Te Hihi	4a	C
Te Kie	2d	B
Te Ranga	3a	B
Tikipunga	2a	A+
Torehape	2b	B
Waikare	3b	C
Waiotira	3a	B
Waiotu	2d	B
Waipu	4b	C
Waipuna	4b	C

Table 2. Hydrologic Soil Group based on Drainage Characteristics of Soils		
Waitakere	2d	C
Warkworth	3a	B
Weymouth	2b	B
Whakapara	4a	B
Whananaki	1a	A
Whangamaire	4b	C
Whangapoua	2b	B
Whangaripo	3b	C
Wharekohe	3b	C
Whareora	4a	C
Whatatiri	2d	B
Whatitiri	2d	B
Whirinaki	3a	B

Table 3. Hydrologic Soil Group based on S-Map Factsheets

SERIES	HSG
Ahuroa	B
Aroha	A
Churchill	B
Dunmore	A
Hauraki	D
Kaawa	B
Kauaeranga	C
Kohemarere	B
Maramarua	C
Okupata	C
Opani	D
Orton	D
Pakau	D
Piako	D
Pukekapia	C
Raglan	C
Rotongaro	D
Tukituki	B
Waikato	A
Whakapai	B
Whangape	C
Whatawhata	C

Appendix D Wastewater time-series

Memos and dataset hosted by Healthy Waters – available on request from fwmt@aucklandcouncil.govt.nz.

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
ARMY BAY MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm

From: Catherine Dagan; Tim Lockie (HAL)
Subject: Wastewater Overflow Time Series for the FWMT– Army Bay Model – Existing Development
Date: 12th February 2019

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Army Bay wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Army Bay wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

- This report should be read in conjunction with references **/1/** and **/2/**, which respectively detail the assumptions and limitations associated with the hydrological data, and the model update and the system performance of the Army Bay (Hibiscus Coast) SMA Model.
- The Army Bay SMA model provided by WSL has not been revised as part of this study; although the model is uncalibrated and based on an assumed hydrology, it is assumed that this model represents the best available model for the existing development at the time of the study. The key assumptions and limitations applied to the model are reproduced below in section 3.1.

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
MANGERE MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm
From:	Catherine Dagan; Tim Lockie (HAL)	
Subject:	Wastewater Overflow Time Series for the FWMT– Mangere Model – Existing Development	
Date:	25th February 2019	

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Mangere SMA wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Mangere SMA wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

See below for the key assumptions and limitations applied to this study:

- This report should be read in conjunction with references /1/ and /2/, which respectively detail the assumptions and limitations associated with the hydrological data and the Mangere SMA wastewater network model build and system performance.
- The Mangere model provided by WSL has not been revised as part of this study; it is assumed that this model represents the best available model for the existing development at the time of the study. The key assumptions and limitations applied to the model are reproduced below in section 3.1.
- A wastewater network model is based on several assumptions and as such the simulated performance should be considered indicative of actual performance. Further as much of the Mangere SMA Model

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
PUKEKOHE MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm

From: Catherine Dagan; Tim Lockie (HAL)
Subject: Wastewater Overflow Time Series for the FWMT– Pukekohe Model – Existing Development
Date: 12th February 2019

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Pukekohe wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Pukekohe wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

- This report should be read in conjunction with references /1/, **Error! Reference source not found.** and /3/, which respectively detail the assumptions and limitations associated with the hydrological data, the Pukekohe wastewater network model build, and the model update and system performance.
- The Pukekohe model provided by WSL has not been revised as part of this study; it is assumed that this model represents the best available model for the existing development at the time of the study. The key assumptions and limitations applied to the model are reproduced below in section 3.1.
- Further to the limitations identified above. A wastewater network model is based on several assumptions and as such, the simulated performance should be considered indicative of actual performance. In addition, the Pukekohe Model was developed based on gauged network flows collected in 2009.

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
ROSEDALE MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm
From:	Catherine Dagan; Tim Lockie (HAL)	
Subject:	Wastewater Overflow Time Series for the FWMT– Rosedale Model – Existing Development	
Date:	12th February 2019	

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Rosedale wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Rosedale wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

- This report should be read in conjunction with references **/1/**, **/2/** and **/3/**, which respectively detail the assumptions and limitations associated with the hydrological data, the model build / validation, and the system performance of the Rosedale SMA Model.
- The overflows in the Rosedale SMA are of 3 types:
    - Engineered Overflow Point (EOP) (Type 1 & 2)
    - Uncontrolled Overflows (Type 3)
    - Uncontrolled Loading Node Overflows, which are recommended to be excluded from the analysis (cf. Section 3.5 for details).

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
WAIUKU MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm

From: Catherine Dagan; Tim Lockie (HAL)
Subject: Wastewater Overflow Time Series for the FWMT– Waiuku Model – Existing Development
Date: 12th February 2019

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Waiuku wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Waiuku wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

See below for the key assumptions and limitations applied to this study:

- This report should be read in conjunction with references /1/ and /2/, which respectively detail the assumptions and limitations associated with the hydrological data and the Waiuku wastewater network model build and system performance.
- The Waiuku model provided by WSL has not been revised as part of this study; it is assumed that this model represents the best available model for the existing development. The key assumptions and limitations applied to the model are reproduced below in section 3.1.
- A wastewater network model is based on several assumptions and as such, the simulated performance should be considered indicative of actual performance. Further as much of the Waiuku Model hydrology

WASTEWATER OVERFLOW TIME SERIES FOR THE FWMT
WARKWORTH MODEL – EXISTING DEVELOPMENT

To:	Coral Grant John Riverson Caleb Clarke	Auckland Council (AC) Paradigm Morphum
Distribution:	Tim Hopley Maria Utting Dustin Bambic	Auckland Council (AC) Watercare Services Limited (WSL) Paradigm

From: Catherine Dagan; Tim Lockie (HAL)

Subject: Wastewater Overflow Time Series for the FWMT– Warkworth Model – Existing Development

Date: 12th February 2019

1 Introduction

1.1 Memo Objective

The objective of this memo is to detail the activities completed to produce a simulated 15-year long-term time series wastewater overflow record from the Warkworth wastewater network model for existing development.

1.2 Memo Scope

The scope of this memo includes:

- Summary of the Warkworth wastewater network model,
- Applied hydrological data,
- Model Setup, and
- Summary of model results and applicability.

1.3 Assumptions and Limitations

- This report should be read in conjunction with references /1/ and /2/, which respectively detail the assumptions and limitations associated with the hydrological data and the Warkworth wastewater network model.
- The Warkworth model provided by WSL has not been revised as part of this study; it is assumed that this model represents the best available model for the existing development at the time of the study. The key assumptions and limitations applied to the model are reproduced below in section 3.1.
- The model review, cf. /2/, mentions several issues with the current Warkworth model. Based on the uncertainty of model predictions, it is recommended to exclude the uncontrolled overflows from the FWMT analysis.

Appendix E Land use impacts

Legend of table below	
Impact	**Description**
0	Split LUIDs. Impact will be assigned at a later stage of the HRU build process
1	Low (relatively low impact area)
2	High (or Medium, depending on LUID)
3	High (Irrigated-Parameterised the same as 2, but irrigation will be turned on)
Split_ GRP	Values with "0" have Impact assigned directly from this table
	Values >0 are subdivided at a later stage of the HRU build process (as numbered)
0	PCTIMP=0: Used as-is from GIS. "Impact" used as defined here.
0	PCTIMP=1: Used for DCIA with "Impact" used as defined here. Split_GRP 1 record(s) further subdivided as described below.
1	Iron Roofs (split after applying DCIA conversions)
2	Rural Landuse Split

Land use	Reclassified land use	Impact	Split group
Pervious:None	Open_Space	1	2
ROAD_VPD:<1000	Dev_Road	1	0
ROAD_VPD:1000-5000	Dev_Road	2	0
ROAD_VPD:5000-20000	Dev_Road	3	0
ROAD_VPD:20000-50000	Dev_Road	4	0
ROAD_VPD:50000-100000	Dev_Road	5	0
ROAD_VPD:>100000	Dev_Road	6	0
Roof_Type:Iron	Dev_Roof	0	1
Roof_Type:Tile	Dev_Roof	1	0
Roof_Type:Other	Dev_Roof	1	0
Paved_Surface:Commercial	Dev_Commercial	1	0
Paved_Surface:Residential	Dev_Residential	1	0
Paved_Surface:Industrial	Dev_Industrial	1	0
Paved_Surface:OpenSpace	Dev_Pervious	1	0
Paved_Surface:Rural	Dev_Pervious	1	0
Waterbodies:Water	Water	1	0
Cereal crops	Horticulture	3	2
Dairy - Irrigated and dry land pasture	Pasture	2	2
Estuary and marine	Forest	1	2
Exotic forest/plantations	Forest	1	2
Exotic Grassland	Open_Space	1	2
Green houses flowers and nurseries	Horticulture	3	2
Idle/unclassed	Horticulture	1	2

Land use	Reclassified land use	Impact	Split group
Lifestyle blocks	Pasture	1	2
Mine and bare ground	Mine_Barren	1	0
Native forest	Forest	1	2
Native grassland and conservation	Open_Space	1	2
Orchards	Horticulture	1	2
Pervious	Horticulture	1	2
Pigs poultry and other	Pasture	1	2
Sheep beef and deer	Pasture	1	2
Tourism areas	Open_Space	1	2
Ungrazed high producing exotic pasture	Open_Space	1	2
Vegetables	Horticulture	3	2
MetalledROAD_VPD:<1000	Road_Rural	1	0
MetalledROAD_VPD:1000-5000	Road_Rural	2	0
MetalledROAD_VPD:5000-20000	Road_Rural	3	0
MetalledROAD_VPD:20000-50000	Road_Rural	4	0
UnMetalledROAD_VPD:<1000	Road_Rural	1	0
UnMetalledROAD_VPD:1000-5000	Road_Rural	2	0
UnMetalledROAD_VPD:5000-20000	Road_Rural	3	0
UnMetalledROAD_VPD:20000-50000	Road_Rural	4	0
Pervious:Grasses<50cm	Open_Space	1	2
Pervious:Grasses<50cm - Cereal crops	Horticulture	3	2
Pervious:Grasses<50cm - Dairy - Irrigated and dry land pasture	Pasture	2	2
Pervious:Grasses<50cm - Estuary and marine	Forest	1	2
Pervious:Grasses<50cm - Exotic forest/plantations	Open_Space	1	2
Pervious:Grasses<50cm - Exotic Grassland	Open_Space	1	2
Pervious:Grasses<50cm - Green houses flowers and nurseries	Horticulture	3	2
Pervious:Grasses<50cm - Idle/unclassed	Open_Space	1	2
Pervious:Grasses<50cm - Lifestyle blocks	Pasture	1	2
Pervious:Grasses<50cm - Mine and bare ground	Mine_Barren	1	0
Pervious:Grasses<50cm - Native forest	Forest	1	2

Land use	Reclassified land use	Impact	Split group
Pervious:Grasses<50cm - Native grassland and conservation	Open_Space	1	2
Pervious:Grasses<50cm - Orchards	Horticulture	1	2
Pervious:Grasses<50cm - Pervious	Open_Space	1	2
Pervious:Grasses<50cm - Pigs poultry and other	Pasture	1	2
Pervious:Grasses<50cm - Sheep beef and deer	Pasture	1	2
Pervious:Grasses<50cm - Tourism areas	Open_Space	1	2
Pervious:Grasses<50cm - Ungrazed high producing exotic pasture	Open_Space	1	2
Pervious:Grasses<50cm - Vegetables	Horticulture	3	2
Pervious:Vegetation>50cm	Forest	1	2
Pervious:Vegetation>50cm - Cereal crops	Horticulture	3	2
Pervious:Vegetation>50cm - Dairy - Irrigated and dry land pasture	Pasture	2	2
Pervious:Vegetation>50cm - Estuary and marine	Forest	1	2
Pervious:Vegetation>50cm - Exotic forest/plantations	Forest	1	2
Pervious:Vegetation>50cm - Exotic Grassland	Open_Space	1	2
Pervious:Vegetation>50cm - Green houses flowers and nurseries	Horticulture	3	2
Pervious:Vegetation>50cm - Idle/unclassed	Forest	1	2
Pervious:Vegetation>50cm - Lifestyle blocks	Pasture	1	2
Pervious:Vegetation>50cm - Mine and bare ground	Mine_Barren	1	0
Pervious:Vegetation>50cm - Native forest	Forest	1	2
Pervious:Vegetation>50cm - Native grassland and conservation	Open_Space	1	2
Pervious:Vegetation>50cm - Orchards	Horticulture	1	2
Pervious:Vegetation>50cm - Pervious	Forest	1	2
Pervious:Vegetation>50cm - Pigs poultry and other	Pasture	1	2

Land use	Reclassified land use	Impact	Split group
Pervious:Vegetation>50cm - Sheep beef and deer	Pasture	1	2
Pervious:Vegetation>50cm - Tourism areas	Forest	1	2
Pervious:Vegetation>50cm - Ungrazed high producing exotic pasture	Open_Space	1	2
Pervious:Vegetation>50cm - Vegetables	Horticulture	3	2

Find out more: fwmt@aucklandcouncil.govt.nz

Auckland Council
Te Kaunihera o Tāmaki Makaurau