Muriwai Golf Project

Water Effects Summary Report

THE BEARS HOME PROJECT MANAGEMENT LIMITED

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8 December 2021

WWLA

Muriwai Golf Project

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Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) was commissioned by The Bears Home Project Management Limited (Applicant" in January 2021 to undertake baseline water quality monitoring and to prepare a water effects assessment to support a resource consent application for the partial conversion of the Muriwai Downs property (Property) for a golf course, Clubhouse, Sports Academy and Lodge development (Project).

WWLA's scope was later expanded to include a range of additional site water related assessments, including:

- An assessment of maximum cut depths upstream of wetlands;
- An Electrical Resistivity Tomography (ERT) survey;
- A groundwater effects assessment of the proposed groundwater supply take;
- A Site Water Balance and Water Strategy Report; and
- A Water Balance Assessment of Lake Ōkaihau.

This report collates and summarises the key conclusions on water related effects associated with the proposed golf resort development. These technical reports are provided as appendices as follows:

- Appendix A: Baseline Environmental Monitoring;
- Appendix B: Site Water Balance and Water Strategy;
- Appendix C: Water Effects Assessment;
- Appendix D: Basalt Extent of Electrical Resistivity Tomography Survey;
- Appendix E: Assessment of Proposed Groundwater Supply and Associated Hydrological Effects;
- Appendix F: Lake Ōkaihau Water Balance Assessment.

In order to gain a full understanding of water related effects associated with the Project, it is recommended the reports are read in the order of the Appendices as outlined above (A to F).

The technical assessments were prepared with frequent consultation and collaboration between technical experts, with numerous site visits and teleconferences held throughout the Project. The primary technical experts WWLA engaged with during the preparation of the water related effects assessments (Appendices A to F) are summarised in **Table 1**.

Table 1. Overview of key technical expert engagement.

Technical Expert / Organisation	Specialisation
RMA Ecology	Ecology and Wetlands
McKenzie and Co.	Engineering Infrastructure, stormwater, wastewater, and construction environmental management
Steve Marsden	Golf course operation, irrigation and fertiliser operations
Dean Nikora	Current farm management

1.1 Report Structure

The report comprises descriptions of:

- The existing environment (**Section 2**);
- The proposed development (**Section 3**); and
- Assessment of effects of the proposed development (**Section 4**).

2. Existing Environment

The Property is approximately 507 hectares in size and located approximately three kilometres north east of Muriwai Beach Township (**Figure 1**), with land holdings on either side of Muriwai Road. The land is currently utilised for a mix of sheep and beef, and dairy farming.

Key site and water related features referred to throughout this report are labelled on **Figure 1**.

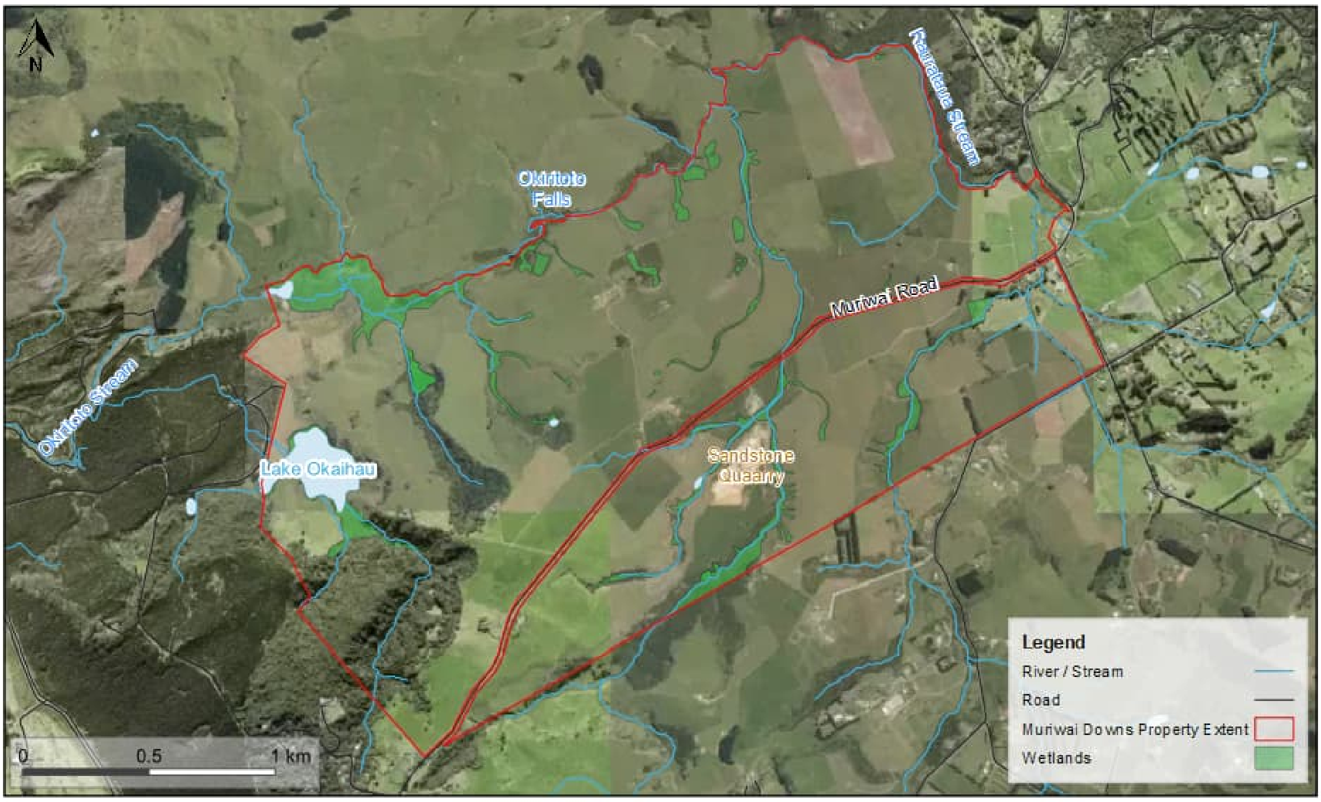

Figure 1. Site overview map.

2.1 Topography

Within the Property, the topography is generally characterised as gently rolling, with an incised river channel along the northern edge of the Property. Elevations range from approximately 10 to 130 metres above sea level (**Figure 2**).

Across the wider Ōkiritoto Stream catchment, the topography is characterised as low to moderately sloped, with low elevation cemented dune ridges with incised river and stream channels. Elevations ranging from approximately 10 to 200 m above mean sea level, with the highest elevations occurring the headwaters to the south-west (**Figure 2**).

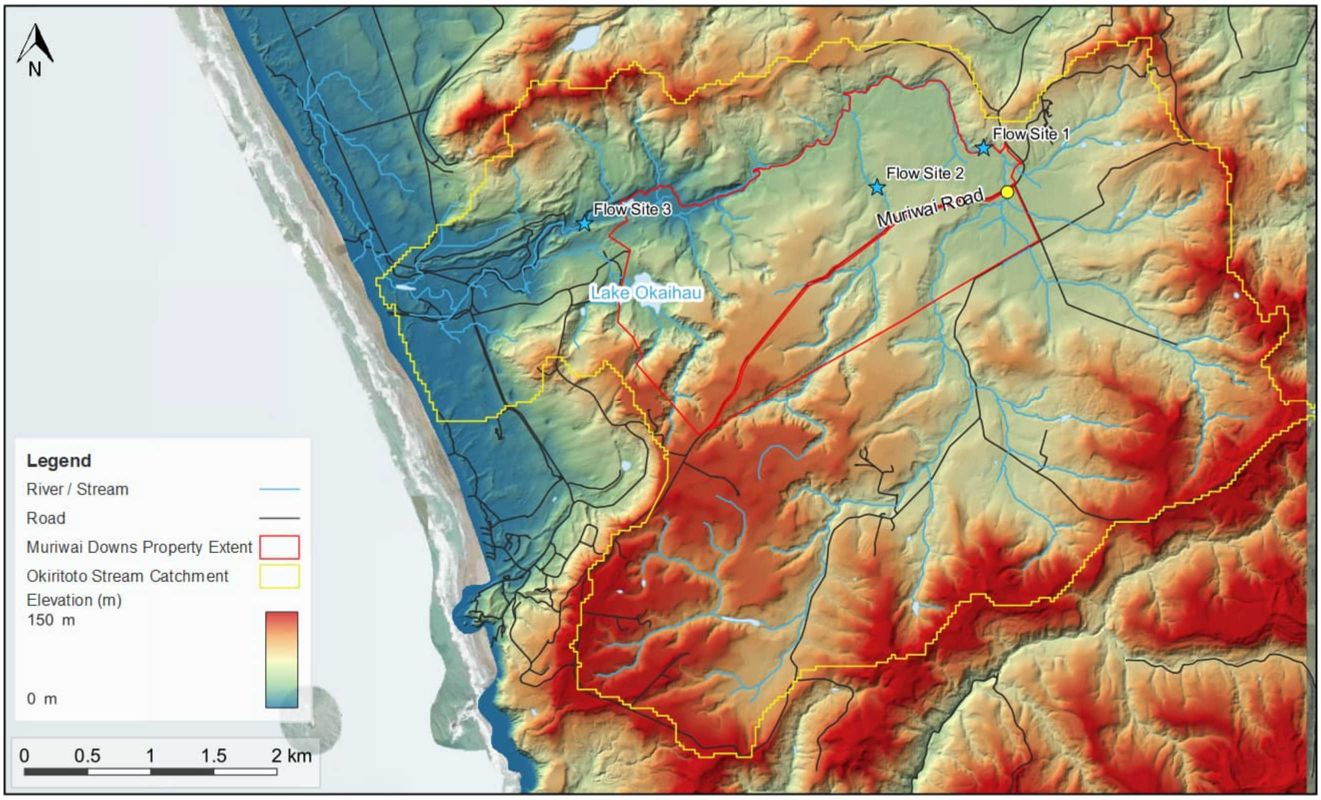

Figure 2. Topography.

2.2 Geology

The surface geology of the Ōkiritoto Stream catchment, as defined by GNS's QMAP dataset, is presented in **Figure 3**, and briefly summarised as follows. **Table 2** summarises the aquifers that are reference in this Project in terms of geologic terminology and the nomenclature used on the Auckland Council Geomaps[1] overlay.

- **Karioitahi Group –** Early Pleistocene to Holocene aged (2 million years (My) to present) coastal sands occurring in the western portion of the study area.
- **The Tauranga Group –** Late Miocene to Holocene aged (10 My to present) alluvium comprised of sand, silt, mud and clay overlying the Awhitu and/or Nohotupu formations deposited on valley floors predominantly in the eastern portion of the study area.
- **The Awhitu Group –** Late Pliocene to Early Pleistocene aged (2 to 3 My) interbedded moderate to poorly consolidated sandstone, with paleosols, lignite and carbonaceous mudstone. This layer is the most predominant surficial unit within the study area.
- **The Nihotupu Formation –** Early Miocene aged (20 My) volcaniclastic sandstone of the Waitakere Group, comprising submarine volcaniclastic grit, sandstone and siltstone, underlying the Awhitu formation.
- **The Waiatarua Formation –** Early Miocene aged (20 My) basalt flows of the Waitakere Group, including pillow lavas with minor basic andesite. A thin outcrop of pillow lava occurs at the pilot bore location and was intersected again at depth.

[1] https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html

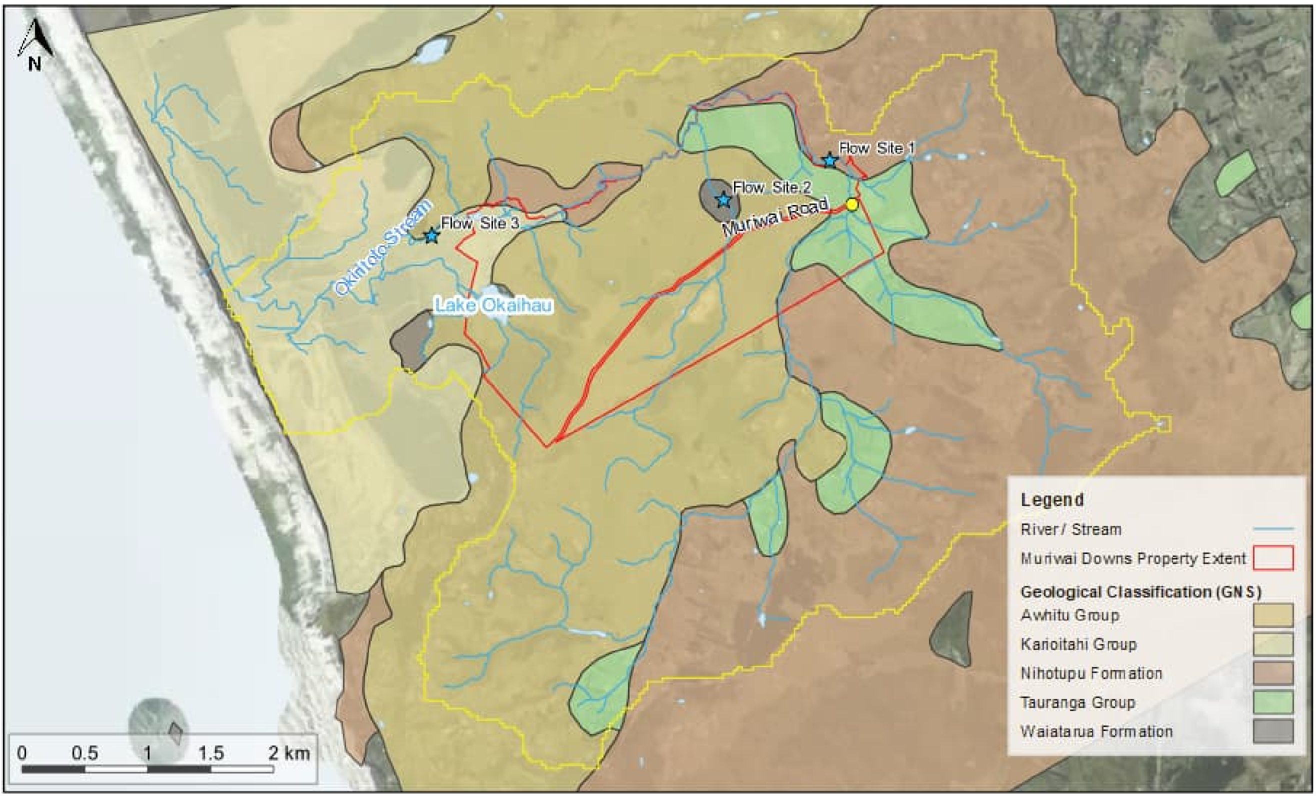

Figure 3. Surface geology.

Table 2. Summary of aquifers referenced in this study (the name in bold is the geological name, and the term in brackets refers to the grouping used on the Auckland Council GeoMaps Groundwater overlay).

Name	Description	Relevance to this Project
Kaipara Sand (Sand Aquifer)	This is the shallow sand aquifer. Within the Property and wider Ōkiritoto Catchment it predominantly occurs near the surface and comprises the Awhitu cemented sand and Kariotahi sand formations.	Proposed stormwater and wastewater discharges to ground will occur to this aquifer. In the wider Ōkiritoto Catchment, there are a number of shallow bores that draw from this aquifer.
Waitakere Volcanic (Volcanic Aquifer)	This is the basalt aquifer. Within the Property, this predominantly exists at depth, with a small surface expression at the location of the production bore. It is hydraulically disconnected from the sand aquifer above.	The production bore and proposed secondary production bore will abstract water from this aquifer.
Muriwai Waitakere Group (Waitakere Group Aquifer)	This aquifer comprises sandstone/mudstone derived from volcanic material. This aquifer exists within the property, and wider Ōkiritoto catchment as Nihotupu Sandstone.	No activities are proposed to occur within this group.
Muriwai Waitemata (Waitemata Aquifer)	The Waitemata aquifer classification refers to all aquifers underlying the Waitemata Basin.	Collectively, all aquifers in the Muriwai area are referred to as Muriwai Waitemata, which is a sub-group of the Waitemata Aquifer grouping.

2.3 Soils

The NZ Sports Turf Institute (2021) - Effects on Soil report describes the three main soil types across the Property (AEE – Appendix 8). These are:

- **Orthic Granular Soils –** a clayey soil formed from weathering of volcanic rocks or ash and is slowly permeable with limited rooting depth and naturally low nutrient reserves.
- **Sandy Recent Soils –** comprised of sand or loamy sand soils. These soils have deep rooting and high plant-available water capacity with high natural fertility.
- **Impeded Allophanic Soils –** have a hard layer that impedes roots and water.

The majority of the Property is classified as Orthic Granular soils. Sandy Recent Soils are found in the north-western corner of the property, and a small area of Impeded Allophanic Soils towards the south-eastern corner of the property, south of Muriwai Road.

2.4 Land Use

The land use across the Property currently comprises a combination of dairy farming, sheep and beef grazing with associated farm buildings and infrastructure, and unproductive pasture (**Figure 4**). The Property contains areas of wetlands and waterways and vegetation, with approximate coverage areas summarised in **Table 3**. Parts of the Property are also classified in the Auckland Unitary Plan (Operative in Part) (AUP) as significant ecological areas and outstanding natural features.

Table 3. Summary of current site land use.

Land use	Area (ha)
Dairy	~70
Sheep and Beef	~290
Unproductive	47.4
Native Bush	65.9

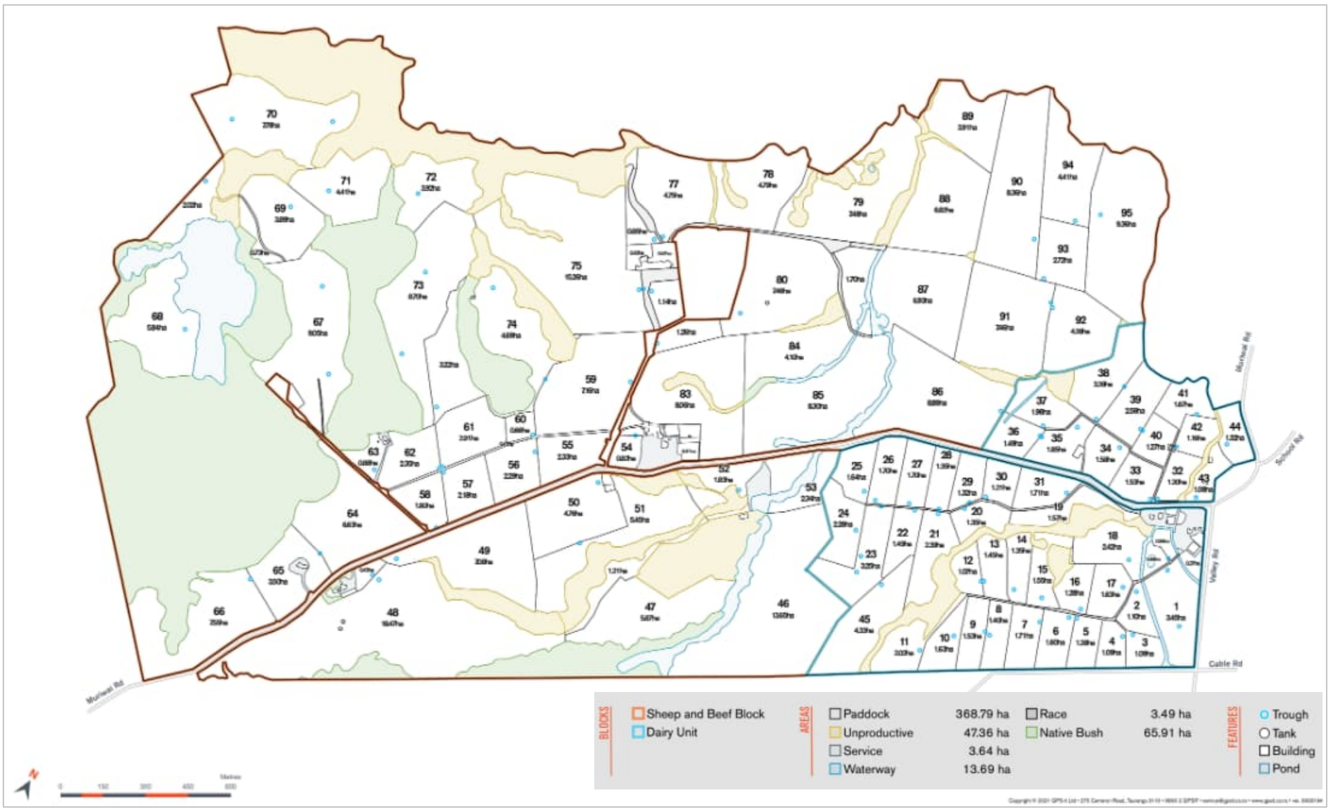

Figure 4. Current site land use.

2.5 Surface Water

The Ōkiritoto Stream enters the site near the middle of the southern Property boundary and flows northwards along the eastern side of the sandstone quarry. The Ōkiritoto Stream has a sharp bend near Site F (**Figure 5**) and flows west-south-west towards the coast, where it discharges on Muriwai Beach. The Rauratua Stream flows along the eastern and northern Property boundary, and joins the Ōkiritoto Stream near Site F. Together the streams are referred to as the Ōkiritoto Stream catchment.

A project-specific baseline water quantity and quality monitoring programme was initiated over the period late February to early August 2021. The objectives of the monitoring programme were to inform the current understanding of water quantity and quality across the site and provide a dataset to calibrate and verify the catchment flow and water quality model. The following items were measured:

- Stream flow (3 x locations);
- Shallow groundwater / wetland water levels (5 x locations);

- Surface water quality (8 x locations); and
- Wetland water quality (8 x locations).
- The locations of these monitoring sites are presented **Figure 5**.

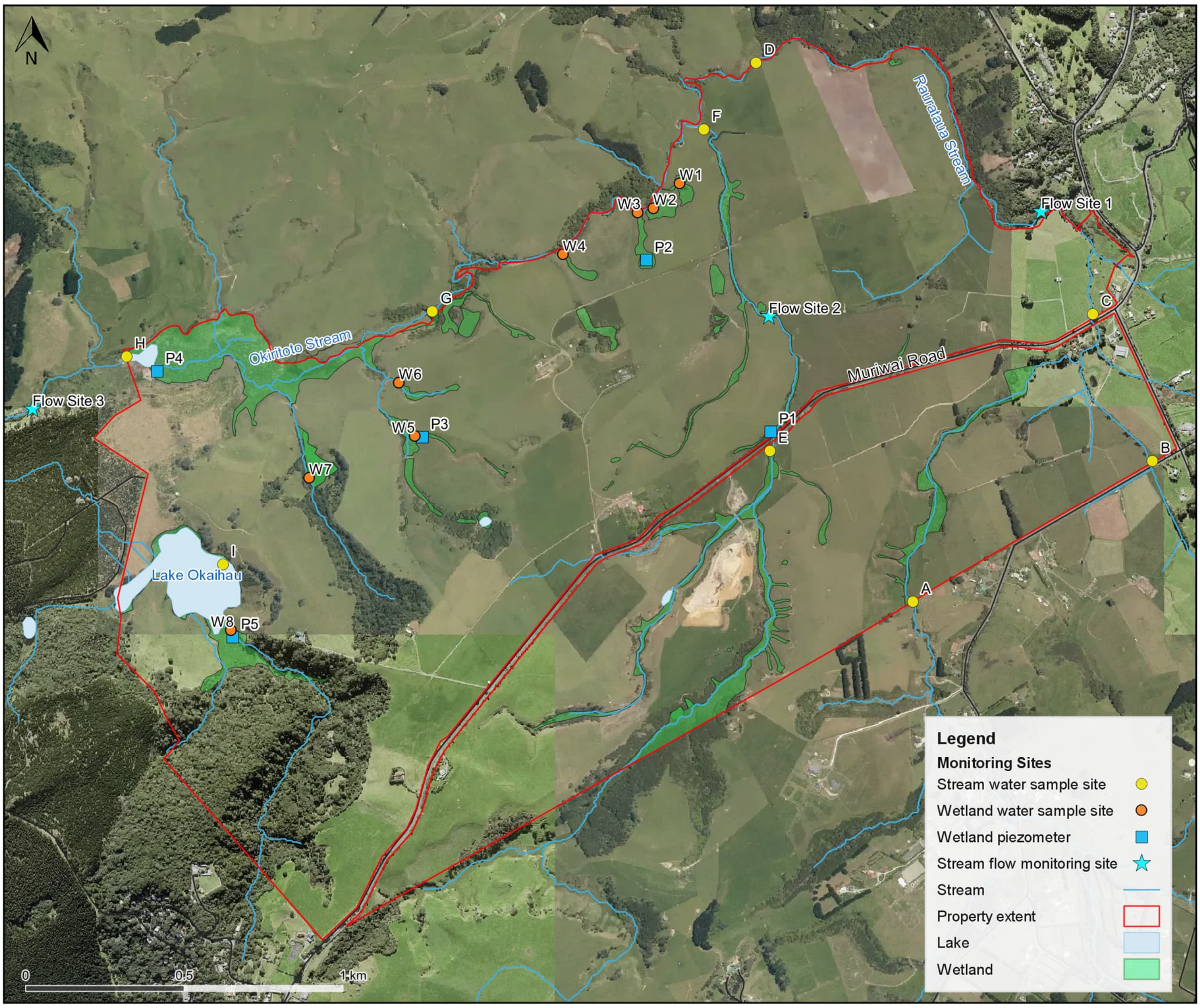

Figure 5. Overview map of environmental monitoring locations.

Full details are of the Baseline Monitoring Programme are presented in in Appendix A to this report.

2.5.1 Water Quantity

Surface water quantity (stream flow) across the site was quantified through the use of a catchment flow model (rainfall runoff model), of the Ōkiritoto Stream catchment. The catchment flow model was calibrated against the flow monitoring data indicated above. Full details on the development and calibration of the catchment flow model are presented in Appendix C to this report.

Site H (**Figure 5**) represents the most downstream point of the Ōkiritoto Stream catchment, as it exists the Property towards the coast. The simulated flow hydrograph and summary flow statistics for this site are presented in **Figure 6** and **Table 4**, respectively, and provide a collective summary of water quantity flowing through the site.

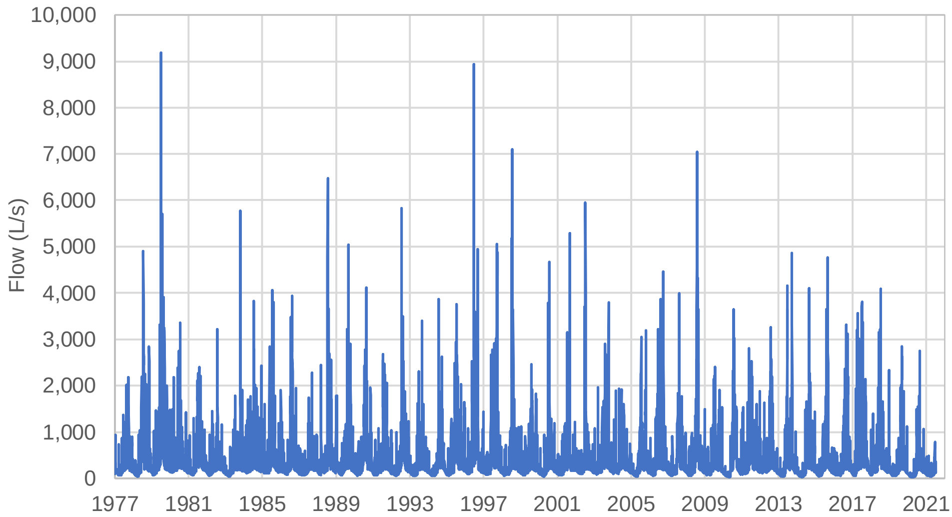

Figure 6. Simulated flow hydrograph at the proposed downstream extent of the Property (Site H).

Table 4. Simulated flow statistics at the downstream extent of the Property (Site H).

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

Simulated flow demonstrates the stream exhibits a typical seasonal pattern with higher flows in winter, and low flows during summer. Simulated flow for the period 1972 through to 2020 from a minimum flow of 22 L/s to a maximum of 9,182 L/s. It should be noted, the simulated flow represents a daily average flow, and therefore instantaneous peak flood flows will be larger than presented here.

2.5.1.1 Allocation

The AUP, provides provisions for the taking and use of water under Chapter E2. The abstraction of water under normal conditions is referred to as core allocation, and the allocation limit defined as 30% of the Mean Annual Low Flow (MALF). During high-flow conditions, defined a times of above median flow, up to 10% of the flow can be abstracted. This is referred to as a high-flow take.

There is one consented surface water take downstream of the Property (WAT60068739). This is a core allocation 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. Therefore, core allocation is considered allocated within the Ōkiritoto catchment. In addition, there may be permitted surface water takes for drinking water and stock use downstream of the proposed take.

There are however no high-flow takes, and thus the full high-flow allocation in the Ōkiritoto Catchment is available.

2.5.2 Water Quality

A full suite of water quality parameters were collected. The key parameters assessed included Nitrite-N (NO_2^-), Nitrate-N (NO_3-N), Ammonia as N (NH_3N), Dissolved Reactive Phosphorus (DRP), Total Suspended Solids (TSS), and E. Coli (E. Coli).

The following key conclusions on water quality were drawn from the baseline monitoring programme (WWLA, 2021a (**Appendix A**):

- Water quality monitoring suggests that on average, the streams tend to show more consistent nutrient concentrations across the monitoring period, while the wetland nutrient levels were more variable with higher average and peak nutrient concentrations.
- Across most other parameters both the average and peak concentrations tend to be higher in the wetlands than in the streams.
- The streams tended to show a steady increase in Nitrate-N (NO_3-N) levels over the monitoring period, with higher levels after wetter weather conditions.
- Wetland sites did not record the same clear seasonal effect.
- Stream sample Site B tended to have higher nutrient concentrations as it entered the Property compared to Site A and E which originated from different catchments (Raurataua Stream, and the Unnamed Tributary, respectively).
- Stream and wetland water quality varied somewhat across the monitoring period, and, for the parameters that could be compared to relevant aquatic ecology guidelines[2], nitrate and ammonia concentrations were generally well below the trigger values set for 95% protection level for "healthy" aquatic ecosystems in slightly to moderately disturbed conditions[3].
- All wetland water quality monitoring samples, and 94% of all stream water quality samples collected were below the Attribute Band A 95th percentile value for DRP. Attribute Band A represents a site where Ecological communities and ecosystem processes are similar to those of natural reference conditions, with no adverse effects attributable to DRP enrichment expected. It is however noted five years of monthly sampling is required to determine a sites Attribute Band, and therefore these are considered indicative only.

2.6 Groundwater

The Waiatarua Basalt (subsurface extension of the basalt displayed in **Figure 3**) functions as an underground reservoir surrounded by the Nihotupu Sandstone Formation. Vertical seepage through the sandstone is the recharge source for the groundwater stored in the basalt.

The volume of water stored within the basalt aquifer is a function of its extent and porosity. The results of initial investigations (as described in the following sections) have determined that there is potential for a productive groundwater yield from the basalt aquifer on the Property. Improving the understanding of the lateral extent of the basalt at depth was a key objective of the various site investigations and modelling described in **Section 2.6.3**.

2.6.1 Site Investigations

Hydrogeological investigations have been undertaken at the Property in order to build the base of known information to support the evaluation of potential groundwater supply and associated environmental effects.

[2] ASNZ Guidelines for Fresh and Marine Water Quality (2000).
[3] Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity[2].

The exercises undertaken were primarily aimed at characterising the basalt extent and hydraulic properties and have informed the broader analysis represented by the numerical model (detailed in Appendix E of this report).

The focus area for the investigations was a small exposure of basalt pillow lava that has previously been quarried at the Property. The surface outcrop is mapped with limited lateral extent of approximately 350 m on the QMAP geology map, however the vertical extent and subsurface volume were previously unknown. The following sections detail a series of investigations aimed at furthering our understanding of the basalt aquifer and sustainable groundwater yield potential.

Drilling

A pilot bore was drilled at the basalt outcrop for investigative purposes. The selected site is adjacent to a very small historic quarry site. The drilling indicated a thin outcrop of pillow lava at surface extending to a depth of only 15 m, underlain by sandstone and siltstone to 120 mBGL, with a deeper highly fractured pillow lava structure encountered from 120 to at least 230 mBGL, where drilling ended. Hence the lower extent of the basalt was not determined by the pilot bore investigations.

As mentioned previously, the fractured basalt/andesitic pillow lava at depth is considered the best prospect for development as a groundwater resource.

Test Pumping

An airlift test on the pilot bore was conducted by Pattle Delamare and Partners (PDP) for a period of three days at a rate of 9 L/s, commencing on 3 March 2021 (PDP, 2021).

The maximum drawdown measured during the test was 4.25 m. However subsequent monitoring indicates that the bore was not in a static state at the time the test started. It is estimated that the true maximum drawdown from the test is only 3.68 m. After the drawdown phase of the test, water level recovery was monitored for one day during which time a recovery of 53% of the peak drawdown relative to the adjusted static water level (SWL) was observed.

WWLA undertook an analysis of the test pumping data to provide an indication of hydrogeologic properties of the basalt, which are important input parameters for establishing the yield potential of an aquifer and hence the actual and potential effects from abstraction. Drawdown dynamics measured in the bore over the abstraction period indicated three phases (summarised below) where different materials were governing the water yield, supporting the conclusion that the basalt where the bore is located is limited in extent.

Test pumping results can be interpreted in the context of regional geology to support the following conclusions:

1. The first phase is primarily influenced by the basalt in close proximity to the bore;
2. The second phase represents influences from a broader (and potentially deeper) extent of basalt flow; and
3. The third phase is influenced by the cone of depression intersecting the massive sandstone of the Nihotupu Formation surrounding the basalt.

Test pumping results were used to calculate a transmissivity value for each material and subsequently to calculate hydraulic conductivity[4] which was used in the groundwater model (WWLA 2021 – Appendix E).

ERT Survey

To better characterise the three-dimensional extent of the basalt and estimate water storage volumes, a series of four electrical resistivity tomography (ERT) surveys were undertaken between 24 June and 1 July 2021 (WWLA, 2021 – Appendix C).

[4] Hydraulic conductivity refers to the rate at which water can flow through a geologic material in units of length over time, and is used to quantify material permeability.

Resistivity data from the four profiles showed a contrast in electrical resistivity between the basalt and the surrounding sandstone of the Nihotupu Formation, which was used to delineate the basalt extent. A key outcome of the survey was improved visualisation of the shape and extent of the basalt, as shown in **Figure 7**. The three-dimensional surface model developed indicates that the basalt is likely a complex of at least three basalt dykes with associated deeper lava flows. The ERT survey suggests that the surface exposure of basalt was derived from the dyke structure (a vertically oriented protrusion of basalt penetrating overlying geological layers) approximately 100 m to the northeast of the pilot bore location.

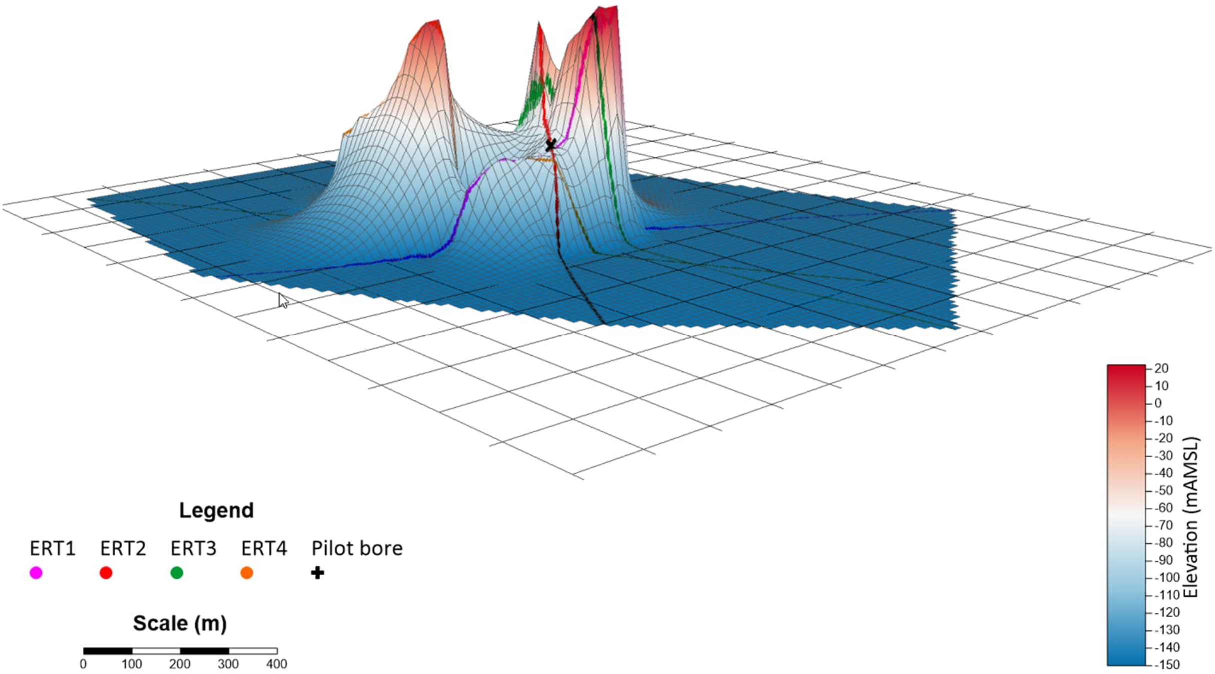

Figure 7. Three-dimensional shape of basalt looking northward (Appendix D to this report).

Monitoring

Over the course of the investigations conducted at the Property four groundwater monitoring sites have been established and equipped with data loggers for continuous groundwater level measurement.

Three other piezometers were installed to the south of Muriwai Road for the purposes of geotechnical investigations at a proposed reservoir site. These sites have not been equipped with data loggers, though static water level has been measured. Additionally, shallow piezometers were installed in a number of the wetlands (indicated in **Figure 8**) and two in the quarry south of Muriwai Road, however at approximately 1 m in depth these are too shallow to be indicative of regional groundwater levels. All monitoring locations are shown in **Figure 8**.

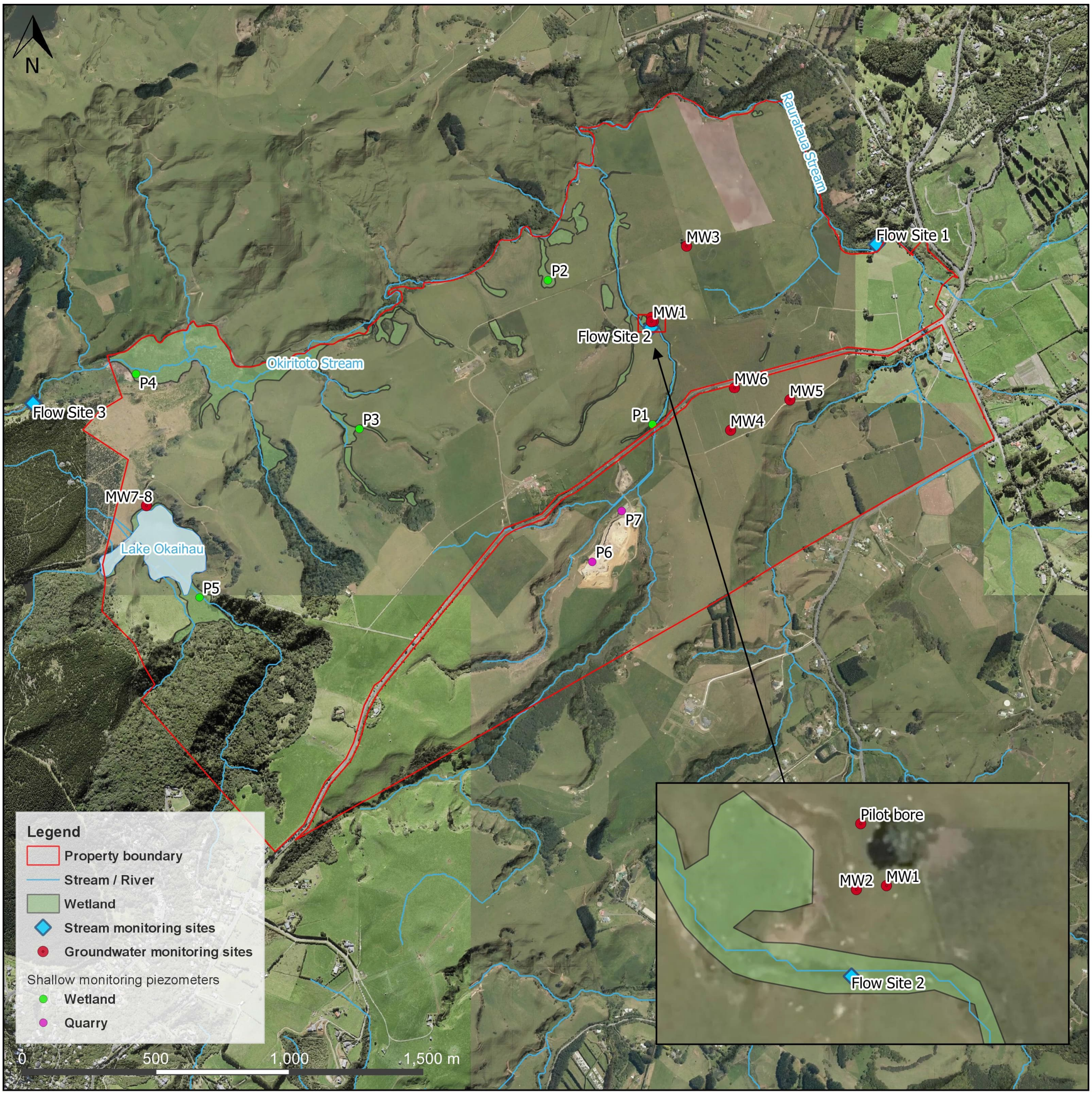

Figure 8. Monitoring locations on Muriwai Downs Property.

2.6.2 Conceptual Model

A conceptual groundwater model was developed to provide an understanding of the hydrogeological conditions in terms of recharge and flow regime on the Property and underpin the construction of a three-dimensional numerical model. The system was schematically conceptualised in terms of inputs (recharge) and outputs (discharge to streams and to the ocean).

As indicated previously, the most viable groundwater resource on the Property is the basalt aquifer. Groundwater within the aquifer originates as rainfall, a portion of which percolates through the soil. The basalt outcropping mentioned in the previous section is the surface expression of a dyke formation that protrudes from a deep basalt flow. This area is likely to be a high recharge zone relative to other areas of the Property due to higher permeability of the basalt. Percolation that flows into the dyke formation is either stored within the dyke or flows into the presumed deep basalt flow where it flows towards the coast, eventually discharging offshore in the ocean.

Sandstone predominates over the rest of the Property, featuring many hard pans with low permeability. The hard pans limit vertical recharge and promote lateral subsurface flow, causing shallow groundwater to emerge as baseflow in streams. The portion of water that does percolate to greater depth is most likely a supplemental recharge source to the deep basalt. The process of further developing the conceptual model begins with the partitioning of rainfall to groundwater, stream flow, and evapotranspiration, with further analysis undertaken to characterise the prevailing conditions that govern the system, identifying the fluxes between groundwater and surface water. These fluxes, along with the framework in which they occur, are the basis for numerical modelling analysis.

The conceptual model indicates that rainfall infiltration is the source of regional groundwater. A large portion of rainfall that occurs over sandstone type geology flows laterally through soil or in the shallow aquifer to emerge as baseflow in the nearest downgradient stream. Regional groundwater in the deep aquifer roughly follows the patterns of flow in the catchment, with flow toward the Ōkiritoto Valley and then west toward the ocean.

2.6.3 Groundwater Model

A numerical groundwater model was developed to simulate groundwater flow within the Muriwai Downs Study Area, defined as the Ōkiritoto Stream catchment to the point where the stream exits the Muriwai Downs Property, in order to quantify available resources and potential impacts from abstraction. The MODFLOW Unstructured Grid (MODFLOW-USG) developed by the United States Geological Survey (USGS) was utilised within the GMS10.4 modelling platform to construct the groundwater flow model in this Project.

The model domain is illustrated in **Figure 9**.

Full details of the groundwater model development, calibration and scenario simulations are presented in Appendix E. A Basecase and a Future Development scenario with the inclusion of the proposed groundwater take (**Section 3.3.3**) were simulated in the groundwater model. Simulated groundwater levels from the Future Development scenario were compared to those from the Basecase scenario to determine and quantify effects associated with the proposed groundwater abstraction. Effects of the proposed groundwater abstraction are presented in **Section 4.2.3**.

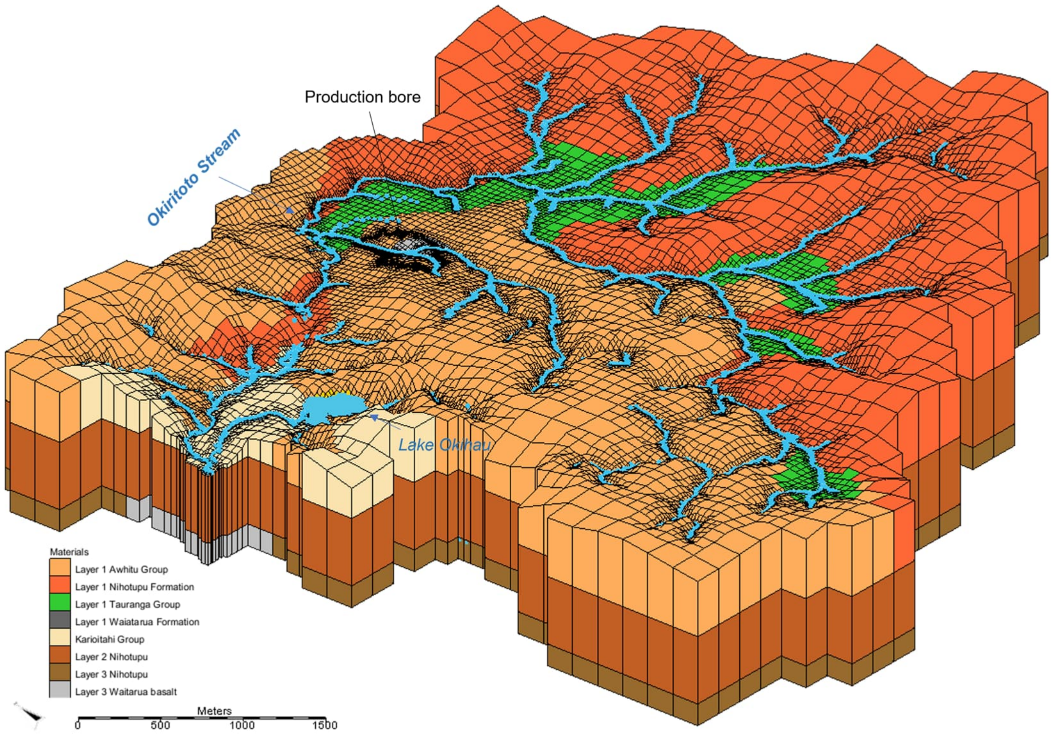

Figure 9. MODFLOW-USG grid (3x vertical magnification).

The process of developing and calibrating the groundwater model supported the assumptions that the basalt-dyke had relatively high hydraulic conductivity whereas the sandstone has comparatively low hydraulic conductivity. It was also found that there is likely to be a deep basalt-flow that underlies the Ōkiritoto Valley below the sandstone layers and serves as a conduit for deep groundwater to discharge into the ocean. This is in keeping with previous geologic analyses that have shown basalt flows occurring at various depths throughout the region.

There is groundwater in both the sandstone and the basalt materials, however the higher conductivity of the basalt makes it a far better prospect for using groundwater resources. Since the basalt occurs below and/or within the Nihotupu sandstone, some water from the sandstone flows into the basalt. Ultimately, the size of the basalt formation has implications for the groundwater yield that can be sustainably abstracted, however the full extent of deep basalt can only be estimated through test pumping, geophysical surveying or additional drilling.

The low permeability of the sandstone material that occurs over most of the surface of the study area limits connection to the deep aquifer in these areas. This limits the effects on surface water features (streams and wetlands) from abstraction of deep groundwater.

2.7 Wetlands

Wetlands were mapped across the Property by the Project Ecologists from RMA Ecology Ltd (AEE Appendix 11). In total, there are 21 wetlands that meet the National Policy Statement for Freshwater Management 2020 (NPS-FM) definition of a natural inland wetland,[5] and cover approximately 37 hectares (**Figure 10**).

The majority of wetlands on site have been degraded through historic farming activities, resulting in significant modifications to the soils and plant communities. They are now dominated by exotic herbs and weed species.

[5] Regulation 3.21.

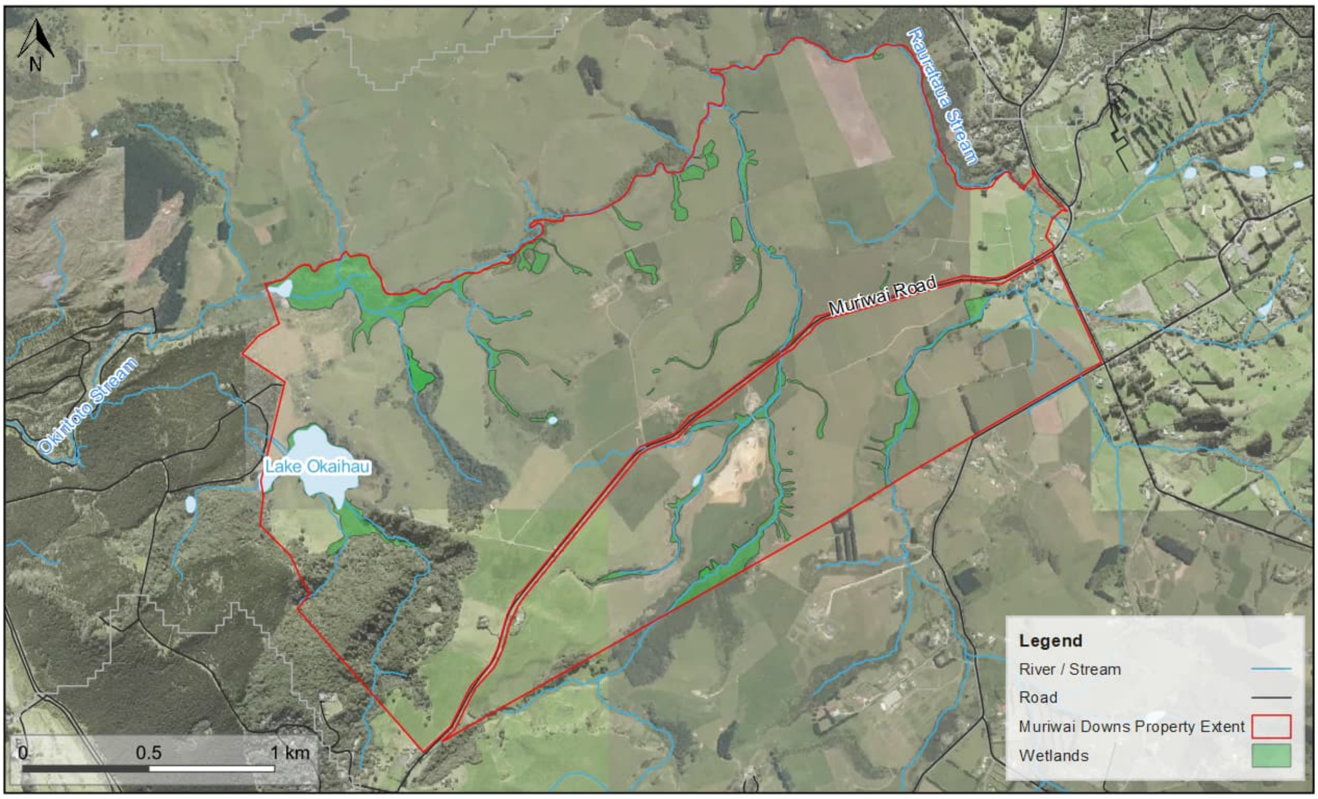

Figure 10. Mapped wetlands within the Property.

2.7.1 Conceptual Wetland Classification

Understanding the hydrological functioning of a wetland (i.e., whether it is fed by rainwater, surface water, groundwater, or a combination of each) enables potential effects specific to a given wetland to be identified. For example, a wetland that is predominately fed and sustained from groundwater would not be expected to be significantly affected by changes to surface water flows.

Wetlands across the Property were conceptually classified by WWLA into four types based on their position in the landscape and assumed hydrological functioning. These classifications are schematically illustrated in **Figure 11**, mapped in **Figure 12**, and summarised as follows:

- **Type 1 – Palustrine wetlands:** found upstream of the saline interface, in low-lying coastal floodplains.
- **Type 2 – Dune Lake wetlands:** formed in the margins around a dune lake.
- **Type 3 – Surface water and groundwater fed wetlands:** maintained primarily through surface water runoff, with smaller groundwater flows within narrow valley floors.
- **Type 4 – Valley wall seepage wetlands:** are found higher in the valley topography than Type 3 wetlands, and are maintained through groundwater seeps along sub-surface impermeable layers.

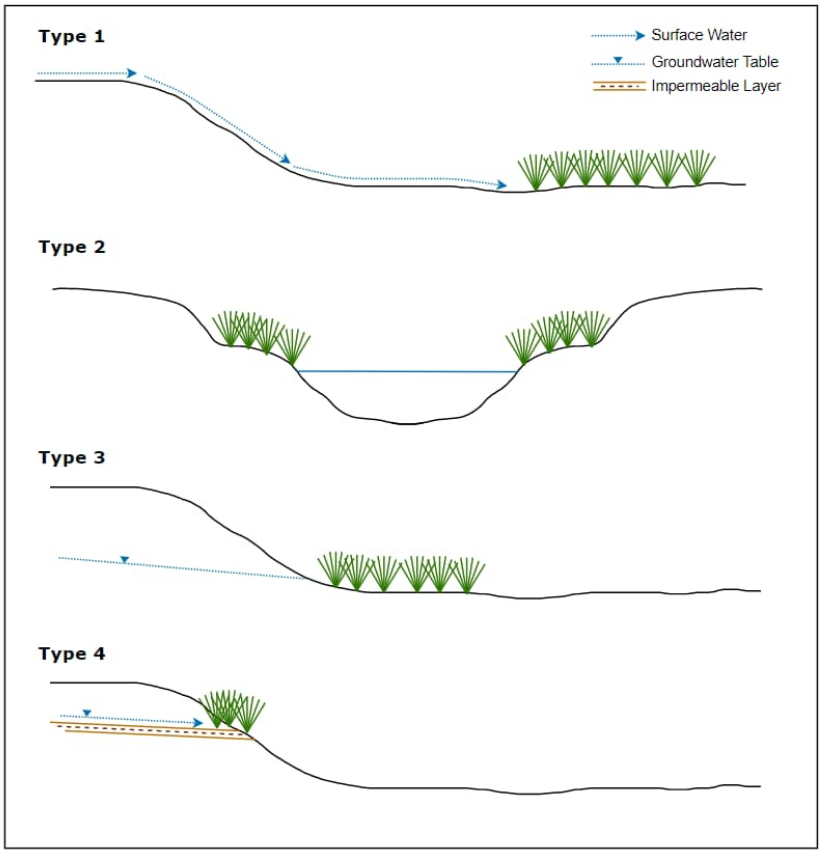

Figure 11. Schematic of conceptual wetland classifications.

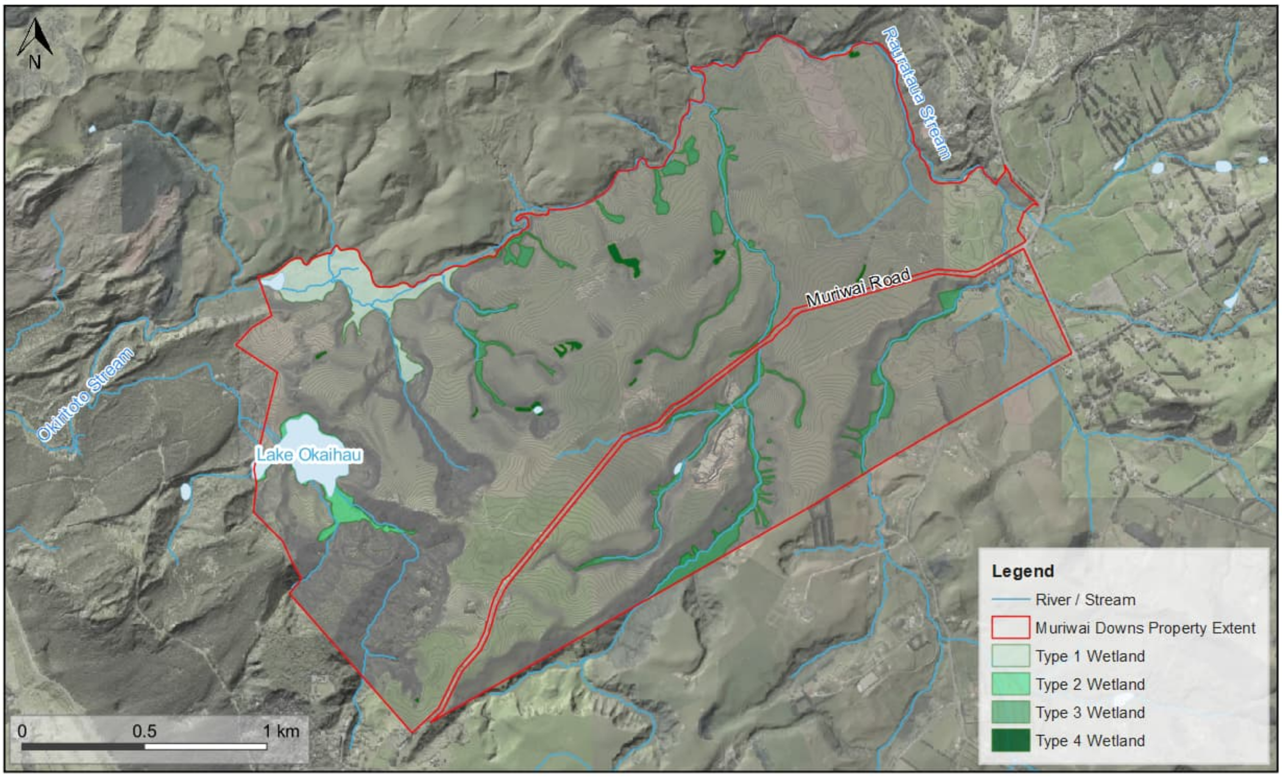

Figure 12. Classification of mapped wetlands.

2.8 Lake Ōkaihau

Lake Ōkaihau is located along the western edge of the Property. The lake is 6.2 hectares in surface area, and up to approximately 10 m deep at its deepest point towards the centre. A photograph of Lake Ōkaihau is presented in **Figure 13**.

The lake is classified as a Significant Ecological Feature under the AUP. However, the lake is classified as having poor ecological health based on Lake Submerged Plant Indicators (RMA Ecology, AEE – Appendix 11).

Figure 13. Lake **Ō**kaihau.

2.8.1 Conceptual Model of Lake Ōkaihau

The conceptual hydrological functioning of Lake Ōkaihau was tested through the development of the Lake Ōkaihau Water Balance Model (**Appendix F**). Through the water balance assessment, the hydrological functioning is understood as follows:

- The lake bed consists of low permeability material, that is thicker on the bottom, and pinches (i.e. thins) towards the margins of the lake;
- This results in low groundwater seepage loss from the lake during periods of low lake water levels (summer), and higher rates of seepage during periods of elevated water levels (winter);
- The largest inflow to the lake is from the stream catchment from the south; and
- The largest net loss from the lake is through groundwater seepage via the sand dunes to the north, towards the Ōkiritoto Stream.

Key components hydrological components are presented in **Figure 16**. In addition, direct rainfall additions, and evaporation losses occur directly from the lakes surface.

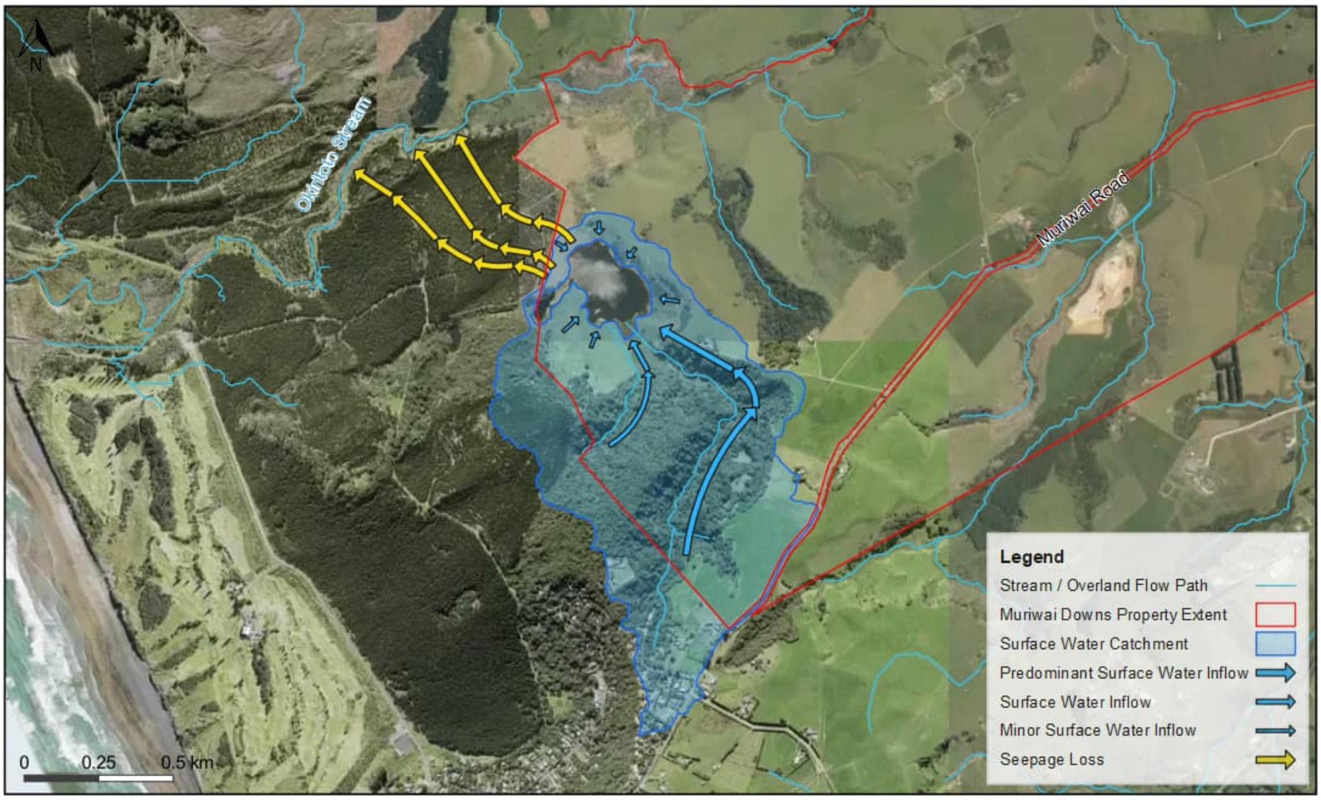

Figure 14. Conceptual hydrological functioning of Lake Ōkaihau.

The conceptual understanding of the lake's hydrological functioning was further supported by the presence of a vertical pressure gradient in groundwater levels measured at a deep (14.5 m), and shallow (5.5 m) monitoring piezometer installed approximately 10 m adjacent to the lake’s shoreline in early October 2021.

3. Description of the Proposed Activity

3.1 Overview

The Project comprises of the construction, operation and maintenance of:

- a 19-hole golf course with warm-up fairway and short-game practice area;
- a Clubhouse;
- a Sports Academy including; an academy building, academy driving range, practice green, 9-hole short course, and indoor and outdoor tennis facilities;
- a Golf and Property Maintenance Complex;
- a luxury lodge;
- groundwater and surface water abstraction facilities;
- off-stream water storage reservoir;
- significant ecological restoration and enhancement works; and
- various supporting infrastructure associated with the above items.

The proposed Project site plan is presented in **Figure 15**.

Figure 15. Proposed development – site overview plan.

Key features of the Project that are associated with or have actual or potential effects on water quantity and quality are further detailed below.

3.2 Water Demand

A summary of key water demand requirements associated with the Project are summarised below.

3.2.1 Irrigation

Irrigation demand forms the largest water requirement of the proposed development. Irrigation is required to maintain the premium quality golf course turf and general landscaping around the development. Irrigation is discussed further in the Golf Course Operations and Maintenance Report (Appendix 3 to AEE).

Prevost Stamper Irrigation (PSI) Estimate

Irrigation expert Jeff Stamper of US consultancy firm Prevost Stamper Irrigation (PSI) was commissioned to provide technical advice and assessment on golf course irrigation water use requirements. A copy of the report is annexed as Appendix 10 to the Golf Course Operations and Maintenance Report (Appendix 3 to AEE).

Golf greens (3.4 ha) will consist of Creeping Bentgrass, while fairways, roughs and tees will consist of Windsor Green Couch grass (41.1 ha). Based on historic climate data, estimated irrigation system efficiency, and monthly crop coefficients, monthly turf irrigation estimates were calculated, and the total annual average water requirement for the golfing area (44.5 ha) was estimated as 167,990 m^3. Of this, 6,970 m^3/ha/year is required for the golf greens (Creeping Bentgrass), and 3,515 m^3/ha/year is required for the fairways, roughs and tees (Windsorgreen Couch).

Creeping Bentgrass and Windowsgreen Couch were specifically selected for the Project as they provide a high-quality golfing surface, and lower irrigation requirements in comparison to alternative golfing grasses/turfs. Full detail on grass/turf selection is provided in the Golf Course Operations and Maintenance Report (Appendix 3 to AEE).

A greater volume of irrigation will be required in the initial stages during the turf grow-in period. Details of irrigation requirements specific to the grow-in period are detailed in Golf Course Operations and Maintenance Report (Appendix 3 to AEE).

WWLA Estimate

As part of the Site Water Balance and Strategy Assessment (**Appendix B**), a historic daily irrigation demand profile was required along with an estimate of general landscaping irrigation requirements. Therefore, WWLA produced a secondary estimate of irrigation water use requirements using their Soil Moisture Water Balance Model – Irrigation Module, which was configured using the crop coefficients, turf adjustment factors, and system efficiency parameters as provided by PSI. The resulting annual irrigation water use estimates are presented in **Table 5**.

The 1-in-10-year annual irrigation water estimate for the golfing area (i.e. excluding general landscaping), was approximately 9% greater than that calculated by PSI. This difference is considered within the general level of uncertainty of both assessments.

Table 5. Summary of annual irrigation water use estimates by WWLA.

Grass Species	Average (m^3/year)	1-in-10-year (m^3/year)	Maximum (m^3/year)
Creeping Bentgrass [3.4 ha]	13,212	20,230	28,244
Windsorgreen Couch [41.1 ha]	90,954	174,305	256,916
General Landscaping [10.5 ha]	28,529	43,575	60,916
Total	132,695	238,110	346,076

3.2.2 Potable Water and Maintenance Facilities

In addition to irrigation, water is also required for potable supply and on-site facilities maintenance. Potable and facilities maintenance water use requirements were estimated by McKenzie and Co. (2021) as part of their Engineering Infrastructure report (Appendix 5 to the AEE).

A daily demand of 25.9 m^3 was estimated for the Lodge, Wellness Centre and Golf Clubhouse, and a daily demand of 11 m^3 was estimated for the Sports Academy and maintenance facilities (total demand of approximately 36.9 m^3 per day).

3.2.3 Summary of Total Site Water Use Requirements

The total site water use requirements comprise of the total irrigation requirements (golfing area plus landscaping), potable water use, and on-site facilities maintenance. Irrigation typically occurs during the spring / summer period (i.e. typically October to April, inclusive) with some irrigation outside these months on rare occasions, whereas potable supply and maintenance use are required year-round. Therefore, spring / summer water use requirements are significantly larger than during autumn / winter.

A summary of estimated total annual water use requirements are presented in **Table 6**.

Table 6. Summary of annual water use requirements.

	Average (m^3/year)	1-in-10-year (m^3/year)	Maximum (m^3/year)
Creeping Bentgrass [3.4 ha]	13,212	20,230	28,244
Windsorgreen Couch [41.1 ha]	90,954	174,305	256,916
General Landscaping [10.5 ha]	28,529	43,575	60,916
Lodge, Wellness Centre & Golf Clubhouse [365 days]	9,454	9,454	9,454
Golf Academy & Maintenance Facilities [365 days]	4,015	4,015	4,015
Total	**146,164**	**251,579**	**359,545**

3.3 Water Supply

3.3.1 Water Storage Reservoir

Irrigation water will be supplied from a 140,000 m^3 “turkeys next” style water storage reservoir constructed on the southern side of Muriwai Road, to the east of the Sandstone Quarry. The reservoir will be approximately 4 m in depth.

The reservoir will be filled through a combination of surface water (**Section 3.3.2**) and groundwater (**Section 3.3.3**) takes. With full details presented in the Site Water Balance and Strategy Report (**Appendix B**).

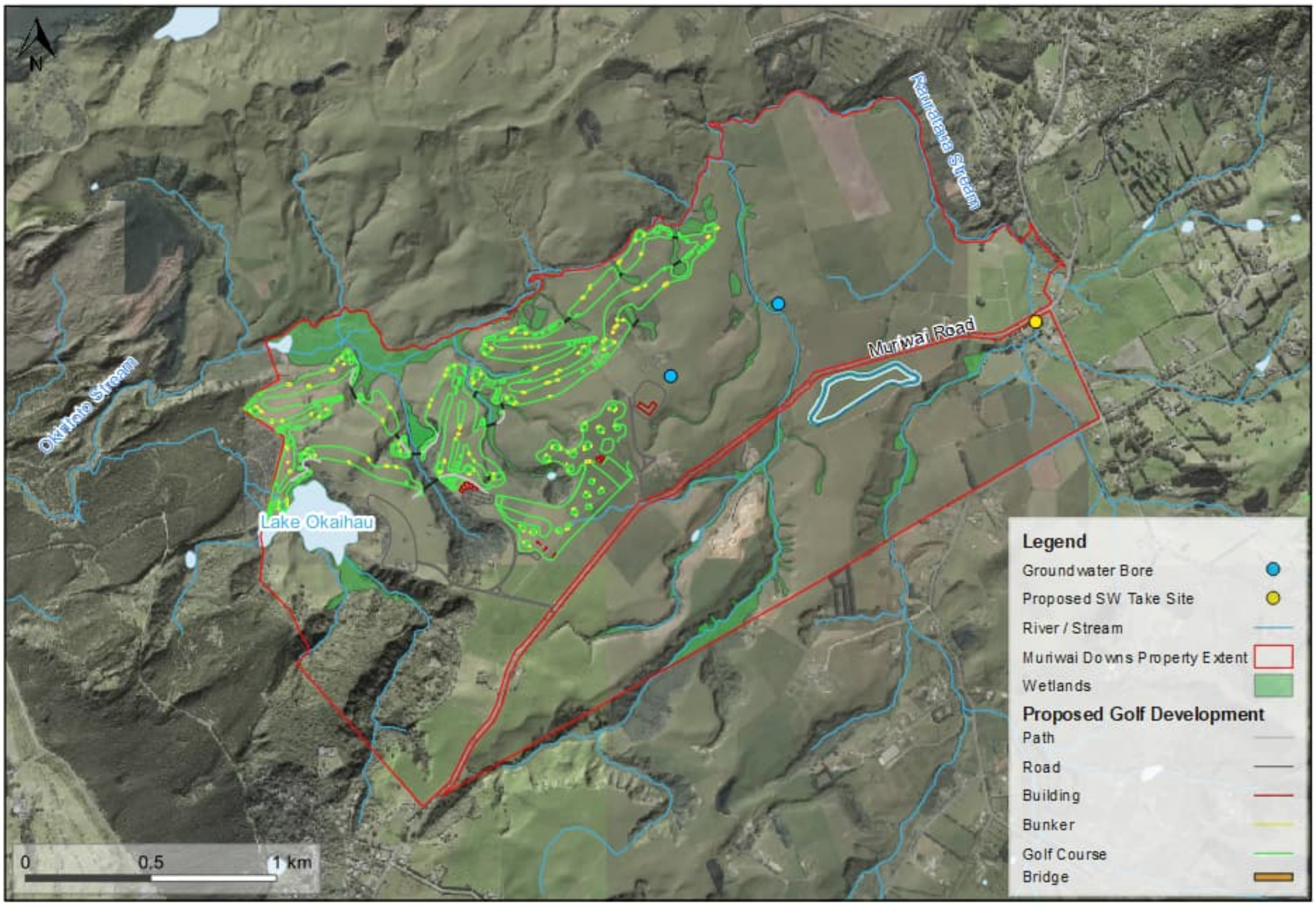

Figure 16. Proposed water storage reservoir and associated infrastructure.

3.3.2 Surface Water Take

A surface water take is proposed from the Raurataua Stream, which is a tributary of the Ōkiritoto Stream, with their confluence approximately 2 km downstream of the proposed take location. Abstracted water will be pumped to the proposed water storage reservoir and subsequently used for golf course irrigation and other non-potable water requirements.

The location of the proposed surface water take is shown in **Figure 16**. It is noted there are no wetlands within 100 m of the proposed take site, with the nearest wetland located approximately 285 m upstream.

The historic streamflow regime of the proposed take site was simulated using WWLA's calibrated catchment flow model of Ōkiritoto Stream, and summary flow statistics presented in **Table 7**.

Table 7. Proposed take site – simulated flow statistics

Statistic	Flow (L/s)
Minimum	11
Mean annual 7-day low flow (MALF)	34
25th percentile	74
Median	131
Mean	274
75th percentile	310
90th percentile	669
Maximum	5,210

The applicant proposes to abstract up to 30 L/s during periods of above median flow. When flows are at or above 161 L/s (i.e., median flow (131 L/s) + 30 L/s), the abstraction would occur at the full take rate of 30 L/s. When flows are above median flow, but less than 161 L/s, the take rate would be proportionally decreased to ensure no more than 10% of the total flow is abstracted. Abstracted water will be pumped directly to the water storage reservoir. When flows are below the median, the surface water take will not operate, and thus there will be no impact on streamflow during these times.

The proposed surface water take regime is summarised in **Table 8**.

Table 8. Proposed high-flow water take regime.

Condition	Flow (L/s)
Minimum high-flow take criterion	131
Maximum take rate	30

3.3.3 Groundwater Take

There is currently an existing production bore on the Property, completed in November 2021. An additional production bore has been proposed to be drilled approximately 500 m to the south-west of the existing bore. A groundwater take from the basalt aquifer sourced from the existing bore (**Figure 16**) is proposed to provide supplementary supply to the storage reservoir for irrigation purposes, and for potable supply when necessary. The primary potable supply is proposed to be supplied directly from the proposed bore, rather than via the reservoir to ensure appropriate water quality is maintained and reduce the water treatment required for potable supply.

The closest mapped wetland to the existing production bore is approximately 13 m away, adjacent to the Ōkiritoto Stream. This wetland will not be affected by the groundwater take in terms of water level because the wetland is above the stream, which effectively controls the wetland's water level; whereas the proposed groundwater take is sourced from a minimum of 120 mBGL and hydrologically separate from the wetland. The proposed bore is 145 m from the closest mapped wetland.

The total proposed maximum daily groundwater abstraction volume is 1,728 m^3/day (equivalent to 20 L/s), with a maximum annual volume of 180,000 m^3 per annum.

It should be noted that further test pumping will be undertaken at the production bore which will provide additional information about how much water is in the aquifer and is available for abstraction. An additional report will be provided once the test pumping and associated data analysis is complete.

3.4 Wastewater

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 proposed development, wastewater will be typical of domestic effluent (i.e. no industrial or trade waste).

The Engineering Infrastructure Report (Appendix 5 to the AEE) details the principal and approach for on-site wastewater management, noting detailed design will follow at an appropriate stage.

Effluent is proposed to undergo primary, secondary, and tertiary treatment prior to disposal (options for these treatments include septic tank(s), textile media treatment and recirculation and UV filtering respectively). 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 on the north-western side of Muriwai Road, to the east of the helipad area (MCCL Drawing 1976-1-500 and 504, Appendix 5 to the AEE). This location was selected to ensure it is accessible, and an appropriate distance away from high risk receiving environments, with the nearest wetland situated approximately 200 metres to the south-east.

4. Assessment of Effects

WWLA undertook a range of assessments to investigate and quantify where possible both temporary and permanent actual and potential effects associated with the proposed golf course development on water quantity and water quality. These assessments were documented across a number of specialist technical reports, and are summarised in the sub-sections below.

4.1 Temporary Effects During Construction

The following section details and summarises the potential temporary water related effects associated with the construction of the proposed development.

4.1.1 Effects of Construction on Water Quality

During development and construction of the proposed golf course and associated infrastructure (e.g. water storage reservoir, pipelines etc), the largest potential water quality impact is sediment runoff associated with earthworks.

Preliminary erosion sediment control plans (ESCP) have been prepared and is detailed in the Construction Environmental Management Plan (McKenzie and Co., 2021) (AEE – Appendix 18). 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 Environmental Erosion and Sediment Control Plan for review and approval by the site Engineer and Regulatory Monitoring Representative.

The preliminary ESCP state 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 as appropriate.

Where work is undertaken in close proximity to streams and wetlands, works are recommended 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 falling debris.

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.

Provided final erosion sediment control plans are designed and implemented in accordance with best practice guidelines of GD05, the risks of earthworks resulting in adverse effects on water quality can be appropriately managed. Accordingly, the potential for earthworks to adversely effect water quality is considered no more than minor.

4.2 Ongoing Operational Effects

The following section details and summarises the potential water related effects (both positive and negative) associated with the operation of the Project.

4.2.1 Surface Water

Surface water effects are assessed in **Appendix C** – Surface Water Effects Assessment Report and summarised as follows.

4.2.1.1 Surface Water Quantity

Actual and potential effects associated with the proposed high-flow take (**Section 3.3.2**) are summarised below.

Water Allocation & Effects of Downstream Water Users

As described in **Section 2.5.1.1**, there is one consented surface water take (Muriwai Links Golf Course) downstream of the Property and proposed high-flow take. This is core allocation (low flow) take. We also anticipate there will be permitted takes (for domestic or stock-water purposes) downstream of the Property.

The proposed high-flow take will only operate during periods of above median flow (i.e. when flows exceed 131 L/s) at the point of take. This means when flows recede below 131 L/s the take will cease, and thus there will be no impact on streamflow.

To demonstrate the change in flow regime downstream of the point of take, the historic streamflow regime was simulated for the period 1972 to 2020, under natural conditions (basecase), and with the proposed take operational. The resulting flow duration curves are presented in **Figure 17**, and demonstrate the proposed high-flow take will not have an impact on low flows, and will only harvest up to 10% of streamflow during times of above median flow.

It should be noted, at the time of undertaking this assessment, the proposed surface water take rate had not yet been confirmed. The assessment of effects of the proposed surface water high-flow take presented in **Appendix C** to this report, and detailed was based on a take rate of 80 L/s, As the applicant is applying for a reduced high-flow take of up to 30 L/s, the actual effects will less than those documented in these reports (i.e. the assessment is considered conservative).

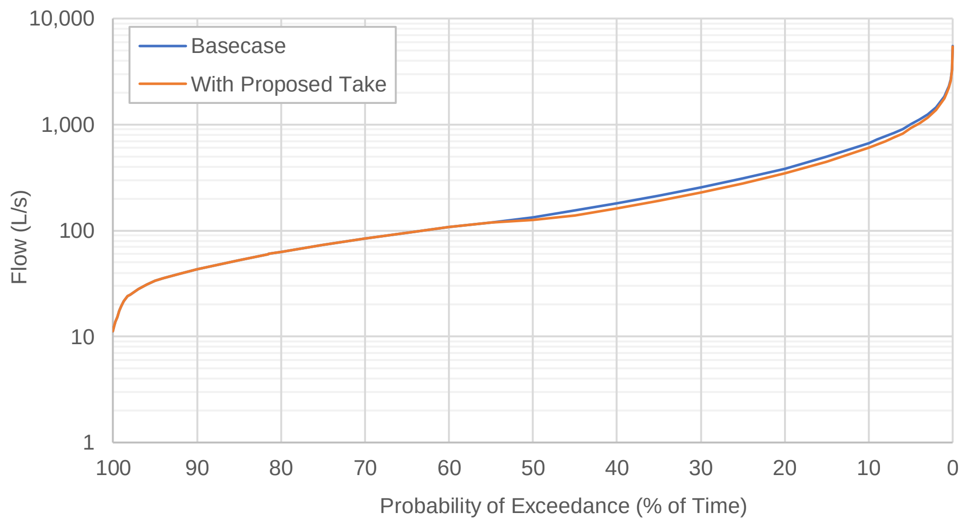

Figure 17. Simulated flow duration curves at the proposed high-flow take site.

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. Therefore, harvested flow as a proportion of total flow decreases with increasing distance downstream (i.e. the volume of flow increases downstream as additional tributaries join);
- as the high-flow take will only operate during periods of high-flow during and / or following high rainfall, irrigation requirements for the Muriwai Links Golf Club are likely nil on the days the high-flow take is operating; and
- given the take is under high flow conditions, plenty of surface water would remain available for both existing and new permitted activity takes downstream of the site.

The proposed high-flow surface water take for the Project is considered to have no more than minor actual effects on downstream water users.

Potential effects on Stormwater Generation and Flood Flows

The impact of increased impermeable surfaces (e.g. due to the construction of buildings, roads, paths and carparks) on catchment flows was negligible and indistinguishable from present. These additional impermeable surfaces 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 (WWLA, 2021 – Appendix C).

A Stormwater Management Plan (SWMP) will be prepared for the proposed development, following the principals of water sensitive design (Auckland Council –GD04, 2014/004).

Given the small (~1% change in impermeable surfaces across the sites) and providing appropriate implementation of water sensitive design principals, actual adverse effects of increased flood flows in the Ōkiritoto Stream associated with an increase in impermeable surfaces within the catchment are considered no more than minor.

4.2.2 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 impact on stream hydrology.

16 m of intermittent stream will be infilled to smooth the local topography. 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.

4.2.2.1 Surface Water Quality

Surface water quality effects associated with the Project and operation are summarised below.

A catchment flow and water quality model (WWLA, 2021 – Appendix B) was developed to assess potential changes in water quality associated with land use change from the current farming operation of the site to the Project. Two scenarios were simulated, one representing the current land use of the Property, and the other a future post golf course development scenario. The catchment flow and water quality model predicted a minor reduction in both TN concentration and in peak TSS concentrations.

While the absolute reduction in TN and TSS concentrations is not an extreme change, it represents a decrease in median concentrations by approximately 5%, 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. It is noted the assessment is considered conservative as it was undertaken prior to the Lodge, Sports Academy, Maintenance Facility, and reservoir being finalised and therefore these were not included in the post-development land use map, and thus these areas were classified as sheep and beef grazing land use. In reality, these areas will not be grazed and thus have a significantly lower N leaching profile than represented in the model.

High activity impermeable areas, such as car parks, paths, and roads, have the potential to result in stormwater contamination. The McKenzie and Co report details how stormwater quality will be managed from these areas (Appendix X of the AEE). A SWMP will be prepared for the Project which adheres to Auckland Council's Stormwater Management Devices in the Auckland Region GD01 guidelines. 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.

From the information in the McKenzie and Co report (AEE – Appendix 5) and the Auckland Council guidelines, we expect the SWMP will ensure all stormwater from high activity impermeable areas will be treated following best practice guidelines, before being discharged back to the environment. Any potential effects on water quality will be no more than minor.

The water quality effects on downstream water users are considered to be less than minor (i.e. potentially not detectable to downstream water users) to positive.

4.2.3 Groundwater

A groundwater model detailed in **Appendix E** was used to assess the effects of the proposed groundwater take on groundwater conditions and neighbouring water users, as well as evaluating whether stream depletion, saline intrusion, or land settlement are likely to occur as a result of the proposed abstraction.

Two scenarios were simulated as follows:

- ***Scenario 1: Basecase*** – The calibrated model was run using historic climate conditions and no groundwater abstraction. This scenario was the baseline for comparison against varying levels of abstraction.
- ***Scenario 2: Proposed Groundwater Abstraction*** – Conditions are identical to the Basecase, except that groundwater is abstracted as a supplemental water supply for the golf course and associated development at a maximum daily rate of 1,728 m^3/day and maximum annual volume of 180,000 m^3.

The model was simulated for a 49-year time period using historic climate records from 1972 through 2020. In effect, conditions of the last 49-years have been utilised to simulate conditions that may occur in the next 49-years for the purpose of evaluating potential effects of the scenarios described above. This approach was taken so that the environmental response to groundwater abstraction could be evaluated over a range of conditions that included wet and dry periods. To assess the worst-case scenario the driest period in the simulation period should be considered, which in this case was the summer of 2019-2020 where the Auckland area experienced the worst drought on record between November and May.

Consideration was given for potential rainfall and recharge conditions that fall outside of the historic range due to climate change. The future climate projections available from NIWA show that the study area is likely to have little change in annual precipitation. The maximum emission scenario shows a change ranging from 0% (unchanged) to a 5% increase in annual rainfall in the study area predicted for 2046-2065[6], a period that extends beyond the length of the proposed consent. For this reason, the range of conditions within the historic data set used in model development were considered sufficient to account for climate change in this region.

4.2.3.1 Effects on Groundwater Levels

The fundamental output of the groundwater modelling investigation is aquifer drawdown, which in this case must be evaluated for each of the three model layers identified in **Appendix E-Section 6.1.1**. Maximum groundwater drawdown will occur at the production bore.

[6] https://ofcnz.niwa.co.nz/#/nationalMaps

The simulated groundwater drawdown at the production bore location is shown for each of the model layers in **Figure 18**. The maximum drawdown over the simulation period was 20.4 m immediately adjacent to the production bore which was predicted to occur in Layer 3 at the end of March 2020 following a drought where reservoir storage levels were low and maximum irrigation was required for the entire preceding month. The maximum drawdown in Layer 1 and Layer 2 is 0.3 and 2.6 m, respectively.

Figure 18 also shows that during non-irrigation seasons the water level usually recovers to within 1 m of the Baseline Scenario water levels, though up to 1.6 m of residual drawdown is predicted in heavy pumping seasons such as 2020. In heavy pumping seasons it typically takes two months for groundwater levels to recover, with the recovery continuing more gradually over the following months until pumping resumes. In seasons with low or moderate abstraction, recovery is more rapid with groundwater levels typically recovering to within 2 to 4 m within one month and continuing to recover more gradually over the following months until pumping resumes.

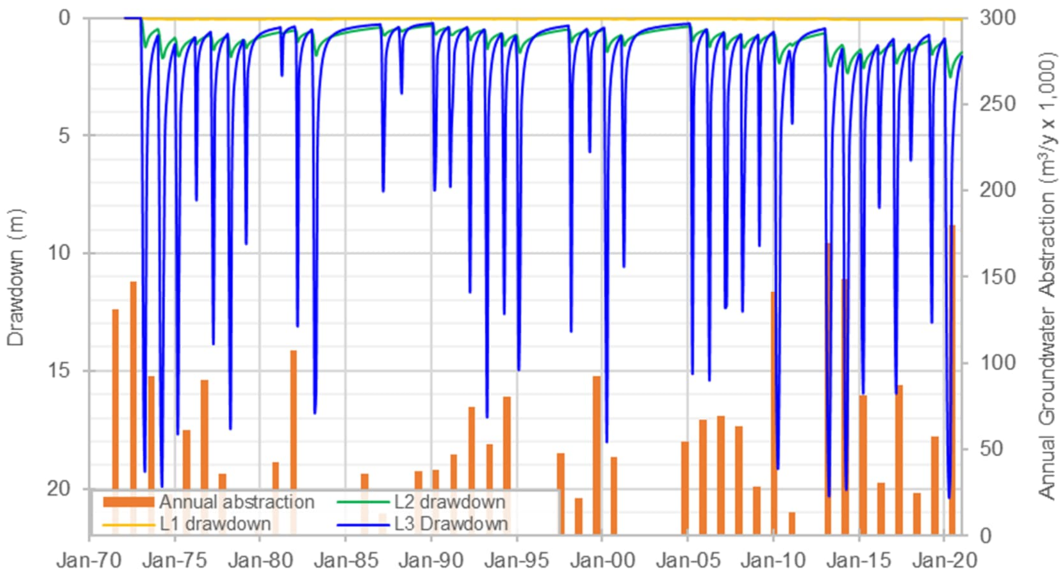

Figure 18. Predicted drawdown relative annual pumping at the pumping bore for each model layer.

The typical cone of depression formed from groundwater abstraction is shown for the top and bottom model layers respectively in **Figure 19** (Layer 1), and **Figure 20** (Layer 3). It is apparent in the figures that abstraction has a far greater effect in the deeper aquifer layer where up to 9.7 m of drawdown is predicted, while the disconnection due to iron pans and impermeable materials precludes significant drawdown from occurring in the shallow aquifer (Layer 1) where a maximum of 0.1 m of drawdown is predicted.

These results indicate that groundwater abstraction in a typical season is likely to produce groundwater level declines around the production bore in the deep aquifer which is the source of groundwater flow into the bore. Groundwater levels in the shallow aquifer show little effect from the same pumping due to low permeability material that limits interaction between the deep and shallow aquifer, as detailed in Appendix E - Section 8.2.1.

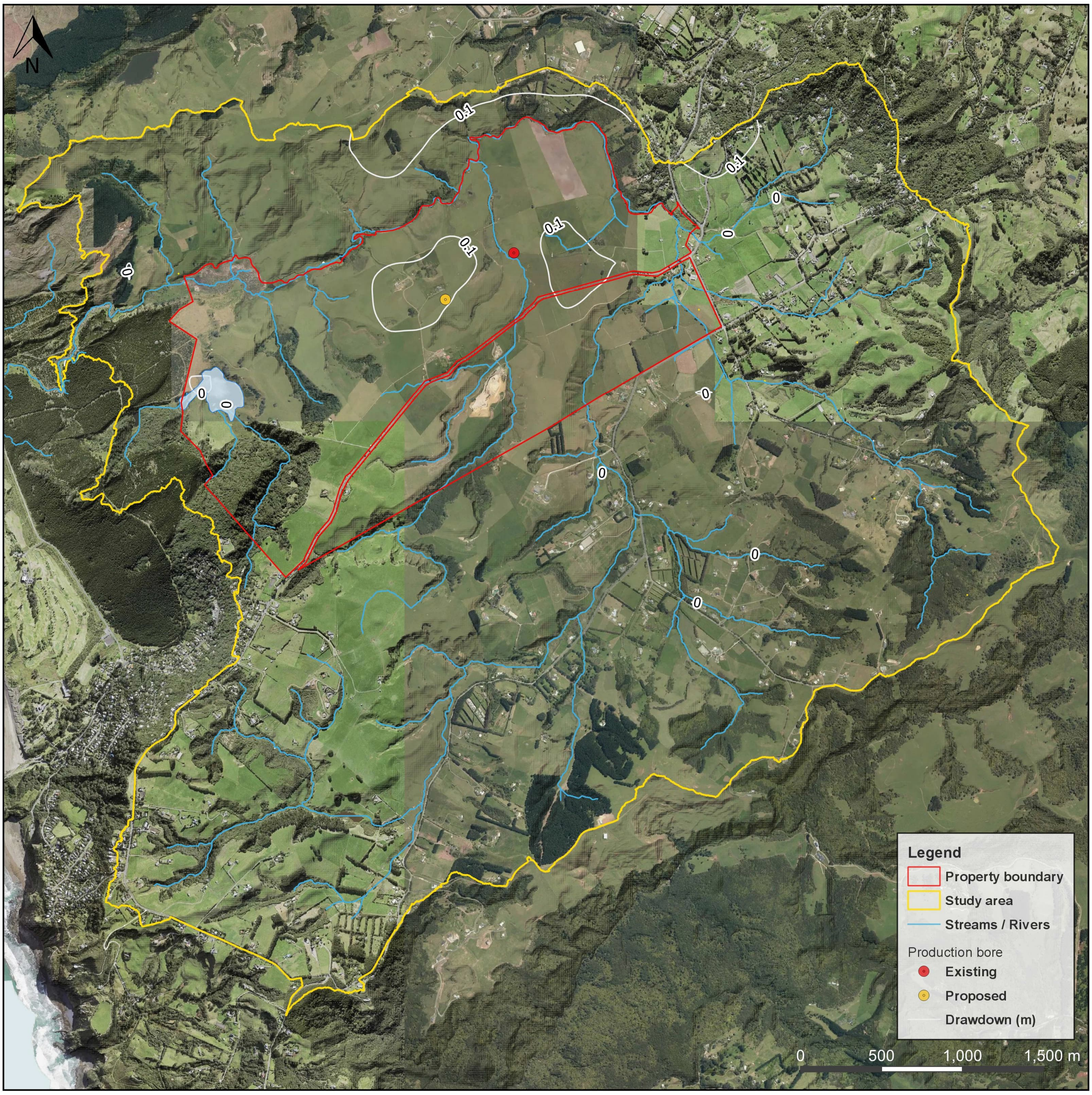

Figure 19. Predicted drawdown in Model Layer 1 for median groundwater abstraction year.

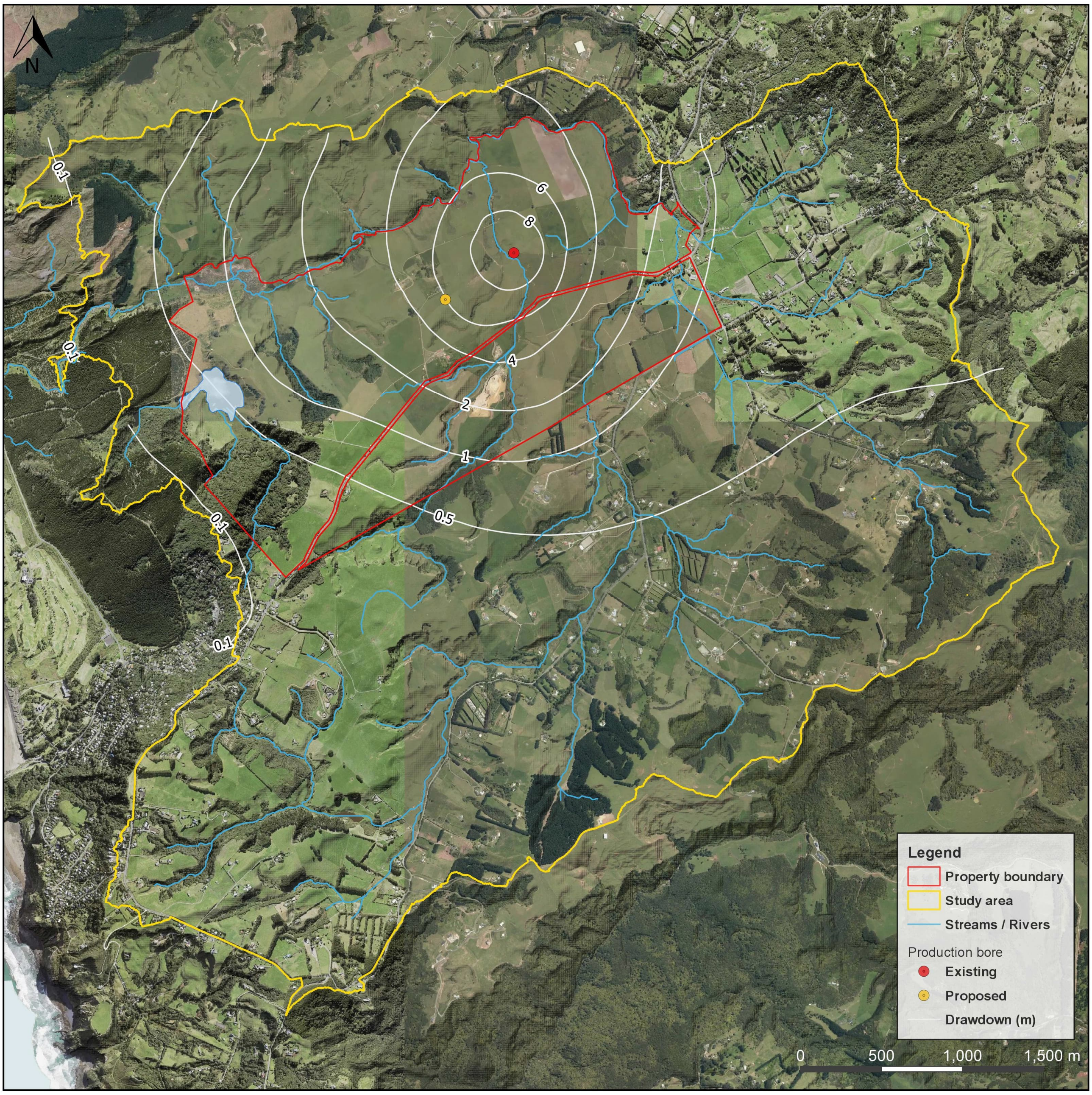

Figure 20. Predicted drawdown in Model Layer 3 for median abstraction year.

Effects on Neighbouring Bores

Forty-three bores are located within a 3 km radius of the proposed abstraction bore, although we note that many of these bores are old exploratory bores and abandoned based on information from Auckland Council database and knowledge from neighbouring landowners. 36 of these bores are outside of the model boundary therefore predicted drawdown can only be inferred from model results. The depth is known for 23 of the 43 bores, which ranges from 40 m to 458 m deep.

The estimated effects on neighbouring bores hinges on the available drawdown at the bores, defined as the vertical distance between the bore pump and the SWL. Details of predicted maximum drawdown at all of these bore and the methods used to evaluate available drawdown are provided in **Appendix E** to this report.

The maximum drawdown of 5.4 m is predicted to occur at the JS & RW Francis bore (NZTM 1730234, 5927752) and the Woppet Gardens Ltd bore (NZTM 1730350, 5927428).

The depth of these bores is greater than 250 m meaning that there is a significant amount of available drawdown, estimated to be 59 m and 154 m in the Francis and Woppet bores, respectively. Maximum expected drawdown as a percentage of the available drawdown is estimated to be 9% for the Francis bore and 3% for the Woppet bore, hence the predicted drawdown is not significant in the context of the available drawdown.

Furthermore, both bores are significantly deeper than the pilot bore and in a different aquifer (Nihotupu sandstone as opposed to basalt), which in practice would likely reduce the amount of drawdown due to the degree of vertical confinement that has been found in the area particularly in the sandstone.

In summary, model results indicate that it is highly unlikely that bores on neighbouring properties will be affected by the proposed groundwater abstraction. Given the available drawdown at the neighbouring bores, the actual effects of the proposed pumping is assessed as no more than minor.

Saline Intrusion

The proposed groundwater take was assessed for potential saline intrusion and/or saline up-coning effects that could arise as a result of the abstraction. In order to assess the level of the saline interface with and without groundwater abstraction a transect was drawn approximately corresponding to the path of the Ōkiritoto Stream, intersecting the area with maximum drawdown.

The results presented in **Figure 21**, show that the potential saline interface is nearly 700 m below the production bore at the time of maximum drawdown. The depth of the potential saline interface is also well below the depth of any other economically feasible production bore. Furthermore, since drawdown adjacent to the coast is only on the order of 0.1 m, only minor change is predicted in the sensitive coastal margin where the saline interface is shallowest.

It is noted that this method of assessing potential saline intrusion is highly conservative because it is based on the maximum drawdown while saline intrusion in reality is a gradual process. The full potential for saline intrusion will not manifest in the timeframe where drawdown occurs and subsequent groundwater level recovery after the pumping season will reverse the landward migration of the salt-wedge.

In summary, the proposed groundwater abstraction will not cause saline intrusion to occur in any way where it will be detectable and therefore the actual or potential effects on groundwater and groundwater users is less than minor.

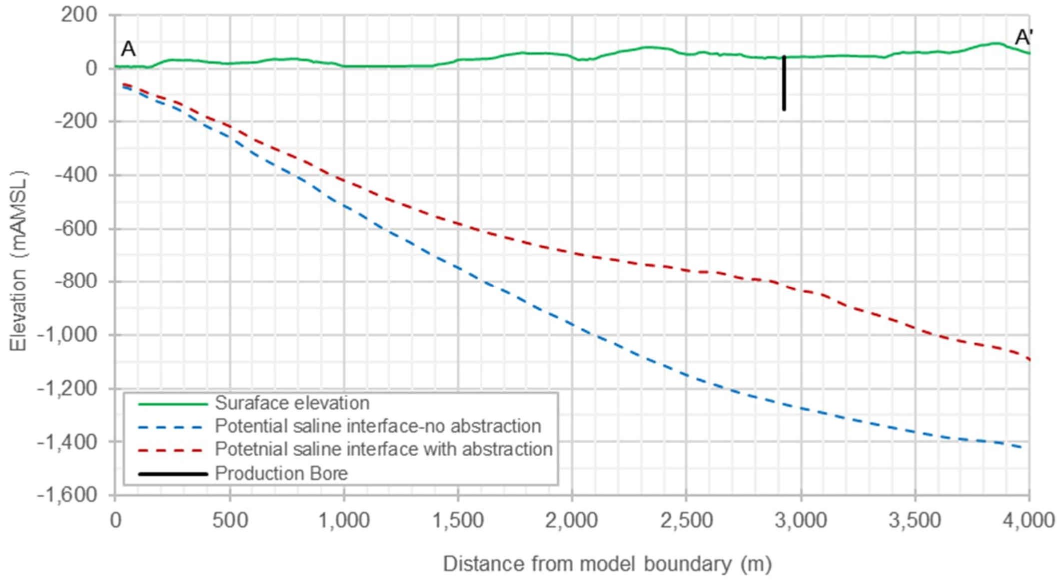

Figure 21. Elevation of saline interface along the Ōkiritoto Valley with and without proposed groundwater abstraction.

Land Subsidence

Land subsidence due to groundwater abstraction and resulting drawdown was assessed for the aquifers within the Ōkiritoto Catchment (Appendix E – Section 9.3). The greatest level of subsidence predicted to occur is 0.17 m. It is predicted to occur approximately 350 m east of the abstraction site due to the somewhat more compressible material in that area as opposed to the incompressible basalt dyke where the bore is located.

The areas that may potentially be affected by land subsidence are primarily pasture and there is no infrastructure in these areas (existing or proposed), hence any actual or potential effects of land subsidence are considered less than minor.

4.2.3.2 Effect on Groundwater-Surface Water Interactions

For the purpose of guiding surface water effects associated with the groundwater take, AUP assessment criteria set out in Chapter E7.8.2 (4)(b) are most relevant. They read as follows:

Whether the proposal…demonstrates that:

the taking will avoid, remedy or mitigate adverse effects on surface water flows, including:

(i) base flow of rivers, streams and springs;

(ii) (ii) any river or stream flow requirements;

The anticipated effects on groundwater-surface water interactions are addressed in the following section based on the relevant provisions in the AUP.

Stream Baseflows

The groundwater model is best suited to assess the relative impact of groundwater abstraction on stream baseflows, rather than the absolute change in flow, because surface runoff is not included in the simulated flow outputs from the groundwater model.

Table 9 summarises the simulated effects on baseflow. The maximum reduction in baseflow relative to the Baseline Scenario occurs during later summer and is predicted to be approximately 3.4% (0.4 L/s) at Flow Site 2 (**Figure 8**), directly adjacent to the pumping location. At Flow Site 1 and Flow Site 3, both on the Ōkiritoto Stream, the maximum baseflow reduction is predicted to be 2.1%. The median baseflow reduction at all sites is under 0.5% and would be unmeasurable for practical purposes.

These findings are consistent with the conclusions derived from monitoring data that baseflows are responsive to conditions in the shallow aquifer that are largely disconnected from the deep aquifer where the abstraction will take place.

Based on these results the actual effects on stream flows are predicted to be less than minor.

Table 9. Summary of maximum baseflow depletion effects.

Scenario	Flow reduction metric	Reference location		
		Flow Site 1	Flow Site 2	Flow Site 3
Scenario 1: Supplemental GW abstraction	Max. flow reduction (L/s)	1.7	0.4	2.7
	Max. flow reduction (%)	2.1%	3.4%	2.1%
	Median flow reduction (L/s)	0.2	0.0	0.4
	Median flow reduction (%)	0.3%	0.4%	0.3%

4.2.3.3 Groundwater Water Quality – Wastewater and Stormwater

As detailed in **Section 3.4**, wastewater will be disposed to ground via pressure compensating dripper lines. The 7,500 m^2 disposal field required to sustainably infiltrate this volume, 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 m to the south-east.

On-site wastewater will undergo primary, secondary and tertiary treatment prior to disposal to ground. The disposal method has been designed in accordance with local guidelines, incorporated conservative assumptions (particularly area to loading rate ratio) throughout, and is located an appropriate distance away from high-risk receiving environments and water bodies. Therefore, the potential for groundwater water quality effects resulting from domestic wastewater discharges to ground are considered to be no more than minor.

Stormwater runoff from all main carparking areas is proposed to be treated via bioretention raingardens. Rain gardens help remove pollutants via filtering through soil and plants before stormwater soaks to the ground or is discharges to the receiving environment. No adverse effects on groundwater quality are anticipated from the proposed carparks provided Auckland Council guidelines (GD01, 2017) are followed.

Both wastewater and stormwater discharges are proposed to undergo a high-level of treatment to remove contaminants prior to discharge to ground. Therefore, the proposed discharges to ground are considered consistent with the policies of the Quality-sensitive Aquifer Areas Management Overlay.

4.2.4 Effects on hydrological functioning of wetlands

As described in **Section 2.7.1**, wetlands within 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 upstream surface water catchment boundary (and thus changes in surface water flows), disruption of subsurface impermeable layers, or changes in hydrology associated with proposed water takes. Each of these are discussed in turn below.

Changes in Wetland Surface Water Catchment Boundary

All four classifications of wetlands, and in particular Type 1 Wetlands, would be affected if the extent of their upstream surface water catchment was significantly reduced in extent (area).

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) demonstrate that post development, the largest change in wetland upstream surface water catchment area resulting from site earthworks and contouring 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.

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 (Reservoir) demonstrate there will be no change in surface water catchment area immediately upstream of any wetlands post construction of the water storage reservoir, . Therefore, potential effects on surface water flows associated with the construction of the reservoir will be less than minor.

Given the minor changes in wetland catchment boundaries associated with site development earthworks and contouring, potential effects on wetland hydrological functioning are considered no more than minor.

Disruption of Subsurface Impermeable Layers

A desktop-based assessment was undertaken to provide an indication of the maximum allowable earthwork depths (i.e. ground cut) of land upstream of Type 4 (predominately fed by groundwater seepage) wetlands. The assessment was based on the assumption that in order for a Type 4 wetland to exist, an impermeable layer must be present, extending from the base of the wetland upstream. These impermeable layers restrict the vertical flow of groundwater and generates horizontal interface drainage that manifests at the surface as a "perched" valley wall seepage, which can sustain the presence of a wetland.

Based on this conceptual model, earthworks and lowering of the ground surface can occur in the catchment of a Type 4 wetland, provided it does not disturb the impermeable layer that results in the "perched" valley wall seepage that supports the wetland.

For the purposes of the analysis, it was assumed these impermeable layers extend horizontally, up-catchment from the base of the wetland. The upstream groundwater catchment was identified for each wetland, based on the local topography. The base elevation of the wetland was determined, and "allowable cut" contours calculated based on the topography above the assumed impermeable layer within the groundwater catchment, and assuming a six-metre vertical buffer (i.e. no cut allowed within six metres vertically of the impermeable layer). This six-metre buffer provides a conservative cover above the impermeable layer and provides an allowance for potential sloping of the impermeable layers.

Where wetland groundwater catchments overlapped, indicating potentially overlapping impermeable layers, "allowable cut" contours were conservatively calculated based on the assumed upper impermeable layer. In addition, it was assumed no earthworks greater than eight metres deep would occur, and thus "allowable cut" contours greater than eight metres are not shown.

A 10 m buffer was also applied because earthworks within, or within a 10m buffer are a non-complying activity under the Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (Regulation 54).

Calculated maximum wetland cut contours are presented in **Figure 22** to **Figure 24**.

Figure 22. Wetland cut analysis output – Property wide overview. (Refer A3 attachment at rear).

Figure 23. Wetland cut analysis output – eastern overview. (Refer A3 attachment at rear).

Figure 24. Wetland cut analysis output – western overview. (Refer A3 attachment at rear).

The maximum wetland cut outputs were provided to the golf course designer (Kyle Phillips of Kyle Philips Golf Course Design) and the project civil engineers McKenzie and Co., who produced the site earthworks plans.

The proposed earthworks and site contouring do not exceed the recommended maximum cut contours, and therefore the potential for negative effects on Type 4 wetland hydrology resulting from the disruption of impermeable layers is considered less than minor.

Changes in Wetland Groundwater Levels Associated with the Proposed Groundwater Abstraction

Effects on wetland groundwater levels associated with the proposed groundwater abstraction were assessed using the groundwater model (**Appendix E** to this report). A summary of predicted water level changes resulting from groundwater abstraction for the shallow aquifer and wetlands at the monitoring locations shown in **Figure 8** is presented in

Table 10.

It is noted that wetland water levels are governed by a combination of surface water inputs and seepage inflows from shallow groundwater, the latter having been shown to be primarily disconnected from the deep aquifer where the abstraction occurs. Furthermore, the water level change that will manifest in a wetland is governed by the porosity of the aquifer material. For example, if an aquifer with a porosity of 10% (typical for wetlands such as those on the Property) experiences a 0.2 m reduction in water level, the corresponding reduction in a standing water body that is connected would be 0.02 m (Williamson, 2018).

Of the wetland monitoring sites listed in

Table 10, the greatest effect is predicted at P2 which is positioned approximately 400 m directly down gradient from the pumping bore. At this location the predicted decline in the shallow aquifer is predicted to translate to less than a 0.02 m reduction in water level in standing water in the wetland, which would in practice, be difficult to measure.

Table 10. Predicted maximum change in shallow groundwater level and corresponding change in wetland water level at wetland monitoring piezometers.

Analysis metric	Wetland monitoring piezometers					
	P1	P2	P3	P4	P5	P6
Maximum change in shallow aquifer water level (m)	0.010	0.179	0.038	0.080	0.006	0.037
Corresponding change in wetland water level (m)	0.001	0.018	0.004	0.008	0.001	0.004

The water level in the wetland that is adjacent to the existing production bore is controlled by the Ōkiritoto Stream that flows through the wetland, which in combination with the disconnection of the shallow aquifer from the deep aquifer, limits the effect of pumping groundwater on this wetland. The greatest reduction in wetland water level is predicted to be a temporary reduction of 0.02 m, occurring in a wetland 500 m to the west of the existing bore. This reduction would occur under conditions equivalent to the worst drought on record and would recover in the weeks following the cessation of pumping or the breaking of the drought.

Effectively, the proposed groundwater take will have little to no actual effect on wetland water levels because of the disconnection between shallow and deep groundwater and the influence of aquifer porosity limiting the effect on standing water levels.

On the whole, at times of maximum groundwater abstraction the actual effect on wetlands from the abstraction will be less than minor. It is also noted that groundwater abstraction is seasonal, meaning that any potential effect on water level will be temporary as the slight reduction that could possibly manifest will readily recover when pumping is not active.

Effects of Irrigation and Fertiliser on Wetlands

Irrigation and fertiliser will not be applied directly to wetlands, but to neighbouring land. Irrigation and fertiliser application will follow best practice management procedures, for example not irrigating or applying fertiliser prior to or during rainfall events where fertiliser could run off. In addition, soil testing will be undertaken to ensure nutrient levels remain at appropriate levels to prevent excess runoff and leaching. Therefore, the potential effects of irrigation and fertiliser on the wetlands is assessed as low.

4.2.5 Lake Ōkaihau

The hydrological functioning of Lake Ōkaihau is summarised in **Section 2.8.1**. Potential water related effects resulting from the proposed development on Lake Ōkaihau include changes to inflows, changes to outflows (i.e. artificial drainage), and changes in waters quality resulting from fertiliser runoff. Each of these are summarised in turn below, with full details provided in **Appendix F** to this report.

Changes in Inflows to the Lake

The largest surface water inflow to the lake occurs from the south, with only minor components entering along the western, northern, and eastern margins (**Figure 14**). No earthworks or development are planned within the surface water catchment to the south of the lake, and therefore there will be no change in inflows on this side of the lake. Minor earthworks and recontouring associated with the development of golf course hole 2 (**Figure 15**) are proposed along the northern margins of the lake (**Figure 25**). The proposed minor recontouring will maintain a gentle slope towards the lake similar to as at present, and thus minor surface water runoff into the lake will still occur along the northern margins of the lake.

Based on the site grading plans, change to inflows to the lake associated with site grading and contouring are considered to be no more than minor.

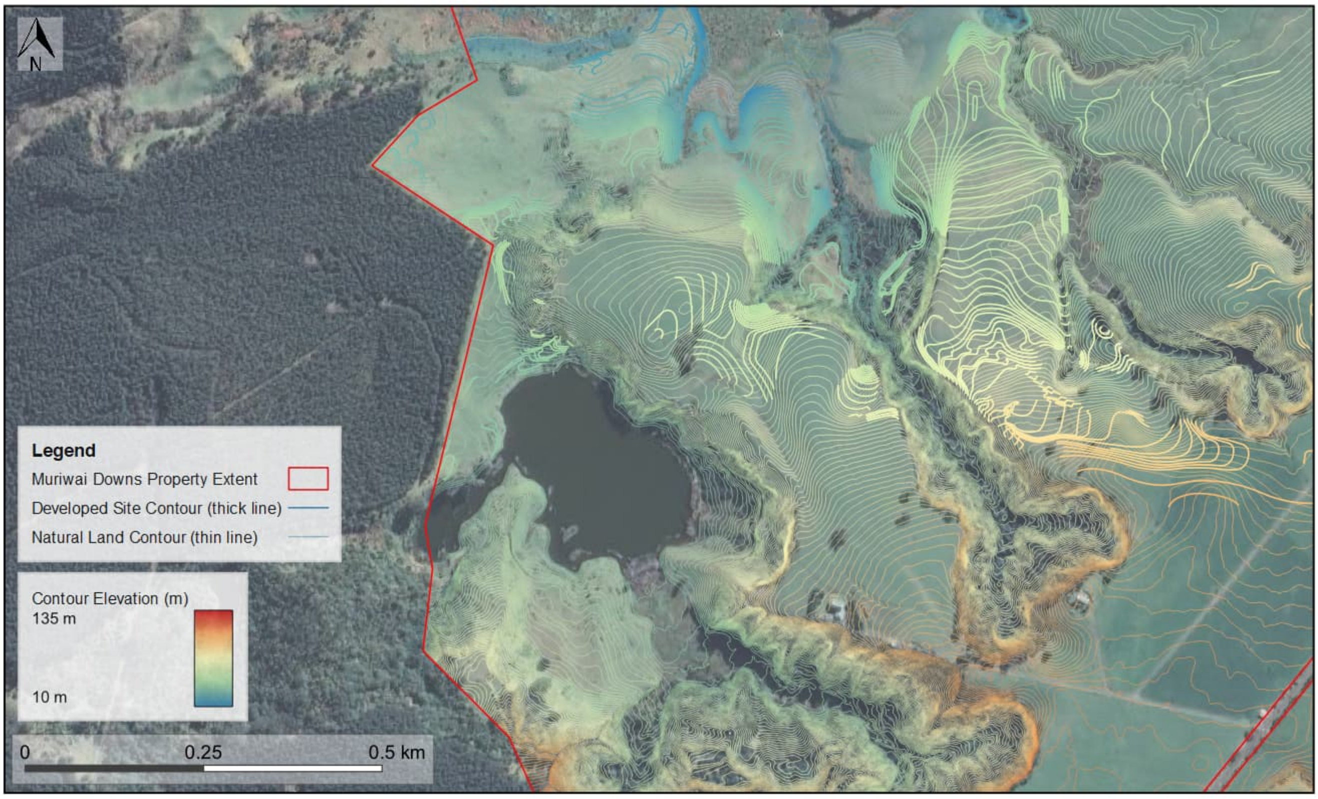

Figure 25. Proposed site grading in the vicinity of Lake **Ō**kaihau.

Changes in outflows from Lake Ōkaihau (artificial drainage)

There is no defined surface water outflow or exit from the lake. Water is lost (removed) from the lake predominately through groundwater seepage in a north-westerly direction to the Ōkiritoto Stream, and to a lesser extent via evaporation direct from the lakes surface.

During the resource consent pre-application site visit with the applicant's core project team and Auckland Council on 22 June, council staff raised concerns that earthworks near the lake could potentially exacerbate seepage loss, and thus artificially drain the lake.

The Lake Ōkaihau Water Balance Assessment (**Appendix F**) in conjunction with the groundwater piezometer monitoring and groundwater modelling assessment (**Appendix E**) reinforces the conceptual understanding that the lake is sustained through a low permeability bed layer, and groundwater seepage losses in a general north-west direction.

Minor recontouring but no major excavation is planned along the northern margin of the lake, and additional flattening of the natural land surface approximately 200 m further north (**Figure 25**). As these are surficial grading and recontouring only, with no deep excavation that could develop tomos or preferential flow paths, the surficial earthworks will not cause or exacerbate seepage loss from Lake Ōkaihau. Therefore, actual effects on in outflows from the lake will be no more than minor.

Effects on Water Quality Associated with Golf Course Fertilisation and Irrigation

A narrow margin of land along the north-western margins of the lake gently slopes down towards the lake, and therefore the lake will be subject to small contributions of surface runoff from this land during high intensity rainfall events, under both the current state and under the Project. Provided best practice fertiliser application and management processes are followed (e.g. not applying fertiliser if heavy rain is forecast), the potential for and effect of fertiliser leaching or runoff causing lake eutrophication is considered low.

5. Key Conclusions

WWLA was commissioned to assess the water related effects of the Project. The assessments undertaken considered potential impacts of the Project activities on:

- Surface water quantity – i.e., flow in streams and water levels in wetlands;
- Surface water quality – i.e., nutrient, sediment and bacteriological constituent concentration in streams and wetlands;
- Groundwater levels within the deep and shallow aquifers and discharge rates to streams;
- Hydrological functionality required to maintain wetlands;
- The water balance of Lake Ōkaihau, and lake water quality; and
- including the actual and potential effects of the development on the environment and existing water users.

The study has concluded that all potential effects are considered less than minor, provided all specialist management plans are followed (e.g. preliminary ESCP, SWMP etc).

6. References

Pattle Delamore Partners Lts (PDP). 2021. Muriwai Downs Golf Course: Airlift Pump Test Result for Exploratory Bore. *Technical Memorandum Prepared for Bears Home Project Management Ltd.*

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Williamson, J.L., 2018. Evidence in Chief for Council Court Hearing Regarding the Motutangi-Waiharara Water User Group Groundwater Take Resource Consent Applications.

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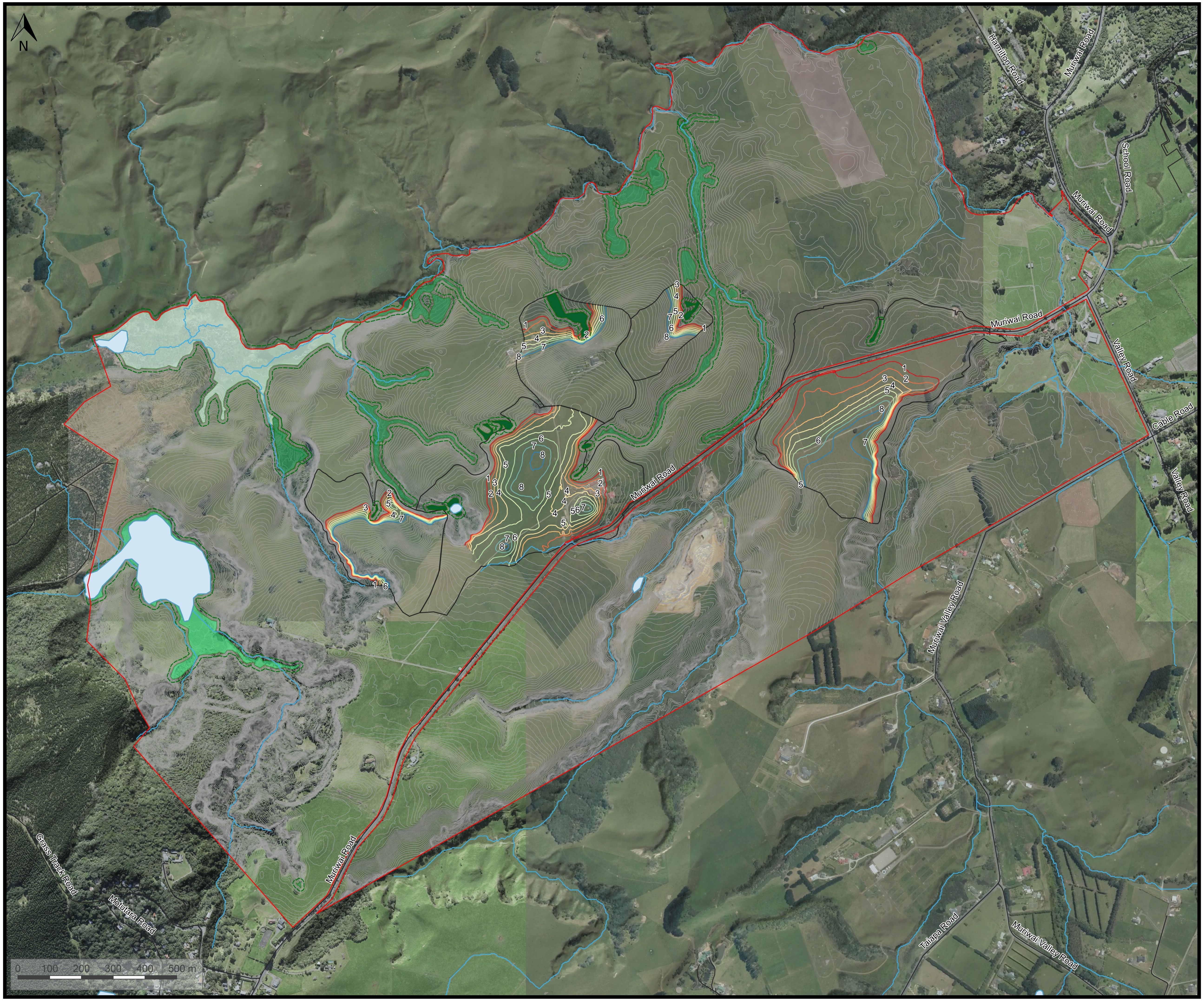


Map Title:

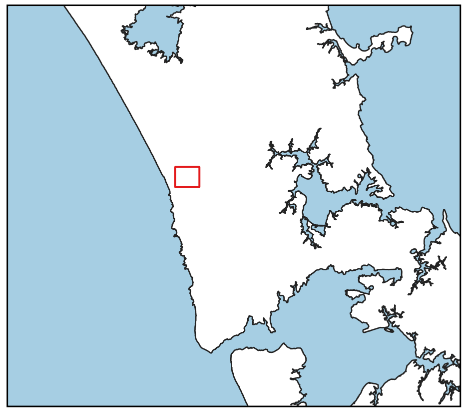
Type 4 Wetlands - Maximum Allowable Cut Analysis

Project:

Muriwai Downs Hydrological Effects

Client:

Bears Home Project Management Ltd



Legend

- Road
- River / Stream
- 1 metre Contour
- Property Extent
- Lake
- Wetland (Type 1)
- Wetland (Type 2)
- Wetland (Type 3)
- Wetland (Type 4)
- Wetland 10 m Buffer
- Wetland Catchment

Allowable Cut Contour (m)

- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- 6.0
- 7.0
- 8.0

Data Provenance

Topographic Data derived from Land Information New Zealand

Layout & Project File

Wetland Cut Analysis Property Overview

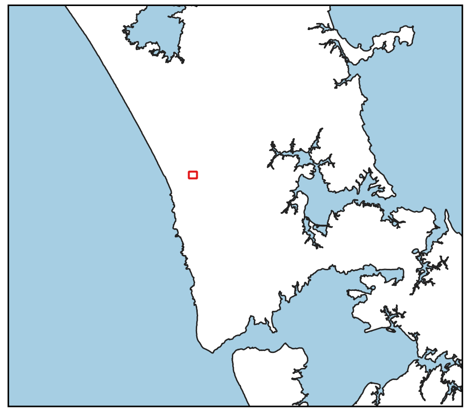
WILLIAMSON WATER & LAND ADVISORY

Figure 22.

Map Title:
Type 4 Wetlands - Maximum Allowable Cut Analysis

Project:
Muriwai Downs Hydrological Effects

Client:
Bears Home Project Management Ltd



Legend

- Road
- River / Stream
- 1 metre Contour
- Property Extent
- Lake
- Wetland (Type 1)
- Wetland (Type 2)
- Wetland (Type 3)
- Wetland (Type 4)
- Wetland 10 m Buffer
- Wetland Catchment

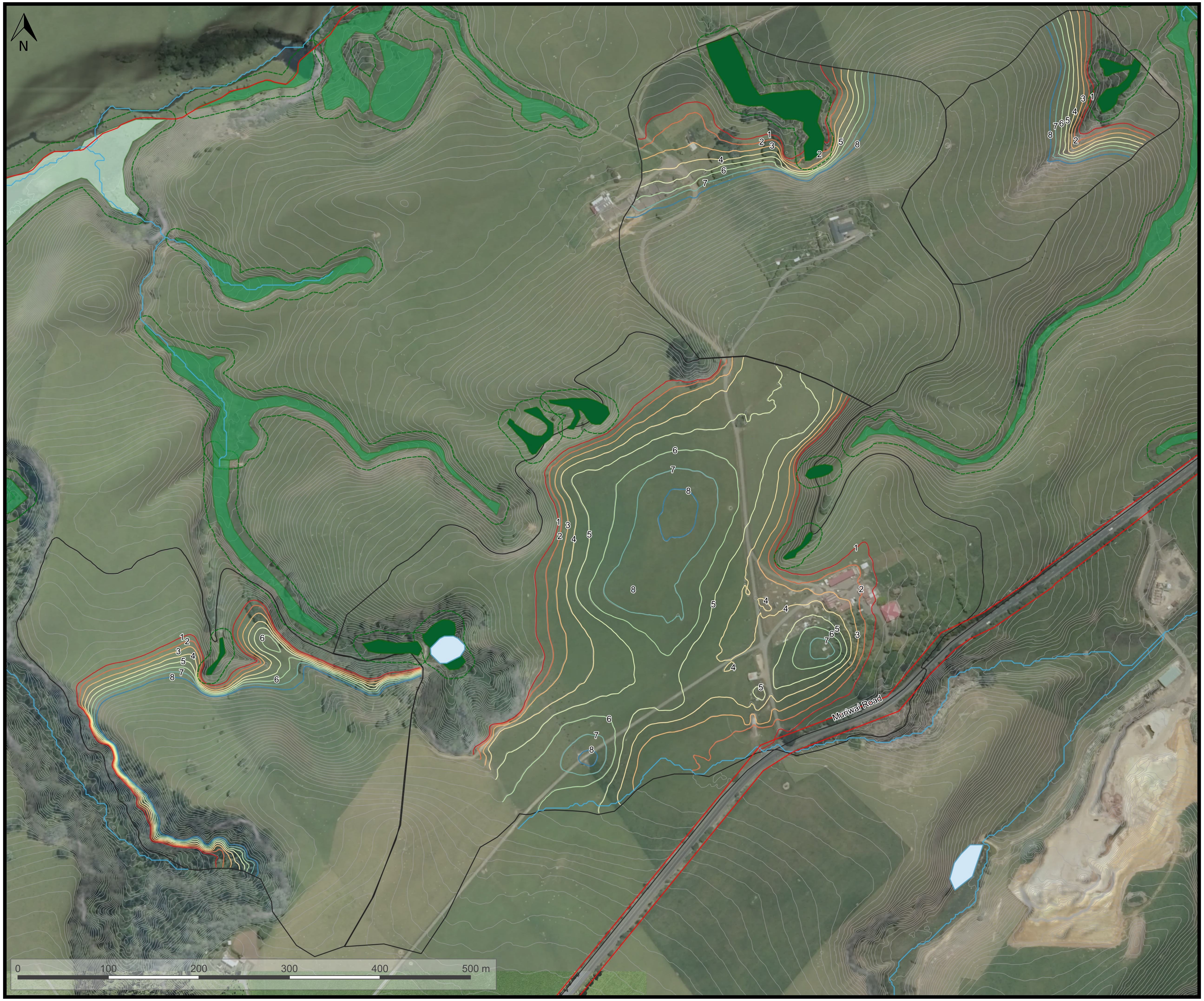
Allowable Cut Contour (m)
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- 6.0
- 7.0
- 8.0

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Wetland Cut Analysis Zoomed 1

WILLIAMSON WATER & LAND ADVISORY

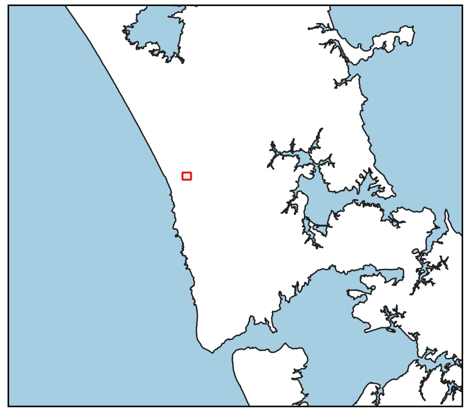
Figure 23.



Map Title:
Type 4 Wetlands - Maximum Allowable Cut Analysis

Project:
Muriwai Downs Hydrological Effects

Client:
Bears Home Project Management Ltd



Legend

- Road
- River / Stream
- 1 metre Contour
- Property Extent
- Lake
- Wetland (Type 1)
- Wetland (Type 2)
- Wetland (Type 3)
- Wetland (Type 4)
- Wetland 10 m Buffer
- Wetland Catchment

Allowable Cut Contour (m)
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- 6.0
- 7.0
- 8.0

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Wetland Cut Analysis Zoomed 2

WILLIAMSON WATER & LAND ADVISORY

Figure 24.

Appendix A. Baseline Environmental Monitoring Report

Appendix B. Site Water Balance and Strategy Report

Appendix C. Water Effects Assessment Report

Appendix D. Basalt Extent of Electrical Resistivity Tomography Survey

Appendix E. Assessment of Potential Groundwater Supply and Associated Hydrological Effects

Appendix F. Lake Ōkaihau Water Balance Assessment