Muriwai Downs Golf Project

Appendix C - Surface Water Effects Assessment Report

THE BEARS HOME PROJECT MANAGEMENT LIMITED

WWLA0321 | Rev. 5

WWLA

Muriwai Golf Project

Project no:	WWLA0321
Document title:	Appendix C - Surface Water Effects Assessment Report
Revision:	5
Date:	8 December 2021
Client name:	The Bears Home Project Management Limited
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File name:	G:\Shared drives\Projects\Bears Home Project Management Ltd\WWLA0321_Muriwai Downs Golf Project\Deliverables\Reports\2. Surface Water Effects Assessment Report\Report_Water_Effects_Assessment - Rev 5.docx

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Document history and status

Rev	Date	Description	By	Review	Approved
1	20 Aug 2021	First draft for project team review	Elise Legarth, Josh Mawer	Josh Mawer, Jon Williamson	Jon Williamson
2	02 Nov 2021	Updated to address project team feedback	Josh Mawer	Jon Williamson	Jon Williamson
3	25 Nov 2021	Updated to address further project team feedback	Josh Mawer	Jon Williamson	Jon Williamson
4	1 Dec 2021	Updated to address further project team feedback	Josh Mawer	Jon Williamson	Jon Williamson
5	8 Dec 2021	Updated to address further project team feedback	Josh Mawer	Jon Williamson	Jon Williamson

Distribution of copies

Rev	Date issued	Issued to	Comments
1	20 Aug 2021	The Bears Home Project Management Limited, Mitchell Daysh	First draft for project team review
2	02 Nov 2021	The Bears Home Project Management Limited, Mitchell Daysh, Buddle Findlay	Updated to address project team feedback
3	25 Nov 2021	The Bears Home Project Management Limited, Mitchell Daysh, Buddle Findlay	Updated to address further project team feedback
4	1 Dec 2021	The Bears Home Project Management Limited, Mitchell Daysh, Buddle Findlay	Updated to address further project team feedback
5	8 Dec 2021	The Bears Home Project Management Limited, Mitchell Daysh, Buddle Findlay	Updated to address further project team feedback

Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) was commissioned by The Bears Home Project Management Limited (Applicant) in January 2021 to prepare a water effects assessment report to support a resource consent application for the partial conversion of the Muriwai Downs farm to a Golf Course, Clubhouse, Sports Academy and Lodge development (Project).

The objectives of the scope of works were to understand and provide the following:

- Description of the existing surface water resource environment in terms of catchment characteristics, flow, and Total Nitrogen (TN) and Total Suspended Solids (TSS) concentrations.
- Description of anticipated positive and any potential adverse surface water related effects associated with the Project's construction and operation.

These objectives were realised through the development of catchment models to simulate streamflow, TN, and TSS. Two scenarios were simulated, the historic base case, and the proposed golf course infrastructure development.

This report is one of a series of technical reports prepared by WWLA for the Project.

Collectively, the WWLA reports are summarised in WWLA (2021) Water Effects Summary Report. The technical reports are appended to the summary report.

This report does not address surface water matters relevant to Lake Ōkaihau as these are addressed in a separate report (WWLA, 2021 – Appendix E).

1.1 Project Overview

The Applicant is proposing the establishment of a golf resort facility located on the Muriwai Downs Farm property (Property). The existing farm site is approximately 507 hectares and located approximately 3 km north east of Muriwai Beach Township. The Property comprises predominantly pastoral farmland (sheep and beef, and dairy), and contains isolated pockets of high value ecological resources such as wetlands and native forest with stands of Kauri trees.

Figure 1. Location Overview. (Refer to A3 attachment at rear).

1.2 Report Structure

The report comprises descriptions of:

- Catchment Characteristics (**Section 2**);
- Catchment Modelling (**Section 3**);
- Constituent Modelling (**Section 4**);
- Scenario Simulation (**Section 5**); and
- Recommendations (**Section 6**).

2. Catchment Characteristics and Available Data

The catchment physical characteristics influence both catchment flow and water quality. An understanding of the catchment physical characteristics is therefore an important step in developing catchment flow and water quality models. For example, porous and permeable soils (e.g. sand) tend to have high infiltration and thus a higher proportion of baseflow rather than flashy surface runoff dominated events. Conversely, impermeable soils (e.g. clays) typically exhibit very flashy hydrological regimes. The different hydrological processes (baseflow and surface runoff) subsequently influence water quality generation and transportation pathways.

The following sub-sections provide an overview of the Ōkiritoto Stream catchment physical characteristics and available data used in defining these characteristics and parameterisation of the catchment flow and water quality model.

2.1 Geology

New Zealand Geological Map (QMap) was used to provide an overview of the surface geology within the Property and surrounding surface water catchments. The majority of the catchment is sandstone (Neogene sedimentary rocks) with small areas of mudstone (Holocene River deposits) and a single area of basalt (Neogene igneous rock).

A detailed description of surface and subsurface geology is provided in the Assessment of Groundwater Effects report (WWLA, 2021 – Appendix E).

Figure 2. Geology. (Refer to A3 attachment at rear).

2.2 Climate

Evaporation and rainfall data were obtained from the National Institute of Water and Atmospheric Research (NIWA) virtual climate station network (VCSN). The VCSN data provides estimates of climate variables on a 5 km regular grid, covering all of New Zealand. Estimates of climate parameters are produced for each VCSN point on a daily time-step based on spatial and temporal interpolation of recorded observation data at the nearest reliable meteorological sites. Daily rainfall and potential evapotranspiration were used in the Soil Moisture Water Balance Model (SMWBM) (**Section 3.2**) and daily minimum and maximum temperature, solar radiation, and rainfall were used in the Agricultural Production SIMulator (APSIM) model.

Estimates of daily rainfall and evaporation were obtained from VCSN Site 21836, located approximately 2 km south of the Property. A summary of annual rainfall and evaporation for this location is presented in **Figure 3**. Further analysis of climate data on a monthly basis is detailed in Section 2.1.2 of WWLA (2021 – Appendix B).

VCSN data was used in preference to nearby rain gauge data, as it provides a long duration (i.e., 1972 to present), and a continuous daily dataset, with no periods of missing data. The use of a long duration climate record is important to ensure climatic variation is represented within the assessment.

The two nearest rain gauges are located at Muriwai Golf Course, and in Kumeū Township. Both gauges are operated by Auckland Council, and have operated since August 2013 and December 1999, respectively. A high-level comparison of overlapping periods of the VCSN data and two rain gauge datasets showed the VCSN rainfall data to be within +/- 15% of the two rain gauges.

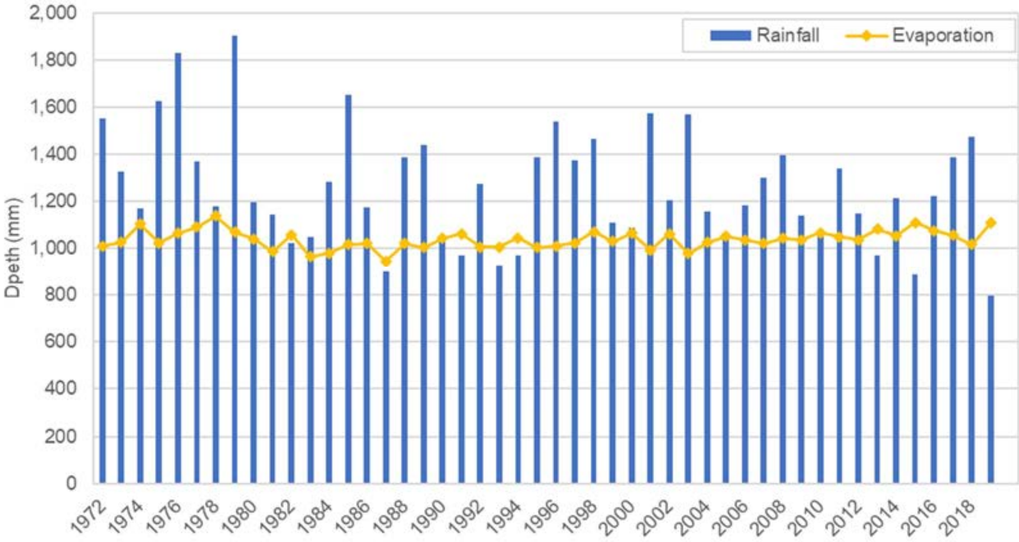

Figure 3. Annual rainfall and evaporation (1972-2021) – VCSN# 21836.

2.3 Soils

The GNS Fundamental Soils Layer (FSL) indicates three main soil types across the catchment; Waitematā Sandy/Silt Loam, Red Hill Sandy Clay Loam, and Waitākere Clay. Soil texture is predominantly classified as sand clay loam, however in the east clay and clay loam dominate. Soil depths range from 0.89 to 1.5 m, and permeability is classed as medium in the west and medium slow in the east.

Figure 4. Soil texture. (Refer to A3 attachment at rear).

The broad scale soil classifications provided by the FSL were seen to be consistent with the more detailed soil mapping and assessment presented in the Muriwai Golf Project: Effect on Soils report (AEE – Appendix 8).

In addition, data from the Auckland Council's Soil Information Inventory was used to define soil physical and hydraulic characteristics (e.g. soil depth, bulk density, field capacity, C:N ratio, % organic carbon, soil albedo and bare soil run off curve number). Data from the Fundamental Soils Layer, Tiaki Farm Environment Plan (Farm Source, 2020) and communication with Steve Marsden of Steve Marsden Turf Services were incorporated into the assessment (Golf Course Construction, Operation and Maintenance Report – AEE Appendix 3, and Soils Report – AEE Appendix 8). Application of these soil parameters within the APSIM model are further detailed in **Section 4**.

2.4 Topography

Auckland Council's 2016 LiDAR data was obtained and utilised to gain an understanding of the local site topography, and across the wider surface water catchments that form the Ōkiritoto Stream. The topography of the catchment is shown in **Figure 5**.

Within the Property itself, the topography is generally characterised as gently rolling, with an incised river channel along the northern edge of the Property. In general, the wider Ōkiritoto Stream catchment is characterised as rolling hills. Across the wider catchment, elevations range from approximately 10 to 200 m NZVD2016, with the highest elevations occurring in the headwaters to the south-west.

Figure 5. Topography. (Refer to A3 attachment at rear).

2.5 Land Use

The Land Cover Database (LCDB v5), developed by Landcare Research, is a temporal classification of land use cover across the whole of New Zealand, updated on five-yearly intervals, and is available for 2012 and 2018. The LCDB 2018 land use map was used a starting point to map land use across the catchment, and further refined based on local aerial imagery and wetland mapping provided by RMA Ecology (ecological consultants as part of the Project team for the Project). The current state land use map (i.e. prior to Project being implemented) is displayed in **Figure 6**.

Figure 6. Ōkiritoto Catchment land use. (Refer to A3 attachment at rear).

2.6 Flow and Water Quality Monitoring

In order to ensure the catchment flow and water quality models sufficiently represented the Ōkiritoto Catchment's current flow and water quality regime, the models were calibrated to a range of measured flow and water quality data.

As part of the Project, a flow and water quality monitoring programme was developed, and monitored over the period late March 2021 to late July 2021. Full details of the monitoring programme are described in WWLA (2021 – Appendix A) and key monitoring sites referred to throughout this report displayed in **Figure 7**.

Figure 7. Monitoring sites. (Refer to A3 attachment at rear).

In addition to the flow monitoring undertaken specifically for the Project, a limited number of spot gauging (i.e. instantaneous spot measurements of flow) were obtained from Auckland Council. Spot gaugings were available from five locations (**Figure 7**) and are summarised in **Table 1**. Although limited in number, these spot gaugings provided a secondary level of verification for the catchment flow model.

Table 1. Auckland Council spot gauge flow measurements.

Site	Number of Measurements	Period
44902	19	1976 - 1998
44903	17	1976 – 1998
44904	17	1976 – 1998
44906	3	1987
44907	2	1987

3. Catchment Modelling

As alluded to in **Section 2** above, catchment models were developed to simulate the historic streamflow regime of the Ōkiritoto Stream catchment, based on historical climate data. The following sub-sections describe the development of the catchment flow model.

3.1 SOURCE Overview

SOURCE is a hydrological modelling platform developed by eWater in Australia. The platform is comprised of a range of models and tools designed to simulate all aspects of water resource systems at a range of spatial and temporal scales. The models and tools include:

- Rainfall-runoff models;
- Water demand models; and
- Constituent generation, retention, transport and decay models.

The fundamental architecture of a SOURCE model comprises a series of connected sub-catchments and drainage networks. SOURCE uses nodes with connecting links that enable the user to control the route of flow and (hydrological and constituent) processes that occur along the flow path.

3.2 SMWBM Overview

The Soil Moisture Water Balance Model (SMWBM) is a semi-deterministic rainfall-runoff model. Model functionality includes surface ponding function, evaporation functions for differing land cover, vadose zone unsaturated flow and travel time, and an irrigation demand module. The version of the model utilised for this Project is denoted as SMWBM_VZ, to reflect the incorporation vadose zone processes (water flow through the unsaturated soil zone).

The SMWBM_VZ was developed into a plugin specific for use as the rainfall runoff model within the SOURCE framework. Within SOURCE, the SMWBM_VZ plugin allows catchment parameters to be set for each of the model sub-catchments, transforming the SMWBM_VZ from a semi-deterministic lumped parameter model into a powerful conceptual distributed model.

The model utilises daily rainfall and monthly evaporation input data to calculate the soil moisture conditions under natural rainfall conditions, and under different irrigation schemes. The model operates on a daily time step during dry days, however when rain days occur, a finer hourly calculation step is implemented to enable peak flows to be assessed more accurately than a daily time step model.

The SMWBM_VZ plugin version utilised in the Project incorporates parameters characterising the catchment in relation to the following processes:

- Interception storage;
- Evaporation losses;
- Soil moisture storage;
- Surface runoff;
- Soil infiltration;
- Sub-soil drainage;
- Flow in the unsaturated zone;
- Stream base flows; and
- The recession and/or attenuation of ground and surface water flow components.

A schematic overview of the SMWBM_VZ, and description of model parameters is provided in **Appendix A**.

3.3 Catchment Delineation

The SOURCE catchment model comprises a series of interconnected sub-catchments that were discretised to reflect the localised physical characteristics of each catchment. This was achieved through identifying areas with similar catchment characteristics, including geology, slope, soil type and land use. In addition, sub-catchments were delineated based on the key flow and water quality monitoring sites as shown in **Figure 7**, and presented in WWLA (2021 – Appendix A).

3.4 SMWBM Parametrisation

WWLA have undertaken a number of similar catchment wide water quantity and water quality modelling projects completed for Bay of Plenty Regional Council for the Kaituna and Rangitāiki catchments (WWLA, 2020a, 2020b), and for Wairakei Pastoral for the catchments between Lake Taupō and Aratiatia Gates (WWLA 2020c, 2020d), and Hawke's Bay Regional Council for the TANK and Ruataniwha catchments (WWLA, 2018; WWLA 2020e). Through these projects, relationships were developed relating SMWBM parameters to catchment physical characteristics. For example, relating the infiltration rate (Zmax parameter) to the soil texture.

These existing relationships were used as a starting point for parameterising the SMWBM, and then further refined and calibrated against site specific local measured flow data (discussed in **Section 2.6** above). The final calibrated model parameter relationships are presented in **Appendix A** of this report, and flow calibration plots presented in **Section 3.5**.

3.5 Flow Calibration

Following the configuration of the SOURCE sub-catchments, rainfall-runoff models were configured for each SOURCE sub-catchment using the SMWBM plugin. The SMWBM parameter values were initially selected based on the individual sub-catchment characteristics with subsequent refinement during the calibration process, which is described in the sections below.

The model was calibrated to the measured flow at the three flow monitoring sites between February to July 2021, although graphs are presented for a full year of simulated flow from June 2020. The calibration process was carried out systematically working downstream. Calibration simulations were repeated multiple times, with SMWBM parameter values manually adjusted in each subsequent run until the highest level of flow calibration that could practically be achieved was produced. The parameter adjustment process maintained a consistent relationship between the model parameters and the physical characteristics of the sub-catchment, which ensured that parameter changes were made in a physically realistic and logical way.

In addition, a secondary calibration check was carried out using the limited historic spot gauging data obtained from Auckland Council dating back to 1977. The secondary flow calibration plots of the simulation period from 1977 to 2021 are presented in **Appendix B** of this report.

3.5.1 Flow Site 1

Flow Site 1 is located on the Raurataua Stream which is the largest tributary of the Ōkiritoto Stream catchment entering the Property. A comparison of the modelled and measured flow hydrograph is presented in **Figure 8**. This shows the simulated flow generally matched the measured rated flow dataset well, and also matched the spot flow gaugings closely.

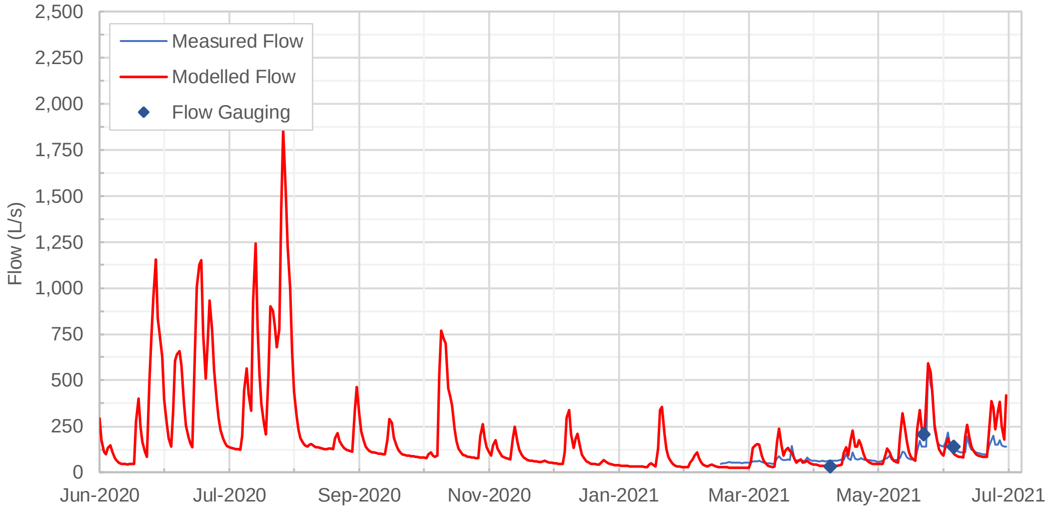

Figure 8. Comparison of modelled flow hydrographs for Flow Site 1.

3.5.2 Flow Site 2

Flow Site 2 is located on the Ōkiritoto Stream, upstream of the confluence with the Raurataua Stream. A comparison of the modelled and measured flow hydrograph for this site is presented in **Figure 9**. This shows simulated flows tended to generally match the measured rated flow dataset well. Although, it appears the low summer flows may be slightly under-simulated. However, it is noted that the site-specific rating curve is thought to over-estimate low flows at this location as the low flow velocity gauged flow on 4 May 2021, was closer to the simulated flow than the rated flow estimate. Overall, the flow calibration achieved at Flow Site 2 is considered reasonable and appropriate.

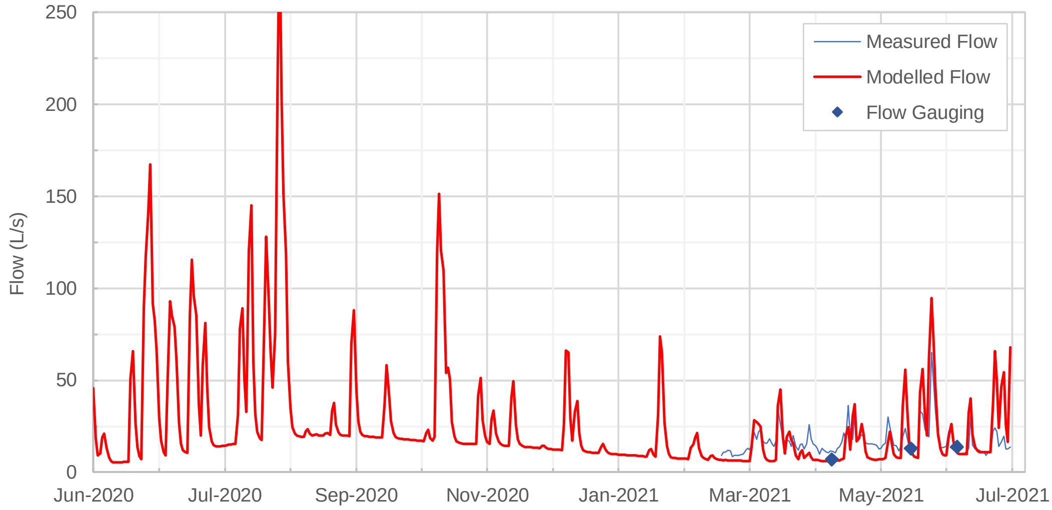

Figure 9. Comparison of modelled flow hydrographs for Flow Site 2.

3.5.3 Flow Site 3

Flow Site 3 is located on the Ōkiritoto Stream, at the downstream extent of the Property, and therefore includes tributaries that join the mainstem within the Property. A comparison of the modelled and measured flow hydrograph this site is presented in **Figure 10**. This shows simulated flow matched the measured rated flow data well and demonstrated good agreement on both the rising and falling limb of rainfall events.

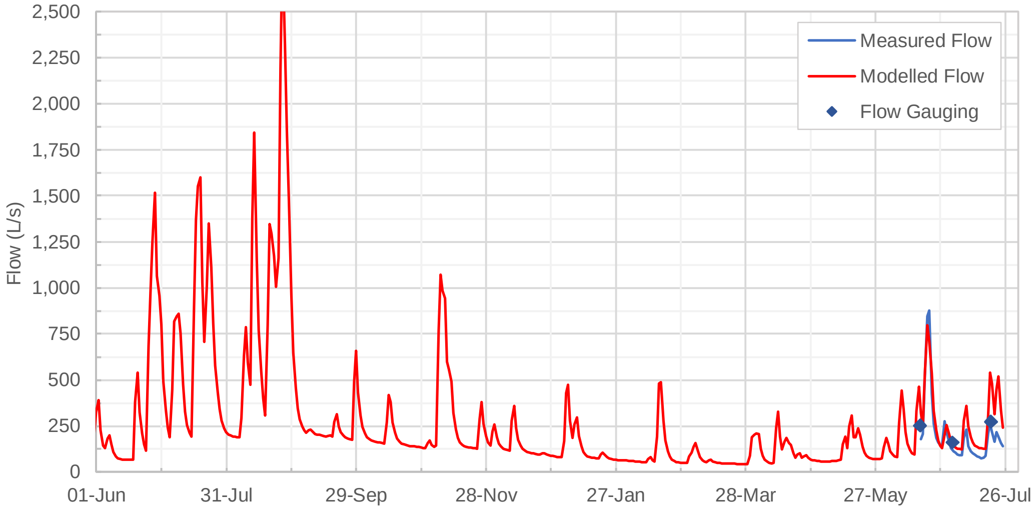

Figure 10. Comparison of modelled flow hydrographs for Flow Site 3.

3.5.4 Overall Statement on Flow Model Calibration

The Flow Model is considered appropriate for the purposes of catchment scale water quantity and water quality analyses. The model showed good agreement to the temporal variability of measured flow (i.e. response to rainfall events), with some "unders" and "overs" in peak magnitude. Small discrepancies in the magnitude of flow are often typical in catchment scale flow modelling and represents a degree of uncertainty in the model itself, plus uncertainty in model input data –for example, the use of VCSN rainfall data in the absence of a local rain gauge installed on site.

Quantitative measures of flow model calibration such Nash-Sutcliffe Efficiency (NSE) was not calculated due to the relatively short period of monitoring data available, and the sensitivity of these statistics to small datasets.

Overall, the catchment flow model is considered fit for purpose.

Streamflow monitoring at the point of take for the proposed high-flow surface water take (**Section 5.1.2 below**) will likely be required as a consent condition (should consent be granted for the golf course development). For this reason, we recommend continuing with streamflow monitoring at Flow Site 1 only. This further monitoring data could be used to provide further verification of the catchment flow models in the future if required.

4. Constituent Modelling

Following development of the catchment flow model, the constituent models were configured in SOURCE for each of the anticipated major land uses described in **Section 4.1**. Constituents are defined as the materials that are generated, transported, and transformed within a catchment and when mixed with catchment flow can influence water quality. The constituent models simulate the generation, transport, and transformation of the constituents.

Similar to the parameterisation of the SMWBM, the constituent models were developed used existing constituent generation techniques, and relationships relating catchment physical characteristics to catchment constituent generation, from a range of previous similar projects undertaken across New Zealand. These were then refined to and calibrated to site specific water quality data collected across the Property (detailed in WWLA, 2021 – Appendix A).

Due to the differing generation mechanisms, transformations, and transport pathways from catchment to the stream network for each constituent, individual constituent models were utilised as follows:

- TN baseflow generation was simulated using the Agricultural Production Systems SIMulator (APSIM) model, as described in **Section 4.2**;
- TN quickflow was simulated using an index based on catchment characteristics (**Section 4.3**); and
- TSS was simulated using the Dynamic SedNET model plugin (**Section 4.6**).

During the constituent calibration process, simulated constituent concentrations were compared against measured constituent data, and constituent generation parameters fine-tuned in order to achieve the best agreement between modelled and measured in-stream constituent concentrations as possible.

An overview of the configuration of the constituent models within SOURCE is provided in **Appendix C** to **Appendix E** of this report.

4.1 Current and Proposed Land Uses

Within the catchment models, the following land uses were represented in the baseline (current) and future scenarios as outlined in **Table 2**

Table 2. Modelled land uses.

Basecase Scenario	Future Scenario
Dairy	Sheep & Beef
Sheep & Beef	Pasture (Sheep & Beef Excluded)
Pasture (Sheep & Beef Excluded)	Forest / Vegetation
Forest / Vegetation	Golf Course Greens
Impermeable Surfaces (e.g. Roads)	Golf Course Fairways
	Impermeable Surfaces (e.g. Roads)

Configuration and parameterisation of these land uses is detailed in the sub-sections below.

4.2 TN Baseflow Simulation

APSIM is a modelling framework developed to simulate biophysical processes in agricultural systems comprising a system model configured from component modules. These modules include a diverse range of crops, pastures, trees, and soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls. APSIM is continuously being developed as a tool for the evaluation of alternative management strategies for improving the economics of land use change and the consequences for the soil resource and the environment.

The baseflow component of TN included in this study included the sub-soil drainage and leaching, and subsequent groundwater transport including vertical percolation to groundwater and horizontal saturated groundwater flow.

A schematic overview of the key TN processes and pathways represented within the SOURCE model is displayed in **Figure 11**.

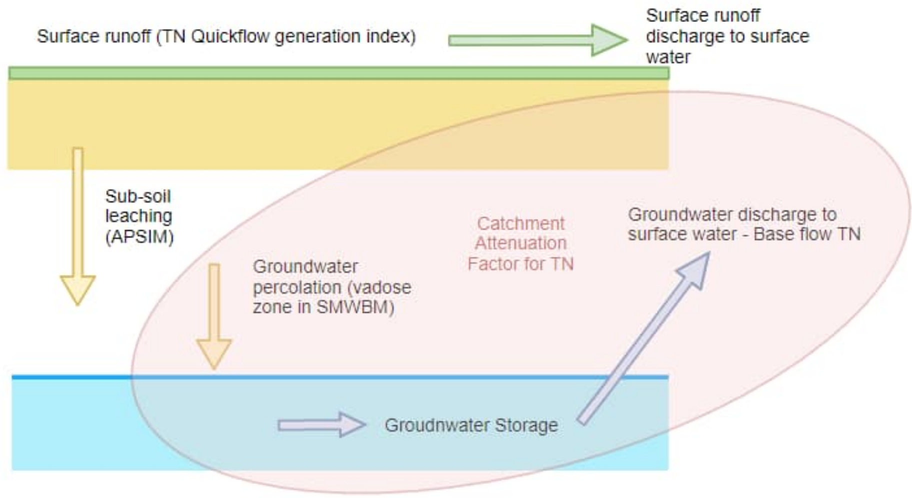

Figure 11. Schematic of TN process represented in the SOURCE model.

APSIM models were configured, representing dairy, sheep and beef, pasture (sheep and beef excluded), and golf course land uses. These land uses were selected as they are predominant current and future land uses of the Property and have significantly different management requirements. However, in the wider catchment additional land uses exist. Properties with horses were represented as sheep and beef, as they are considered to likely have similar levels of N leaching. Forest and areas of vegetation were represented as a single forest / vegetation dataset, which was adapted from the background sheep and beef sub-model (a background sheep and beef model that did not include stocking units or fertiliser inputs). Similarly, the background sheep and beef model excluding fertiliser inputs was used to represent the fringes of the golfing area where stock would be excluded from grazing.

APSIM generates a daily times-series of TN leaching in the units of mass per hectare per day(kg/ha/day) for each land use. To incorporate these into SOURCE an aggregation process was used to combine the simulated TN loads for each land use in each sub-catchment. After the individual land uses were aggregated to provide an area weighted average TN value for the sub-catchment, the daily mass was then converted into a daily concentration using the vadose zone process described **Appendix D** of this report.

4.2.1 Benchmarking Drainage with SMWBM

The APSIM hydrological model - SoilWat - simulates the movement of water and nutrients within the soil zone. Although the hydrological model within APSIM simulates a number of the same processes as the SMWBM, they are simulated using different methods and techniques. Therefore, it was important to confirm the sub-soil drainage simulated by the two models were similar before applying the load of TN leached from the soil as predicted by APSIM to the baseflow component of the flow regime as predicted by the SMWBM in SOURCE.

A comparison of the daily drainage rates between APSIM and the SMWBM model is presented **Figure 12**, and **Table 3**. This shows that in general there is reasonably good agreement between the two in terms of magnitude and timing. The magnitude of peak summer (i.e. periods of low drainage / percolation) match well, while APSIM occasionally overstimulated drainage / percolation in comparison to the SMWBM.

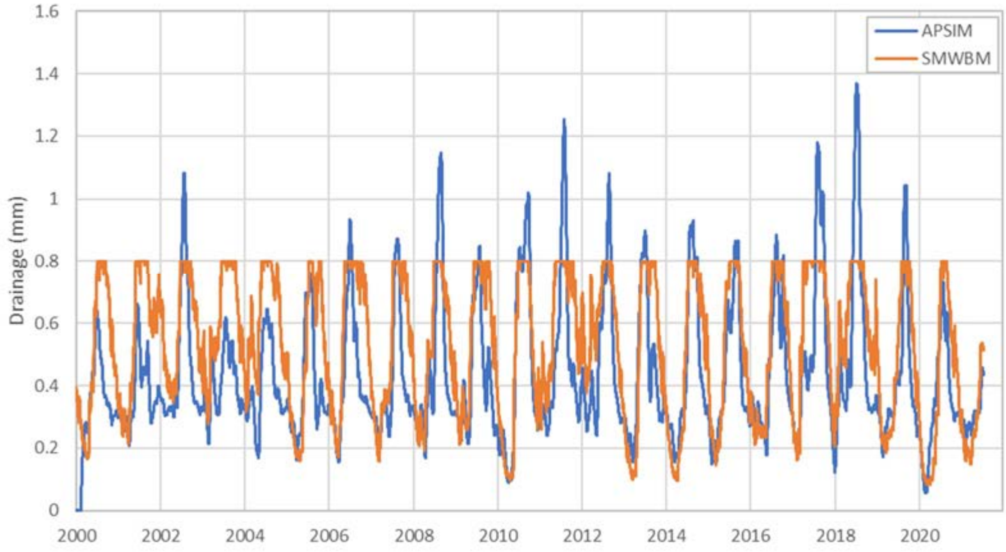

Figure 12. Comparison of SMWBM and SoilWat drainage for a representative catchment within the property.

Table 3. Comparative summary drainage (mm/day) statistics for the APSIM and SMWBM models.

Model	Min	Max	Mean	Std. Dev.
APSIM	0.057	1.37	0.43	0.22
SMWBM	0.084	0.80	0.53	0.22

4.2.2 Benchmarking N Leaching

The model was first benchmarked against nitrate (NO_3-N) leaching for Sheep and Beef, and Dairy land use types based on nitrogen balance estimations from FARMAX, and typical literature values of N leaching. Summary statistics of simulated N leaching are presented in **Table 4**.

The simulated mean annual leaching rate of 76.8 kg/ha/year is similar to the estimated Nitrogen balance from the Muriwai Downs FARMAX model of 84 kg/ha/yr. No farm specific information was available for leaching rates from sheep and beef land use. However, the simulated mean annual leaching rate of 36 kg/ha/year for sheep and beef is consistent with the typical range expected for New Zealand (Meener, et. al., 2004).

Table 4. Descriptive statistics of mean annual NO_3-N leaching.

Land use	Mean Annual NO_3-N leaching (kg/ha/year)						
	Mean	Standard Deviation	Minimum	25^{th} percentile	50^{th} percentile	75^{th} percentile	Maximum
Dairy	76.8	31.0	2.4	52.9	79.3	98.5	147.8
Sheep and Beef	36.0	16.2	0.8	24.6	36.6	47.5	78.2
Golf Course Greens	67.9	12.6	18.7	60.3	66.7	76.3	96.0
Golf Course Fairways	9.4	1.5	2.9	8.7	9.2	10.3	13.2

4.3 TN Quick Flow Simulation

Quick flow also provides a pathway for the transport of TN to surface waterways. TN quick flow operates on parcels of land which have poorly drained or sloping soils or in response to significant rainfall events. Quick flow is an intermittent process (as opposed to baseflow which is continuous) that can cause temporarily large increases in TN loads when the pathway operates. The generation of the surface runoff component of TN was simulated through the development of a TN generation index, which characterised each sub-catchment based on slope, stocking rate and vegetation cover.

The TN generation index was based on the following factors which were considered the key controls affecting the supply of TN directly to surface waters via quick flow:

- **Slope** – It is assumed that runoff generated in catchments with steeper slopes will transport TN more readily due to the erosivity across the surface compared to flat land.
- **Vegetation cover** – It is assumed that increased vegetation density will likely produce a buffer, and act to limit the quick flow transport of TN to the river and stream network.
- **Stocking Rate** – It is assumed higher stocking rates correlate to higher fertiliser application and dung and urine patches and therefore, more TN available to be mobilised. Stocking rate was derived from actual farm numbers for each month for sheep and beef and dairy and was set to zero for the golf course model.

The TN generation index was then calculated as the weighted sum of the three catchment properties for each sub-catchment. A weighting factor of four, one and eight were assigned to the area weighted catchment average slope, vegetation cover and stocking rate, respectively.

4.4 TN Catchment Attenuation Factor

Attenuation of TN occurs in the groundwater system and riparian margin due to a combination of factors such as biogeochemical transformations (e.g. denitrification, volatilisation etc.). Mass loss also occurs via instream processes including various biological growth-related uptakes e.g. bacteria, riparian plants and submerged macrophytes. In particular, wetlands remove significant amounts of nitrogen through denitrification.

These processes are not explicitly simulated in the model and are therefore accounted for by applying a scaling factor (referred to as the “Catchment Attenuation Factor” (CAF)). This was used as a calibration factor that was applied on a spatially variable basis to reduce simulated groundwater TN concentrations to match the measured baseflow concentrations.

4.5 TN Calibration Results

As described in **Section 2.6** above, an extensive baseline water quality monitoring programmed was conducted over the period February to July 2021, with both routine and wet weather event sampling undertaken. Analyses of water quality samples were undertaken by Analytica Laboratories and used to calibrated the water quality model.

The location of the water quality sampling sites is presented in **Figure 7**, and the calibration plot for each site presented in turn below (**Figure 13** to **Figure 20**). In general, simulated TN concentrations match those measured reasonably well, with elevated concentrations occurring in response to rainfall events, and generally low concentrations during periods of dry conditions.

In general, the level of calibration demonstrated is considered appropriate for the purposes of assessing relative land use change impacts. Caution is advised in considering absolute changes in TN concentration, until the model could be verified against a longer period of monitoring data (i.e. multiple years).

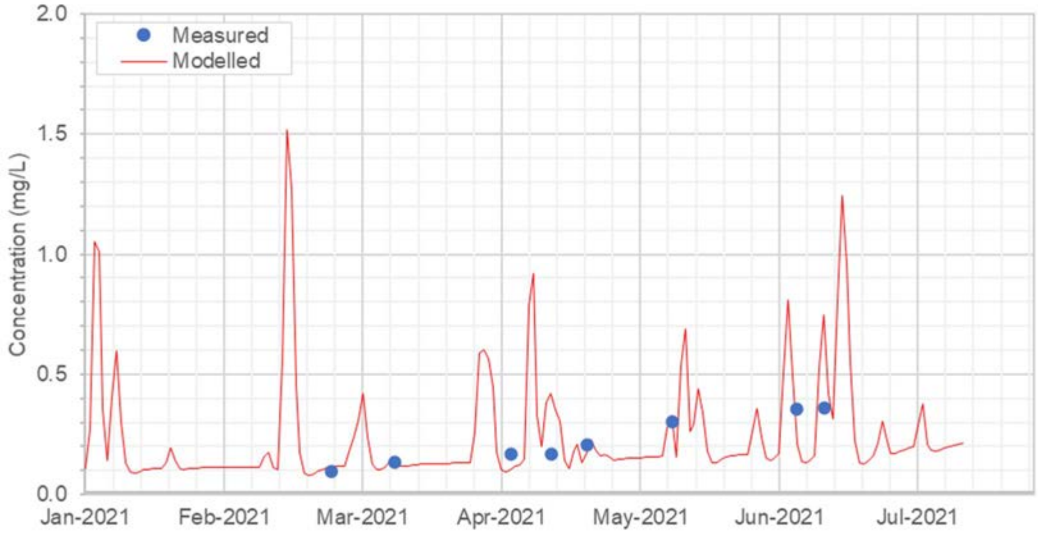

Figure 13. Monitoring Site A – TN calibration plot.

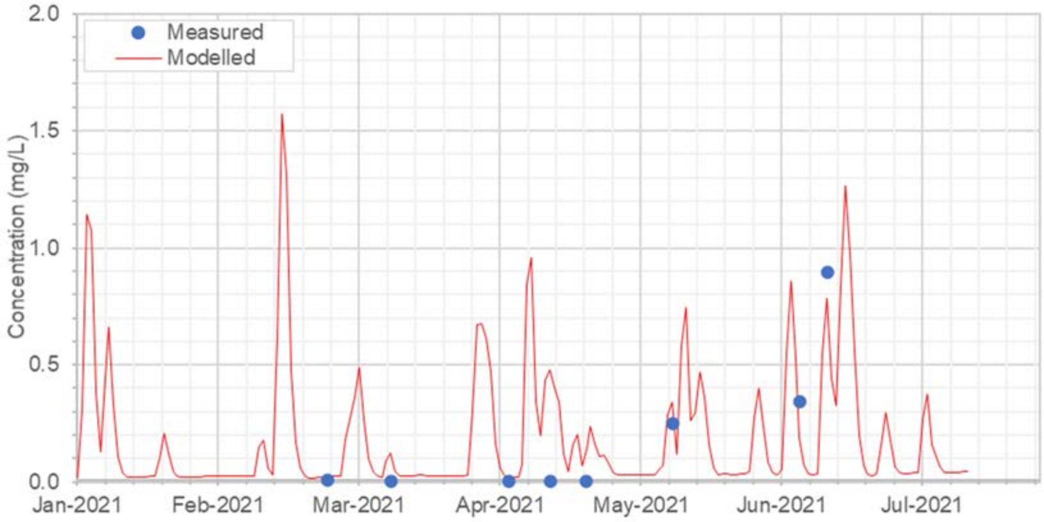

Figure 14. Monitoring Site B – TN calibration plot.

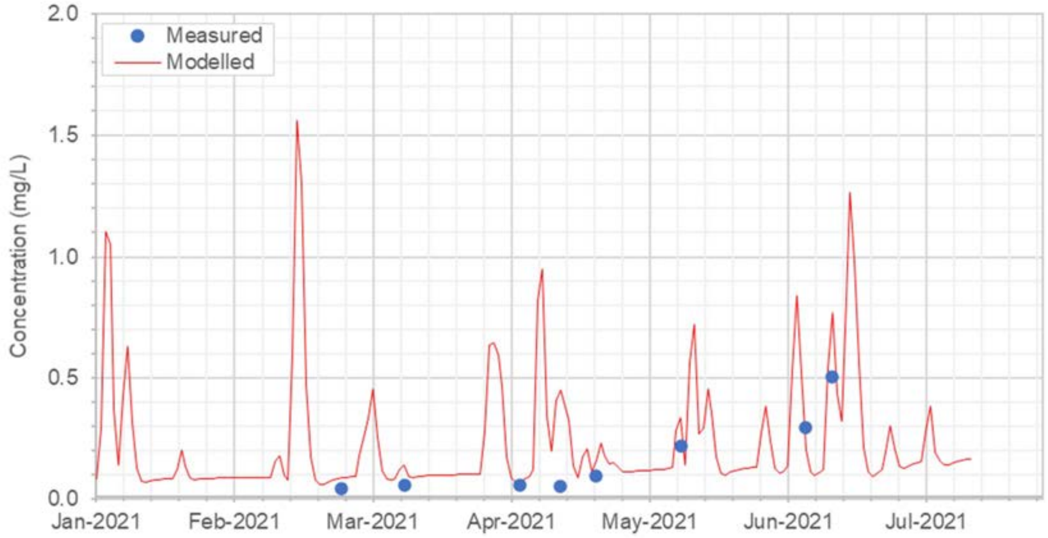

Figure 15. Monitoring Site C – TN calibration plot.

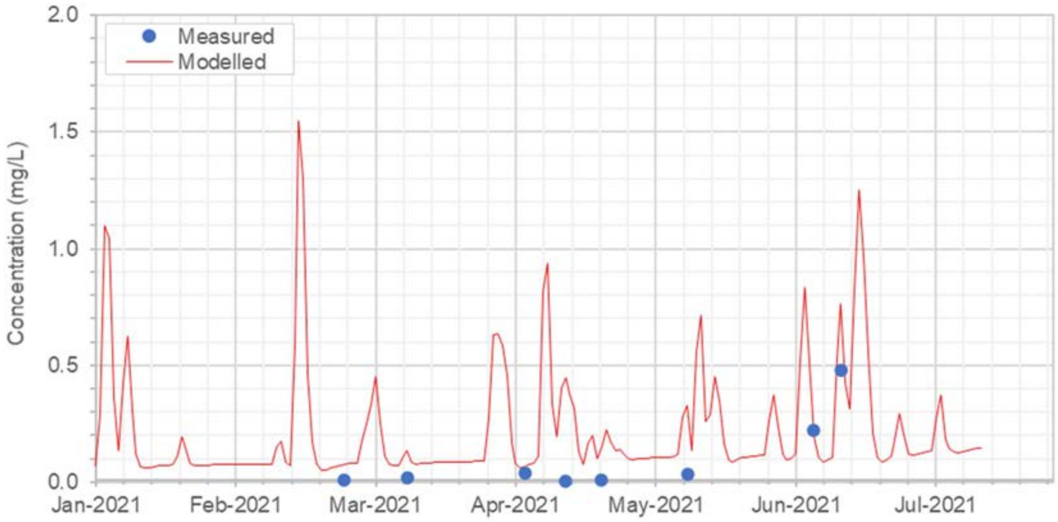

Figure 16. Monitoring Site D – TN calibration plot.

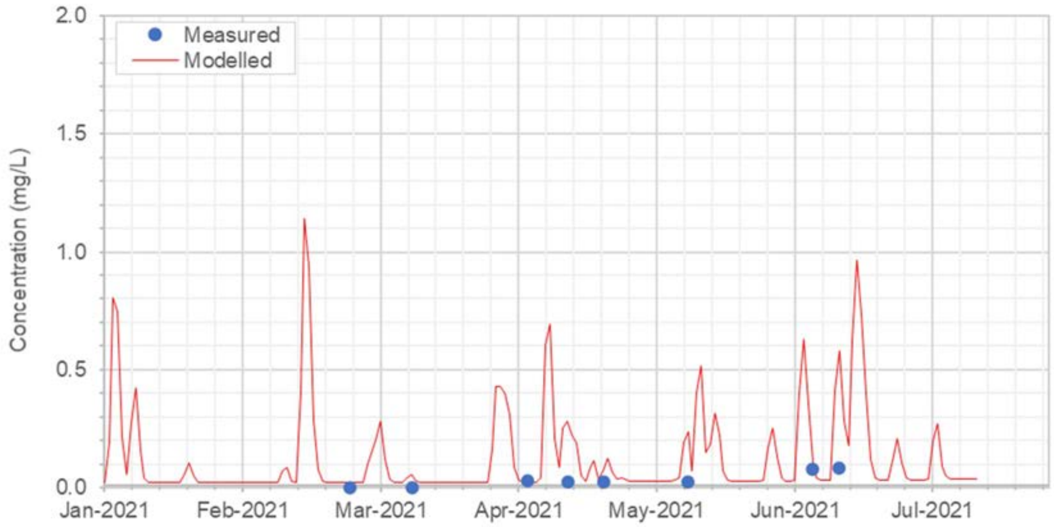

Figure 17. Monitoring Site E – TN calibration plot.

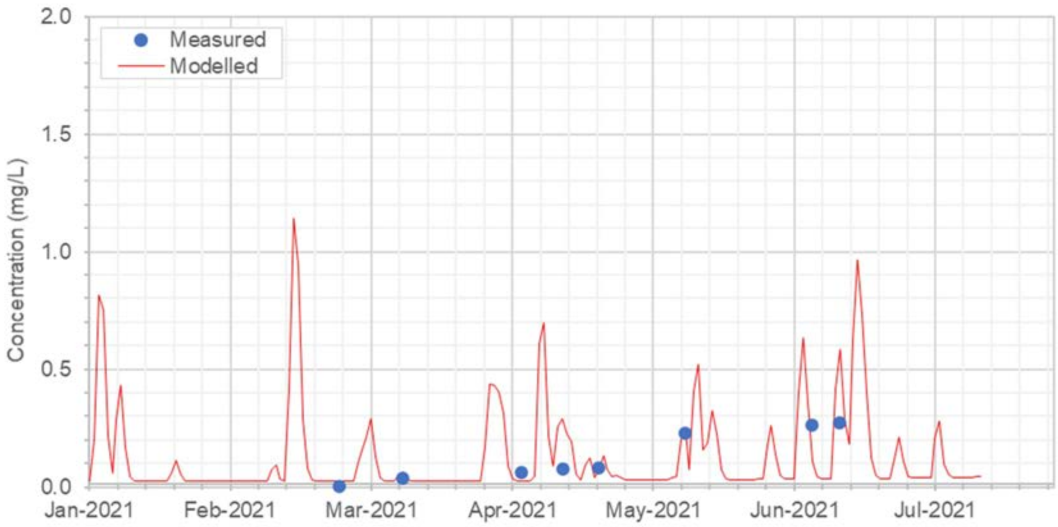

Figure 18. Monitoring Site F – TN calibration plot.

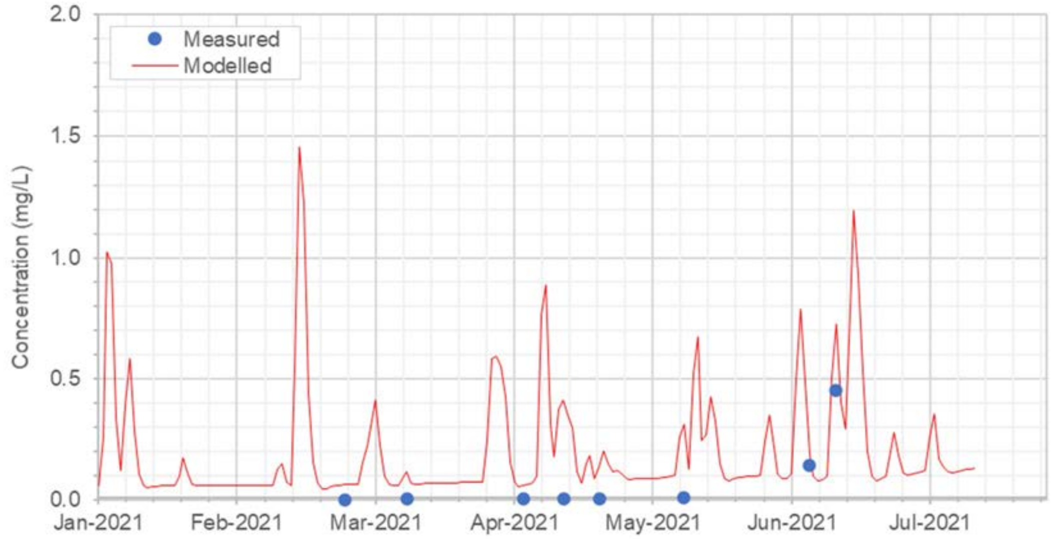

Figure 19. Monitoring Site G – TN calibration plot.

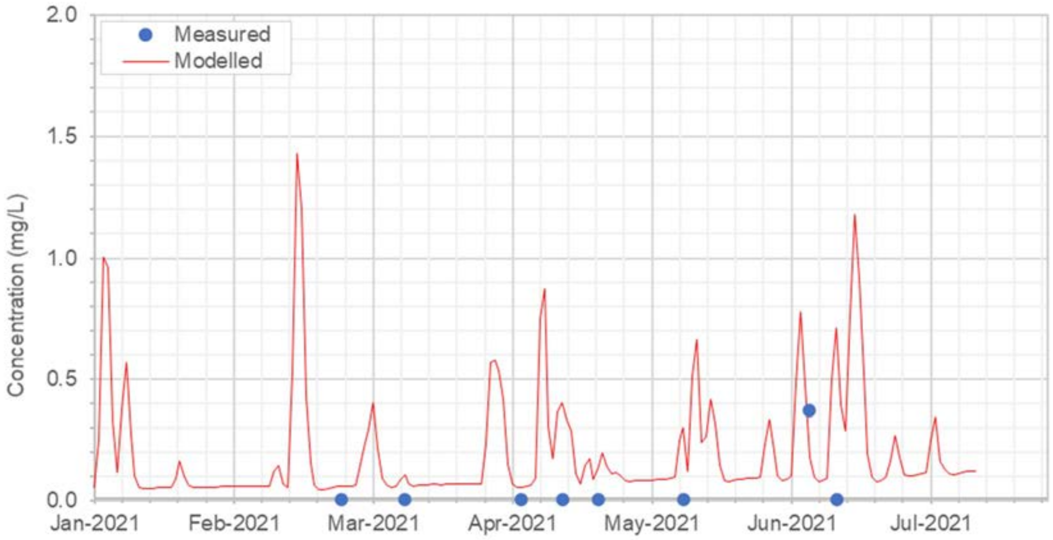

Figure 20. Monitoring Site H – TN calibration plot.

4.6 Total Suspended Solids

TSS refer to the material in a stream network that is held in suspension due to the turbulence and velocity of the water. TSS typically include fine particles such as clay and silt, organic matter, and under high flows, occasionally sand and coarser material. Sediment generation and the delivery of sediment to the stream network can be caused by natural erosion process and through a range of anthropogenic processes associated with land use, land management practices, and land disturbance. TSS in streams and rivers can significantly degrade the ecological health by reducing light infiltration, suffocating sediment sensitive flora and fauna, and causing significant build up and sediment deposition in low velocity areas.

4.6.1 dSedNET Overview

TSS was modelled using Dynamic SedNET (dSedNET). dSedNET is a SOURCE plugin, designed to simulate the generation and transportation of sediment through a hydrological network on a daily time scale. It is applied as a constituent generation model and simulates sediment generation and delivery processes from surficial hillslope and gully erosion separately. The model operates by generating mean annual hillslope erosion loads, using the Modified Universal Soil Loss Equation (MUSLE). The loads are then disaggregated internally to produce daily sediment concentrations using the rainfall and runoff component of SOURCE (the SMWBM).

While dSedNET is primarily a sediment generation model, it has been calibrated against measured total suspended solids data. Therefore, dSedNET was applied to provide a representation of all total suspended solids, rather than only the suspended sediment component. For this Project only hillslope erosion processes were generated, and it was assumed that gully erosion was implicitly included in the calibration outputs for hillslope processes by calibrating to measured instream TSS concentration data. We consider this is an appropriate assumption. The assumption and approach have been accepted and successfully used on a number of similar recent projects, such as the Kaituna and Rangitāiki SOURCE modelling project for Bay of Plenty Regional Council (WWLA, 2020a), and the Ruahuwai Decision Support Tool for Wairakei Pastoral (WWLA, 2020c).

The derivation of model parameters is described in **Appendix E**.

4.6.2 TSS Calibration Results

Similar to the calibration process for TN, TSS was calibrated to the project specific environmental baseline water quality monitoring data, collected between February to July 2021. In comparison to TN, TSS typically exhibits a larger range in concentrations over time and can naturally vary by an order of magnitude. Elevated concentrations typically occur during wet weather when flows are higher, which results in greater entrainment and transportation of sediment and bed materials.

TSS calibration plots are presented for each of the stream water quality monitoring sites in turn below (**Figure 21** to **Figure 27**). In general, simulated TSS concentrations were similar in magnitude to those measured at each site. It is noted that elevated TSS concentrations occurred at Sites B, C, E in late February, which were not simulated by the model. A longer period of environmental monitoring during wet weather events would be required to further understand the likely frequency and typical magnitude of these higher concentration events.

Overall, given the level of calibration achieved, the model’s ability to simulate TSS is considered appropriate for the purposes of assessing relative changes in TSS in response to land use change. However, the model's ability to predict absolute concentrations throughout the stream network is not considered appropriate, as high temporal frequency sampling over a range of wet weather events would be required for further model calibration.

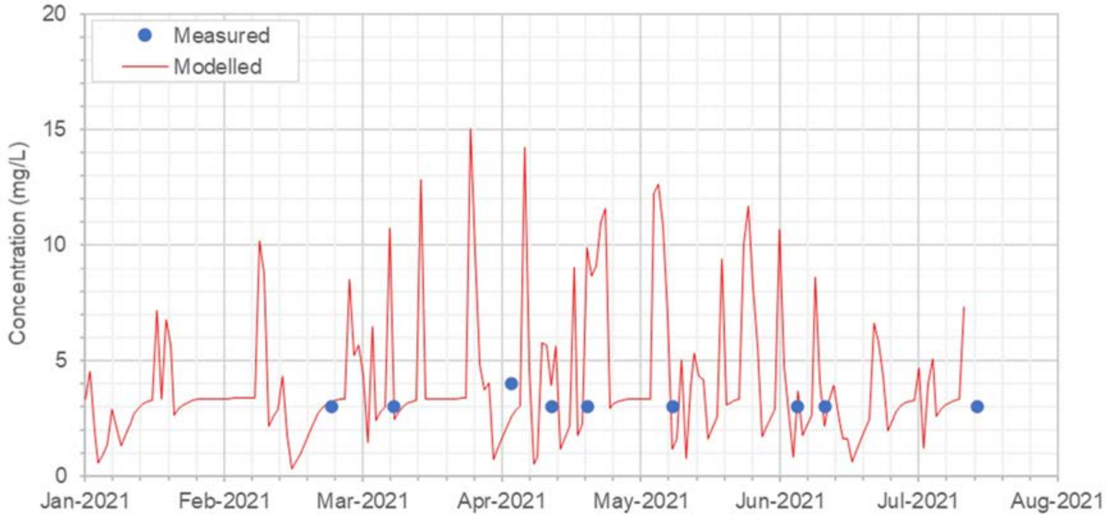

Figure 21. Monitoring Site A – TSS calibration plot.

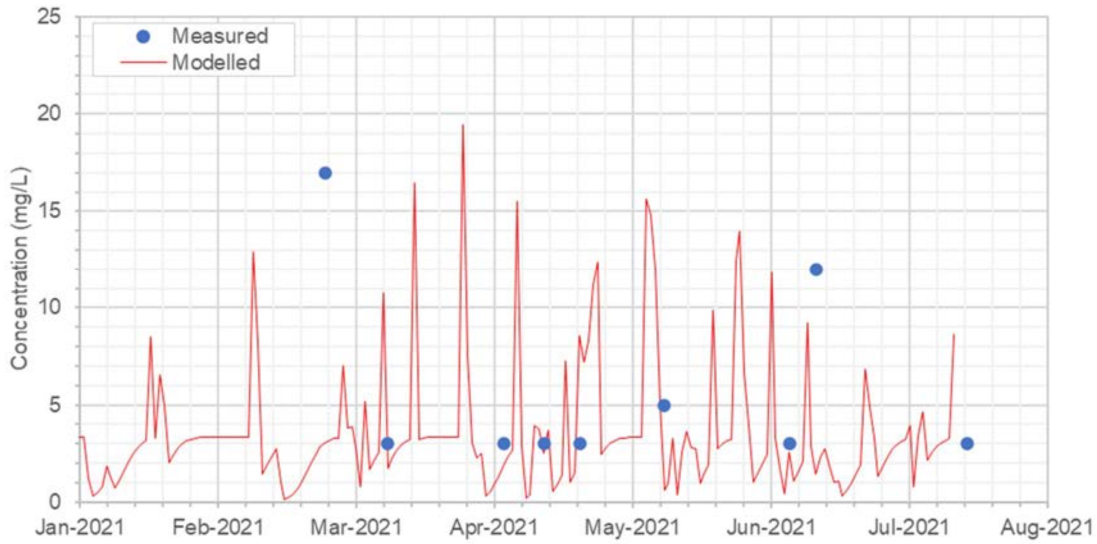

Figure 22. Monitoring Site B – TSS calibration plot.

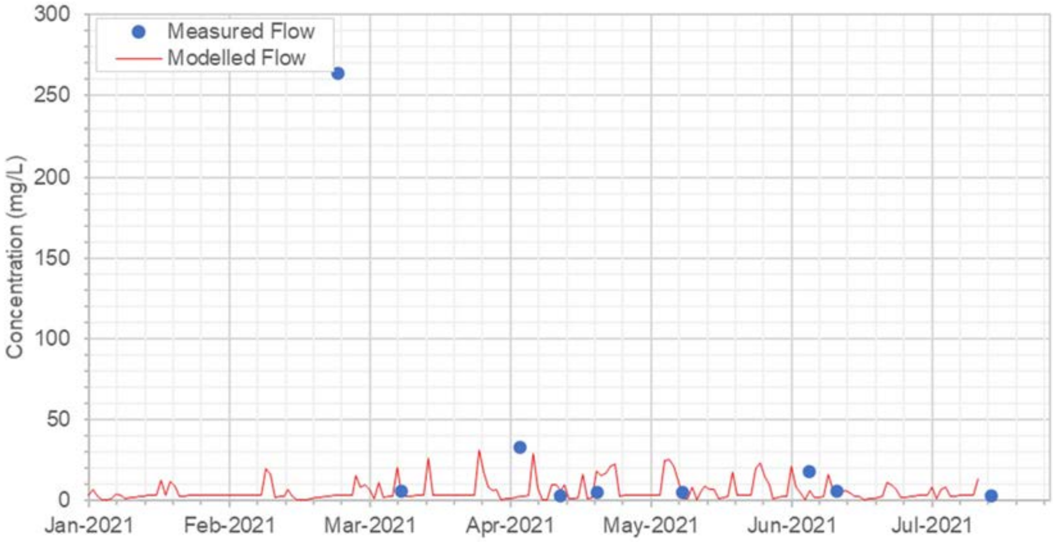

Figure 23. Monitoring Site C – TSS calibration plot.

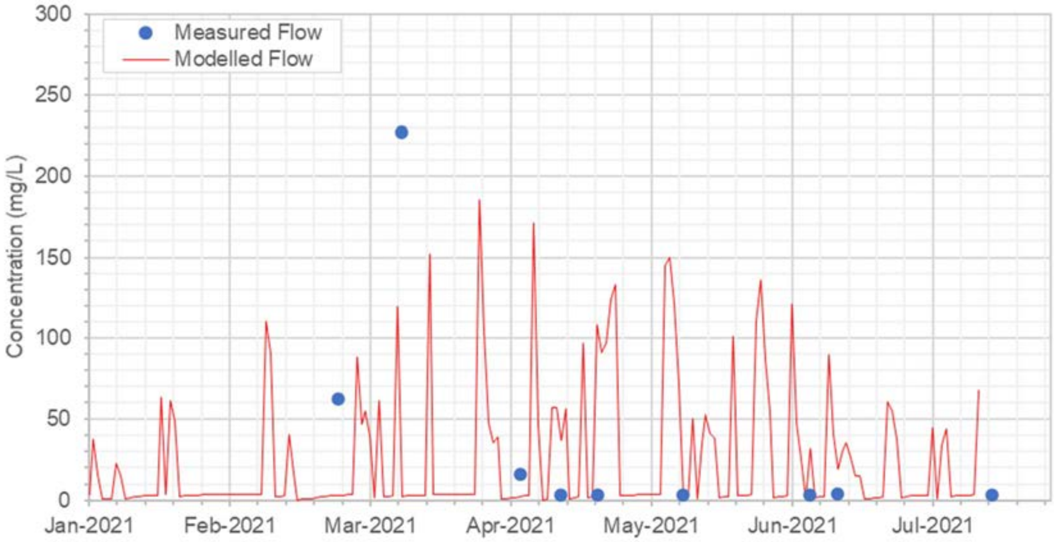

Figure 24. Monitoring Site D – TSS calibration plot.

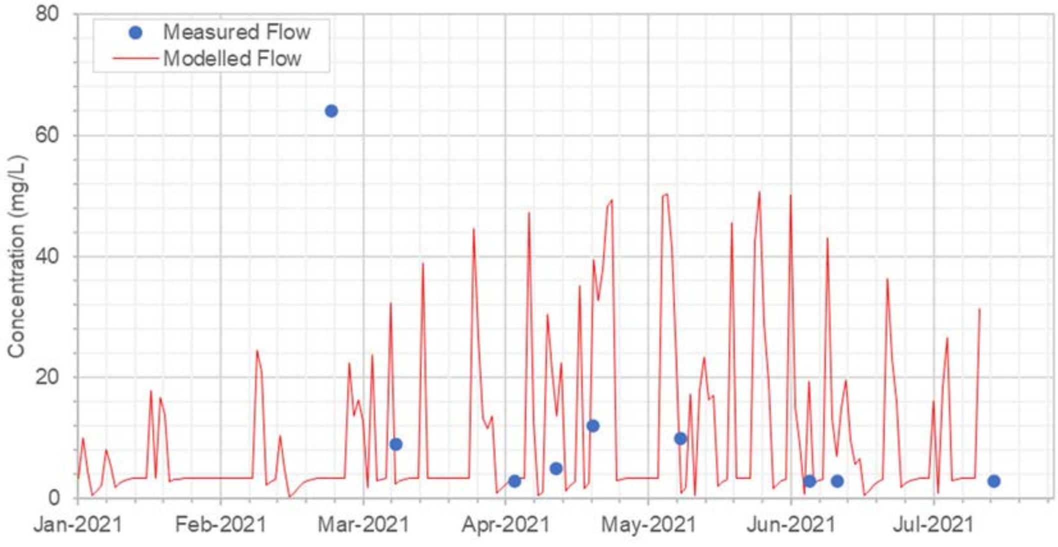

Figure 25. Monitoring Site E – TSS calibration plot.

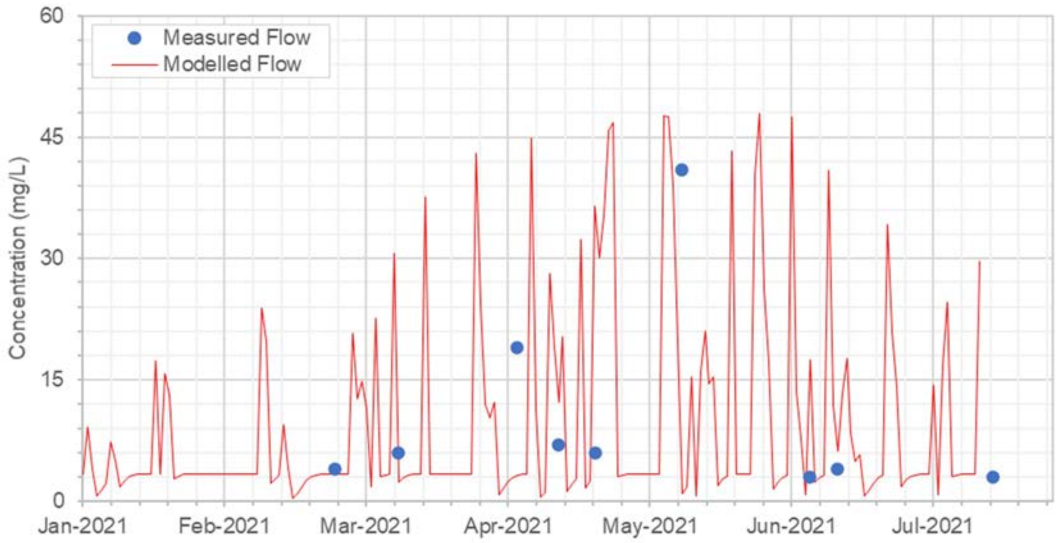

Figure 26. Monitoring Site F – TSS calibration plot.

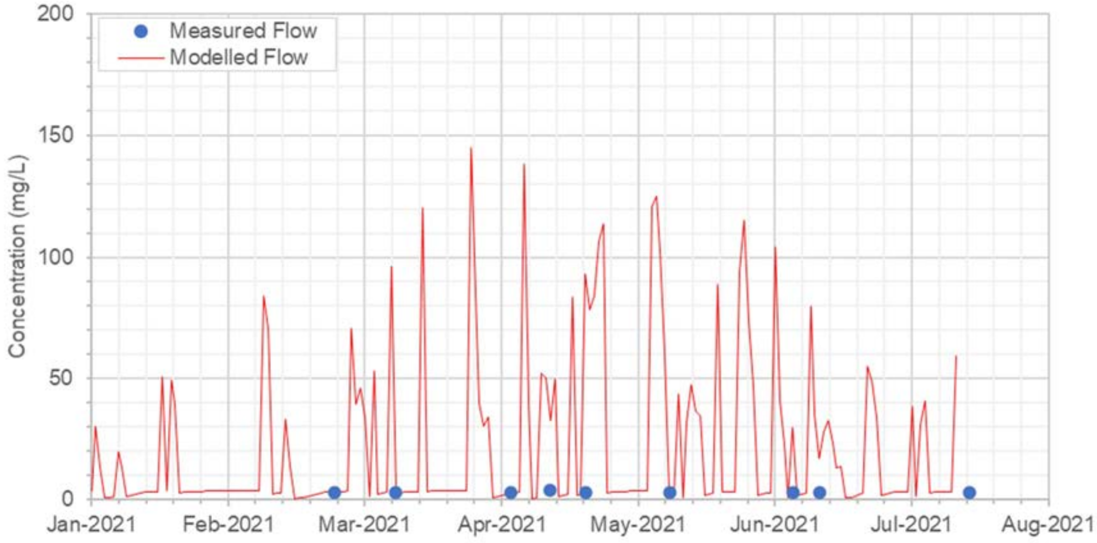

Figure 27. Monitoring Site G – TSS calibration plot.

4.7 Concluding Statement on Water Quality Model Calibration

Overall, the level of calibration demonstrated for both the TN and TSS of the catchment model are considered appropriate for the purpose of this Project, i.e., a catchment scale water quality assessment of land use change.

The model demonstrated good agreement to the measured TN concentrations across the eight calibration sites, and successfully simulated elevated TN concentrations associated with wet weather events.

The model demonstrated reasonable calibration to measured TSS concentrations including the general range in dry weather and wet weather TSS concentrations across the eight monitoring sites. The model's ability to simulate TSS concentrations is considered appropriate for the purposes of quantifying the relative change in concentrations associated with land use change, but not for predicting absolute concentrations through the network.

5. Scenario Simulation

5.1 Scenario Setup

In order to characterise and quantify the effects of proposed golf course development on stream flow and water quality, two scenarios were simulated. These were:

- **Historical Basecase** – representing the current land use of the Property; and
- **Proposed Golf Course Development** – representing the proposed future golf course development and future farming activity within the Property, while land use outside the Property remains the same as the present day.

To enable direct comparison between the two scenarios, simulations were analysed at two representative locations (**Figure 28**) these were:

1. the proposed high-flow take location – immediately downstream of this location is likely to be the location of greatest flow impact; and
2. the Ōkiritoto Stream at the downstream extent of the Property, which is immediately down gradient of the proposed golfing area in the north-western portion of the Property, hence an ideal location to assess for any potential change in environmental conditions.

5.1.1 Historical Basecase Scenario

This scenario represents the current day land use, and for the purposes of comparative scenario analysis assumes this land use (i.e., the diary, and sheep and beef operation on the Property) occurred as present over the historical 48-year assessment period.

5.1.2 Proposed Golf Course Development Scenario

This scenario represents the future land use of the Property, where the proposed golf course development is complete, and the proposed future farming activity is progressed. Outside of the Property, land use within the wider Ōkiritoto Catchment was assumed to remain unchanged from that of today.

The catchment flow and water quality model were updated to represent the golf course development in the north-western extent of the Property. It was assumed the current dairy operation on the Property would be retired once the golf course development was operational, while sheep and beef grazing would continue across the Property outside of the main golfing areas, with lower density sheep and beef grazing potentially occurring around the margins of the golfing area. The assumed future land use map, based on the most up to date provided at the time of undertaking this modelled assessment (early August, 2021), is presented in **Figure 28**.

A future land use map has been further refined since our assessment was undertaken in early August 2021. A copy of the latest future land use map is presented in **Figure 33**. This shows that a Lodge, Clubhouse, Sports Academy facility, Maintenance Complex, car parking, stormwater management devices (e.g., rain gardens and swales) and a water storage reservoir are also proposed. These facilities were not accounted for in the model because their exact location, size and designs were not confirmed at the time of undertaking the catchment flow and water quality modelling assessment. These facilities will further remove land that was assumed to be grazed by sheep and beef in this modelling analysis, and thus further reduce nutrient leaching from the Property. This means that the results from the modelling of the Project are conservative and will over-estimate the nutrient leaching under the proposed golf course scenario.

Assessment of effects associated with site wastewater discharges are detailed in **Section 6.3.2**, and from impermeable surfaces and proposed stormwater management are detailed in **Section 6.3.3**,

Figure 28. Proposed Golf Course Development Scenario – land use map. (Refer A3 attachment at Rear).

Figure 29. Refined proposed golf Course development land use map.

APSIM models were developed representative of golf course greens, fairways and grass (with stock grazing excluded). The golf course APSIM models were adapted from the Basecase APSIM models and updated to reflect the proposed golf course irrigation and fertiliser regimes based on information provided by Steve Marsden of Steve Marsden Turf Services. Full details on the parameterisation of APSIM models is presented in **Appendix C** of this report.

This scenario also includes the proposed high-flow surface water take that will be used to fill the proposed 140,000 m^3 water storage reservoir, and subsequently be used for irrigation. The high-flow take will only operate during periods of above median flow, and harvest water at a rate of up to 30 L/s. The location of the proposed take and water storage reservoir are depicted in **Figure 28**. Full details of the proposed high-flow take and further details of the water storage reservoir are provided in WWLA (2021 – Appendix F).

It should be noted, at the time of undertaking this modelling assessment the maximum high-flow surface water rate of take had not yet been confirmed. The assessment was undertaken on the assumption of a maximum rate of take of 80 L/s. The maximum rate of take has now been determined as 30 L/s, and therefore this assessment is considered very conservative (i.e., the actual maximum take rate will be 2.6 times lower than assessed in this report).

The catchment flow and water quality assessment was also undertaken on the conservative assumption that the high flow surface water take will occur at all times possible. In reality, this would be very unlikely because the high-flow take would not occur when the reservoir is already full (e.g. likely during the later stages of winter).

5.2 Historical Basecase – Scenario Results

The following sub-sections present the model results for the historical Basecase Scenario. These outputs are then compared to the proposed Golf Course Development Scenario in **Section 5.3**.

5.2.1 Flow

Analysis of simulated flow are presented for two representative locations (discussed above). Simulated flow for the Historical Basecase scenario at these two locations are presented below. Simulated outputs of the proposed Golf Course Development Scenario are then presented and compared in **Section 5.3**.

5.2.1.1 Basecase Flow at the Proposed High-Flow Take Site

The simulated flow hydrograph and flow duration curve for the proposed high-flow take site are presented in **Figure 30** and **Figure 31** respectively and summary flow statistics presented in **Table 5**.

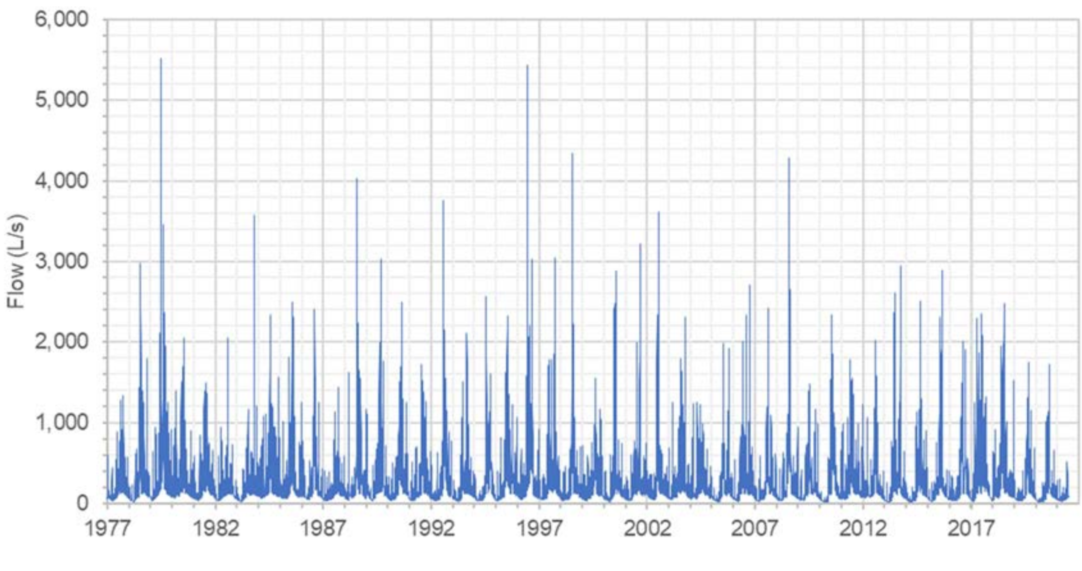

Figure 30. Simulated flow hydrograph curve at the proposed high-flow take site.

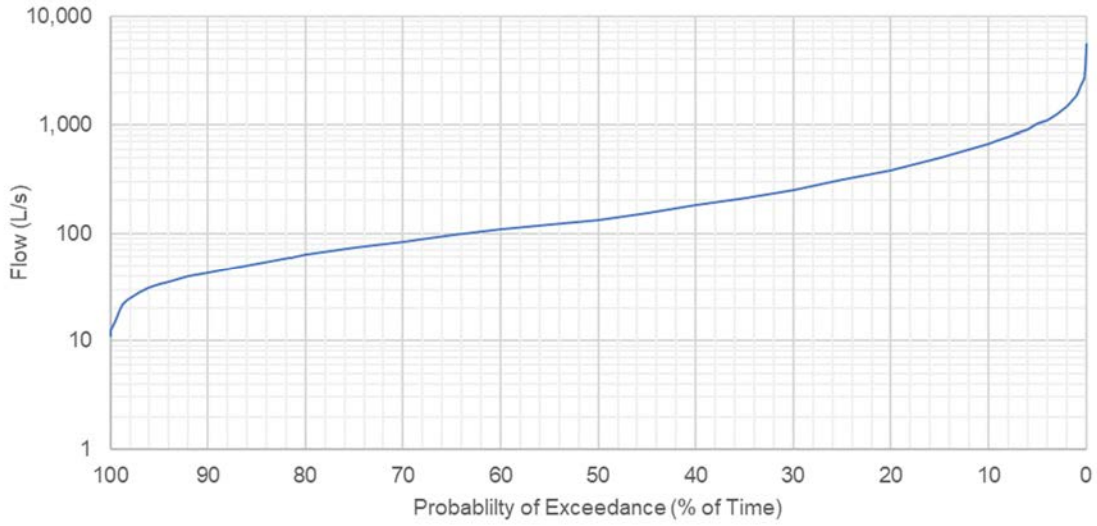

Figure 31. Simulated flow duration curve at the proposed high-flow take site.

Table 5. Simulated flow statistics at the proposed high-flow take site.

Statistic	Flow (L/s)
Minimum	11
25th percentile	74
Median (50th percentile)	131
Mean	274
75th percentile	310
90th percentile	669
Maximum	5,210

5.2.1.2 Basecase Flow at the Downstream Extent of the Property

The simulated flow hydrograph and flow duration curve for the downstream extent of the Property site are presented in **Figure 32** and **Figure 33**, respectively and summary flow statistics presented in **Table 6**. As expected, flows are higher at this location in comparison to the proposed high-flow take site due to the additional upstream catchment area and number of small tributaries that join the Ōkiritoto Stream between these two assessment locations.

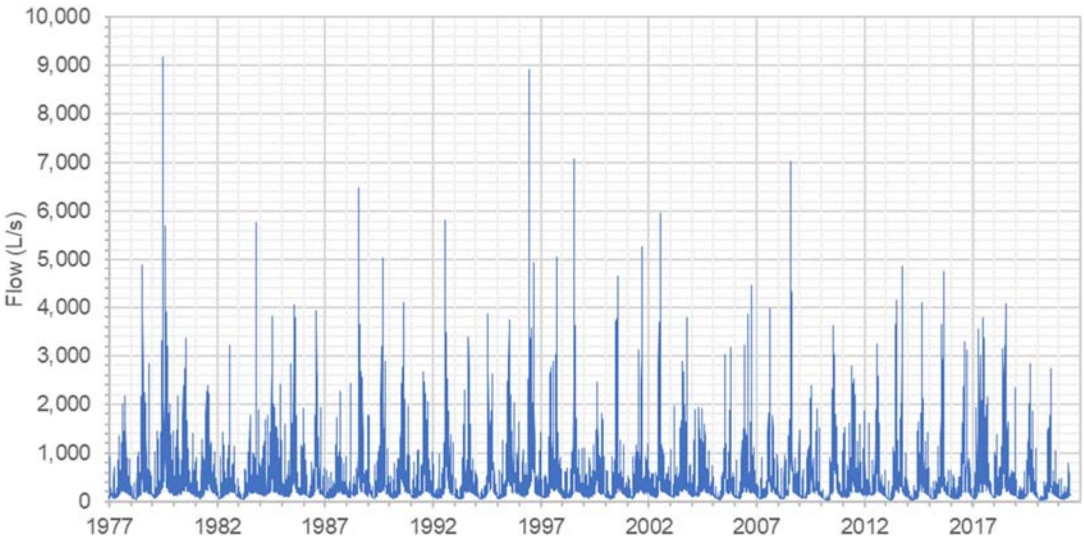

Figure 32. Simulated flow hydrograph curve at the proposed downstream extent of the Property.

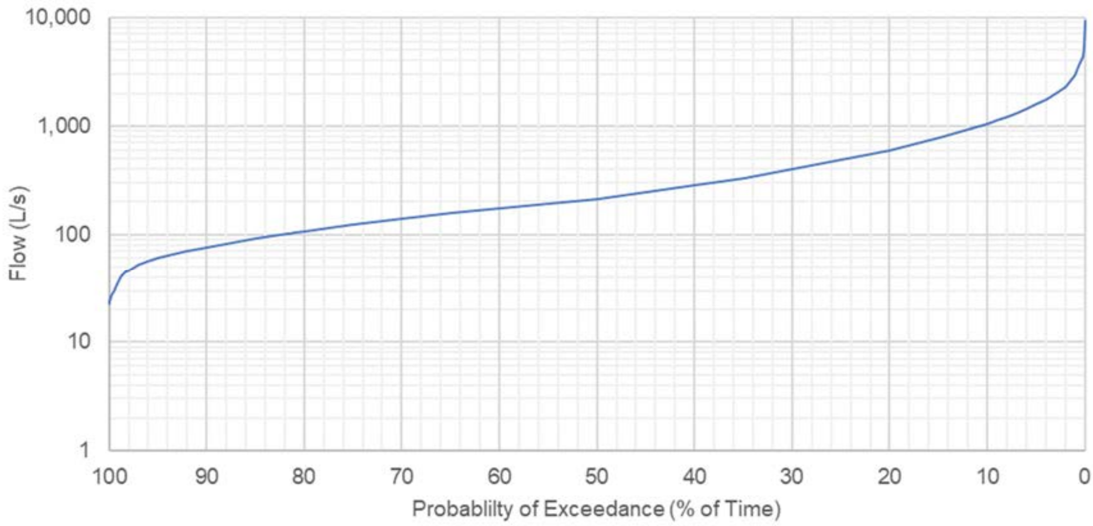

Figure 33. Simulated flow duration curve at the downstream extent of the Property.

Table 6. Simulated flow statistics at the downstream extent of the Property.

Statistic	Flow (L/s)
Minimum	22
25th percentile	123
Median (50th percentile)	212
Mean	435
75th percentile	482
90th percentile	1,047
Maximum	9,182

5.2.2 TN

Simulated TN concentrations at the downstream extent of the property for the historical Basecase Scenario are presented in **Figure 34**, and summary statistics provided in **Table 7**.

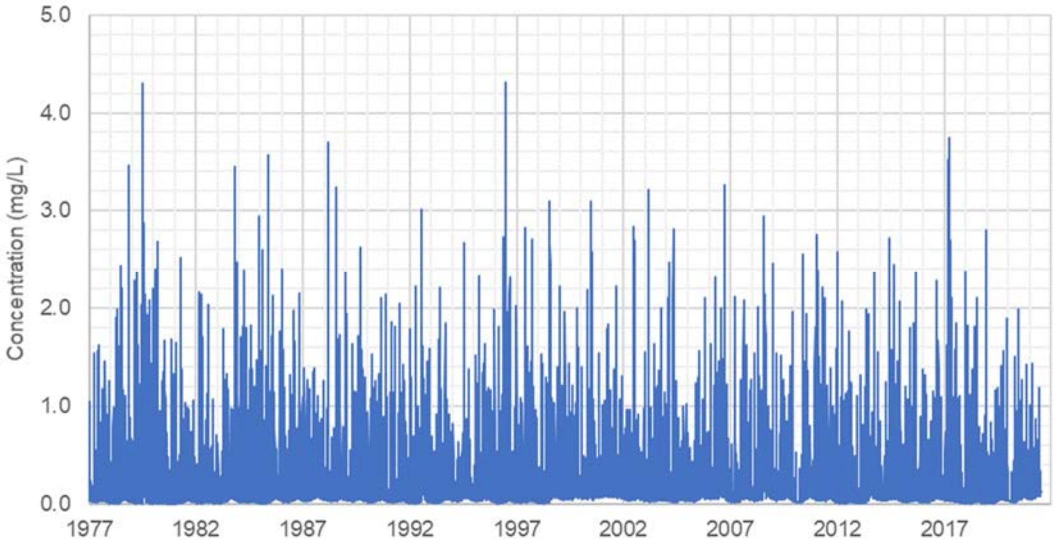

Figure 34. Time series of simulated TN concentration at the downstream extent of the Property.

Table 7. Simulated TN concentration statistics at the downstream extent of the Property.

Statistic	Concentration (mg/L)
Minimum	0.0005
25th percentile	0.0339
Median (50th percentile)	0.0770
Mean	0.2538
75th percentile	0.3144
90th percentile	0.7227
Maximum	4.3151

5.2.3 TSS

Simulated TSS concentrations at the downstream extent of the Property are presented in **Figure 35**, and summary statistics presented in **Table 8**.

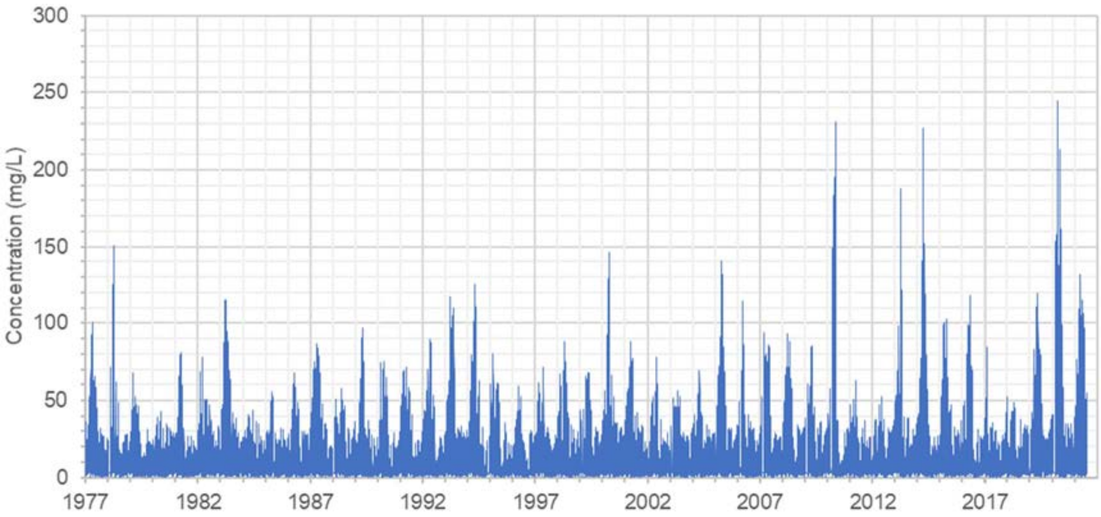

Figure 35. Time series of simulated TSS concentration at the downstream extent of the Property.

Table 8. Simulated TSS concentration statistics at the downstream extent of the Property.

Statistic	Concentration (mg/L)
Minimum	0.1
25th percentile	2.5
Median (50th percentile)	3.3
Mean	10.7
75th percentile	12.5
90th percentile	28.6
Maximum	244.8

5.3 Proposed Golf Course Development – Scenario Results

The following sub-sections present the results of the proposed Golf Course Development Scenario.

5.3.1 Flow

In order to characterise and quantify the impact of the proposed high-flow surface water take on downstream flows the Basecase Scenarios (i.e. no take) and proposed Golf Course Development Scenario are compared at the two flow assessment locations. These comparisons are presented below.

5.3.1.1 Proposed Golf Course Development Flow at Proposed High-flow Take Site

A comparison of the simulated flow hydrographs and flow duration curves for the Basecase Scenario and with the proposed surface water take included are presented in **Figure 36**, and **Figure 37**, respectively, and summary statistics presented in **Table 9**.

The modelling and analysis illustrate that impact of the proposed high-flow take on the downstream flow regime will be greatest immediately downstream of the proposed take location. The comparisons presented below demonstrate the impact at this location is considered to be minor in comparison to the overall streamflow regime. Flows at or below the median and not harvested, and therefore the low flow regime does not change.

Flow above the median is proposed to be harvested at a rate of 10% of total streamflow at the point of take, up to a maximum of 30 L/s. Restricting the maximum allowable high-flow take rate to 10% of the total streamflow as per the Auckland Unitary Plan ensures the natural variability in streamflow is largely maintained.

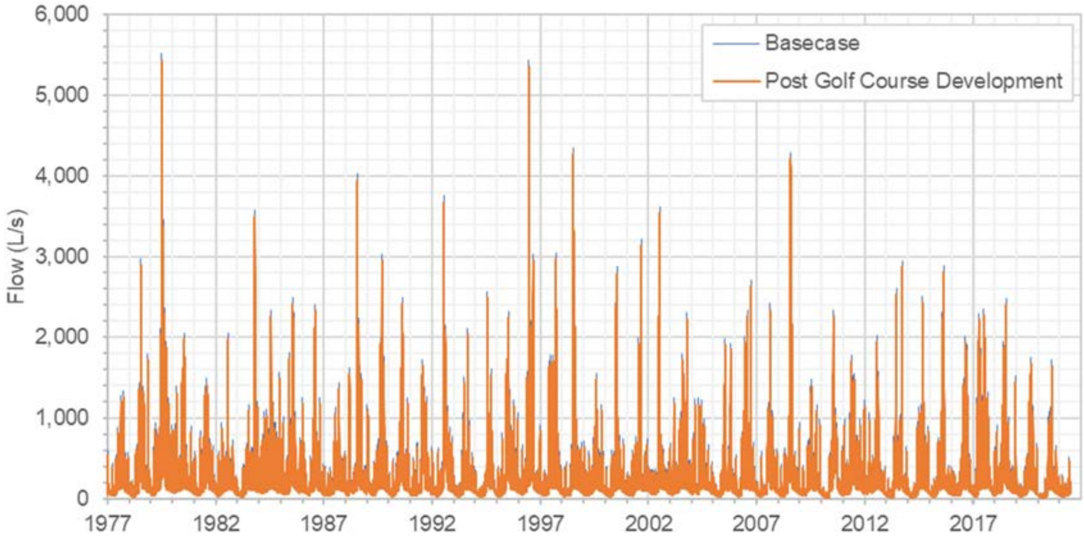

Figure 36. Comparison simulated flow hydrographs at the proposed high-flow take site.

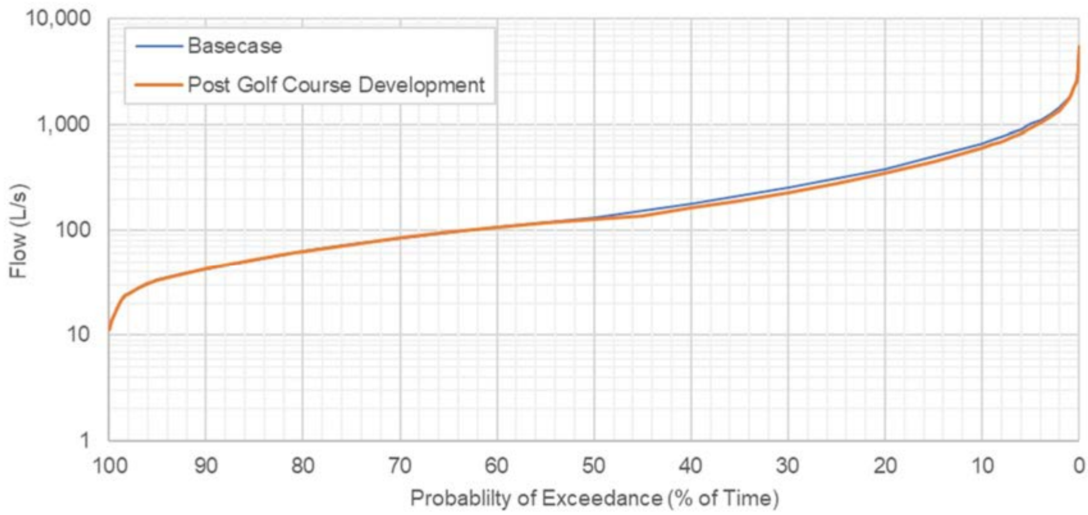

Figure 37. Simulated flow duration curves at the proposed high-flow take site.

Table 9. Simulated flow statistics at the proposed high-flow take site.

Statistic	Flow (L/s)	
	Basecase	Post Golf Course Development
Minimum	11	11
25th percentile	74	74
Median (50th percentile)	131	131
Mean	274	254
75th percentile	310	279
90th percentile	669	602
Maximum	5,520	5,440

5.3.1.2 Proposed Golf Course Development Flow at Downstream Extent of the Property

A comparison of the simulated flow hydrographs and flow duration curves for the Basecase Scenario and with the proposed take included are presented in **Figure 38**, and **Figure 39**, respectively, and summary statistics presented in **Table 10** for the downstream extent of the Property assessment location.

The comparisons demonstrate that impact of the proposed high-flow take as a proportion of total flow at the downstream extent of the Property has further decreased, in comparison to the proposed high flow take assessment site, due to the addition of a number of small tributaries joining the Ōkiritoto Stream between the two assessment locations. The effects on streamflow at this location are considered to be no more than minor.

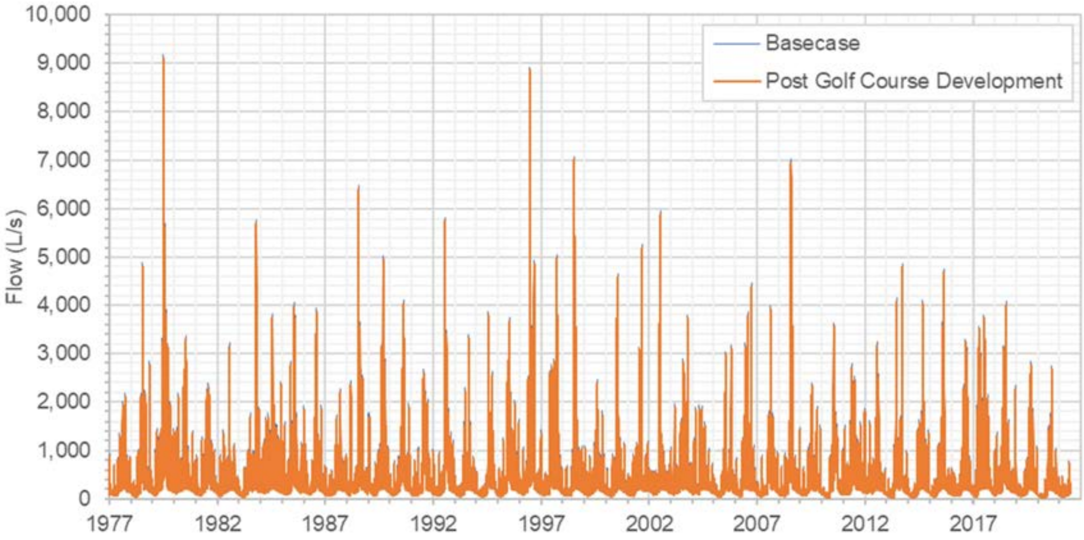

Figure 38. Comparison simulated flow hydrographs at the downstream extent of the Property assessment site.

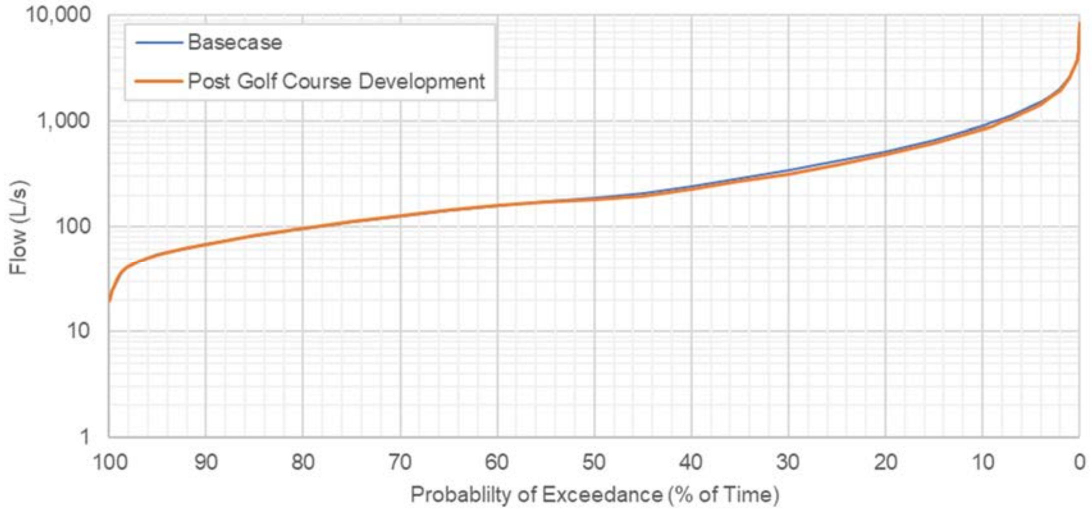

Figure 39. Simulated flow duration curves at the downstream extent of the Property.

Table 10. Simulated flow statistics at the downstream extent of the Property.

Statistic	Flow (L/s)	
	Basecase	Post Golf Course Development
Minimum	22	22
25th percentile	123	123
Median (50th percentile)	212	212
Mean	435	414
75th percentile	482	451
90th percentile	1,047	981
Maximum	9,182	9,102

5.3.2 TN

In order to characterise and quantify the impact of the proposed golf course development on TN concentrations, the Basecase Scenario and proposed Golf Course Development Scenario are compared at the downstream Property extent assessment location.

A comparison of simulated TN concentrations is provided in **Figure 40**, and summary statistics presented in **Table 11**. Both the time series plot and summary statistics predict a decrease in TN concentrations under the proposed Golf Course Development Scenario. While the absolute reduction in TN concentrations is not an extreme change, it represents a decrease in median concentrations by approximately 5% and a 5% reduction in TN load in the Ōkiritoto Stream at the downstream extent of the Property, which is an environmental improvement. The reason the reduction is not greater than approximately 5% is because the area retired of sheep and beef, and dairy cows on the Property represents only approximately 7% of the total Ōkiritoto Stream catchment, upstream of the downstream extent of the Property. The reduction in TN load in the Ōkiritoto Stream can be attributed solely to this proposal and therefore changes within the Property. This represents a 25% reduction in TN load from the Property.

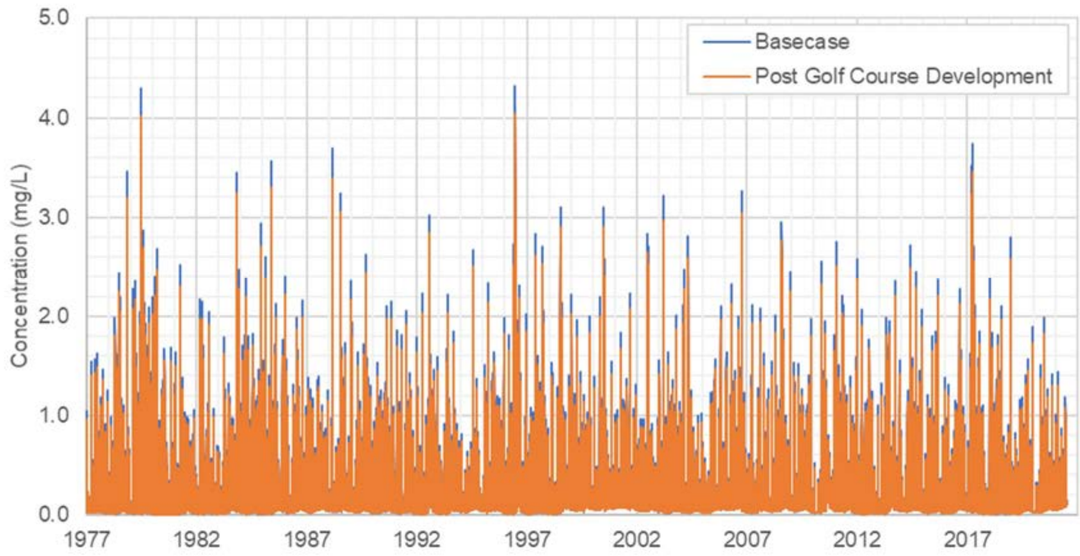

Figure 40. Time series of simulated TN concentration at the downstream extent of the Property.

Table 11. Simulated TN concentration statistics at the downstream extent of the Property.

Statistic	Concentration (mg/L)	
	Basecase	Post Golf Course Development
Minimum	0.0005	0.0005
25th percentile	0.0339	0.0327
Median (50th percentile)	0.0770	0.0729
Mean	0.2538	0.2350
75th percentile	0.3144	0.2886
90th percentile	0.7227	0.6673
Maximum	4.3151	4.0437

5.3.3 TSS

In order to characterise and quantify the impact of the proposed golf development on TSS concentrations, the Basecase Scenario and proposed Golf Course Development Scenario are compared at the downstream Property extent assessment location.

A comparison of simulated TSS concentrations is provided in **Figure 41**, and summary statistics are presented in **Table 12**. While a change in TSS concentrations is not visible in the time series plot, the summary statistics show the model predicted a small reduction in maximum TSS concentration. Only a minor change is expected, given the proposed Golf Course Development Scenario does not include widespread land use change throughout the catchment, and is essentially converting grass grazed by sheep and beef to improved condition grass across the golfing area.

Furthermore, it is noted approximately 28.9 hectares of ecological planting are proposed across the site, the majority of which will form riparian planting and wetland restoration. Full details of the ecological restoration planning are provided in the Ecology Report (AEE – Appendix 11). This will likely have a beneficial effect on water quality, with riparian planting filtering TSS prior to reaching the surface water environments (i.e., in stream).

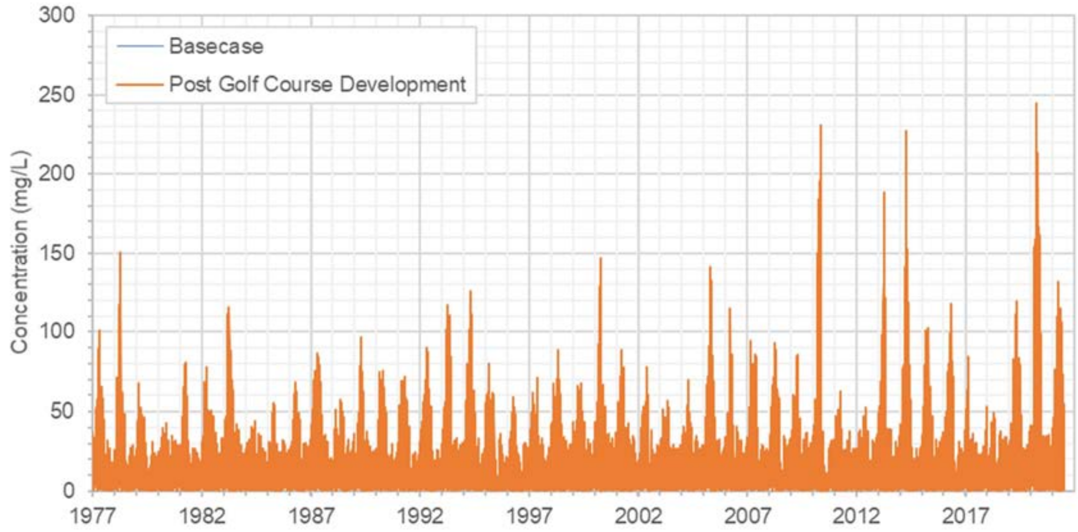

Figure 41. Time series of simulated TSS concentration at the downstream extent of the Property.

Table 12. Simulated TSS concentration statistics at the downstream extent of the Property.

Statistic	Concentration (mg/L)	
	Basecase	Post Golf Course Development
Minimum	0.1	0.1
25th percentile	2.5	2.5
Median (50th percentile)	3.3	3.3
Mean	10.7	10.7
75th percentile	12.5	12.5
90th percentile	28.6	28.6
Maximum	245.4	244.8

6. Water Effects Analysis – Quantity and Quality

The following section presents a summary discussion of water related effects associated with the construction and development of the Project.

6.1 Effects During Construction

The modelling analyses presented in this report considered the effects of the golf course development post construction only (i.e. does not consider potential effects during construction). During development and construction of the proposed golf course, the largest potential water quality impact is sediment runoff associated with earthworks while the recontouring and grading of the golf course area, and construction of buildings is undertaken.

Preliminary erosion sediment control plans (ESCP) have been prepared and are detailed in the Construction Management Plan (McKenzie and Co., 2021b). The ESCP were designed in accordance with Auckland Council Guideline Document GD05 – Erosion and Sediment Control for Land Disturbing Activities in the Auckland Region.

Once awarded, and prior to construction, the contractor will review the approved Resource Consent conditions and prepare a final ESCP for review and approval by the site Engineer and Regulatory Monitoring Representative.

The Preliminary ESCP states sediment control measures will be constructed on site prior to stripping of topsoil and earthworks. Sediment control measures will include sediment erosion ponds, decanting earth bunds, flocculation equipment, contour drains, separate clean water and dirty water diversion bunds, and silt fences.

Where work is undertaken in close proximity to streams and wetlands, the Preliminary ESCP recommends work is to be undertaken where practical between October and April, during which rain events and runoff are lowest. Silt fences and straw bales are recommended to catch any flowing debris.

The Preliminary ESCP notes specific stream works methodologies will be prepared by the contractor for each works location and type, and to be approved and signed off by the site Engineer and Regulatory Monitoring Representative.

From our high-level review of the Preliminary ESCP, we consider these to be appropriate to mitigate any potential and actual adverse effects on surface water due to construction works.

The risk of earthworks resulting in a water quality risk is considered low given the preliminary ESCP will be developed with further detail prior to construction and adhered to throughout construction.

Minor temporary changes in site overland flow and hydrology will occur due to the installation of silt fences, sediment-laden, and clean water diversion bunds, etc. These measures would only be temporary during construction and removed once completed.

The actual effects on water quantity and quality during the construction phase are considered no more than minor as the detailed final ESCP will be designed and implemented in accordance with best practice guidelines of GD05.

6.2 Effects on Water Quantity

The following sub-section details effects of the Project on water quantity once the development is constructed and operational.

6.2.1 Effects on Downstream Water Users

There is one existing consented surface water take downstream of the Property (WAT60068739). This is a core allocation (low flow) take for the Muriwai Links Golf Course, towards the mouth of the Ōkiritoto Stream. This consent authorises the take of up to 1,150 m^3/day, with a maximum instantaneous rate of 25 L/s, up to a maximum volume of 130,000 m^3/year for the purposes of irrigation.

In addition, there may be permitted surface water takes for drinking water and stock use downstream of the proposed take.

The proposed high-flow take (**Section 5.1.2**) will only operate during periods of above median flow (i.e. when flows exceed 131 L/s) at the point of take. This means at least 131 L/s will remain untouched instream at all times these flows naturally occur, and the take will cease when flows drop below this limit. In addition, the existing Muriwai Links Golf Course water take is approximately 5 kilometres further downstream of the proposed take site, and a number of tributaries join the stream, thereby further increasing the flow prior to location of the existing consented take. The downstream Property extent flow assessment location (**Section 5.1.2**) showed a median flow of 212 L/s at this location (which is still 1-2 km upstream of the existing consented take), and no changes in flow regime below this rate. When the high flow take is operating, it is very unlikely irrigation would be required in the district due to the recent rainfall that generated the high flow conditions in the stream. Nevertheless, if other irrigation was occurring, streamflow will be at least eight times greater than the consented take rate (25 L/s) for the Project. Accordingly, there will be plenty of water in the stream for the two takes to operate concurrently. Therefore, it is considered the proposed high flow surface water take would not have any adverse effect on the Project in regards to available water quantity.

Under the AUP (Table E7.4.1), the taking and use of surface water of up to 5 m^3/day (equivalent to 0.058 L/s) of freshwater from a river or spring is a Permitted Activity (PA). While the location and exact number of PA takes downstream of the proposed high-flow surface water take is not known, significant volumes of water for PA takes will remain. For example, as it is a high-flow take, flows below the median will not be affected. The median flow at the proposed point of take is 131 L/s, which is equivalent to 2,258 PA takes of 5 m^3/s, significantly greater than the number of properties neighbouring the Ōkiritoto Stream, downstream of the take site. In addition, a number of small tributaries join the Ōkiritoto Stream downstream of the take point and lateral inflow will increase with increasing distance downstream. Thereby, further increasing the water available for PA takes downstream of the Property. The actual effects of the Project on the quantity of water available for PA takes is considered no more than minor.

6.2.2 Effects on Stormwater Generation and Flood Flows

The additional impermeable surfaces (e.g. due to the construction of buildings, roads, paths and carparks) associated with the proposed development represent approximately 1% of the total site area, and less than 0.25% of the total Ōkiritoto Stream catchment, upstream of the downstream extent of the Property. The impact of increased impermeable surfaces on catchment flows was negligible and indistinguishable from the Basecase Scenario.

A Stormwater Management Plan (SWMP) will be prepared for the proposed development. The SWMP will follow the principles of water sensitive design (Auckland Council – GD04, 2015/004), and retention provided through a combination of at source soakage and infiltration at source and a number of buildings will be fitted with rainwater tanks for reuse. Detention of additional runoff generated from impervious services such as roads and carparks will be managed through a combination of raingardens, filter strips and soakage basins. There is no risk (i.e. no actual effects) of increased flood flows of the Ōkiritoto Stream associated with an increase in impermeable surfaces within the catchment from the Project, provided the SWMP is developed in accordance with the relevant guidance and is adhered to.

6.2.3 Effect on Changes in Surface Water Catchments on Wetlands

As detailed in the Water Effects Summary Report (WWLA, 2021 – Section 2.7.1), wetlands across the Property were classified into one of four types based on their topographic location and conceptual hydrological functioning. Potential changes to the hydrological functioning of wetlands could result from changes in catchment boundary (and thus changes in surface water flows), disruption of subsurface impermeable layers, or changes in hydrology associated with proposed water takes.

McKenzie and Co Drawings 1976-1-450 to 1976-1-457 (AEE – Appendix 5), and the associated stormwater runoff calculations (SW-Q100-TP108 Calcs-Pre & Post) present the change in wetland upstream surface water catchment area resulting from site earthworks and contouring.

The minor adjustments in wetland upstream surface water catchment area were reviewed in detail for each wetland. As the changes are considered small, only a summary description is presented below, rather than individual assessment of each wetland. The largest reduction in wetland upstream surface water catchment area would be -5.5% (Wetland C5 – Drawing 1976-1-451). The average reduction in wetland catchment area is less than 1%. Six of the twenty-three wetland catchments increased in extent by between 1 to 5%.

These small reductions in upstream catchment area, and thus contributing surface water flow, are not expected to have a measurable difference in wetland standing water or extent.

Construction of the water storage reservoir will not result in a change in immediate upstream catchment to any wetlands on site (McKenzie and Co. Drawings 1976-1-450 to 1976-1-457, AEE – Appendix 5).

Overall, the actual effects associated with changes in catchment boundaries, and thus reduction in surface water flows, associated with recontouring and grading of the golf course development and constructions of the water storage reservoir are assessed as being no more than minor.

6.2.4 Effects of Culverting and Infilling of Streams

The Project includes the culverting of 175 m of stream, and infilling / reclamation of 16 m of intermittent stream (AEE Appendix – 11, Figures 11 and 12).

While the size (diameter) of the culvert has not yet been determined, it is anticipated it will be sized appropriately to allow the conveyance of flood flows up to a given design level in order to prevent flood flows washing over the Golf Course area. When flows are below this design level, water will flow through the culvert unhindered. If the capacity of the culvert is exceeded during flood flows, overland flow above or around the culvert will occur, and this will not have an adverse effect on stream hydrology.

16 m of intermittent stream will be infilled to smooth the local topography at the top of Stream I9 (As defined in AEE Appendix 11 – Figure 12). As the stream is intermittent, it typically only flows during and after periods of rainfall. The proposed infilled land surface slopes in the same direction and the natural ground, and therefore water will continue to runoff (as overland flow) from the proposed infilled land surface into the same stream catchment as that naturally occurs.

The potential and actual effects of culverting and infilling streams associated with the Project are assessed as less than minor.

6.3 Effects on Water Quality

The following sub-section details effects of the Project on water quality once the development is completed and operational.

6.3.1 Effects Associated with Land Use Change

In order to characterise and quantify the effects (both positive and/or negative) on surface water quality of the Ōkiritoto Stream, the Basecase and the Golf Course Development Scenarios were compared. The catchment flow and water quality model predicted a minor reduction in both TN concentration and in peak TSS concentrations under the Golf Course Development Scenario. The effect of these reductions on downstream water users is considered negligible (i.e. potentially not detectable to downstream water users) to positive.

As detailed in **Section 5.3.2**, based on the modelling assessment an approximate 5% reduction in median TN concentration is anticipated due to the retirement of the dairy operation and partial conversion of the Property to the Project. Similarly, a small reduction in TSS concentrations was also simulated. Reductions in TN and TSS concentrations are considered positive environmental benefits.

6.3.2 Effects Associated with Wastewater Discharges

The modelling analyses presented in this report considered the effects of the proposed surface water take and land use change only, as design of the wastewater treatment was not available at the time of undertaking the modelling. Since completion of the water effects modelling, details of on-site wastewater treatment and disposal have been advanced, and are discussed below.

The Property cannot be connected to any public wastewater network, and therefore wastewater will be managed on-site, and discharged to ground. Given the nature of the Project, wastewater will be typical of domestic effluent (i.e. no industrial or trade waste).

The Engineering Infrastructure Report (AEE – Appendix 5) details the principles and approach for on-site wastewater management, noting detailed design has not been undertaken at this stage.

Effluent will undergo primary (septic tank(s)), secondary (textile media treatment and recirculation), and tertiary (UV filtering) treatment prior to disposal. Disposal of effluent is proposed via pressure compensating dripper lines. Configuration of dripper lines and application rates will be determined in accordance with Auckland Council guidelines (TP58).

The 7,500 m^2 disposal field and reserve area is located in on the north-western side of Muriwai Road, to the east of the helipad area (MCCL Drawing 1976-1-500 and 504). This location was selected to ensure it is accessible, and clear from high risk receiving environments, with the nearest wetland situated approximately 200 metres to the south-east.

The effluent disposal method has been designed in accordance with local guidelines, incorporated conservative assumptions throughout, and located clear of high-risk receiving environments and water bodies. Therefore, the potential for surface water body water quality issues resulting from domestic wastewater discharges to ground is considered to be low. Accordingly, the actual effects of the proposed wastewater system on receiving environment water quality are assessed as being no more than minor.

6.3.3 Effects Associated with Car Parks and Paths/Roads

High activity impermeable areas, such as carparks, paths, and roads, could result in stormwater contamination The SWMP will detail how stormwater from these areas will be managed, and how the proposed stormwater management approach adheres to Auckland Council’s Stormwater Management Devices in the Auckland Region GD01 guidelines. It is proposed that runoff from carparks and roads, where practical, will be treated with at-source green infrastructure treatment devices, constructed upstream of discharge points. Proposed bioretention treatment devices include vegetated swales, filter strips, and rain gardens (Engineering Infrastructure Report (AEE – Appendix 5).

Provided the SWMP is prepared in accordance with Auckland Council's guidelines and is followed, all stormwater from high activity impermeable areas will be treated following best practice guidelines, before being discharged back to the environment, and thus resulting in any potential effects on water quality that will be no more than minor.

6.4 Positive Environmental Effects

As described in **Section 6.3**, the catchment flow and water quality model predicted an approximately 5% decrease in median TN concentration in the Ōkiritoto Stream at the downstream extent of the Property, and small reduction in maximum TSS concentration. Both of these are considered positive environmental effects of the proposed golf course development.

In addition, it is noted the assessment was undertaken assuming a number of conservative assumptions, such as the exclusion of the water storage reservoir, buildings, roads, and paths when defining the post Golf Course Development Scenario, as their locations had not been finalised at the time of undertaking the modelling. The further removal of sheep and beef grazing land to accommodate these infrastructure assets will further reduce nutrient leaching.

Furthermore, approximately 28.9 hectares of ecological planting are proposed across the site, the majority of which will form riparian planting and wetland restoration. This will likely have a beneficial effect on water quality, with riparian planting providing a form of biofiltration of TSS and nutrients from runoff prior to reaching the receiving surface water environments (i.e., in stream).

On the basis of the above, the assessment of TN and TSS concentrations are considered conservative, and the positive environmental effects are therefore likely to be greater than assessed.

7. Recommendations

The catchment scale water quantity and quality modelling detailed in these reports have demonstrated the water related effects of the Project on the Property are considered to be either no more than minor with regard to flow, or negligible to an improvement with regard to water quality effects.

While the modelling assessment demonstrated effects associated with the proposed high-flow surface water take will be no more than minor on downstream water users and the environment, it is standard practice to require monitoring of surface water takes as a consent condition. Our expectations for this is detailed below.

7.1 Water Monitoring Plan for Ongoing Operations

The high-flow take (**Section 5.1.2**) will require on-going monitoring as a consent condition. It is expected the consent will require the monitoring of streamflow at the point of take to ensure the take only operates during periods of above median flow, and that it does not result in streamflow dropping below the median flow value when operational. Additionally, a water meter on the take will likely be required to ensure the consented maximum take rate (30 L/s) is not exceeded.

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Appendix A. SMWBM Overview and Parameters

Table 13. SMWBM_VZ parameters.

Parameter	Name	Description
ST (mm)	Maximum soil water content	ST defines the size of the soil moisture store in terms of a depth of water
SL (mm)	Soil moisture content where drainage ceases.	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity	Together with POW, FT (mm/day) controls the rate of percolation to the underlying aquifer system from the soil moisture storage zone. FT is the maximum rate of percolation through the soil zone.
ZMAX (mm/hr)	Maximum infiltration rate	ZMAX and ZMIN are nominal maximum and minimum infiltration rates in mm/hr used by the model to calculate the actual infiltration rate ZACT. ZMAX and ZMIN regulate the volume of water entering soil moisture storage and the resulting surface runoff. ZACT may be greater than ZMAX at the start of a rainfall event. ZACT is usually nearest to ZMAX when soil moisture is nearing maximum capacity.
ZMIN (mm/hr)	Minimum infiltration rate	
POW (>0)	Power of the soil moisture-percolation equation	POW determines the rate at which sub-soil drainage diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of drainage and hence baseflow, as well as the total yield from a catchment.
PI (mm)	Interception storage capacity	PI defines the storage capacity of rainfall that that is intercepted by the overhead canopy or vegetation and does not reach the soil zone.
AI (-)	Impervious portion of catchment	AI represents the proportion of the catchment that is impervious and directly linked to drainage pathways.
R (0,1)	Evaporation – soil moisture relationship	Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. Two different relationships are available. The rate of evapotranspiration is estimated using either a linear (0) or power-curve (1) relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches, full, evaporation occurs at a near maximum rate based on the mean monthly pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases according to the predefined function.
DIV (-)	Fraction of excess rainfall allocated directly to pond storage	DIV has values between 0 and 1 and defines the proportion of excess rainfall ponded at the surface due to saturation of the soil zone or rainfall exceeding the soils infiltration capacity to eventually infiltrate the soil, with the remainder (and typically majority) as direct runoff.
TL (days)	Routing coefficient for surface runoff	TL defines the lag of surface water runoff.
GL (days)	Groundwater recession parameter	GL governs the lag in groundwater discharge or baseflow from a catchment.
QOBS (m^3/s)	Initial observed streamflow	QOBS defines the initial volume of water in the stream at the model start period and is used to precondition the soil moisture status.
K_v (m/s)	Vertical hydraulic conductivity at full saturation	K_v defines the vertical hydraulic conductivity of the parent geology type when at full saturation. The Kv value sets the upper limit on the rate of flow in the vadose zone.
VGn (-)	van Genuchten constant soil type	VGn is a text book value used to define the relationship between soil moisture status and hydraulic conductivity of soil. It is used to determine the actual vertical hydraulic conductivity, which reduces as the soil dries.
n_s (-)	Soil zone porosity	n_s defines the porosity of the soil zone.

n_{vz} (-)	Vadose zone porosity	n_{vz} defines the porosity of the vadose zone and is therefore determined from an understanding of the parent geology material.
D (m)	Thickness of vadose zone (depth to water table)	D defines the thickness or the depth of the vadose zone.
GW_OnOff (True/False)	Groundwater on or off Selection	This feature of the SMWBM allows you to turn off the groundwater component of a sub-catchment so it does not report back to the river. This feature is useful when integrating with groundwater models.
AA, BB	Coefficients for rainfall disaggregation.	Used to determine the rainfall event duration and pattern. Default values usually suffice.

A conceptual diagram of the key components of SMWBM_VZ model structure and functionality is shown in **Figure 42**.

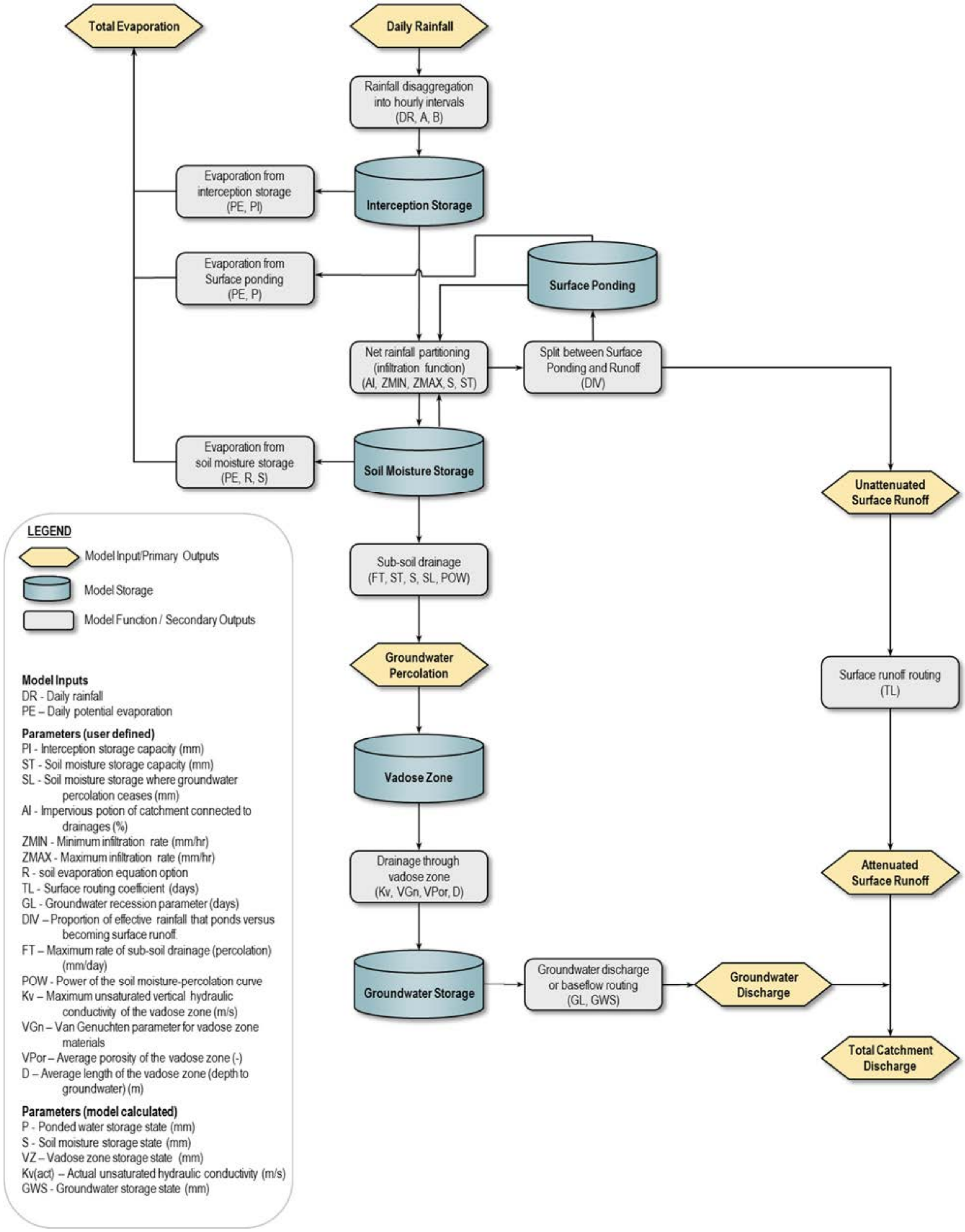


Figure 42. Flow diagram of the SMWBM_VZ structure and parameters.

SMWBM Relationships with parameters

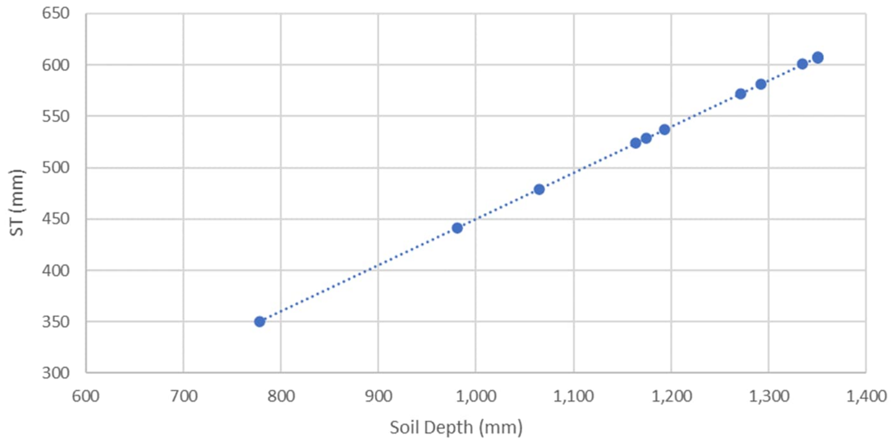


Figure 43. Relationship between soil depth and SMWBM ST parameter.

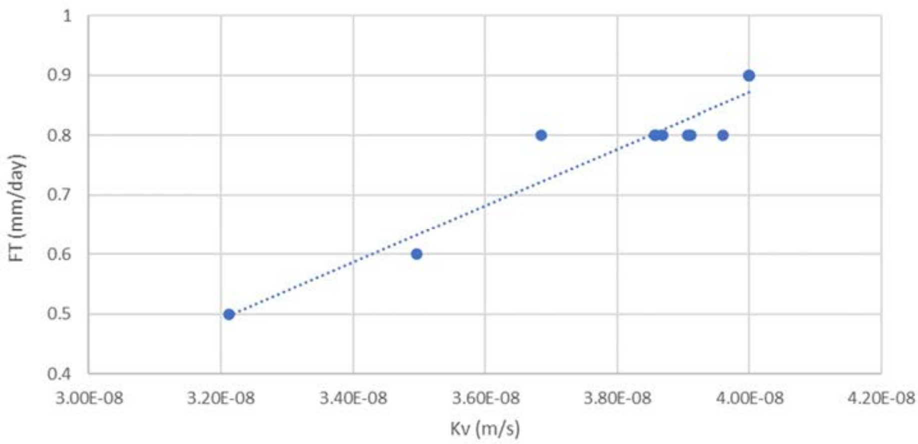


Figure 44. Relationship between Kv and SMWBM FT parameter.

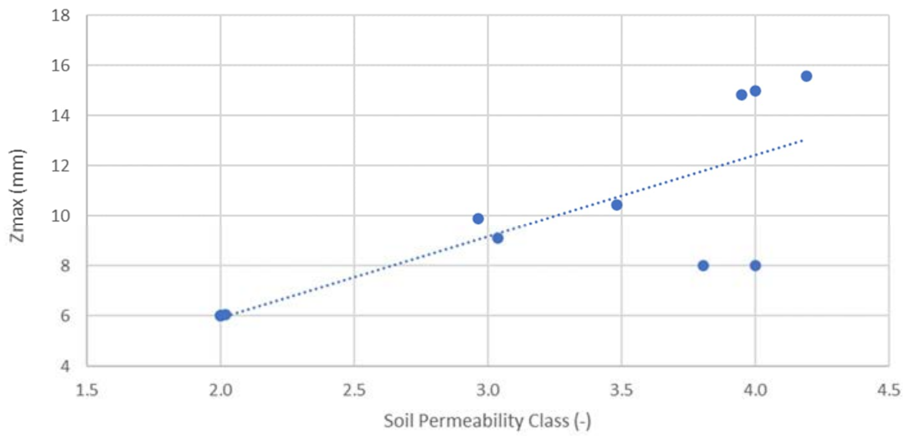


Figure 45. Relationship between soil permeability and SMWBM Zmax parameter.

Appendix B. Secondary Calibration

A secondary calibration check of the SMWBM was undertaken using historical spot gauge flow data obtained from Auckland Council (**Section 2.6**). Preliminary calibration plots for the six spot gauge sites are presented in **Figure 46**. Note, the plots are displayed on a logarithmic y-axis to emphasise the low flow calibration. Locations 44901 and 44906 were located downstream of the catchment model extent, and therefore simulated flows were pro-rated based on catchment area to provide an indicative comparison for these secondary calibration locations.

In general, the flow model matches the limited measured spot gauge data well. This is consistent with the calibration observed to the three continuous measured flow data sets.

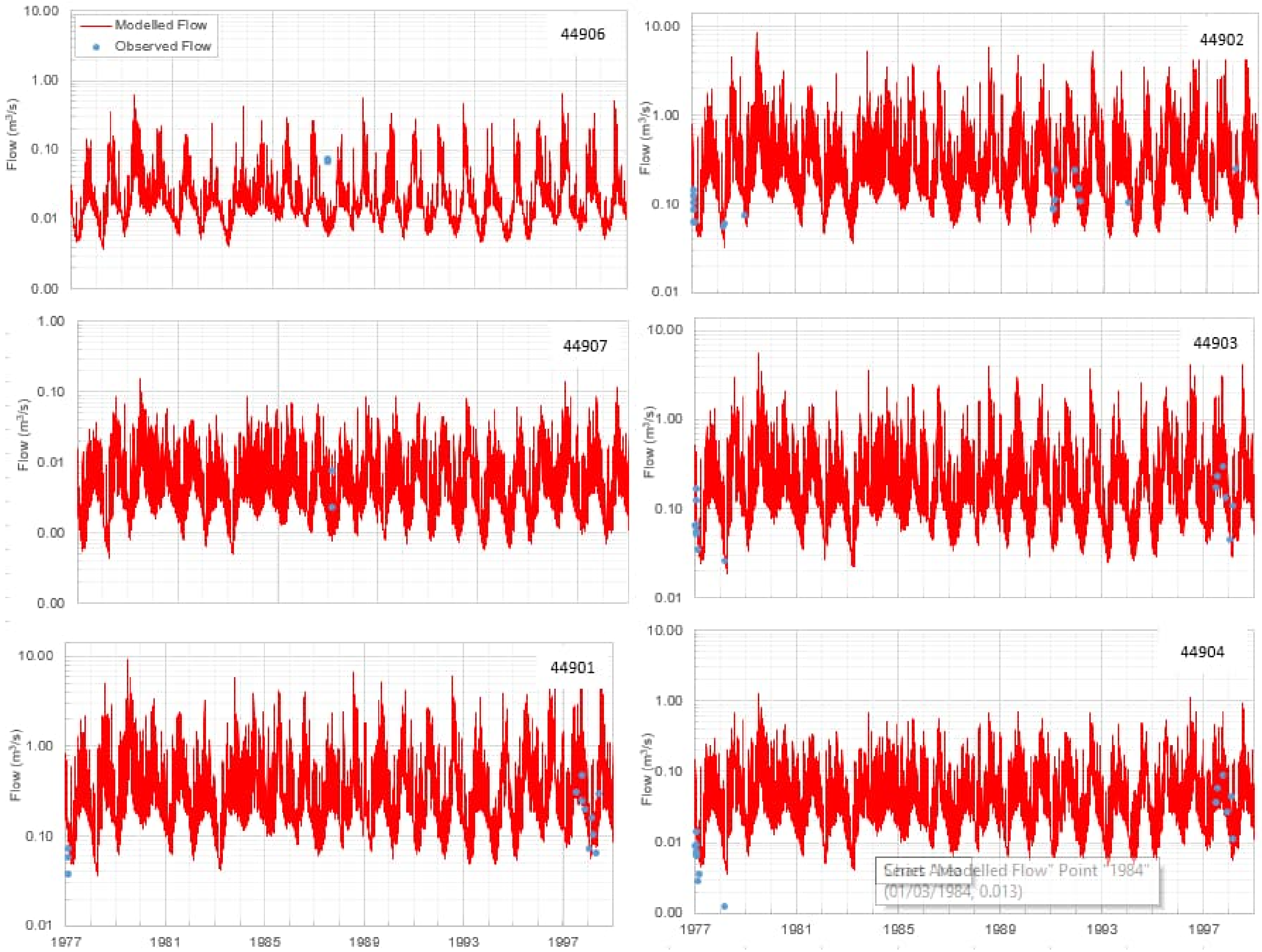


Figure 46. Preliminary calibration to available spot gauge data.

Appendix C. APSIM Model Setup

APSIM models consist of a series of sub-models. Separate sub-models were developed for dairy, sheep and beef and golf course land uses. The same climate, soil and pasture sub-models were used for both dairy and sheep and beef.

C.1 Climate

Daily interval climate data from 1972 to present were sourced from NIWA's Virtual Climate Station Network (VCSN) as described in **Section 2.2**. Climate inputs required include; daily minimum and maximum temperature, solar radiation, and rainfall.

C.2 Soil

The soil was parameterised based on local soil physical and hydraulic characteristics (e.g. soil depth, bulk density, field capacity, C:N ratio, % organic carbon, soil albedo and bare soil run off curve number). Data from the Fundamental Soils Layer, Tiaki Farm Environment Plan (Farm Source, 2020), and Auckland Council Soil Information Inventory were utilised to inform soil model parameterisation.

The main soil physical properties required for SoilWater include:

- Bulk density (BD).
- Soil moisture (Air dry).
- LL15 lower limit of soil moisture at 15 bar (LL15). It is approximately the driest water content achievable by plant extraction.
- Drained upper limit (DUL), It is the content of water retained after gravitational flow, sometimes referred to as "Field Capacity".
- Saturation (SAT).
- Saturated hydraulic conductivity (KS).
- Coefficient to define the proportion of difference between soil moisture and drained upper limit that cascades down to the next layer SWCON.

These properties were required for each individual soil layer specified in APSIM. An average soil depth of 115cm was used split into 5 layers.

Additional crop parameters were required for each soil depth layer to use soils with separate crop components (e.g. AgPasture). These include factors for daily crop water extraction (crop KL/day) and extraction lower limits (crop LL), used to calculate crop Plant Available Water Capacity (PAWC). Crop values were adapted from values provided within the example APSIM simulations and documentation (Dalgleish *et al*., 2015).

Input parameters include soil-wide constants for the C:N ratio (root and soil), root weight and erosion enrichment coefficients. The transportation of nitrogen is dependent on the C:N ratio (APSIM initiative, 2016). The parameters used to define the C:N ratio in the root and soil zone are summarised in **Table 14**. In the greens model the soil organic matter content was increased in layers below 40cm to represent the underlying clay, while the porosity in the top layer was increased to represent the sand carpet.

Table 14. Parameters used to define the C:N ratio in the root and soil zone.

Parameter	Pasture	Golf Course Greens	Golf Course Fairways
Root C:N ratio	40:1	35:1	40:1
Root Weight (kg/ha)	1,000	900	900
Soil C:N ratio	14:1	14:1	14:1
Erosion enrichment coefficient A	7.4	7.4	7.4
Erosion enrichment coefficient B	0.2	0.2	0.2

Table 15. Summary of soil physical characteristics for soils.

Model (soil depth – mm)	Bulk Density	Air Dry	Lower limit at 15 bar	Drained upper limit	Saturation	SWCON	Saturated hydraulic conductivity
	g/cm^3	mm/mm	mm/mm	mm/mm	mm/mm	-	mm/day
0-500	1.5	0.3	0.4	0.8	1	0.4	155
500-700	1.5	0.3	0.4	0.8	1	0.1	65
700-1000	1.5	0.3	0.4	0.8	1	0.07	45
1000-1200	1.5	0.3	0.4	0.8	1	0.02	15
1200-1400	1.5	0.3	0.4	0.8	1	0.02	2.3

The organic carbon distribution in the vertical soil profile is rarely available. Therefore, constants for the fraction of biomass and inert C have been adapted from example soil/crop simulations using the recommendations of Dalgleish *et al.,* (2016). Reference values for inert C (Finert) as a fraction are summarised in **Table 16**. Finert is used for initialisation of the SoilCarbon module, and therefore if appropriately initialised, model results are not sensitive to this parameter.

Table 16. Reference values for inert fraction (Finert) of soil carbon.

AgPasture soil example		Vertosol-Inert (Dalgleish *et al.*, 2016)	
Depth (cm)	Value	Depth (cm)	Value
0-10	0.3	0-15	0.4
10-30	0.5	15-30	0.6
30-60	0.6	30-60	0.8
60-100	0.8	60-180	0.95

The range of initial fractions of carbon in each soil organic matter pool is summarised in **Table 17**.

Table 17. Summary of initial fractions of carbon.

Land use	Soil Depth (cm)	Average OC (%)	Fbiom 0-1	Finert 0-1
Fairways	0-20	3.400	0.030	1.000
	20-40	2.700	0.020	1.000
	40-60	1.700	0.020	1.000
	60-80	0.850	0.010	1.000
	80-115	0.340	0.000	1.000
Greens	0-20	3.400	0.030	0.550
	20-40	2.700	0.020	0.625
	40-60	1.700	0.020	0.700
	60-80	0.850	0.010	0.875
	80-115	0.340	0.000	0.950
Dairy	0-20	1.400	0.020	0.750
	20-40	0.700	0.010	0.825
	40-60	0.700	0.010	0.900
	60-80	0.650	0.000	0.975
	80-115	0.240	0.000	0.975
Sheep and Beef	0-20	1.400	0.020	0.850
	20-40	0.700	0.010	0.925
	40-60	0.700	0.010	0.950
	60-80	0.650	0.000	0.975
	80-115	0.240	0.000	0.975

C.3 Soil Water Parameters

Table 18. Water mass balance comparison from selected APSIM and SMWBM model.

Water budget component	APSIM drainage		SMWBM percolation	
	(mm/day)	(%MAP*)	(mm/day)	(%MAP*)
rain	3.85	100.0	3.85	100.0
runoff	0.96	24.9	0.97	25.0
Interception + evapotranspiration	1.60	41.5	1.61	41.8
drain	1.29	33.4	1.28	33.3

Table 19. Values used in the SoilWater module.

SoilWater Parameter	Description	Value
Summer Cona	Second stage evaporation-coefficient of cumulative second stage evaporation against the square root of time for the summer period	10
Summer U	First stage evaporation amount of cumulative evaporation before soil supply falls below atmospheric demand for the summer period	10
Summer Date	Summer date	22-Dec
Winter Cona	Second stage evaporation-coefficient of cumulative second stage evaporation against the square root of time for the winter period	10
Winter U	First stage evaporation amount of cumulative evaporation before soil supply falls below atmospheric demand for the winter period	10
Winter Date	Winter date	22-Jun
Diffusivity Constant	Coefficients for computing proportional flow of water content gradient between layers when soil water content is below field capacity	80
Diffusivity Slope		
Soil Albedo	Soil albedo	35
Bare soil runoff curve number:	Curve number for average antecedent rainfall conditions for bare soil, defining the partition between infiltration and runoff	95
Max. reduction in curve number due to cover:	Surface residue inhibits the transport of the water across the soil surface during runoff event*. The reduction in curve number due to the cover on the land use.	5
Cover for max curve number reduction:	The maximum cover for the reduction in curve number. A threshold surface cover above which there is no effect on the curve number	1

C.4 Pasture

The AgPasture component was used to simulate N dynamics within pasture. It contains dry matter parameters and calculations for a ryegrass-white clover pasture. The component default comprised an initial pasture with 1,750 kg/ha above ground dry matter weight and 600 kg/ha root dry matter weight split between 90% ryegrass and 10% white clover. The pasture utilisation was set at 85% for dairy and 70% for sheep and beef. The same pasture target and residuals were used for both dairy and sheep and beef. However, for sheep and beef pasture was consumed at a 3x lower rate than dairy.

Table 20. Parameterisation of the AgPasture component.

Land use/Year	Pasture Composition (%)		Initial Above Ground Dry Matter Weight (kg DM/ha)		Initial Root Dry Matter Weight (kg DM/ha)		Initial Rooting Depth (mm)	
	Ryegrass	*White Clover*	*Ryegrass*	*White Clover*	*Ryegrass*	*White Clover*	*Ryegrass*	*White Clover*
3-5 years since pasture establishment	75	25	1,500	500	450	150	250	250

Fairways and greens were both modelled using the ryegrass model as a base, changes were then made to better reflect Windsor Green Couch and Creeping Bentgrass, as specified in **Table 21**.

Table 21. Changes to ryegrass model.

	Greens	Fairways
Photosynthesis Pathway	C3	C4
Maximum fraction of new shoot growth allocated to leaves	0.7	0.8
Default initial shoot DM	1500	1800
Initial rooting depth	200	450
Initial root DM weight	750	750

C.5 Management

A number of management components are available within APSIM to represent farming practices (e.g. irrigation, fertilisation, stock management, grazing and harvest, etc). The AgPasture plant module was used to simulate pastural processes, with rotational grazing selected as the grazing management process for dairy and sheep and beef. The inputs that vary between these models are the target and residual pasture mass (kg/ha), the amount of pasture consumed per day, the fraction of ingested nitrogen returned to the soil as dung and urine, and the depth of urine return. For the Golf Course model, cut and carry was used for the greens which allowed residual to be removed from the paddock. WWLA modified this script to allow harvest days per week for each season and typical residual grass heights to be set so the model could replicate information provided by Steve Marsden of Steve Marsden Turf Services. For the fairways harvesting ag pasture was used which allowed the residual to be applied to the field.

Within the APSIM modelling framework, the basic AgPasture management modules do not include a setup for multiple paddocks within a farm. Therefore, parameters reflecting differing N inputs across paddocks have been averaged into a single paddock model. This has been applied to:

1. Harvestable herbage and residual pasture to account for seasonal demand and supply of pasture;
2. Daily consumption for the grazing herd to facilitate varying paddock stay times and thus influence the timing of grazing recurrence; and,
3. Nitrogen removed and return fractions to account for variability in the proportion of pasture harvested for silage (all nitrogen removed) or grazed (a proportion of nitrogen is returned through excrement).

The primary source of nitrogen that is leached from dairy farms is urine excreted from cattle. Over multiple grazing days throughout a year approximately 15-25% of the paddock can be affected by urine patches.

Leaching from overlapped urine patches is typically 40% greater than single urine patches (Romera *et al*., 2012). To model the variation in urine patch loads within a paddock, 'background' (i.e. no urine deposited) and 'urine patch' paddocks were simulated and then spatially weighted and combined. A similar approach was used in the sheep and beef model. The method to represent concentrated urine return is summarised in **Table 22**.

Table 22. Summary of sub-paddocks in the dairy model.

Model	Dairy support	Background	Single or Low-Leach Urine patch	Multiple or High Leaching Urine Patch
Composition	20%	60%	16%	4%
Operation	Represented by dairy background	• No urine deposition; • Manure deposited on each grazing event; • Fertiliser applied; and • Used to ensure yearly harvest supports modelled herd.	• Represented by urine patches deposited in January based on selection of 'upper middle' yearly leaching rate from test models of urine deposited in single alternating months; • Grazing during January results in urinary and faecal n returned to soil; • Grazing during other months only results in faecal n returned to soil; • Timing of graze events and mass of pasture consumed on paddock based on typical intervals and harvest of background sub-paddock (i.e. fixed days between graze and fixed harvest amount); and • Fertiliser applied as per background paddock.	• Represented by urine patches deposited during February and in winter (i.e. June-August), based on the middle yearly leaching rate from selected trials of urine deposition on two months of the year; • Grazing during February, June or July results in urinary and faecal n returned to the soil; • Grazing during other months only results in faecal n returned to the soil; • Timing of gaze events and mass of pasture consumed on paddock based on typical intervals and harvest of background sub-paddock (i.e. fixed days between graze and fixed harvest amount); and • Fertiliser applied as per background paddock.

Table 23. Summary of sub-paddocks in the sheep and beef model.

Model	Sheep and beef support	Background	Single or Low-Leach Urine patch
Composition	20%	68%	12%
Operation	Represented by dairy background	• No urine deposition • Manure deposited on each grazing event • Fertiliser applied • Used to ensure yearly harvest supports modelled herd.	• Represented by urine patches deposited in January based on the peak of cattle stocking within the summer/autumn period (shown to be the time period associated with the greatest risk of leaching). • Grazing during January results in urinary and faecal n returned to soil • Grazing during other months only results in faecal n returned to soil • Timing of gaze events and mass of pasture consumed on paddock based on typical intervals and harvest of background sub-paddock (i.e. fixed days between graze and fixed harvest amount). • Fertiliser applied as per background paddock

A SMWBM irrigation model was set up as an APSIM plug in to mimic the irrigation in the golf course model, the parameters shown in **Table 24** equated to 441mm of irrigation per year.

Table 24. SMWBM irrigation parameters

Parameter	Value
Irrigation efficiency (0-1) - eff	1.0
The earliest date irrigation will be applied (dd-mmm) - start	1-oct
The latest date irrigation will be applied (dd-mmm) - end	31-mar
The deficit will be calculated to this soil layer (0 for full profile) - maxlayer	1
Application Rate (mm/day) - PAR	5
Allowable Deficit level (%) - AD	75
Critical Deficit level (%) - CD	20
Rain Threshold (mm) - RT	4

C.6 Dairy Model

The dairy model was developed based on an existing representative dairy farm model, and adjusted based on information provided in the Farm Environment Plan (Farm Source, 2020). Key model inputs and assumptions are presented **Table 25**. Two dairy models were set up to represent areas with and without effluent applied.

Table 25. Key dairy model inputs.

Parameter	Value
Stocking Rate	2.5 cows per ha
Additional feed	Farm grown crop, grass and maize silage and imported supplements
Nitrogen returned as excreta	72%
Effluent area	15 ha
Effluent application dates	1-jan 1-feb 1-mar 1-apr 1-oct 1-nov 1-dec
Fertiliser area applied	70ha
Fertiliser application dates	March, April, Jan and May
Application depth	10 mm

Fertiliser is applied in November, September, July and March. The percentage and content of nitrogen is calculated within.

At the level of the single paddock, the nitrogen return factor reflects the metabolism of the stock on the paddock. Based on available literature, a default value for milking cattle of 0.72 (72% of nitrogen excreted) was adopted, which was modified based on spatial and temporal patterns of harvesting methods or grazing rotations, or nutrient content of cattle feed.

C.7 Sheep and Beef Model

The model was set up to simulate both areas with no urine deposition and areas with low leaching urine patches. Key model inputs are detailed **Table 26**.

Table 26. Key sheep and beef model inputs.

Parameter	Value
Stocking Rate	Equivalent of 0.8 cows per ha
Nitrogen returned as excreta	85%
Fertiliser area applied	Whole Farm
Fertiliser application dates	May, Aug
Application depth	10 mm

An average of 110 kg/ha/year of Nitrogen fertiliser was assumed across the productive paddocks (Dairy and Sheep and Beef) of the Property.

C.8 Golf Course Model APSIM Parameters

Table 27. Golf course fertiliser model inputs.

Parameter	Fairways	Greens
Fertiliser application dates	Two granular applications with N per year, along with four to five times a year applying liquid fertiliser to the leaf.	Applied two to three weekly during Spring to Autumn, and once month during winter.
Annual fertiliser quantity	58 kg/N/ha	93 kg/N/ha
Irrigation Application depth	10 mm	10 mm

Appendix D. APSIM Model Post-Processing

APSIM simulates the leaching of TN to the bottom of the soil zone or sub-soil drainage, which then travels through the vadose zone before reaching groundwater. As the TN mass travels through the vadose zone the mass is attenuated (the signal is smoothed, and total mass is conserved) before reaching the groundwater store, as shown in **Figure 44**.

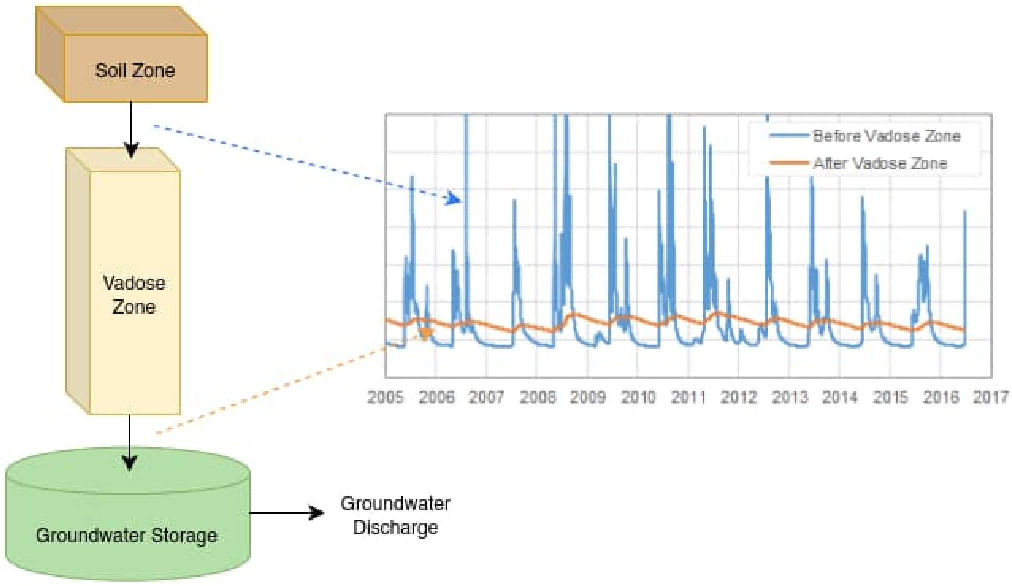


Figure 47. Transformation of TN mass in the vadose zone.

The Muskingum routing procedure was used for the vadose zone process (Williamson, 2017) to simulate the change in response (attenuation) of the sub-soil drainage hydrograph as water moves through vadose zone (reservoir), as given by **Equation 1**.

Equation 1. Muskingum routing equation.

O2 = C1 * (I1 - O1) + C2 * (I2 - I1) + O1

Where:

C1 = 1/(T + 0.5)

C2 = 0.5 * C1

O1 is the output (previous day)

O2 is the output (current day)

I1 = input (previous day)

I2 = input (current day)

T = cumulative average vertical travel time

The analysis was undertaken as a pre-processing step (prior to SOURCE), that utilised APSIM output as the input (I2), and the cumulative average vertical travel time (T) calculated in the Vadose Zone Module of the SMWBM for each sub-catchment in SOURCE. The output from the vadose zone processing for TN was an attenuated time series of leaching load ($mg/m^2/day$) per sub-catchment.

D.1 Groundwater Mixing

The daily variable TN mass load is converted to a discharge concentration via a process that uses the simulated groundwater store (GWS[1]) for mixing and tracking of groundwater concentration, and the simulated groundwater discharge to surface from the SMWBM. This process ensures that the delivery of TN load to the surface waters is consistent with the simulated groundwater discharges in the SOURCE model.

Equation 2 performs mass balance calculations from concentration in the GWS, using the calculated mass attached to the water storage and discharge volumes simulated in the SMWBM**.**

Equation 2. Ground water storage mass balance equation	GWS mass (current day) = GWS mass (previous day) + mass input load (current day) – mass output load (previous day)

Concentration in the GWS is calculated from the mass of constituent and volume of water residing in the store, as shown in **Equation 3**. The initial mass in the GWS is assigned at the start of the simulation through an optimisation process, whereby the calculated concentration on day one is equal to the average of the calculated concentrations over the entire simulation period.

Equation 3. Groundwater Store concentration.

$$\text{GWS concentration } \left(\frac{\text{mg}}{\text{L}}\right) = \frac{\text{GWS mass (mg/m2)}}{\text{GWS volume (L/m2)}}$$

D.2 Catchment Attenuation Factor

Mass losses of TN in a catchment are known to occur in the groundwater system and riparian margin due to a combination of factors such as biogeochemical transformations (e.g. denitrification, volatilisation etc.). Mass loss also occurs via instream processes including various biological growth-related uptakes e.g. bacteria, riparian plants and submerged macrophytes. The uptake of nitrogen by biological processes is a physical process however the biogeochemical and biological process are not explicitly accounted for in the modelling process utilised for this study. Therefore, to represent these processes a scaling factor (referred to as the “Catchment Attenuation Factor” (CAF)), was developed to capture the cumulative effect of biogeochemical processes on instream TN concentrations.

The CAF was intended to adjust modelled TN mass to reflect natural attenuation of TN for each sub-catchment. Using only days where there was a measured TN concentration recorded, the TN constituent mass was calculated for measured and modelled data. The total measured mass and total modelled mass were then compared, and the difference calculated. The difference is then converted to a percentage, equating to the percentage reduction (mass reduction) required overall for modelled TN to match measured TN. The revised time series of TN per sub-catchment were then imported and re-run through the SOURCE model and compared to the measured data. Reiterations and adjustments of the CAF were made until the highest level of calibration possible was achieved.

[1] GWS is an arbitrary volume or depth (in mm) that increases or decreases in a relative sense depending on whether groundwater recharge (PERC) exceeds groundwater discharge to surface water (GWQT) and vice versa.

Appendix E. TSS Parameterisation

Table 28. dSedNET Parameters.

Parameter	Unit	Description
Mean annual rainfall	mm	The mean annual rainfall for each functional unit in each sub-catchment for the period of 1972 – 2020.
Mean summer rainfall	mm	The average summer rainfall for each functional unit in each sub-catchment for the period of 1972 – 2020.
R Factor Rainfall Threshold	mm	The threshold of minimum rainfall required before rainfall erosion will occur.
Alpha	Dimensionless	Alpha defines latitude and Beta and Eta are factors that define the erosivity nature of rainfall from the Earth's latitude. The values are not considered sensitive and default values were applied.
Beta	Dimensionless	
Eta	Dimensionless	
DWC	mg/L	The dry weather concentration of sediment (I.e. the base flow concentration present when no sediment is being generated or deposited in a catchment).
KLSC	Dimensionless	A factor that represents the soil erodibility, the slope length, the slope gradient and the vegetation cover of the sub-catchment.
HSDR	Ratio	The Hill Slope Delivery Ratio (HSDR) determines the percentage of sediment that arrives at the stream after generation.
Off Set	Days	The lag in time it takes sediment generated to be deposited into the stream network.

The dSedNET parameters were defined for every sub-catchment. A weighted average was applied to each land use type in the sub-catchment, based on percentage of area covered, to determine the average catchment KLSC value. The DWC, R factor and HSDR all used components of the KLSC value to produce separate relationships. The mean annual rainfall and mean summer rainfall parameters were calculated using the NIWA VCSN data. The offset parameter was set to 180 to ensure high loads were simulated in winter. The remaining parameters (Alpha, Beta and Eta) were set to their default values.

The KLSC parameter was calculated using the method outlined in Cetin *et al.* (2016), Wilkinson *et al.* (2014), and Dymond *et al.* (2014). The equation applied to calculate KLSC is shown in **Equation 4**, while **Table 29** describes each component and shows its method of calculation.

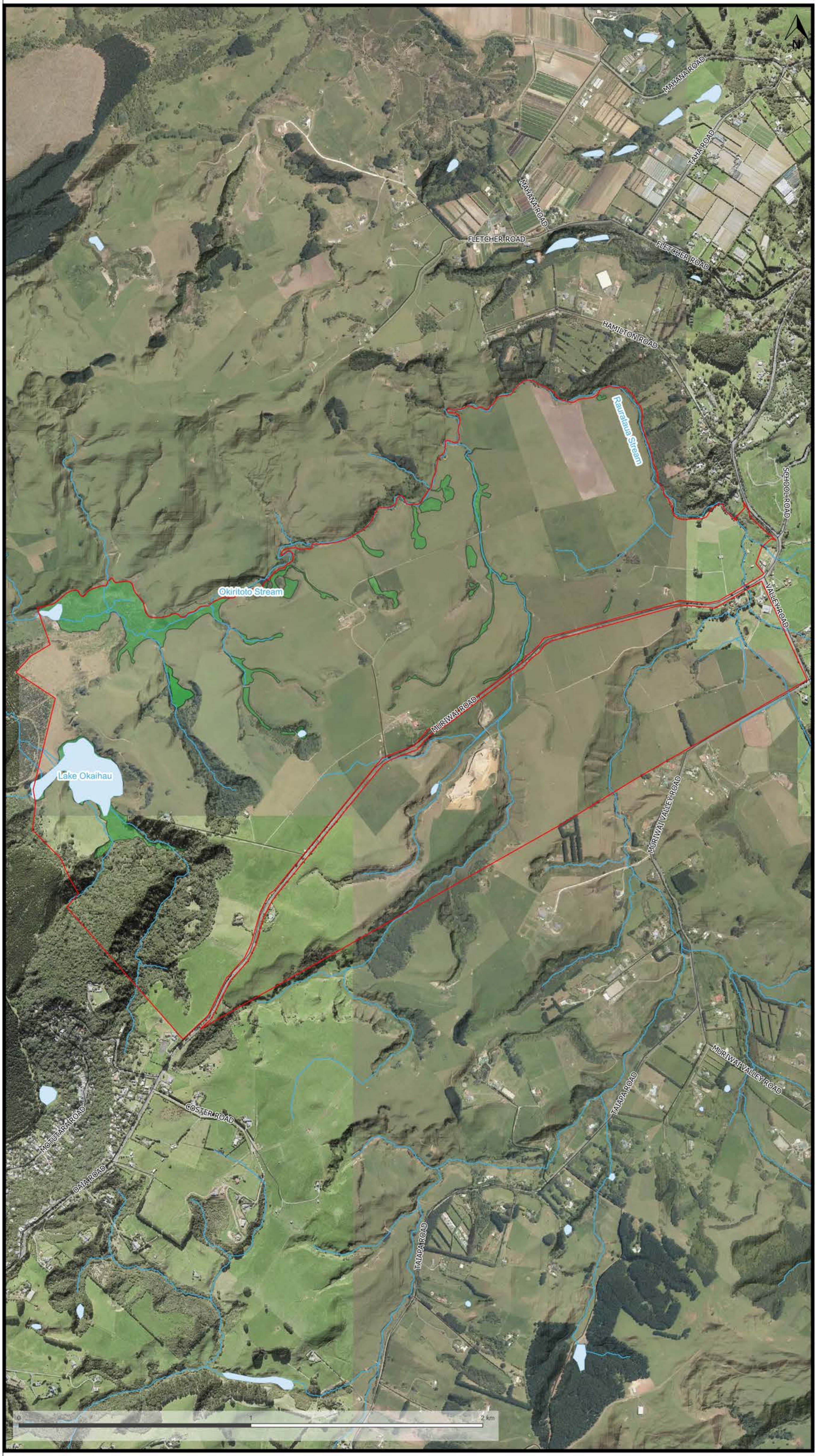
Equation 4. The KLSC factor of the modified universal soil loss equation.

$$KLSC = K * LS * C$$

Table 29. Data requirements, methods and assumptions used to calculate the KLSC value.

Variable	Data required	Method
K – Soil erodibility	SMap soil texture geospatial layer and SMap particle size geospatial layer.	Different soil textures were identified within both WMAs and assigned a K factor based on previous values utilised by Dymond *et al.* (2014); • Sand = 0.05 • Silt = 0.35 • Clay = 0.20 • Loam = 0.25

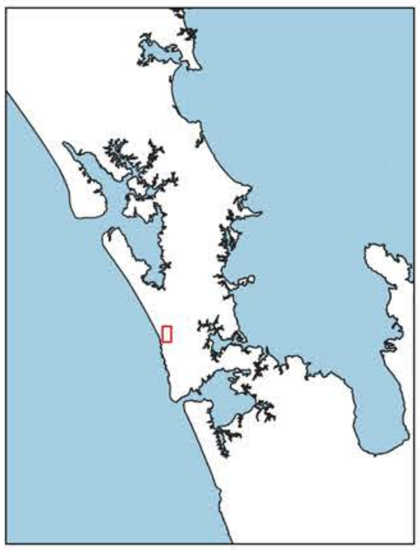
		Previous studies have also applied a uniform value of 0.25 to all areas, this was trialled and deemed unsatisfactory for this Project on the basis the uniform 0.25 value did not simulate the level of variability in TSS concentration that was observed in the available measured data.
LS – Slope length and gradient factor	Raster files of the slope gradient and slope length (generated from the LINZ 15m DEM).	
C – Vegetation Cover	Land use spatial layer	The C factor is applied to each land use based on vegetation cover. Using previous New Zealand examples (i.e. Dymond *et al.* 2014) the following C Factor values where applied; • Bare ground, roads, rail and urban areas = 1.0 • Pasture and developed land = 0.01 • Forest and dense scrub = 0.005 • Golf Course = 0.009



Map Title:
Location Overview

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

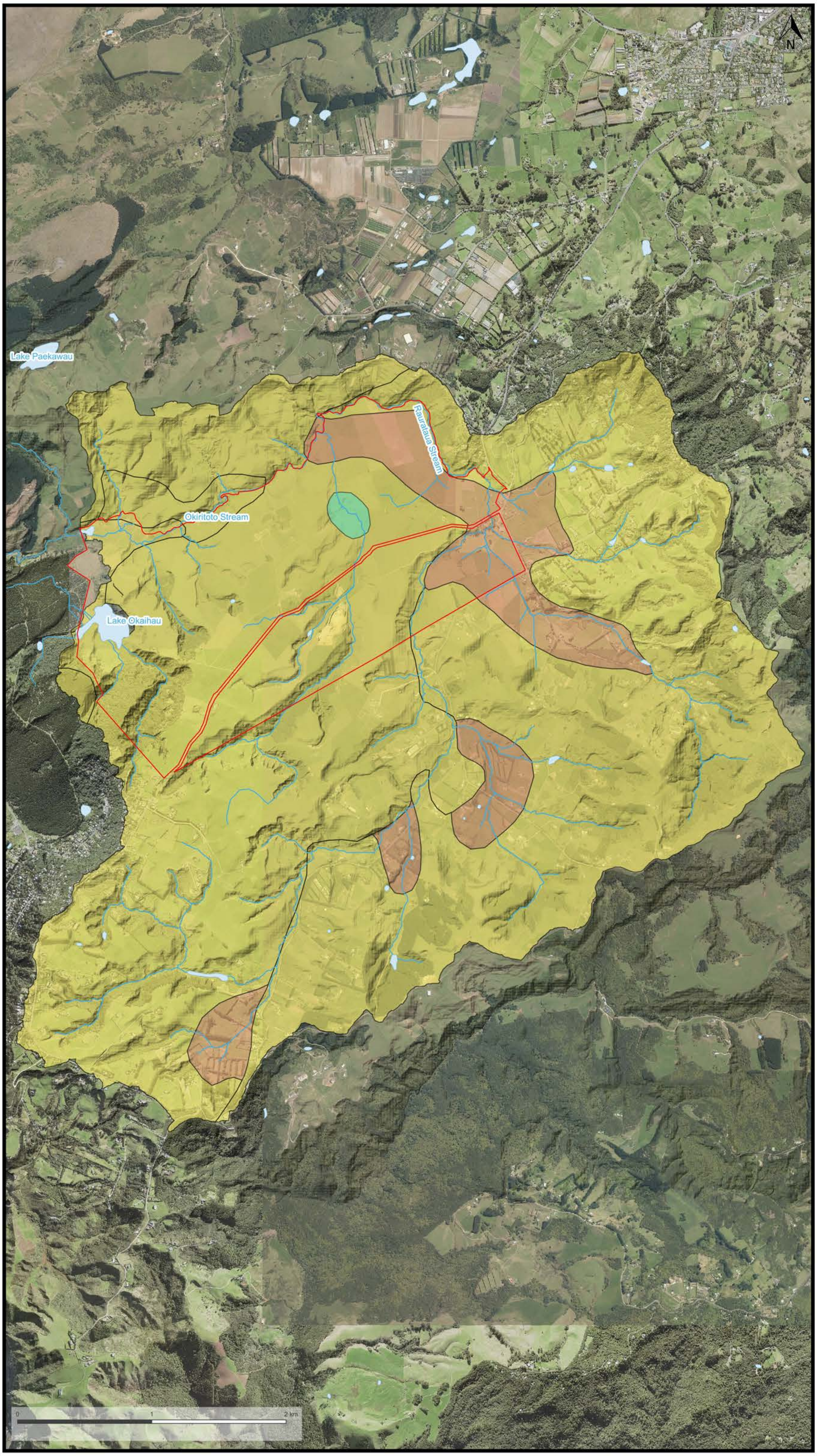
- Road
- River / Stream
- Property Extent
- Lake
- Wetland

Data Provenance
Aerial Imagery derived from Land Information New Zealand

Layout & Project File
Location Overview Map
Surface Water Catchment Modelling.qgz

WILLIAMSON WATER & LAND ADVISORY

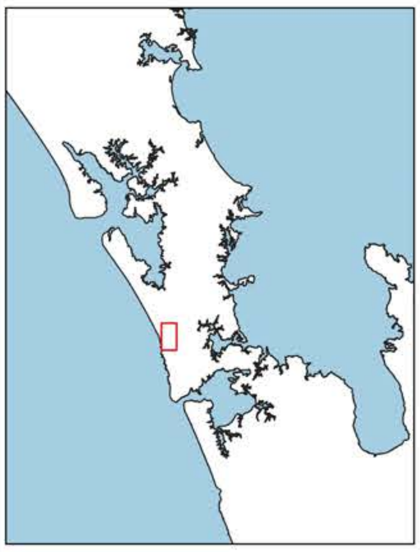
Figure 01.



Map Title:
Geology

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

- Stream / River
- Property Extent
- Lake

Geological Units

- Basalt
- Mudstone
- Sandstone

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Geology
Surface Water Catchment Modelling.qgz

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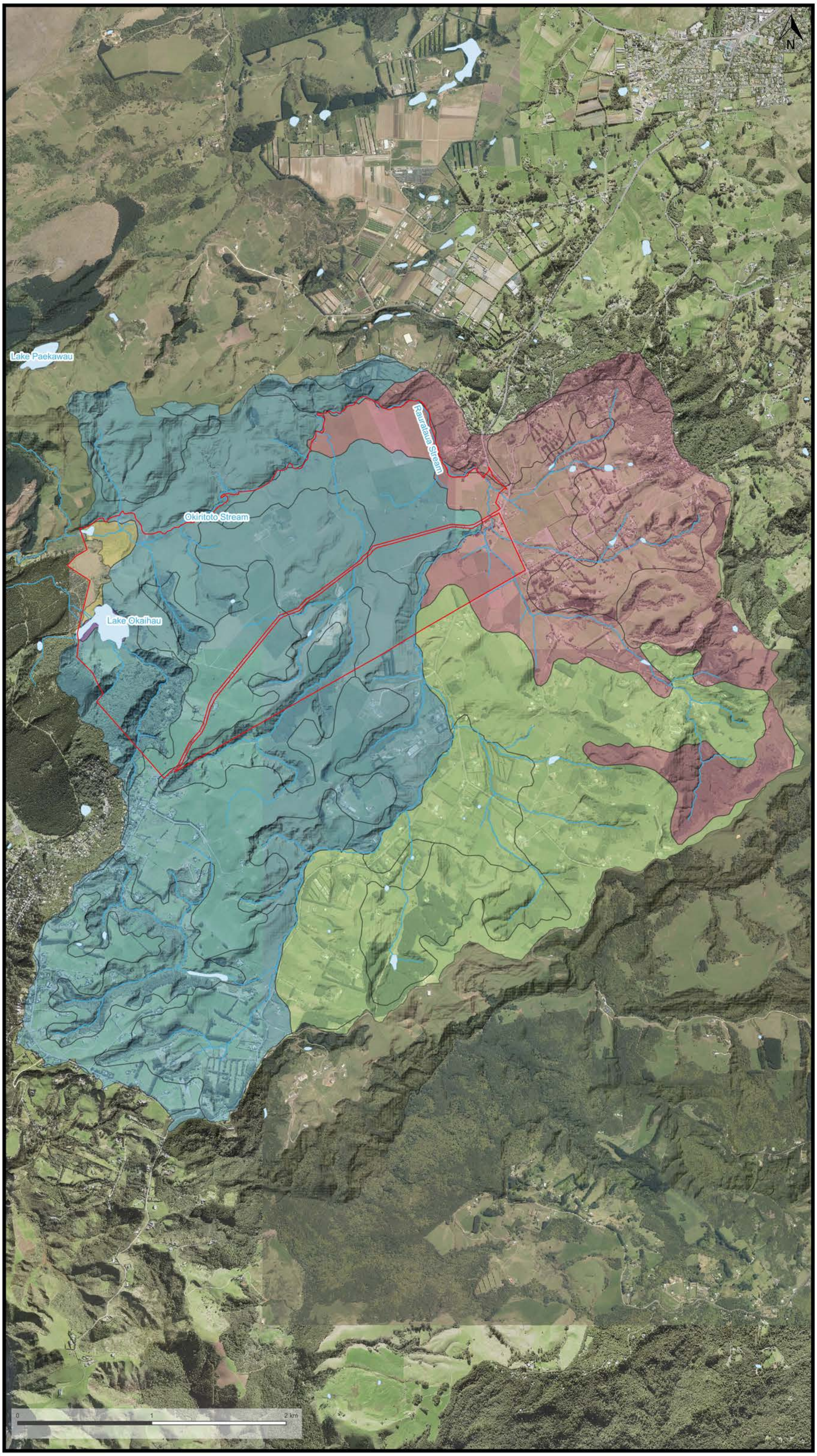
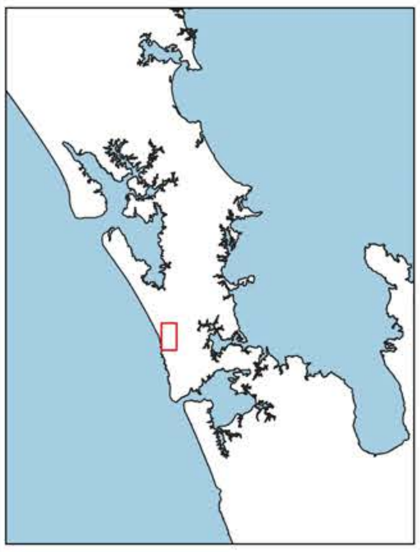
Figure 02.



Map Title:
Soil Texture

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

Stream / River

Property Extent

Lake

Soil Texture

Clay

Clay loam

Sand

Sandy clay loam

Data Provenance

Aerial Imagery derived from Land Information New Zealand

Layout & Project File

Soil

Surface Water Catchment Modelling.qgz

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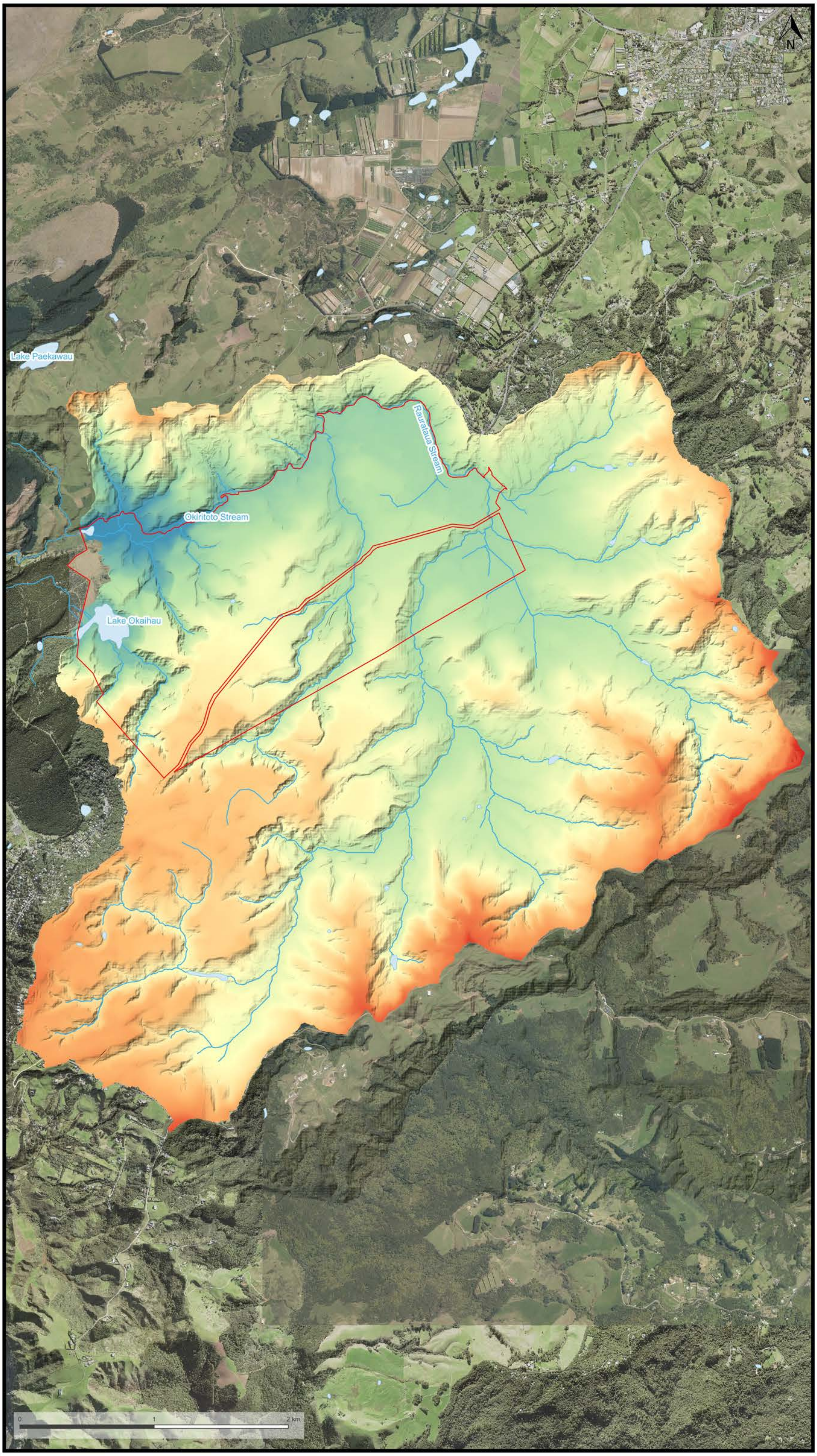
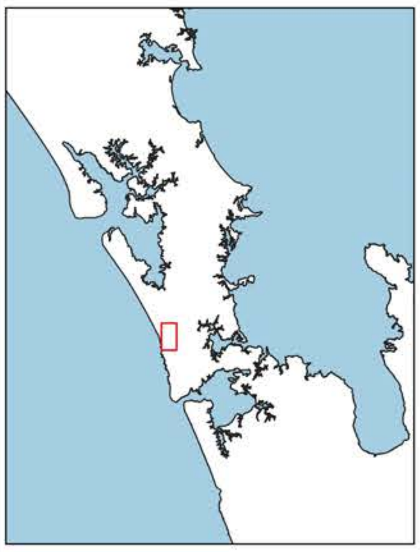
Figure 04.



Map Title:
Topography

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

Stream / River

Property Extent

Lake

Elevation (m)

200 m

0 m

Data Provenance

Aerial Imagery derived from Land Information New Zealand

Layout & Project File

Topography

Surface Water Catchment Modelling.qgz

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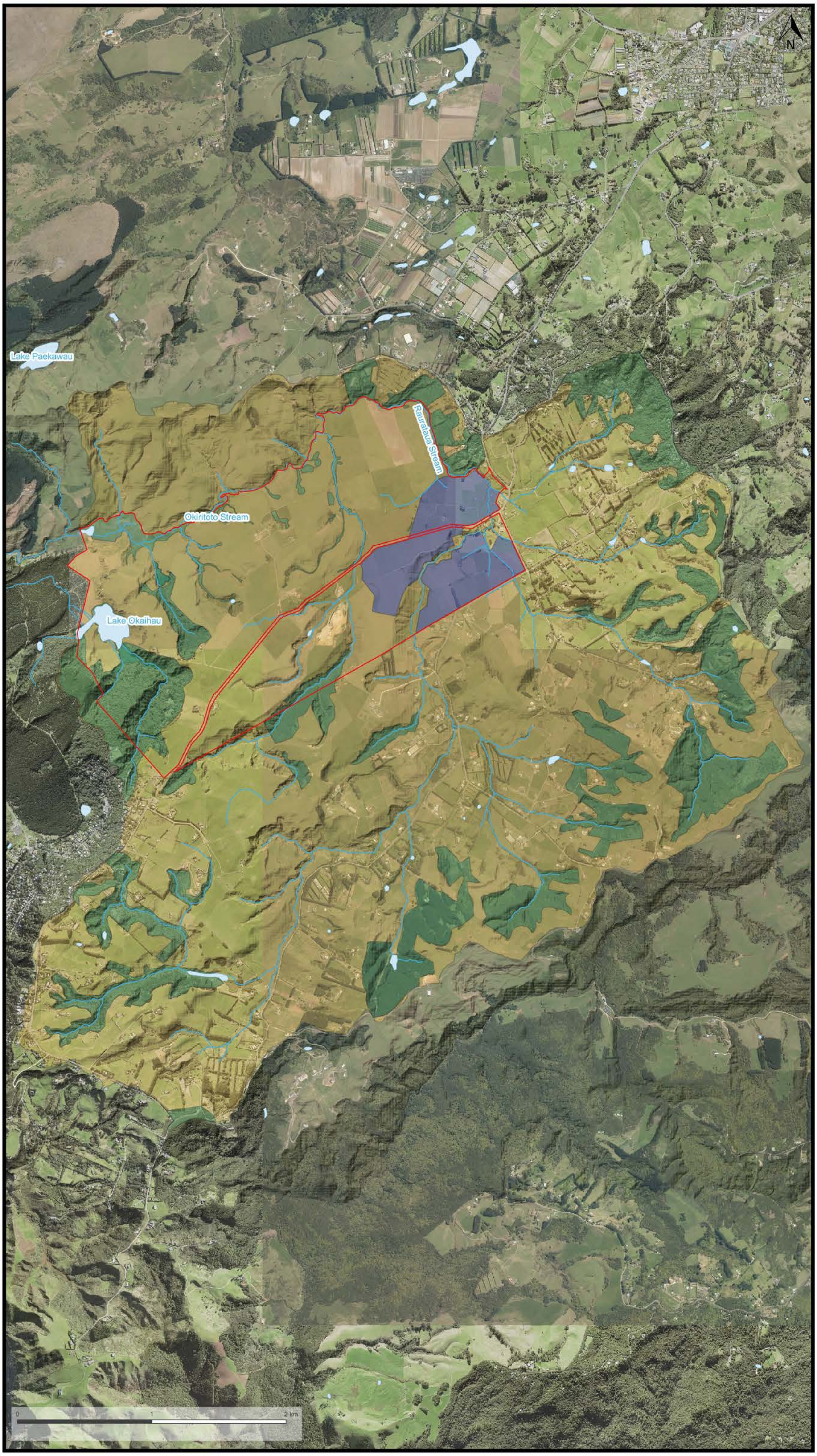
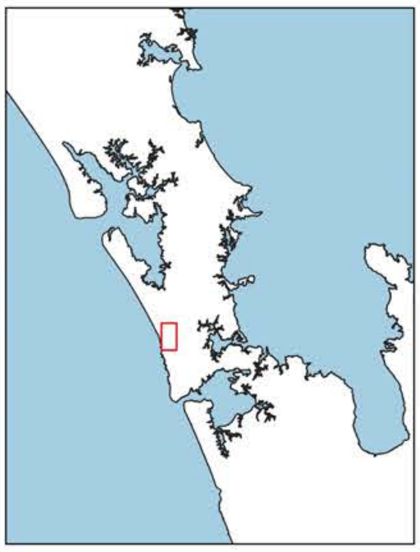
Figure 05.



Map Title:
Okiritoto Catchment land use

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

- Stream / River
- Property Extent
- Lake

Landuse

- Dairy
- Forest / Wetland
- Sheep and Beef

Data Provenance

Topographic Data derived from Land Information New Zealand

Layout & Project File

Geology

Surface Water Catchment Modelling.qgz

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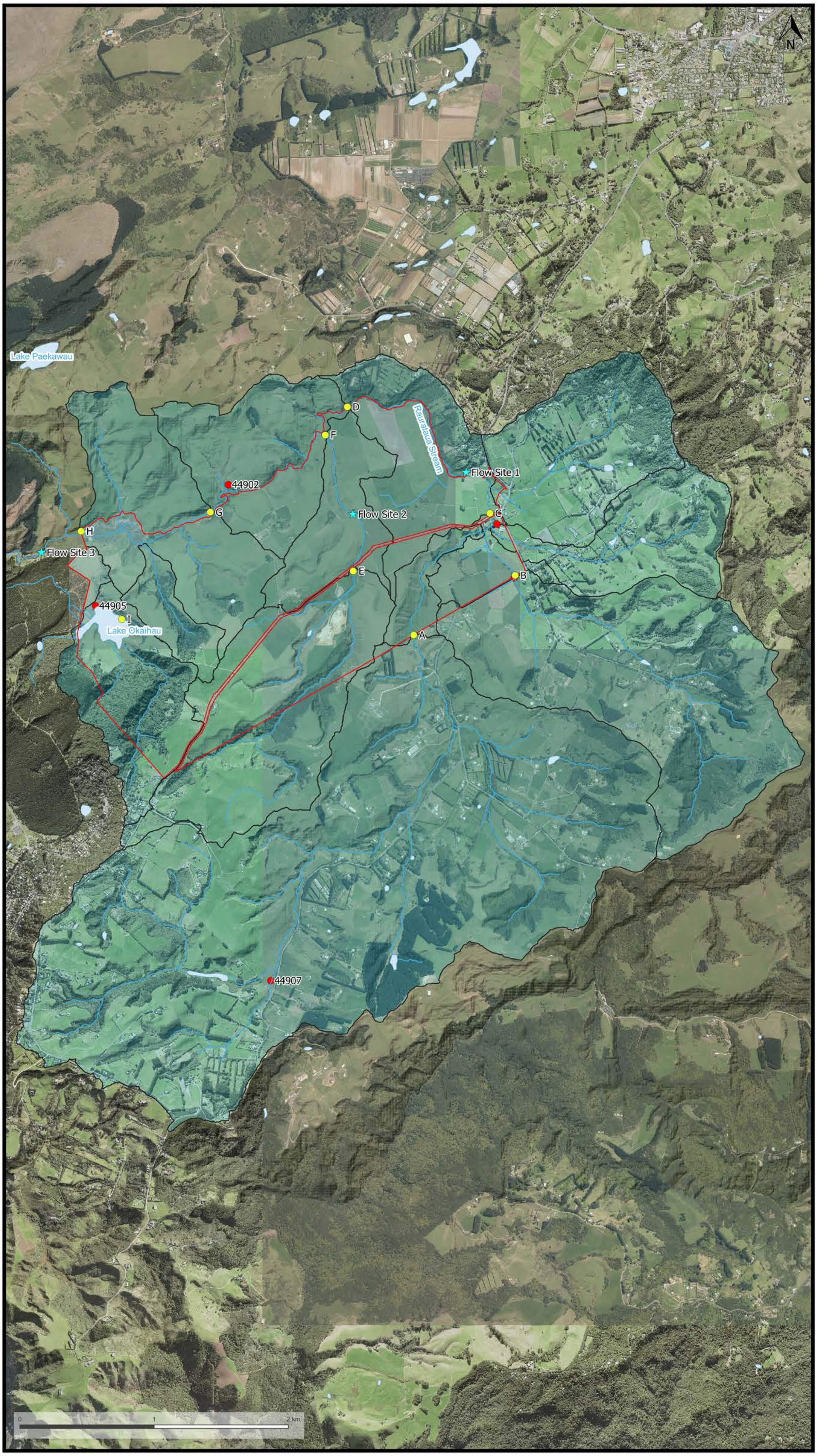
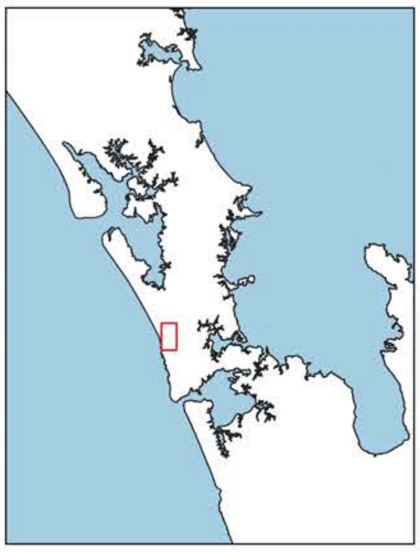
Figure 06.



Map Title:
Monitoring Sites

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

- Flow Monitoring Site
- Water Quality Monitoring Site
- Auckland Council Flow Spot Gauge
- Stream / River
- Property Extent
- Lake
- SOURCE Sub-Catchment

Data Provenance
Aerial Imagery derived from Land Information New Zealand

Layout & Project File
Topography
Surface Water Catchment Modelling.qgz

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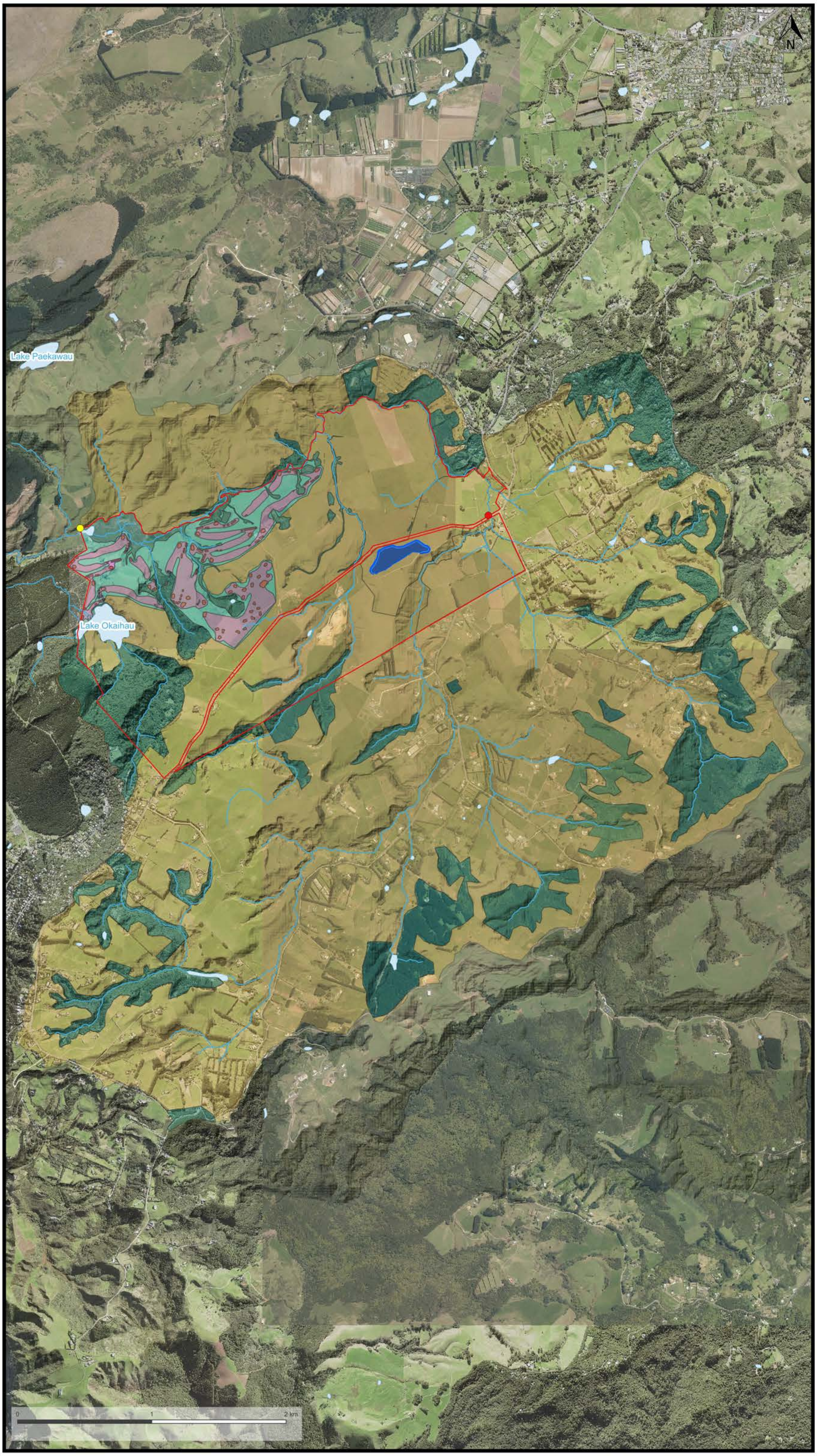
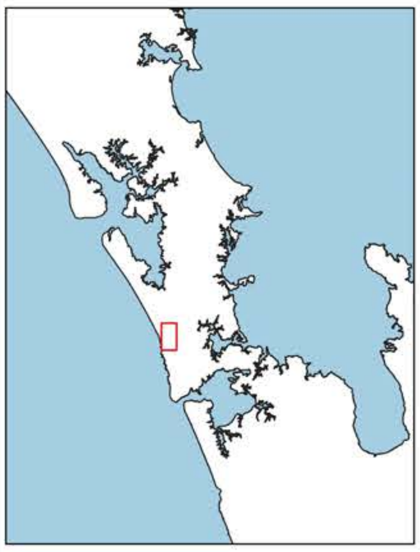
Figure 07.



Map Title:
Post Golf Course Development Land Use Map

Project:
Water Effects Assessment

Client:
Bears Home Project Management Ltd



Legend

- D/s Extent Assessment Location
- Highflow Take Location
- Stream / River
- Property Extent
- Lake
- Reservoir

Land use

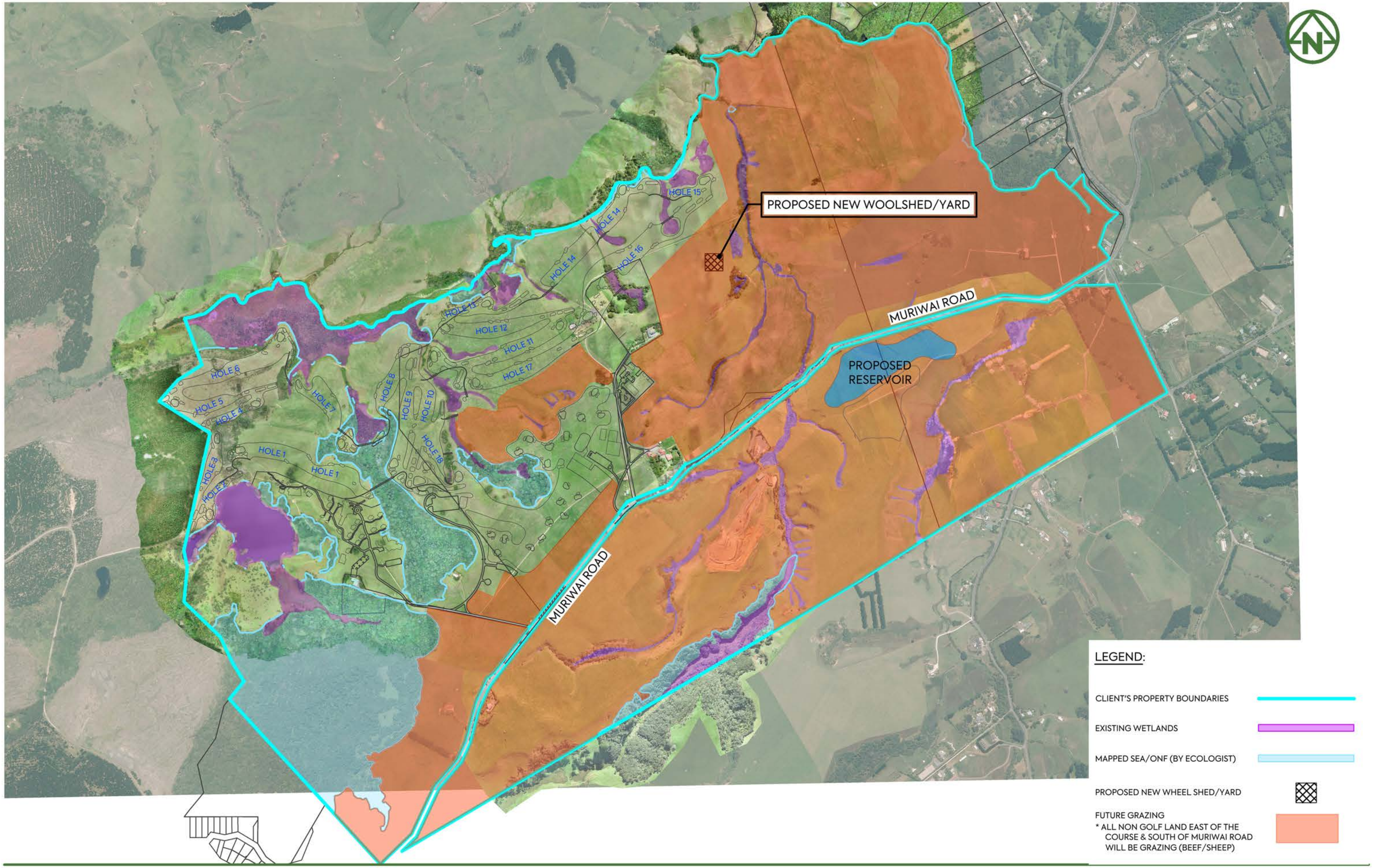
- Fairway
- Forest / Wetland
- Sheep and Beef
- Green / Tee
- Grass (Sheep and Beef Excluded)

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Geology
Surface Water Catchment Modelling.qgz

WILLIAMSON WATER & LAND ADVISORY

Figure 28.



CLIENT:
THE BEARS HOME PROJECT LIMITED

PROJECT:
MURIWAI DOWNS GOLF COURSE
610 & 697 MURIWAI ROAD
MURIWAI VALLEY

TITLE:
FUTURE GRAZING AREA
OVERALL PLAN

PURPOSE OF ISSUE:
FOR INFORMATION

SCALE:
1:11500
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DRAWING NO: 1976-0-060
REV: A

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REV	DESCRIPTION	DRN BY	CHK BY	APP BY	DATE
A	FIRST ISSUE	MO	CIM	JSD	09/11/21