To Take and Use Groundwater

Resource Consent Application and AEE

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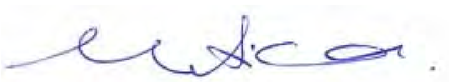

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Document History and Status

Revision	Date	Author	Reviewed by	Approved by	Status
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Revision Details

Revision	Details
1	50% Draft review
2	Client review
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1 Introduction

Te Rarawa Farming Limited and Te Make Farms Limited (the applicant) are applying to the Northland Regional Council (Council) to replace water permit AUT.020995.01.03 which is currently held by Landcorp Farming Limited and Te Rūnanga o Te Rarawa.

Consent to take groundwater was first obtained in May 2011 with a consent term of 10 years. Several variations to this consent have subsequently been sought and approved. These changes sought to address issues and challenges caused by the initial consent conditions, in particular the rigidity of bore location conditions.

Water permit AUT.020995.01.03 supports agricultural and horticultural irrigation on the landholding known as Sweetwater Station to the northwest of Kaitaia in the Far North District. The permit currently authorises the taking and use of groundwater at a rate of not more than 180 litres per second (L/s), 15,525 cubic metres per day (m^3/day) not exceeding a maximum annual volume of 2,317,000 m^3/year. The permit allows for groundwater to be taken from not less than 3 and up to 14 production bores on Pt Lot 3 DP 40865, Pt Lot 2 DP 40865, Lot 2 DP 170525, Lot 1 DP 156631, Lot 2 DP 156631, Lot 3 DP 156631 and Sec 4 SO 64336.

Water permit AUT.020995.02.03 will expire on the 30th of November 2021 and an application is being made for an early replacement of the permit to reconfigure consent conditions so that they are fit for purpose and to increase the quantities of take.

Consent conditions have been proposed in Section 3.4 of this report, in particular, this application seeks the following quantities of groundwater cumulatively taken across a minimum of three (3) and a maximum of up to fourteen (14) bores;

- 180 L/s;
- 26,230 m^3/day; and
- 3,093,000 m^3/year, being the period 1 July to 30 June in the following year.

This cumulative amount is to be taken across the Sweetwater and Ahipara sub-aquifer management units (SAMU). Table 1 and Table 2 below present evidence that there is allocation available within these SAMU's.

A consent term of 25 years is sought.

This application is being made in part in accordance with Section 124(1) of the Resource Management Act 1991 (the Act). This means that the water that is currently allocated will be prioritised for allocation to the applicant in accordance with Section 124B of the Act.

The increases sought have been assessed in the order to which they are expected to be received by NRC with regard to any prior applications made for groundwater allocation.

1.1 Purpose of Report

This report has been prepared in accordance with Section 88 and the 4th Schedule of the Act, including the preparation of an Assessment of Environmental Effects (AEE) in accordance with the 4th Schedule. The

report is Part B to Council's prescribed application form which is attached as Appendix A Application Form

Appendix A.

1.2 Summary Application Details

DETAILS	
Applicant and Consent Holder:	Te Rarawa Farming Limited & Te Make Farms Limited 16 Mathews Avenue Kaitaia 0410
Zoning:	Far North District Council (FNDC) Rural Production Zone NRC Coastal environment (bores 1, 4, 6, 7 & 9) Aupouri Aquifer – Sensitive to Bore Construction Aupouri-Sweetwater sub-aquifer management unit Aupouri-Ahipara sub-aquifer management unit Small river water quantity management unit Coastal river water quantity management unit
Address for service (Consent Processing only):	WSP Opus PO Box 553 Whangarei 0140 Martell.Letica@wsp-opus.co.nz
Site Address:	Sandhills Road, Awanui
Property Ownership:	Te Waka Pupuri Pūtea Trust Te Rūnanga o NgāiTakoto Custodian Trustee Limited

1.3 Other Activities & Resource Consents

1.3.1 *AUT.020995.02.02*

This application is to replace AUT.020995.01.03 only. No application is being made to replace AUT.020995.02.02 which authorises the take and use of surface water from the Awanui River. This is because AUT.020995.02.02 expires on 30 November 2031.

1.3.2 *Transfer of Consent Holder*

An application for transfer of ownership in accordance with Section 136(2)(a) of the Act is being made to transfer the ownership of AUT.020995.02.02 and AUT.020995.02.03 from Landcorp Farming Limited and Te Rūnanga o Te Rarawa (Transferor) to Te Rarawa Farming Limited & Te Make Farms Limited (Transferee). No prescribed form was made available from the Northland Regional Council (Council) upon request as such the following is presented as notice of the required transfer.

The Transferor intends to transfer the whole of the Water Permits AUT.020995.02.02 and AUT.020995.01.03 to the Transferee in perpetuity.

The Water Permits have not lapsed, been cancelled or surrendered.

The Transferee is the owner and occupier of the site for which the permit has been granted with further explanation provided as follows.

Te Rarawa Farming Limited is the operational farming unit of Te Rūnanga o Te Rarawa Iwi. Te Waka Pupuri Pūtea is Te Rūnanga o Te Rarawa's asset holding group and is a subsidiary of Te Rūnanga o Te Rarawa with the primary function of holding, protecting and growing the Iwi assets. Through the entity Te Waka Pupuri Pūtea Trust, Te Rarawa owns 50% of the land identified as Sweetwater Farms.

The remaining 50% of the Sweetwater Farms complex is owned by Te Rūnanga o NgāiTakoto Iwi with Te Rūnanga o NgaiTakoto Custodian Trustee Limited being the registered title holders. Te Make Farms Limited is an investment entity formed by Te Rūnanga o NgaiTakoto with the primary function of growing the Iwi assets of the Te Make area of the Sweetwater Farm complex.

Certificates of incorporation and company extracts for the applicant entities are attached as Appendix B.

Joint signatory information can be provided as evidence that the transfer can be legitimised by Council if required and it is requested that the Council issue a form to document this.

1.3.3 *Construction or Alternation of Bores*

The existing production bores were constructed under resource consent granted by the NRC. The construction of a new bore is a discretionary activity under Rule 26.4.1 of the Regional Water and Soil Plan for Northland 2004 as the bores would be located within an aquifer identified in Schedule F of this plan. However, under the decision version of the Proposed Regional Plan for Northland 2017, new bores are a controlled activity under Rule C.8.5.3.

Given that a change of consent condition would be a discretionary activity in accordance with Section 127(1) of the Act, the applicant will continue to seek individual bore consents as they are needed as these should be considered as if they are for a controlled activity. Furthermore, given that bore details and pump test requirements are a matter for control, continuation of these conditions on any new groundwater consent granted as a result of this application are not pursued as proposed consent conditions.

1.3.4 *Discharges from Production Land Use*

The development may require the use of agrichemicals, fertilisers, and other discharges associated with productive land use (i.e., burn-offs, horticultural wastewater discharges). Subject to standards and conditions, the discharges are permitted under the Regional Air Quality Plan for Northland 2004 (RAQP), the Regional Water and Soil Plan for Northland 2004 (RWSP), and the Proposed Regional Plan for Northland 2017 (PRP).

1.3.5 *Land Preparation and Cultivation*

An application for Land Use Consent for excavation and fill activity has been lodged with both the FNDC and NRC. Resource consent 2190498-RMALUC lodged with the FNDC is currently awaiting further information while NRC granted Land Use Consent AUT.040832.01.01 subject to conditions on 29th April 2019.

1.3.6 *Conclusion*

It is considered that no other resource consents are required from Northland Regional Council or from the Far North District Council for this proposal.

2 The Site and Surrounding Environment

2.1 Title Information

Copies of the certificates of title and related documents are attached in Appendix C.

The bores are proposed to be drilled within the property titles as specified in Table 1 below.

Table 1: Bore Information with associate title information.

Title Ref.	Appellation	Bore Ref.
719746	Lot 2 DP 170525	SW1
		SW2
	Lot 1 DP 156631	SW3
		SW4
		SW5
		SW6
	Section 2 SO 472393	SW7
		SW8
		SW9
719735	Section 5 SO 64336	SW10
719735	Section 7 SP 64336	SW11
NA94A/635	Lot 4 DP 156631	SW12
NA94A/636	Lot 5 DP 156631	SW13
		SW14

Water use areas are proposed within the property titles as specified in Table 2: below.

Table 2: Water use areas and associated property title information.

Title Ref.	Appellation	Owner
719746	Lot 2 DP 170525	Te Rūnanga o NgaiTakoto Custodian Trustee Limited
	Lot 1, 2 DP 156631	
	Section 1, 2, 3, 4, 5, 6, 7, 8 SO 42207	
	Section 2, 3, 4, SO 472393	
NA80D/321	Pt Lot 2, 3 DP 40865	
719762	Section 1 SO 472393	
719764	Section 4 SO 472393	
719735	Section 5, 7 SO 64336, Section 8, 11 SO 472393	Te Waka Pupuri Pūtea Trust
719763	Section 1 SO 472393	
NA33A/925	Allotment 118 Parish of Ahipara	
719765	Section 4 SO 472393	
NA94A/635	Lot 4 DP 156631	

NA94A/636	Lot 5 DP 156631	
NA94A/637	Lot 6 DP 156631	
465298	Lot 1 DP 416984	

2.2 Site Description

Sweetwater Station consist of multiple parcels and titles, some geographically separated (See Figure 1). The land holding predominantly consist of three main soil types

- Pinaki Sand, 856Ha - Sand dunes and sand plains on recent relatively unstable windblown sands;
- Otonga Loamy Peat, 738Ha – Flat to undulating land with organic soils on alluvial and estuarine plains;
- Houhora Sand, 532Ha – Rolling to strong rolling slopes on old coastal dune landforms.

The sands are described as being well to excessively well drained, with localised presence of pan, whist the loamy peat has had extensive drainage networks developed with water tables still near the surface during the winter.

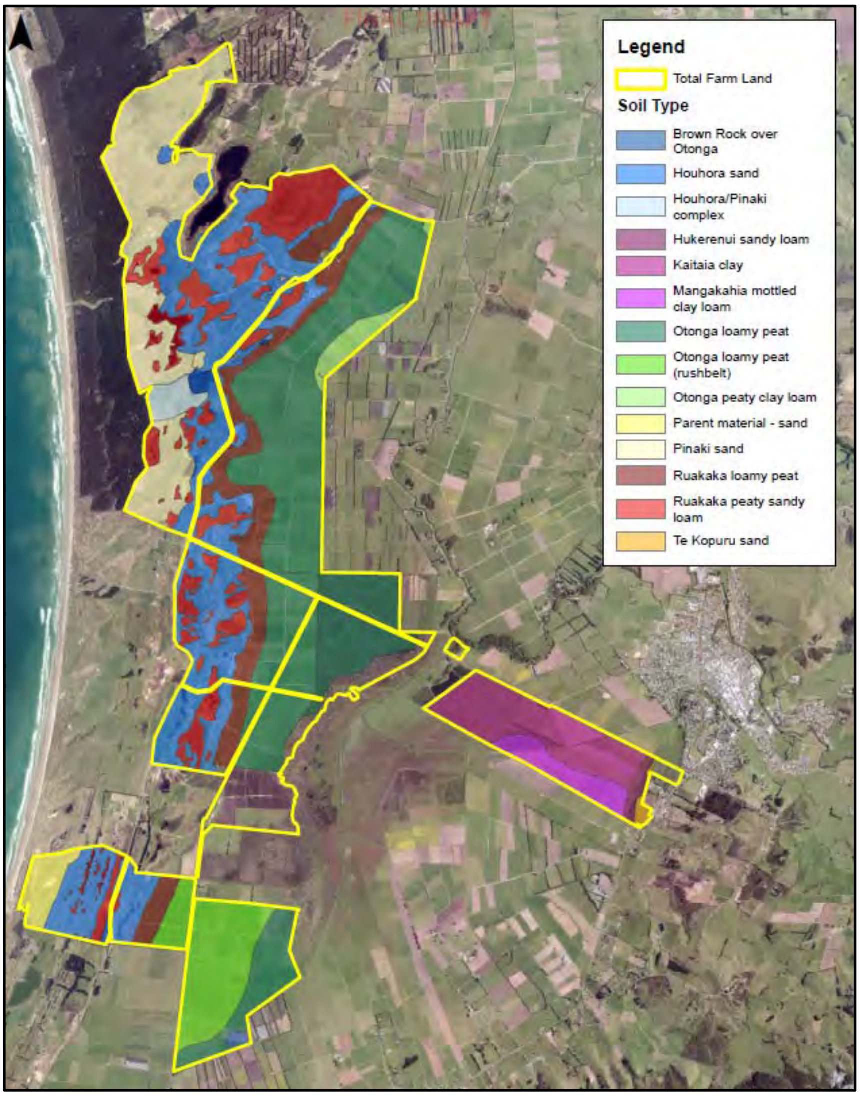


Figure 1: Sweetwater Farms, Soils Classification (WSP Opus, 2018)

Approximately 90% of the property is considered to be flat to undulating with 0 to 3 degrees slope according to the Slope maps of the New Zealand Land Resource Inventory[1] (See Figure 2)

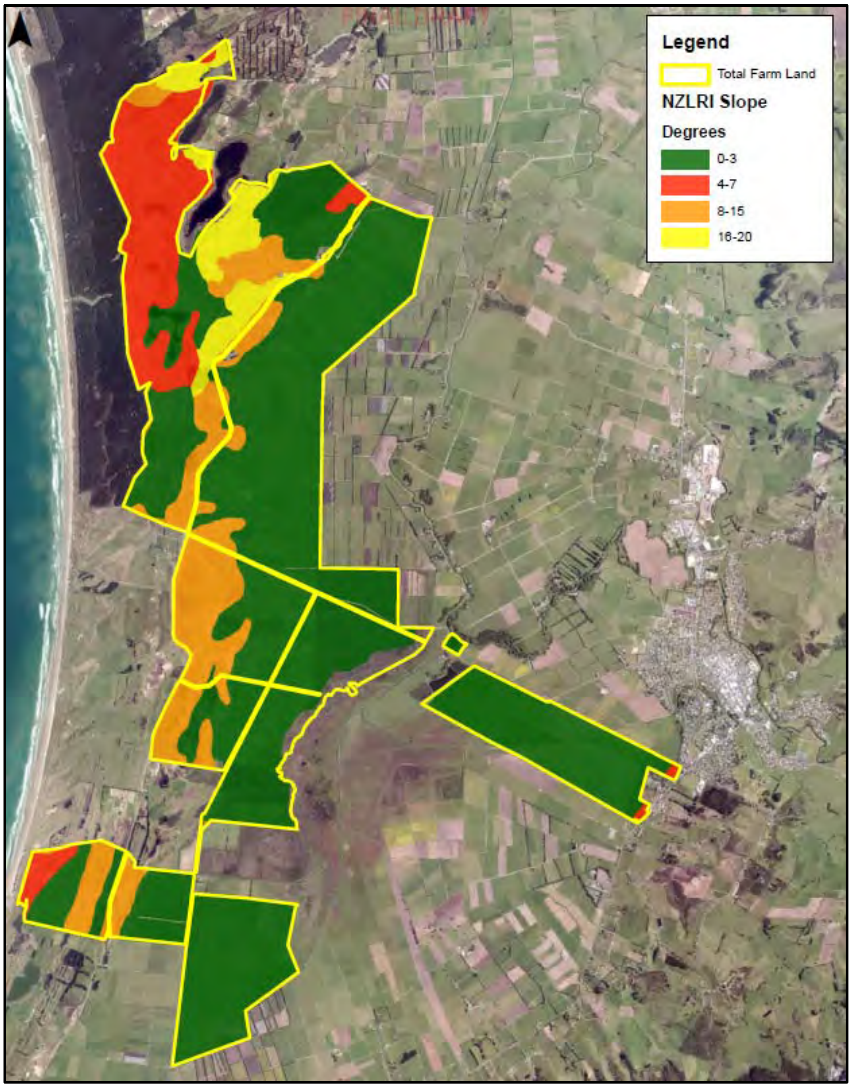


Figure 2: Sweetwater Farms, the New Zealand Land Resource Inventory - Slope Map (WSP Opus, 2018)

2.2.1 *Land Use*

Land Use Capability (LUC) is a dataset that classifies land areas according to their capability to sustain continuous production. It is a hierarchical classification that looks at the versatility for productive use, the factor most limiting to production and other characteristics such as landform, soil, erosion potential, etc.

This database suggests that the majority of Sweetwater Farm is Class 3 land, corresponding to land with moderate limitations for arable use, but suitable for cultivated crops, pasture or forestry. The next most common classes are Class 4 (suitable for occasional cropping, pasture or forestry) and Class 6 (Non-arable land with moderate limitations for use under perennial vegetation such as pasture or forest).

[1] Slope data from NZRLI database is granular in nature and should be taken as indicative only.

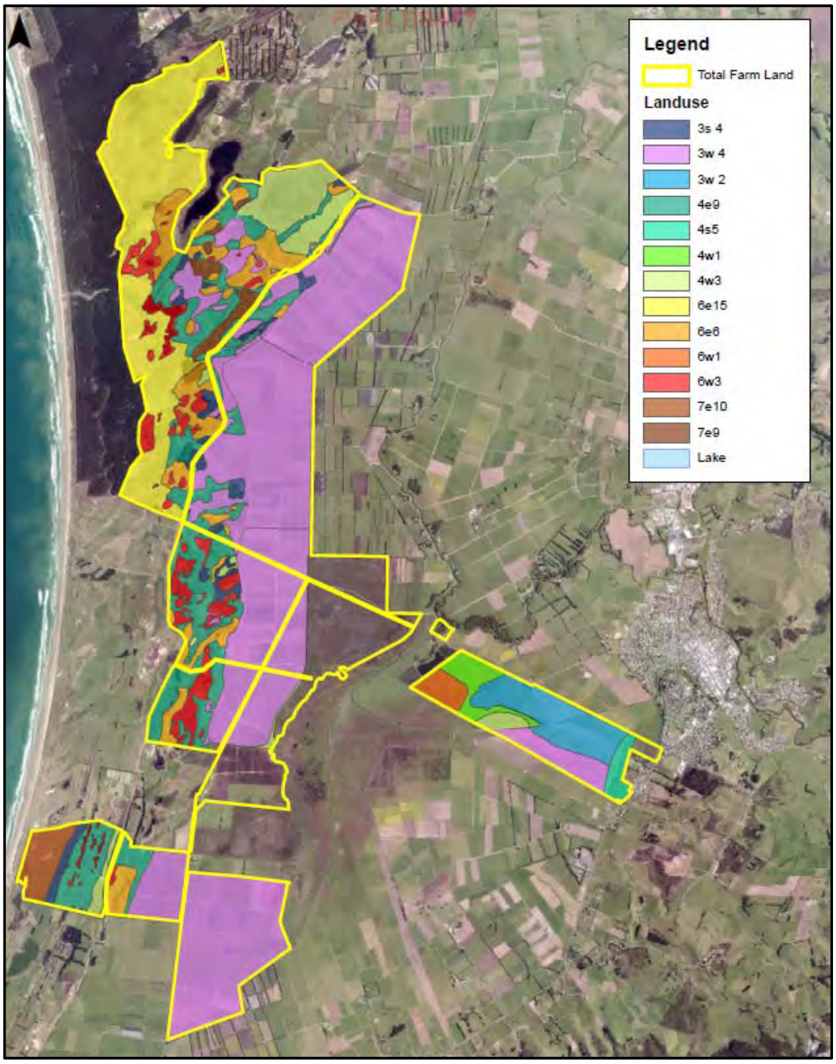


Figure 3: Sweetwater Farms, Land Use Classification (LUC) (WSP Opus, 2018).

2.2.2 *Natural Features*

Sweetwater Farm, and adjacent land, has substantial areas of wetlands and/or areas with QEII covenants upon them, as shown on Figure 4. There is approximately 300ha of QEII covenanted land that makes up 10% of the property which has been protected due to significance.

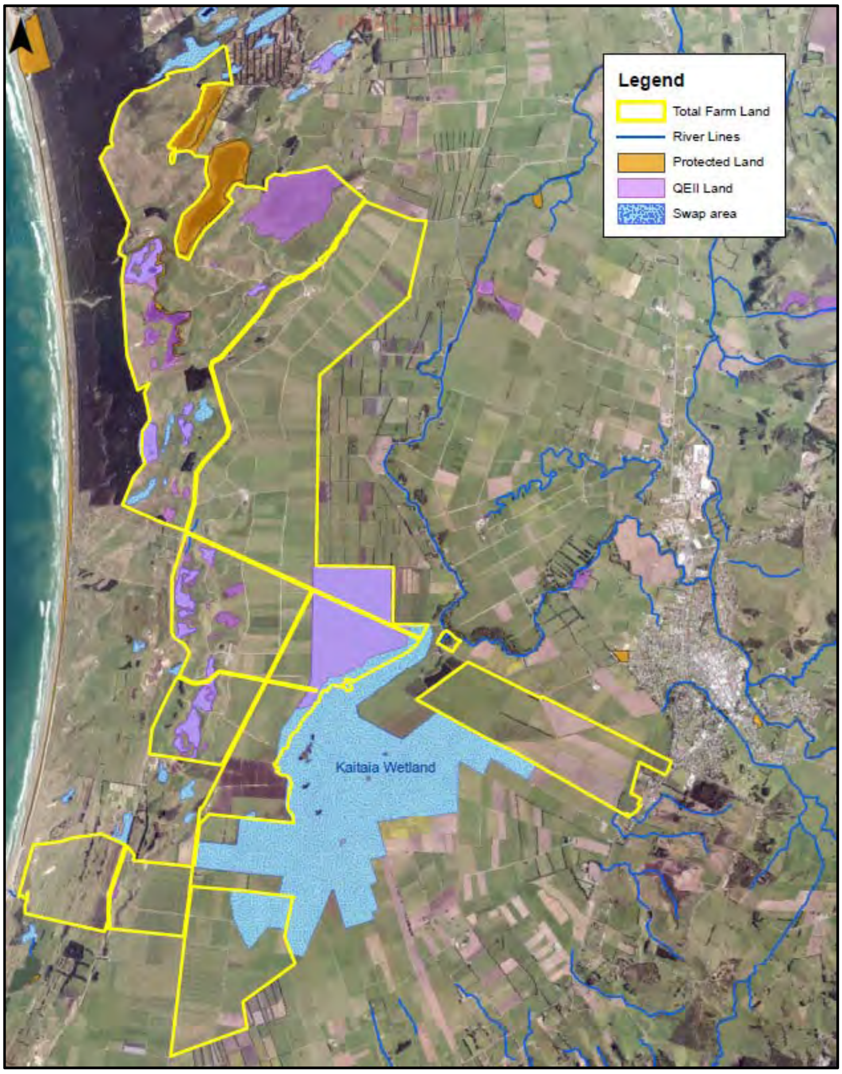


Figure 4: Sweetwater Farms, Natural Features and Protected Land (WSP Opus, 2018).

2.2.3 *Existing farm infrastructure and irrigation System*

The property is currently utilised almost solely for pastoral farming as three dairy units and land use for beef/support. These farming operations mean that there is a variety of buildings located across the property as well as typical farm infrastructure such as fences, bridges, culverts, stock water systems, etc.

2.3 Climate

The Northland Region experiences a mild, humid and relatively windy climate. Summers are warm and tend to be humid, while winters are mild with many parts of the Region experiencing few, if any frosts. Mean annual temperatures on the Aupōuri Peninsula range between 15.5 to 16.5°C, with most areas receiving around 2,000 sunshine hours each year.

There are numerous rainfall records in the vicinity of Sweetwater Farm; although only five are suitable for this analysis. All records are located in Cliflo (NIWA national climate database) except the Sweetwater Farm gauge which is owned by Sweetwater Farm. Although the Sweetwater farm record is considered too short to use for significant analysis, the median monthly rainfalls can be used to determine annual patterns within the records and comparison is presented below in Figure 5.

Figure 5: Comparison of the median monthly rainfalls for the five rainfall gauges near Sweetwater Farm (WSP Opus, 2018).

Long-term monitoring identifies that there is a rainfall gradient that covers Sweetwater Farm (Figure 6). This suggests that the gauges near Kaitaia township will over-represent rainfall that occurs nearer the coast which is important when identifying water requirements.

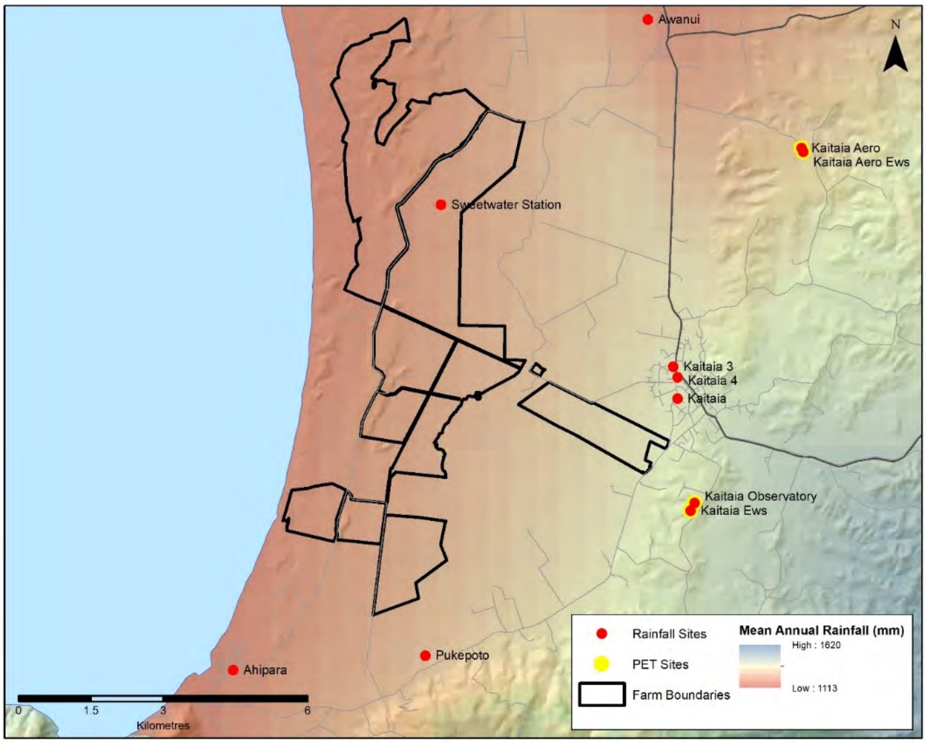


Figure 6: Location of Sweetwater Farm, nearby climate stations and the NIWA mean annual rainfall layer (WSP Opus, 2018).

Potential evapotranspiration (PE) data from a number of sites near to Sweetwater Station show that there is a strong seasonal pattern to PE (Figure 7). During summer PE tends to be very high because of sunshine, energy, high temperatures and wind; while during winter PE is low. The total annual potential evapotranspiration also varies significantly over time.

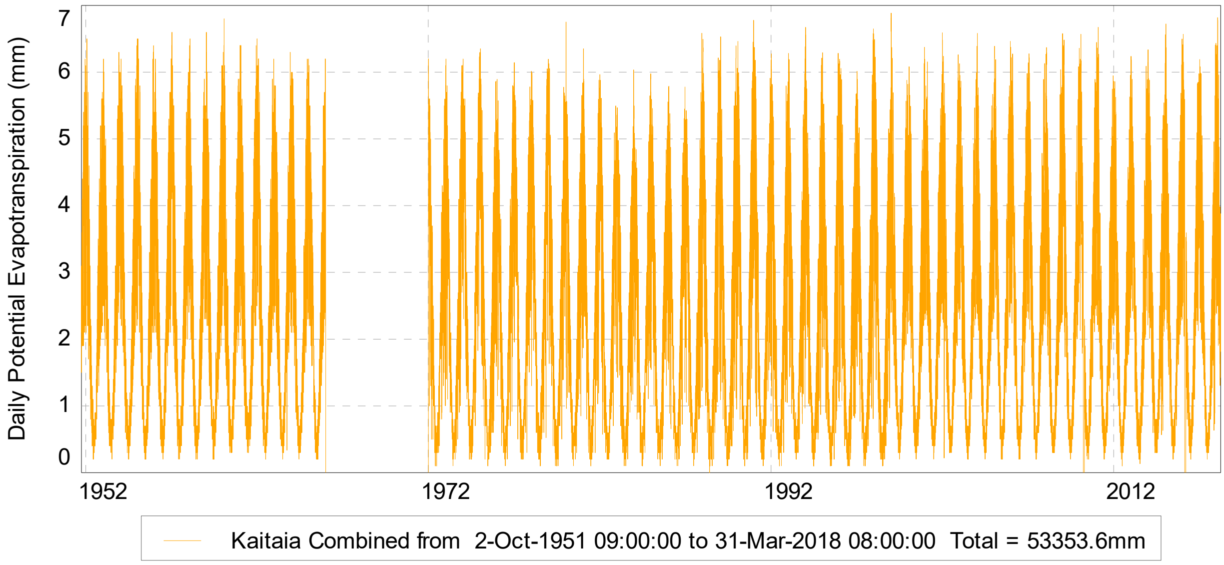


Figure 7: Combined Kaitaia potential evapotranspiration record (WSP Opus, 2018).

While Northland experiences a relatively wet climate, extended periods of low rainfall and high evapotranspiration are frequently experienced during the summer and autumn. Such 'dry spells' have an average duration of around 20 days, but may extend much longer in dry years.

Data from Kaitāia Airport indicate, on average, soil moisture deficit occurs on 62 days/year, with a cumulative seasonal deficit of 254 mm occurring between November and April (Chappell, 2013).

2.4 Groundwater availability

2.4.1 *Existing Bores*

There are currently two production bores at Sweetwater farm used for groundwater abstraction (PB6 and PB2). There are also 11 monitoring/observation bores across the wider Sweetwater Farm.

2.4.2 *Hydrogeology*

The Sweetwater farm is located within the Aupouri Aquifer System extents. The Aupōuri Aquifer covers an area of approximately 75,000 ha extending along the whole length of Ninety Mile Beach on the west coast, and from Kokota (The Sandspit) to Waimanoni on the east coast. It also includes the low-lying land between Waimanoni and Ahipara.

Williamson Water & Land Advisory Ltd (WWLA), in their Model report (March 2019) attached as Appendix D, describes the sedimentary deposits of the Aupouri Peninsula as

Pleistocene and Holocene unconsolidated sedimentary materials deposited in beach and dune (abandoned shorelines and marine terraces) and associated alluvial, intertidal estuarine, shallow marine, lakebed and wetland environments. The sediments near the surface typically comprise fine-grained sands, interspersed with sporadic iron pan, peat, lignite, silt, gravel and shellbeds.

With distance inland from the coast, the sand deposits become progressively older and have a higher degree of compaction and weathering compared to the younger foredune sands located at the coast.

With increasing depth, the occurrence of shellbed layers increases. The shellbeds comprise layers that typically range in composition from 30-90% medium to coarse shell and 10-70% fine sand. The shellbed aquifer typically resides from approximately 70 to 120 mBGL and is the most prolific water yielding aquifer in the region and hence the target for irrigation bores.

Underlying the shellbed aquifer are basement rocks of the Mount Camel Terrain, which typically comprise hard grey to dark green / black igneous rocks described in Isaac (1996) as intercalated basalt and basaltic andesite lava, pillow lava, rhyolitic tuff, tuff-breccia, with sedimentary deposits of conglomerate, sandstone and mudstone also present.

Drilling data from bores in the Aupouri aquifer indicates that the sedimentary sequence can be broadly classified into two lithological units. The upper bulk layer comprises the fine-grained sands, interspersed with iron pan, peat, lignite, and silt. The lower layer comprises mostly shellbeds, although recent drilling has identified the existence of two discrete shell units separated by a thin fine sand or silt layer, hence the lower layer is sub-divided into three distinct layers.

WWLA also describe the geological strata that occurs within the aquifer as;

Layer 1 – Sand / Silt. A sequence of predominately unconsolidated fine sand intersperses with discontinuous layers of alternating iron pan, silt and peat. The layer varies in thickness from approximately 45 m to 110 m with the thickest regions located around the model area peak elevations.

Layer 2 – Upper Shellbed. A sequence of shellbeds comprising medium to coarse shell with some fine sand in the matrix. The proportion of shell typically varies from 30% to 90%. The layer is typically encountered at a depth of 60 - 110 mBGL and varies in thickness from typically 5 m - 15 m.

Layer 3 – Sand. A thin layer of finer sediment separating the upper and lower shellbed.

Layer 4 – Lower Shellbed. A sequence of shellbeds typically comprising a higher proportion of shell with coarser grain size than the upper shellbed. In some locales, the shell is more consolidated and described by drillers as shell rock. Drillers also report circulation losses when drilling this formation. The layer is typically encountered at depths of 80 - 145 mBGL and varies in thickness from typically 5 m - 30 m.

The aquifer system is unconfined at the surface but does develop confinement progressively with depth such that there is no clear hydraulic boundary between the shellbeds and overlying sand deposits. This is attributable to the absence of a well-defined extensive confining layer. However, occurrences of low-permeability iron pans, peat and lignite layers within the sand deposits collecrively provide a degree of confinement that lends to the development of vertical pressure gradients.

As a result, the shellbeds are best characterised as forming a semi-confined water-bearing layer which exhibits varying degrees of hydraulic connection to the overlying sand deposits depending on the local geological setting (e.g. depth and lateral continuity of low permeability layers within the sand deposits).

The proportion of rainfall that infiltrates the soils and ultimately recharges the groundwater system is relatively large, due to the high infiltration capacity of the sandy soils.

Aquifer test data typically show aquifer transmissivity values of less than 100 m^2/day in the sand deposits, increasing up to 500 m^2/day in the shellbeds. Aquifer storage values vary according to bore depth (and presumably localised geology) with calculated values ranging between 0.06 and 0.0002 (typically <0.001 in bores recorded as being screened in the shellbeds).

Groundwater flow within the unconfined aquifer is interpreted to occur predominantly in the horizontal direction due to anisotropy of the sand deposits. As a result, groundwater flow is interpreted to occur from an approximate alignment along the axis of the Aupōuri Peninsula, approximately perpendicular to the coastline. The overall hydraulic gradient is determined by the elevation difference between the water table along the axis of the peninsula and sea level along the coastal margin. As a result, low-lying areas such as Ahipara which extend laterally some distance from the central axis exhibit a low hydraulic gradient toward the eastern coastline.

Although there is no laterally continuous confining layer within the sedimentary sequence of the Aupōuri Peninsula, the occurrence of numerous, low-permeability layers (e.g. iron pan, brown (organic) sand, silt, peat) that vary in depth and thickness, appear to collectively provide a degree of confinement to deeper water-bearing layers hosted in shellbed sediments. However, the degree of confinement of deeper water-bearing units varies spatially reflecting the geological heterogeneity of the aquifer materials. Localised perched water tables also occur in areas where infiltration is impeded by the accumulation of fine-grained sediments (typically silt or organic-rick sediments deposited in interdune areas) and iron pans within the sand deposits.

2.4.3 *Recharge and Discharge*

Groundwater underlying the Aupōuri aquifer is primarily recharged by infiltration of rainfall through the surficial sand deposits. This recharge varies temporally reflecting seasonal variations in rainfall and evapotranspiration with a majority of recharge occurring during the winter months.

Rainfall recharge model estimates indicate that average groundwater recharge across the Aupōuri Aquifer is likely to range between 10 and 43 percent of annual rainfall, depending on topography and soil hydraulic properties. Estimated recharge is highest in recent, unconsolidated sand deposits and lower in low-lying areas where peat soils overlie iron pans. Total annual average recharge to the Aupōuri Aquifer was estimated to be approximately 374 million m^3/year (equivalent to a spatial average of 4,968 m^3/ha/year) (Wilson & Shokri, 2015). The rate of recharge may also be significantly influenced by overlying landcover, particular plantation forestry which reduces recharge due to canopy interception.

Groundwater flow through deeper sections of the aquifer system is driven by the pressure of the overlying water column, including the unconfined aquifer. However, groundwater in the semi-confined shellbed layers has a reduced ability to discharge upwards because of structural confinement by overlying low permeability silt, clay and peat horizons. As a result, the shellbed aquifer can be considered to be a discharge-driven system rather than a recharge driven system as groundwater recharge can only enter the deeper water-bearing layers if there is discharge to accommodate it. The rate of groundwater flow in its natural state is likely to be small because the low vertical permeability of overlying sediments limits the rate of aquifer discharge to the sea. The rate of groundwater flow into the confined-leaky system can be increased by groundwater abstraction, which induces groundwater downwards via leakage from the overlying sand deposits.

2.4.4 *Available Allocation*

WWLA has assessed the availability of allocation from the Sweetwater and Ahipara sub-aquifer management units using the PRP allocation limits. Their assessment concludes that the allocation status for the Aupouri-Sweetwater and Aupouri-Ahipara SAMU's are 88% and 11% of the available allocations

Table 3 shows that the Aupouri-Sweetwater management zone is currently 88% allocated and granting the proposed Sweetwater Farms groundwater take (216,000 m^3/yr) will account for an additional 4.6% of the allocation limit. If the other current proposals are granted (Elbury Holdings) the total allocation status for the Aupouri-Sweetwater zone will increase to 97%.

Table 3: Aupouri - Sweetwater aquifer limits and allocation status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)[A]		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (216,000), Elbury Holdings (200,000)	
	m³/year	% mean annual recharge	Allocated groundwater (m³/year)	% of allocation limit	Allocated groundwater (m³/year)	% of allocation limit
Aupouri - Sweetwater	4,675,000	35	4,124,480	88%	4,540,480	97%

Notes:
A. Includes currently consented Sweetwater Farms take (2,317,000 m³/yr)

Table 4 shows that the Aupouri-Ahipara management zone is currently 9% allocated and granting the proposed Sweetwater Farms groundwater take (a combined 560,000 m³/yr) will increase the total allocation status for the Aupouri-Ahipara zone will increase to 57%.

Table 4: Aupouri - Sweetwater aquifer limits and allocation status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (560,000)	
	m³/year	% mean annual recharge	Allocated groundwater (m³/year)	% of allocation limit	Allocated groundwater (m³/year)	% of allocation limit
Aupouri - Ahipara	922,500	15	100,202	11%	660,202	72%

2.5 Zoning and Resource Information

Copies of the relevant planning maps are attached at Appendix F.

2.5.1 *Regional Policy Statement*

Parts of the proposal will take place within the area identified as Coastal Environment in the Regional Policy Statement for Northland 2016 (RPS). Furthermore, potential drawdown effects are indicated to extend to within parts of the Coastal Environment.

2.5.2 *Regional Plans*

Under the RWSP, the groundwater resource is not identified in any Schedules for the taking and use of groundwater. The Aupouri Aquifer is identified in Schedule F as an aquifer sensitive to bore construction.

Under the PRP, the groundwater resource is identified as the Aupouri aquifer management unit. Sub-aquifer units have been identified within this aquifer management unit. The sub-aquifers relevant to this application are the Sweetwater and Ahipara sub-aquifer units. The available allocation from these sub-aquifers is described in Table 3 and Table 4 above in Section 2.4.4.

Schedule D of The RWSP identifies that the Proposal is adjacent, with some irrigation areas falling within, the existing Kaitaia drainage district.

Schedule E of the RWSP lists dune lakes in Northland including Lake Rotoroa, Round Lake, and Waimimiha Lakes which are identified as being present within the assessed area of effect of the Proposal

2.5.3 *District Plan*

The application site is primarily zoned Rural Production zone under the Far North District Plan with a small component of the development located within General Coastal zone.

3 Description of the Proposal

3.1 Current Water Usage

The current groundwater abstraction of Sweetwater Farm is used to irrigate approximately 380 Ha via a central pivot irrigation system.

As part of the existing consent conditions, the usage of water has been monitored at Sweetwater Farm. Table 5 summarises the water usage at Sweetwater Farm, which, from the 2017/2018 irrigation season, includes the groundwater resource used from both production bores (PB6 and PB2).

Table 5: Water usage from Sweetwater Farm [Source: Council Monitoring reports (2015, 2016, 2017 and 2018)].

Monitoring Period	Consented	2014/2015	2015/2016	2016/2017	2017/2018
Production Bores	-	PB6	PB6	PB6	PB6 and PB2
Irrigation Period	-	2 Jan 15-10 Apr 15	21 Oct 15-6 May 16	3 Nov 16 – 15 Feb 17	4 Dec 17 – 17 Jan 18
Max. daily abstraction (m^3/day)	15,525	5,687	6,789	10,729	6,100 (PB6) 5,300 (PB2)
Max. instantaneous rate (L/s)	180	-	-	75	71 (PB6) 62 (PB2)
Total usage	2,317,000	265,502	291,620	404,099	391,311

3.2 Proposed Groundwater Take

The applicant seeks to increase the volume of groundwater to be cumulatively taken from the Sweetwater and Ahipara sub-aquifer management zones (AMZ).

Based on the peak daily demand and the average seasonal demand over the previous four water seasons (excluding the 2014/15 season for the reasons outlined above), and a 3% buffer to allow for future demand increases for the duration of the consent, the applicant proposes to take and use groundwater for developments totalling approximately 362 Ha for pastoral irrigation and 470 ha for avocado or other horticultural land use requiring the construction of up to a maximum of 12 new bores (plus the two established bores).

The change in the location of the production bores reflects an improved understanding of the future land development relative to when the consent was initially granted under previous ownership. The new bores will be located in the Aupouri-Sweetwater allocation zone (9 bores, 2 existing 7 new bores) and the Aupouri-Ahipara allocation zone (5 new bores).

The current consent, AUT.020995.01.03 is for a groundwater take up to 2,317,000m^3/year or 15,525m^3/day, and specifies a maximum of 14 production bore locations. Only two of these bores have been constructed and are currently in use. The current application proposes to leave the two bores that are currently operating in place at the locations labelled 1 and 2 in Figure 8.

Figure 8: Location of consented and proposed bores.

Table 6 summarises the proposed pumping volume and NRC groundwater allocation zone for the existing and proposed bores.

Table 6: Proposed bore locations and annual groundwater take for Sweetwater Farms resource consent application.

Bore Ref.	Bore Type	X Coordinate (NZTM)	Y Coordinate (NZTM)	Annual (m^3)	Daily (m^3)
SW1	Existing	1617473	6119002	632,000	6,320
SW2	Existing	1617846	6119771	436,000	4,360
SW3	Proposed	1617109	6120717	385,000	2,750
SW4	Proposed	1616465	6120787	1,080,000	8,800
SW5	Proposed	1617267	6121591		
SW6	Proposed	1616868	6120002		
SW7	Proposed	1617043	6118433		
SW8	Proposed	1616978	6116808		
SW9	Proposed	1617279	6117495		
SW10	Proposed	1617702	6114717	210,000	1,500
SW11	Proposed	1617254	6113920		
SW12	Proposed	1616055	6112008	350,000	2,500
SW13	Proposed	1616563	6111903		
SW14	Proposed	1616889	6111890		

		Total	3,093,000	26,230

In order to ensure reasonable use of water, the applicant proposes the development and implementation of an Irrigation Scheduling Plan, the nature of which is provided in the proposed conditions below in Section 3.4.

Further, as the new water permit will replace the existing resource consent (AUT.020995.01.03) the applicant offers to surrender the existing consent prior to its first exercise of the new water permit.

3.3 Irrigation Proposal

Given the size of Sweetwater Station, and myriad of soil types and irrigable land use options, the volume being sought is only enough to irrigate about one-third of the entire land holding.

At this stage the actual mix of possible crop combinations within Sweetwater Farm is unknown and almost limitless.

Land use will be a mixture of horticultural and pastoral with varying crop water requirements. It is proposed that water use efficiency between crop rotations will be demonstrated through the provision of an ISP for approval prior to executing consent to ensure water use efficiency.

3.4 Proposed Conditions

This section contains the proposed conditions for the new water permit sought by the applicant.

Te Rarawa Farming Limited & Te Make Farms Limited, C/- Ngā Rūnanga o Ngāi Takoto ko Te Rarawa, 16 Mathews Avenue, Kaitaia 0410

AUT.020995.01.04 Water Permit to take and use groundwater from no less than three and up to fourteen production bores located within the Aupouri-Sweetwater and Aupouri-Ahipara sub-aquifer management units for the purposes of horticultural irrigation purposes.

LOCATION
Address of Site
Sandhills Road, Awanui, Far North

Legal Description of Site
Site of take: Lot 2 Deposited Plan 170525, Section 2 Survey Office 472393, Section 5 & 7 Survey Office 64336, Lots 1, 4 & 5 Deposited Plan 156631.

Sites of use: Lot 2 Deposited Plan 170525, Lots 1 – 7 Deposited Plan 156631, Section 1 - 8 Survey Office 42207, Sections 2 - 4 Survey Office 472393, Part Lot 2 & 3 Deposited Plan 40865, Section 1, 4, 8, 11 Survey Office 472393, Section 5, 7 SO 64336, Allotment 118 Parish of Ahipara.

Map Reference (New Zealand Transverse Mercator Projection)

Bore Ref.	X Coordinate (NZTM)	Y Coordinate (NZTM)
SW1	1617473	6119002
SW2	1617846	6119771
SW3	1617109	6120717
SW4	1616465	6120787
SW5	1617267	6121591
SW6	1616868	6120002

SW7	1617043	6118433
SW8	1616978	6116808
SW9	1617279	6117495
SW10	1617702	6114717
SW11	1617254	6113920
SW12	1616055	6112008
SW13	1616563	6111903
SW14	1616889	6111890

Note: An error accuracy of +/- 50 metres apply to these map references.

CONSENT DURATION

This consent is granted for a period expiring 25 years from commencement of consent

Conditions of AUT.038610.01.01

1 The activities authorised by these consents shall be undertaken in general accordance with the application and documents submitted as part of the application. For the avoidance of doubt, where information contained in the application documents conflicts with any of the conditions of these consents, the conditions of this consent shall prevail.

2 The consent holder shall pay all charges relating to the recovery of cost for the administration, monitoring and supervision of this consent fixed by Council under Section 36 of the Resource Management Act 1991.

3 The combined volumes of water taken across all bores shall not exceed the following;

(a) 26,230 cubic metres in any 24 consecutive hours; and
(b) 3,093,000 cubic metres between 1 July in a year and 30 June in the following year; and
(c) That required to replace soil moisture depleted by evapotranspiration over the irrigated area.

Notification of Irrigation

4 The Consent Holder shall advise the Council's assigned Monitoring Officer in writing when irrigation is to commence for the first time each season, at least five working days beforehand.

Metering and Abstraction Reporting

5 Prior to the first exercise of this consent, a meter shall be installed to measure the volume of water taken, in cubic metres, from each production bore. Each meter shall:

(a) Be able to provide data in a form suitable for electronic storage;
(b) Be sealed and as tamper-proof as practicable;
(c) Be installed at the location from which the water is taken; and
(d) Have an accuracy of +/-5%.

The Consent Holder shall, at all times, provide safe and easy access to each meter installed for Council to undertake visual inspections and record water take measurements.

6 The Consent Holder shall verify that the meter required by Condition 5 is accurate. This verification shall be undertaken prior to 30 June:

(a) Following the first taking of water from each production bore in accordance with this consent; and
(b) At least once in every five years thereafter.

Each verification shall be undertaken by a person, who in the opinion of the Council's Compliance Manager, is suitably qualified. Written verification of the accuracy shall be provided to the council's assigned Monitoring Officer no later than 31 July following the date of each verification.

7 The Consent Holder shall keep a record of the daily volume of water taken from each production bore in cubic metres, including all nil abstractions, using the readings from the meter required by Condition 5.

8 The water meter required by Condition 5 shall have an electronic datalogger for automatic logging of meter data.

9 A copy of the records required to be kept by Condition 7 shall be forwarded to the Council's assigned Monitoring Officer on a monthly basis, by the seventh of the following month. In addition, a copy of these records shall be forwarded immediately to the Council's assigned Monitoring Officer on written request. The records shall be in an electronic format that has been agreed to by the Council.

Advice Note: *If no water is taken during any calendar month then the Consent Holder is still required to notify the council's Monitoring Manager in writing of the nil abstraction. Water use record sheets in an electronic format are available from the council's website at www.nrc.govt.nz/wur.*

Water Use Efficiency

10 The Consent Holder shall prepare an Irrigation Scheduling Plan (ISP) that outlines how irrigation decisions will be made. The purpose of the ISP is to set out how the irrigation will be undertaken to ensure that at least 80 percent of the annual volume of water applied to the irrigable area is retained in the soil in the root zone of the crop, compared to the average gross depth of water applied to the crop. The ISP shall be prepared by a suitably qualified and experienced person and submitted to the Council's Compliance Manager for written certification that it will achieve the purpose of the ISP. The ISP shall, as a minimum, address:

(a) Water balance and crop water requirements;
(b) Subsurface drainage; and
(c) Overall irrigation strategy.

11 For each irrigation area, the ISP should include:

(a) A description of how water requirements for each irrigation cycle are calculated;
(b) Method(s) for assessing current soil moisture levels;
(c) Method(s) for assessing potential evapotranspiration (PET) and rainfall to date;
(d) Soil moisture target to be maintained in each zone by irrigation;
(e) How measured data will be used to assess irrigation requirements over the next irrigation cycle; and
(f) A description of proposed method(s) for remaining within consent limits at each borehole or group of boreholes.

12 The Consent Holder shall not exercise this consent until the ISP required by Condition 11 has been certified by the Council's Compliance Manager.

13 The ISP certified in accordance with Condition 12 shall be implemented prior to the first irrigation season, unless a later date has been approved in writing by the Council's Compliance Manager.

14 The Consent Holder shall, within six months of the first exercise of this consent, undertake an audit of the irrigation system and of the certified ISP. The audit shall be undertaken by a suitably qualified and experienced person. The irrigation system audit shall be prepared in accordance with Irrigation New Zealand's "Irrigation Evaluation Code of Practice" (dated 12 April 2010), and shall include recommendations on any improvements that should be made to the system to increase water efficiencies or any amendments to the ISP. The results of the audit and its recommendations shall be submitted in writing to the Council's assigned Monitoring Officer within one month of the audit being undertaken. Any recommended amendments to the ISP shall be submitted to the Council's Compliance Manager for written certification that it will achieve the purpose of the ISP before they take effect. A follow-up audit shall occur at five yearly intervals throughout the term of this consent with the intent of confirming an irrigation efficiency of at least 80%.

15 The Consent Holder shall, within three months of notification in writing by the Council's Compliance Manager, implement any recommendations of the audit referred to in Condition 14.

16 The reticulation system and its component parts shall be maintained in good working order to minimise leakage and wastage of water.

17 The rate at which water is applied to the irrigated area shall not result in ponding of irrigated water within any irrigated area, or runoff from either surface or subsurface drainage to a water body, as a result of the exercise of this consent.

Advice Note: *The ISP seeks to ensure that at least 80% of the annual volume of water applied to the irrigable area is retained in the soil in the root zone of the crop, compared to the average gross depth of water applied to the crop.*

Review Condition

18 The Council may, in accordance with Section 128 of the Resource Management Act 1991, serve notice on the Consent Holder of its intention to review the conditions annually during the month of September for any one or more of the following purposes:

(a) To deal with any adverse effects on the environment that may arise from the exercise of the consent and which it is appropriate to deal with at a later stage; or
(b) To review the allocation of the resource.

The Consent Holder shall meet all reasonable costs of any such review.

Lapsing Condition

19 This consent shall lapse five years after the date that the consent commences in accordance with section 116(1) of the Resource Management Act 1991, unless the consent has been given effect to before this date.

4 Reasons for the Application

4.1 Resource Management Act 1991

Section 14 of the RMA places restrictions on the take and use of water. Section 14 of the RMA states that:

> *(2) No person may take, use, dam, or divert any of the following, unless the taking, using, damming, or diverting is allowed by subsection (3):*
>
> > *(a) Water other than open coastal water; […]*
>
> *(3) A person is not prohibited by subsection (2) from taking, using, damming, or diverting any water, heat, or energy if—*
>
> > *(a) The taking, using or damming is expressly allowed by a national environmental standard, a rule in a regional plan as well as a rule in a proposed regional plan for the same region (if there is one), or a resource consent.*

The proposed water take and use is not expressly allowed by a National Environmental Standard, and therefore needs to be allowed by a rule in a regional plan, or by a resource consent (water permit).

The Regional Plans applicable to the proposal currently are:

- Regional Water and Soil Plan for Northland 2004 (RWSP); and
- Proposed Regional Plan for Northland 2017 (PRP).

The RWSP is the operative plan, however, the rules in the PRP have legal effect and therefore both sets of rules will apply to any development proposal until the PRP has been made operative. A plan is made operative in whole or in part for those provisions of that plan which have been decided upon and which have not been appealed.

The PRP was notified in September 2017 and a decision on the PRP was released on 4th May 2019. The decisions version of the PRP replaces the version notified in September 2017, however, the rules are not yet operative as appeals have been lodged.

4.2 Regional Water and Soil Plan (RWSP)

The operative regional plan is the Regional Water and Soil Plan for Northland August 2004 (RWSP). The RWSP contains permitted activity rules for taking and using groundwater. However, the proposed takes are not able to comply with permitted rules as they are not for domestic or stock watering use (Rule 25(A)) and exceed the daily volume of 10 m3/day and/or instantaneous rate of 5 L/s per bore (Rule 25.01.01).

Discretionary Activity Rule 25.03.01 of the RWSP states that the taking, use or diversion of groundwater from an aquifer, and any associated discharge of groundwater onto or into land or into water, which does not meet the requirements of the permitted, controlled or non-complying activity rules is a discretionary activity.

In this regard, resource consent for a Discretionary Activity is required for this proposal under the RWSP.

4.3 Proposed Regional Plan for Northland (Notified September 2017) (PRPN)

Rule C.5.1.12 of the PRP states that the taking and use of freshwater that is not subject to any other rule in the PRP is a discretionary activity. The proposed application to take and use groundwater exceed permitted and controlled activity thresholds.

Under the PRP, it is a non-complying activity to take and use freshwater which exceeds an allocation limit set in Section H.4 'Environmental Flows and levels' of the PRP. There no prohibited activities in the decision version of the PRP.

Technical evidence from Mr Williamson demonstrates that the proposal is for a Discretionary Activity under Rule C.5.12 of the PRP as no allocation limit for an aquifer will be exceeded.

4.4 Overall Activity Status

Overall, the proposal requires resource consent as a Discretionary activity under the RWSP and the PRP.

5 Notification

The notification provisions of the Act were amended by the Resource Legislation Amendment Act 2017 and commenced on 18 October 2017. Sections 95A and 95B of the Act now set out a step by step process for determining whether an application should be publicly notified or subject to limited notification. This process is summarised in Table 7 & Table 8, together with an assessment of this application against each step.

5.1 Public Notification – Section 95A RMA

Table 7: Resource Consents Sought under the RWSP and PRP

	DESCRIPTION OF PROCESS	ASSESSMENT
STEP 1	Mandatory public notification in certain circumstances. An application must be publicly notified if: • the applicant requests public notification • public notification is required under Section 95C (which relates to notification after a request for further information or report) • the application is made jointly with an application to exchange recreation reserve land.	The applicant has not requested public notification. Public notification is not required following a request for further information or report. This application is not made jointly with an application to exchange recreation reserve land. PROCEED TO STEP 2

STEP 2	If not required by step 1, public notification is precluded in certain circumstances.
	An application cannot be publicly notified if:
	• a rule or national environmental standard (NES) precludes notification
	• the application is for one or more of the following, but no other, activities:
	  • a controlled activity
	  • a restricted-discretionary or discretionary application for:
	    o a subdivision of land
	    o a residential activity (defined in new Section 95A(6))
	    o a boundary activity (defined in Section 87AAB)
	• an activity prescribed in regulations.
	If the application is for multiple activities, public notification is only precluded for the application as a whole if each individual activity is precluded from public notification.
	
	If public notification is precluded under this step, then step 3 doesn't apply but consideration under step 4 is required (special circumstances).
		No rule or NES precludes notification of the application.
		
		The application is not for a controlled activity or a restricted discretionary application for subdivision of land, a residential activity or a boundary activity.
		
		The application is not for an activity prescribed in regulations.
		
		PROCEED TO STEP 3

	DESCRIPTION OF PROCESS	ASSESSMENT
STEP 3	If not precluded by step 2, public notification is required in certain circumstances. Other than for those activities in step 2, public notification is required if: • a rule or NES requires public notification • the assessment under Section 95D determines that the activity will have, or is likely to have, adverse effects on the environment that are more than minor. If the application is for multiple activities, and any part of that application meets either of the above criteria, the application must be publicly notified in its entirety	Nor rules or NES require public notification of the application. The assessment of effects in Section 6 below concludes that overall, effects on the environment will be no more than minor. PROCEED TO STEP 4
STEP 4	Public notification in special circumstances If notification is precluded under step 2, or isn't required under step 3, consideration must be given to whether special circumstances exist that warrant public notification of the application. The presumption for special circumstances has changed so that, if the consent authority determines special circumstances exist, the council must notify the application (i.e. it is not discretionary).	There are no special circumstances relevant to this application. PUBLIC NOTIFICATION NOT REQUIRED

5.2 Limited Notification – Section 95B RMA

Table 8 : Step by Step Process for Limited Notification

	DESCRIPTION OF PROCESS	ASSESSMENT
STEP 1	Certain affected groups and affected persons must be notified. If the consent authority determines that certain people or groups are affected, these persons/groups must be given limited notification: • affected protected customary rights groups • affected customary marine title groups (in the case of an application for a resource consent for an accommodated activity) • an affected person under Section 95E to whom a statutory acknowledgement is made (if the proposed activity is on or adjacent to, or may affect, land that is the subject of a statutory acknowledgement)	There are no protected customary rights or marine title groups (within the meaning of the Marine and Coastal Area Takutai Moana Act 2011) in the area of the application site. The applicants are the Iwi for which the Crown has stated association and relationship to the statutory areas within or adjacent to the application areas through the Te Rarawa Claims Settlement Act 2015 and the NgaiTakoto Claims Settlement Act 2015. PROCEED TO STEP 2
STEP 2	If not required by step 1, limited notification is precluded in certain circumstances. An application cannot be limited notified if:	This application does not seek a controlled land use activity under a district plan nor an activity prescribed through regulations.

	DESCRIPTION OF PROCESS	ASSESSMENT
	• a rule or NES precludes limited notification of the application • it is for either or both of the following, but no other, activities: - a controlled land use activity under a district plan - an activity prescribed through regulations. If the application is for multiple activities, limited notification is only precluded for the application as a whole if each individual activity is precluded from limited notification. If limited notification is precluded under this step, then step 3 doesn't apply but consideration under step 4 is required.	PROCEED TO STEP 3
STEP 3	If not precluded by step 2, certain other affected persons must be notified. • Except for boundary activities and any activities prescribed under the regulations relating to notification of consent applications (section 360G(1)(b)), the consent authority must notify any other person they determine to be affected under Section 95E. For boundary activities, only those persons whose written approval would have been required under new Section 87BA are eligible to be notified. These eligible persons must be notified if they are determined to be affected persons under Section 95E. For activities prescribed in regulations made under Section 360G(1)(b), limited notification can only be served on persons specified as being eligible to be affected. These eligible persons must be notified if they are determined to be affected persons under Section 95E.	Potentially affected parties could include other groundwater users and occupiers of the land. However, the Aupouri Aquifer Groundwater Model (AAGWM) detailed in Section 6 and the assessment of effects on other groundwater and surface water uses detailed in Section 6.11 concludes that the proposed abstraction is unlikely to adversely impact on the reliability of supply for existing groundwater users. No other persons or parties have been identified to be impacted by the proposal in a manner that would define them as an affected party in terms of the Act, and more specifically section 95E. PROCEED TO STEP 4
STEP 4	Further notification in special circumstances. The determination of special circumstances is new to limited notification. If the consent authority determines special circumstances exist that warrant limited notification of the application to any other persons not already determined to be eligible for limited notification (excluding persons assessed under Section 95E as not being affected persons), the council must give limited notification to those persons (i.e. it is not discretionary).	There are no special circumstances relevant to this application. LIMITED NOTIFICATION NOT REQUIRED

5.3 Summary of Notification

In light of the above, there are no preclusions, or special circumstances which require public or limited notification of this application. On this basis, the application can proceed without notification.

6 Assessment of Environmental Effects

6.1 Matters for Assessment

Clause 7 of the Schedule 4 of the RMA contains a description of matters which must be addressed in an assessment of an activity's effects on the environment, but these matters are also related to any requirement to address a matter contained in the relevant plan(s).

There are no specific assessment criteria listed in the PRP, however, Policies contained in Section D.4 of the PRP are prescriptive as to what an application must consider with regard to water quantity and integrated catchment management.

The RWSP contains assessment criteria generally and specifically for groundwater takes, as identified below. This assessment criteria has been used as a guide to the preparation of this AEE.

Section 36.2.1 General Assessment Criteria

(a) The adequacy of the Assessment of Environmental Effects, in terms of the Fourth Schedule of the Act.
(b) The adequacy of information substantiating the applicant's need for water.
(c) The extent to which the taking of water from the proposed source will impact on the resource, and on other users, including any cumulative effects of the takes on the resource.
(d) The adequacy of the assessment of any alternative water sources considered, or other water management strategies and the reasons for selecting the proposed water source.
(e) The adequacy of any water conservation and mitigation measures for the proposed system.
(f) The number, location and type of point source discharges which could contribute nutrients and organic material to the river, and the effect of the water take on the ability of the water body to assimilate those contaminants.
(g) The extent to which the natural character of the environment is maintained.
(h) The extent to which amenity, cultural, recreational and social values and economic well-being are adversely affected.
(i) The adequacy of any proposed monitoring programme to monitor the effects of the taking, use, damming or diverting of water

Section 36.2.6 Assessment Criteria for Groundwater Takes

(j) The cumulative effects of the proposed groundwater take and existing groundwater users in relation to the average annual recharge of the aquifer.
(k) The extent to which the proposed groundwater take may adversely affect other groundwater and surface water users, and the adequacy of any pump test analysis to confirm those effects.
(l) The proximity to the freshwater/seawater interface and the likelihood of any seawater intrusion affecting groundwater users.
(m) The proximity of the bore and the standing groundwater level to any effluent disposal field and the likelihood of contaminants being drawn into the aquifer as a result of pumping.

6.2 Existing Environment

Section 104(1) requires a consideration of any actual and potential effects on the environment of allowing an activity. For the purposes of this consideration, it is necessary to establish the correct environment on which the effects are to be assessed. The term 'environment' in s2 of the Act is reasonably easy to distinguish with components that are tangible. However, the term 'effect, as defined in s3 of the RMA, is more difficult to apply in real-terms as it has dimensionless application without further refinement. The terms receiving environment and existing environment are not defined within the RMA they are concepts developed to assist practitioners to prepare appropriate assessment of effects on the environment. Consequently, 'environment' is taken to mean;

- the environment as it actually exists now, including the effects of past resource use (by whomever);
- the environment as it is likely to be in the future taking into account the permanent and non-transitory effects of use of the resource; and
- the environment as it is likely to be from time to time, taking into account further effects of past activity and further effects of existing consented activity.

The existing state of the environment has been outlined in Section 2 of this report. It is noted that the WWLA report refers to the existing environment as the 'permitted baseline' which we address in the following Section.

6.3 Permitted Baseline

Section 104(2) of the RMA allows for a consent authority to disregard any adverse effect of an activity on the environment if a plan permits an activity with that effect. The permitted baseline is a term that has evolved to mean the level of environmental effect that would be generated by a permitted activity. Council may choose to apply the baseline such that only the adverse effects arising from the proposal over and above the permitted baseline are relevant when assessing who may be affected and when forming an opinion on actual and potential effects on the environment of allowing the activity.

The RWSP and the PRP allow for minor groundwater abstractions as permitted activities. The proposal exceeds these thresholds significantly. Given the magnitude of the proposed groundwater take, the following assessment of effects accounts for the total volume of groundwater proposed to be taken.

6.4 Technical Assessment Approach

Williamson Water and Land Advisory Ltd has prepared a technical assessment comprising analysis of pumping scenarios undertaken using a numerical groundwater model developed to represent the Aupouri Aquifer, the model is referred to as the Aupouri Aquifer Groundwater Model (AAGWM). This report is contained in Appendix E.

The AAGWM domain represents the area occupied by the Aupouri Shellbed Aquifer which occurs from Ahipara to Ngataki, an area of 535 km^2 and is shown in Figure 9 below.

Model grid spacing ranges from 40 m at the highest resolution, centred around large groundwater extraction points, to 1,000 m in the northwest portion of the model area where high resolution is unnecessary.

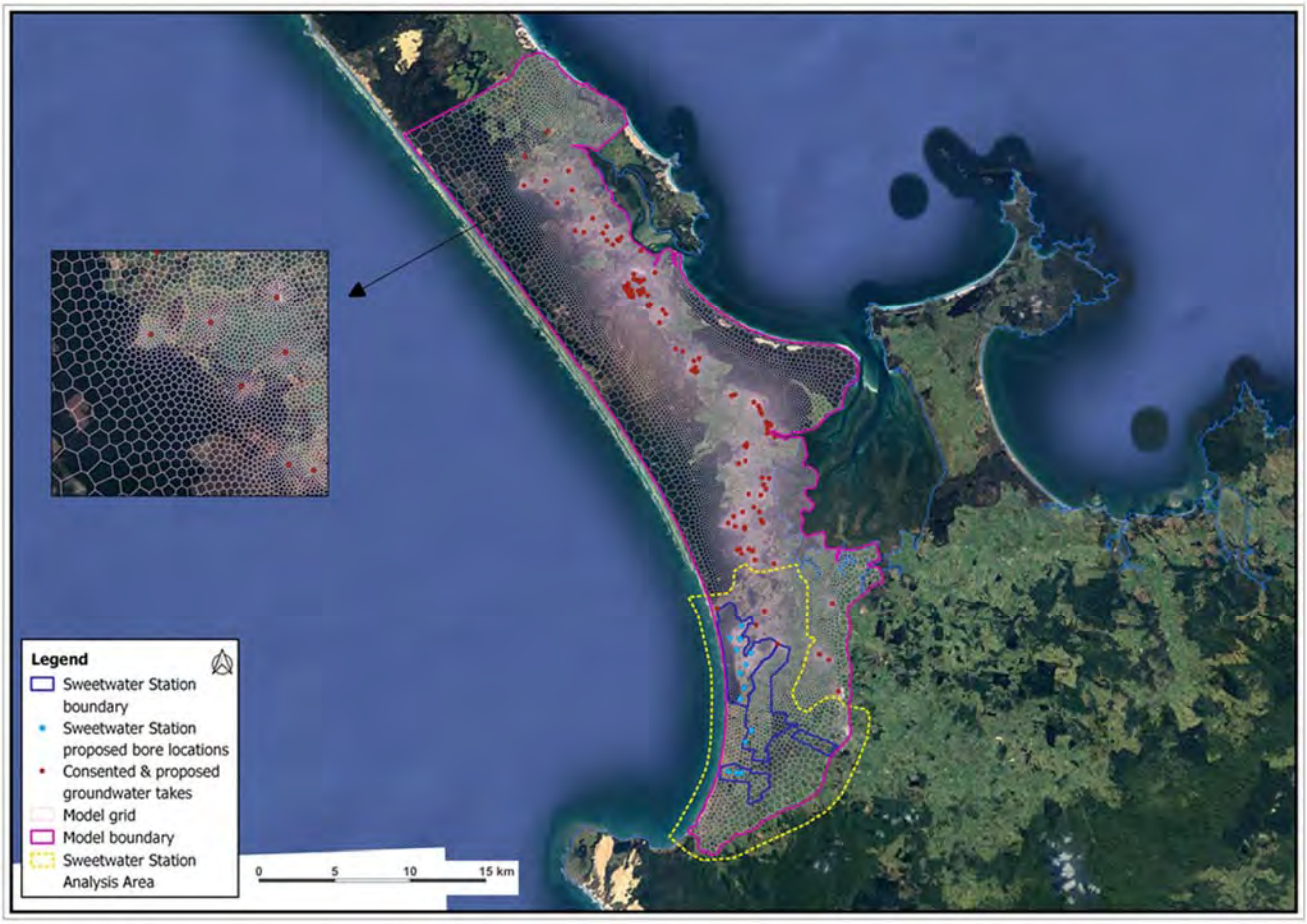


Figure 9: Aupouri Aquifer Model Domain.

The model was constructed based on six layers representing the primary geologic strata that occur within the model domain. Details of the groundwater model development and calibration are provided in a separate report prepare by WWLA attached as Appendix E.

The scope of technical assessment reporting limited to the application of the calibrated model for the purpose of assessing the groundwater take now proposed is contained in Appendix F.

6.5 Demonstrated Need for Water

Policy D.4.20 of the PRP provides guidance as to the reasonable and efficient use and allocation of groundwater including that the annual volume of water allocated must meet an irrigation application efficiency of at least 80% and that the volume of water allocated is sufficient to maintain soil moisture for crops for at least 9 out of 10 years.

The proposed rates and volumes of groundwater abstraction outlined above were calculated from a number of water balance scenarios for a selection of crops and derived from irrigation requirements of these crops for a 1-in-10-year climate scenario. The water balance applied includes soil moisture storage and the Ahipara median monthly rainfall.

The pores within a soil can store moisture and therefore act as a buffer against the natural inputs and losses of moisture which would occur solely as a result of the climate. The soil's Profile Readily Available Water content (PRAW) describes the water that can be readily absorbed by plant roots without resulting in water deficit stress. This is generally assumed to be the water content difference between field capacity and permanent wilting point. Field capacity describes the maximum amount of water a soil can hold against gravitational force. Wilting point is the moisture content in which plants can no longer extract water because of capillary tension. At this point plants will suffer extreme water stress and possibly die.

Almost all of the farm has either low or moderate PRAW (Figure 10). This is largely a reflection of the classification being a function of the potential rooting depth (Newson et al., 2006). Soils with a low PRAW require lower frequency irrigation application; although not necessarily the total volume of water required.

To provide a realistic, but representative, value of PRAW for use in the water balance the mid value of the two most common PRAW classes was used for analysis of water requirement (i.e. 37 and 62mm).

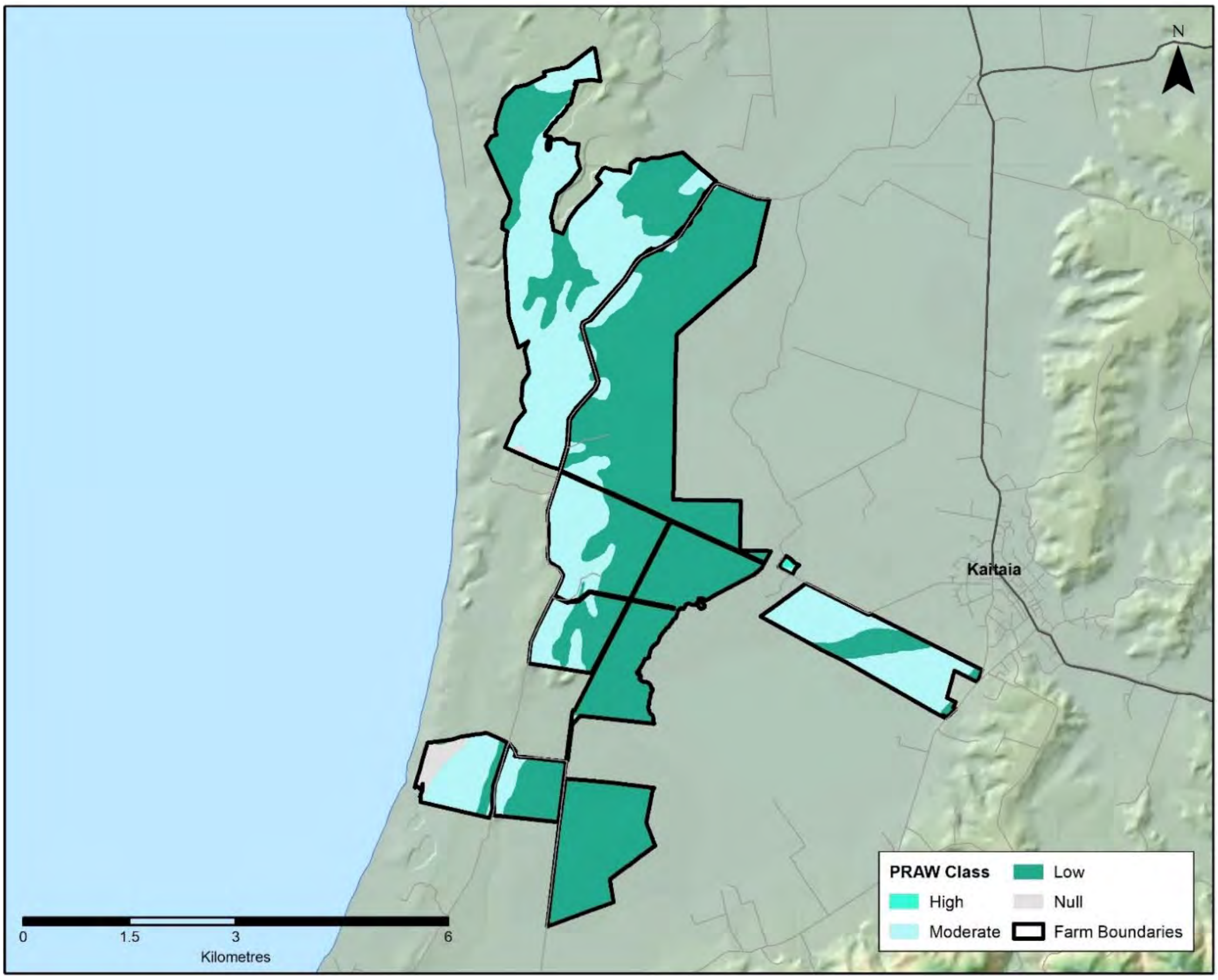


Figure 10: Soil profile readily available water (PRAW) on Sweetwater Farm (WSP Opus, 2018).

The water balance also assumes that the planting dates start in October or end in April to allow for the assumption that in the Northland climate, all crops can be grown from October to May. The growing seasons have been derived from international literature but have been verified by local experts. Consequently, as particular growers and particular cultivars also alter the season duration of crops, these water balances are considered to be estimates only and further analysis should be completed to define these further as part of the ISP process.

Crop specific irrigation demand has been weighted via crop evapotranspiration coefficients using the method proposed by Priestley-Taylor and more recently in (Allen, Pereira, Raes, & Smith, 1998)

Table 9 and Table 10 show the monthly deficit for each crop that has been weighted via the crop factors. Both scenarios show a need for the most irrigation in December and January. Obviously, the amount of water that is needed for each crop is dependent on the time of year it is grown i.e.

lettuce will need 145mm of irrigation if grown from October to December, however, the same lettuce will only need 49mm of irrigation if grown from February to April.

Table 9: The monthly deficit determined using the weighted crop factors for various irrigated crops where the 'season' starts in October (mm). The Ahipara rainfall and a soil moisture deficit of 37mm were used

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigated pasture	115	75	44	0	0	0	0	0	0	0	51	87
Avocados	93	57	29	0	0	0	0	0	0	0	0	58
Corn (maize)	18									12	72	96
Potatoes	125	46								0	0	128
Watermelon	78									0	12	63
Lucerne	108									0	14	158
Lettuce										9	53	83

Table 10: The monthly deficit determined using the weighted crop factors for various irrigated crops where the 'season' finishes in April (mm). The Ahipara rainfall and a soil moisture deficit of 37mm were used

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigated pasture	115	75	44	0	0	0	0	0	0	0	51	87
Avocados	93	57	29	0	0	0	0	0	0	0	0	58
Corn (maize)	81	75	63	0								44
Potatoes	76	76	59	0								16
Watermelon	17	27	29	0								
Lucerne	17	52	71	0								
Lettuce		27	22	0								

Therefore, to assess the likely requirement for irrigation over the farm, the volume needed per hectare per crop type has been estimated overall in Table 11 below. It must be remembered that this is per hectare of crop/trees i.e. this is the canopy area.

Table 11: The monthly volume determined for the various crops for a 1-in-10-year scenario (m^3/ha). (Using information derived in Table 9 and Table 10).

	PASTURE	AVOCADOS	CORN (MAIZE)	POTATOES	WATERMELON	LUCERNE	LETTUCE	PASTURE	AVOCADOS	CORN (MAIZE)	POTATOES	WATERMELON	LUCERNE	LETTUCE
	Season starts in October							Season finishes in April						
Jan	1150	930	180	1250	780	1080		1150	930	810	760	170	170	
Feb	750	570		460				750	570	750	760	270	520	270
Mar	440	290						440	290	630	590	290	710	220
Apr	0	0						0	0	0	0	0	0	0
May	0	0						0	0					
Jun	0	0						0	0					
Jul	0	0						0	0					
Aug	0	0						0	0					
Sep	0	0						0	0					
Oct	0	0	120	0	0	0	90	0	0					
Nov	510	0	720	0	120	140	530	510	0					
Dec	870	580	960	1280	630	1580	830	870	580	580				
Total (m^3/ha/ season)	**3720**	2370	1980	2990	1530	2800	1450	**3720**	2370	2770	2110	730	1400	490
Peak (mm/day)	3.7	3.0	3.1	4.1	2.5	**5.1**	2.7	**3.7**	3.0	2.6	2.5	0.9	1.7	0.9

** bold values are the highest values for each scenario.

Table 11 shows that of the two scenarios analysed; season starting in October, and season finishing in April; irrigated pasture needs the greatest annual volume of irrigation to sustain it. However, irrigated pasture does not have the peak amount of irrigation needed, potatoes need at least 4.1mm/day in December and Lucerne needs 5.1mm/day under the 'season starting in October' scenario. However, if potatoes or lucerne are grown in December – April, then the highest peak irrigation needed is only 2.5 or 1.7mm/day respectively. Therefore, the crop type grown and when it is grown has a huge impact on the peak rate of take for irrigation.

It is possible to grow a number of these crops within a single year i.e. lettuce from Oct to Dec and then potatoes from Jan to Apr for example. This particular scenario would need approximately 3,560m^3/ha of irrigation.

The above assessment demonstrates that there is a need for water at these properties and the volumes sought are not fanciful. It is however acknowledged that the volume of water required annually will vary as crops vary and as seasonal rainfall varies. This is not an unusual occurrence.

6.6 Efficient Allocation and Use of the Resource

It is imperative that the consent holder efficiently irrigates their crops for the success of the crops. Too little water, and the crop will wilt and die while too much water may lead to root rot and leaching of nutrients.

Policy D.4.20 of the proposed regional plan requires applications to take water for irrigation purposes include an irrigation assessment which has been prepared above, taking into account that actual crop water requirement cannot be distinguished in absolute terms as yet due to decision-making on crop type, rotation, and areas.

Should consent be granted, we have proposed the preparation of a Irrigation Scheduling Plan (ISP) which takes into account environmental and crop parameters to determine suitable application depth and frequency of application. This will be supported by field soil moisture monitoring and water meter records. In conjunction, the ISP and associated monitoring will identify whether at least 80% of the annual volume of water applied to the irrigable area is retained in the soil in the root zone of the crop, compared to the average gross depth of water applied to the crop. This will ensure that losses of water are minimised to the extent practicable, consistent with the relevant policy framework.

6.7 Effects in Relation to Long-term Aquifer Storage

The potential effect of the proposed abstraction on long-term aquifer storage identifies that the proposed cumulative volume of groundwater abstraction (current + proposed, i.e. Scenario 2) represents approximately 1.8% of the total water budget within the groundwater system and concludes that potential effects of the proposed abstraction on groundwater storage are likely to be no more than minor.

The operative RWSP does not set specific groundwater allocation limits. However, Policy 10.5.1 refers to the sustainable use of groundwater resources by avoiding groundwater takes that exceed recharge which result in nominated adverse effects on the environment. With regard to the Aupōuri Aquifer, the proposed abstraction represents only a small proportion of the recharge to the whole aquifer system. However, given the spatial extent of the Aupōuri Aquifer, evaluation of the cumulative effects of groundwater abstraction long-term aquifer storage at a whole-aquifer scale fail to adequately account for potential constraints on abstraction that occur at a local scale (such as saline intrusion or effects on wetlands).

The PRP approach is to manage allocation on the basis of sub-aquifer areas which represent subdivisions of the larger groundwater management unit representing the Aupōuri Peninsula. An allocation limit has been established for each sub-aquifer area based on recommendations in the Lincoln Agritech (2015) report which take into consideration estimated recharge volumes and specific environmental constraints identified for each area.

Policy D.4.10 of PRP requires that "*…no decision will likely result in over-allocation*" by applying the allocation limits set in H.4 when considering and determining applications for resource consents to take and use water. It is noted that these policies are not yet operative but do hold some statutory weight as the notified decision version.

A summary of the current allocation, proposed allocation, and changes to allocation as a result of the proposal is set out in Tables Table 12 and Table 13 below (all volumes m³/year):

Table 12: Aupouri-Sweetwater SAMU limits[2] and allocation status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)[A]		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (216,000), Elbury Holdings (200,000)	
	m³/year	% mean annual recharge	Allocated groundwater (m³/year)	% of allocation limit	Allocated groundwater (m³/year)	% of allocation limit
Aupouri - Sweetwater	4,675,000	35	4,124,480	88%	4,540,480	97%

Notes:
A. Includes currently consented Sweetwater Farms take (2,317,000 m³/yr)

Table 13: Aupouri-Ahipara SAMU limits[3] and allocation status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (560,000)	
	m³/year	% mean annual recharge	Allocated groundwater (m³/year)	% of allocation limit	Allocated groundwater (m³/year)	% of allocation limit
Aupouri - Ahipara	922,500	15	100,202	11%	660,202	72%

While it is acknowledged that the proposed allocation is within the groundwater allocation limits specified in the proposed plan, there remains an element of uncertainty with regard to potential local-scale effects due to the overall heterogeneity of the groundwater system. In particular, it is noted that the sub-aquifer allocation zone boundaries represent arbitrary subdivision of a larger management unit (the Aupōuri Aquifer) for the purposes of resource management and therefore do not represent hydraulic boundaries. As a consequence, the potential for the effects of groundwater abstraction to propagate between the individual sub-aquifer areas has to be considered with regard to cumulative effects of abstraction.

Therefore, although the relevant policies regarding sustainable allocation of freshwater will be met, further assessment of local scale effects that may be contingent upon long-term aquifer storage in the Aupōuri aquifer and are addressed further below.

6.8 Likelihood of Saline Intrusion

The lateral intrusion of saline groundwater into a freshwater aquifer can occur where the ground water balance is sufficiently imbalanced to reverse current lateral outflow of fresh groundwater. Given the geometry and geology, the potential for saline intrusion is a significant constraint on sustainable groundwater allocation on the Aupōuri Peninsula. The Lincoln Agritech (2015) report

[2] According to NRC's allocation maps at http://gis.nrc.govt.nz/LocalMaps-Viewer/?map=895e0785f7054d47b10a72edc38022dc

[3] According to NRC's allocation maps at http://gis.nrc.govt.nz/LocalMaps-Viewer/?map=895e0785f7054d47b10a72edc38022dc

recommended provisional allocation limits for various sub-aquifer areas across the peninsula based on the calculated volume of groundwater able to be abstracted without drawing groundwater levels below thresholds established at the coast to maintain the saline interface offshore (i.e. to prevent the migration of the saline interface inland of the coastal margin). As assessed above, the requested volumes do not exceed the recommended limits.

Section 5.3.1 of the modelling report provides an assessment of potential lateral migration of the saline interface resulting from the proposed abstraction based on the Ghyben-Herzberg relation. The report specifically states that,

Based on the estimated depth to the basement rock at the coastal margins, the Ghyben-Herzberg relation was used to back-calculate the minimum hydraulic head required to maintain the saline interface below the shellbed aquifer (i.e. the lateral migration "Trigger Level"). This relation essentially states that due to the density difference between fresh and saline water, for every metre of freshwater in an aquifer above sea level, there will be 40 metres of freshwater in the aquifer below sea level. This calculation was performed at approximately 200 m intervals along the coastal margin of the western model boundary, adjacent to the Sweetwater Station Analysis Area where saline intrusion would be most likely to occur due to pumping at Sweetwater Station. The analysis was not performed for the east coast or northern half of the west coast because these locations were beyond the extent of predicted drawdown.

The assessment conducted by WWLA concluded the risk of saline intrusion as a result of the proposed abstraction is assessed as being minor. Monitoring of groundwater level and salinity water quality monitoring in production bores is proposed as part of this application. However, this monitoring is proposed to be developed in collaboration with the NRC.

6.9 Likelihood of Ground Subsidence

The WWLA assessment of land settlement effects uses the Bouwer (1977) equation at the maximum rate in the simulation.

The assessment by WWLA reports that predicted settlements at the 14 bores ranging from 0.00 to 0.02m. They have also compared such settlement predictions to settlement effects which could occur through general rural activity such as rotary hoeing and have also indicated that rural zoned land does not anticipate development of infrastructure which would be sensitive to such levels of settlement. It is reasonable to conclude subsidence effects are likely to be no more than minor.

6.10 Effects on Surface Waterbodies

The potential effects of the proposed abstraction on surface water features has been assessed through a water budget whereby shallow aquifer drawdown has been simulated to reduce discharges in surface water features contained in the model domain. The simulated impact on drain flows with a leaky aquifer model configuration was negligible, with predicted impact on annual low flows being a reduction of approximately 0.4%

The assessment notes that the model does not capture any hydraulic separation between the shallow aquifer and surface water features by a discontinuous iron pan. Therefore, the calculated effect on the shallow aquifer and therefore surface water is likely to represent a conservative upper estimate of the potential magnitude of effect. This observation is particularly relevant given that the dune lakes in particular are typically classified as being perched with recharge predominantly sourced from rainfall (Hicks, Campbell, & Atkinson, 2001). The probability of the proposed abstraction resulting in a reduction on groundwater levels or drain flow of the magnitude calculated by Scenario 2 is therefore assessed as being low.

6.11 Effects on other groundwater and surface water users

Pumping groundwater from the Applicant's bores may have an adverse effect on hydraulically connected neighbouring bores. The abstraction of groundwater creates a drawdown cone that extends laterally from the pumping bore and may result in a lowering of groundwater levels in neighbouring bores. Such lowering may adversely affect existing users by preventing them from taking their authorised volume or abstraction rate, and may also result in increased costs for such users through having to lower their pump, change from a surface to submersible pump or by using more electricity to abstract water.

WWLA statement on drawdown analysis approach is paraphrased as follows;

*The simulated groundwater level for the end of 2010 irrigation season for Scenarios 2 and 3 were subtracted from the head simulated at the corresponding time from the Base Case Model in the case of Scenario 2, and a revised version of the Base Case Model with low permeability in Layer 2 for Scenario 3, to produce regional drawdown maps (*Error! Reference source not found. *and* Error! Reference source not found.*). The resulting drawdown predictions are used to evaluate the magnitude and extent of potential impacts resulting from the proposed pumping on both the shallow and deep aquifers for both scenario conditions.*

Further reasoning on simulation choice is contained in their application assessment report attached as Appendix E.

The nature of this proposal includes a quantum of drawdown which forms part of the existing environment. Given the movement of production bores to new locations, WWLA have illustrated groundwater contours as both negative and positive drawdown values. The positive contour values can be disregarded from the assessment as they merely illustrate that there would be no negative displacement of water level at bore locations currently specified as abstraction points on the Water Permit. These contours do not override cumulative negative drawdown predictions which are also illustrated in Figures 10 and 11 of the WWLA report attached as Appendix E.

The WWLA report attached as Appendix E specifies the drawdown calculated for wells with existing known bores (i.e., from Council records) in the model domain assuming additional pumping at the proposed rates and volumes.

The Scenario 2 assessment indicates that drawdown of less than 0.6m would not likely occur in bores outside of the Sweetwater Farms properties as depicted in Figure 11 below. The exceptions were an area extending 150 m west from the proposed Sweetwater-10 groundwater take, an area extending 70 m west from the Sweetwater-11 groundwater take, and an area extending 125 m north from the proposed Sweetwater-14 groundwater take.

In Scenario 3, the 0.6 m drawdown contour extended into most of the area west of Sweetwater Station up to the coast with the mid-southern extent of the area of drawdown extending over other landholdings and potentially affecting existing bores registered on these landholdings.

Figure 11: Simulated drawdown of deep aquifer (Scenario 2 (Source: Appendix E attached)).

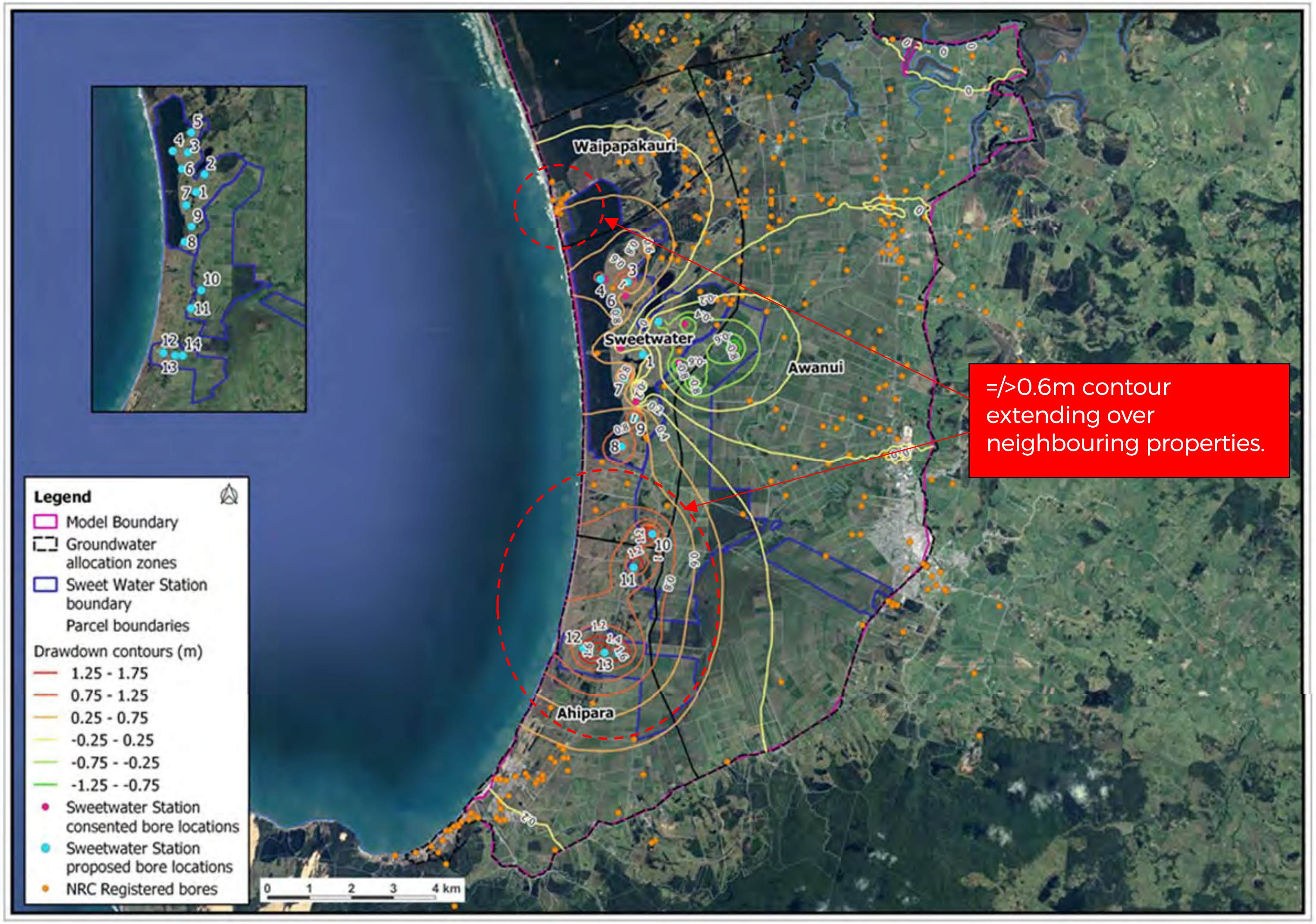


Figure 12: Simulated drawdown of deep aquifer (Scenario 3) [Source: Appendix E attached].

This magnitude of drawdown is assessed as minor given the available drawdown in bores screened and properly constructed in the shellbed layer. Furthermore, the information on recorded bores in the area suggests that most if not all bores are screened within the shellbed layer.

From available aquifer pump testing, the Shellbed aquifer exhibits moderate permeability and has a limited saturated thickness as such vertical leakage from the overlying sand aquifer provides a large storage volume which acts as an offset to drawdown from pumping.

Overall, based on the modelling assessment provided, it is reasonable to conclude that the proposed abstraction is unlikely to adversely impact on the reliability of supply for existing groundwater users.

6.12 Effects on the natural character of the environment

As stated in the Far North District Plan, the majority of the land in the Far North is rural, where rural production is the main activity. In consequence, the character of the rural environment is linked to the rural production activities developed in the area and changes in response to economic imperatives, namely to the different types of productive activities that take place on the land.

The proposed water takes aims at converting pastoral farming and grazing land to mixed horticultural cropping. The resulting development of horticultural activities will not detract from the amenity values associated with the rural environment's attributes and character.

6.13 Effects on amenity, recreational and social values

The proposed water takes will support approximately 920ha of avocado orchard development and 112ha of irrigated pastoral and cropping land. It is considered that the scale of horticulture development proposed will positively impact the local economy and the social fabric of the Far North.

Ngāi Tokoto and Te Rarawa propose to take and use groundwater to support primary industry optimisation on Sweetwater Station. Land use optimisation of the Sweetwater Station properties is but one part of the many Iwi led solutions being generated in the Far North; supporting whānau to pursue opportunities in education and careers in the primary industries. Such opportunity drives overall improvement to living standards shared by hapū and whānau.

As noted above, the properties are zoned for rural production purposes, therefore, no adverse effects on neighbourhood amenity are anticipated through the use of the water.

Regarding effects on the recreational and amenity values of surface waterbodies through connection to the groundwater resource, these were assessed as being less than minor. Consequently, effects on such values are considered to be less than minor.

6.14 Effects on tangata whenua and their taonga

The concept of "Te mana o te wai" is embedded as an objective in the NPS on Freshwater Management, and also throughout the operative and regional plan objectives and policies. Cultural values associated with the mauri of water recognise the interconnected physical and metaphysical values of water in relation to environmental and human health and wellbeing. Rather than taking a strictly technical approach to allocation of water and assessment of potential environmental effects the interconnectedness of water to social, environmental and cultural wellbeing is to be acknowledged and considered in the allocation of water.

Ngāi Takoto and Te Rarawa are joint owners of the Sweetwater Farm complex through settlement of their claims for breaches of Te Tiriti o Waitangi. The Aupouri Aquifer is one of the significant water catchment areas in the rohe of both Te Rarawa and Ngāi Takoto, and other Te Hiku Iwi. It is recognised as a taonga but also as a catalyst for the future wellbeing of the people.

The proposal has been developed in consideration of the relationship of māna whenua with their taonga: the Aupouri Aquifer and the wider environment.

From the perspectives of the applicants, the effects of the take and use of groundwater as proposed on tangata whenua and their taonga are considered to be beneficial.

6.15 Cumulative effects assessment

As stated before, abstracting groundwater from the proposed bores may have an impact on the Aupouri Aquifer, which will occur if the volume of groundwater extracted over an entire season is significant compared to the volume of groundwater inputs into the aquifer over the same period.

The allocation limits set by the Proposed Regional Plan have been taken in consideration in the development of the proposal. As detailed in Section 6.7 above, sustainable allocation of freshwater will be met.

The potential cumulative effects of the proposal, in addition to causing a localised depression in groundwater levels, are the contribution towards saline intrusion in coastal aquifers like the Aupouri Aquifer, adverse effects on surface waterbodies and on other groundwater and surface water users. An assessment of these effects has been detailed in Sections 6.8, 6.10, 6.11 above.

Overall, the cumulative effects of the proposal are considered to be no more than minor.

7 Statutory Assessment

Schedule 4 of the Act requires that an assessment of activities against the matters set out in part 2 and any relevant provisions of a statutory document referred to in s104(1)(b) of the Act is provided when applying for a resource for any activity. These matters are discussed as follows.

7.1 Part 2 of the Act

The overriding purpose of the Act is "to promote the sustainable management of natural and physical resources" (Section 5). The broader principles (Sections 6 to 8) are to inform the achievement of that purpose.

Section 104 of the Act (considered above in Section 6) is expressly subject to Part 2 of the RMA (s104(1)). Case law findings have directed that decision makers should now only have recourse to Part 2 of the RMA, including higher order policy documents, if it is determined that:

1. If any part or the whole of the relevant plan(s) are invalid;
2. If the relevant plan(s) did not provide complete coverage of the Part 2 matters;
3. If there is uncertainty of the meaning of provisions as they affect Part 2.

In essence, what this means is that decisions makers only need to 'go back to' Part 2 of the Act if the relevant planning documents have not fully addressed the Part 2 matters. If a Regional or District Plan has not fully addressed the Part 2 matters, then decision makers can 'go up the tree' to the RPS and then any relevant NPS in relation to any Part 2 matters.

It is considered that the relevant regional and district plans give appropriate effect to the relevant higher order policy documents such that a separate Part 2 analysis is unlikely to add anything to the evaluative exercise. Based on the assessment of the proposal against the objectives and policies as set out in Section 7.2 below, the proposal is considered to be consistent with Part 2 of the Act.

7.2 Section 104(1)(b) of the RMA

Documents referred to in Section 104(1)(b) of the RMA are:

(a) A national environmental standard;
(b) Other regulations;
(c) A national policy statement;
(d) A regional policy statement or proposed regional policy statement
(e) A plan or proposed plan

The relevant provisions of these documents are given regard to in the following sections.

7.2.1 *National Environmental Standards*

There are no national environmental standards which are applicable to these proposed activities.

7.2.2 *Other Regulations*

The Applicant proposes to monitor the water abstraction from all bores in accordance with the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010. This requirement is reflected in the proposed conditions in Section 3.4 of this report.

7.2.3 *National Policy Statements*

The National Policy Statement for Freshwater Management 2014 (revised 2017) (NPSFM) recognises Te Māna o te Wai and sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits.

The following objectives and policies of the NPS are relevant to this proposal:

Te Māna o te Wai

Objective AA1 *To consider and recognise Te Mana o te Wai in the management of fresh water.*

Policy AA1 *By every regional council making or changing regional policy statements and plans to consider and recognise Te Mana o te Wai, noting that: a) te Mana o te Wai recognises the connection between water and the broader environment – Te Hauora o te Taiao (the health of the environment), Te Hauora o te Wai (the health of the waterbody) and Te Hauora o te Tangata (the health of the people); and b) values identified through engagement and discussion with the community, including tangata whenua, must inform the setting of freshwater objectives and limits*

Engagement and discussion with the community, including tangata whenua, is understood to have taken place by the Council as part of the setting of freshwater objectives and limits in the PRP. As the proposal seeks to remain within the allocation limits now specified through the PRP, the proposal is considered to be consistent with Te Māna o te Wai.

Water Quantity

Objective B1 *To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water, in sustainably managing the taking, using, damming, or diverting of fresh water.*

Objective B4 *To protect significant values of wetlands and of outstanding freshwater bodies.*

Policy B1 *By every regional council making or changing regional plans to the extent needed to ensure the plans establish freshwater objectives in accordance with Policies CA1-CA4 and set environmental flows and/or levels for all freshwater management units in its region (except ponds and naturally ephemeral water bodies) to give effect to the objectives in this national policy statement, having regard to at least the following: a) the reasonably foreseeable impacts of climate change; b) the connection between water bodies; and c) the connections between freshwater bodies and coastal water.*

Policy B5 *By every regional council ensuring that no decision will likely result in future over-allocation – including managing fresh water so that the aggregate of all amounts of fresh water in a freshwater management unit that are authorised to be taken, used, dammed or diverted does not over-allocate the water in the freshwater management unit.*

The proposal seeks to take water within allocation levels set in the PRP. Monitoring and contingency measures using an adaptive management regime may be necessary as an added safeguard to sustaining the life-supporting capacity of the freshwater resource.

Objective B3 *To improve and maximise the efficient allocation and efficient use of water.*

Policy B3 *By every regional council making or changing regional plans to the extent needed to ensure the plans state criteria by which applications for approval of transfers of water take permits are to be decided, including to improve and maximise the efficient allocation of water.*

Policy B4 *By every regional council identifying methods in regional plans to encourage the efficient use of water.*

The proposal includes an analysis of reasonable and efficient use of water for irrigation purposes using available field information, climate factors, rainfall variability and crop water requirement.

An exact specification of reasonable water requirement was not able to be determined as final crop selection has not been made and furthermore, crop rotation would need to be factored into the calculation. It is proposed that an ISP is submitted which sets out how irrigation will be undertaken to ensure that at least 80% of the authorised annual volume is retained in the soil root zone of the crop.

Objective B5 To enable communities to provide for their economic well-being, including productive economic opportunities, in sustainably managing fresh water quantity, within limits.

Policy B8 By every regional council considering, when giving effect to this national policy statement, how to enable communities to provide for their economic well-being, including productive economic opportunities, while managing within limits.

The grant of resource consent to the applicants will achieve Objective B5 and B8 of the NPS-FM as the gain from the water abstraction goes back to the people of Te Rarawa and NgaiTakoto. The government has recognised through its Essential Freshwater Work Programme that the current way water resources are allocated in scarce catchments (both water takes and rights to discharge to water) has led to limited economic opportunities, inefficiencies and the exclusion of some groups, in particular Māori, from accessing the resource to develop underdeveloped land.

Integrated Management

Objective C1 To improve integrated management of fresh water and the use and development of land in whole catchments, including the interactions between fresh water, land, associated ecosystems and the coastal environment.

Policy C1 By every regional council: a) recognising the interactions, ki uta ki tai (from the mountains to the sea) between fresh water, land, associated ecosystems and the coastal environment; and b) managing fresh water and land use and development in catchments in an integrated and sustainable way to avoid, remedy or mitigate adverse effects, including cumulative effects.

Policy C2 By every regional council making or changing regional policy statements to the extent needed to provide for the integrated management of the effects of the use and development of: a) land on fresh water, including encouraging the co-ordination and sequencing of regional and/or urban growth, land use and development and the provision of infrastructure; and b) land and fresh water on coastal water.

The technical analysis prepared by WWLA has considered the interaction of the groundwater resource on surface water. The RPS directs District Council's to consider the effects of the use and development of land on freshwater through District Plan performance standards.

Water Quality

The potential effects of the proposal on water quality are related to the possibility of saline intrusion as a result of the proposed abstraction. Sections 6.8 of this report address this issue, and confirms compliance of the proposal with the objectives and policies of the NPSFM in relation to water quality.

The proposal is overall considered to be consistent with the NPSFM.

7.2.4 *Regional Policy Statement*

The following Objectives are considered relevant to this proposal:

- *Objective 3.2* seeks to maintain and improve water quality for human use and ecological health.

- *Objective 3.3* seeks to safeguard the flows and flow variability required to maintain water's life-supporting capacity, for ecological processes, and to support indigenous species.
- *Objective 3.5* requires that the region's resources are sustainable managed in a way that is attractive for business and investment that will improve the economic wellbeing of the region and its communities.
- *Objective 3.10* requires efficient use and allocation of common natural resources with a particular focus on maximising the security and reliability of supple for users.

The following Policies give effect to the above Objectives, and therefore are considered relevant to this application:

- *Policy 4.2.1* seeks to establish freshwater objectives, reduce contaminant loads to water and promote active management, enhancement and creation of riparian margins and wetlands.
- *Policy 4.3.2* requires regulatory methods to avoid over-allocation of region-wide ecological flows and water levels.
- *Policy 4.3.3* requires the allocation and use of water efficiently within allocation limits.

The proposal has been assessed to be consistent with the objectives and policies of the RPSN because,

- The proposal will at least maintain the water quality of the Aupouri Aquifer;
- Flows and flow variability will be safeguarded as connectivity with surface waterbodies is determined to be very low;
- The proposed groundwater take is requested to satisfy the demand for water for the proposed horticultural development. The grant of resource consent to take and use groundwater would provide secure and reliable water supply that would enable the applicant to develop their land;
- The proposed groundwater take will not exceed the allocation limits for the freshwater unit;
- The use of water will be via efficient methods.
- The quantity of water sought is considered to be an efficient volume of water for the land use proposed. An ISP is proposed to manage the eventual decisions on crop and crop rotations during the proposed term of consent.

7.2.5 *Regional Plan*

7.2.5.1 RWSPN Objectives and Policies

The following objectives and policies of the RWSPN are considered relevant to this proposal:

- *Objective 6.3.1 The management of the natural and physical resources within the Northland region in a manner that recognises and provides for the traditional and cultural relationships of tangata whenua with the land and water.*
- *Policy 6.4.1 To recognise and, as far as practicable provide for the relationship of Māori and their culture and traditions with respect to the use, development and protection of natural and physical resources in the Northland region.*
- *Objective 7.4 Requires the maintenance or enhancement of water quality of natural water bodies in the Northland region.*
- *Objective 10.4.1 The sustainable use and development of the region's groundwater resources while avoiding, remedying, or mitigating actual and potential adverse effects on groundwater quantity and quality.*
- *Policy 10.5.1 To ensure the sustainable use of resources by avoiding takes that exceed recharge which result in any of the following:*

  a) *Saltwater intrusion or reduced groundwater quality;*
  b) *A lowering of the groundwater table below existing efficient bore takes;*
  c) *A lowering of the temperature of geothermal waters in geothermal aquifers and springs;*
  d) *Adverse effects on surface water resources.*
- *Policy 10.5.2 To recognise that aquifers 'at risk' to adverse effects may be in locations where:*
  a) *The overlying soils are suitable for water intense land uses; or*
  b) *There are limited surface water resources; or*
  c) *There are numerous springs; or*
  d) *One of the aquifer's boundaries is sea water; or*
  e) *On-site effluent disposal occurs over unconfined aquifers; or*
  f) *There is geothermal activity; or*
  g) *The aquifer's recharge area is compromised by inappropriate subdivision, use or development.*
- *Policy 10.5.4 When allocating groundwater resources, to take into account any reduction in time, as a result of land uses over groundwater recharge areas.*
- *Policy 10.5.7 Requires the Northland Regional Council to consider effects of a groundwater take and use on surface water bodies.*

The application is considered to align with the objectives and policies of the RWSPN because,

- The proposal seeks to sustainably use Northland's groundwater resource for the development of rural productive activities that are of significance to the area;
- As discussed in Section 6, the potential adverse effects of the proposal can be avoided, and the monitoring of the resource and proposed conditions of consent can mitigate any such effects;
- The proposed abstraction will not exceed the aquifer recharge rate and, as concluded by the modelling, saline intrusion is of little to no risk to the users of the freshwater management units;
- The existing limits to the water abstraction and the proposed amendments have been developed in consideration of the effects the proposal may have on other users;
- The proposal is consistent with the policies in that the take and use is not expected to have significant effects on surface water bodies in or around the farm complex.

7.2.5.2 Proposed Regional Plan for Northland

- *Objective F.1.1 Managing the taking, use, damming and diversion of fresh water so that:*
  1) *The life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water are safeguarded, and*
  2) *The significant values, including hydrological variation in outstanding freshwater bodies and natural wetlands are protected, and*
  3) *The extent of littoral zones in lakes are maintained, and*
  4) *Continually flowing rivers sufficient flows and flow variability to maintain habitat quality, including to flush rivers of deposited sediment and*

nuisance algae and macrophytes and support the natural movement of indigenous fish, and

5) *Flows and water levels support sustainable mahinga kai, recreational, amenity and other social and cultural values associated with freshwater bodies, and*
6) *Adverse effects associated with saline intrusion and land subsidence above are avoided, and*
7) *It is a reliable resource for consumptive and non-consumptive use.*

- *Objective F.1.4 Northland's natural physical resources are managed in a way that is attractive for business and investment that will improve the economic well-being of Northland and its communities.*
- *Policy D.2.2 Regard must be had to the social, cultural and economic benefits of a proposed activity, recognising significant benefits to local communities, Māori and the region including local employment and enhancing Māori development, particularly in areas of Northland where alternative opportunities are limited.*
- *Policy D.2.3 Particular regard must be had to the potential effects of climate change on a proposed development requiring consent under this Plan, taking into account the scale, type and design-life of the development proposed and with reference to the latest national guidance and best available climate change projections.*
- *Policy D.2.4 Regard should be had to the appropriateness of an adaptive management approach where:*
  1) *there is an inadequate baseline of information on the receiving environment, and*
  2) *the occurrence of potential adverse effects can be effectively monitored, and*
  3) *thresholds can be set to require mitigation action if more than minor adverse effects arise, and*
  4) *potential adverse effects can be remedied before they become irreversible.*
-
- *Policy D.4.11 Prepare and consider applications for resource consents to take groundwater so that surface and groundwater resources are managed in an integrated way.*
- *Policy D.4.14 An application for a resource consent to take or use water for community or public water supplies must include a water management plan to demonstrate water use efficiency and must set out the current and likely future demand for water that addresses:*
  1) *The number and nature of the properties that are to be supplied, and*
  2) *How the water supplier will manage water availability during summer flow periods and drought event, and*
  3) *The effectiveness and efficiency of the distribution network.*

As stated above, the proposed take and use of groundwater from the Aupouri Aquifer is intended to be carried out in a sustainable way in consideration of the natural recharge rate of the aquifer and other users of the resource. The proposal will allow the development of Sweetwater Farms, an entity owned by representatives of the local rohe, who will benefit socially and economically from the intended horticultural development.

7.3 Section 104(1)(c) of the RMA

In achieving the purposes of the Act, the matters summarised in the Iwi Management Plan for Ngāi Takoto have been considered relevant and reasonably necessary to the application.

7.3.1 *Ngāi Takoto Environmental Management Plan*

Wai – Water

- *Objective 1* That the concept of kaitiakitanga as defined by Ngāi Takoto is applied to the management of natural and physical resources.
- *Objective 5 Water abstraction is sustainably managed.*
- *Objective 6 The impact of intensive farming is better controlled.*
- *Policy 1* The Ngāi Takoto identify in conjunction with Council's water management areas that are most affected by nutrient enrichment and/or bacterial contamination and water extraction and promote innovative, sustainable management practices concerning water in these areas.

Allocation

- *Objective 1* Water allocation is managed in a sustainable manner.
- *Objective 2* Active involvement and participation of Ngāi Takoto in the water allocation process.
- *Policy 1* That Ngāi Takoto develop a framework with the relevant Council's where co-management principles of particular awa catchments can be developed and acknowledge in the Fresh Water Plan – Regional Policy Statement.
- *Policy 2* That those activities that impact significantly on water are monitored by relevant agencies and Ngāi takoto participate in the monitoring feedback process to and policy development cycle (improvements and additions to the Fresh Water Plan)

The proposed daily and yearly volumes of water abstraction have been estimated in consideration of the recharge rates of the aquifer and other users. The proposed use of the water take will be managed efficiently in accordance with an ISP. As such, the proposal is considered to align with the concept of kaitiakitanga as guardianship, protection and preservation of the resource.

7.4 Section 1042A of the RMA

When considering an application affected by Section 124, the consent authority must have regard to the value of the investment of the existing consent holder.

Over the past three years, Sweetwater Farm has been developing irrigation infrastructure across its three dairy platforms. This has been in alignment with the development masterplan and so far, six pivots have been installed irrigating close to 380ha split almost evenly across the three dairy units. Ultimately, the current masterplan indicates there will be almost 600ha irrigated with nine centre pivot irrigators.

Consents to take water from both surface and ground water were obtained in May 2011 with consent terms of 20 years and 10 years granted respectively. A significant amount of time and money were invested into gaining these consents by Landcorp Farming including an extensive drilling programme and hearings process. Several variations to this consent have subsequently been sought and approved, due to issues and challenges caused by the initial consent conditions.

The applicant has reviewed the suitability of the Station for other productive land use activity and has commissioned experts to assess land use suitability for varying horticultural activity.

Overall, the value of the investment that has been made with respect to the ability to take and use groundwater is substantial.

7.5 Consent Term, Lapse and Review

7.5.1 *Consent Term and Lapse Dates*

A consent term of 25 years is sought, subject to a lapse of 5 years from commencement of consent.

Policy D.2.12 of the PRP states that when determining the expiry date for a resource consent, particular regard will be had to:

> 1) *security of tenure for investment (the larger the investment, then generally the longer the consent duration), and*
>
> 2) *the administrative benefits of aligning the expiry date with other resource consents for the same activity in the surrounding area or catchment, and*
>
> 3) *certainty of effects (the less certain the effects, the shorter the consent duration), and*
>
> 4) *whether the activity is associated with regionally significant infrastructure (generally longer consent durations for regionally significant infrastructure), and*
>
> 5) *the following additional matters where the resource consent application is to re-consent an activity:*
>
> > a) *the applicant's past compliance with the conditions of any previous resource consent or relevant industry guidelines or codes of practice (significant previous non-compliance should generally result in a shorter duration), and*
> >
> > b) *the applicant's voluntary adoption of good management practice (the adoption of good management practices that minimise adverse environmental effects could result in a longer consent duration).*

A term of 25 years has been sought to align with consent durations of other Water Permits within the Aupouri Peninsula. The applicant has made significant investment into land development opportunity within the Sweetwater Station complex including numerous studies into crop selection, water requirements and most recently into the groundwater model to enable assessment of effects of the proposed abstraction and use.

There are inherent uncertainties in using a model to determine magnitude of environmental effects. However, adaptive management is able to be applied in this instance.

Past compliance with the prior consent has been good, with only minor issues with administrative activity, such as notifying Council of bore drilling.

The applicant adopts voluntary good management practice in the form of an ISP and also participation in adaptive management of the resource through monitoring, management and contingency planning.

7.5.2 *Consent Review*

Review conditions have been proposed for the purposes laid out in Section 3.4 of this report.

8 Conclusion

Te Rarawa Farming Limited and Te Make Farms Limited are the commercial arms of Te Aupouri and Te Rarawa, that now own and operate Sweetwater Station. An opportunity exists at Sweetwater Station to diversify some of the areas of higher value uses through using water for irrigation to support agricultural and horticultural development on the landholding. In order to do so, the applicants seek to replace water permit AUT.020995.01.03 currently held by Landcorp Farming Limited and Te Rūnanga o Te Rarawa, with a new permit with an increase to the quantities of take.

A description of the proposed groundwater take through the construction of 12 new bores is summarised in Section 3 of this report. A numerical groundwater model for the Aupouri Aquifer was developed by Williamson Water & Land Advisory (Project No. WWLA 0091 – Dated March 2019) for evaluating the sustainability of the proposed groundwater abstraction; as well as for the assessment of the potential effects of the proposed groundwater extraction with regard to:

- Surface water effects
- Drawdown in the shallow and deep aquifer
- Pumping interference on neighbouring bores
- Saline intrusion
- Ground settlement

The proposed rates of take would be managed to ensure that drawdown effects on other groundwater users and on the wider environment are no more than minor. A monitoring and irrigation plan would be used to ensure reasonable and efficient use of the resource while promoting productivity.

The AEE has demonstrated that the potential adverse effects of the proposed water take and use on the environment will be no more than minor as well as the effects on persons. Further, the overall effects of this proposal on the wider community are considered to be beneficial by creating employment opportunities and contributing to economic benefits to both the community and the mana whenua.

The proposal is also considered to be consistent with the relevant objectives and policies of the NPS, the RPS, the RWSPN, the PRPN, Ngāi Takoto Environmental Management Plan and Part 2 of the Act.

Under Section 104B of the RMA it is considered that there is no impediment to granting the application on a non-notified basis.

9 References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). *Crop evapotranspiration - Guidelines for computing crop water requirements - FAO irrigation and drainage paper 56*. Rome: Food and Agricultural Organization of the United States.

Chappell, P. (2013). *The Climate and Weather of Northland (3rd ed).* NIWA Science and Technology Series 59. Retrieved from NIWA website.

Hicks, D., Campbell, D. J., & Atkinson, I. (2001). *Options for managing the Kaimaumau wetland, Northland, New Zealand.* Wellington: Department of Conservation.

Wilson, S., & Shokri, A. (2015). *Aupouri Aquifer Review - Report 1056-1-R1*. Christchurch: Lincoln Agritech Limited.

WSP Opus. (2018). *Sweetwater Productive Water Optimisation Study.* Whangarei.

Appendix A
Application Form for Resource Consent

Part A

Appendix A Application Form

Appendix A

APPLICATION FORM FOR RESOURCE CONSENT

Northland REGIONAL COUNCIL

Whangārei Office	Phone:	09 470 1200
	Fax:	09 470 1202
Kaitāia Office	Phone:	09 408 6600
Waipapa Office	Phone	09 470 1200
Ōpua Office	Phone:	09 402 7516
Dargaville Office	Phone:	09 439 3300
Free Phone		0800 002 004
E-mail		mailroom@nrc.govt.nz
Website		www.nrc.govt.nz

This application is made under section 88/127 of the Resource Management Act 1991

To: Consents Department
Northland Regional Council
Private Bag 9021
Whangārei Mail Centre
Whangārei 0148

IMPORTANT NOTES TO APPLICANTS

(a) Please read fully the notes below and the Information Brochures and Explanatory Notes available from the council, before preparing your application and any supporting information.

(b) The Resource Management Act 1991 sets out the information you must provide with your application for a resource consent. If you do not provide adequate information, your application cannot be received nor processed by the council and will be returned to you. If you are unsure of what information should be included with your application, please contact the council before submitting the application.

(c) Applications require notification (public advertising calling for submissions) unless the council is satisfied that the adverse effects on the environment of the activity for which consent is sought will be minor; and written approval has been obtained from every person who the council is satisfied may be adversely affected by the granting of the consent. The council also has available a form "Form 8A – Affected Person's Written Approval", to help you record such approvals for applications that may be processed without public notification.

PART A – GENERAL

APPLICANT	Full Names
(1) Full Name of Applicant(s): (in full e.g. Albert William Jones and Mary Anne Jones. For Companies, Trusts and other Organisations, commonly used name)	Te Rarawa Farming Limited & Te Make Farms Limited
Phone Number – Business:	094303345 (Consultant) Fax:
Home:	Mobile: 0275587126 (Consultant)
E-mail:	admin@ngaitakotoiwi.co.nz; admin@terarawa.co.nz

For applications by a company, private trusts or other entity/organisations, the Directors; Trustees and Officers' full names *must be supplied and Section (12) completed and signed.*

(2) Postal Address: (in full)	16 Mathews Avenue
	Kaitaia 0410

(3) Residential Address: (if different from postal address)	

Application Form continued on next page

(4) Address for Service of Documents: (if different from postal address e.g. Consultant)	WSP Opus, PO Box 553, Whangarei 0140
	ATTENTION: Martell Letica
	Martell.Letica@wsp-opus.co.nz

(5) Owner/Occupier of Land/ Water Body: (if different from the Applicant)	

(6) Type(s) of Resource Consent sought from the Regional Council:

You will need to fill in a separate Assessment of Environmental Effects Form for each activity.
These forms can be obtained from the Northland Regional Council.

Coastal Permit

- ☐ Mooring
- ☐ Marine Farm
- ☐ Structure
- ☐ Pipeline/Cable
- ☐ Other (specify) __________

Land Use Consent

- ☐ Vegetation Clearance
- ☐ Quarry
- ☐ Structure in/over Watercourse
- ☐ Earthworks
- ☐ Construct/Alter a Bore
- ☐ Dam Structure
- ☐ Other (specify) __________

Water Permit

- ☐ Stream/Surface Take
- ☐ Damming
- ☒ Groundwater Take
- ☐ Diverting Water
- ☐ Other (specify) __________

Discharge Permit

- ☐ Domestic Effluent to Land
- ☐ General Discharge to Land
- ☐ Farm Dairy Effluent to Land/Water
- ☐ Air
- ☐ Water
- ☐ Other (specify) __________

(7) Other Resource Consents required from the District Council:

Where other resource consents are required for the same activity, they must be applied for at the same time.
Not doing so will delay the processing of this application.

What other Resource Consents are required from the District Council?

☐ None ☒ Land Use Consent ☐ Subdivision Consent

Have the applications been made? ☒ Yes ☐ No

(8) Description of the Activity:

Please briefly describe the activities and duration for which consent(s) are being sought. It is important you fill this out correctly, as the council cannot grant consent for any activity you do not apply for.

Take and use groundwater - see full description of the activity contained in the AEE report.

Application Form continued on next page

(9) Location of Property/Waterbody to which Application relates:

Describe the location in a manner which will allow it to be readily identified, e.g. street address, legal description, harbour, bay, map reference etc. Attach appropriate plans and/or diagrams.

Property Address: 284 Sandhills Road, RD 3, Kaitaia Locality: Sweetwater Station
(see rate demand)

Legal Description: Multiple - see AEE Blk: ______ SD: ______

Other Location Information: see AEE

PART B – ASSESSMENT OF EFFECTS ON THE ENVIRONMENT

You must include an assessment of the effects of your activity on the environment as part of your application.

The Resource Management Act 1991 requires that each application include an assessment of the actual and potential effects of the activity on the environment in accordance with the Fourth Schedule.

To assist you to supply this assessment of effects, the council has prepared specific forms for various consent activities. For minor activities, all that will be required is for you to complete the specific form. Where the potential effects of the activity are more significant, we recommend you undertake a full assessment of effects, with professional assistance if necessary.

If you are unsure of what information to include with you application and the assessment of effects, please contact the council before submitting your application. A pre-lodgement meeting with relevant consent staff is recommended.

PART C – GENERAL

(10) Renewal of an Existing Resource Consent:

☒ Yes ☐ No ☐ A change in conditions of a current Resource Consent

(11) Fee/Deposit Enclosed with Application(s):

Application to be processed as: ☐ Notified ☐ Limited Notified ☒ Non-notified

☐ Coastal Permit:	$ ______	☐ Land Use Consent:	$ ______
☒ Water Permit:	$ ______	☐ Discharge Permit:	$ ______
☐ Bore Permit:	$ ______	☐ Change Conditions:	$ ______

(12) Signature of Applicant(s) or Persons authorised to sign on behalf of Applicant(s):

IMPORTANT NOTES TO APPLICANTS

(a) Your application must be accompanied by the minimum fee (deposit) as determined by the council. A schedule of the minimum estimated initial fees for different consent applications is annexed. Please note that applications by private trusts and other group entities require the personal guarantees of the Trustees and/or Officers for the payment of costs to be submitted with the application.

- For complex applications, the council may require an additional deposit pursuant to section 36(3) of the Act, based on the estimated costs for processing such complex applications and may require progressive monthly payments during consent processing.
- The final fee is based on actual and reasonable costs including disbursements and where this fee exceeds the fee/deposit, the additional fee is subject to objection and appeal.

(b) All accounts are payable by the 20th of the month following the date of invoice. Any actual and reasonable costs, including but not limited to legal costs, debt collection fees or disbursements incurred as a result of any default in payment, shall be recoverable from the Applicant and is so notified in compliance with the Credit Contracts and Finance Act 2003. Submitting this application authorises the council to, if necessary, provide your personal information to a Credit Reporter in order to employ in its debt collection services in compliance with the Credit Reporting Privacy Code 2004, should payment default occur.

(c) Resource consents usually attract an annual fee to recover the reasonable costs of the council's monitoring, supervision and administration of the consent during its term.

(d) The information you provide is official information. It will be used to process the application and, together with other official information, assist the management of the region's natural and physical resources. Access to information held by the Northland Regional Council is administered in accordance with the Local Government Official Information and Meetings Act 1987 and the Privacy Act 1993.

Application Form continued on next page

I/we declare that, to the best of my/our knowledge and belief, the information given in this Application and attached Assessment of Environmental Effects is true and correct. I/we unconditionally guarantee jointly and severally to pay the actual and reasonable costs of processing this Application as and when charges become due and payable. I/we acknowledge that I/we understand the consequences of signing this declaration.

Signature: [signature]	Signature:
Full Name (print): Martell Letica	Full Name (print):
Date: 27/08/2019	Date:

Continue with Trustees' and Authorised Officers' signatures below, as necessary.

Personal details and signatures of Trustees*, or Officers authorised to sign on behalf of and to bind Trusts, Societies and Unincorporated Entities.

* Private and Family Trusts only

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

CHECKLIST – Have you remembered **to…**

- ☒ Complete all details set out in this Application Form
- ☒ Include an Assessment of Effects of the activity on the environment, set out in the attached form
- ☒ Sign and date the Application Form
- ☒ Include a Site Plan
- ☒ Include the appropriate fee as set out in the *"Schedule of Minimum Estimated Initial Fees"*
- ☒ Complete details of Trustees and/or Authorised Officers on this page

Appendix B
Certificate of Incorporation, Companies Database Extract

Appendix B Certificate of Incorporation, Companies Database Extract

Appendix B

NEW ZEALAND COMPANIES OFFICE | COMPANIES REGISTER

Certificate of Incorporation

TE RARAWA FARMING LIMITED

5787947

NZBN: 9429041950005

This is to certify that TE RARAWA FARMING LIMITED was incorporated under the Companies Act 1993 on the 2nd day of September 2015.

Registrar of Companies
13th day of April 2019

REGISTRAR OF COMPANIES NEW ZEALAND

Certificate generated 13 April 2019 10:10 AM NZST

NEW ZEALAND COMPANIES OFFICE | COMPANIES REGISTER

Certificate of Incorporation

TE MAKE FARMS LIMITED

5869607

NZBN: 9429042159032

This is to certify that TE MAKE FARMS LIMITED was incorporated under the Companies Act 1993 on the 3rd day of February 2016.

Registrar of Companies
13th day of April 2019

REGISTRAR OF COMPANIES NEW ZEALAND

Certificate generated 13 April 2019 10:12 AM NZST

NEW ZEALAND COMPANIES OFFICE | COMPANIES REGISTER

Company Extract

TE RARAWA FARMING LIMITED
5787947
NZBN: 9429041950005

Entity Type:	NZ Limited Company
Incorporated:	02 Sep 2015
Current Status:	Registered
Constitution Filed:	Yes
Annual Return Filing Month:	July

Ultimate holding company: No

Company Addresses

Registered Office
TE RUNANGA O TE RARAWA, 16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

Address for Service
TE RUNANGA O TE RARAWA, 16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

Directors

BROWN, Tracy Lee
371a Matai Road, Rd 2, Matamata, 3472, NZ

WALSH, John
47 Tangonge Road, Pukepoto, Kaitaia, 0481, NZ

WHITE, Paul Irven
18 Honey Street, Rawene, Kaikohe, 0473, NZ

Shareholdings

Total Number of Shares: 100

Extensive Shareholdings: No

100 2577801
TE WAKA PUPURI PUTEA TRUST
16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

For further details relating to this company, check http://app.companiesoffice.govt.nz/co/5787947
Extract generated 13 April 2019 10:12 AM NZST

Company Extract

TE MAKE FARMS LIMITED
5869607
NZBN: 9429042159032

Entity Type:	NZ Limited Company
Incorporated:	03 Feb 2016
Current Status:	Registered
Constitution Filed:	No
Annual Return Filing Month:	July
Ultimate holding company:	No

Company Addresses

Registered Office
Te Runanga o NgaiTakoto, 16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

Address for Service
Te Runanga o NgaiTakoto, 16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

Directors

HUDSON, Hetaraka Wesley
50 Coronation Road, Mangere Bridge, Auckland, 2022, NZ

WELLS, Craig John
13 Parkland Crescent, Kamo, Whangarei, 0112, NZ

Shareholdings

Total Number of Shares: 100

Extensive Shareholdings: No

100	5873407 PIOKE CORPORATE LIMITED Te Runanga o NgaiTakoto, 16 Matthews Avenue, Kaitaia, Kaitaia, 0410, NZ

Appendix C
Certificates of Title

Appendix C Certificates of Title

Appendix C

RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**NA94A/637**
Land Registration District	**North Auckland**
Date Issued	20 August 1993

Prior References
NA87A/185

Estate	Fee Simple
Area	207.3200 hectares more or less
Legal Description	Lot 6 Deposited Plan 156631

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 3 Petroleum Act 1937

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

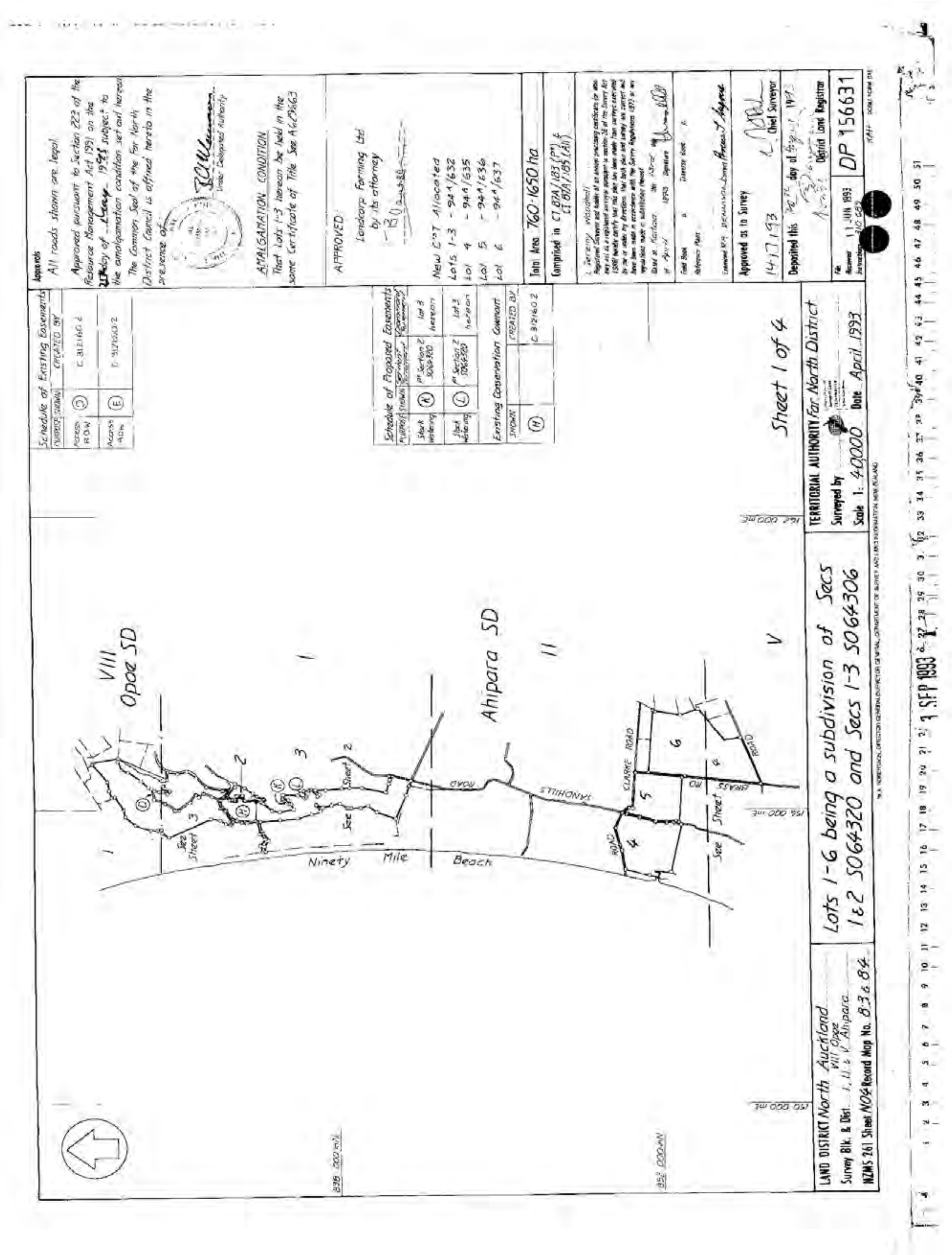
Subject to Sections 6 and 8 Mining Act 1971

Subject to Section 5 Coal Mines Act 1979

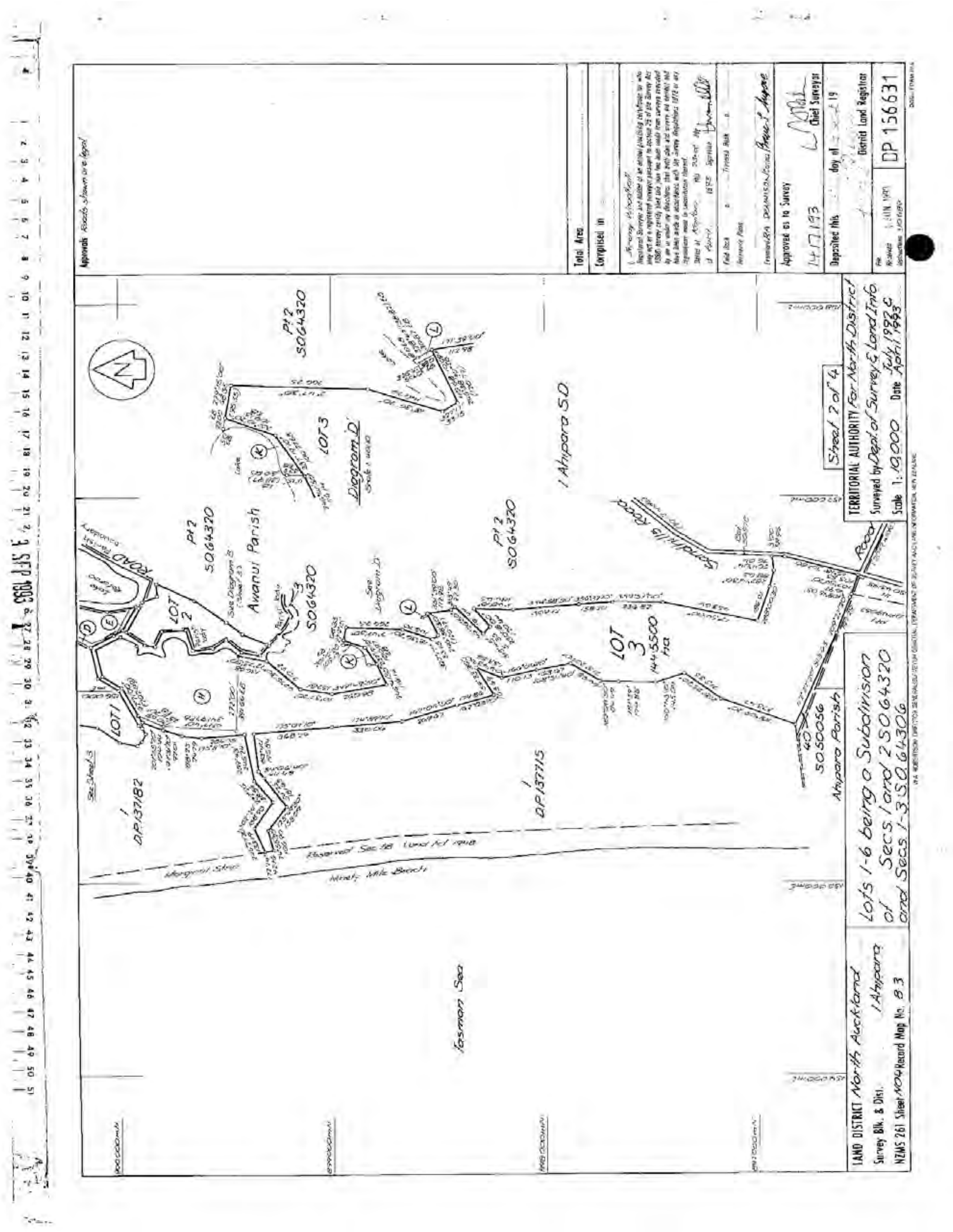
Subject to Section 261 Coal Mines Act 1979

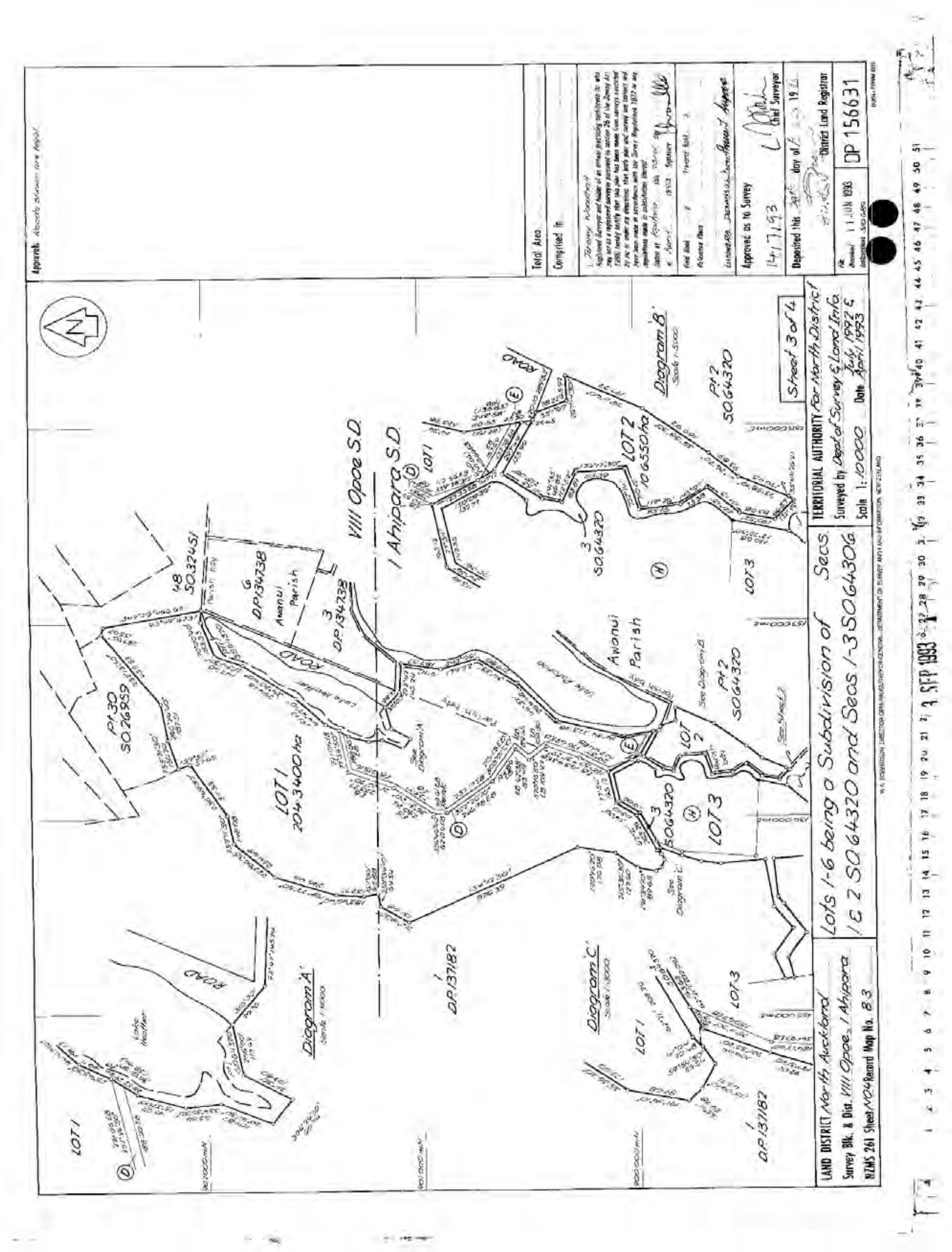
Subject to Part IV A Conservation Act 1987 (but sections 24(2A), 24A and 24AA of that Act do not apply)

Subject to Section 11 Crown Minerals Act 1991

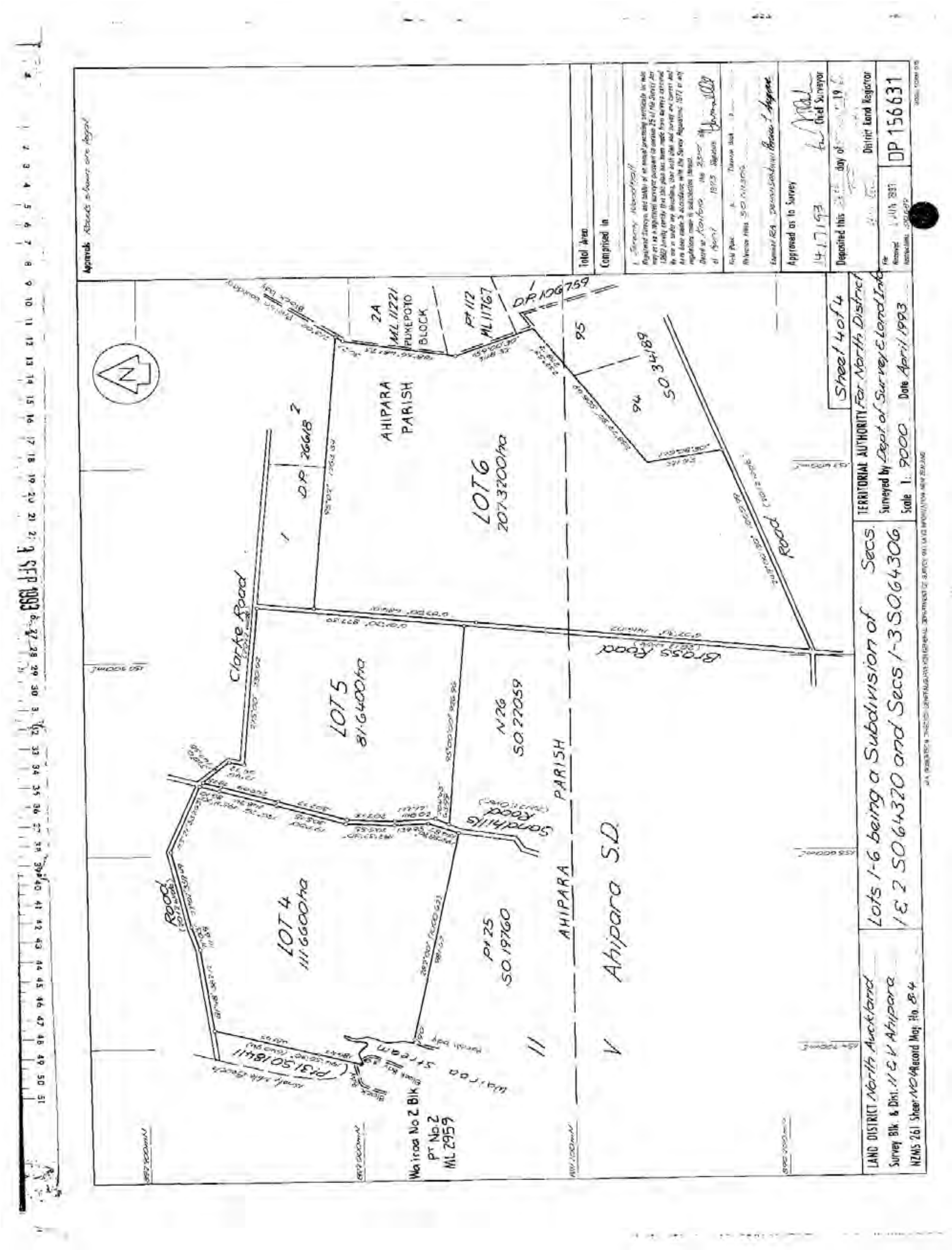

Lots 1-6 being a subdivision of Secs 1&2 SO64320 and Secs 1-3 SO64306
Sheet 1 of 4
TERRITORIAL AUTHORITY Far North District
Scale 1: 40000 Date April 1993
LAND DISTRICT North Auckland
DP 156631
Total Area 760·1650 ha
New CT Allocated
Lots 1-3 - 94A/632
Lot 4 - 94A/635
Lot 5 - 94A/636
Lot 6 - 94A/637
AMALGAMATION CONDITION
That Lots 1-3 hereon be held in the same Certificate of Title See A629663
All roads shown are legal
Schedule of Existing Easements
Schedule of Proposed Easements
Existing Conservation Covenant
Landcorp Farming Ltd by its attorney
VIII Opoe SD
Ahipara SD
Ninety Mile Beach
Clarke Road
Shipwreck Road
Approved as to Survey
Deposited this
District Land Registrar
Chief Surveyor
1 SEP 1993
11 JUN 1993

Identifier **NA94A/637**




DP 156631
Lots 1-6 being a Subdivision of Secs
1 E 2 SO 64320 and Secs 1-3 SO 64306
LAND DISTRICT North Auckland
TERRITORIAL AUTHORITY Far North District
Sheet 3 of 4
LOT 1
204.3400 ha
LOT 2
10.6550 ha
LOT 3
Diagram 'A'
Diagram 'B'
Diagram 'C'
VIII Opoe S.D
I Ahipara S.D
Awanui Parish
ROAD
Scale 1:10000

Identifier **NA94A/637**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**NA94A/636**
Land Registration District	**North Auckland**
Date Issued	20 August 1993

Prior References
NA87A/185

Estate	Fee Simple
Area	81.6400 hectares more or less
Legal Description	Lot 5 Deposited Plan 156631

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 3 Petroleum Act 1937

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

Subject to Sections 6 and 8 Mining Act 1971

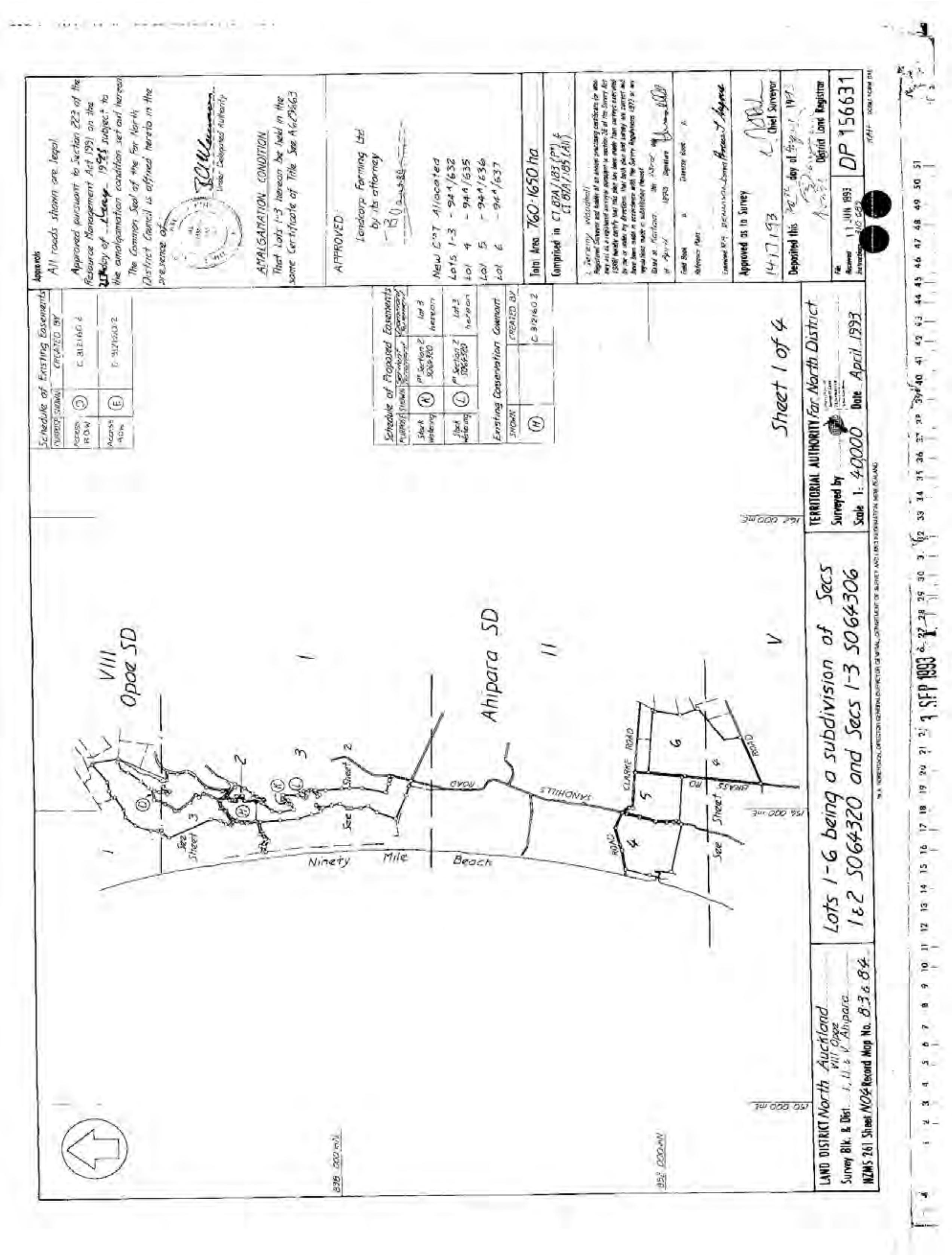
Subject to Section 5 Coal Mines Act 1979

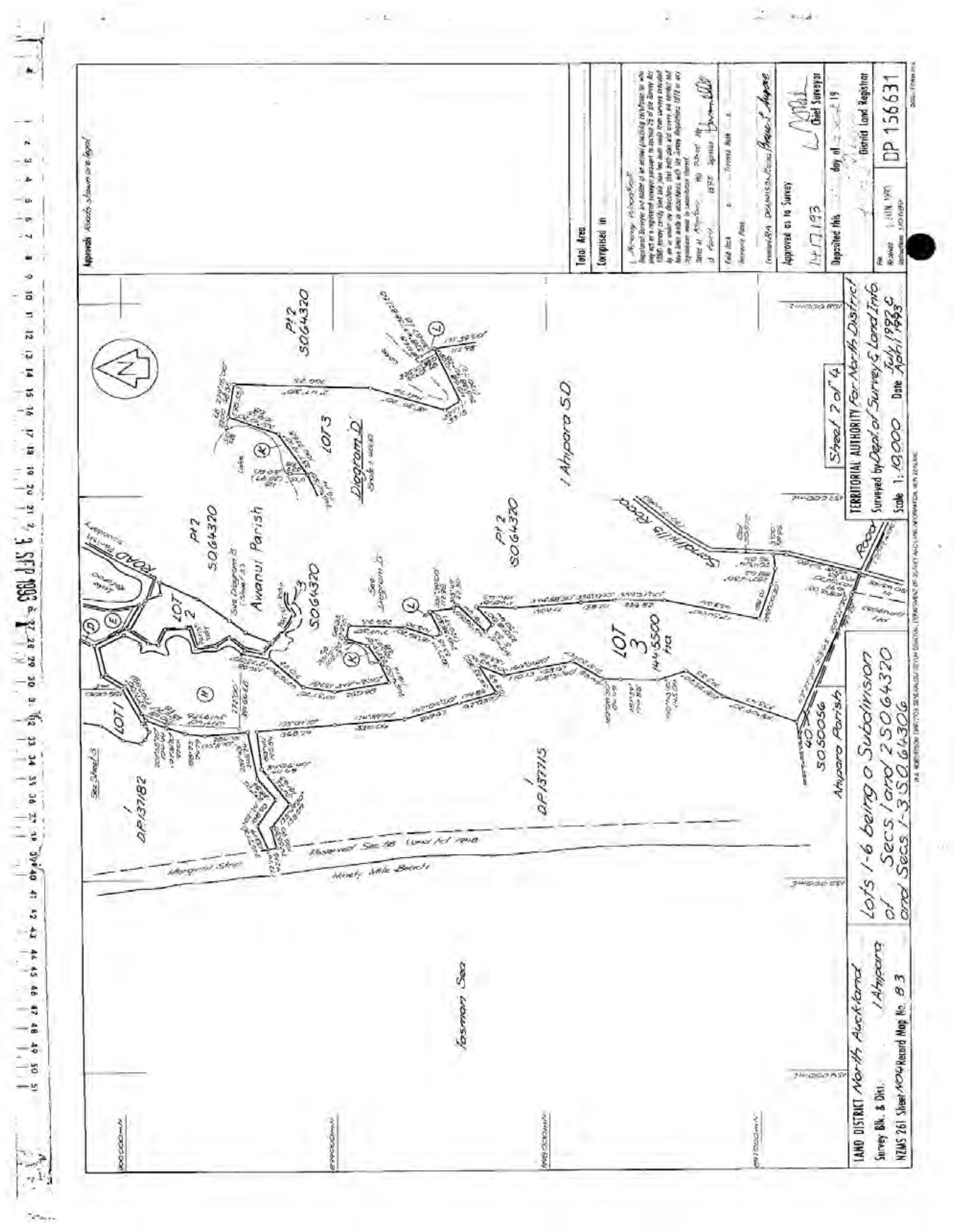
Subject to Section 261 Coal Mines Act 1979

Subject to Part IV A Conservation Act 1987 (but sections 24(2A), 24A and 24AA of that Act do not apply)

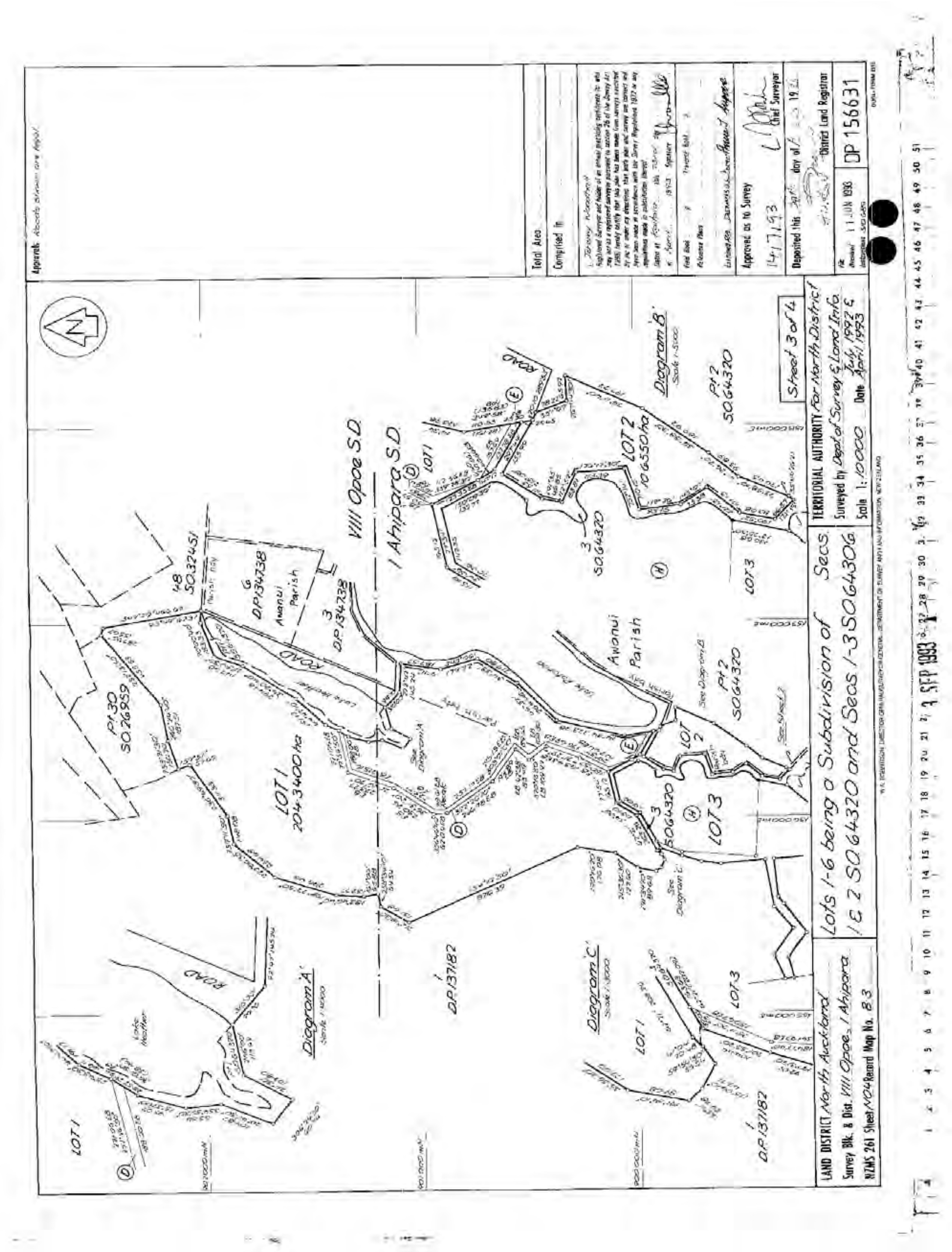
7867103.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 4.7.2008 at 9:00 am.

Subject to Section 11 Crown Minerals Act 1991

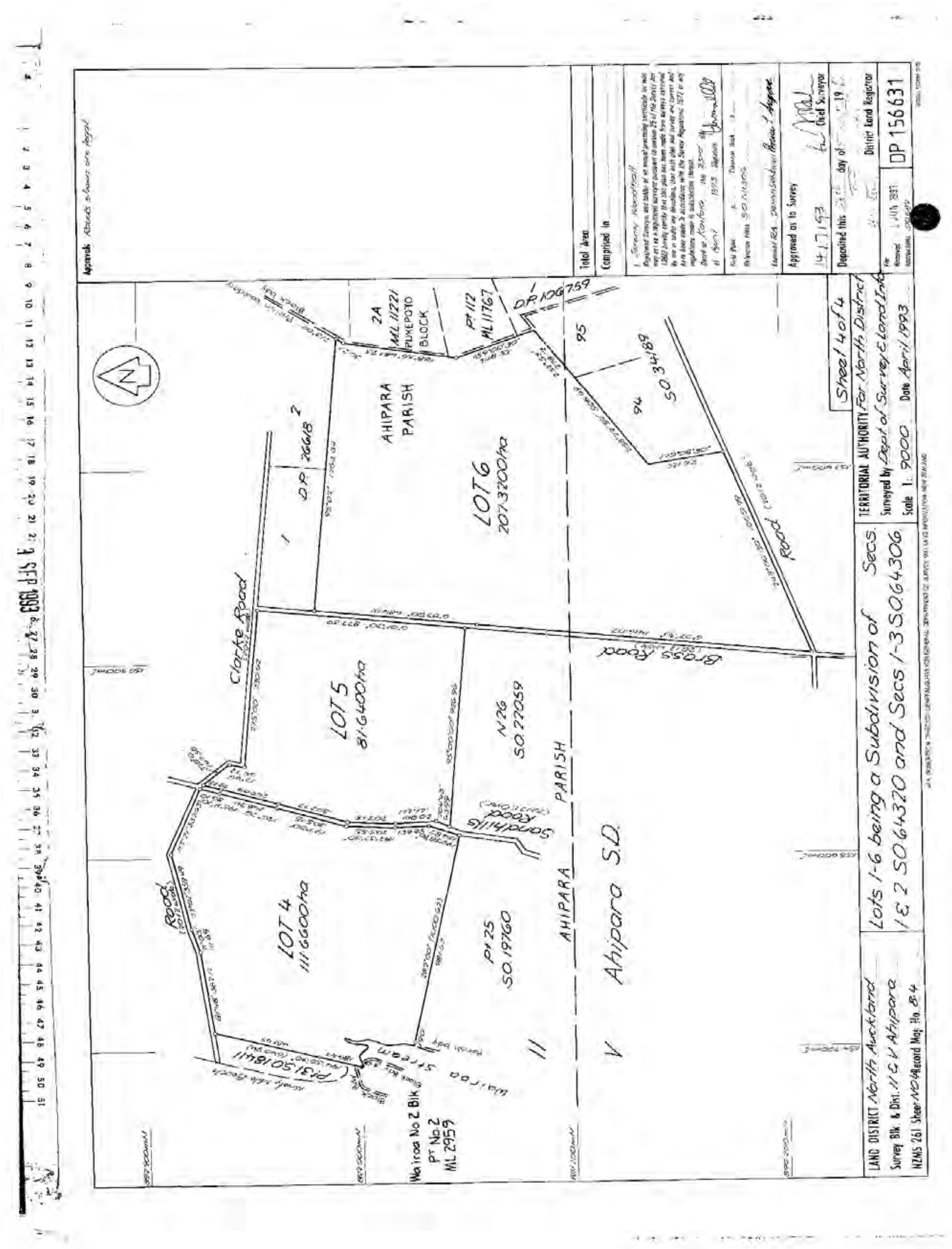

Lots 1-6 being a subdivision of Secs 1&2 SO64320 and Secs 1-3 SO64306
Sheet 1 of 4
DP 156631
LAND DISTRICT North Auckland
TERRITORIAL AUTHORITY Far North District
Scale 1: 40000 Date April 1993
Ahipara SD
VIII Opoe SD
Ninety Mile Beach
Total Area 760·1650 ha
AMALGAMATION CONDITION
That Lots 1-3 hereon be held in the same Certificate of Title See A629663
New C of T Allocated
Lots 1-3 - 94A/632
Lot 4 - 94A/635
Lot 5 - 94A/636
Lot 6 - 94A/637


Tasman Sea
Ninety Mile Beach
LOT 1
LOT 2
LOT 3
144.5500 ha
Awanui Parish
Ahipara Parish
1 Ahipara SD
Pt 2 SO 64320
1 DP 137182
1 DP 137715
Diagram D
Sandhills Road
Sheet 2 of 4
TERRITORIAL AUTHORITY Far North District
Scale 1:10,000
Lots 1-6 being a Subdivision of Secs 1 and 2 SO 64320 and Secs 1-3 SO 64306
LAND DISTRICT North Auckland
Total Area
Comprised in
Approved as to Survey
Chief Surveyor
Deposited this
District Land Registrar
DP 156631

Identifier **NA94A/636**



Identifier **NA94A/636**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier NA94A/635
Land Registration District North Auckland
Date Issued 20 August 1993

Prior References
NA87A/185

Estate	Fee Simple
Area	111.6600 hectares more or less
Legal Description	Lot 4 Deposited Plan 156631

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 3 Petroleum Act 1937

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

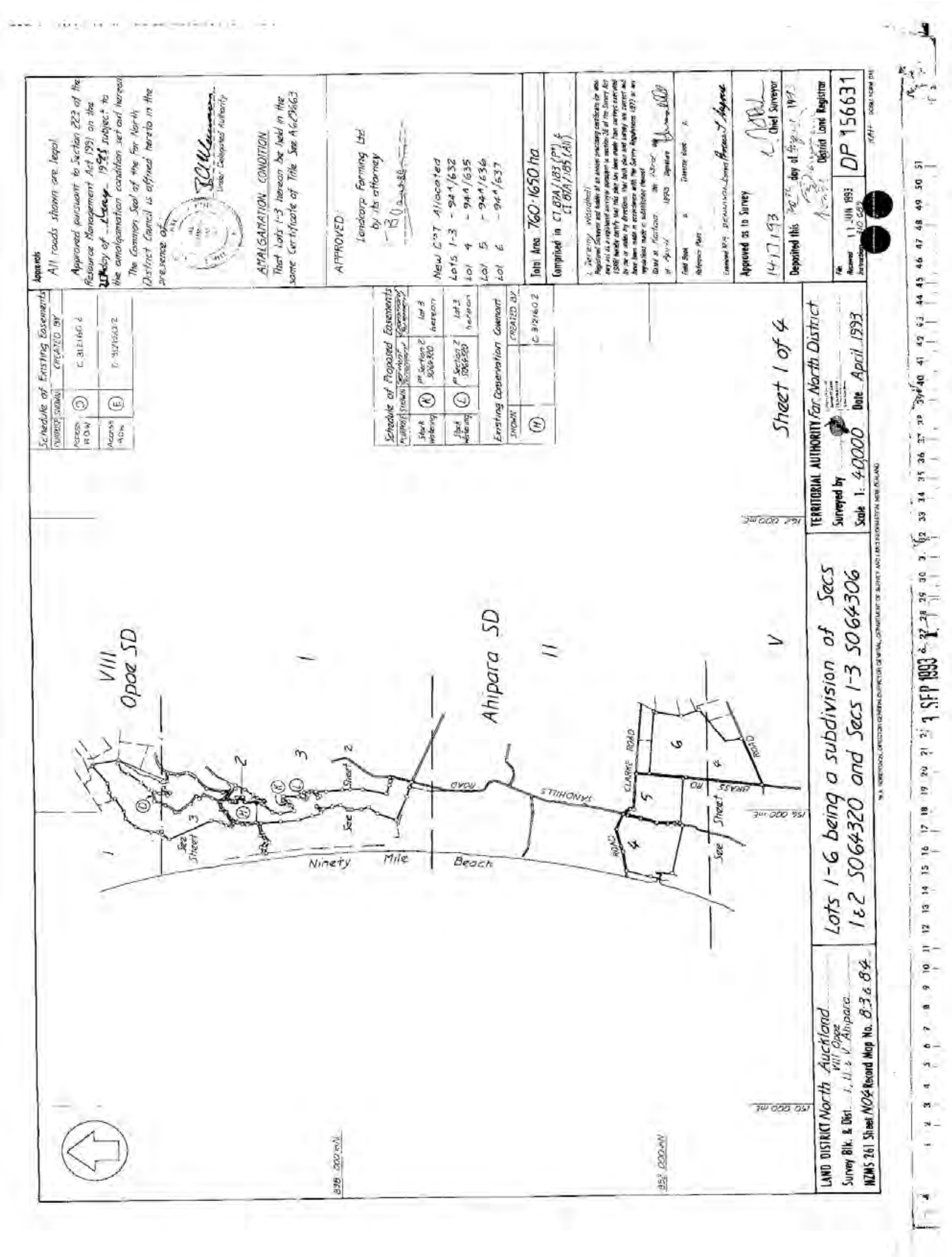
Subject to Sections 6 and 8 Mining Act 1971

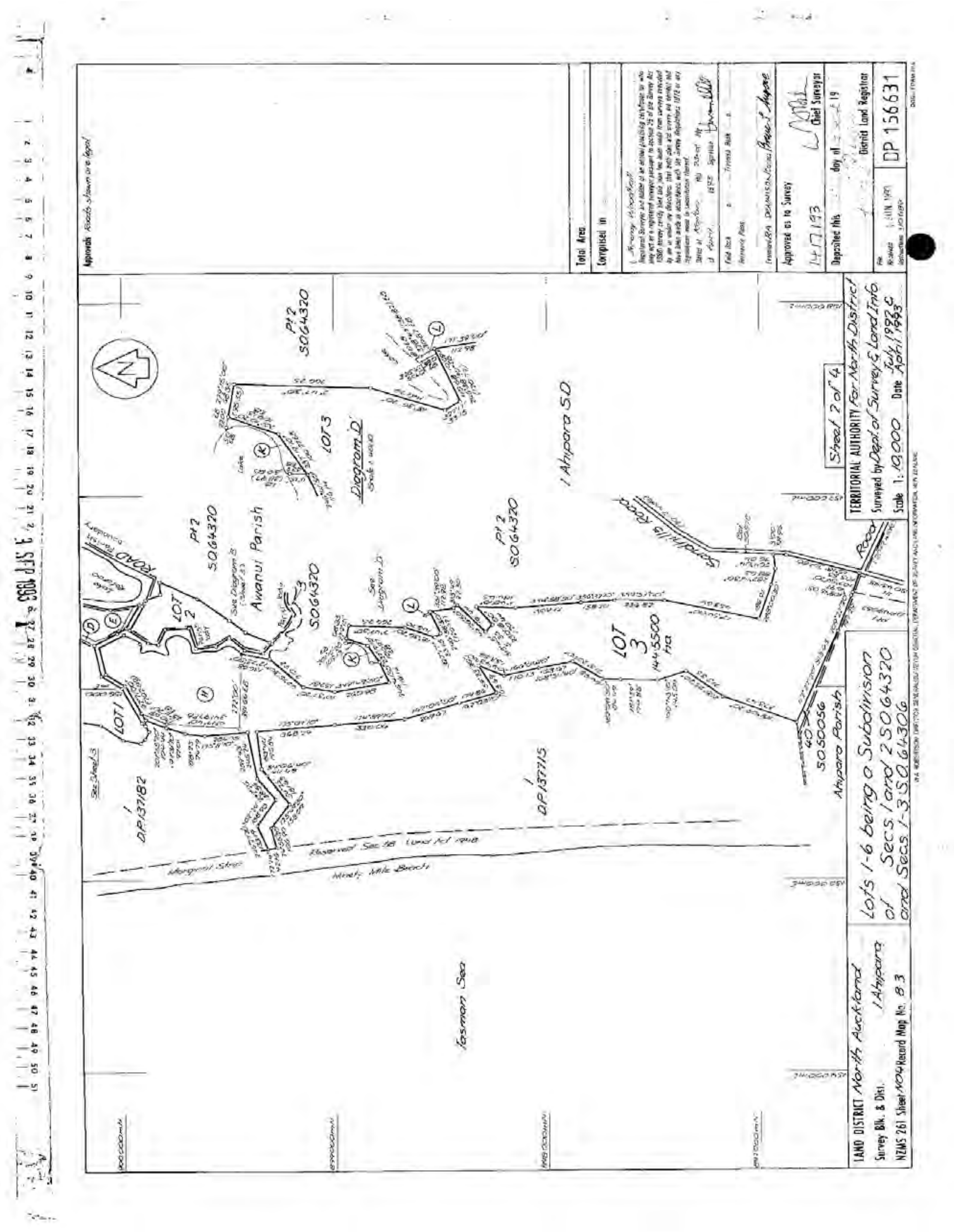
Subject to Section 5 Coal Mines Act 1979

Subject to Section 261 Coal Mines Act 1979

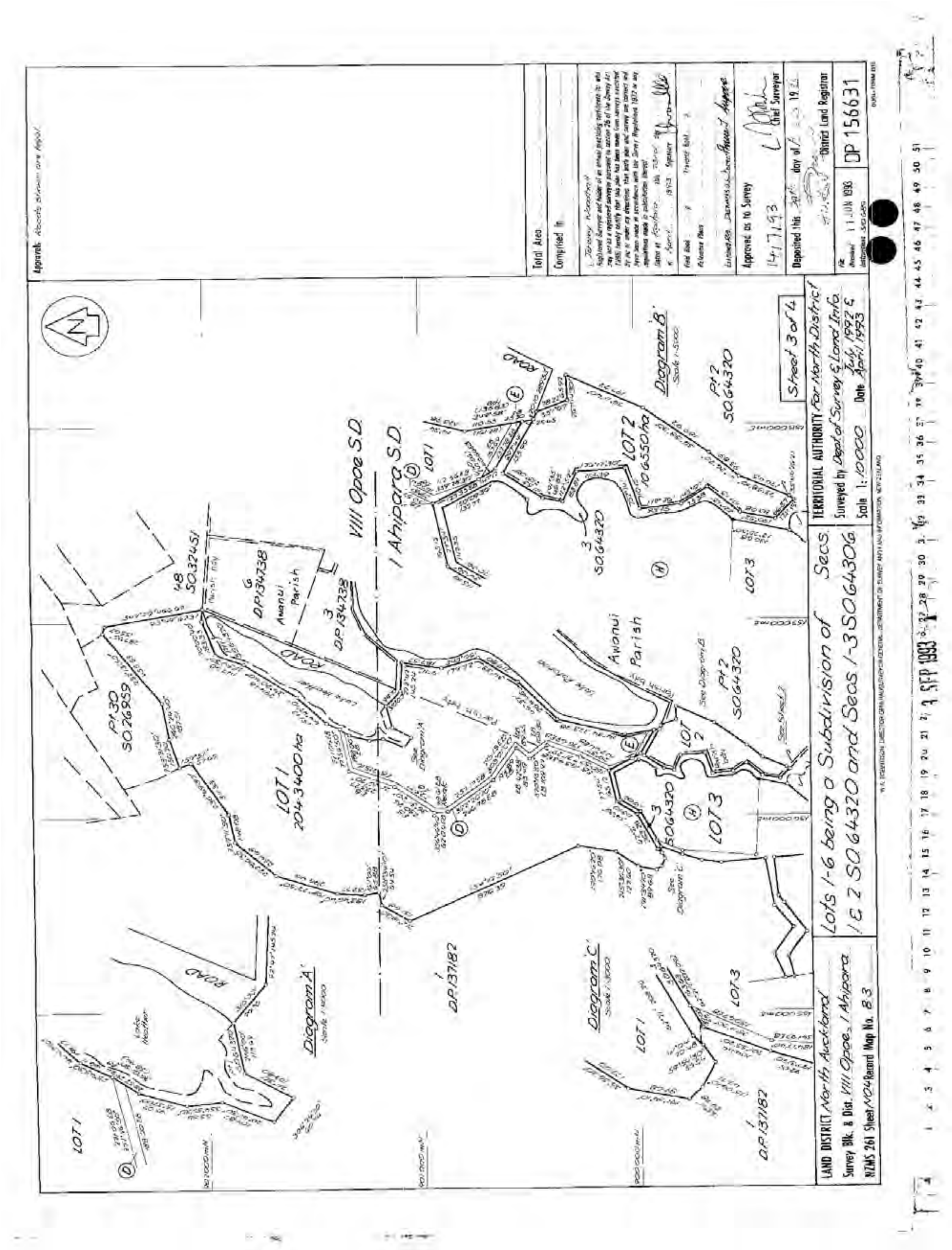
Subject to Part IV A Conservation Act 1987 (but sections 24(2A), 24A and 24AA of that Act do not apply)

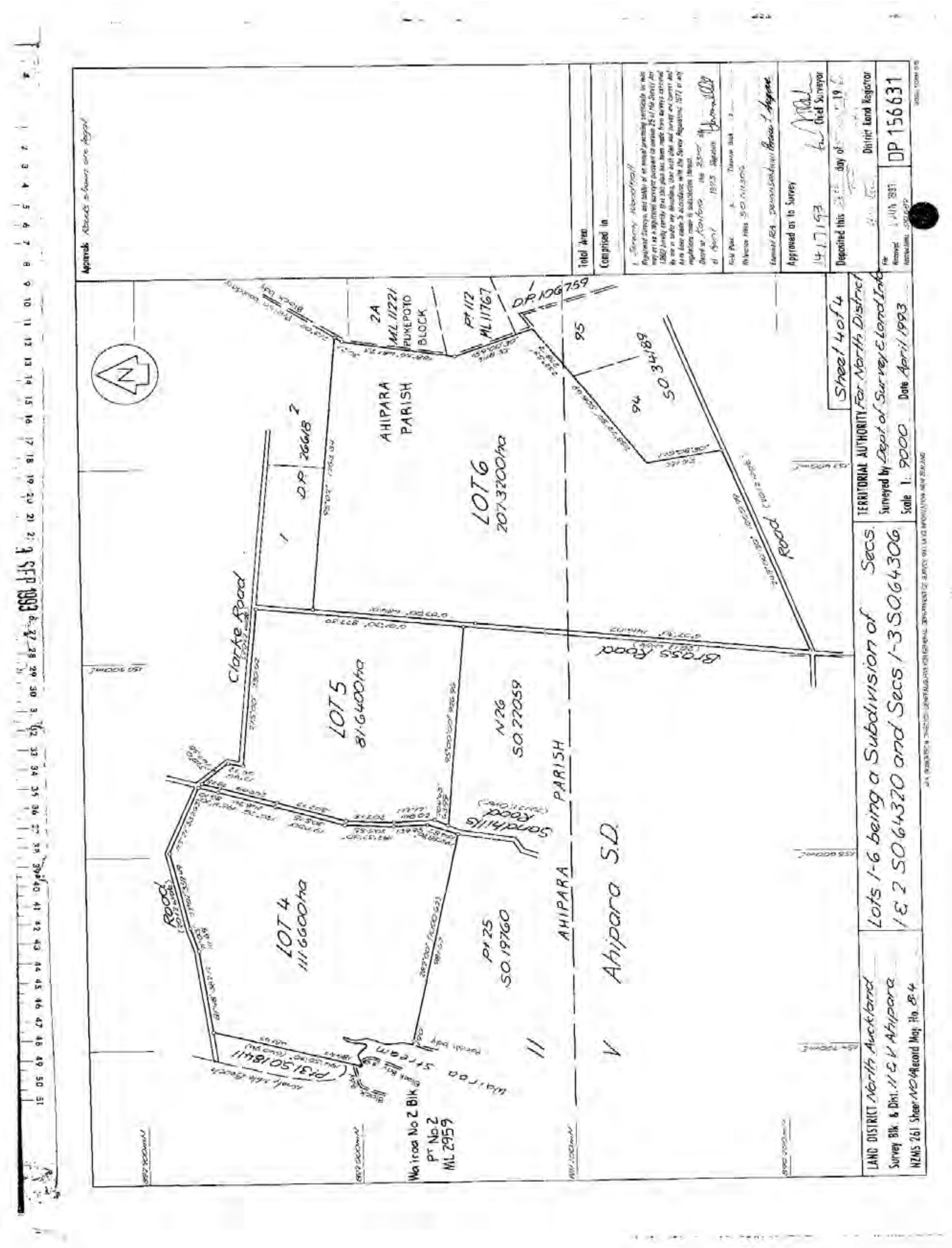
Subject to Section 11 Crown Minerals Act 1991


Lots 1-6 being a subdivision of Secs 1&2 SO64320 and Secs 1-3 SO64306
Sheet 1 of 4
DP 156631
TERRITORIAL AUTHORITY Far North District
Scale 1: 40000 Date April 1993
LAND DISTRICT North Auckland
VIII Opoe SD
Ahipara SD
Ninety Mile Beach
CLARKE ROAD
Total Area 760·1650 ha
AMALGAMATION CONDITION
That Lots 1-3 hereon be held in the same Certificate of Title See A629663
All roads shown are legal.
Schedule of Existing Easements
Schedule of Proposed Easements
Existing Conservation Covenant
APPROVED
New C/T Allocated
Lots 1-3 - 94A/632
Lot 4 - 94A/635
Lot 5 - 94A/636
Lot 6 - 94A/637
Approved as to Survey
Chief Surveyor
District Land Registrar


DP 156631
District Land Registrar
Chief Surveyor
Approved as to Survey
Deposited this
Total Area
Comprised in
TERRITORIAL AUTHORITY Far North District
Sheet 2 of 4
Surveyed by Dept of Survey & Land Info
Scale 1:10,000
Date April 1993
Lots 1-6 being a Subdivision of Secs 1 and 2 SO 64320 and Secs 1-3 SO 64306
Ahipara Parish
LAND DISTRICT North Auckland
1 Ahipara SD
Pt 2 SO 64320
Awanui Parish
LOT 1
LOT 2
LOT 3
144.5500 ha
Diagram D
1 DP 137182
1 DP 137715
40 SO 50056
Tasman Sea
Ninety Mile Beach
ROAD

Identifier **NA94A/635**




LOT 4
11.6600ha
LOT 5
81.6400ha
LOT 6
207.3200ha
Clarke Road
Bross Road
Sandhills Road
Road
AHIPARA PARISH
Ahipara S.D.
PUKEPOTO BLOCK
Wairoa No 2 Blk
Pt No 2
ML 2959
Wairoa Stream
Sheet 4 of 4
DP 156631
Lots 1-6 being a Subdivision of Secs 1E 2 SO 64320 and Secs 1-3 SO 64306
LAND DISTRICT North Auckland
TERRITORIAL AUTHORITY Far North District
Scale 1: 9000
Date April 1993
Approved as to Survey
Deposited this
District Land Registrar
Chief Surveyor
Total Area
Comprised in

RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**NA80D/321**
Land Registration District	**North Auckland**
Date Issued	30 July 1990

Prior References
NA1100/218

Estate	Fee Simple
Area	262.2785 hectares more or less
Legal Description	Part Lot 2-3 Deposited Plan 40865

Registered Owners
Te Runanga o NgaiTakoto Custodian Trustee Limited

Interests

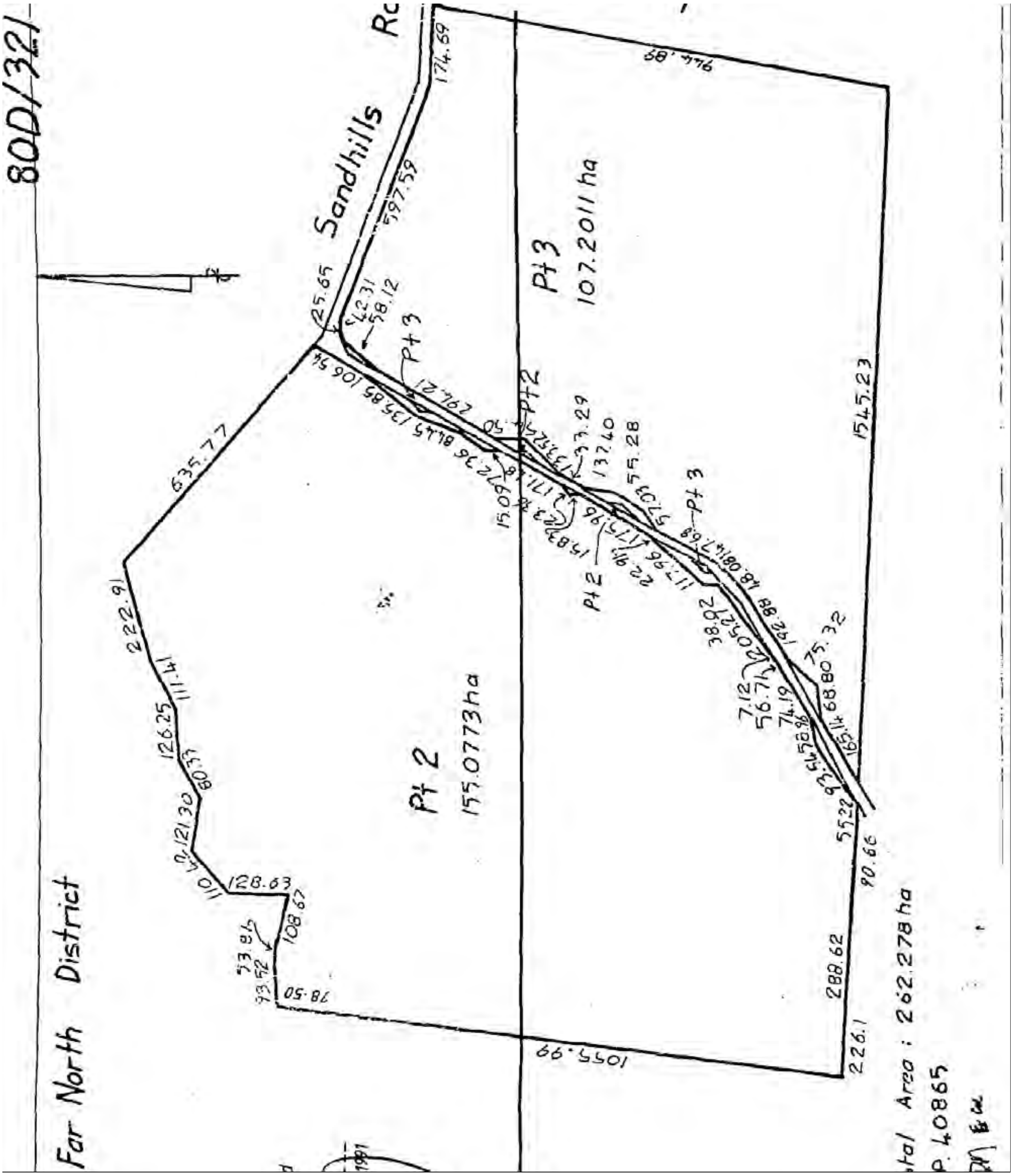
Subject to Part IV A Conservation Act 1987 (but section 24(2A), 24A and 24AA of that Act does not apply)

Subject to a right of way (in gross) over part marked A on Plan 146631 in favour of Her Majesty the Queen created by Transfer C406968.1 - 24.8.1992 at 1.30 pm (Affects Part Lot 2 DP 40865)

7287697.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 22.3.2007 at 9:00 am.

Subject to Section 11 Crown Minerals Act 1991

Identifier **NA80D/321**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier NA33A/925
Land Registration District North Auckland
Date Issued 09 November 1976

Estate Fee Simple
Area 13.5190 hectares more or less
Legal Description Allotment 118 Parish of Ahipara

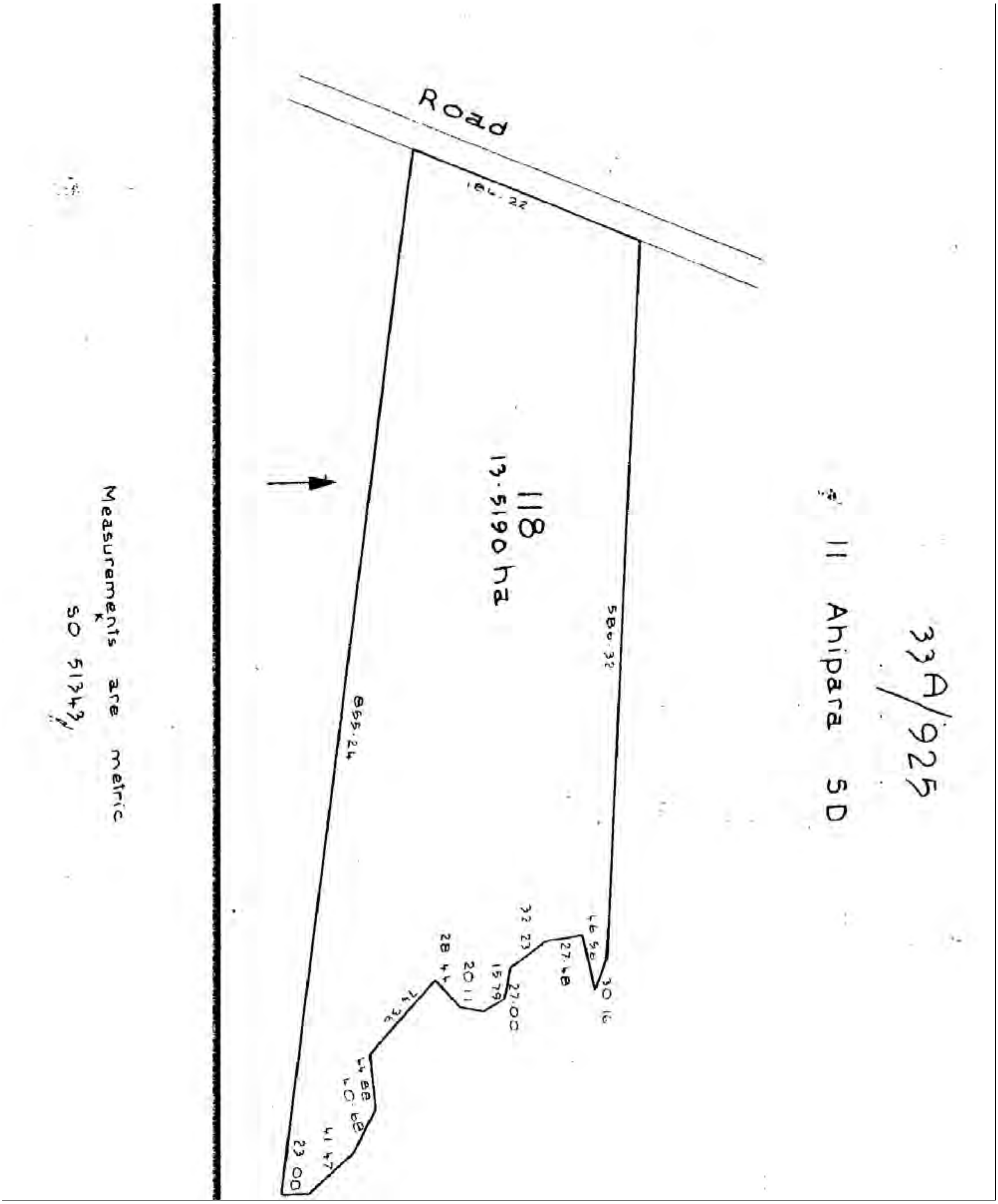
Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 8 Mining Act 1971

Subject to Section 168A Coal Mines Act 1925

Identifier **NA33A/925**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**719765**
Land Registration District	**North Auckland**
Date Issued	24 March 2016

Prior References
NA99C/561

Estate	Fee Simple - 1/2 share
Area	307.5850 hectares more or less
Legal Description	Section 4 Survey Office Plan 472393

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Petroleum Act 1937

Subject to Section 3 Geothermal Energy Act 1953

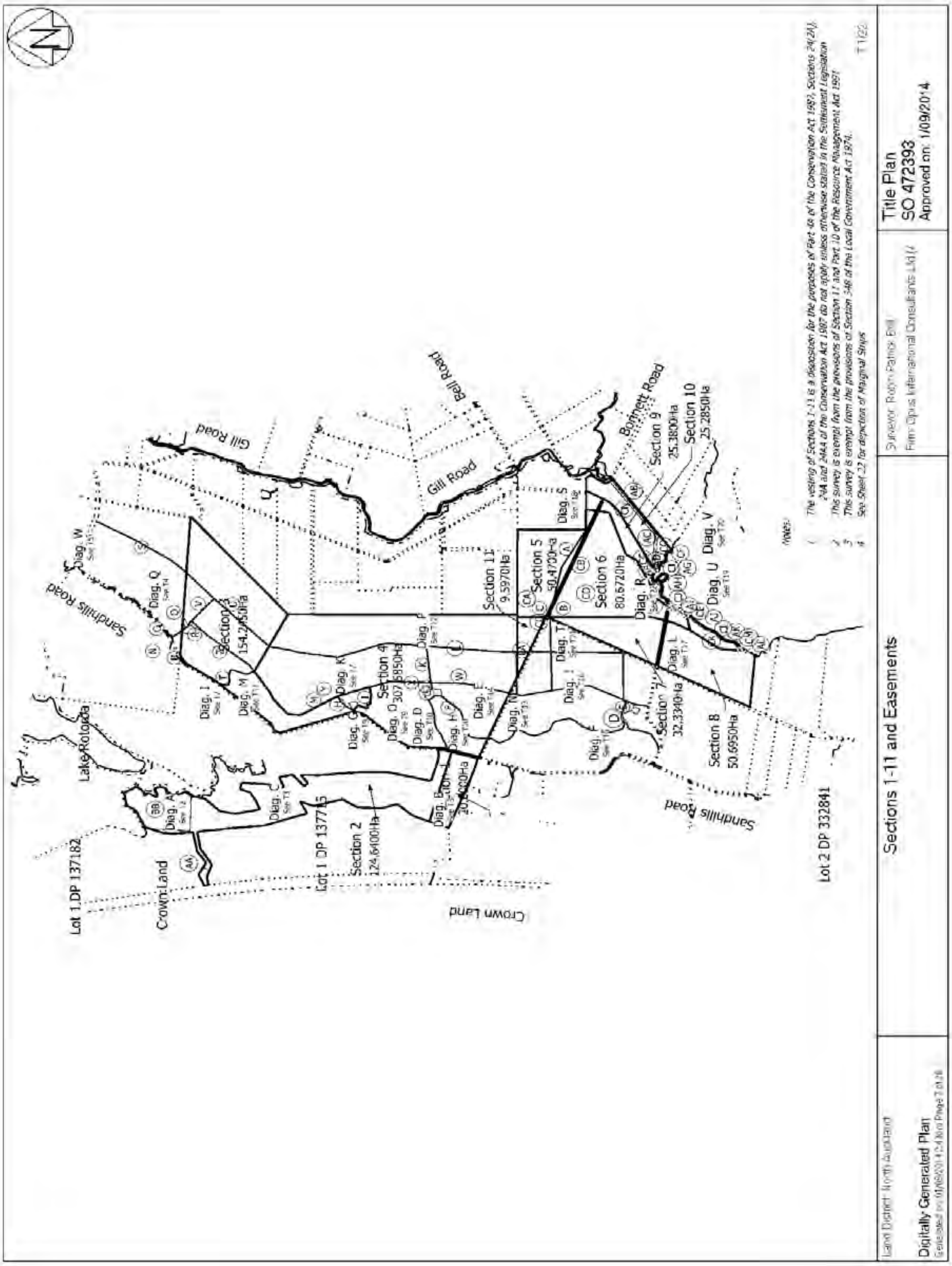
Subject to Part IV A Conservation Act 1987 (but Sections 24(2A), 24A and 24AA of that Act do not apply)

Subject to Sections 6 and 8 Mining Act 1971

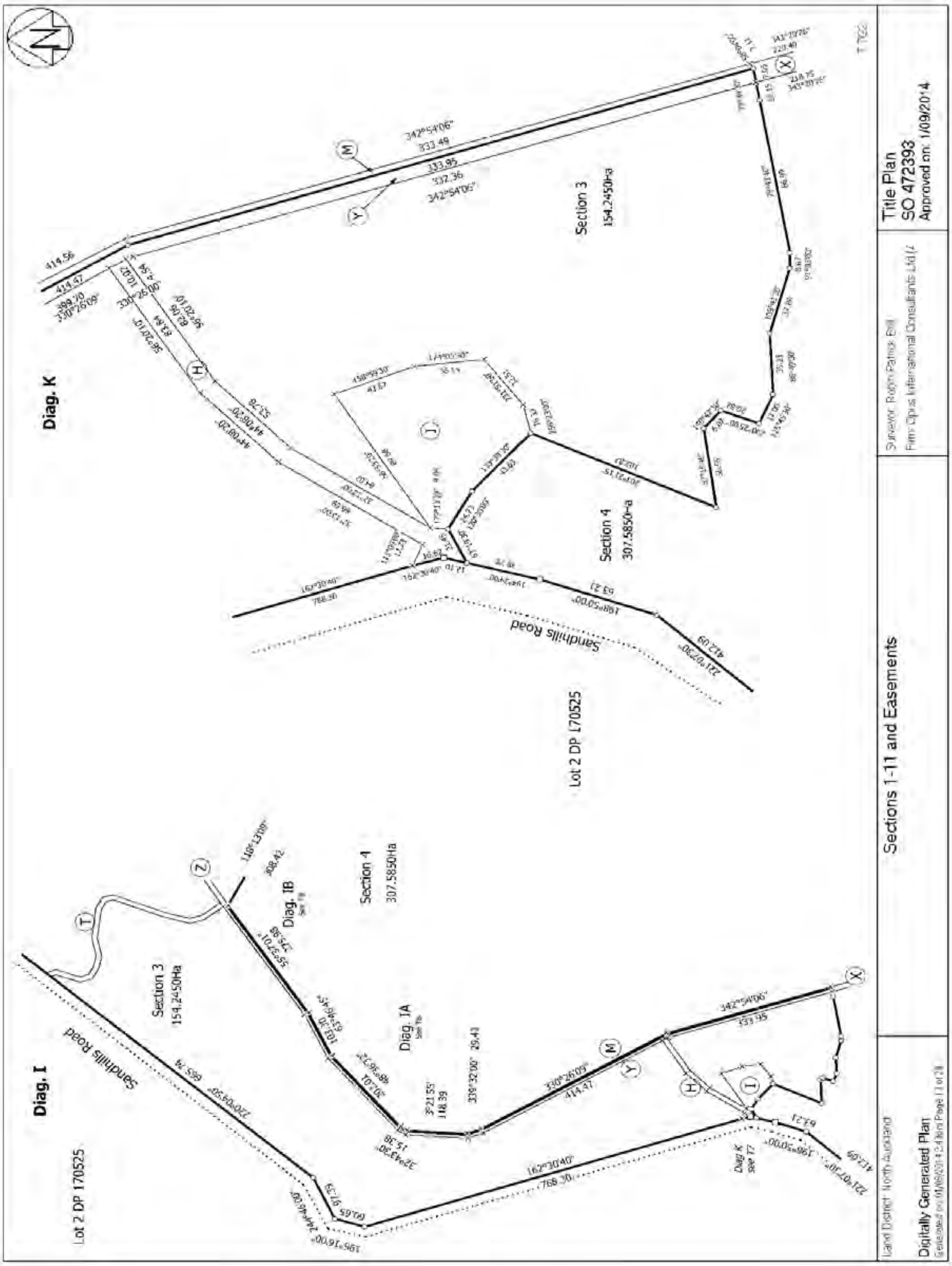
Subject to Sections 5 and 261 Coal Mines Act 1979

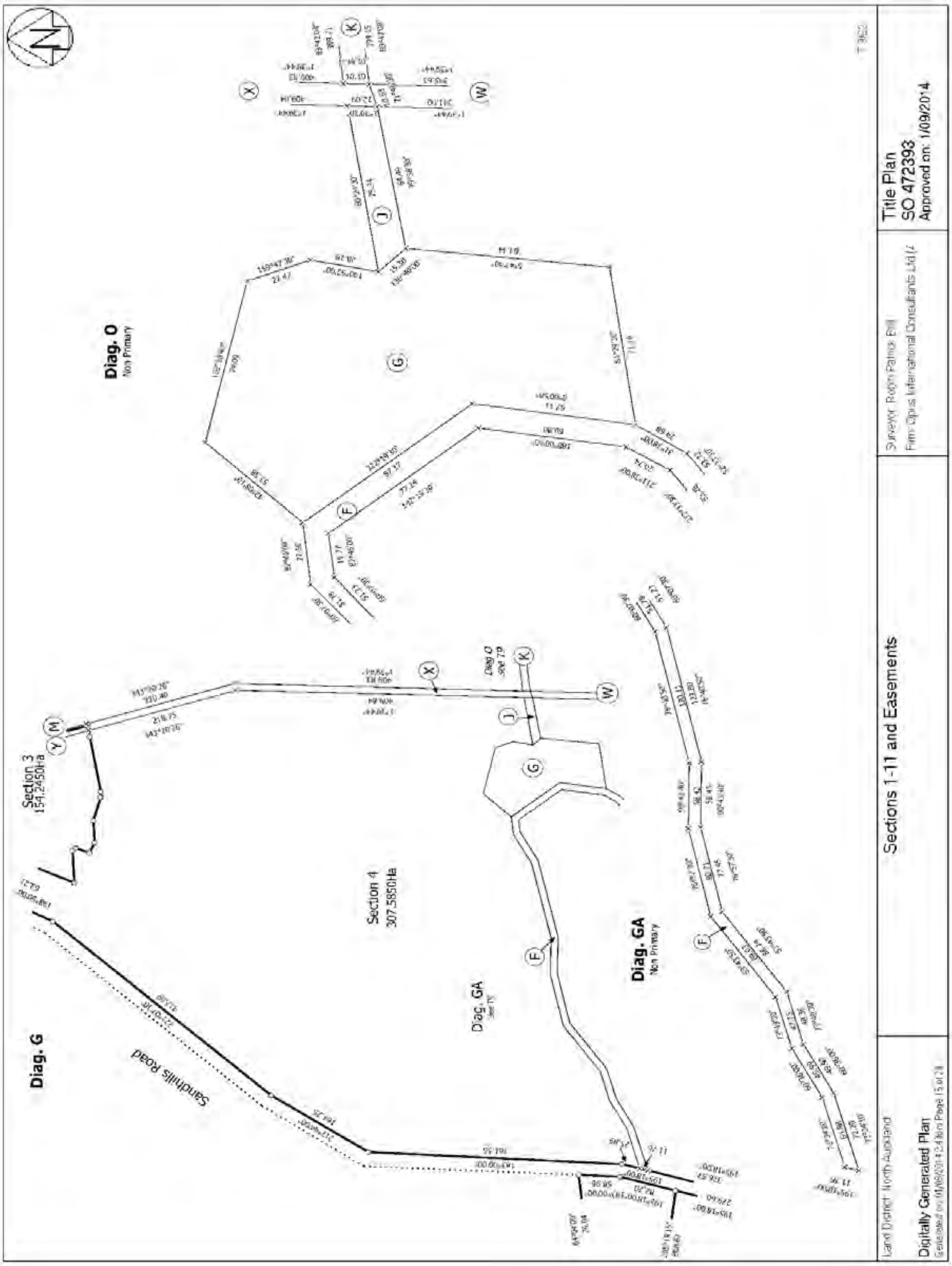
Subject to Section 11 Crown Minerals Act 1991

Identifier **719765**

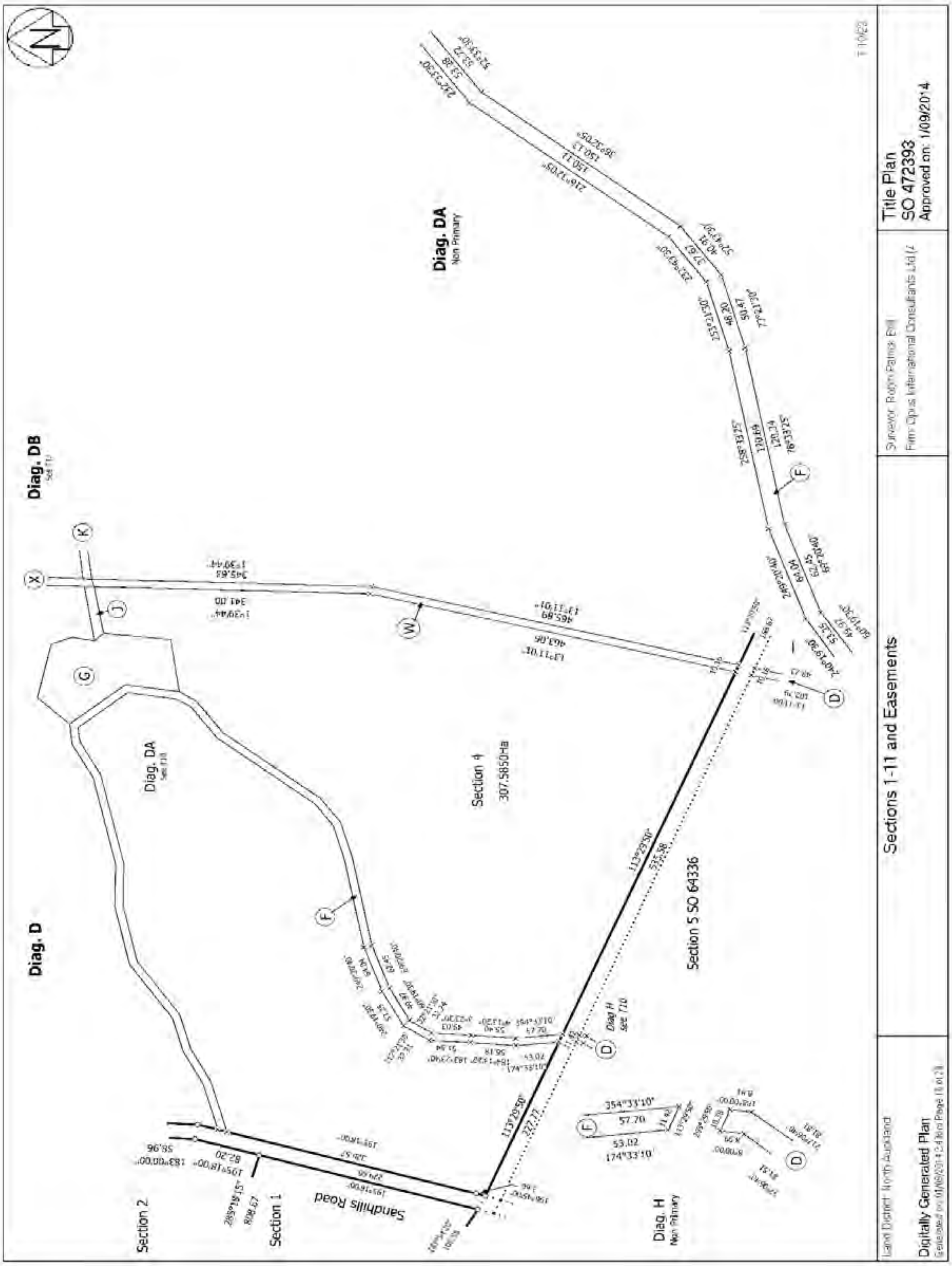


Identifier **719765**

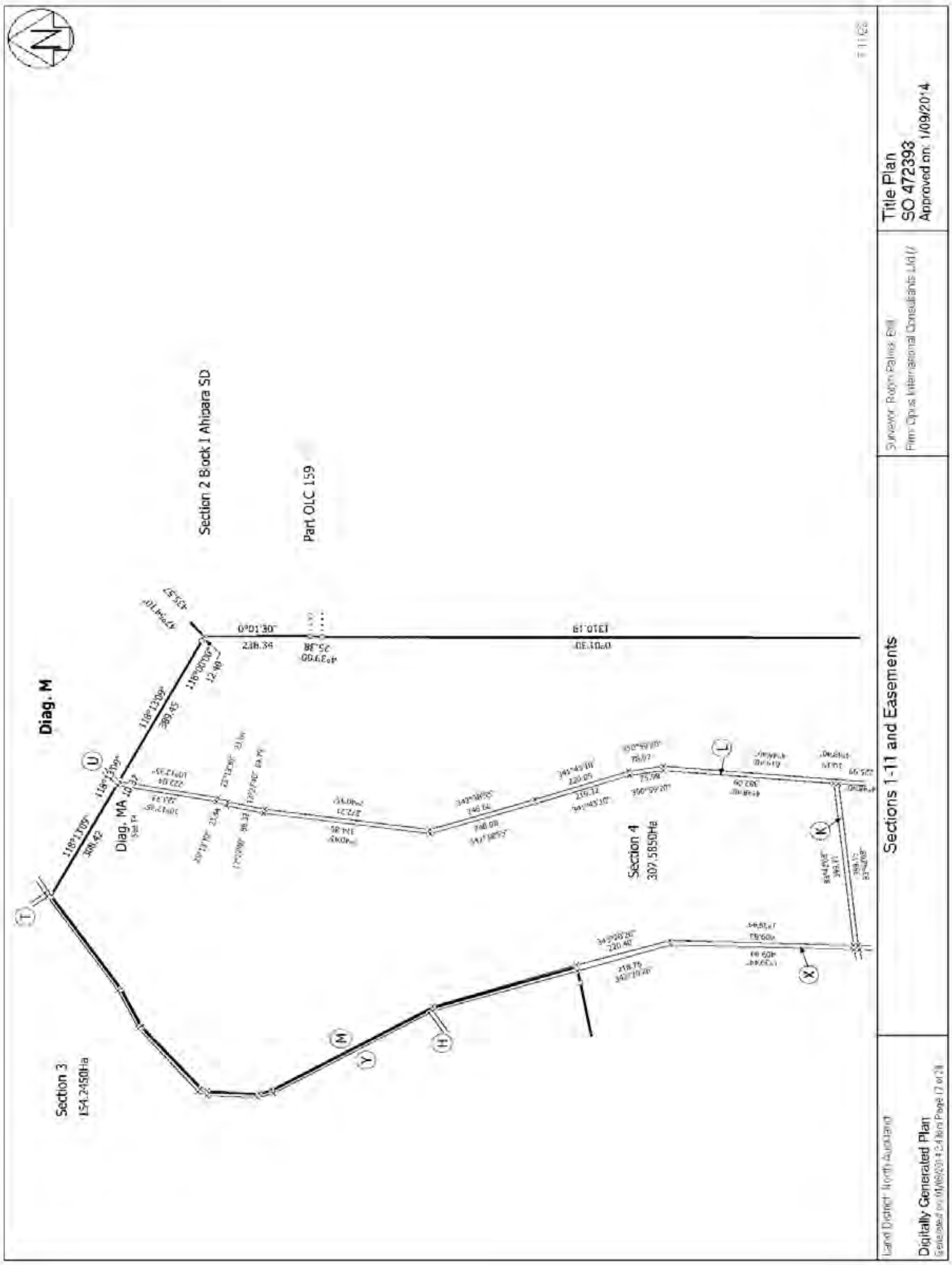



Title Plan
SO 472393
Approved on: 1/09/2014
Sections 1-11 and Easements
Land District: North Auckland
Digitally Generated Plan
Diag. O
Diag. G
Diag. GA
Section 3
154.2450Ha
Section 4
307.5850Ha
Sandhills Road

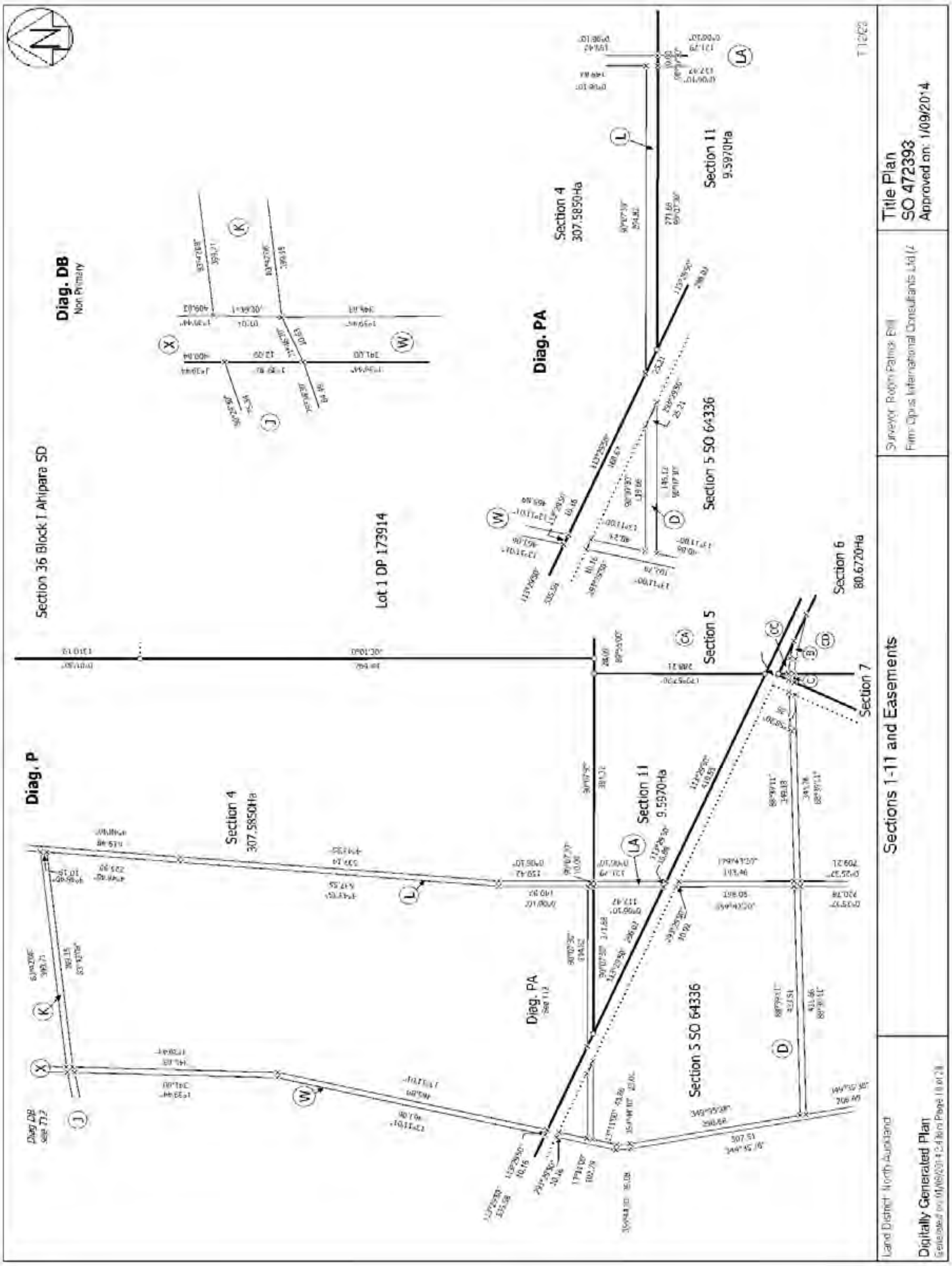
Identifier **719765**



Identifier **719765**



Identifier **719765**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier 719764
Land Registration District North Auckland
Date Issued 24 March 2016

Prior References
NA99C/561

Estate	Fee Simple - 1/2 share
Area	307.5850 hectares more or less
Legal Description	Section 4 Survey Office Plan 472393

Registered Owners
Te Runanga o NgaiTakoto Custodian Trustee Limited

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Petroleum Act 1937

Subject to Section 3 Geothermal Energy Act 1953

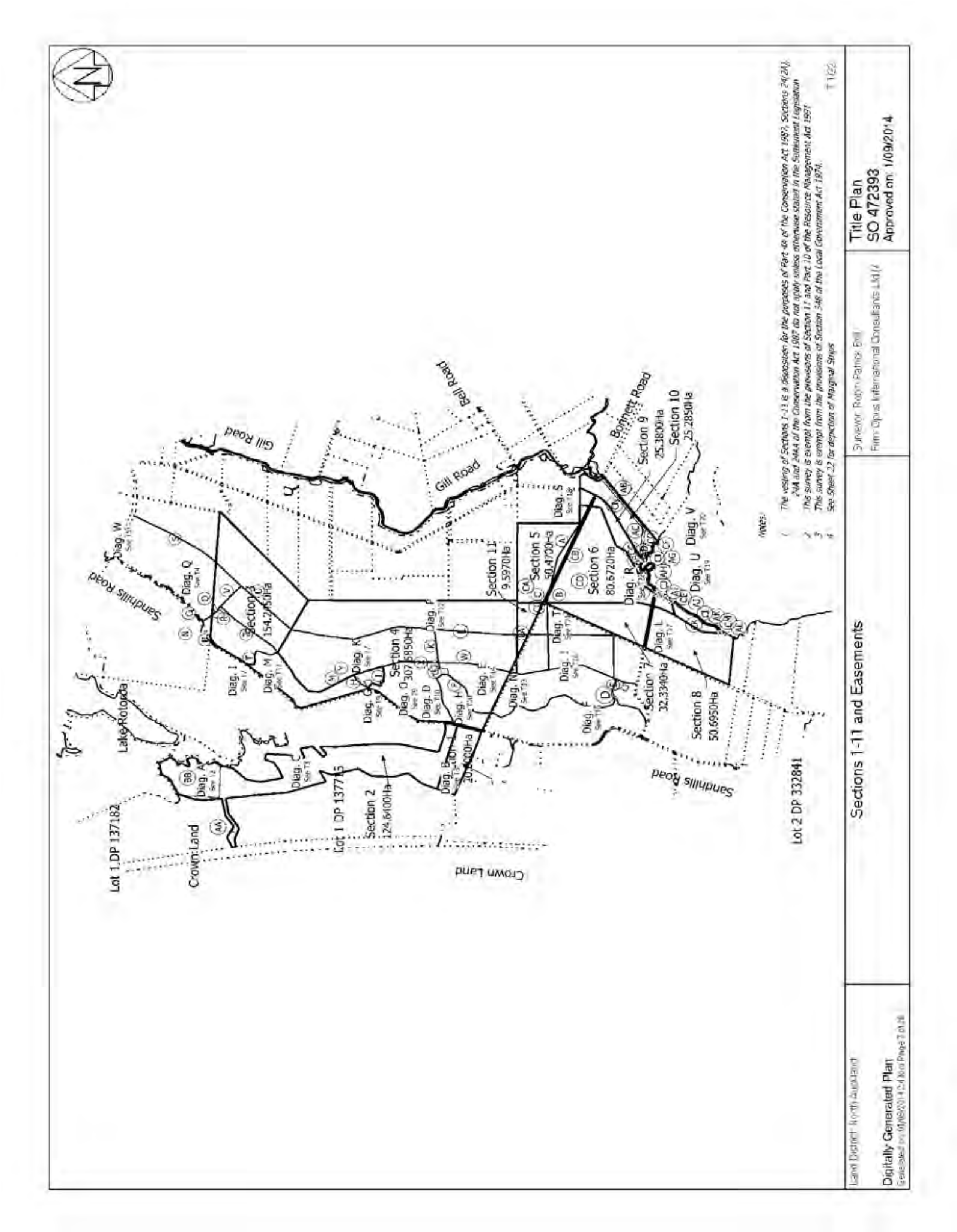
Subject to Part IV A Conservation Act 1987 (but Sections 24(2A), 24A and 24AA of that Act do not apply)

Subject to Sections 6 and 8 Mining Act 1971

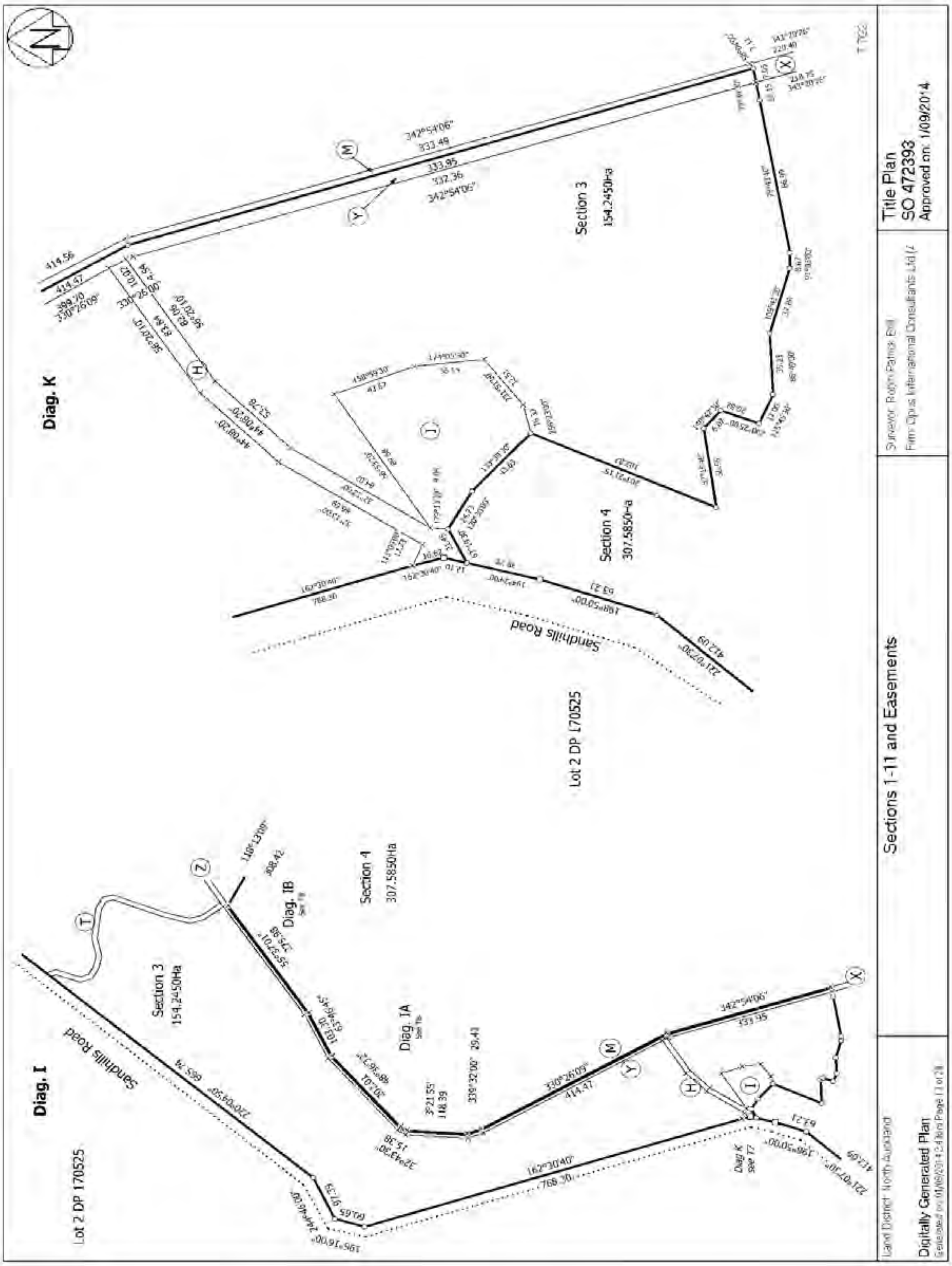
Subject to Sections 5 and 261 Coal Mines Act 1979

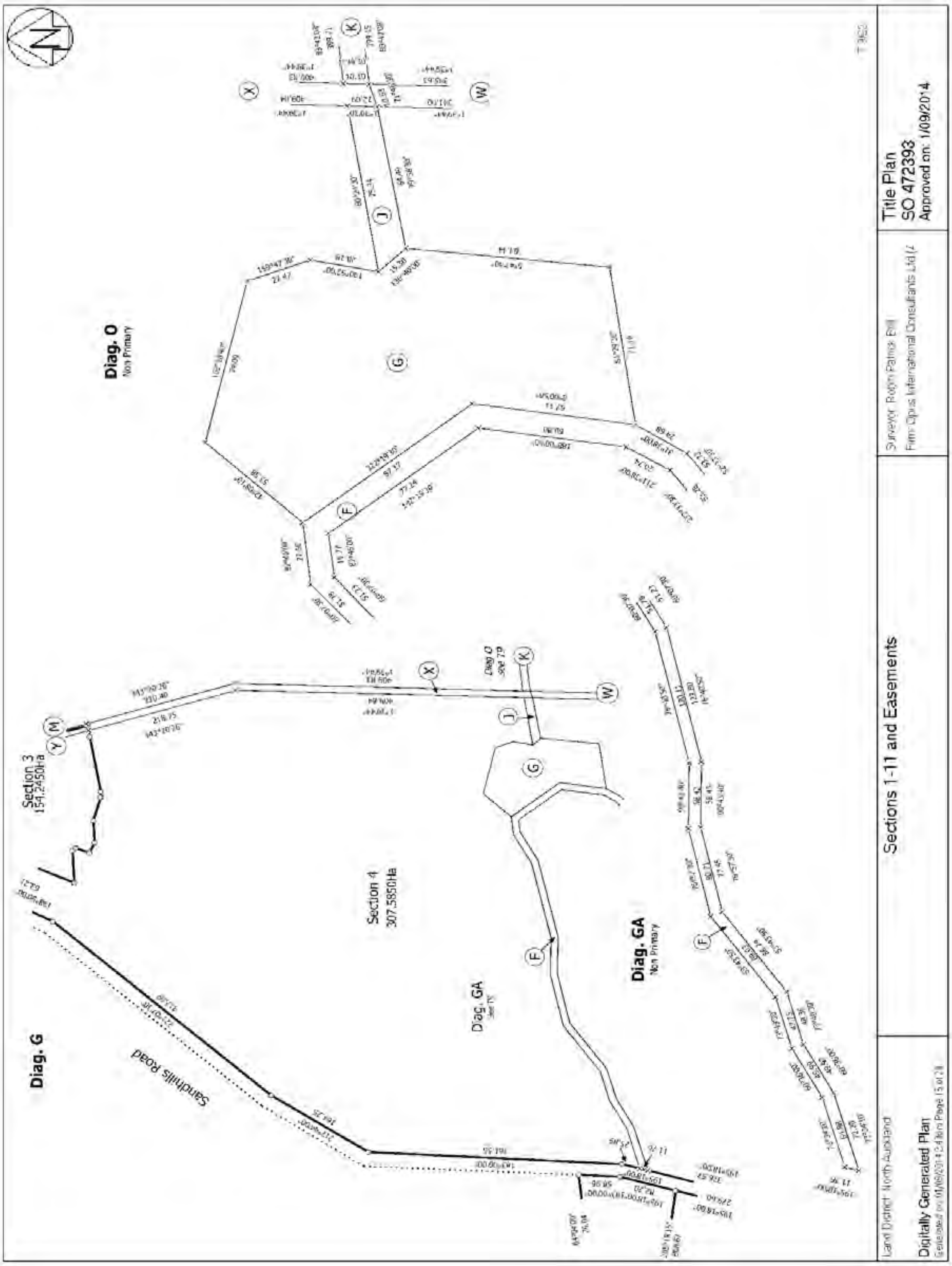
Subject to Section 11 Crown Minerals Act 1991

Identifier **719764**

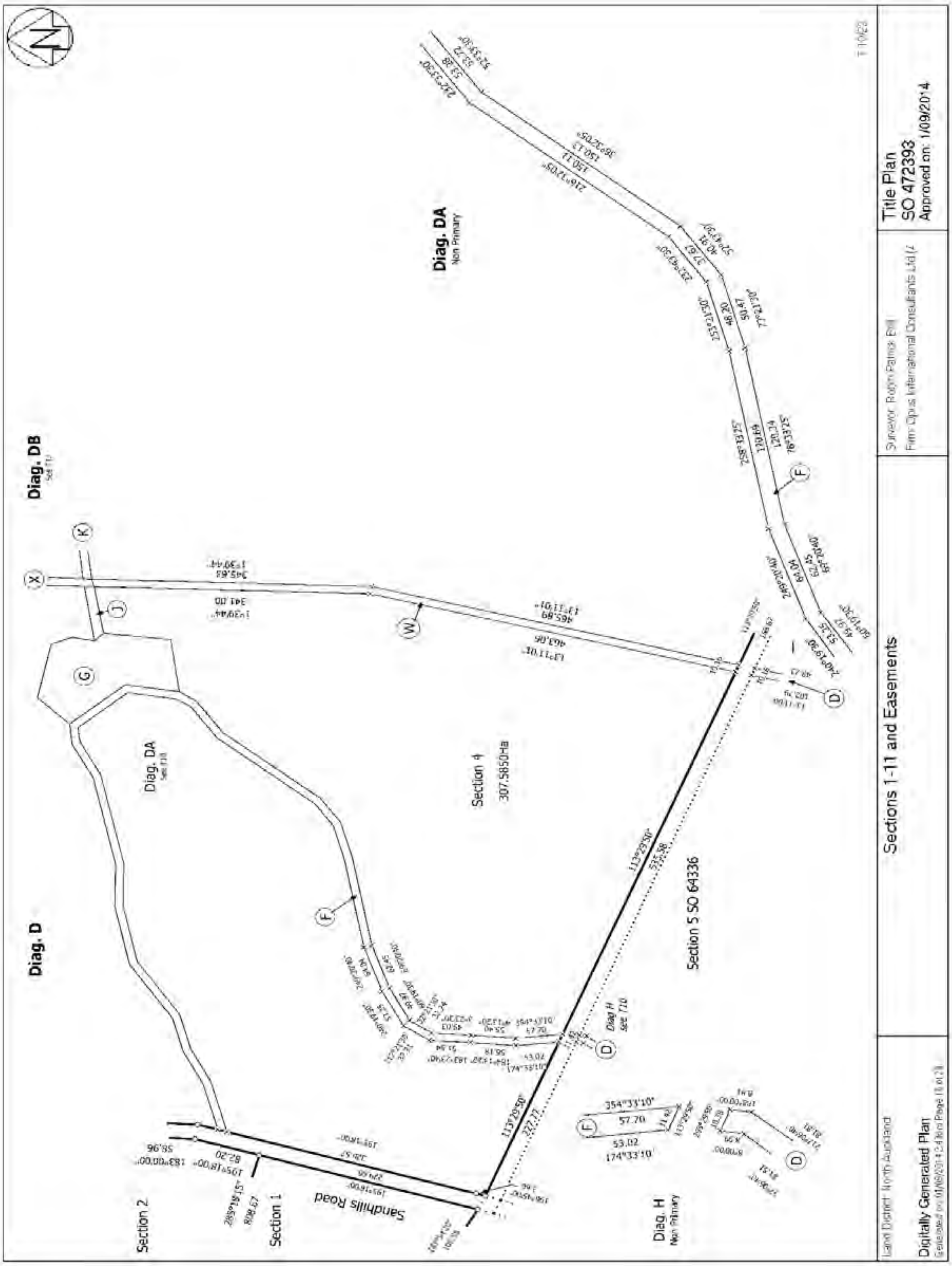


Identifier **719764**

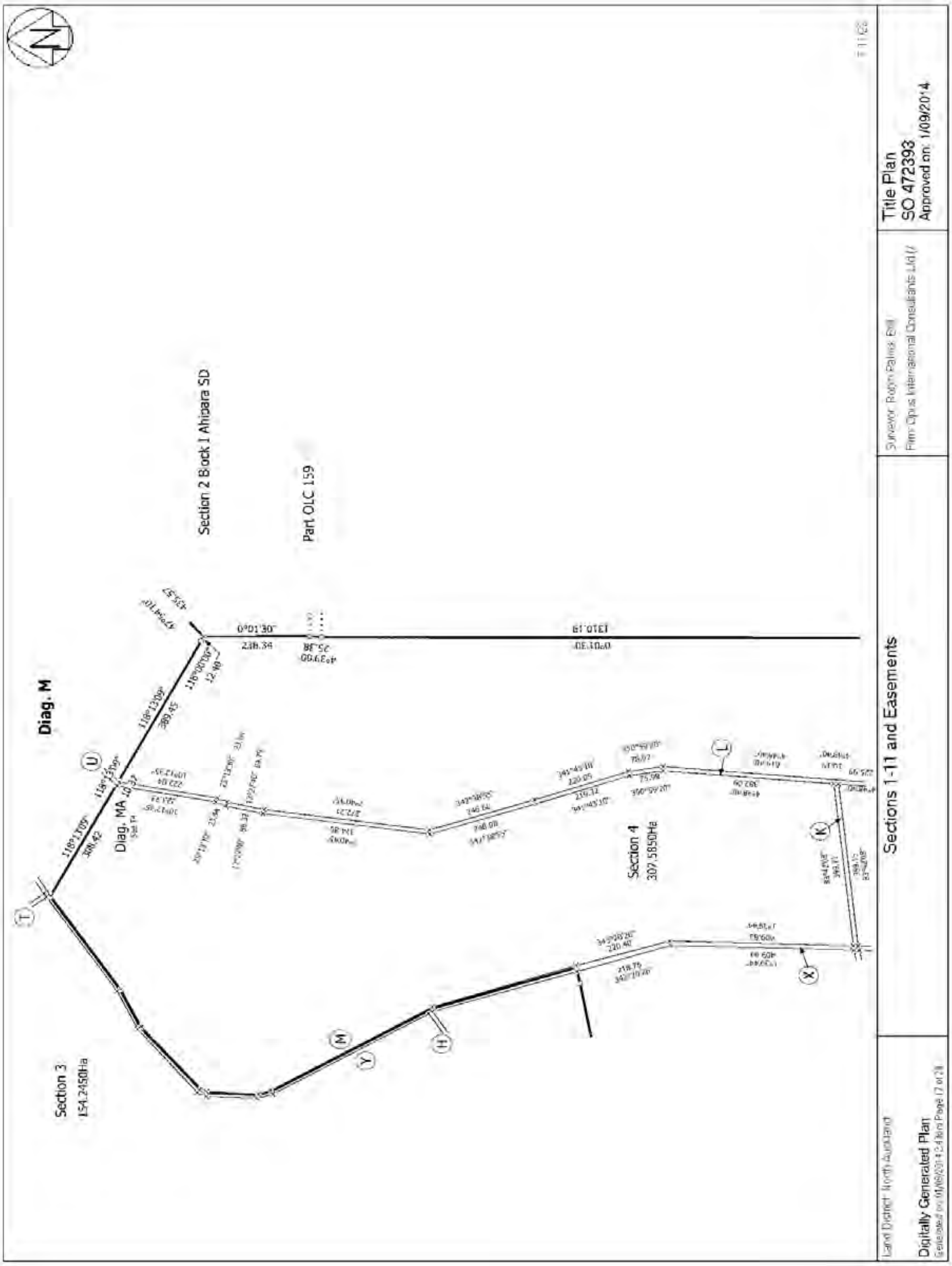



Title Plan
SO 472393
Approved on: 1/09/2014
Sections 1-11 and Easements
Land District: North Auckland
Digitally Generated Plan
Surveyor: Robin Patrick Bell
Firm: Opus International Consultants Ltd
Diag. O
Non Primary
Diag. G
Diag. GA
Non Primary
Section 3
154.2450Ha
Section 4
307.5850Ha
Sandhills Road

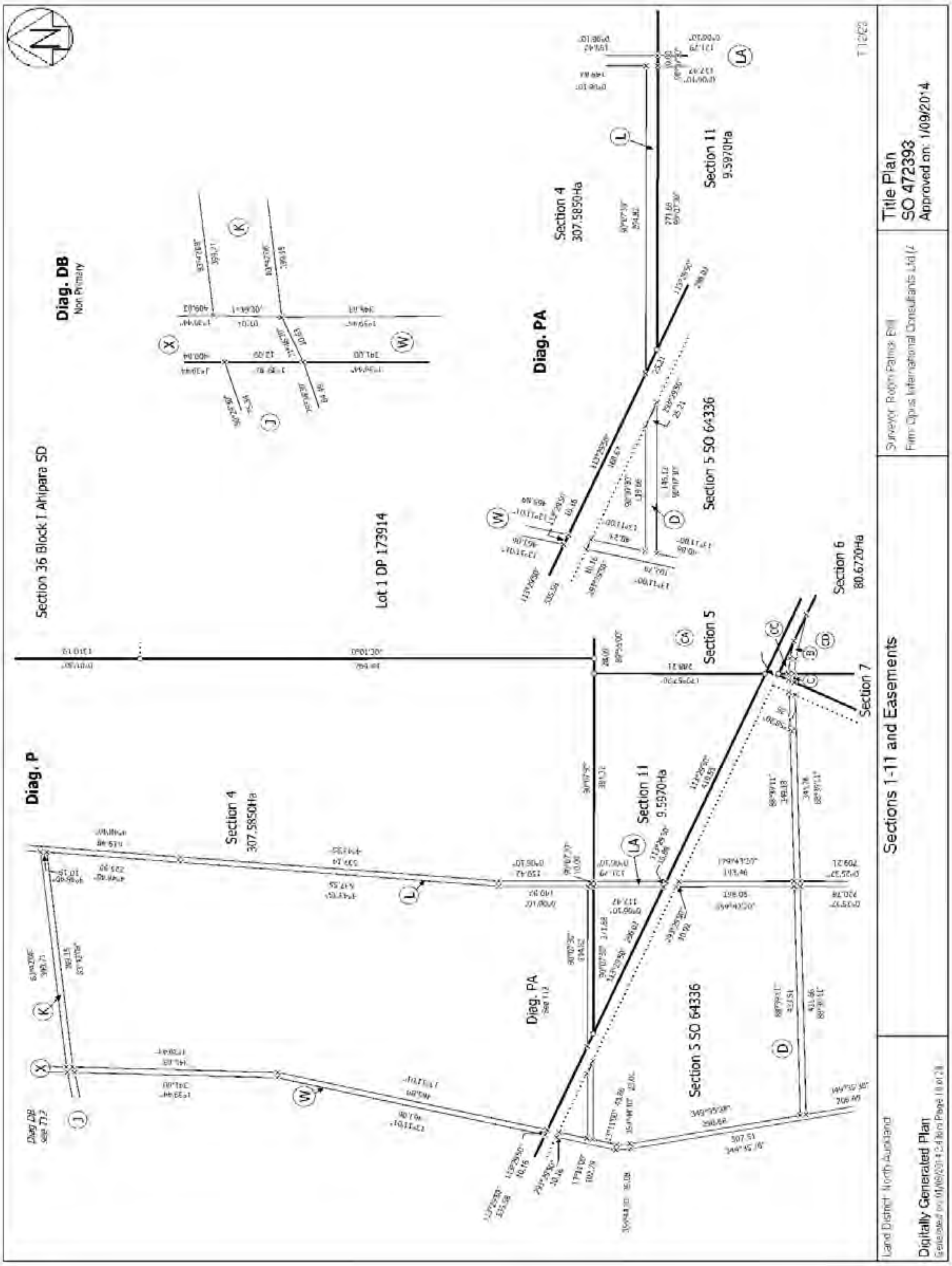
Identifier **719764**



Identifier **719764**



Identifier **719764**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier 719763
Land Registration District North Auckland
Date Issued 24 March 2016

Prior References
NA94A/632

Estate	Fee Simple - 1/2 share
Area	20.0000 hectares more or less
Legal Description	Section 1 Survey Office Plan 472393

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

Subject to Section 3 Petroleum Act 1937

Subject to Sections 6 and 8 Mining Act 1971

Subject to Part IV A Conservation Act 1987 (but Sections 24(2A), 24A and 24AA of that Act do not apply)

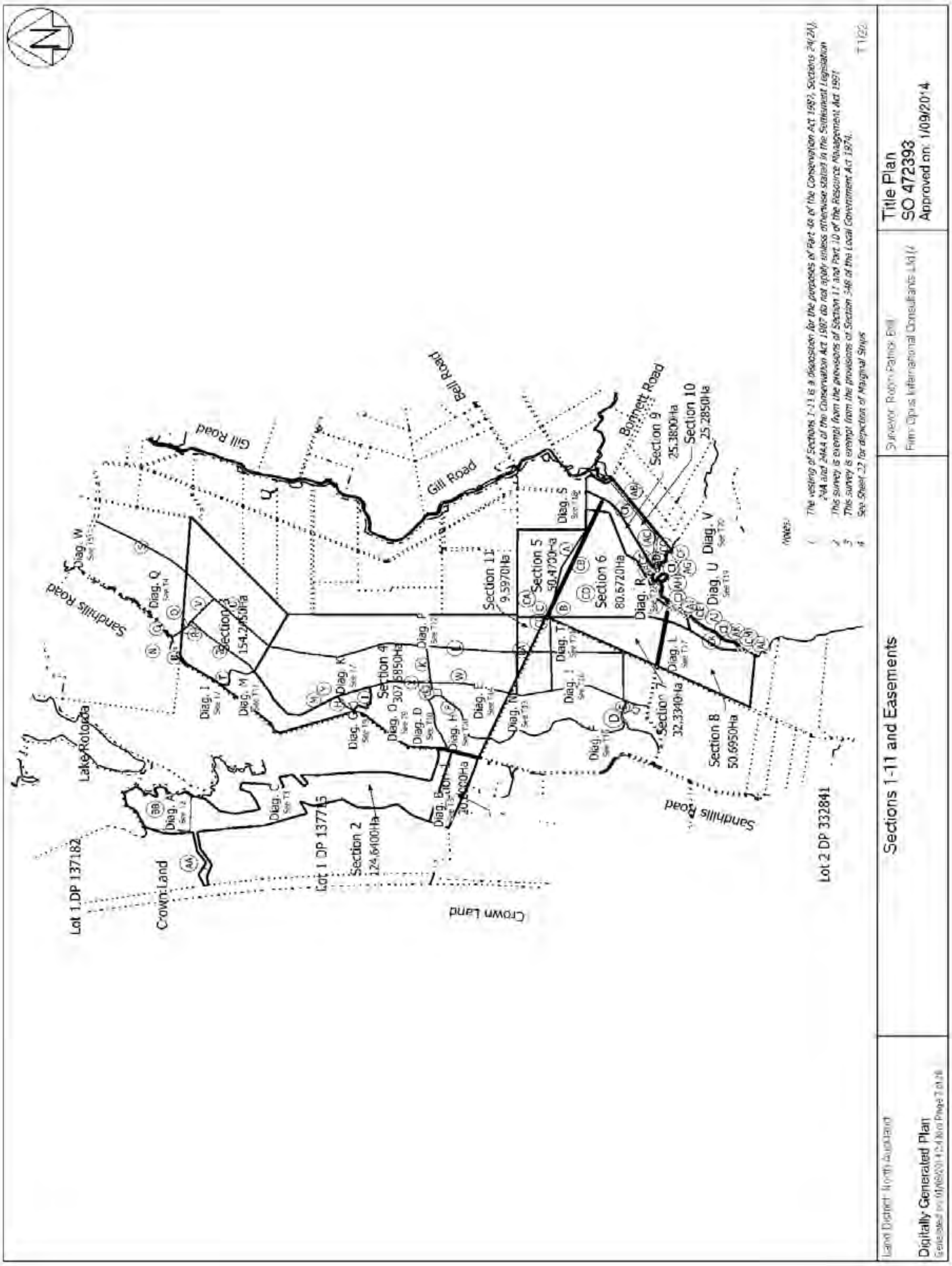
Subject to Sections 5 and 261 Coal Mines Act 1979

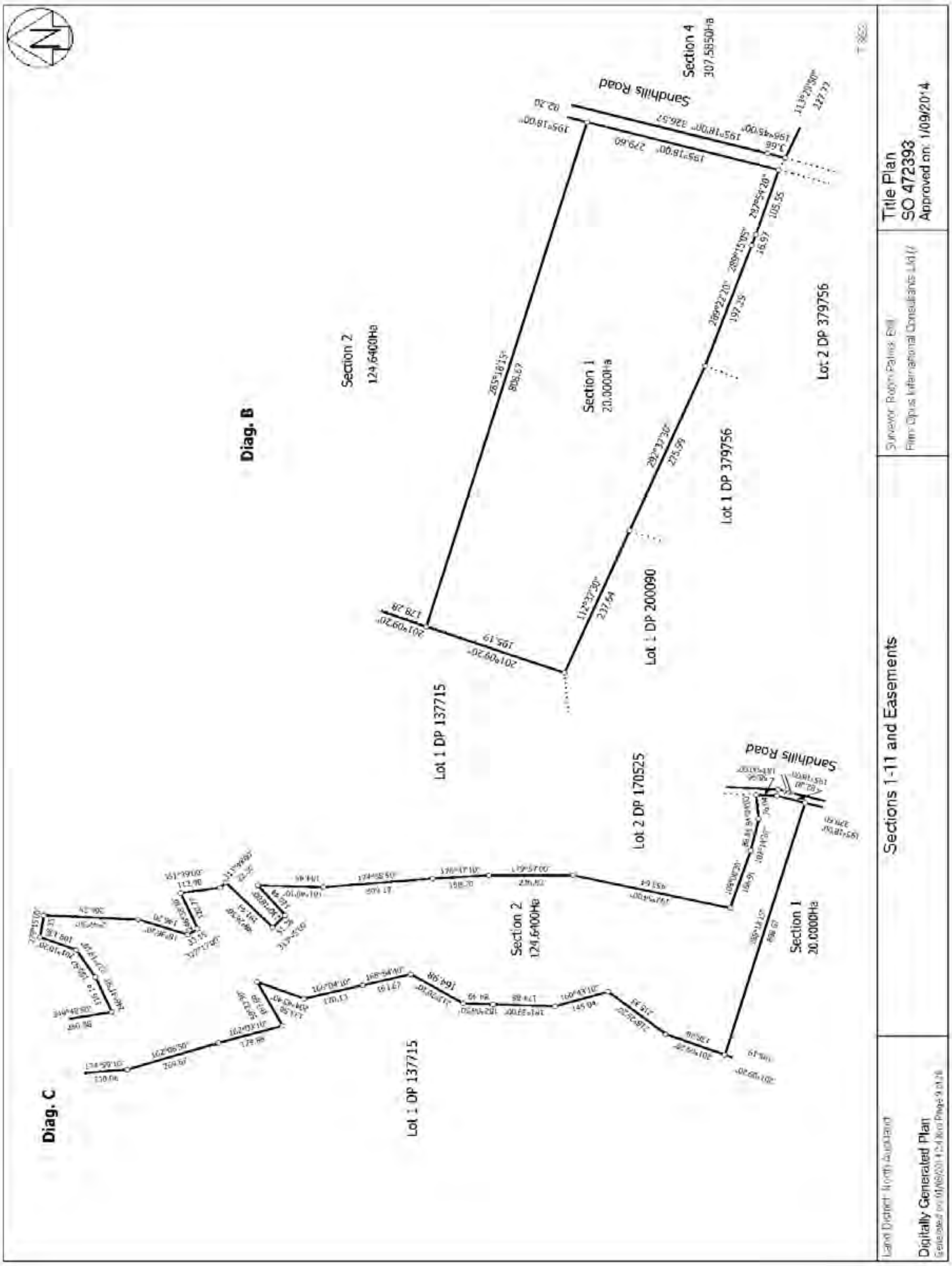
Appurtenant hereto is a right of way created by Certificate C312160.2

8220253.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 9.7.2009 at 9:00 am (affects part)

Subject to Section 11 Crown Minerals Act 1991

Identifier **719763**




Title Plan
SO 472393
Approved on: 1/09/2014
Sections 1-11 and Easements
Land District: North Auckland
Digitally Generated Plan
Diag. B
Diag. C
Section 4
307.5850Ha
Section 2
124.6400Ha
Section 1
20.0000Ha
Sandhills Road
Lot 2 DP 379756
Lot 1 DP 379756
Lot 1 DP 200090
Lot 1 DP 137715
Lot 2 DP 170525

RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**719762**
Land Registration District	**North Auckland**
Date Issued	24 March 2016

Prior References
NA94A/632

Estate	Fee Simple - 1/2 share
Area	20.0000 hectares more or less
Legal Description	Section 1 Survey Office Plan 472393

Registered Owners
Te Runanga o NgaiTakoto Custodian Trustee Limited

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

Subject to Section 3 Petroleum Act 1937

Subject to Sections 6 and 8 Mining Act 1971

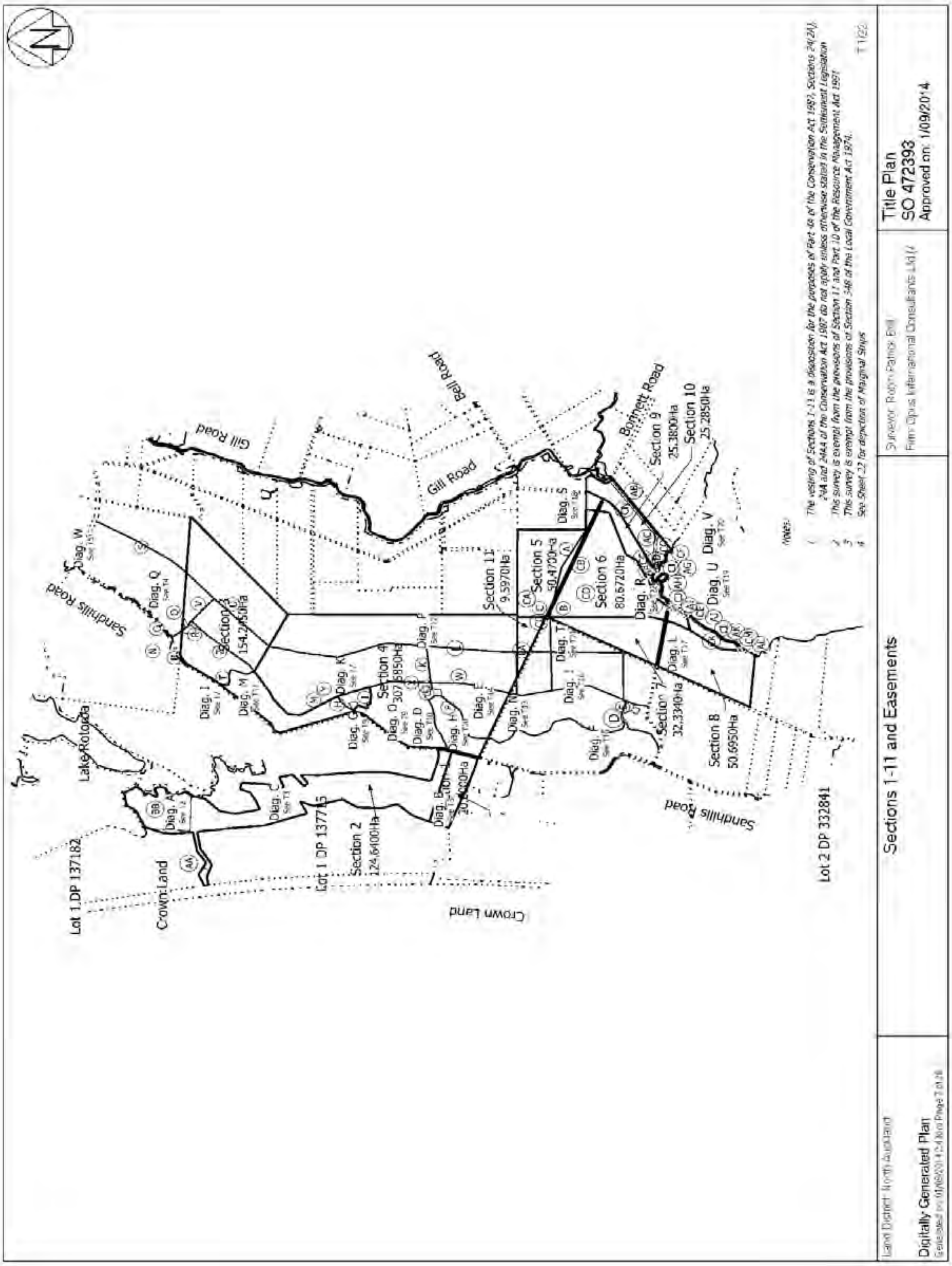
Subject to Part IV A Conservation Act 1987 (but Sections 24(2A), 24A and 24AA of that Act do not apply)

Subject to Sections 5 and 261 Coal Mines Act 1979

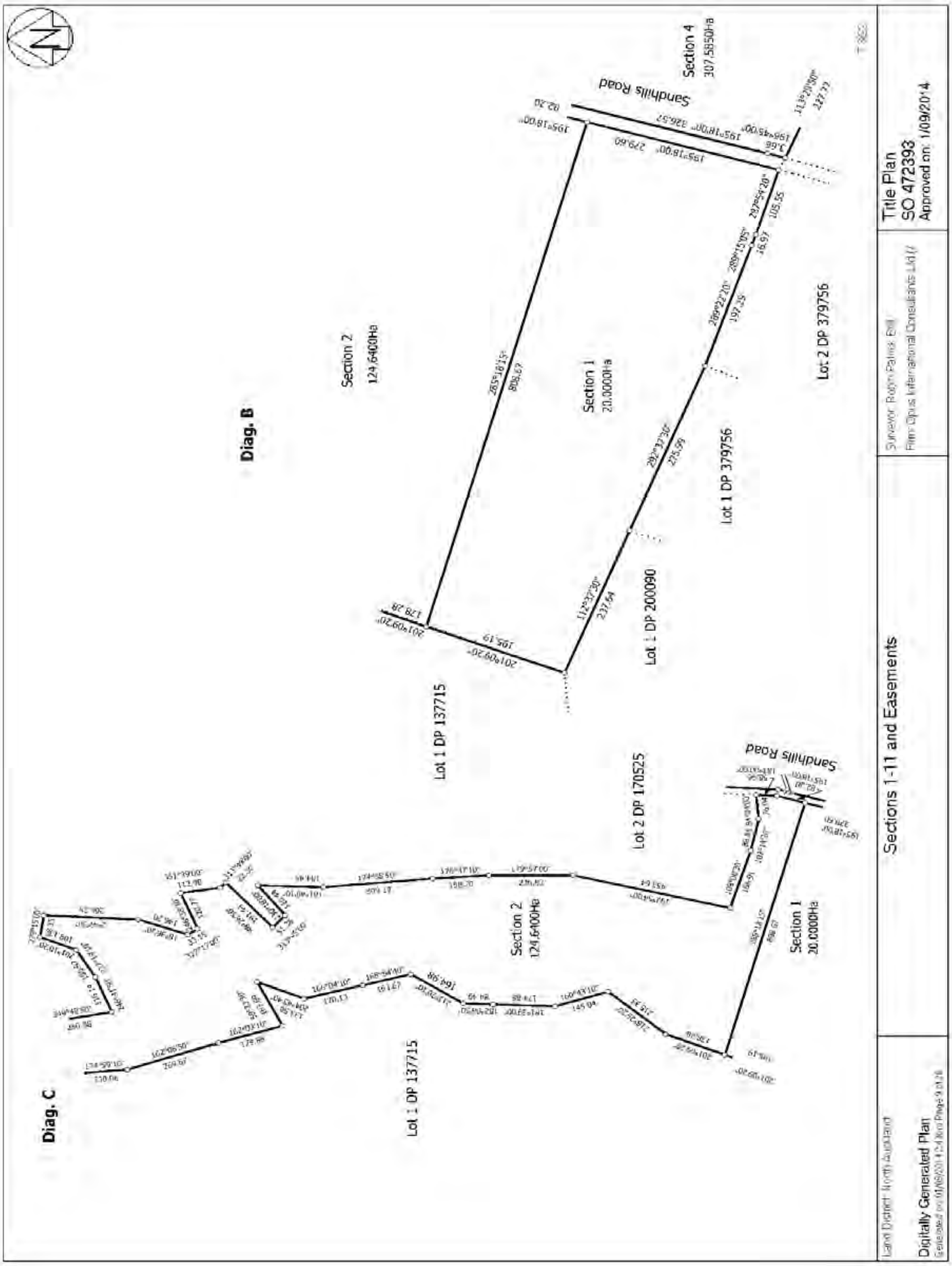
Appurtenant hereto is a right of way created by Certificate C312160.2

8220253.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 9.7.2009 at 9:00 am (affects part)

Subject to Section 11 Crown Minerals Act 1991


Title Plan
SO 472393
Approved on: 1/09/2014
Sections 1-11 and Easements
Land District: North Auckland
Digitally Generated Plan
Surveyor: Robin Patrick Bell
Firm: Opus International Consultants Ltd
Gill Road
Bell Road
Bonnett Road
Sandhills Road
Lake Rotokawa
Crown Land
Lot 1 DP 137182
Lot 1 DP 137735
Lot 2 DP 332841
Section 2
124.6400Ha
Section 4
307.5850Ha
Section 5
50.4700Ha
Section 6
80.6720Ha
Section 7
32.3340Ha
Section 8
50.6950Ha
Section 9
25.3800Ha
Section 10
25.2850Ha
Section 11
9.5970Ha
Section 3
154.2650Ha
Notes

Identifier **719762**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General of Land

Identifier **719746**
Land Registration District **North Auckland**
Date Issued 05 October 2016

Prior References
735251 738050

Estate	Fee Simple
Area	737.3562 hectares more or less
Legal Description	Lot 1-2 Deposited Plan 156631 and Lot 1-2 Deposited Plan 170525 and Section 1-8 Survey Office Plan 42207 and Section 2-3 Survey Office Plan 472393

Registered Owners
Te Runanga o NgaiTakoto Custodian Trustee Limited

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

Subject to Sections 6 and 8 Mining Act 1971

Subject to Section 3 Petroleum Act 1937

Subject to Sections 5 and 261 Coal Mines Act 1979

Subject to Part IV A Conservation Act 1987 (but section 24(2A), 24A and 24AA of that Act does not apply)

Appurtenant to Lot 1 and Lot 2 DP 170525, Lot 1 DP 156631 and Section 2 SO 472393 are rights of way and appurtenant to Lot 1 DP 170525 and Lot 1 DP 156631 are rights to convey water created by Certificate C312160.2 - 9.10.1991 at 1:39 pm

Subject to a right of way (in gross) over part Lot 2 DP 170525 marked E and K on SO 64320 and part Lot 1 DP 156631 marked D and E on DP 156631 in favour of Her Majesty the Queen created by Certificate C312160.2 - 9.10.1991 at 1:39 pm

Subject to a conservation covenant under Section 77 of the Reserves Act 1977 as specified in Certificate C312160.2 (affects part Lot 2 DP 170525 and part Section 2 SO 472393) - 9.10.1991 at 1:39 pm

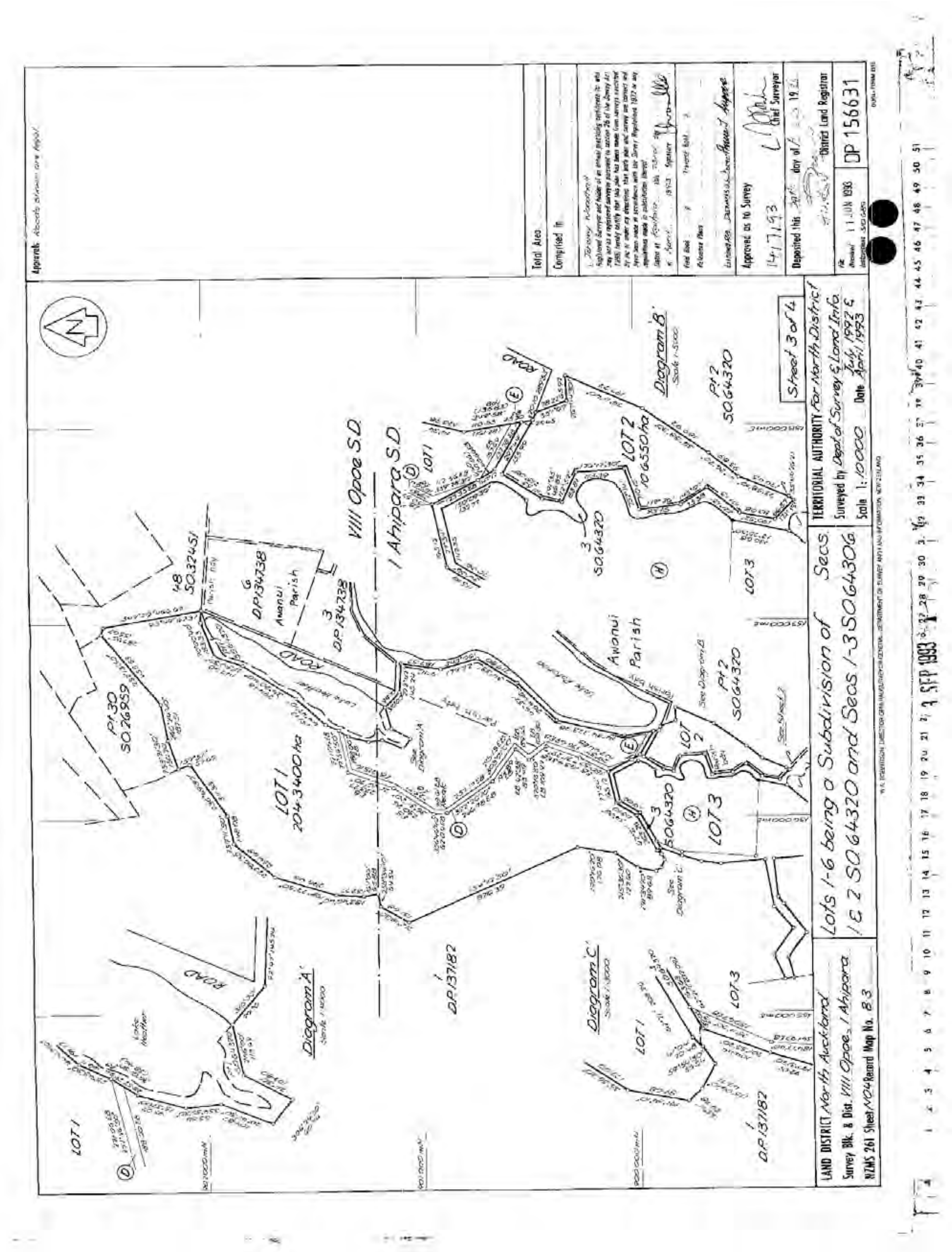
Subject to a right to convey water over part Lot 1 DP 170525 marked L and N on SO 64320 created by Certificate C312160.2 - 9.10.1991 at 1:39 pm

Subject to a right of way over part Section 2 SO 472393 marked AA on SO 472393 created by C936254.1 - 19.12.1995 at 1.48 pm

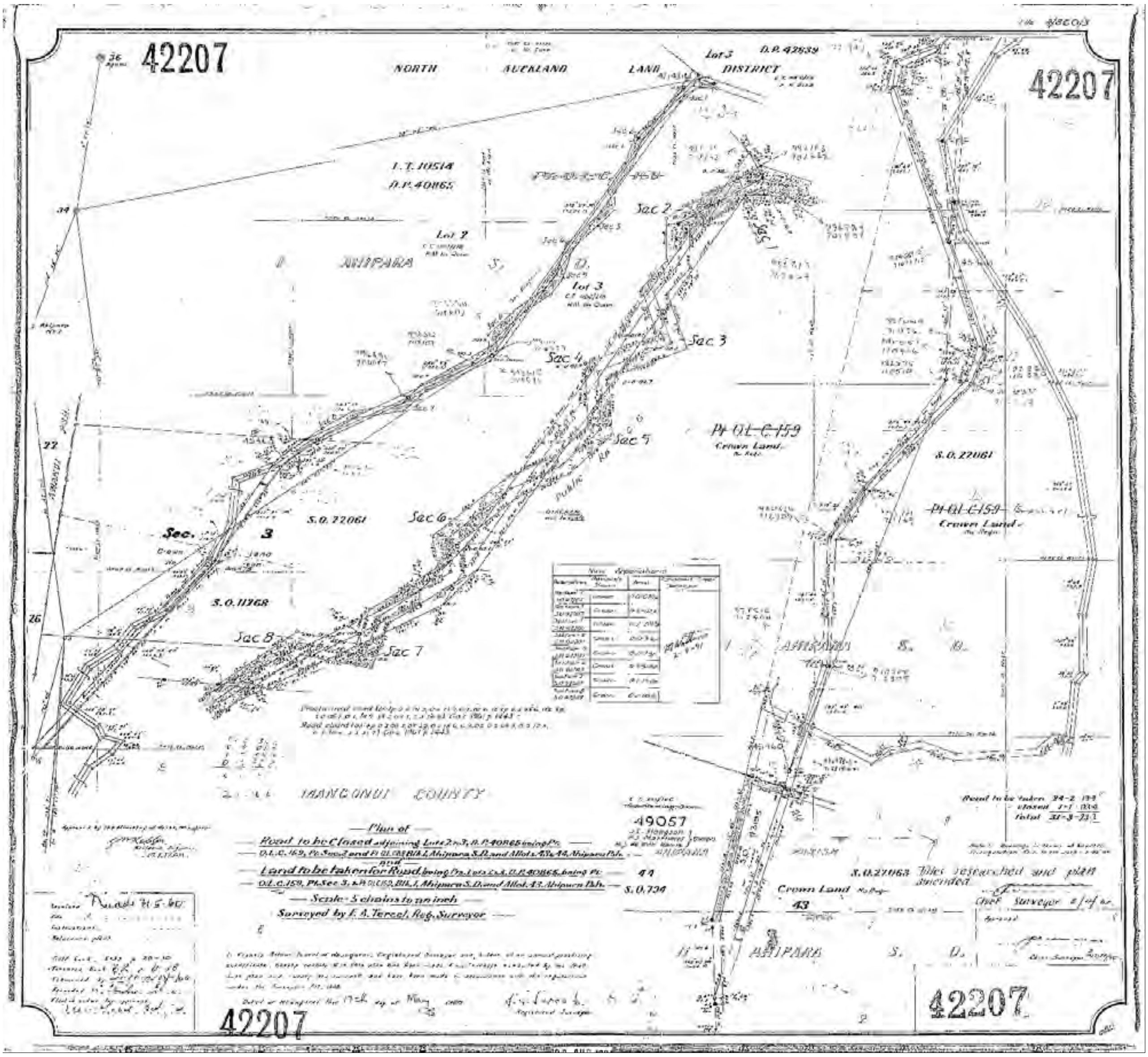
8220253.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 9.7.2009 at 9:00 am (affects parts of Section 2 SO 472393 and part Lot 2 DP 170525)

Subject to Section 11 Crown Minerals Act 1991

Identifier **719746**



Identifier **719746**



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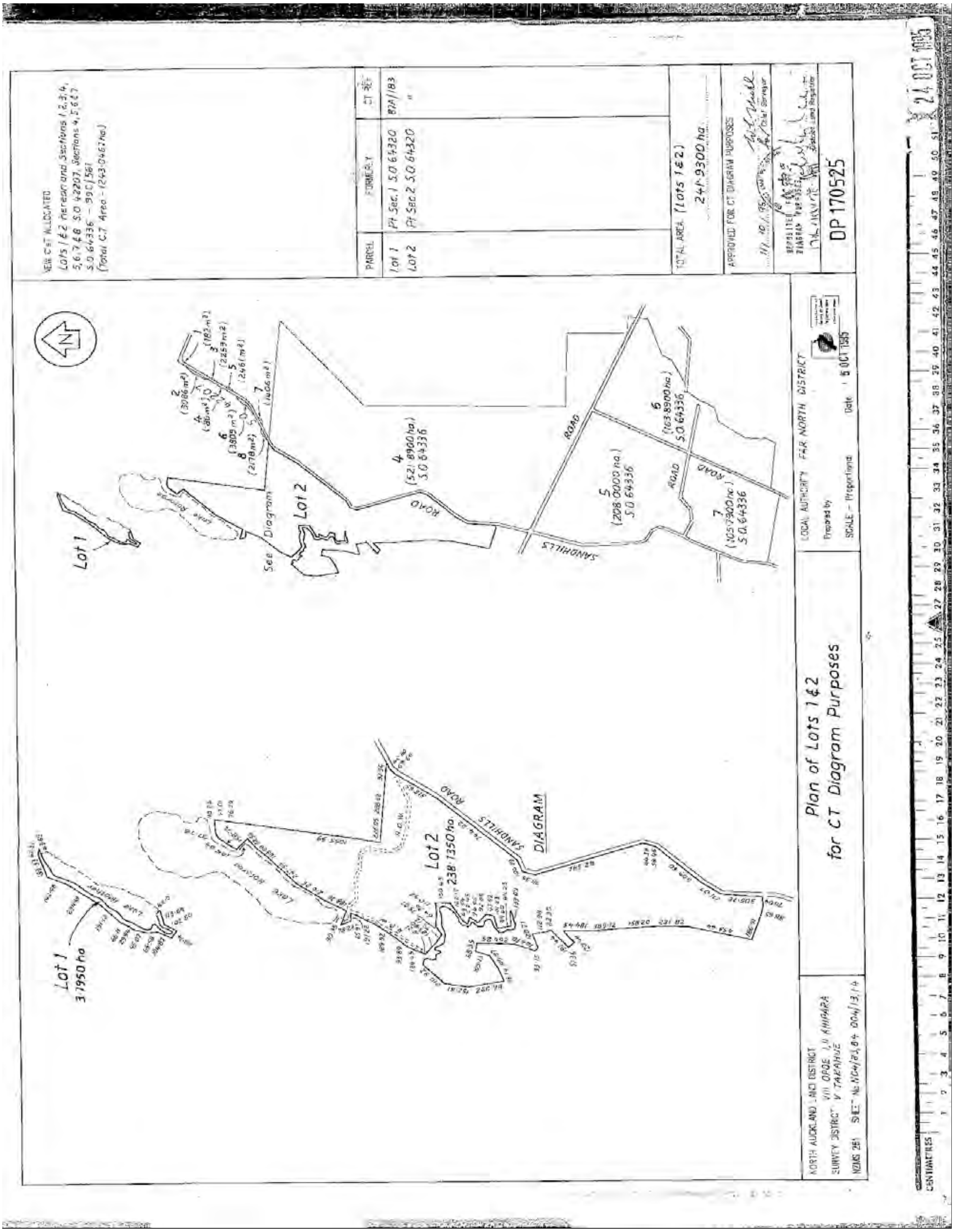
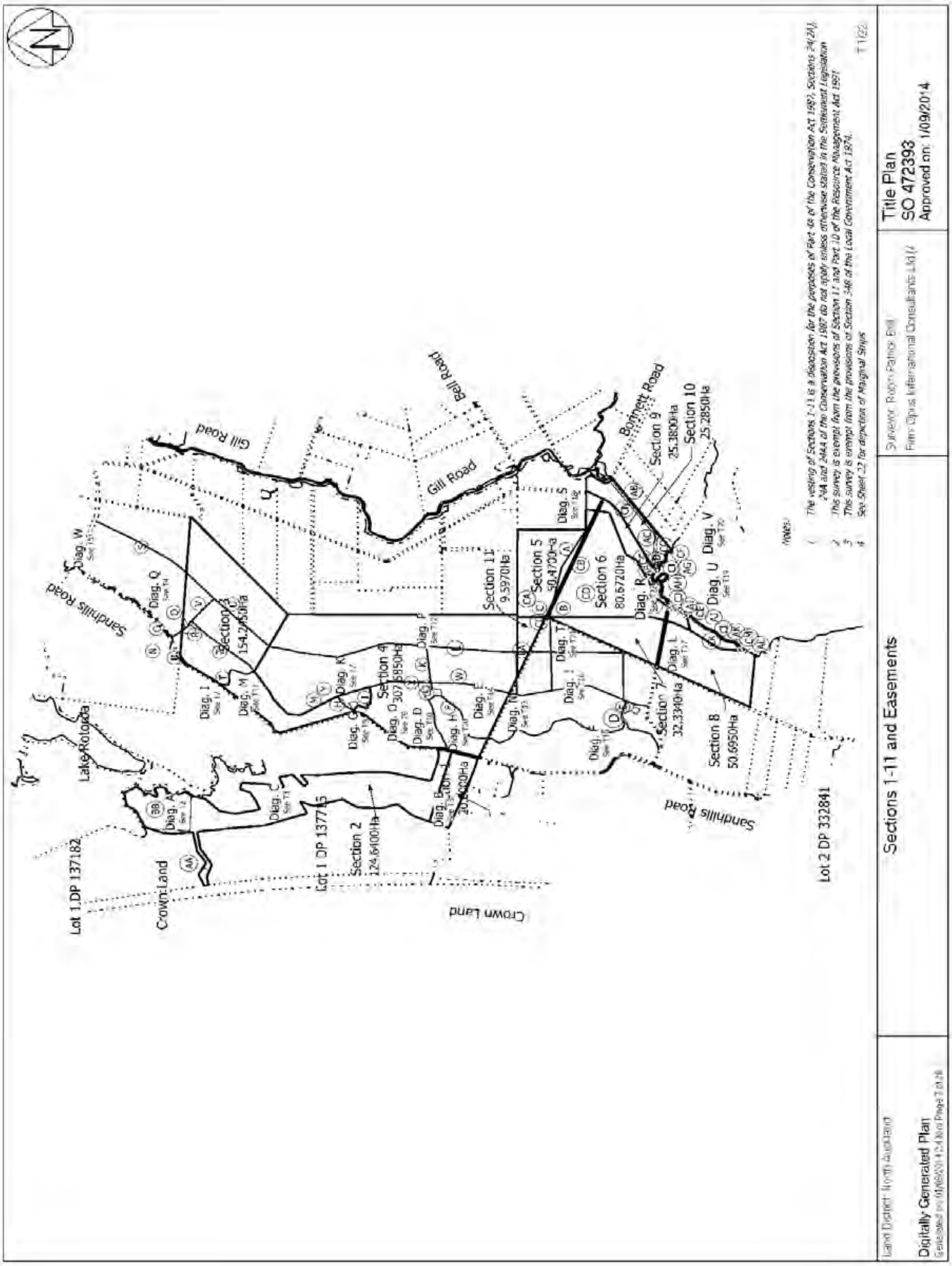
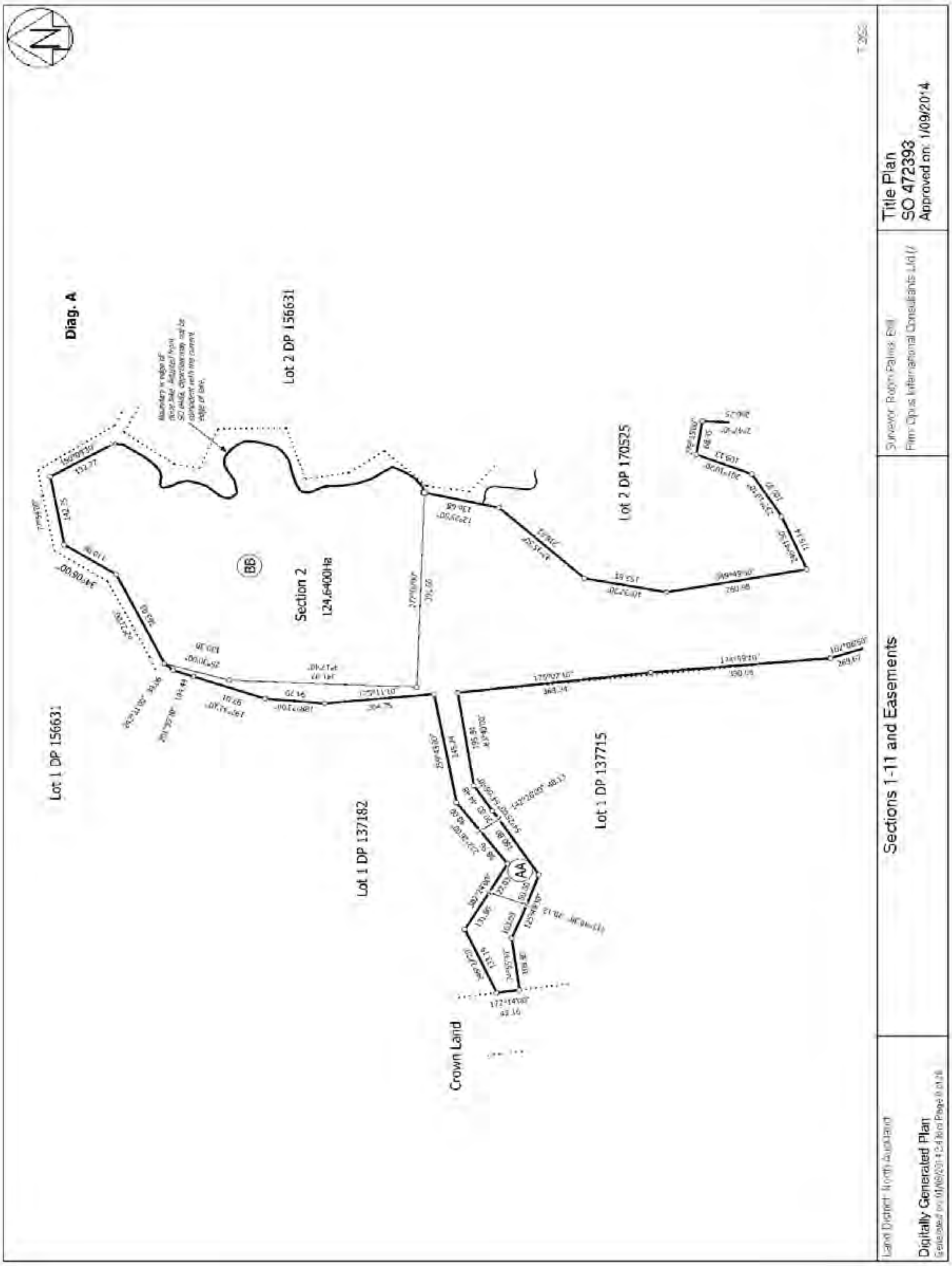
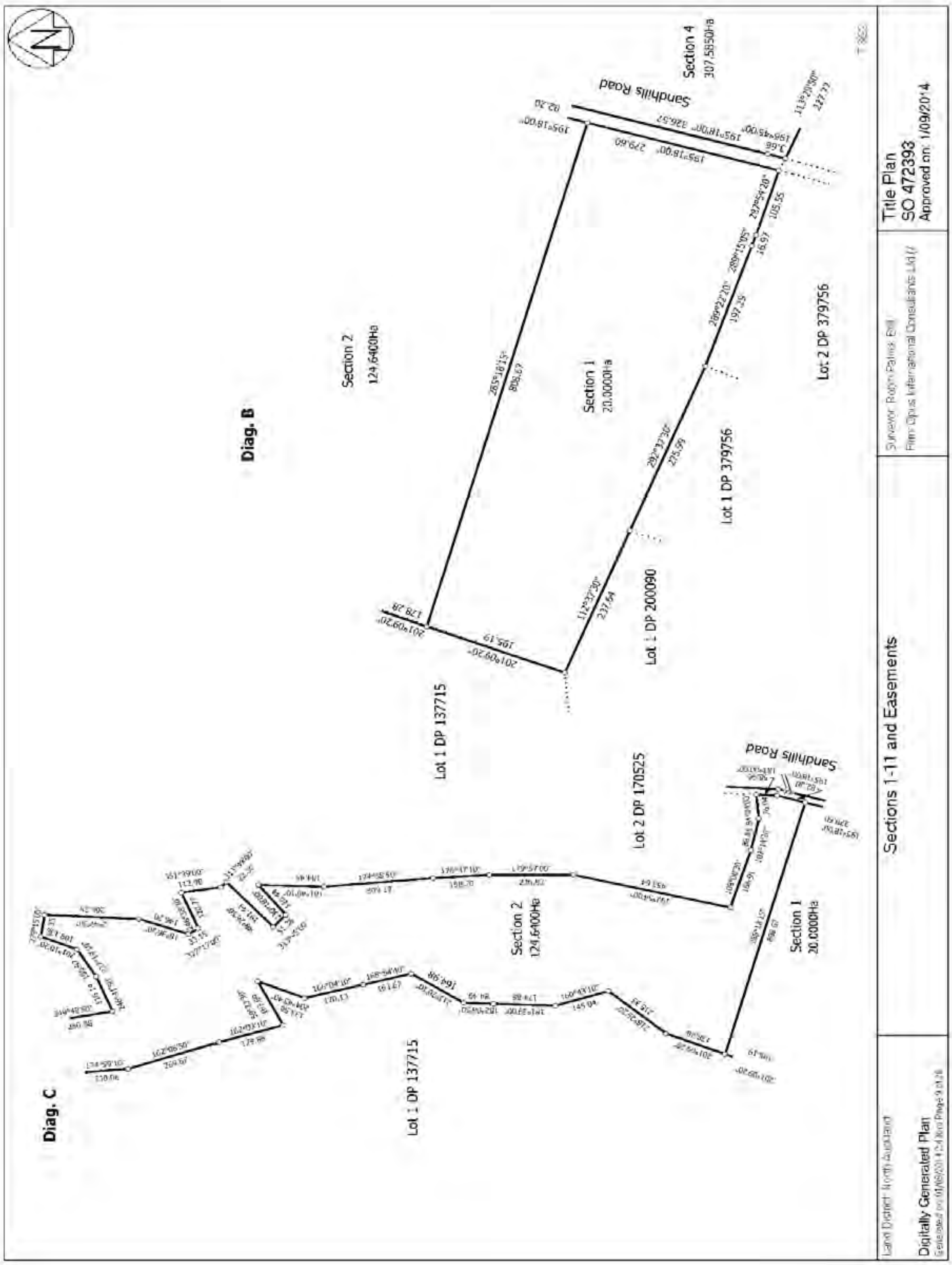


Identifier **719746**

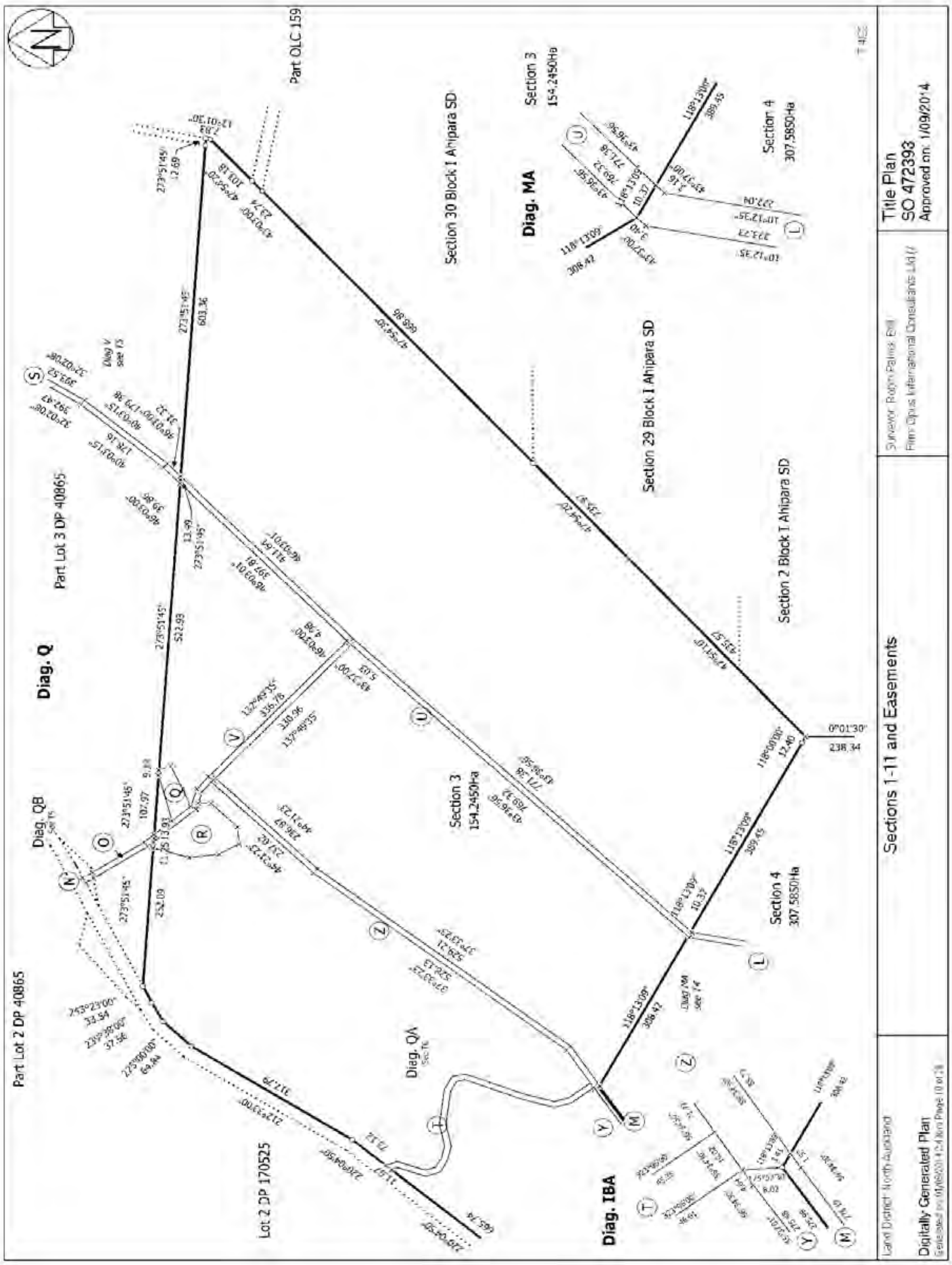



Title Plan
SO 472393
Approved on: 1/09/2014
Sections 1-11 and Easements
Land District: North Auckland
Digitally Generated Plan
Diag. A
Lot 2 DP 156631
Lot 1 DP 156631
Section 2
124.6400Ha
Lot 2 DP 170525
Lot 1 DP 137182
Lot 1 DP 137715
Crown Land
AA
BB

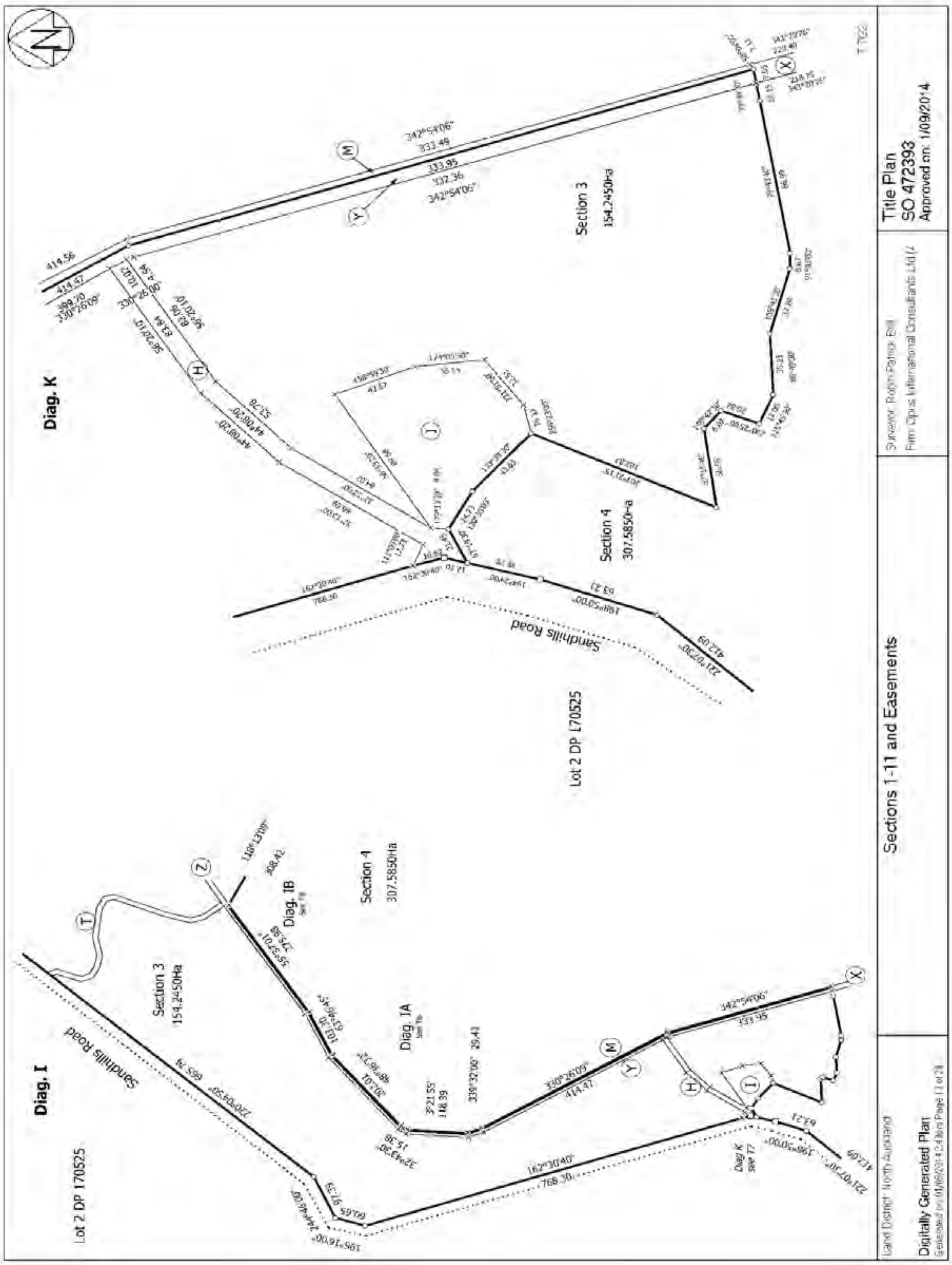
Identifier **719746**



Identifier **719746**



Identifier **719746**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**719735**
Land Registration District	**North Auckland**
Date Issued	17 December 2015

Prior References
NA99C/561

Estate	Fee Simple
Area	406.4160 hectares more or less
Legal Description	Section 5, 7 Survey Office Plan 64336 and Section 7-8, 11 Survey Office Plan 472393

Registered Owners
Te Waka Pupuri Putea Trust

Interests

Subject to Section 8 Atomic Energy Act 1945

Subject to Section 3 Geothermal Energy Act 1953

Subject to Sections 6 and 8 Mining Act 1971

Subject to Section 3 Petroleum Act 1937

Subject to Sections 5 and 261 Coal Mines Act 1979

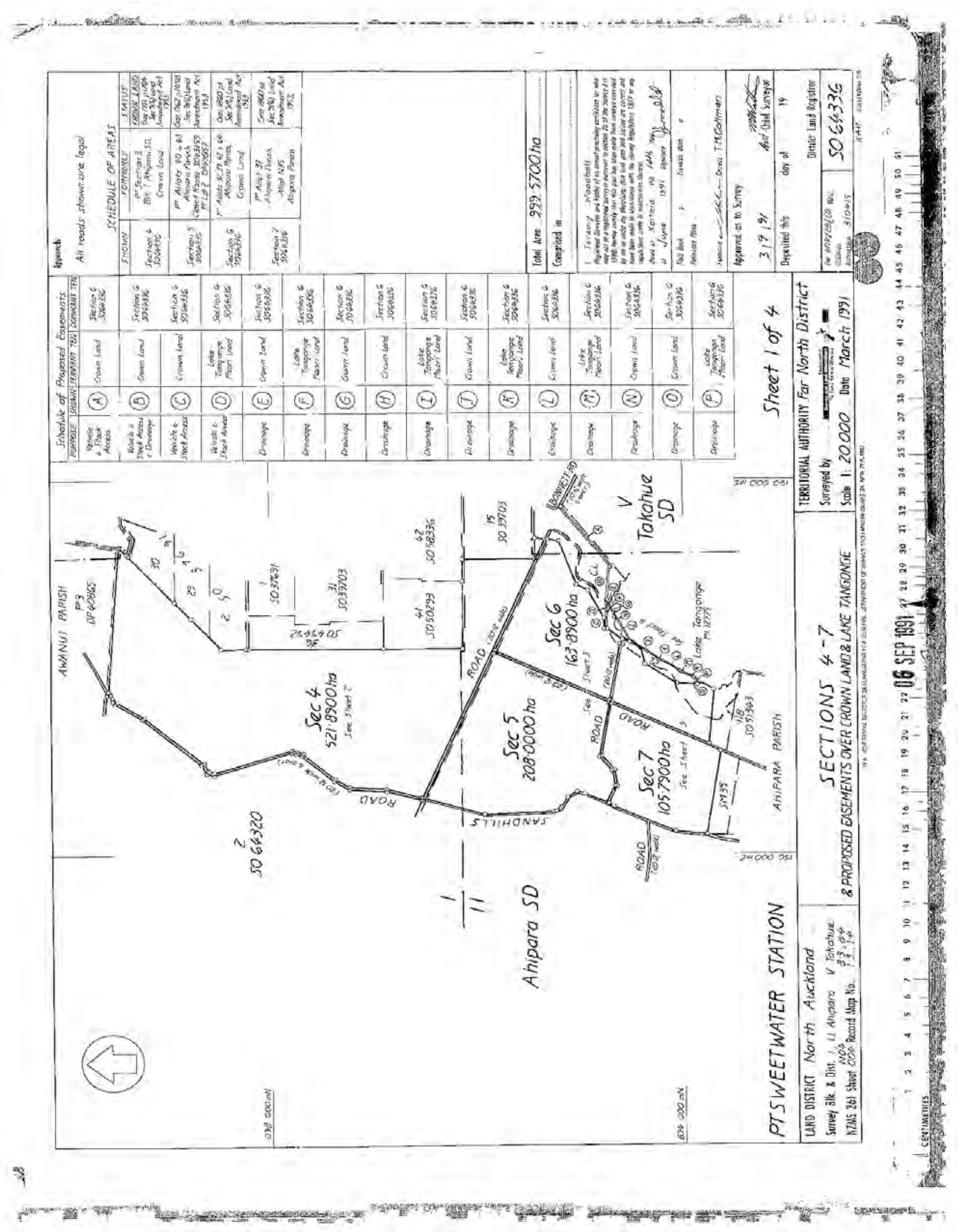
Subject to Part IV A Conservation Act 1987 (but sections 24(2A), 24A and 24AA of that Act do not apply)

Appurtenant to Sections 7 and 8 both on SO 472393 is a right of way and a right to drain water created by Certificate C312160.2

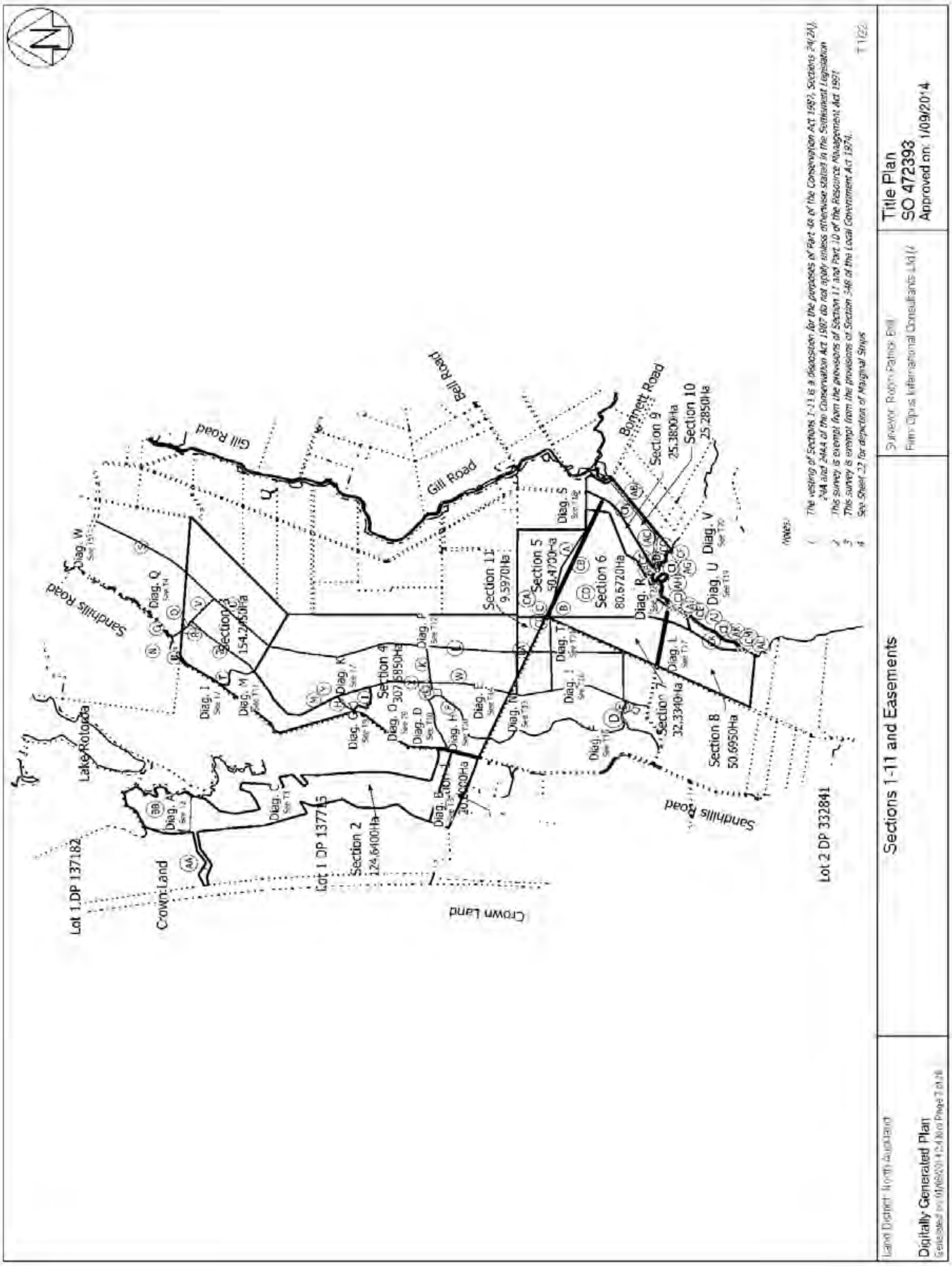
7867065.1 Open Space Covenant pursuant to Section 22 Queen Elizabeth The Second National Trust Act 1977 - 4.7.2008 at 9:00 am (affects Sections 5 and 7 both on SO 64336)

Subject to Section 11 Crown Minerals Act 1991

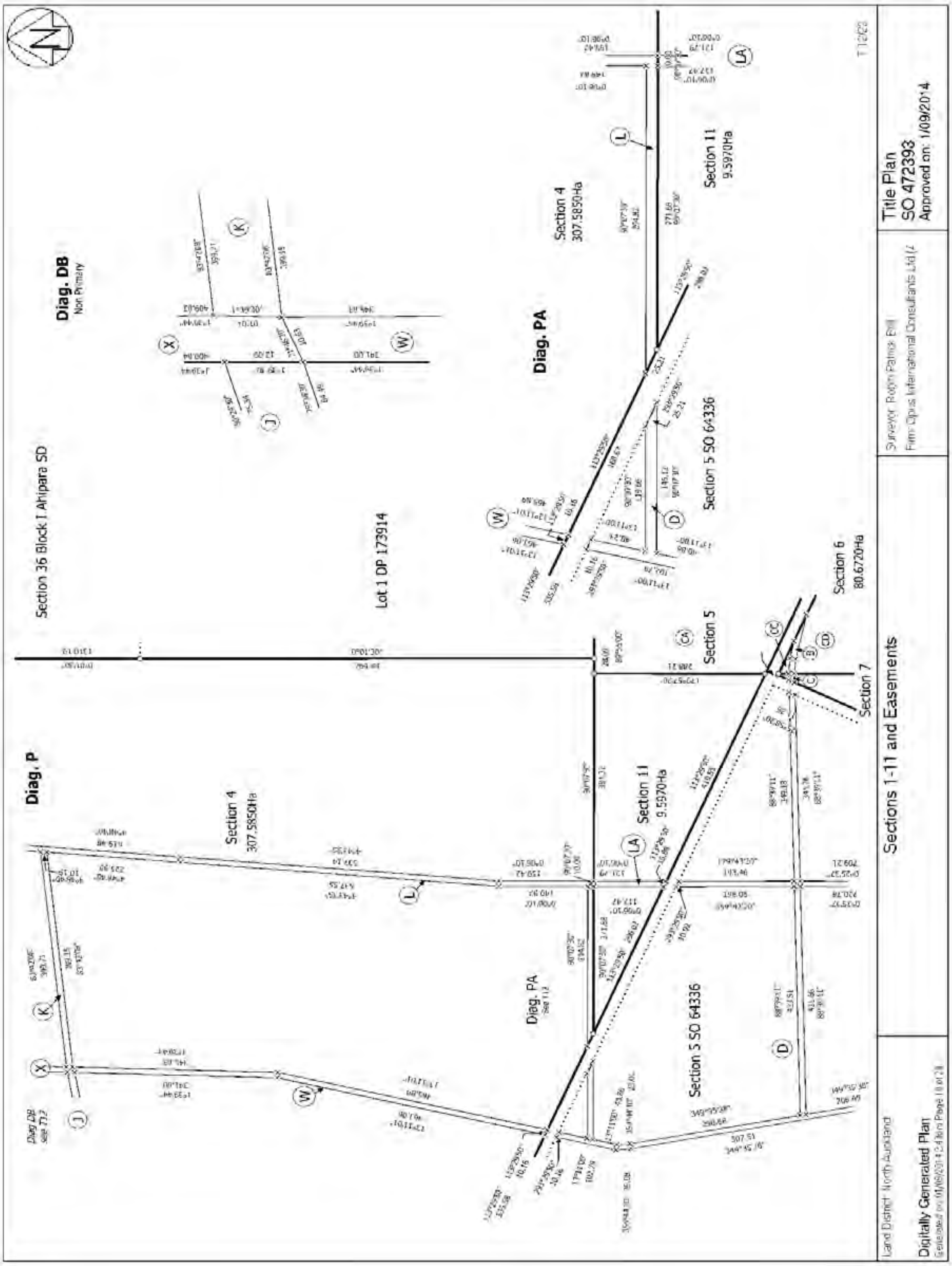
Appurtenant hereto is a right of way created by Easement Instrument 10388054.2 - 6.4.2016 at 7:00 am


PT SWEETWATER STATION
SECTIONS 4-7
& PROPOSED EASEMENTS OVER CROWN LAND & LAKE TANGONGE
LAND DISTRICT North Auckland
TERRITORIAL AUTHORITY Far North District
Scale 1: 20,000 Date March 1991
Sheet 1 of 4
SO 64336
All roads shown are legal
SCHEDULE OF AREAS
Schedule of Proposed Easements
Total Area 999·5700 ha
Sec 4 521·8900 ha
Sec 5 208·0000 ha
Sec 6 163·8900 ha
Sec 7 105·7900 ha
Ahipara SD
Takahue SD
AWANUI PARISH
AHIPARA PARISH
SANDHILLS ROAD
BONNETT RD
Lake Tangonge
06 SEP 1991

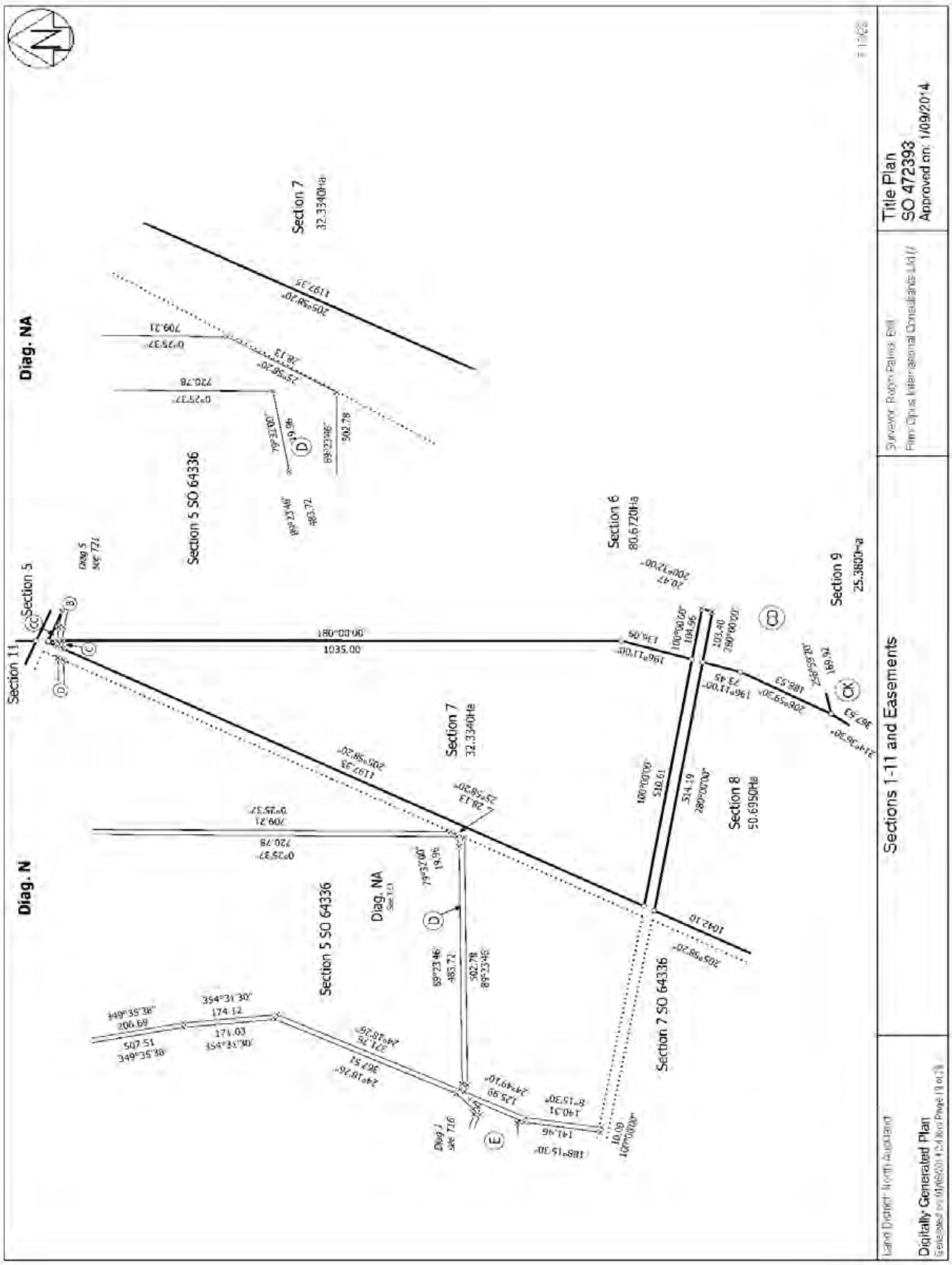
Identifier **719735**



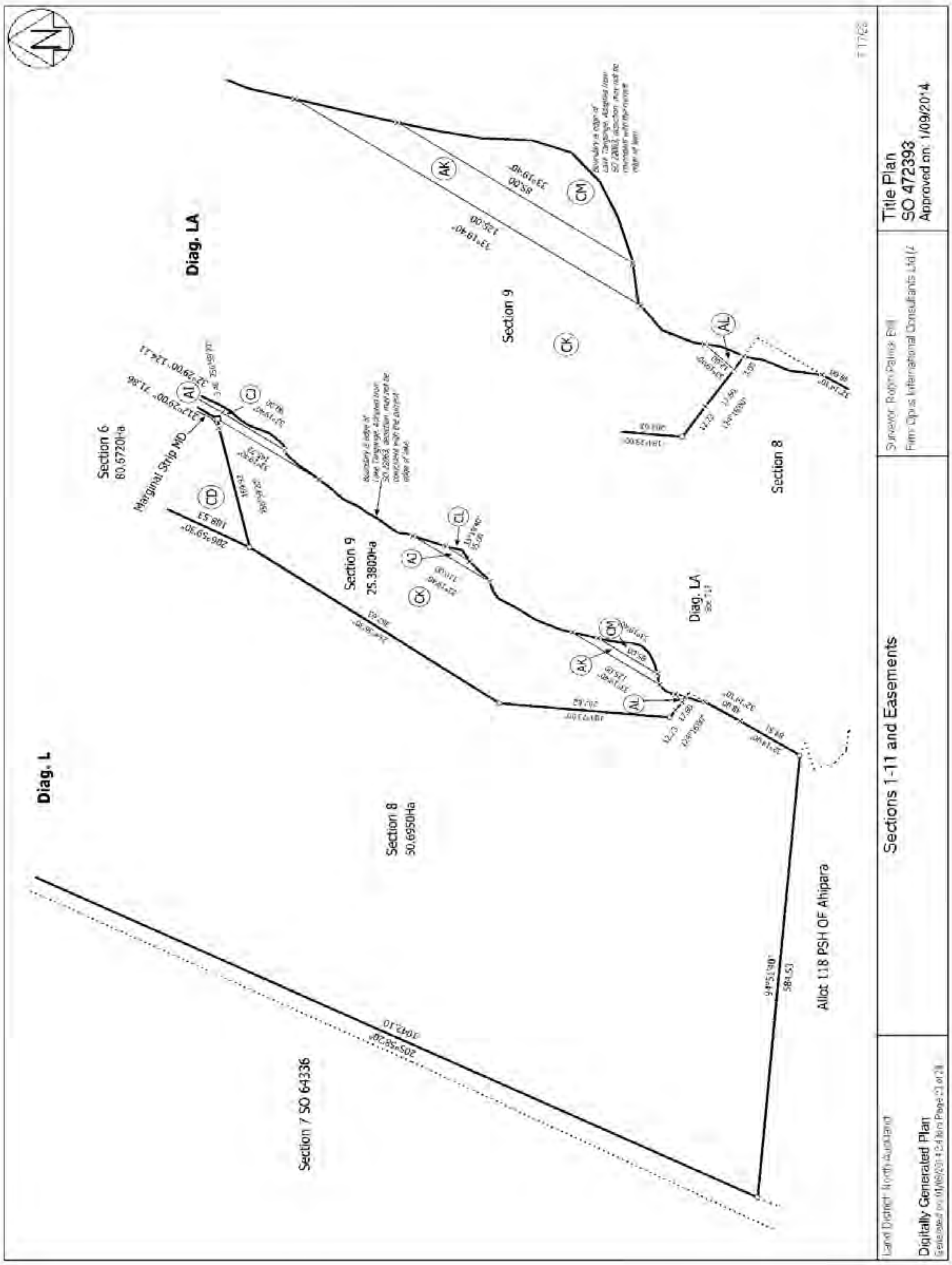
Identifier **719735**



Identifier **719735**



Identifier **719735**



RECORD OF TITLE
UNDER LAND TRANSFER ACT 2017
FREEHOLD

Guaranteed Search Copy issued under Section 60 of the Land Transfer Act 2017

R.W. Muir
Registrar-General
of Land

Identifier	**465298**
Land Registration District	**North Auckland**
Date Issued	03 April 2009

Prior References
NA694/27 NA75C/305

Estate	Fee Simple
Area	52.9200 hectares more or less
Legal Description	Lot 1 Deposited Plan 416984

Registered Owners
Te Waka Pupuri Putea Trust

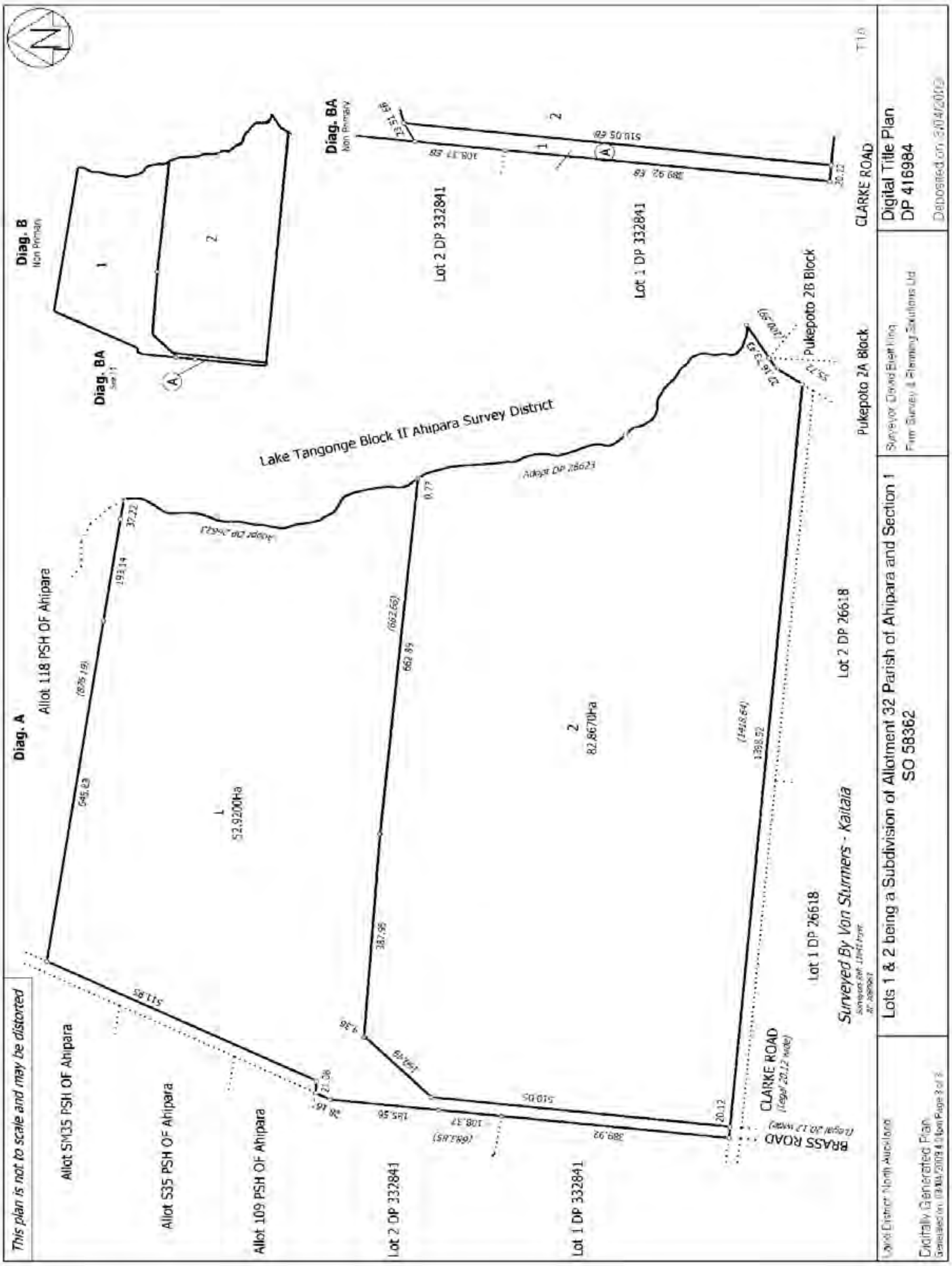
Interests

8123521.1 Consent Notice pursuant to Section 221 Resource Management Act 1991 - 3.4.2009 at 9:14 am

Subject to a right of way and a right to convey electricity and telecommunications over part marked A on DP 416984 created by Easement Instrument 8123521.3 - 3.4.2009 at 9:14 am

The easements created by Easement Instrument 8123521.3 are subject to Section 243 (a) Resource Management Act 1991

Identifier **465298**



Appendix D
Aupouri Aquifer Groundwater Model Factual Technical Report – Modelling, Williamson Water & Land Advisory Ltd, 21 March 2019

Appendix D Aupouri Aquifer Groundwater Model Factual Technical Report – Modelling, Williamson Water & Land Advisory Ltd, 21 March 2019

Appendix D

Aupouri Aquifer Groundwater Model

Factual Technical Report - Modelling

WILLIAMSON WATER & LAND ADVISORY
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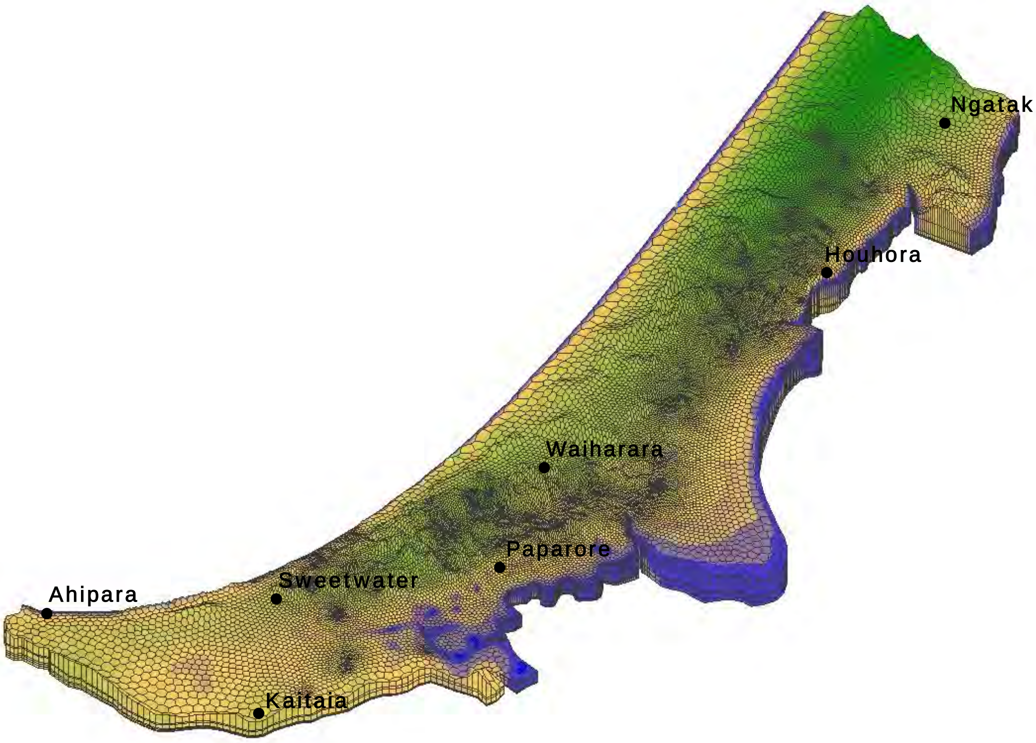

Aupouri Aquifer Groundwater Model

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Executive Summary

Williamson Water & Land Advisory (WWLA) has undertaken the development of a numerical groundwater model for the Aupouri Aquifer, a shellbed aquifer located on the Aupouri Peninsula of Northland, New Zealand. The purpose of developing the Aupouri Aquifer Groundwater Model (AAGWM) was for evaluating the sustainability of proposed groundwater allocations. To facilitate this, the model compiles all existing information relating to hydrogeological conditions and water use on the Aupouri Peninsula.

The model was developed using the MODFLOW Unstructured Grid (MODFLOW-USG) developed by the United States Geological Survey (USGS) within the GMS10.2 modelling platform.

A conceptual model framework was developed based on a review of 198 bore logs within the model area. Bore logs were interpreted to characterise materials within a basic stratigraphic framework. Four primary layers were identified with their base elevations interpolated between the bore locations. The primary geologic layers used in the model are interbedded dune sand, weathered sand, peat and clay as an upper layer, followed by an upper shellbed, a layer of compact sand, and a lower shellbed. The shells beds comprise the primary aquifer in the model. The lower model boundary was determined by interpolating the elevation where basement rock was encountered as noted in bore logs.

The upper layer of the model was sub-divided into three layers to account for surface conditions and heterogeneity within the material. The upper model layers were classified into coastal sand, weathered sand, and clay/peat, based on soil types.

Climate data and water use data were evaluated to develop a time series data set for groundwater recharge and groundwater pumping.

Time series observations of groundwater levels were available from 56 bores. This data was the basis for model calibration. A steady state model was first calibrated to determine an initial estimate of parameter values and initial conditions for the transient model.

The model was calibrated in both steady state and transient modes, with the most weight given to transient calibration as this reflects long term temporal change. The mean of the RMSE for all gauges was 1.89 m, which is 7.1% of the observed range in groundwater head (26.5 m), while the RMSE for all groundwater level measurements used for model calibration was 2.10 m, or 7.9 % of the range of observations. A simulated RMSE of less than 10% of the measured range is considered a good calibration so both analysis criteria meet this standard. Temporal variability in groundwater levels was well simulated throughout the model while there was, in some cases, a discrepancy between simulated and observed groundwater elevation.

This report documents the methodology applied in the development of the AAGWM and presents the factual results of this modelling study.

1. Introduction

Williamson Water & Land Advisory (WWLA) has undertaken the development of a numerical groundwater model for the Aupouri Aquifer, a shellbed aquifer located on the Aupouri Peninsula of Northland, New Zealand. The purpose of developing the Aupouri Aquifer Groundwater Model (AAGWM) was for evaluating the sustainability of proposed groundwater allocations. To facilitate this, the model compiles all existing information relating to hydrogeological conditions and water use on the Aupouri Peninsula.

The Aupouri aquifer is managed by the Northland Regional Council and is divided into 10 allocation zones for management purposes, with the total amount of groundwater available for pumping within each management zone based on 15% of estimated total recharge for the given zone. The process of developing the AAGWM has entailed an assessment of both natural conditions and management practices related to the following aspects of the model area:

- Geologic and hydrogeologic conditions;
- Climate records over the past 60 years;
- Aquifer recharge based on rainfall and ground cover;
- Current and historic groundwater use;
- Surface water, including lakes, streams, and agricultural drains; and
- Coastal conditions with regard to ongoing or potential saline intrusion into the aquifer.

Consideration of these aspects of physical conditions within the Aupouri Peninsula were the basis for developing a conceptual framework that was used as the basis for the numerical model. A transient simulation of groundwater levels was calibrated to data from monitoring piezometers located within the model area. The resulting hydrological parameters were then considered in comparison to previous studies and known characteristics of the predominant materials that comprise the model domain. The calibrated model was then used to quantify the water balance for the entire Aupouri aquifer, making the model a tool that can be used to evaluate changes in the water balance that may result from management proposals or variability in climate.

This report is a comprehensive documentation of the methodology applied in the development of the AAGWM and presents the factual results of this modelling study. **Figure 1** presents the location of the model area and NRC groundwater management zones.

Figure 1. Project locality map. (See A3 attachment at rear).

1.1 Report Structure

The structure of this technical report is as follows:

- **Section 2** provides an overview of the conceptualisation of the groundwater flow model
- **Section 3** details the model construction and configuration.
- **Section 4** details the calibration of the steady-state and transient models**.**
- **Section 5** provides a summary of the key findings and conclusions of this project.

2. Model Conceptualisation

This section describes the conceptualisation of regional hydrogeological conditions and the methods applied in representing these conditions in the numerical groundwater flow model.

2.1 Soils

The western to central part of the project area is predominately comprised of sandy brown soils. Along both coastal strips there are coastal dunes, which are unconsolidated and windblown with little to no soil development and are excessively drained.

The eastern area is mixed with a variety of peat, sand and pockets of clay soils. The prevalent soils in the eastern areas are loamy peat and peaty sand. The loamy peat soils are organic, characterised by high water available capacity and low bulk density. The peat in these soils is moderately decomposed.

The peaty sand soils are pan podzols, which have cemented pans within the B horizon and have naturally low fertility and low permeability, limiting root depth.

It is interesting to note that most boreholes display units of peat and iron pan at multiple depths, suggesting the sand dune sequences have shifted in location and hence are highly dynamic through geological time.

Long-time local farmers and orchard developers provided the following anecdotal information on iron pans:

- “The iron pans vary in both thickness and number of layers” (pers. com. Stanisich, Broadhurst, Hayward).
- “There are multiple layers of pan at varying depths and our pan breaking for planting rows only seems to create vertical drainage at the top” (pers com. McClarnon).
- “Monitoring of bores screened in different zones during test pumping often show no effect at shallower levels to the pumping bore, indicating some separation of zones” (pers. com. Stanisich, Hayward).
- “From bore logs, iron pans are often recorded as consolidated brown sands. However, these may not be the only confining layers. Consolidated mica sands and silts are also good barriers” (pers. com. Stanisich).

2.2 Geology

The geology of the Aupouri Peninsula consists of Pleistocene and Holocene unconsolidated sedimentary materials deposited in beach and dune (abandoned shorelines and marine terraces) and associated alluvial, intertidal estuarine, shallow marine, lakebed and wetland environments.

The geologic units in the model domain were identified through the available bore logs sourced from NRC. The sediments near the surface typically comprise fine-grained sands, interspersed with sporadic iron pan, peat, lignite, silt, gravel and shellbeds.

With distance inland from the coast, the sand deposits become progressively older and have a higher degree of compaction and weathering compared to the younger foredune sands located at the coast.

With increasing depth, the occurrence of shellbed layers increases. The shellbeds comprise layers that typically range in composition from 30-90% medium to coarse shell and 10-70% fine sand. The shellbed aquifer typically resides from approximately 70 to 120 mBGL and is the most prolific water yielding aquifer in the region and hence the target for irrigation bores.

Underlying the shellbed aquifer are basement rocks of the Mount Camel Terrain, which typically comprise hard grey to dark green / black igneous rocks described in Isaac (1996) as intercalated basalt and basaltic andesite lava, pillow lava, rhyolitic tuff, tuff-breccia, with sedimentary deposits of conglomerate, sandstone and mudstone also present.

Drilling data from bores in the Aupouri aquifer indicates that the sedimentary sequence can be broadly classified into two lithological units. The upper bulk layer comprises the fine-grained sands, interspersed with iron pan, peat, lignite, and silt. The lower layer comprises mostly shellbeds, although recent drilling has identified the existence of two discrete shell units separated by a thin fine sand or silt layer, hence the lower layer is sub-divided into three distinct layers. The lithological unit classification developed for this study is exemplified in **Figure 2A** and **Figure 2B** using three reliable bore logs, and is described as follows:

- ***Layer 1 – Sand / Silt.*** A sequence of predominately unconsolidated fine sand intersperses with discontinuous layers of alternating iron pan, silt and peat. The layer varies in thickness from approximately 45 m to 110 m with the thickest regions located around the model area peak elevations.
- ***Layer 2 – Upper Shellbed.*** A sequence of shellbeds comprising medium to coarse shell with some fine sand in the matrix. The proportion of shell typically varies from 30% to 90%. The layer is typically encountered at a depth of 60 - 110 mBGL and varies in thickness from typically 5 m - 15 m.
- ***Layer 3 – Sand.*** A thin layer of finer sediment separating the upper and lower shellbed.
- ***Layer 4 – Lower Shellbed.*** A sequence of shellbeds typically comprising a higher proportion of shell with coarser grain size than the upper shellbed. In some locales, the shell is more consolidated and described by drillers as shell rock. Drillers also report circulation losses when drilling this formation. The layer is typically encountered at depths of 80 - 145 mBGL and varies in thickness from typically 5 m - 30 m.

Honey Tree Farm Bore
(Drilled on 20 June 2016)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	1	Brown pan	
1	4	Brown sands	
4	5	White/green sands	
5	8	Brown sands	
8	22	Grey/brown Sands	
22	37.6	Very fine green/grey sands	Layer 1 - Sand/Silt
37.6	38.4	Brown silt	
38.4	40.1	Grey silt	
40.1	42.2	Fine brown/grey sands	
42.2	47	Green/grey sandy silts	
47	58	Green sandy silt- some shell	
58	58.9	Cemented black sand	
58.9	60	Shellbed 40% shell	
60	65	Shellbed 70% shell	
65	68	Coarse shells, gravels	Layer 2 - Upper Shellbed
68	72.6	80% shell/coarse gravel 30mm	
72.6	72.8	Silty sand	
72.8	82	Fine sands, some shell	Layer 3 - Sand
82	83	10% shell/ sand	
83	110	Consolidated shell - soft shell - rock	Layer 4 - Lower Shellbed
110.3	110.7	Grey soft rock	
110.7	111.6	Harder black rock	

Mapua Orchard Bore
(Drilled on 19 April 2017)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	6	Brown dune sands	
6	12	Green/grey sands	
12	15	Black sandy peat/silts	
15	24	Fine grey sands	
24	25	Brown organic silts	
25	28	Brown fine sand, silica	
28	29	Peat/timber	
29	40	Silica sands/brown sands	
40	44	Fine grey sands/silica	Layer 1 - Sand/Silt
44	47	Brown sands/organic silts	
47	48.5	Grey sandy silt	
48.5	60	Clean fine grey sands, Mica	
60	62	Grey sands, flecks of organics	
62	82	Dark grey sands, some black sand	
82	83.2	Fine black/grey sand	
83.2	86	30% Medium shell	
86	87	50% Medium shell	
87	91	60% Medium shell	
91	94	Fine sand, traces of shell	Layer 2 - Upper Shellbed
94	97	60% Medium/ coarse shell, a few lenses of silt. Balance sand	
97	98	50% M/c blk shell	
88	99	60% M/c blk shell	
99	101	90% Medium/coarse black shell	
101	102	Fine grey sand	Layer 3 - Sand
102	103	90% Coarse blk shell	
103	104	70% Coarse blk shell	
104	105	50% Coarse blk shell	
105	106	25% Coarse blk shell	
106	107	40% Coarse blk shell	Layer 4 - Lower Shellbed
107	108	30% Coarse blk shell	
108	110	Fine grey sand, shell fragments	
110	111.4	30% Coarse shell	
111.4	112	Dark grey rock	

Largus Orchard Bore
(Drilled on 12 April 2017)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	1	Golden dune sand	
1	4.5	Peat and timber	
4.5	18	Brown/green fine sands	
18	42.7	Grey/white sands	Layer 1 - Sand/Silt
42.87	45.5	Firm grey sandy silts	
45.5	47	Brown peaty silts	
47	53	Brown/grey fine sands	
53	63	Green/grey fine sands, some thin bands fine gravel	
63	67.5	Sandy silt, flecks of shell	
67.5	68.5	Cleaner silt, shell	
68.5	73	Grey silt	
73	74.1	Cleaner sand, shell	
74.1	76	60% Coarse shell	
76	77	20% Coarse shell	
77	78	50% Coarse shell	
78	80	20% Coarse shell	
80	83	70% Coarse shell	Layer 2 - Upper Shellbed
83	84	50% Coarse/med shell	
84	86	50% Medium shell	
86	88	30% Medium shell	
88	89	50% Medium shell	
89	91	30% Medium shell	
91	93.6	50% Coarse/med shell	
93.6	93.8	Light green silt	Layer 3 - Sand
93.8	105	Firm, clean, grey/white shell rock	Layer 4 - Lower Shellbed
105	106	Softer mushy shell rock	
106	107	Clean firm shell rock	
107	110.9	Softer mushy shell rock	

Figure 2A. Lithological unit classification from example borelogs.

Valic-1
(Drilled on 16 August 2006)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	1	Fine sand-brown	Layer 1 - Sand/Silt
1	2	Fine sand-dark brown	
2	4	Fine sand-light brown/grey	
4	6	Fine sand-light orange/brown	
6	13	Fine sand-light orange/brown. Trace organics	
13	15.5	Fibrous peat with wood/roots. Black	
15.5	18	Fine sand-dark brown/grey. Siliceous. Trace mica	
18	20	As above-becoming greyish brown	
20	26	Fine sand-dark brown/grey. Siliceous. Trace mica	
26	29	Amorphous peat, dark brown/black	
29	33	Fine sand, dark brown/brownish grey	
33	45	Fine sand, dark brown/brownish grey. Minor medium to coarse sand (quartz/silica). Trace mica	
45	52	Fine to medium sand-grey	
52	56	Medium sand, greyish brown. Minor coarse sand quartz/silica and mica	
56	62	Fine sand-orange brown	
62	67	Fine sand as above becoming grey	
67	68	Fine-med brown	
68	75	Fine sand , greenish grey, glauconitic, siliceous, minor mica	
75	83	Fine sand-greenish grey with minor mica; glauconitic, siliceous	
83	85	Fine sand as above. Trace fine shell	
85	86	As above, coarser shell	Layer 2 - Upper Shellbed
86	88	Fine grey sand. Coarse shell up to 40%	
86	90	Fine sand. 10% Coarse shell	
90	93	Silty fine sand with marine mud. Trace fine to coarse shell	Layer 3 - Sand
93	98	Silty fine sand with marine mud. Coarse shell 10-40% increasing with depth	Layer 4 - Lower Shellbed
98	100	Coarse granular shell (65%) with fine grey	
100	108	Fine sand, grey. 10% shell	
108	117	Fine sand, grey, trace shell	

George Ujdar Bore
(Drilled on 06 April 2006)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	5	Topsoil/brown-grey sand	Layer 1 - Sand/Silt
5	48	Brown/grey sands	
48	55	Grey sand	
55	74	Brown Sand	
74	87	Compacted grey sand	
87	92	Brown sand with peate and shell	
92	97	Coarse shell	Layer 2 - Upper Shellbed
97	101	Fine shell with fine sand	Layer 3-Sand
101	104	Coarse shell	Layer 4-Lower Shellbed
104	105	Basement rock	

Sweetwater Monitoring Well 1
(Drilled on 10 October 2007)

From (mBGL)	To (mBGL)	Lithology	Model layers
0	1	Golden dune sand	Layer 1 - Sand/Silt
1	6	Peat and timber	
6	25	Fine brown sand/silt, well sorted	
25	27	Peat	
27	30	Sandy grey silt, trace shell (fine)	
30	36	Peat, black and fibous. Sand content increasing with depth	
36	40	Well sorted fine sand, increasingly silty with depth	
40	46	Clayey sand, fine, well sorted	
46	48	Fine shell	
48	51	Peat	
51	74	Grey sand, minor silt, clay and fine to medium shell	
74	86	Shell bed with minor sand, silt, and fine to medium gravels. Shell fraction 70-90%	Layer 2 - Upper Shellbed
86	89	Sandy shell with fine medium grey sand	Layer 3-Sand
89	96	Shell bed with fine grey sand, silt. Shell fraction 30-60%	Layer 4 - Lower Shellbed
96	98	Sandstone (hard, grey-basement rock)	

Figure 2B. Lithological unit classification from example borelogs.

2.3 Aquifer Hydraulic Parameters

Groundwater is found throughout the unconsolidated sedimentary materials that occur within the model area, although these materials vary in their ability to store and transmit water, primarily due to grain size, cementation, weathering and compaction.

Test pumping and numerical modelling exercises for irrigation take resource consent applications have been undertaken over the years and summarised in the reports of HydroGeo Solutions (2000), SKM (2007a), SKM (2010), Lincoln Agritech (2015) and most recently by Williamson Water Advisory in 2017 (WWA, 2017). Data from these reports has been reproduced in tables provided **Appendix A**, and is summarised below in **Table 1** where it is presented in the context of our conceptual model as described in the previous section of this report.

Table 1. Summary of previously measured and modelled hydraulic properties for WWLA layer conceptualisation.

Unit	K_x (m/s)			S (-)		
	Min	Max	Arithmetic Mean	Min	Max	Arithmetic Mean
Layer 1 - Sand / silt	1.0×10^{-5}	1.1×10^{-4}	8.4×10^{-4}	2×10^{-2}	1.5×10^{-2}	9.6×10^{-3}
Layer 2 – Upper shellbed	2.1×10^{-4}	7.3×10^{-4}	3.65×10^{-4}	2×10^{-2}	4×10^{-4}	3×10^{-4}
Layer 3 - Sand	Assume same as Layer 1			Assume same as Layer 1		
Layer 4 – Lower shellbed	1.3×10^{-4}	7.3×10^{-4}	4.4×10^{-4}	3×10^{-4}	4.4×10^{-3}	1.6×10^{-3}

2.3.1 Perched Aquifers and Progressive Confinement

There is anecdotal evidence of localised perched water within the wetlands and lakes in the area. For example, Lake Waiparera, located near the centre of the study area has an average lake stage of 33.8 mAMSL, yet the groundwater level estimated from an adjacent bore is around 7 mAMSL.

Before the intervention of man, lake and wetland complexes that formed in dune swales were self-accentuating over time. As fine sediment was washed into the swale with stormwater runoff, bed permeability progressively decreased due to clogging, which led to widening and deepening of the wetland or lake. As this progressed, acid conditions in the wetland environment led to dissolution of metals and as the sediment substrate conditions shifted from aerobic to anaerobic (or reducing conditions) and pH became more neutral, subsequent precipitation of the dissolved metals occurred as metal hydroxides, particularly iron hydroxide. Iron hydroxide is the primary constituent of iron humus pan or iron pan, which is the main factor (along with peat and silt deposits) in restricting vertical drainage in the Aupouri aquifer.

The aquifer system is unconfined at the surface but behaves in a manner that suggests a progressive degree of confinement with depth (leaky confinement). There is no well-defined regionally extensive confining layer but there are numerous low-permeability layers (e.g. iron pan, brown (organic) sand, silt, peat) that vary in depth and thickness, which over multiple occurrences collectively provide a degree of confinement that lends to the development of vertical pressure gradients, as discussed in **Section 2.6**.

Data collected from shallow and deep monitoring bores shows strong evidence for confinement throughout the model area. The groundwater elevations measured in shallow monitoring bores are substantially higher than the deeper monitoring bores at Sweetwater Farms in the southern portion of the model, Valic Orchards in the middle, and at the Browne and Waterfront monitoring locations in the north portion of the model area. It is likely that this is due to multiple low permeability paleosols (buried iron pans), deeply buried by successive accumulations of sand (Hicks, et. al., 2001).

2.4 Recharge

The proportion of rainfall that infiltrates the soils and ultimately recharges the groundwater system is relatively large, due to the high infiltration capacity of the sandy soils.

The model used in the Aupouri Aquifer Review by Lincoln Agritech (2015) suggested an annual recharge rate of 540 mm for the dune sand beneath Aupouri Forest, which accounts for 43% of annual rainfall. In other groundwater studies for the region, the percentage of rainfall recharging the dune sands ranged from 10.4% to 43.7%, while for the floodplains the recharge range was 4.2% to 12.0% of annual rainfall (HydroGeo Solutions, 2000; SKM, 2007a; SKM, 2007b).

Climate data obtained from VCSN and select gauging stations within the model area was processed through the Soil Moisture Water Balance Model (SMWBM) to generate the groundwater recharge data set to be used for model input. For the purpose of assessing recharge, FSL soil classifications are used to divide the model area into four primary recharge zones based on permeability. The zones are coastal sand, weathered sand, plains, and peat/wetlands (**Figure 3**).

Variation in rainfall and PET across the model area was accounted for by defining four regions along the north-south axis of the model and assigning climate data from an appropriate reference location for each region. The regions, included in **Figure 3**, were referred to as North, Motutangi, Waiharara-Paparore, and South. The recharge zones were then used to determine parameter inputs for SMWBM and generate daily recharge estimates based on the distribution of rainfall across the model area as defined by the climate regions described above. Further details on the process of generating the groundwater recharge data set for use in the model are provided in **Appendix B**.

This assessment resulted in 43% of mean annual rainfall applied as recharge in the coastal sand zone, 38% for the weathered sand zones, 26% for the plains in the southern portion of the model and 10% for the peat/wetlands zones. The work of WWA (2017) has been adopted in this study and is summarised in **Table 2**.

Figure 3. Recharge zones. (See A3 attachment at rear).

Table 2. The average annual water mass balance for each recharge zone from the SMWBM.

Recharge Zone	Groundwater Recharge	Evapo-transpiration	Runoff	Description
Coastal sand zone	43%	48%	9%	Loose sand, high infiltration capacity, low surface runoff
Weathered sand zone	38%	49%	13%	Relatively more compacted sand, high infiltration capacity, reduced surface runoff
Plains zone	26%	54%	20%	Moderate infiltration capacity, medium soil moisture storage, moderate surface runoff
Wetlands/Estuary zone	10%	60%	29%	High peat content, low infiltration capacity, medium soil moisture storage, high surface runoff

2.5 Drainage

In the lower-lying farmland area, there is a man-made drainage network that typically connects to short fetch streams that discharge to the coast. The drains were installed to lower the shallow groundwater table to promote more manageable farming conditions (**Figure 4**).

Figure 4. Drainage map. (See A3 attachment at rear).

2.6 Groundwater Level Data

There are 49 reliable monitoring piezometers located within the model area. These can be grouped into three generalized areas which are identified in **Figure 5** as the northern, central, and southern piezometer groups. Many of the piezometers have a nested configuration where up to 4 piezometers are located together with screened intervals at different depths to simultaneously monitor groundwater levels across a vertical profile. The majority of monitoring piezometers used for model calibration are maintained by the NRC, however some piezometers are privately managed.

The northern piezometer group includes five multi-level piezometers constructed by the Northland Catchment Commission in the 1980s and two single piezometers that are currently maintained for groundwater monitoring purposes in the Houhora area by the Northland Regional Council, collectively defined as the Hukatere piezometer transect.

Figure 6 shows a cross-section of bore depths and static water levels in multi-level piezometers along the Hukatere transect (not-to-scale). The groundwater gradient shown from each piezometer nest is governed by the hydrogeological position of the piezometer on the landscape, i.e. within the recharge or discharge zone. For piezometers that are close to the groundwater divide (Browne piezometer) the observed vertical downward gradient indicates the occurrence of recharge from the surface to the deep aquifers. The piezometers near the coast at the waterfront showed an upward flow potential, indicating groundwater discharge to the sea.

The nested piezometers Burnage 1, 2 and 3 all consistently show similar groundwater levels. It likely that this is due to leakage within the piezometers at this location, thus, these three piezometers were excluded in the model calibration.

The central group of monitoring piezometers, shown in **Figure 7**, includes NRC monitoring bores at Ogle Drive and Paparore. The latter of these has four nested monitoring piezometers ranging in depth from 18 to 75 mBGL. There are four monitoring locations on the Valic Avocado Orchard. Each location features a monitoring bore drilled into the deep aquifer at a similar depth to the nearby production bore and an additional monitoring bore in the shallow aquifer. Vertical hydraulic gradients between the shallow and deep aquifer at the Valic Avocado Orchard range from 6 to 11 meters. By contrast the monitoring piezometers at Paparore measure a minimal vertical hydraulic gradient between the two aquifers, with a slightly greater head measured at the deeper bores relative to the shallow ones.

The southern group of monitoring piezometers are shown in **Figure 8**. The majority of these bores are managed by Sweetwater Farms, where there are 5 pairs of deep and shallow monitoring bores, as well as several additional bores where only one depth is monitored. There are also NRC operated bores at Lake Heather and several independently operated bores where water level data is available, specifically, at Vinac, Waipapa, and Welch.

A vertical downward gradient of groundwater head is evident at Sweetwater Monitoring Wells #1, #3, #4, and #5, though in the case of #4 it is likely that the shallow piezometer is measuring a perched water table based on the groundwater elevation being higher than what is measured in other shallow monitoring wells located further inland. Sweetwater Monitoring Well #2 is the only case where groundwater level measurements indicate an upward groundwater gradient.

Figure 5. Location of monitoring piezometers. (See A3 attachment at rear).

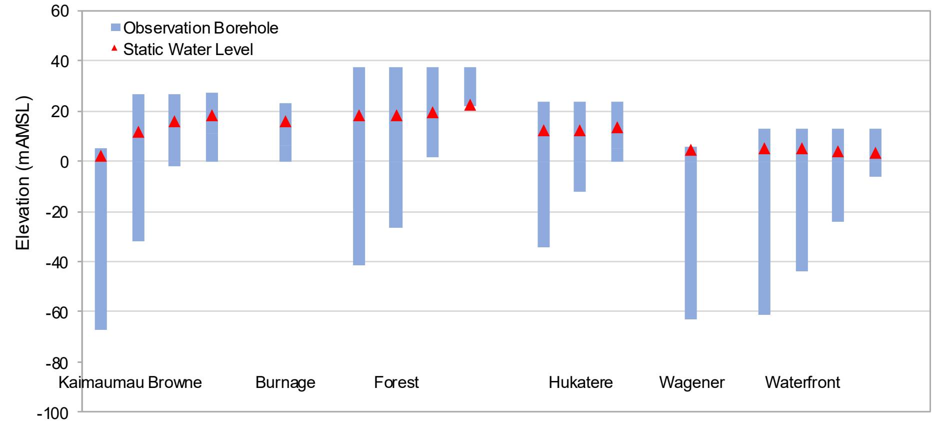

Figure 6. Mean groundwater levels of monitoring piezometers in the northern portion of the model area

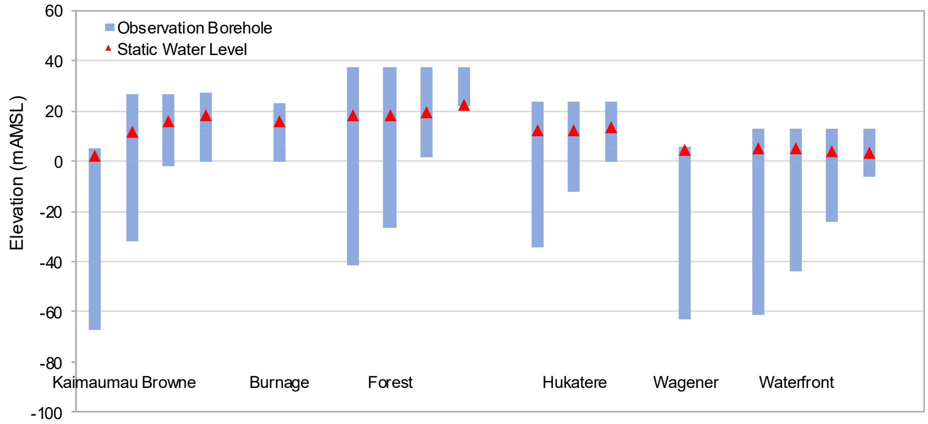

Figure 7. Mean groundwater levels of monitoring piezometers in the central portion of the model area

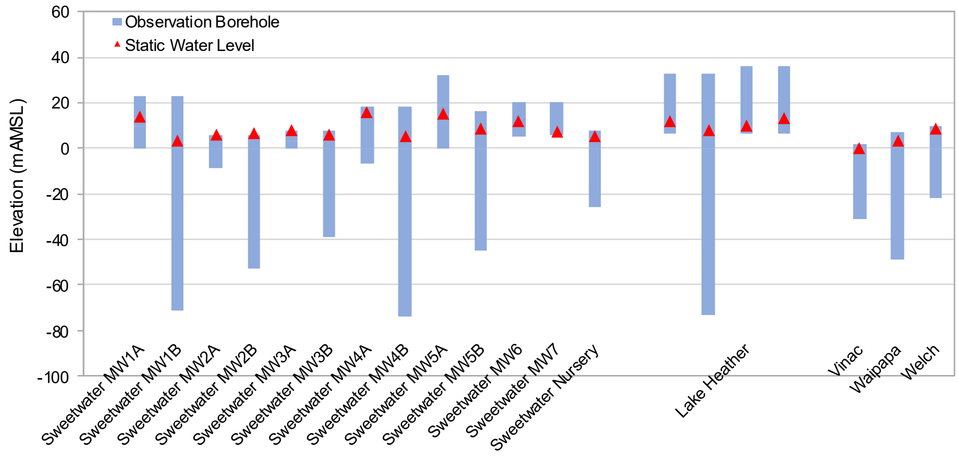

Figure 8. Mean groundwater levels of monitoring piezometers in the southern portion of the model area

2.7 Groundwater Abstraction

Figure 9 shows the location of existing and recently proposed groundwater abstraction consents.

The current level of annual groundwater abstraction from the Aupouri aquifer is 4.79x10^6 m^3/year distributed among 58 consents that are currently being exercised. Some of these consents are exercised through the operation of multiple bores.

An additional 3.13x10^6 m^3/year have been granted but are not currently being exercised. The unexercised consents include the newly granted groundwater takes for the 17 irrigators collectively known as the Motutangi Water Users Group, a portion of the water that has been allocated to Sweetwater Farms, and the Far North District Council groundwater take for Kaitaia.

There are also 28 expired groundwater take consents within the model area, totalling 8.53x 10^6 m^3/year of abstraction. These takes were not included in the total amount of currently allocated groundwater, but they were used for developing a historical dataset. **Appendix C** provides consented and proposed groundwater takes corresponding to the locations shown in **Figure 9A** through **Figure** 9**C**.

Figure 9A. Location of existing and proposed groundwater take bores in northern portion of model. (See A3 attachment at rear).

Figure 9B. Location of existing and proposed groundwater take bores in central portion of model. (See A3 attachment at rear).

Figure 9C. Location of existing and proposed groundwater take bores in southern portion of model. (See A3 attachment at rear).

2.7.1 Actual Use Dataset

A historical actual use dataset is required to more accurately calibrate a groundwater model and to thereafter use the model to simulate the effects of groundwater extraction on the aquifer and surface water resources.

The SMWBM Irrigation Module was used to develop an estimate of historical actual use. The exercise combined typical irrigation scheduling (Oct - Apr) and the commencement dates that the consents were granted, along with an allowance for orchard development and tree growth rates to maximum water requirement. Details and results of the development of the actual use dataset are provided in **Appendix D**.

A complete dataset of historic groundwater use within the model area was not available, therefore a conservative estimate of groundwater use was generated by assuming that all active consents were available from the beginning of the simulation period with the exception of the two Sweetwater Farms production bores that were known to have initiated operation in 2015 and 2017, respectively and the Valic 1 through 3 production bores where pumping operations are known to have stated in 2007. **Figure 10** shows the total annual volume of simulated actual use as applied in the model.

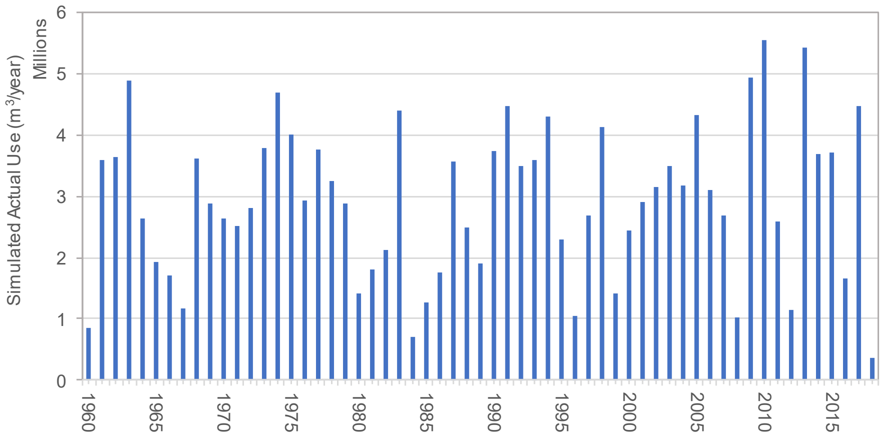

Figure 10. Simulated groundwater extraction (m3/year; partial groundwater use in 2018 due to the end of the model simulation).

3. Model Configuration

The MODFLOW Unstructured Grid (MODFLOW-USG) developed by the United States Geological Survey (USGS) was utilised within the GMS10.2 modelling platform to construct the groundwater flow model in this project. The unstructured discretisation of the model domain provides the capacity of fitting irregular boundaries into the model and increasing the resolution in the areas of maximum interest and decreasing resolution in other areas, hence increasing the efficiency in model computation compared to the equivalent regular MODFLOW grid.

3.1 Model Domain

The model was constructed based on six layers, with a total of 147,252 active Voronoi cells (or polygons), and covers an area of 535 km^2. Grid spacing ranges from 40 m at the highest resolution, centred around large groundwater extraction points, to 1,000 m in the northwest portion of the model area where high resolution is unnecessary. This spatially varying discretisation approach reduces model computational time while maintaining better model resolution at the points of interest (**Figure 11**).

Figure 11. Plan view of unstructured model grid discretisation (See A3 attachment at rear).

The boundary conditions included in the model are constant head, general head, drain, and no-flow boundaries.

3.1.1 Constant Head Boundaries

The constant head boundary was assigned an elevation of 0 mAMSL along the eastern and western coastlines in Layer 1 of the model to represent the mean hydraulic head of the ocean at these locations.

3.1.2 General Head Boundaries

A general head boundary (GHB) is typically used to simulate the flow interaction between groundwater and external water sources to the model domain.

There are 16 lakes within the model area that are large enough to occupy the majority of a model cell and were therefore incorporated into the model. It was determined that these lakes occur due to buried hard pans causing localized perching without a direct connection to the regional water table. The conclusion that there is disconnection between surface lakes and regional groundwater is consistent with the findings of other studies such as Lincoln Agritech (2015) and WWA (2017). A GHB was assigned to cells primarily occupied by lakes, to simulate lake water seeping to the underlying groundwater system, with consideration of the impedance provided by the lower-permeability lake bed sediments and/or iron pan. The head stage assigned for the GHB for each lake was determined by extracting the average elevation for each lake based on the model area DEM.

Lake Waiparera, located in the middle the model domain is the largest lake in the model domain. It was observed to have an average lake stage of 33.8 mAMSL while the groundwater level, estimated from the adjacent bore, was around 7 mAMSL, indicating that Lake Waiparera is perched above the regional groundwater system. This is also consistent with the conclusion made in the Aupouri Aquifer Review Report that the main aquifer is situated well below the surface of Lake Waiparera (Lincoln Agritech, 2015).

Similar findings can be demonstrated at Lake Heather where the mean surface elevation of the lake was determined to be 32.1 mAMSL whereas shallow monitoring piezometers located near the lake show groundwater elevations of 12.0 and 13.1 mAMSL.

The cells along the coastline from Layer 2 to 6 were also assigned with GHBs. The head values for all the cells were assigned as 0 mAMSL and the conductance value of each layer decreases with depth. This is to reflect the progressively increasing disconnection of the groundwater with the free water surface of the ocean (i.e. the impedance of flow to the ocean floor increases with depth) and also the resistance of higher-density seawater offshore. It was estimated based on the model calibration that the cells along the west coast boundary had approximately one order of magnitude lower conductance than the cells along the east coast boundary.

3.1.3 No-Flow Boundaries

The AAGWM was designed to encompass the entire Aupouri aquifer therefore no-flow boundaries were assigned to cells located on the northern and southern boundaries of the model domain representing the margin of the aquifer. In the north groundwater is expected to predominantly flow downgradient toward the south and laterally to the coasts while in the south bedrock outcroppings form a boundary to groundwater flow. The base of the model was also assigned a no-flow boundary on the basis that the significantly lower permeability of the basement rocks has negligible bearing on the overall flow budget of the aquifer system above.

3.1.4 Drain Boundaries

Drain boundaries were assigned in the model to simulate the groundwater discharged to the major surface drains, and to simulate the estuary that occurs along the east coast portion of the model area. The drain bed elevations were derived from the Digital Elevation Model (DEM), with a nominal depth assignment depending on locality as follows:

- Drains in farmland – DEM minus 3 m;
- Drains in estuary – DEM minus 0.5 m;
- Drains in wetland outside of estuary – DEM minus 3 m.

The conductance value of the drains was set relatively high to reflect limited impedance to water removal (or drain functionality), to account for the significant water drainage in the farmland area and flow of water over the surface in the wetland.

3.1.5 Well Boundaries

Well points were used to represent the groundwater extraction from within the model. The corresponding model cells were assigned with negative pumping rates to represent the groundwater extraction from the model.

3.2 Simulation Package

3.2.1 Sparse Matrix Solver

The Sparse Matrix Solver (SMS) package was utilised to solve linear and non-linear equations. A maximum head change of 0.01 m between iterations was set as the model convergence criteria. Default values were used for the maximum number of iterations for linear and non-linear equations.

3.2.2 Ghost Node Correction Package

MODFLOW-USG is built on the control volume finite difference formulation, which enables the model cell to be connected to an arbitrary number of adjacent cells (Panday et al., 2013). However, this formulation will be reduced to a lower order of approximation, when the line between two connected nodes does not bisect the shared face at right angles, which will lead to errors in the simulation (Edwards, 1996). To account for this, the ghost node correction package was utilised to improve the simulation results by adding higher order correction terms in the matrix solver. Ghost nodes are implicitly built into the simulation through the interpolation factors. The simulated head is systematically corrected through the ghost nodes to achieve a correct solution.

3.3 Model Layer Configuration

3.3.1 Layer Geology

The model comprises six layers that are used to represent the varying geology located in the area. The geological units assigned to each layer of the numerical model are shown in **Table 3**.

Table 3. Geological units in the model conceptualisation.

Model Layer	Stratigraphic Layer	Name	Description	Locality
1-3	1	Coastal sand	Loose coastal sand, highly permeable	Western and eastern coastal strips.
	1	Weathered sand	Weathered dune sand, moderately compacted	Inland hilly or rolling country areas.
	1	Wetland/Estuary	Peaty and clayey sediments, low permeability	Low lying region along east coast including Kaimaumau wetland. Only applied for Model layer 1.
	1	Plains	Peaty and clayey sediments with some sand, low-moderate permeability	Inland low-lying plains areas in southern region of model. Only applied for Model layer 1.
4	2	Shellbed	Sand presented with shells, highly permeable	Throughout model, albeit thickness varies.
5	3	Fine sand	Old sand deposits, fine sand, moderately permeable	
6	4	Shellbed	Sand presented with more shells, highly permeable	

Model Layers 1-3 are used to represent a complex stratigraphic unit comprising alternating sands, silt, peat, clay and iron pans in a bulk sense (not discretely). The sub-division of this stratigraphic unit into layers is complex because layering is varied both horizontally and vertically. For modelling purposes, horizontally continuous and vertically discrete layers are required to enable anisotropy to be incorporated in the model calibration process; hence the base of model Layer 1 was defined as an elevation of -2.0 mAMSL, while the base of model Layer 2 was set at 22 m above the base of model Layer 3. Based on the 10 m vertical hydraulic gradient observed in the monitoring data at Valic-2 from the Valic-2 shallow and deep piezometers, it is likely that there is a localised zone of low permeability in the subsurface in this region. This was incorporated into the model as a limited region of low conductivity relative to the surrounding material.

All model layer bases other than model Layer 1 and 2 conform to stratigraphic interpolations as discussed in the following section.

3.3.2 Layer Elevations

The top and bottom elevation for the geological unit contacts were determined through a process of reviewing 198 bore logs at locations within the model area. The majority of the bore logs were obtained by request through the NRC while some additional bore logs were provided directly through the bore owners. Each bore log was reviewed to characterize the primary material types within the context of the conceptual geological configuration incorporated into the model. The bottom elevations for each unit were then interpolated using the Kriging geospatial method to generate a digital elevation surface.

The geometry of the basement rocks has been recognised through interpolation of the basal contact from the available bore logs in the area and was considered to be the lower model boundary where interfaced with the lower shellbed. During interpolation, rules were applied so that geological layers did not overlap, and the surface is stratigraphically continuous.

Figure 12 through **Figure 15** show interpolated elevation contours used for the model layer interfaces and basement elevation (i.e. the model bottom).

Figure 12. Bottom elevation of sand and peat layers (model Layers 1-3 base). (See A3 attachment at rear).

Figure 13. Bottom elevation of upper shellbed (model Layer 4 base). (See A3 attachment at rear).

Figure 14. Bottom elevation of compact sand layers (model Layer 5 base). (See A3 attachment at rear).

Figure 15. Basement rock elevation contours (model Layer 6 base). (See A3 attachment at rear).

Geological cross-sections were developed from selected transects through the kriged surfaces in north-south (N-S) and west-east (E-W) directions to demonstrate the relative thickness of each geological unit. Transects are identified by the section of the model where they are located and are shown in **Figure 16** while the cross-sections themselves are shown in **Figure 17** to **Figure 24**. The constructed model grid based on the interpolated layer elevations is shown in **Figure 25**.

Figure 16. Hydrogeological cross section locations. (See A3 attachment at rear).

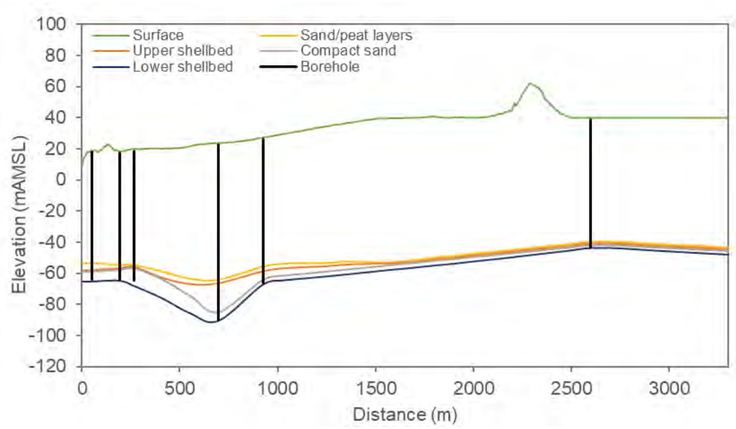

Figure 17. Interpolated cross-section **A to A' showing** bore locations (refer to Figure 16 for location).

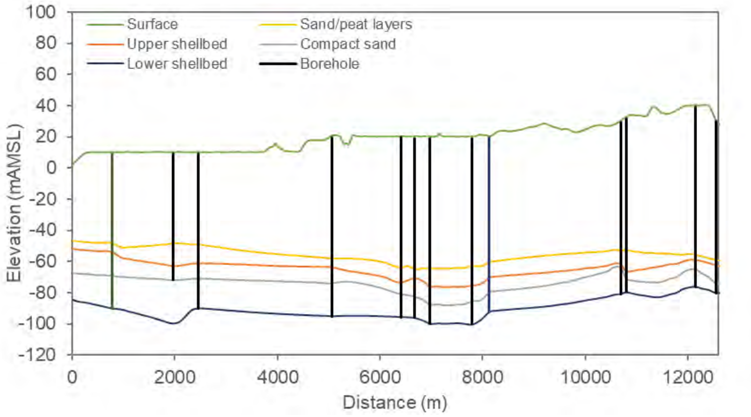

Figure 18. Interpolated cross-**section B to B' showing bore locations** (refer to Figure 16 for location).

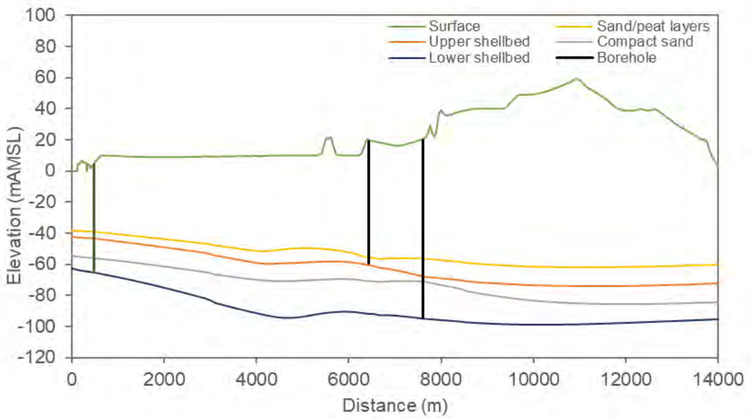

Figure 19. Interpolated cross-**section C to C' showing bore locations** (refer to Figure 16 for location).

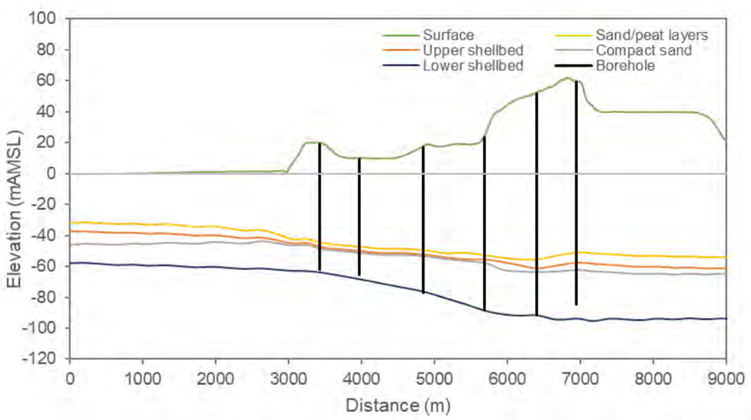

Figure 20. Interpolated cross-**section D to D' showing bore locations** (refer to Figure 16 for location).

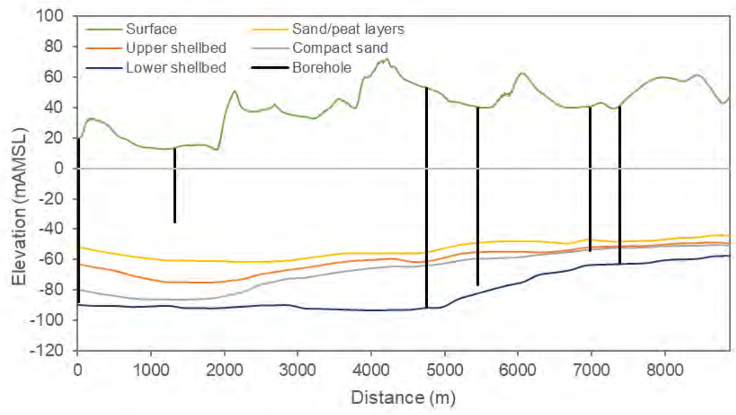

Figure 21. Interpolated cross-section E to E' **showing bore locations** (refer to Figure 16 for location).

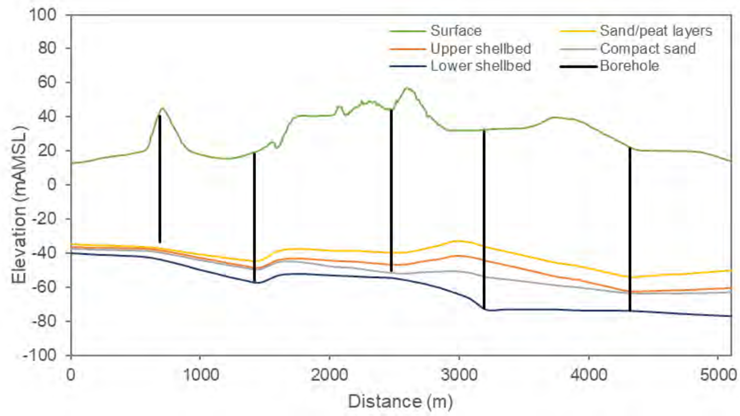

Figure 22. Interpolated cross-section F to F' **showing bore locations** (refer to Figure 16 for location).

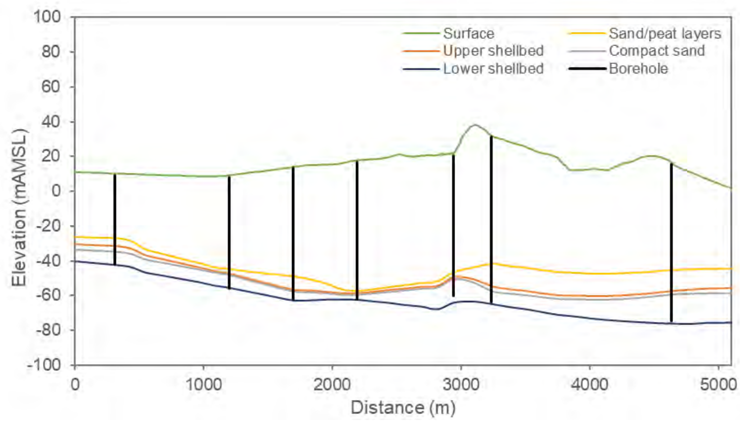

Figure 23. Interpolated cross-section G to G' **showing bore locations** (refer to Figure 16 for location).

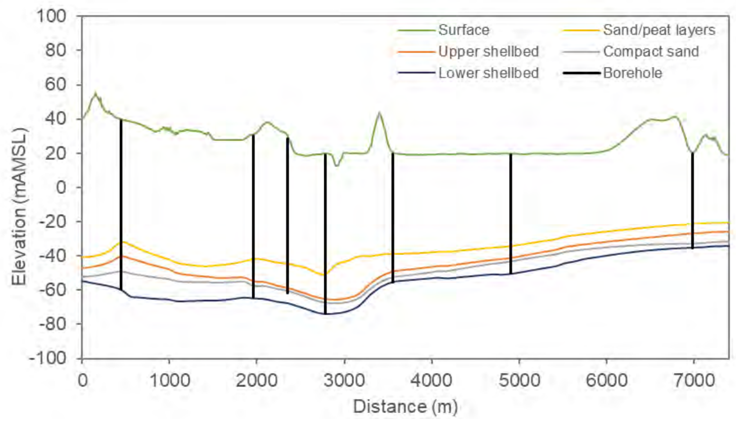

Figure 24. Interpolated cross-**section H to H' showing bore locations (refer to Figur**e 16 for location).

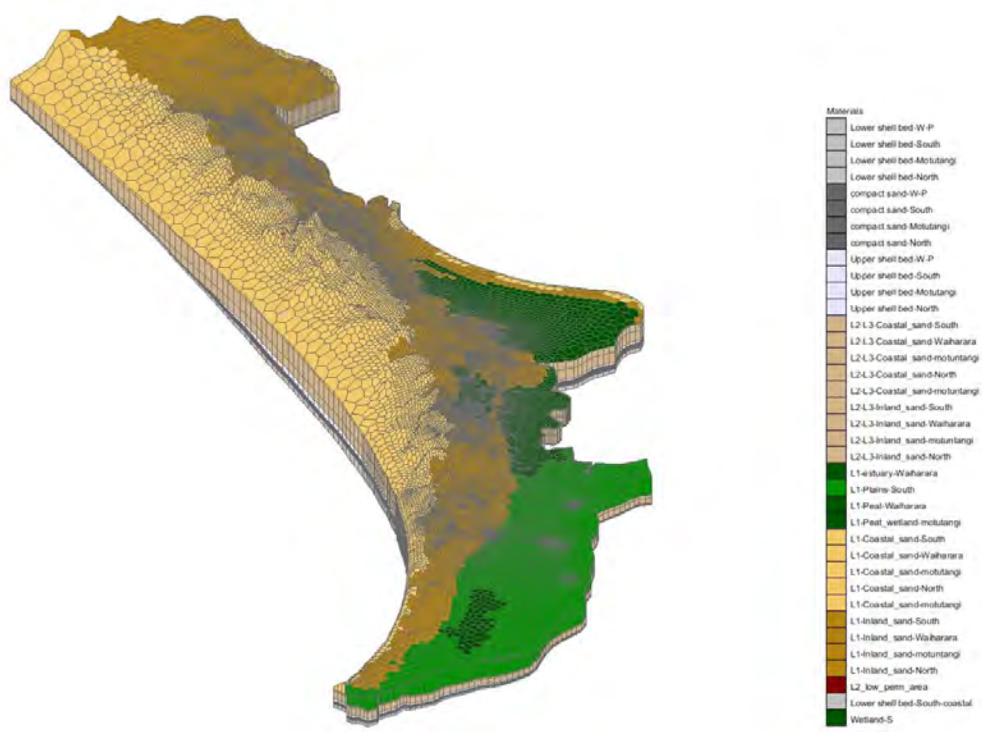

Figure 25. MODFLOW grid with vertical magnification of 25.

4. Model Calibration

The model calibration was conducted by manually changing the model hydraulic parameters to achieve an acceptable fit to measured groundwater levels. Groundwater recharge was not considered a calibration parameter.

4.1 Observation Points

The piezometers used for calibration of the model are shown in **Figure 5** and the key properties of the piezometers relevant to model calibration are summarised in **Error! Reference source not found.**. The piezometers include nested piezometer configurations comprising adjacent standpipes installed to different depths or aquifer levels and standalone piezometers measuring a single depth. Vertical pressure gradients are evident where there are concurrent measurements from nested piezometers measuring different depths at a single location. Achieving a simulated vertical pressure gradient requires multiple layers with vertical anisotropy to be incorporated in the model (as discussed in **Section 2.6**). To achieve this, a finer vertical discretisation of the model was required, and this was a key driver for splitting stratigraphic Layer 1 into three model layers as described in **Section 3.3**. The discrete layers enabled vertical anisotropy to be considered in model calibration as a bulk property within each layer while providing flexibility to vary anisotropy vertically to account for the heterogeneous nature of the materials.

Table 4. Key specifications of the observation bores used for model calibration.

Model Region	Site	Piezometer Description	Mean groundwater level (mAMSL)	Standard deviation (m)	Bore depth (m)	Model Layer
Hukatere Transect	Waterfront	NRC shallow monitoring bore	3.46	0.36	19.0	2
		NRC middle monitoring bore	3.99	0.36	37.0	2
		NRC deep monitoring bore	5.33	0.28	57.0	3
		NRC deep monitoring bore	5.30	0.29	74.0	4
	Hukatere	NRC shallow monitoring bore	13.79	1.26	19.0	1
		NRC middle monitoring bore	12.68	1.15	36.0	2
		NRC deep monitoring bore	12.26	1.11	58.0	2
	Forest	NRC shallow monitoring bore	20.45	1.07	16.0	1
		NRC middle monitoring bore	19.47	1.31	36.0	1
		NRC deep monitoring bore	18.20	1.17	64.0	2
		NRC deep monitoring bore	18.18	1.17	79.0	3
	Burnage	NRC shallow monitoring bore	16.14	0.71	17.0	1
	Browne	NRC shallow monitoring bore	18.67	0.93	16.0	1
		NRC shallow monitoring bore	15.81	0.82	29.0	1
		NRC deep monitoring bore	11.53	0.78	59.0	2
	Wagener Golf Club	Deep monitoring bore	4.48	0.28	69.0	4
	Fishing Club at Houhora	Deep monitoring bore	3.43	0.61	78.0	5

Model Region	Site	Piezometer Description	Mean groundwater level (mAMSL)	Standard deviation (m)	Bore depth (m)	Model Layer
Waiharara-Paparore Region	Kaimaumau Deep	NRC	2.44	0.82	72.0	6
	Ogle Drive	NRC Monitoring Bore	14.90	0.32	68.0	3
	Paparore	NRC deep monitoring bore	6.88	0.66	75.0	6
		NRC deep monitoring bore	6.88	0.63	65.0	4
		NRC middle monitoring bore	6.46	0.26	35.0	2
		NRC shallow monitoring bore	6.42	0.27	18.0	1
	Valic-1	Shallow Monitoring Bore	21.74	0.47	17.0	1
		Deep monitoring bore	11.65	0.83	103.0	6
		Production Bore	11.41	0.83	103.0	6
	Valic-2	Shallow Monitoring Bore	22.88	0.77	55.0	1
		Deep monitoring bore	12.24	1.00	121.0	6
		Production Bore	12.06	0.85	121.0	6
	Valic-3	Shallow Monitoring Bore	20.99	0.76	45.0	1
		Deep monitoring bore	11.28	1.94	124.0	6
		Production Bore	11.32	2.23	124.0	6
	Valic-4	Shallow Monitoring Bore	20.99	0.76	45.0	1
		Deep monitoring bore	11.28	1.94	124.0	6
		Production Bore	10.75	0.55	93.0	6
Sweetwater Farms Monitoring Wells	Sweetwater MW1	Shallow Monitoring Bore	13.84	0.48	13.3	1
		Deep monitoring bore	2.83	2.13	94.0	6
	Sweetwater MW2	Shallow Monitoring Bore	5.82	0.19	14.5	2
		Deep monitoring bore	6.35	0.27	59.0	6
	Sweetwater MW3	Shallow Monitoring Bore	7.61	0.29	5.0	1
		Deep monitoring bore	5.83	0.30	47.0	6
	Sweetwater MW4	Shallow Monitoring Bore	15.56	0.50	25.0	2
		Deep monitoring bore	4.98	0.22	92.0	6
	Sweetwater MW5	Shallow Monitoring Bore	15.09	0.92	6.0	1
		Deep monitoring bore	8.67	0.74	61.0	6
	Sweetwater MW6	Shallow Monitoring Bore	11.88	0.81	15.0	1
	Sweetwater MW7	Shallow Monitoring Bore	15.92	NA	7.0	1
	Sweetwater Nursery	Monitoring bore	10.50	0.43	33.8	3
Lake Heather Monitoring Bores	Lake Heather Piezometer 1	NRC shallow monitoring bore	11.97	0.93	26.0	1
		NRC deep monitoring bore	8.04	0.66	105.5	6
	Lake Heather Piezometer 2	NRC shallow monitoring bore	9.56	0.94	29.5	1
	Lake Heather Piezometer 3	NRC shallow monitoring bore	13.11	0.74	29.0	1

Model Region	Site	Piezometer Description	Mean groundwater level (mAMSL)	Standard deviation (m)	Bore depth (m)	Model Layer
Private Bores in Southern Aupouri Aquifer	Vinac	Private bore	0.04	0.75	33.0	4
	Waipapa	Private bore	2.93	0.14	56.0	4
	Matich	Private bore	4.73	0.18	Unknown	1
	Welch	Private bore	8.12	0.39	31.7	3
	Shanks	Private bore	7.20	0.39	Unknown	1

4.2 Steady-State Calibration

A steady-state model was developed and calibrated to validate the conceptualisation of the groundwater flow model. The objective of the calibration was to obtain approximate values of the model parameters, and to obtain initial heads for transient model simulation. An automated parameter estimation tool, PEST, was used to calibrate hydraulic conductivity and vertical anisotropy of materials for each of the 6 model layers with constraints based on previous modelling studies for the region and literature values.

For calibration purposes material zones within the model domain were defined vertically based on the model layers described in **Section 3.3** and divided horizontally into four sections along a north-south axis. These zones are shown in **Figure 26** and referred to herein, from north to south as North, Motutangi, Waiharara-Paparore, and South.

Figure 26. Aupouri Aquifer Groundwater Model parameter calibration zones (See A3 attachment at rear).

These divisions were made to enable a model calibration that reflects the fact that the material is heterogeneous and therefore hydraulic characteristics are spatially variable within a given material. The four zones that were defined for the north-south axis were based on geographic areas where groundwater takes are concentrated or where landscape variability was considered likely to indicate variation in hydrogeological characteristics.

Through this method the best possible calibration for the data set was achieved for the setup while ensuring that calibrated parameters were reasonable for the given material types.

The average water levels from 56 piezometers registered on the NRC bore database were used as the calibration targets. The simulated head is plotted against the observations (**Figure 27**). The steady-state simulation has a mean head residual of -0.42 m (indicating a net over-simulation of groundwater head), and root mean square error (RMSE) of 2.1 m, which is approximately 7.9% of the range of observations. The RMSE has been affected by the following observations:

- ***Paparore (Middle and Shallow Bores)*** - Simulated vertical hydraulic gradient is greater than what has been observed indicating a local variation in stratigraphy not captured by the model.
- ***Browne-1*** - Simulated head was greater than observed data, however given that the 2 shallowest of the nested piezometers at this location both correspond to model layer 1, yet have a difference of 4.3 m in mean head it would be impossible to match both piezometers given the construct of the model (i.e. groundwater head will be hydrostatic within a single layer). The match for simulated head in the deeper of the two piezometers, Browne-2 is within 1.3 m of the mean measured value.

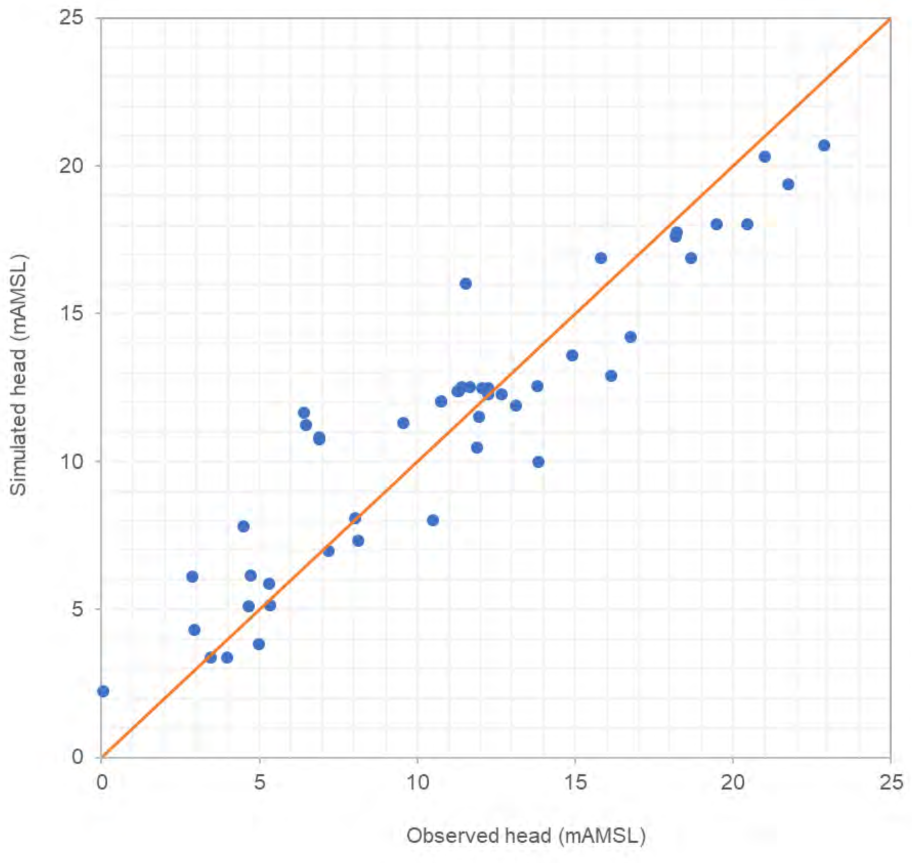

Figure 27. Simulated head versus observed head.

4.3 Transient Calibration

The calibrated parameters from the steady state PEST simulation were used as a starting point for calibrating the transient model. Targeted adjustments were made to hydraulic conductivity, vertical anisotropy, drain elevation, and the conductivity of subsurface boundaries (only on the west coast).

The model was simulated approximately 75 times to obtain a satisfactory calibration. Each transient simulation takes 30 minutes to run, and post processing of results takes 3 minutes, hence a cycle time of approximately 33 minutes is needed for each model simulation. This cycle time enabled a significant number of calibration and sensitivity assessment runs to be undertaken.

After each run, simulated heads from the relevant model layer and cell were extracted and processed with Python code that automatically developed hydrographs and calculated RMSE for each gauge individually, which permitted rapid comparison of simulated versus measured data.

The transient calibration setup is described in the following sections.

4.3.1 Stress Periods and Time Steps

The model was simulated in transient mode for 58.6 years from 1/01/1960 to 31/07/2018. The simulation was subdivided into 371 stress periods, where imposed stresses (e.g. recharge and pumping) remain constant. The number of stress periods was selected on the basis of i) temporal variation of the transient dataset values; and ii) computational time. The resulting stress period lengths ranged from 13 to 185 days. Stress periods were locked on 1 October and 30 April in each year for the start and end of the irrigation season, respectively, to ensure the irrigation demands were distributed to the correct timeframe.

Each stress period consisted of five time-steps, with head and flow volume in each model cell evaluated at the end of each time step.

4.3.2 Groundwater Pumping

The estimated historical use dataset described in **Section 2.7.1** was implemented in the calibration simulations.

4.3.3 Initial Conditions

The transient model used the steady-state model heads as the starting condition. During the transient calibration process, the starting heads were re-set periodically as parameters were updated. This enabled the starting condition to better reflect the dynamic head distribution within the model under the imposed set of stresses and resulted in minimisation of rapid fluctuations in simulated levels and flows at the start of the simulation (i.e. increased stability).

4.3.4 Model Parameters

The model was calibrated by adjusting parameters for materials both horizontally and vertically to best simulate groundwater elevations measured at observation bores. The calibrated model parameters are shown in **Table 5**. The calibrated model parameters, where applicable, are consistent with calibrated model parameters used in previous modelling (WWA, 2017; WWA, 2018).

The calibrated model hydraulic conductivity for the upper shellbed aquifer ranges from 2.2×10^{-4} m/s in the Waiharara-Paparore region to 4.9×10^{-4} m/s in the Motutangi region. In the lower shellbed aquifer conductivity ranges from 3.1×10^{-4} m/s in the Motutangi region to 5.8×10^{-4} m/s in the South region. As shown in **Table 1,** these values are within the range of horizontal hydraulic conductivity measured and modelled in the past for both the upper and lower shellbed aquifers (Layer 2 and 4). Similarly, for the various sand units, the calibrated model values range from 1.0×10^{-5} m/s to 8.3×10^{-5} m/s, which is consistent with the range in previously documented values as shown in **Table 1.** Calibrated hydraulic conductivity in the wetland, estuary and peat zones is somewhat lower in the Motutangi and Waiharara regions.

Table 5. Calibrated model parameters.

Model Layer	Model Geological Units	Kx		Vertical Anisotropy	Sy	Ss
		(m/d)	(m/s)	(-)	(-)	(m-1)
Layer 1: Interbedded sand, peat, and iron pans	Coastal sand-North	4.20	4.9E-05	8	-	0.30
	Coastal sand-Motutangi	4.85	5.6E-05	56	-	0.30
	Coastal sand-Waiharara-Paparore	2.75	3.2E-05	24	-	0.30
	Coastal sand-South	6.69	7.7E-05	24	-	0.30
	Inland sand-North	2.40	2.8E-05	16	-	0.25
	Inland sand-Motutangi	2.93	3.4E-05	103	-	0.25
	Inland sand-Waiharara-Paparore	1.65	1.9E-05	51	-	0.25
	Inland sand-South	0.90	3.5E-06	85	-	0.25
	Peat wetland-Motutangi	0.12	1.4E-06	12	-	0.05
	Peat-Waiharara-Paparore	0.6	6.9E-06	12	-	0.05

Model Layer	Model Geological Units	Kx		Vertical Anisotropy	Sy	Ss
		(m/d)	(m/s)	(-)	(-)	(m-1)
	Estuary-Waiharara-Paparore	1.00	1.2E-05	12	-	0.10
	Plains-South	5.00	5.8E-05	12	-	0.20
Layers 2 & 3: Interbedded sand, peat, and iron pans	Coastal sand-North	4.20	4.9E-05	8	5.0E-04	-
	Coastal sand-Motutangi	4.80	5.6E-05	24	5.0E-04	-
	Coastal sand-Waiharara-Paparore	2.55	3.0E-05	32	5.0E-04	-
	Coastal sand-South	12.00	1.4E-04	32	5.0E-04	-
	Inland sand-North	4.20	4.9E-05	8	5.0E-04	-
	Inland sand-Motutangi	3.36	3.9E-05	72	5.0E-04	-
	Inland sand-Waiharara-Paparore	2.25	2.6E-05	48	5.0E-04	-
	Inland sand-South	1.20	1.7E-05	50	5.0E-04	-
Layer 4: Upper Shellbed	Upper Shellbed-North	36.00	4.2E-04	1	1.1E-03	-
	Upper Shellbed-Motutangi	42.00	4.9E-04	1	1.1E-03	-
	Upper Shellbed-Waiharara-Paparore	19.20	2.2E-04	1	1.1E-03	-
	Upper Shellbed-South	30.00	3.5E-04	1	1.1E-03	-
Layer 5: Compact Sand	Compact sand-North	1.20	1.4E-05	48	1.6E-04	-
	Compact sand-Motutangi	7.20	8.3E-05	29	1.6E-04	-
	Compact sand-Waiharara-Paparore	0.60	6.9E-06	48	1.6E-04	-
	Compact sand-South	1.50	1.7E-05	72	1.6E-04	-
Layer 6: Lower Shellbed	Lower Shellbed-North	36.00	4.2E-04	1	1.1E-03	-
	Lower Shellbed-Motutangi	26.40	3.1E-04	1	1.1E-03	-
	Lower Shellbed-Waiharara-Paparore	42.00	4.9E-04	1	1.1E-03	-
	Lower Shellbed-South	50.00	5.8E-04	1	1.1E-03	-

4.4 Calibrated Model Output

4.4.1 Groundwater Levels

As previously stated in **Section 2.6**, groundwater levels recorded within 17 NRC monitoring piezometers were used to calibrate the transient groundwater model. **Appendix E** provides hydrographs and water level maps of simulated groundwater levels plotted against observed data for comparison purposes, and calibration results for each observation bore are shown in **Table 6**. The observation bores referenced in **Table 6** are the same as those described in **Section 4.1** and shown in **Figure 5**

Table 6. Model calibration results at observation bores.

Model Region	Site	Piezometer Description	Root Mean Squared Error	Mean groundwater level (mAMSL)	Bore depth	Model Layer
Hukatere Transect	Waterfront	NRC shallow monitoring bore	0.36	3.46	19.0	2
		NRC middle monitoring bore	0.73	3.99	37.0	2
		NRC deep monitoring bore	0.36	5.33	57.0	3
		NRC deep monitoring bore	0.57	5.30	74.0	4
	Hukatere	NRC shallow monitoring bore	1.69	13.79	19.0	1
		NRC middle monitoring bore	0.99	12.68	36.0	2
		NRC deep monitoring bore	0.77	12.26	58.0	2
	Forest	NRC shallow monitoring bore	2.83	20.45	16.0	1
		NRC middle monitoring bore	1.97	19.47	36.0	1
		NRC deep monitoring bore	1.08	18.20	64.0	2
		NRC deep monitoring bore	1.18	18.18	79.0	3
	Burnage	NRC shallow monitoring bore	3.54	16.14	17.0	1
	Browne	NRC shallow monitoring bore	2.18	18.67	16.0	1
		NRC shallow monitoring bore	0.89	15.81	29.0	1
		NRC deep monitoring bore	4.22	11.53	59.0	2
	Wagener Golf Club	Deep monitoring bore	3.42	4.48	69.0	4
	Fishing Club at Houhora	Deep monitoring bore	3.22	3.43	78.0	5
Waiharara-Paparore Region	Kaimaumau Deep	NRC Monitoring Bore	0.58	2.44	72.0	6
	Ogle Drive	NRC Monitoring Bore	1.45	14.90	68.0	3
	Paparore	NRC deep monitoring bore	4.03	6.88	75.0	6
		NRC deep monitoring bore	4.08	6.88	65.0	4
		NRC middle monitoring bore	4.88	6.46	35.0	2
		NRC shallow monitoring bore	5.32	6.42	18.0	1
	Valic-1	Shallow Monitoring Bore	1.85	21.74	17.0	1

Model Region	Site	Piezometer Description	Root Mean Squared Error	Mean groundwater level (mAMSL)	Bore depth	Model Layer
		Deep monitoring bore	1.55	11.65	103.0	6
		Production Bore	1.77	11.41	103.0	6
	Valic-2	Shallow Monitoring Bore	1.80	22.88	55.0	1
		Deep monitoring bore	1.21	12.24	121.0	6
		Production Bore	1.19	12.06	121.0	6
	Valic-3	Shallow Monitoring Bore	0.76	20.99	45.0	1
		Deep monitoring bore	2.42	11.28	124.0	6
		Production Bore	2.63	11.32	124.0	6
	Valic-4	Shallow Monitoring Bore	0.76	20.99	45.0	1
		Deep monitoring bore	2.42	11.28	124.0	6
		Production Bore	1.77	10.75	93.0	6
Sweetwater Farms Monitoring Wells	Sweetwater MW1	Shallow Monitoring Bore	2.77	13.84	13.3	1
		Deep monitoring bore	4.98	2.83	94.0	6
	Sweetwater MW2	Shallow Monitoring Bore	0.80	5.82	14.5	2
		Deep monitoring bore	0.61	6.35	59.0	6
	Sweetwater MW3	Shallow Monitoring Bore	0.34	7.61	5.0	1
		Deep monitoring bore	1.82	5.83	47.0	6
	Sweetwater MW4	Shallow Monitoring Bore	11.53	15.56	25.0	2
		Deep monitoring bore	0.38	4.98	92.0	6
	Sweetwater MW5	Shallow Monitoring Bore	4.99	15.09	6.0	1
		Deep monitoring bore	0.95	8.67	61.0	6
	Sweetwater MW6	Shallow Monitoring Bore	0.80	11.88	15.0	1
	Sweetwater Nursery	Monitoring bore	2.56	10.50	33.8	3
Lake Heather Monitoring Bores	Lake Heather Piezometer 1	NRC shallow monitoring bore	0.82	11.97	26.0	1
		NRC deep monitoring bore	0.70	8.04	105.5	6
	Lake Heather Piezometer 2	NRC shallow monitoring bore	2.16	9.56	29.5	1
	Lake Heather Piezometer 3	NRC shallow monitoring bore	1.24	13.11	29.0	1
Private Bores in Southern Aupouri Aquifer	Vinac	Private bore	2.34	0.04	33.0	4
	Waipapa	Private bore	1.61	2.93	56.0	4
	Matich	Private bore	1.46	4.73	0.0	1
	Welch	Private bore	0.90	8.12	31.7	3
	Shanks	Private bore	0.41	7.20	Unknown	1

The mean residual head is -0.08 m showing that there is not a strong bias for the simulations overpredicting or underpredicting observed groundwater levels. The mean of the RMSE for all gauges is 1.89 m, which is 7.1% of the observed range in groundwater head (26.5 m) while the RMSE for all observation in the model is 2.10 m, or 7.9 % of the range of observations. The latter number reflects a bias for gauges where more data is available whereas the former metric gives equal weight to a gauge with limited data. A simulated RMSE of less than 10% of the measured range is considered a good calibration so both analysis criteria meet this standard. Simulated and observed hydrographs for all monitoring wells used for model calibration are provided in **Appendix E**.

For the inland piezometers along the Hukatere transect in the Motutangi region (e.g. Hukatere and Forest), the trend of simulated groundwater level generally follows the observed groundwater level. However, the increase in groundwater levels over recent years has not been replicated in the simulation.

A potential reason for this is that variations in seasonal recharge rates have changed in response to land use. The groundwater model has been set up with recharge rates that were simulated based on a constant land use over the model period. However, land use changes and the associated spatial distributions of land cover will affect the quantity and quality of water being recharged to the groundwater system. In fact, the plantation forestry felling cycles on the western side of the peninsula may significantly affect the variation of groundwater recharge. In general, compared to bare land, forestry land tends to decrease the groundwater recharge due to increased interception and evapotranspiration.

Changes in land use take time to propagate to the groundwater system. Depending on the climate, geology, intensity and extent of the land use change, recovery of the groundwater system may vary from 3 to more than 20 years (Moore and Wondzell, 2005). In the meantime, this effect on groundwater system is masked by the climate variation.

It is therefore likely that the mismatch in calibration is in fact due to a temporal variation in groundwater recharge in response to land use change. However, detailed historical land cover data was not available. Reconstructing historical land use change would be a separate study in its own right and it was therefore not possible to incorporate the transient variability of recharge into the groundwater model to reflect the land use change in the area.

The Browne and Waterfront piezometers are generally well represented by the simulation, with good correlation of seasonal and annual trends, though in some cases, a discrepancy in water level elevation was observed. In some cases, this reflects the fact that piezometers at different depths correspond to the same model layer, for example the midpoint of the screened interval for Browne piezometers 2 and 3 are 16 and 29 m BGL, respectively, however both fall within model Layer 1 and therefore reflect the same simulation results.

Measured data at all deep aquifer bores at the Valic locations and at Ogle Drive were well represented by the model as evident in the hydrographs provided in **Appendix E**. Simulated groundwater levels at the deep bores in the Valic orchards are generally within 1 meter of measured values except Valic-3 where there is a greater discrepancy in earlier data; however, the last 5 years of the measured data set is similar to simulation results.

In the Waiharara-Paparore region the monitoring piezometer at Paparore is significantly oversimulated with measured groundwater levels typically 3 to 5 m above measured levels for each of the monitoring levels. The vertical hydraulic gradient was not well simulated indicating that a localised variation in permeability, reflecting the complex stratigraphy in the model area, may impede model calibration at this location as has been encountered in other modelling efforts (SKM, 2007b).

The monitoring bore at Ogle Drive was very well simulated in terms of temporal trends and the magnitude of seasonal water level variation. The overall simulated water level was 1 to 2 m below observed water levels.

Water levels were generally well simulated at the four Valic Orchards deep monitoring bores. At the shallow monitoring bore the simulated water levels were 2 to 3 m below observed levels, with the exception of Valic Monitoring Bore #3 where the simulated water level was similar to observations. A recent trend of declining groundwater levels in the Valic area was not well captured by the simulations, which may reflect land use changes not captured in the process of generating estimated recharge input into the model.

The discrepancy between simulated water levels in the shallow and deep monitoring bores around Valic Orchards shows that there are layers effecting the vertical hydraulic gradient that are not captured in the conceptual model.

A low permeability zone applied in Layer 2 of the model yielded some improvement in this regard, but it remains likely that the conceptual model does not capture some of the geologic complexity in this area.

In the southern portion of the model area the majority of monitoring wells are associated with Sweetwater Farms. There are 5 locations with paired shallow and deep monitoring piezometers and several additional single monitoring piezometers at Sweetwater Farms, as well as several bores where groundwater level data is collected by private land owners. Many of these data sets are limited in their historic extent.

In the case of the Sweetwater farms monitoring wells the vertical hydraulic gradient is not well captured in monitoring wells 1, 3, 4 and 5, though in the case of monitoring well 4 the shallow piezometer is likely measuring a perched water table based on the groundwater elevation being inconsistent with the general groundwater gradient in the surrounding area. The simulated water table is generally closer to observations in the case of the deep bores relative to the shallow monitoring wells due to the difficulty of representing the geologic complexity of the region within the constraints of the conceptual model.

4.4.2 Model Flow Budget

Table 7 provides the long-term average water budget for the transient calibration model. The main input to the model is groundwater recharge at 80% of the total inflow. The predominant discharge component from the model are the subsurface coastal discharges, which are comprised of the constant head in Layer 1 (44%) and the GHB in Layer 2 to 6 (12%). Surface water discharges in the form of drains and wetlands account for 24% of the model water budget. Discharge through groundwater pumping is a small component (<1%) of the model water budget which reflects the fact that many of the large groundwater takes within the model were initiated in the last several years of the simulation period whereas the water balance presented in **Table 7** represents an average for the entire simulation period. At the time of peak irrigation over the simulation period, December 2010, groundwater pumping accounts for 4.9% of the groundwater budget.

Table 7. Average daily mass balance for 58-year simulation from 1/01/1960 to 31/07/2018.

Mass balance	Components	Baseline Model	
		Flow (m^3/d)	Percentage of Flow (%)
Inflow	Storage	160,059	19.7
	CH	13	0.0
	Recharge	651,587	80.3
	Lakes	170	0.0
	Cross Boundary Flow	NA	NA
	Total inflow	**811,828**	**100**
Outflow	Storage	160,681	19.8
	Shallow Coastal Discharge (CH)	353,960	43.6
	Wells	5,668	0.7
	Drains/Wetlands (DC)	193,270	23.8
	Deep Coastal Discharge (GHB)	98,246	12.1
	Cross Boundary Flow	NA	NA
	Total outflow	**811,825**	**100**
Percentage discrepancy		0.0%	

Note: CH = constant head; GHB = general head boundary; DC = drain cells. Changes in storage are due to the difference in climatic and hence water table conditions between the start and the end of the model run.

5. Conclusions

A numerical groundwater flow model was developed for the Aupouri aquifer of Northland, New Zealand to be used to assess groundwater resources at the basin scale in the context of historic, present and future conditions. The calibrated model is intended to provide a tool for the evaluation of proposed groundwater extractions and its potential impact on both groundwater and surface water. In particular, the model can be used to define the potential impact from seasonal pumping on the aquifer system water budget, aquifer groundwater levels, surface water drain flows, and the position of the saltwater/fresh water interface.

Model Development

The framework for the model was based on review of all available borelogs, of which 198 were considered reliable enough to inform the development of the model stratigraphy. Geologic material noted in the borelogs was classified into four primary geologic layers; interbedded dune sand and peat, upper shellbed, compact sand, and lower shellbed; with the shellbed representing the aquifer material. The upper strata were sub-divided into 3 layers to account for the vertical heterogeneity in the material and allow for associated variability in conductivity and anisotropy to enable model calibration. The model layer base elevations were interpolated from the bore log data with the bottom of the lower shellbed being the lower model boundary.

Recharge to the model area was determined through an assessment of historic climate date and soil types processed using the SMWBM tool to develop a time series input based on historic rainfall and PET. Groundwater pumping was determined through an assessment of groundwater allocation over the model area and demand based on historic climate conditions.

Model Calibration

The model was calibrated to a historic dataset that included groundwater level observations measured at 56 locations. Each observation bore was assigned a model layer based on the depth of the bore and corresponding material within the model. A sensitivity analysis was performed to determine that hydraulic conductivity was the most sensitive model parameter, followed by vertical anisotropy.

The model was calibrated by systematically adjusting parameters in both a steady state and transient application to achieve the best possible agreement between simulated and measured water levels while maintaining realistic parameter values. In the case of the steady state simulation the parameter estimation tool, PEST, was used to determine the parameter values that best fit the observed data. These parameters were then used as the basis for the transient calibration.

The transient model was run for a simulation period of 58 years. A mean RMSE for all gauges of 1.89 m was achieved which was 7.1% of the range of observations. Many of the observation bores were well simulated in terms of their temporal trends while having a vertical displacement of the simulated water levels which may indicate the limitations of the 8 m DEM that was used to determine surface elevations in the model and subsequently the elevations of the model layers.

In some cases, vertical hydraulic gradients measured by nested piezometers were not well replicated in the simulation which reflects the limitations of capturing real world geologic complexity in a numerical model. Nonetheless model results indicate that the calibration is satisfactory for the intended application of the model.

Water Budget

Groundwater recharge in the Aupouri aquifer occurs through the percolation of rainfall and account for the majority of groundwater inflow. Groundwater outflows occur primarily as discharge to the coasts with some discharge also occurring as baseflow in streams and agricultural drains. Groundwater pumping is a small fraction of the overall groundwater budget; however, it has been increasing in recent years as groundwater allocation for agricultural use increases. At the time of peak irrigation total groundwater abstraction under current conditions accounts for 4.9% of the groundwater budget.

6. References

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Appendix A. Summary of Aquifer Hydraulic Properties

The following tables summarise hydraulic property values that have been measured and estimated in models across the Aupouri Peninsula from various reports since 2000.

Table A1. Analysis of aquifer test data (Lincoln Agritech, 2015).

Pump	Screen depth	Test name	Lithology	T	B	Kx	S	K'/B'	B'	K'z
	(mBGL)			(m^2/d)	(m)	(m/d)	(-)	(d)	(m)	(m/d)
200048	18.8	Hukatere 1	Sand	60	6.4	9.4	0.0017	0.1475	13.5	2.0
200048	18.8	Hukatere 1	Sand	60	6.4	9.4	0.0107	0.2927	13.5	4.0
200048	18.8	Hukatere 3	Sand	50	6.4	7.8	0.0022	0.1909	13.5	2.6
200048	18.8	Hukatere 3	Sand	62	6.4	9.7	0.0154	0.1909	13.5	2.6
200060	64	Browne	Sand	400	10.4	38.5	0.0004	0.0014	21.2	0.03
200081	31.2	Ogle Drive	Sand	7.4	8.1	0.9	0.0467	0.8771	10.2	8.9
200229	73	Fitzwater	Shell/sand	130	6	21.7	0.0002	0.0001	26.0	0.004
200229	73	Fitzwater	Shell/sand	110	6	18.3	0.0004	0.0004	11.0	0.004
201025	27	Sweetwater	Sand	52	6.3	8.3	0.0004	0.0018	11.0	0.02
201037	27.2	Welch	Sand/shell	9	1.8	5	0.0005	0.0087	11.9	0.1
209606	110.5	King Avo	Shell	305	26	11.7	0.0007	0.0003	15.5	0.004
209606	110.5	King Avo	Shell	370	17	21.8	0.0011	0.0003	15.8	0.005
			Min	7.4	1.8	0.9	0.0002	0.0001	10	0.004
			Mean	135	8.9	13.5	0.0067	0.14	15	1.7
			Max	400	26	38.5	0.0467	0.88	26	8.9

Table A2. Analysis of aquifer test data (HydroGeo Solutions, 2000).

NRC Bore	Depth	Top of screen	Aquifer type	SWL	T	K	S
	(m)	(mBGL)		(mBGL)	(m^2/d)	(m/s)	(-)
43	55	52	Fine sand	9.3	240 - 280	6E-05 to 7.1E-05	-
48	67	19	Med sand	5.3	80 - 300	6.1E-05 to 7.1E-05	0.01-0.001
59 (s)	6	-	Fine sand	2.8	140	5.10E-04	-
59 (d)	55	49	Fine sand	13.4	190	5.30E-05	-
60	60	-	Fine sand	14.9	220 - 850	5.6E-06 to 1.3E-04	-
81	32	31	Fine sand	20.9	12 - 28	1.25E-05 to 2.9E-05	0.07-0.03
152	66	60	Fine sand	30.1	260	8.40E-05	-
184	110	101	Shelly sand	17.2	140 -340	1.7E-05 to 4.2E-05	-
229 (211)	79	70	Shelly sand	2.6	140	2.10E-05	1.4E-04 to 1.8E-03
230	88	63	Shelly sand	4.6	240 - 310	4.3E-05 to 3.3E-05	-

NRC Bore	Depth	Top of screen	Aquifer type	SWL	T	K	S
	(m)	(mBGL)		(mBGL)	(m^2/d)	(m/s)	(-)
1007	50	45	Fine sand	33.7	275 -305	2.1E-04 to 1.9E-04	-
1025	30	27	Fine sand	1.55	60 -103	2.2E-05 to 3.7E-05	2.5E-04 to 5.0E-04
1374	32	26.6	Fine sand	0.8	48	1.80E-05	1.0E-05 to 2.0E-05
1424*	82	70	-	-	260	-	-

Table A3. Summary of aquifer test data (SKM, 2010).

Bore Owner	Well ARC No	Easting (NZMG)	Northing (NZMG)	Test Type	Test Dur. (hrs)	Rate (m^3/day)	Obs. Bores	Screen Geology	K (m/s)	Information Source
King	201374	2533400	6681500	Constant Rate	24	576	Yes (1)	Shell	1.8E-05	HydroGeo Solutions (2000)
Sweetwater Orchards	201424	2529558	6684434	Constant Rate	72	1,176	Yes (1)	Shell	1.9E-04	Woodward Clyde (1998)
Kaurex Corporation	200230	2530331	6697328	Constant Rate	9.5	273	No (PB only)	Shell	4.3 – 3.3E-05	HydroGeo Solutions (2000)
Matai Orchards	201507	2529399	6691299	Constant Rate	88.5	497	Yes (1)	Shell	4.0 – 2.0E-04	SKM (2007)
Hopkins	200184	2520300	6706800	Constant Rate	24	260	No (PB only)	Shell	4.2 – 1.7E-05	HydroGeo Solutions (2000)
Fitzwater	200229	2529743	6690648	Constant Rate	24	864	Yes (4)	Shell	2.1 – 1.4E-04	HydroGeo Solutions (2000) and SKM (2007)
Brown	200060	2521699	6706300	Constant Rate	22	708	Yes (3)	Sand	5.6E-06 – 1.3E-04	HydroGeo Solutions (2000)
Hogg	201007	2528300	6685799	Constant Rate	20.9	160	No (PB only)	Sand	2.1 – 1.9E-04	HydroGeo Solutions (2000)
Waiharara	209499	2528580	6690100	Constant Rate	91	1,113	Yes (2)	Shell	2.0E-04	SKM (2007)
King Avocado Ltd	209606	2527482	6690562	Constant Rate	168	2,393	Yes (3)	Shell	4.3 – 1.5E-04	SKM (2007)
Hamilton Nurseries	201025	2531401	6684155	Constant Rate	6	300	Yes (2)	Sand	1.2E-04	SKM (2001)
Stanisich Orchard	200192	2528600	6695799	Constant Rate	1	1,442	No (PB only)	Shell	5.0E-05	SKM (2002a)
Terra Nova Orchard	200335	2521199	6706499	Constant Rat	39	674	Yes (6)	Shell	4.0 – 3.0E-04	SKM (2002b)
Northland Catchment Commission	200048	2519855	6701857	N/A	N/A	N/A	N/A	Sand	7.1 – 6.1E-05	HydroGeo Solutions (2000)
Northland Catchment Commission	200081	2528583	6689795	N/A	N/A	N/A	N/A	Sand	2.9 – 1.25E-05	HydroGeo Solutions (2000)

Colville	200059	2521792	6705887	Step (4)	22.3	63 - 233	No (PB only)	Sand	5.3E-05	HydroGeo Solutions (2000)
Fraser	201002	2525552	6671053	Step (3)	22	89 - 163	No (PB only)	Sand	3.0E-04	NRC database
Richards Enterprises	200043	2522513	6708792	Step (4)	19	149 -333	No (PB only)	Sand	7.1 – 6.0E-05	HydroGeo Solutions (2000)
Herbert	200152	2528178	6688977	Step (4)	20	127 - 319	No (PB only)	Sand	8.4E-05	HydroGeo Solutions (2000)

Table A4. Calibrated model parameters (SKM, 2007a).

Material ID	Hydraulic Conductivity		Vertical anisotropy	Sy
	(m/d)	(m/s)	(-)	(-)
Loose dune sand	10	1.20E-04	10	0.2
Weathered dune sand	6	6.90E-05	10	0.2
Fine sand	3	3.50E-05	25	0.25
Peat and sand	0.1	1.20E-06	30	0.2
Upper alluvium	0.55	6.40E-06	10	0.3
Alluvium	0.06	6.90E-07	20	0.05
Shellbed	50	5.80E-04	2	0.3

Table A5. Aquifer hydraulic parameters derived from SKM102PB test pumping (SKM, 2007b).

Bore	T	K	
	(m^2/s)	(m/d)	(m/s)
SKM101b	3.70E-03	32	3.70E-04
SKM102b	1.50E-03	13	1.50E-04
SKM103b	3.50E-03	30	3.50E-04
SKM104b	4.30E-03	37	4.30E-04

Table A6. Material parameters used within PLAXIS geotechnical subsidence model (SKM, 2007b).

King Avocado Orchard Groundwater Take Consent Application (AEE Final)							
Material	Density (KN/$m^{3)}$		Permeability (m/d)		Stiffness (kN/m^2)	Cohesion (kN/m^2)	Friction Angle (°)
	δunsat	δsat	Kx	Ky	E50ref	cref	ø
Loose Dune Sand	15	17	5	0.25	10000	0.2	28

Compact Dune Sand	17	19	0.7	0.07	15000	0.2	28
Shellbed	18	20	22	2.2	30000	1	30

Table A7. Hydrogeological data calculated from pumping tests (WWA, 2017).

Farm	**Rate (L/s)**	**Bore**	**Screen Depth (mBGL)**	**Method**	**T (m^2/d)**	**S (-)**	**B (m)**	**K (m/d)**	**K (m/s)**
Stanisich Farm	25	Pumping bore	87-101	Single well Jacob	485	-	14	35	4.1E-04
				Theis Recovery	512	-		37	4.3E-04
	-	Monitoring bore	77-85	Theis (point match)	356	0.0044	8	45	5.2E-04
Honeytree Farm	29	Pumping bore	62-68, 68-71,84-93	Single well Jacob	618	-	18	34	3.9E-04
				Theis Recovery	511	-		28	3.2E-04
	-	Monitoring bore	63-69, 69-72,86-95	Theis (point match)	751	0.0003	18	42	4.9E-04
				Cooper Jacob	784	0.0003		44	5.1E-04
De Bede Farm	2.3	Pumping bore	91-97	Single well Jacob	377	-	6	63	7.3E-04
				Theis Recovery	363	-		61	7.1E-04
				Max	784	0.0044		63	7.3E-04
				Min	356	0.0003		28	3.2E-04
				Mean	528	0.0016		43	5.0E-04

Table A8. Calculated hydrogeological property from Single well Jacob method (WWA, 2017).

Farm	**Q (L/s)**	**Bore**	**Screen Depth (mBGL)**	**Evaluation time (s)**	**T (m^2/d)**	**B (m)**	**K (m/d)**	**K (m/s)**	**Time (s) evaluation criteria**	
									Minimum	**Maximum**
Stanisich	25	Pumping bore	87-101	210 - 1200	471	14	34	3.9E-04	183	1728
De Bede	2.3	Pumping bore	91-97	330 - 1470	273	6	46	5.3E-04	86	1728

Table A9. Estimated hydrogeological parameters from Hantush – Jacob method (WWA, 2017).

Bore	**T**	**K_h**	**K_h**	**K'/B'**	**S_s**
	m^2/d	**m/d**	**m/s**	**d^{-1}**	**m^{-1}**
Stanisich observation bore 2 (monitoring bore)	138	10	1.14E-04	1.83E-03	1.55E-04
	408	29	3.38E-04	1.35E-03	3.07E-04
	348	25	2.88E-04	7.36E-04	3.13E-04
Honeytree farm production bore 1(monitoring bore)	579	32	3.72E-04	1.50E-04	1.63E-05
	484	27	3.11E-04	2.84E-04	2.17E-05
	707	39	4.54E-04	5.09E-05	1.70E-05

Table A10. Calibrated Model Parameters (WWA, 2017).

Model Geological Units	Model Layer	K_x		Vertical Anisotropy	S_y	S_s
		(m/d)	(m/s)	(-)	(-)	(m^{-1})
Coastal sand	1	4.5	5.2E-05	70	0.3	-
Weathered sand	1	2.8	3.2E-05	90	0.25	-
Plain zone	1	0.1	1.2E-06	15	0.01	-
Coastal sand	2&3	4	4.6E-05	30	-	0.0005
Weathered sand	2&3	3	3.5E-05	80	-	0.0005
Shellbed	4	35	4.1E-04	1	-	0.0016
Sand	5	6	6.9E-05	30	-	0.0005
Shellbed	6	22	2.5E-04	1	-	0.0016

Table A11. Test pumping results for Sweetwater Farms (WWA, 2018).

Test	Analysis	Pumping rate		Screen length	Transmissivity (T)	Hydraulic conductivity (K)	Specific storage (/m)
		L/s	m^3/d	m	m^2/d	m/s	
Constant pumping	PB6 Cooper-Jacob	64	5,495	17	5,700	3.9E-03	9.6E-04
	PB2 Cooper-Jacob	64	5,495	17	430	2.9E-04	-
Recovery	PB2 Theis	64	5495	17	354	2.4E-04	-

Appendix B. Recharge Modelling

B.1 Model Parameters

The soil moisture water balance model (SMWBM) is a deterministic lumped parameter model originally developed by Pitman (1976) to simulate river flows in South Africa. The code was reworked into a Windows environment and the functionality extended to include a surface ponding function, additional evaporation functions and an irrigation module.

The model utilises daily rainfall and potential evaporation data to calculate soil moisture conditions and the various components of the catchment water balance under natural rainfall or irrigated conditions. The model operates on a time-step with a maximum length of daily during dry days, with smaller hourly time-steps implemented on wet days.

The model incorporates parameters that characterise the catchment in terms of:

- interception storage,
- evaporation losses,
- soil moisture storage capacity,
- plant available water capacity,
- soil infiltration,
- sub-soil drainage;
- vadose zone vertical drainage'
- surface runoff (quickflow);
- stream baseflows (groundwater contribution); and
- the recession and/or attenuation of groundwater and surface water flow components, respectively.

B.2 Fundamental Operation

The fundamental operation of the model is as follows and in **Table B1**:

When a rainday occurs, daily rainfall is disaggregated into the hourly time-steps based on a pre-defined synthetic rainfall distribution, which includes peak intensities during the middle of the storm. This time stepping approach ensures that rainfall intensity effects and antecedent catchment conditions are considered in a realistic manner by refined accounting of soil infiltration, ponding and evaporation losses.

Rainfall received must first fill a nominal interception storage (PI – see below) before reaching the soil zone, where the net rainfall is assessed as part of the runoff/infiltration calculation.

Water that penetrates the soil fills a nominal soil moisture storage zone (ST). This zone is subject to evapotranspiration via root uptake and direct evaporation (R) according to the daily evaporation rate and current soil moisture deficits. The soil moisture zone provides a source of water for deeper percolation to the underlying aquifer, which is governed by the parameters FT and POW.

If disaggregated hourly rainfall is of greater intensity than the calculated hourly infiltration rate (ZMAX, ZMIN) surface runoff occurs. Surface runoff is also governed by two other factors, which are the prevailing soil moisture deficit and the proportion of impervious portions of the catchment directly linked to drainage pathways (AI).

Rainfall of sufficient intensity and duration to fill the soil moisture storage results in excess rainfall that is allocated to either surface runoff or groundwater percolation depending on the drainage and slope characteristics of the catchment (DIV).

Finally, the model produces daily summaries of the various components of the catchment water balance and calculates the combined surface runoff/percolation to groundwater to form a total catchment discharge.

Table B1. Summary of SMWBM parameters and value assignments for this study.

Parameter	Name	Parameter Values			Description
		Coastal sand	Weather-ed sand	Plain zone	
ST (mm)	Maximum soil water content.	178.5	178.5	100	ST defines the size of the soil moisture store in terms of a depth of water. ST is approximately equivalent to root zone depth divided by soil porosity.
SL (mm)	Soil moisture content where drainage ceases.	0	0	0	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.
ZMAX (mm/hr)	Maximum infiltration rate.	20	20	5	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. ZMIN is usually assigned zero. ZMAX is usually assigned the saturated infiltration rate from field testing. 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.	0	0	0	
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity.	5	3.8	0.8	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.
POW (>0)	Power of the soil moisture-percolation equation.	2	2	2	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.
AI (-)	Impervious portion of catchment.	0	0	0.01	AI represents the proportion of impervious zones of the catchment directly linked to drainage pathways.
R (0,1,10)	Evaporation-soil moisture relationship	0	0	0	Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. Three different relationships are available. The rate of evapotranspiration is estimated using either a linear (0,1) or power-curve (10) 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.	0	0	0	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.
Kv (m/s)	Vertical hydraulic conductivity	8E-6	5E-6	2E-8	Kv along with the VGn parameter and the soil moisture status governs the unsaturated hydraulic conductivity and travel times within the vadose zone.

Parameter	Name	Parameter Values			Description
		Coastal sand	Weather-ed sand	Plain zone	
VGn (-)	van Genuchten parameter	2.68	2.68	1.09	Defines the soil moisture to unsaturated conductivity relationship according to van Genuchten's equation.
VPor (-)	Average porosity of the vadose zone	0.15	0.15	0.40	This is typically fixed and not changed during calibration as changes can easily be compensated for in Kv.
D (m)	Average depth of the vadose zone	10	10	1	The deeper the vadose zone, the longer the travel times.
TL (days)	Routing coefficient for surface runoff.	1	1	1	TL defines the lag of surface water runoff. This is not necessary to define for this study as we are only interested in the groundwater percolation component of the water balance.
GL	Groundwater recession parameter.	1	1	1	GL governs the lag in groundwater discharge or baseflow from a catchment.

B.3 Vadose zone discharge functionality

Based on the simulated groundwater percolation from the soil moisture model, the vadose zone discharge functionality was utilised to simulate the vertical movement of water in the unsaturated zone. The depth and hydraulic properties of the vadose zone govern the delay in groundwater response to climate variation.

The vadose zone functionality built into the SMWBM is premised on three principals:

1. ***Unsaturated hydraulic conductivity -*** The van Genuchten (1980) equation was used to determine unsaturated hydraulic conductivity in the vadose zone, which is governed by the saturated hydraulic conductivity that sets the upper value, and the degree of saturation in the soil zone as a proxy for general sub-surface degree of wetness.

2. ***Vertical flux rate*** - The simplified Richard's equation is used to estimate the vertical flux rate of water, which is assumed to be driven by gravitational force (only) and therefore governed by unsaturated hydraulic conductivity and porosity.

3. ***Transport time*** - The Muskingum equation was used to translate the vertical flux into a routing scheme, using the depth of the vadose zone and vertical flux rate (velocity) as the time component of the equation.

The delay in groundwater recharge was observed for coast sand, weathered sand and peat and clay to different extents. The simulated results for weathered sand suggest that the groundwater recharge has approximately 2-3 months delay in responding to the rainfall variation, depending on locality. **Figure B1.** provides an example of the functionality of the vadose zone model.

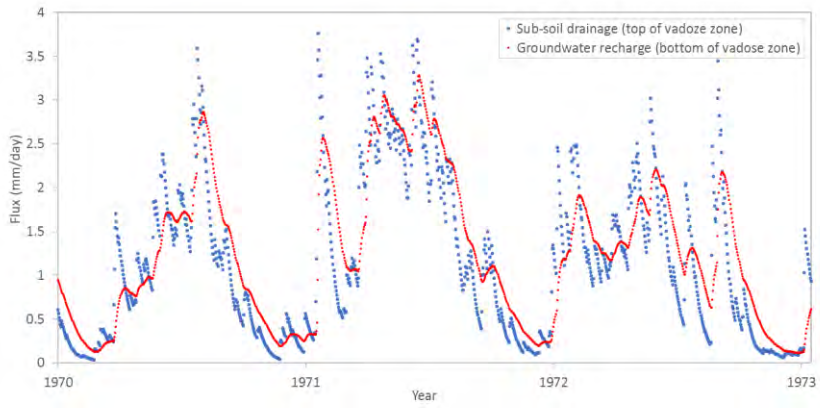


Figure B1. Graph comparing inputs and outputs from vadose zone model.

Appendix C. Groundwater Takes

All groundwater takes incorporated in the model are listed in **Table C1** through **Table C3**. Bores with figure reference identification numbers beginning with “C” are for bores with a consented groundwater take. Bores with figure reference identification numbers beginning with “P” are for bores with a proposed groundwater take.

Table C1. Consented and proposed groundwater users in Northern portion of the model corresponding to Figure 9A

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take-Consented Total (m^3/yr)	Groundwater Take per Bore (m^3/yr)	X coordinate	Y coordinate
C1		Henderson Bay Avocados-Consented	13,000	13,000	1605547	6154694
C2		Waikopu Avocados-Consented	44,640	44,640	1604046	6153129
C3	AUT.029091.01.01	G J & D J Price	7,500	7,500	1606898	6152070
C4	AUT.003768.01.04	L & P Trust	6,000	6,000	1606061	6149936
C5	APP.039244.01.01	Kelvin Thomas*	59,600	59,600	1610222	6147542
C6	AUT.037292.01.01	Fullam GW take	14,000	14,000	1609975	6147378
C7	APP.039381.01.01	Brien Lamb*	14,900	14,900	1610058	6147313
C8	AUT.002890.01.02	LL & DF Rasmussen	43,200	43,200	1611481	6146609
C8	AUT.004543.01.03	Wagener Houhora Heads Properties Ltd	45,000	45,000	1612372	6145137
C9	AUT.003883.01.03	Longbeach Trust	26,400	26,400	1610973	6145083
C10	AUT.003841.01.02	Tomo Orchard Ltd	14,800	14,800	1610945	6144743
C11	AUT.008203.01.02	Ongare Trust-2	55,056	37,200	1611610	6144688
C12	AUT.026611.01.01	Alligator Pear Partnership	49,752	49,752	1611191	6144687
C13	APP.039345.01.01	McLarnon-Ongare trust*	23,520	23,520	1611284	6144679
C14	AUT.012472.01.01	Ongare Trust-1	55,056	17,856	1611345	6144535
C15	AUT.009808.01.02	B C Smith	51,200	51,200	1610575	6144488
C16	AUT.020726.02.02	E J Williams	33,000	33,000	1610309	6144289
C17	AUT.028511.01.02	Far North Avos Limited	32,000	32,000	1610547	6144269
C18		Far North Avocados (Blake Powell) - Consented	32,000	32,000	1610547	6144269
C19	AUT.020727.02.02	Honeytree Farms Ltd	33,000	33,000	1610360	6144161
C20	AUT.023557.01.02	Whispering Pines Ltd	46,000	46,000	1611525	6144087
C21	AUT.003726.01.02	Hine & Associates current	74,400	74,400	1610798	6144048
C22	AUT.008605.01.02	Trebcombe Limited-1	78,120	52,080	1611216	6143980
C23	AUT.007735.01.04	S127 GW take	66,000	66,000	1610514	6143937
C24	AUT.038075.01.01	McQuarrie	12,000	12,000	1611559	6143858
C25	AUT.003527.01.02	Trebcombe Limited-2	78,120	26,040	1610842	6143760
C26	AUT.003888.01.02	RB Freeman-1	60,480	34,560	1611320	6143725
C27	AUT.008586.02.01	EJ Wagener	30,000	30,000	1611836	6143656
C28	AUT.007108.01.02	Matalaka Trust	16,740	16,740	1610610	6143652

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take- Consented Total (m^3/yr)	Groundwater Take per Bore (m^3/yr)	X coordinate	Y coordinate
C29	AUT.003372.01.02	RB Freeman-2	60,480	25,920	1610829	6143550
C30	AUT.037274.01.01	Whalers Rd Houhora	74,500	74,500	1611997	6143025
C31	AUT.036910.01.02	Soltysik-Freeman Fam Trust	135,000	135,000	1611801	6142975
C32	APP.038732.01.01	Valadares*	22,350	22,350	1611872	6142927
C33	partial	Mapua Avocados-1	418,000	139,333	1612784	6142645
C34	partial	Mapua Avocados-2	418,000	139,333	1612979	6142360
P1		Henderson Bay Avocados	19,000	19,000	1605623	6154872
P2		Far North Avocados (Blake Powell)	32,000	32,000	1605981	6154581
P3		Waikopu Avocados	83,360	83,360	1603347	6153388
P4		Te Raite Station_Waihopo	120,000	60,000	1605333	6151462
P5		Te Raite Station_other	157,500	157,500	1603898	6151179
P6		Te Raite Station_Waihopo	120,000	78,750	1607102	6150752
P7		Te Raite Station-Hourhora	875,000	125,000	1608383	6148854
P8		J. Evans	160,000	160,000	1609502	6148854
P9		Te Raite Station-Hourhora	875,000	125,000	1609287	6148271
P10	APP.040652.01.01	S. & L. Blucher	96,000	96,000	1610145	6148091
P11		Te Raite Station-Hourhora	875,000	125,000	1607182	6148084
P12		Te Raite Station-Hourhora	875,000	125,000	1607771	6147949
P13		Te Raite Station-Hourhora	875,000	125,000	1609016	6147852
P14		Te Raite Station-Hourhora	875,000	125,000	1609296	6147373
P15		Te Raite Station-Hourhora	875,000	125,000	1609655	6147078
P16	APP.040397.01.01	A. Matthews	12,000	12,000	1611037	6146088
P17	APP.039644.01.01	D. Wedding & Doody	304,000	304,000	1610296	6145329
P18	APP.040121.01.01	M. Evans	36,400	36,400	1610444	6144926
P19		Temp Consent for M Evans (only 1 year)	24,000	9,100	1610444	6144926

*Members of the Motutangi Water Users Group. Applications have been consented but are unexercised as of the completion of this report.

Table C2. Consented and proposed groundwater users in Northern portion of the model corresponding to Figure 9B

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take-Consented Total (m^3/yr)	Groundwater Take per Bore (m^3/yr)	X coordinate	Y coordinate
C36	AUT.008340.01.03	Shirttail Orchards	158,520	158,520	1613554	6140038
C37	AUT.003964.01.03	Subritzky	67,106	67,106	1614010	6139855
C38	AUT.038379.01.01	De Bede	70,000	70,000	1615069	6139351
C39	APP.039332.01.01	Candy Corn Ltd*	78,400	78,400	1614723	6139203
C40	APP.038589.01.01	Thompson*	35,280	35,280	1614798	6138773
C41	AUT.008647.01.03	KSL Ltd	52,800	52,800	1614554	6138575
C42	APP.038591.01.01	Cypress Hills Ltd1*	35,280	35,280	1614898	6138495
C43	AUT.028834.01.01	JR Avocados Ltd	20,000	20,000	1614800	6138422
C44	partial	GT&MT Covich-1	223,500	111,750	1617353	6136859
C45	APP.038410.01.01	GT&MT Covich-2*	223,500	111,750	1617128	6136793
C46	partial	Honeytree2	346,425	173,213	1618611	6136321
C47	APP.038471.01.01	Honeytree1*	346,425	173,213	1618903	6136060
C48	APP.038513.01.01	Ngai Takakto1*	193,700	96,850	1618987	6135795
C49	partial	Ngai Takakto2	193,700	96,850	1619097	6135520
C50	AUT.017559.02.01	IJ & BM Broadhurst	105,000	105,000	1619399	6134994
C51	AUT.016914.02.01	I M Fulton-2	60,000	40,000	1619585	6134880
C52	AUT.029171.01.01	J P Broadhurst	24,000	24,000	1619442	6134796
C53	APP.038380.01.01	Holloway*	14,900	14,900	1619702	6134754
C54	AUT.029109.01.01	I M Fulton-1	60,000	20,000	1619452	6134520
C55	APP.038328.01.01	KB&SD Shine*	39,200	39,200	1619411	6134224
C56	APP.038454.01.01	Elbury Holdings-King*	113,700	113,700	1619904	6133984
C57	AUT.027391.01.01	Stanisich1	180,000	120,000	1618046	6133608
C58	APP.027391.01.02	Stanisich-proposed*	64,070	64,070	1617846	6133480
C59	APP.038420.01.01	Matijevich2*	193,700	96,850	1618003	6133379
C60	partial	Matijevich1	193,700	96,850	1617905	6132480
C61	APP.038650.01.01	Hewitt*	39,200	39,200	1617436	6132318
C62	AUT.038339.01.01	Broadhurst	50,000	50,000	1618994	6131326
C63	AUT.020533.02.01	Luca Vista	24,200	24,200	1619057	6130879
C64	AUT.038402.01.01	Bell	35,000	35,000	1619211	6130581
C65	AUT.036868.01.01	Stanisich2	180,000	60,000	1618376	6129421
C66	AUT.003580.01.03	Rangaunu	35,000	35,000	1618726	6129089
C67	AUT.017045.01.02	VALIC3	558,000	186,000	1616982	6128849
C68	AUT.004564.01.04	Far North Farms Ltd	80,000	80,000	1618816	6128564
C69	AUT.017045.01.02	VALIC2	558,000	186,000	1616610	6128425
C70	AUT.003968.01.03	DG&HA Inglis	25,000	25,000	1618916	6128385
C71	AUT.017045.01.02	VALIC1	558,000	186,000	1617061	6128196
C72	AUT.014520.02.01	Millpara	183,920	91,960	1617699	6128150

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take-Consented Total (m^3/yr)	Groundwater Take per Bore (m^3/yr)	X coordinate	Y coordinate
C73	AUT.014520.01.02	Millpara	183,920	91,960	1617696	6127997
C74	AUT.002459.01.03	Avocado Investments Ltd	18,600	18,600	1617322	6126681
C75	AUT.008589.01.02	RA&LS Huddart	11,040	11,040	1617926	6126666
C76	AUT.003788.01.03	Javo	18,600	18,600	1617131	6126650
C77	AUT.004350.01.03	Hayward	24,000	24,000	1618191	6126546
C78	AUT.008177.01.02	JB & GM Clark	24,000	24,000	1618190	6126545
C79	AUT.003798.01.04	NG Rouse	16,500	16,500	1617423	6126357
C80	AUT.028476.01.01	J Jones	60,000	60,000	1618328	6125903
C81	AUT.004571.01.03	DC&MA Olsen	45,000	45,000	1619564	6125618
P20	APP.040130.01.01	Tuscany	36,000	36,000	1614331	6138447
P21	APP.040386.01.01	Robert Campbell	360,000	360,000	1615815	6135787
P22	APP.039841.01.02	Yelavich	52,000	52,000	1616834	6134008
P23	APP.040363.01.01	Wataview	33,750	33,750	1619441	6131282
P24	APP.040361.01.01	Tiri	581,250	290,625	1618056	6130290
P25	APP.040361.01.01	Tiri	581,250	290,625	1618856	6130196
P26	APP.040362.01.01	Valic	173,700	173,700	1617589	6129130

Table C3. Consented and proposed groundwater users in Northern portion of the model corresponding to Figure 9C

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take-Consented Total (m³/yr)	Groundwater Take per Bore (m³/yr)	X coordinate	Y coordinate
C82		Te Urungi O Ngati Kuri LTD	18,250	18,250	1623319	6122860
C83		Far North Holiday Park-Non irrigation	10,920	10,920	1615677	6122797
C84		J A Trussler	148,800	148,800	1618833	6122488
C85		FNDC: GW take for Kaitaia	1,460,000	1,460,000	1618250	6121600
C86		Sweetwater Farms_PB16	1,210,242	110,022	1616968	6121153
C87		Sweetwater Farms_PB3	1,210,242	110,022	1616579	6120782
C88		Sweetwater Farms_PB1	1,210,242	110,022	1617060	6120384
C89		Landcorp Farming Limited	200,000	200,000	1619617	6120296
C90		Sweetwater Farms_PB2	1,106,760	598,000	1617891	6119767
C91		Sweetwater Farms_PB7	1,210,242	110,022	1618481	6119718
C92		KJ & FG King : GW for Awanui Straight-1	278,262	92,754	1622335	6119515
C93		KJ & FG King : GW for Awanui Straight-3	278,262	92,754	1622365	6119515
C94		Sweetwater Farms_PB5	1,210,242	110,022	1617613	6119386
C95		Sweetwater Farms_PB10	1,210,242	110,022	1619652	6119162
C96		Sweetwater Farms_PB4	1,210,242	110,022	1616934	6119154
C97		KJ & FG King : GW for Awanui Straight-2	278,262	92,754	1622954	6119131
C98		Sweetwater Farms_PB6	1,106,760	508,760	1617450	6119000
C99		Sweetwater Farms_PB9	1,210,242	110,022	1618334	6118808
C100		Sweetwater Farms_PB13	1,210,242	110,022	1618755	6118360
C101		Sweetwater Farms_PB11	1,210,242	110,022	1617376	6118236
C102		Sweetwater Farms_PB14	1,210,242	110,022	1617307	6117876
C103		RF & MH Barber-Tudorwood Orchard	23,760	23,760	1623509	6117021
P27		Sweetwater-5	1,080,000	180,000	1617267	6121591
P28	APP.040364.01.01	Elbury Holdings	200,000	100,000	1618634	6121359
P29	APP.040364.01.02	Elbury Holdings	200,000	100,000	1618542	6121003
P30		Sweetwater-4	1,080,000	180,000	1616465	6120787
P31		Sweetwater-3	385,000	385,000	1617109	6120717
P32		Sweetwater-6	1,080,000	180,000	1616868	6120002
P33		Sweetwater-2	436,000	436,000	1617846	6119771
P34		Sweetwater-1	632,000	632,000	1617473	6119002
P35		Sweetwater-7	1,080,000	180,000	1617043	6118433
P36		Sweetwater-9	1,080,000	180,000	1617279	6117495
P37		Sweetwater-8	1,080,000	180,000	1616978	6116808

Figure reference	IRISID (where available)	Bore Owners	Groundwater Take-Consented Total (m^3/yr)	Groundwater Take per Bore (m^3/yr)	X coordinate	Y coordinate
P38		Sweetwater-10	210,000	105,000	1617702	6114717
P39		Sweetwater-11	210,000	105,000	1617254	6113920
P40		Sweetwater-12	350,000	116,667	1616055	6112008
P41		Sweetwater-13	350,000	116,667	1616563	6111903
P42		Sweetwater-14	350,000	116,667	1616889	6111890

Appendix D. Irrigation Scheduling and Actual Irrigation Use

D.1 Development of an irrigation scheduling dataset

The irrigation module of Soil Moisture Water Balance Model was utilised to optimise irrigation applications for avocado orchards in the area and to provide input into the transient irrigation scenario for groundwater modelling purposes. The parameters and associated values used in the model are shown in **Table C1**.

Table C1. Summary of parameters used in the irrigation model

Parameter	Description	Values	Basis of Values
Maximum Soil Moisture Content (ST)	The capacity of water in mm in the soil at field capacity.	178.5	Estimated from potential rooting depth (PRD) and macroporosity (n). ST = PRD x n/100. 1190 mm x 15%= 178.5 mm
Plant Available Water (PAW)	The amount of water physically accessible by the plants in the root zone in mm.	125	Table 22 of Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements from the Food and Agricultural Organisation of the United Nations (FAO)[1] states that 70% of Total Available Soil Water (interpreted as equivalent to ST in the SMWBM) can be depleted before the point where avocado trees suffer stress. Therefore, PAW = 0.7 x ST
Allowable Deficit (AD)	Soil moisture level where irrigation ceases.	90% of PAW	The avocado is very flood-sensitive with even short periods of waterlogging resulting in reduced shoot growth, altered mineral uptake and root death. To avoid flooding and surface runoff, soil moisture levels during irrigation should not exceed 90% of field capacity.
Minimum/ Critical Deficit (CD)	Percentage of PAW at which further drying of soil would start to have an impact on plant growth rates, and hence CD represents the soil moisture level at which irrigation commences.	40% of PAW	The rule of thumb for critical deficit is 50% of PAW. However, a grower aiming to maximise crop yield may want a small critical deficit of only 20% (80% PAW)[2]. A balance is also required between a small critical deficit (high soil moisture levels) and water wastage, which results under high moisture conditions when rainfall occurs during summer. Through trial and error, we have used CD values of 40% PAW.
Peak Application Depth	Maximum daily irrigation depth applied to soil (mm/day).	4.0 mm	Selected through optimisation target of minimisation in losses, while maintaining moisture levels at or above the CD. Note. This is the amount of irrigation water reaching the soil surface, which is less that the amount applied by the irrigator *per se*. due to application inefficiencies (losses).
Application Duration	Duration in hours over which the peak application depth is applied	2 hours	Data estimated
Rain Threshold	Daily rainfall total in mm when a farmer would choose not to irrigate.	10 mm	Judgement
Season	Irrigation season start and finish	October – April	General irrigation season length.

The historical rainfall record from 01/01/1960 to 31/07/2018 was used in the model. The simulated soil moisture content with/without irrigation are shown in **Figure C1**.

1 http://www.fao.org/docrep/x0490e/x0490e0e.htm
2 Anon. Scheduling overview. NZ Avocado Industry 11 Mar 2010. (accessed 16 Jul 2015) <http://www.hortinfo.co.nz/factsheets/fs110-68.asp>.

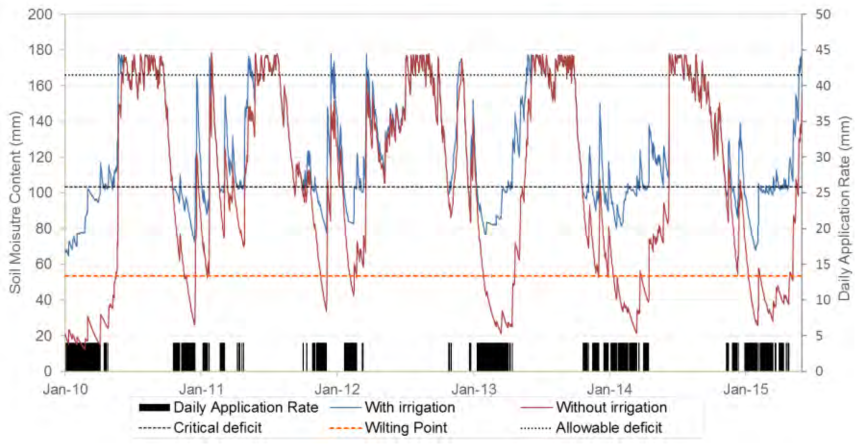


Figure C1. Irrigation simulation output for time period 2010-2015

The daily peak application rate was optimised through a set of simulations, aiming to minimize the water losses through surface runoff and percolation to groundwater system, while maintaining a soil moisture content that is above the plant critical deficit.

The simulations indicate an optimized peak application rate of 4 mm/day. The relationship between annual irrigation amount and peak application rate is shown in **Figure C2**.

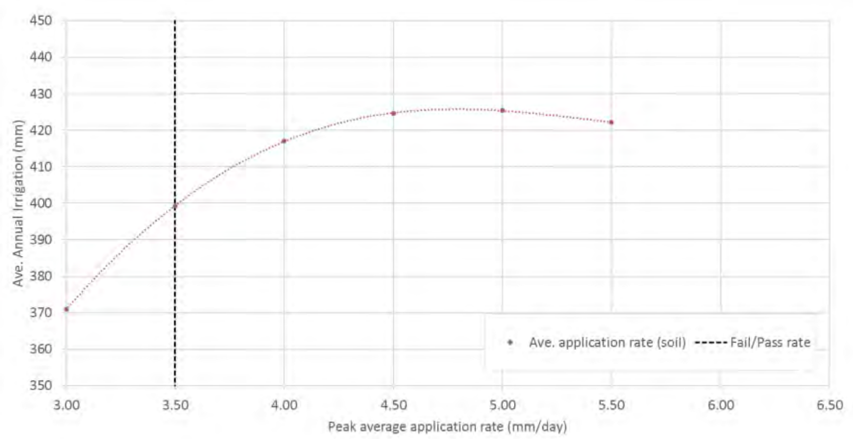


Figure C2. Assessment of peak application rate that is water conservative for sandy soils.

The irrigation demand was simulated for the period of 01/01/1960 to 31/07/2018 and a summary graph showing the number of days irrigation was required per season is shown in **Figure C3**.

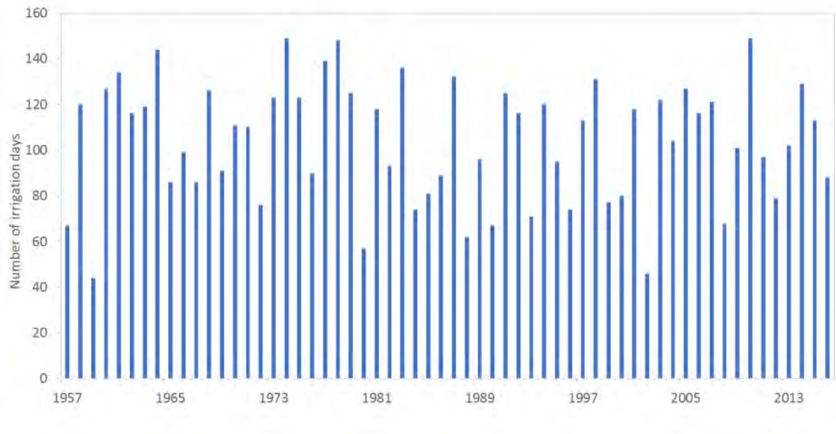


Figure C3. Simulated number of irrigation days per season.

The statistical distribution of monthly irrigation application totals, with 10% additional water added to account for irrigation inefficiency, is shown in **Figure C4**.

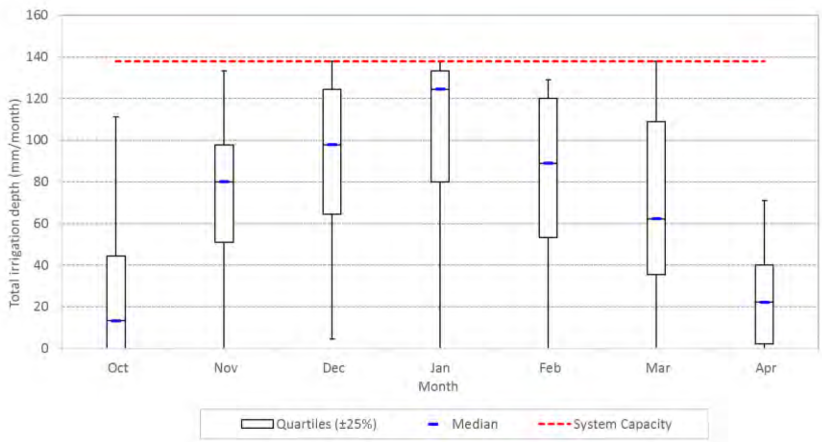


Figure C4. Seasonal irrigation demand for sandy soil.

The annual irrigation demand volume and commensurate number of days of irrigation was calculated and it was found that the 90%ile of simulated annual demand is equivalent to approximately 150 days pumping at the peak rate. This closely aligns with the annual volumes specified in consents granted.

D.2 Development of an irrigation actual use dataset

The simulated irrigation demand time series was applied to one of the currently consented groundwater bores with a peak allocation rate of 720 m^3/day owned by Ivan Stanisich (NRC consent No. CON20102739101). The total amount of demand simulated during the irrigation period was calculated and compared with available historical use records, as shown in **Figure C5**.

The simulated demand varies with climate conditions from a minimum of 44 days irrigation to a maximum of 149 days irrigation during the irrigation season. For the years where records were available for comparison, measured demand is approximately 30% of simulated demand. There are a number of minor reasons for this including human operational decision and actual rainfall not being totally consistent with site rainfall, but the primarily reason is that the orchard is not fully developed.

Considering the scope and purpose of this modelling, this irrigation demand time series is a conservative estimate and therefore appropriate to use in effects assessment from the abstraction of groundwater.

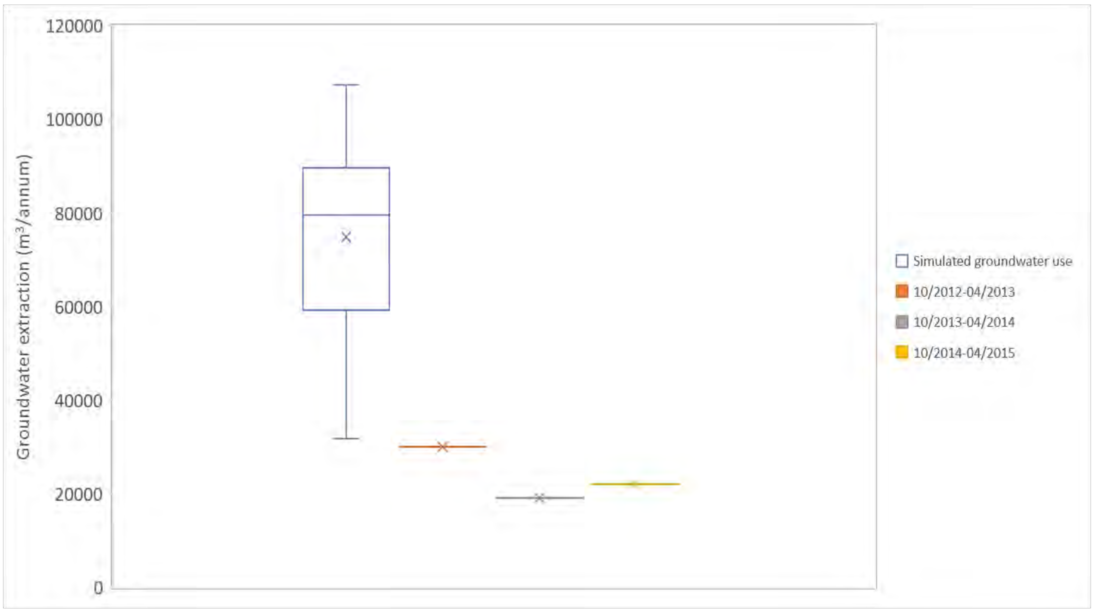
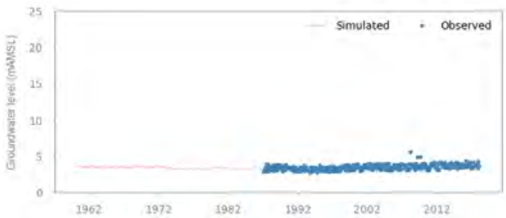


Figure C5. Comparison between the simulated groundwater demand and the historical records.

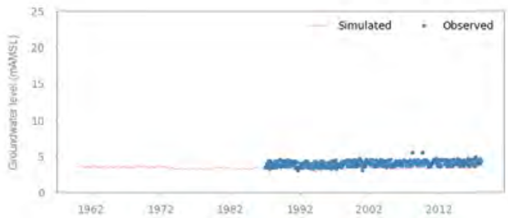
The irrigation demand pattern from **Section C.1** was applied to all the groundwater irrigation bores in the model area to construct transient pumping time series input for the model.

Appendix E. Calibrated Model Hydrographs

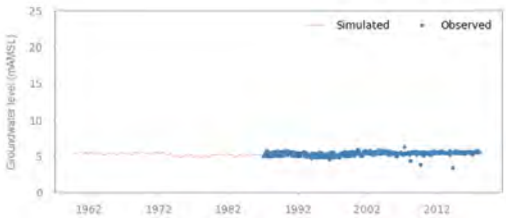
Waterfront (19 m)



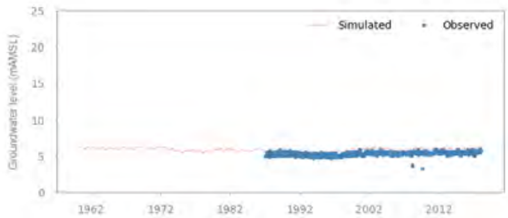
Waterfront (37 m)



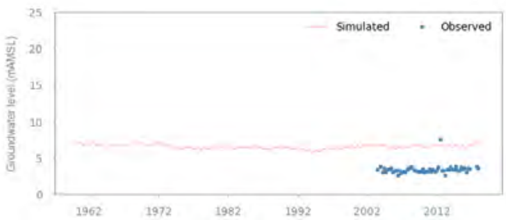
Waterfront (57 m)



Waterfront (74 m)

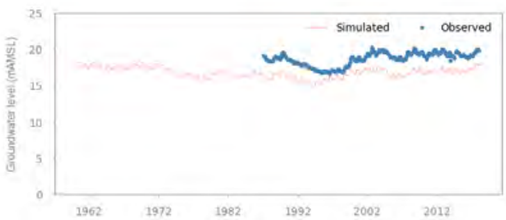


Fishing Club (78 m)

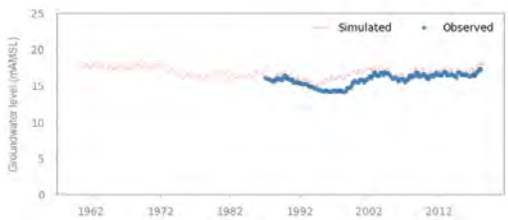


Wagener (69 m)

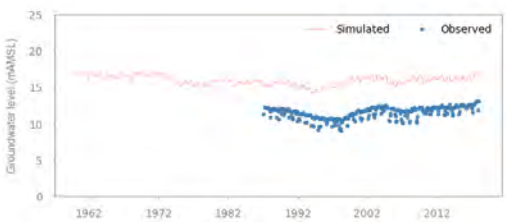
Browne (16 m)



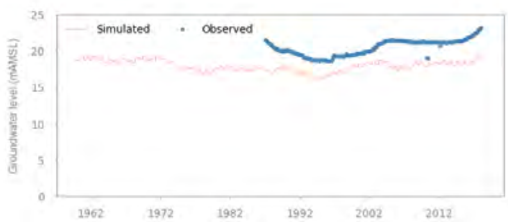
Browne (29 m)



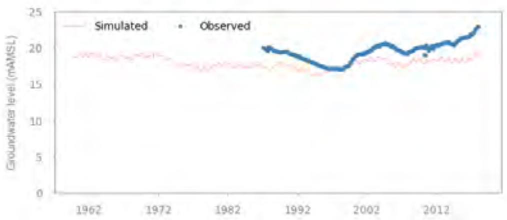
Browne (59 m)



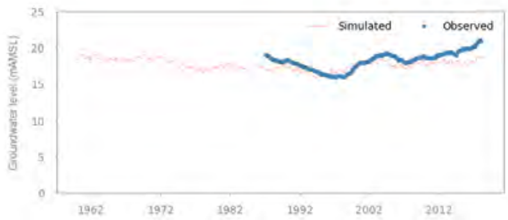
Forest (16 m)



Forest (36 m)

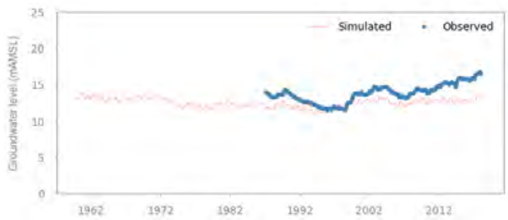


Forest (64 m)



Forest (79 m)

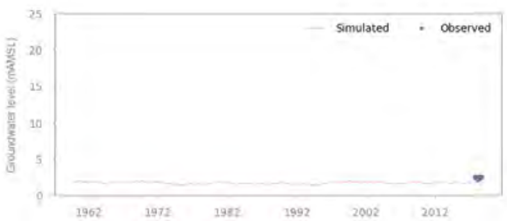
Hukatere (19 m)



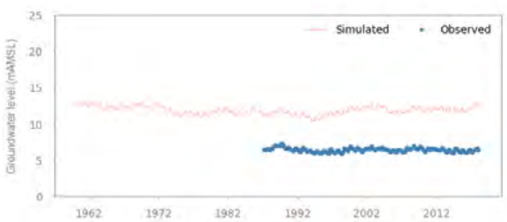
Hukatere (36 m)

Hukatere (58 m)

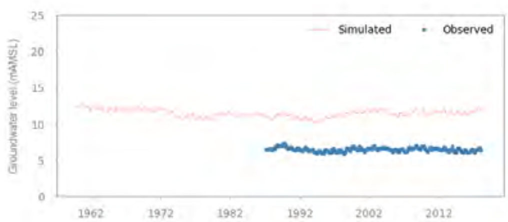
Kaimaumau Deep (72 m)



Paparore (18 m)



Paparore (35 m)



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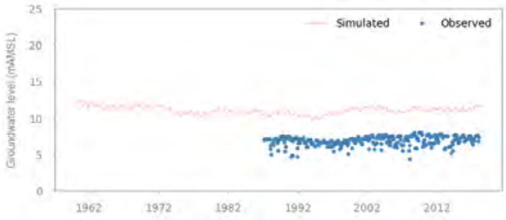
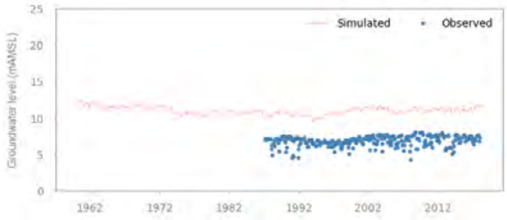
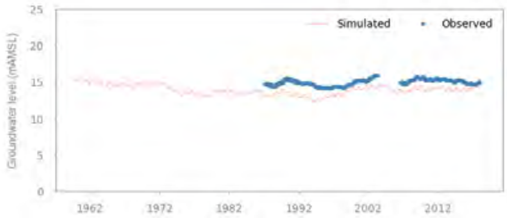


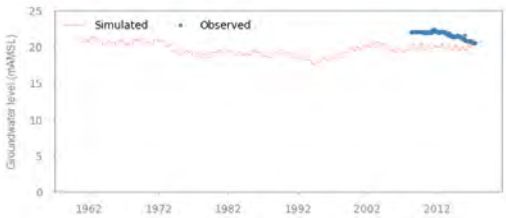
Paparore (75 m)



Ogle Drive (68 m)

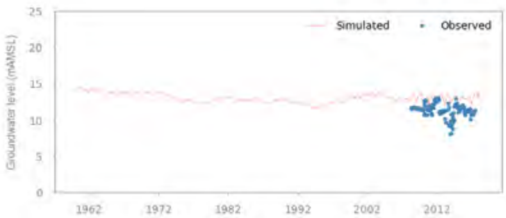


Valic-1 (Shallow Monitoring-17 m)



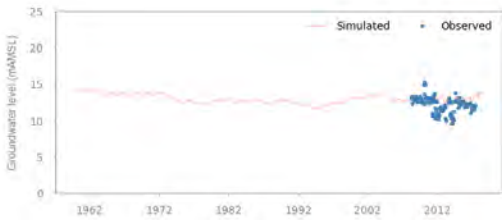
Valic-1 (Deep Monitoring-103 m)

Valic-1 (Production Bore-103 m)

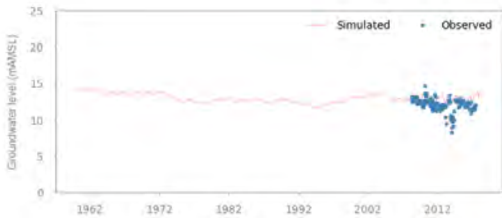


Valic-2 (Shallow Monitoring-55 m)

Valic-2 (Deep Monitoring-121 m)

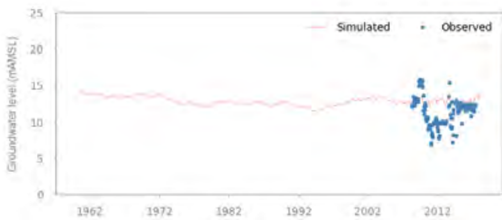


Valic-2 (Deep Production-121 m)

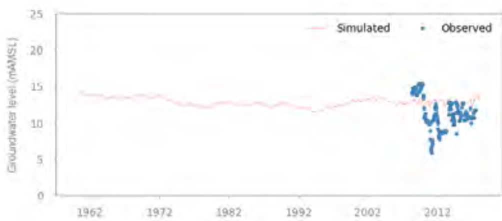


Valic-3 (Shallow Monitoring-45 m)

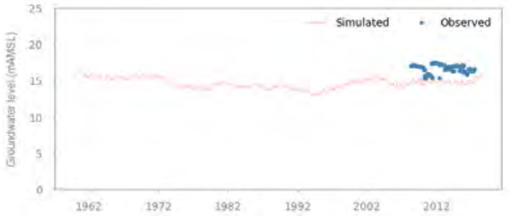
Valic-3 (Deep Monitoring-124 m)



Valic-3 (Deep Production-124 m)



Valic-4 (Shallow Monitoring-13 m)



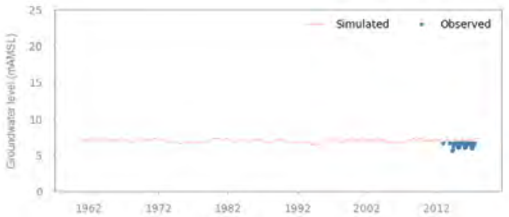
Valic-4 (Deep Monitoring-93 m)

Valic-4 (Deep Production-93 m)

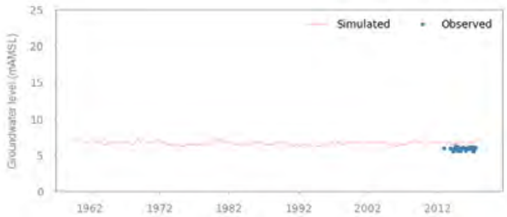
Sweetwater MW1 (13 m)

Sweetwater MW1 (94 m)

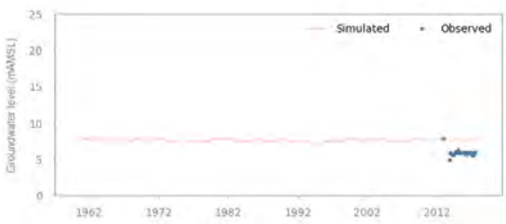
Sweetwater MW2 (15 m)



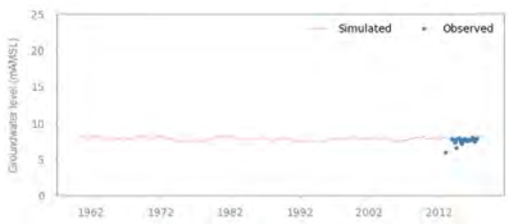
Sweetwater MW2 (59 m)



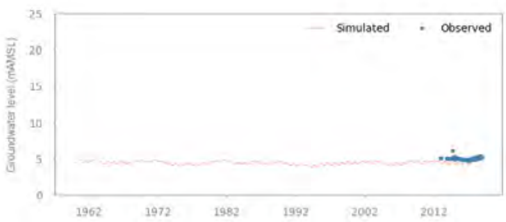
Sweetwater MW3 (5 m)



Sweetwater MW3 (47 m)

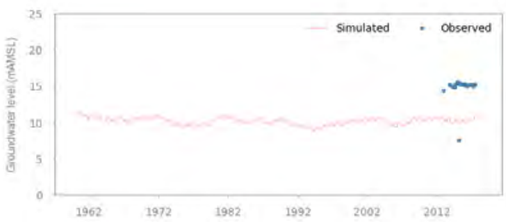


Sweetwater MW4 (25 m)

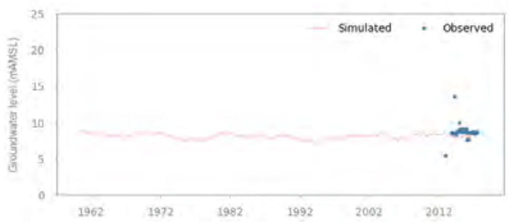


Sweetwater MW4 (92 m)

Sweetwater MW5 (6 m)

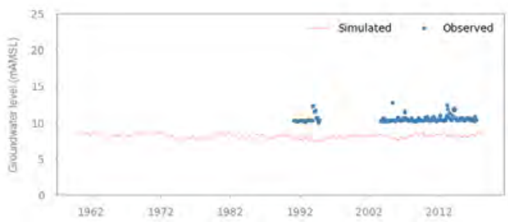


Sweetwater MW5 (61 m)



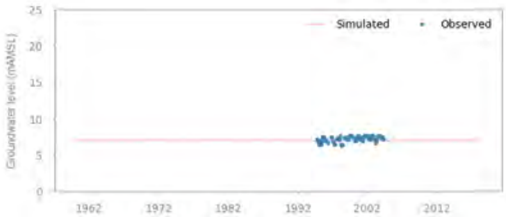
Sweetwater MW6 (15 m)

Sweetwater Nursery (34 m)

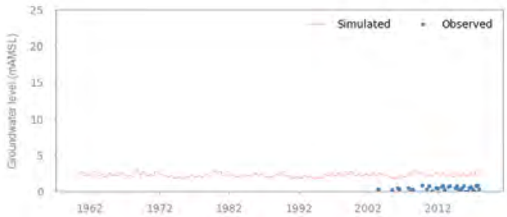


Waipapa (56 m)

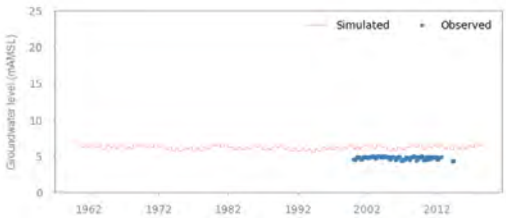
Shanks (Unknown depth)



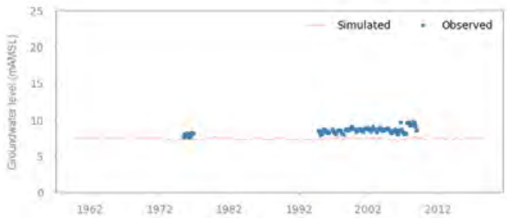
Vinac (33 m)



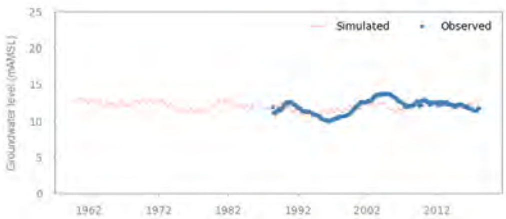
Matich (Unknown depth)



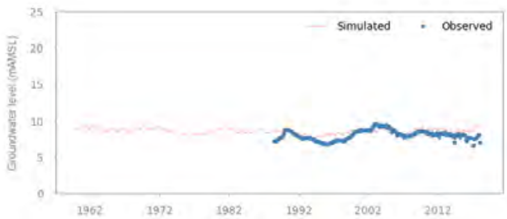
Welch (32 m)



Lake Heather 1 (26 m)



Lake Heather 1 (105 m)



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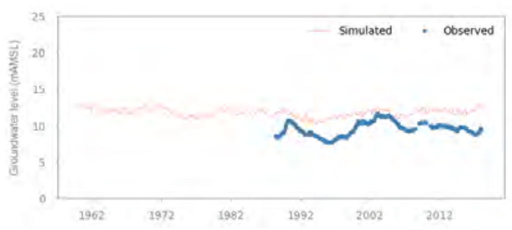


Lake Heather 3 (29 m)

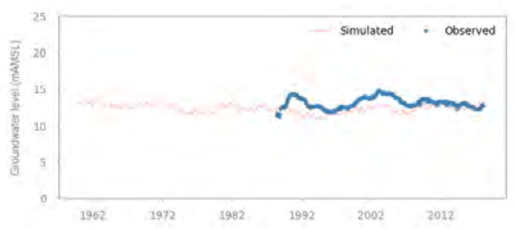


Figure E1. Hydrographs of simulated versus observed groundwater levels.

Appendix E
Sweetwater Station Irrigation Water Take Consent, Assessment of Effects on the regional aquifer system and the hydrological condition of surface water, Williamson Water & Land Advisory Ltd, 29 March 2019

Appendix E Sweetwater Station Irrigation Water Take Consent, Assessment of Effects on the regional aquifer system and the hydrological condition of surface water, Williamson Water & Land Advisory Ltd, 29 March 2019

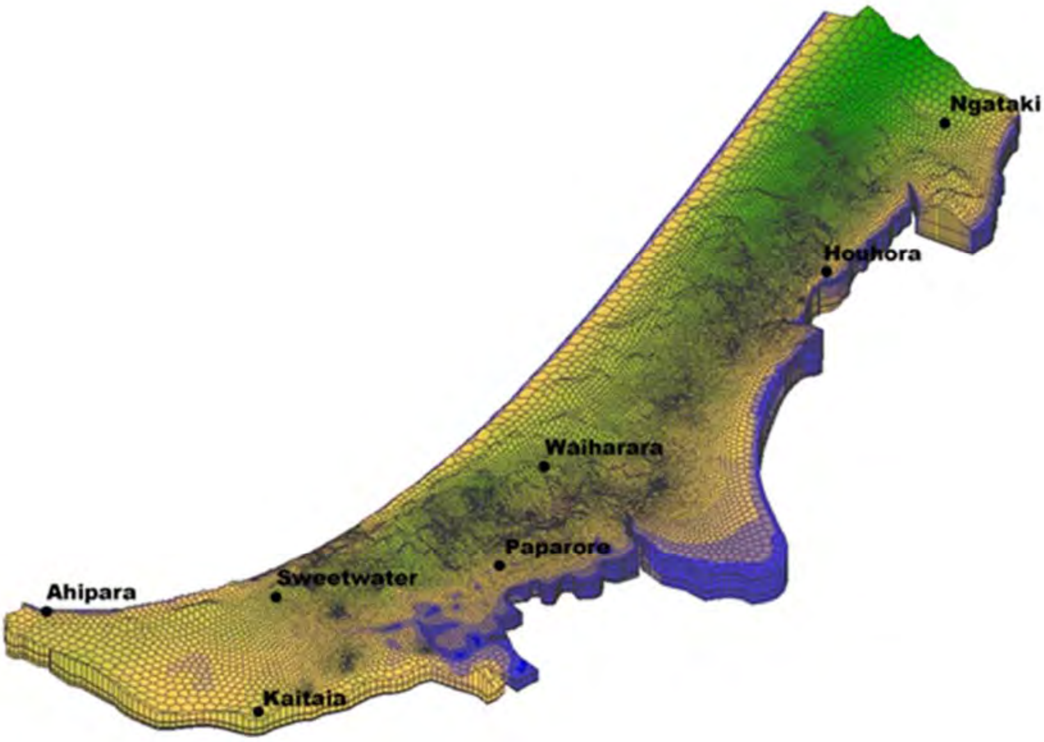
Appendix E

Sweetwater Station Irrigation Water Take Consent

Assessment of effects on the regional aquifer system and the hydrological condition of surface water

WSP OPUS
WWA0091 | Rev. 4

29 March 2019



Sweetwater Station Irrigation Water Take Consent

Project no:	WWA0091
Document title:	Resource Consent Application & Assessment of Environmental Effects
Revision:	4
Date:	29 March 2019
Client name:	WSP Opus
Project manager:	Jon Williamson
Author(s):	Jacob Scherberg, Jon Williamson
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Rev	Date	Description	By	Review	Approved
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2	20 March 2019	Internal review	Jacob Scherbreg	Louise Soltau	Jon Williamson
3	21 March 2019	Internal review	Jacob Scherbreg		Jon Williamson
4	29 March 2019	Client Review	Jacob Scherbreg	WSP Opus	Jon Williamson

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Rev	Date issued	Issued to	Comments
3	21 March 2019	Chris Frost (WSP-Opus)	For client review.
4	1 April 2019	Chris Frost (WSP-Opus)	

Contents

Figures

Executive Summary

Williamson Water & Land Advisory (WWLA) were commissioned in a sub-consulting role by WSP-Opus to utilise a numerical model for assessment of groundwater effects and prepare a technical report for the re-configuration and increase of a groundwater take at Sweetwater Station in the Kaitaia region of Northland. Sweetwater Station has a current groundwater consent for 2,317,000 m^3/year to be extracted at up to 14 locations. In practice, the water is obtained through 2 pumping bores, effectively exercising 48% of the consent.

Sweetwater Station is currently seeking to change the locations for some of the consented bores and increase the total groundwater take by 776,000 m^3/year with the water to be used for agricultural and horticultural irrigation purposes. With this consent the total groundwater allocation for Sweetwater Station would be 3,093,000 m^3/year.

An existing numerical groundwater flow model was re-configure for Sweetwater Station to determine the potential impact from the proposed groundwater abstraction on the regional aquifer system and the hydrological condition of relevant surface water. In particular, the model was used to define the potential impact from seasonal pumping on the aquifer system water budget, aquifer groundwater levels, surface water drain flows, and the position of the saltwater/fresh water interface. The development and calibration of the model are documented in a separate report while this document provides an assessment of effects predicted for the proposed groundwater pumping activities. The assessment considers the impact of groundwater extraction with regard to:

- Surface water effects
- Drawdown in the shallow and deep aquifer
- Pumping interference on neighbouring bores
- Saline intrusion
- Ground settlement

To address these items four scenarios were developed using the numerical groundwater model and simulated with the model representing a) the current base case (calibration model); b) the base case with pumping distributed between all currently consented bore locations c) the future given the proposed takes assuming a leaky aquifer model, and d) the future given the proposed takes assuming a relatively non-leaky aquifer model.

Model results were used to inform an assessment of environmental effects for the proposed Sweetwater Station groundwater take. It was determined that the anticipated impact on surface waters would be limited to a less than 0.5% decline in annual minimum flows. Under the more conservative scenario conditions the greatest drawdown predicted for a bore on a neighbouring property was 0.79 m where available drawdown is typically 70 to 100 m. The proposed groundwater extraction was determined to be unlikely to induce saline intrusion into the aquifer and to have a negligible impact in terms of land settlement. These results lead to the conclusion that the proposed groundwater take will have a less than minor impact on all criteria evaluated for the assessment of effects on the regional aquifer system.

This report presents the factual results of the modelling study and will form a part of the Assessment of Environmental Effects report.

1. Introduction

Williamson Water & Land Advisory (WWLA) has been commissioned by WSP-Opus Consultants, on behalf of Sweetwater Station to develop a numerical model and prepare an assessment of environmental effects (AEE) report addressing the environmental effects on the regional aquifer system and the hydrological condition of relevant surface water resulting from proposed groundwater abstractions for irrigation of agricultural and horticultural crops.

Sweetwater Station currently holds a consent for a 2,317,000 m^3/year groundwater take (AUT 020995.01.03). Details relating to the consent for this groundwater take are available in NRC (2017). To date the consented take has not been fully exercised, with groundwater currently being sourced from two production bores. In this application Sweetwater Farms are seeking to increase their consented groundwater allocation by 776,000 m^3/year for a total 3,093,000 m^3/year, distributing the water take among 14 bores located in the Aupouri-Sweetwater and Aupouri-Ahipara groundwater allocation zones.

WWLA has applied a numerical modelling analysis to assess the proposed groundwater take in terms of its effects on:

- Groundwater level
- Neighbouring bores
- Groundwater availability
- Saline intrusion
- Surface waterways
- Land subsidence

WWLA's scope of work included:

Data Review - Review and update of the lithological characteristics of the subsurface profile from bore logs and aquifer hydraulic parameters as determined from recent test pumping, where available.

Groundwater modelling - Development of a calibrated three-dimensional groundwater model using MODFLOW, to enable assessment of:

- Groundwater level and availability;
- Interference effects on individual bores;
- Cumulative effects on surface water features (streams, lakes and swamps); and
- Saline intrusion.

Reporting - Preparation of a comprehensive report and associated maps.

This report presents the factual results of the modelling study and will form a part of the Assessment of Environmental Effects report.

1.1 Report Structure

The structure of this technical report is as follows:

- **Section 2** – a description of the proposed activity and proposed consent conditions;
- **Section 3** – background details of the application;
- **Section 4** – a numerical modelling overview;

- **Section 5** – an assessment of environmental effects;
- **Section 6** – summary and conclusions.

2. Description of Proposed Activity

2.1 Location

The location of the property in question for this consent application, Sweetwater Station, is shown in **Figure 1**.

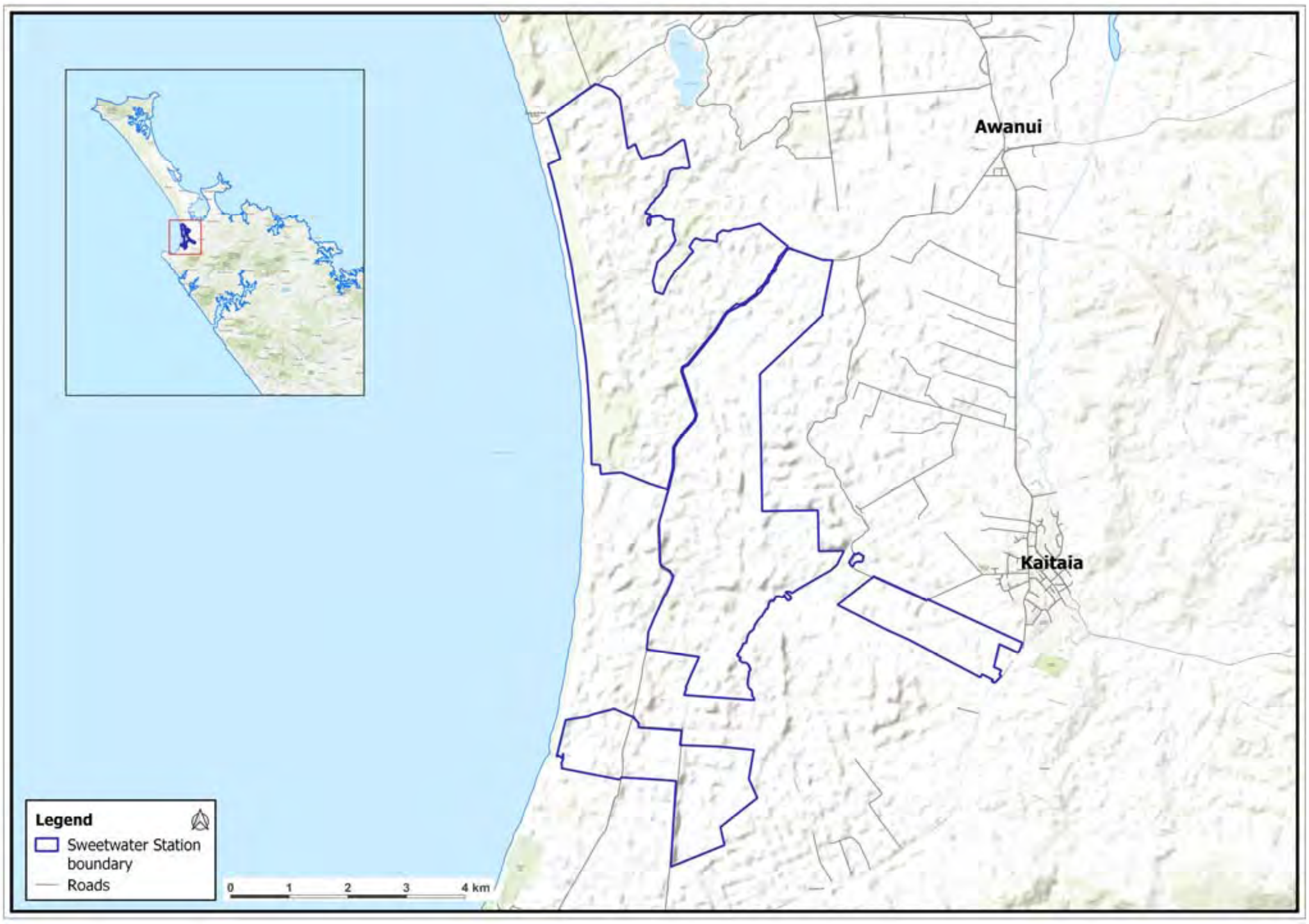

Figure 1. Project locality map.

2.1 Proposed Additional Groundwater Take

The resource consent application for Sweetwater Farms is to take and use groundwater for developments totalling approximately 428 ha and requiring the construction of up to a maximum of 12 new bores.

The additional groundwater take will be exercised yearly from October to April, in accordance with the following volumes:

- Maximum daily volume of 10,705 m^3/day; and
- Maximum annual volume of 776,000 m^3/yr.

The proposed groundwater take constitutes an increase upon an existing groundwater take for Sweetwater Farms. The current consent, AUT.020995.01.03, is for a groundwater take of up to 2,317,000 m^3/year or 15,525 m^3/day. The current consent specifies 13 production bore locations. Only two of these bores have been constructed and are currently in use. All consented bore locations are shown in

Figure 2.

The current application proposes to leave the two bores that are currently operating in place at the locations labelled 1 and 2 in

Figure 2, while constructing new bores at the other locations shown in **Figure 2**.

Table 1 provides the proposed pumping volume and NRC groundwater allocation zone for the existing and proposed bores. Under the proposed pumping scheme 216,000 m^3/year of the increased allocation would be pumped in the Aupouri-Sweetwater allocation zone and 560,000 m^3/year would be pumped in the Aupouri-Ahipara allocation zone.

Table 1. Proposed bore locations and annual groundwater take for Sweetwater Farms resource consent application

Bore ID	X Coordinate (NZTM)	Y Coordinate (NZTM)	Bore type	Annual (m^3)	Daily (m^3)	NRC Groundwater Allocation Subzone
Sweetwater-1	1617473	6119002	Existing	632,000	6,320	Sweetwater
Sweetwater-2	1617846	6119771	Existing	436,000	4,360	
Sweetwater-3	1617109	6120717	Proposed	385,000	2,750	
Sweetwater-4	1616465	6120787	Proposed	1,080,000	8,800	
Sweetwater-5	1617267	6121591	Proposed			
Sweetwater-6	1616868	6120002	Proposed			
Sweetwater-7	1617043	6118433	Proposed			
Sweetwater-8	1616978	6116808	Proposed			
Sweetwater-9	1617279	6117495	Proposed			
Sweetwater-10	1617702	6114717	Proposed	210,000	1,500	Ahipara
Sweetwater-11	1617254	6113920	Proposed			
Sweetwater-12	1616055	6112008	Proposed	350,000	2,500	
Sweetwater-13	1616563	6111903	Proposed			
Sweetwater-14	1616889	6111890	Proposed			
Total				3,093,000	26,230	

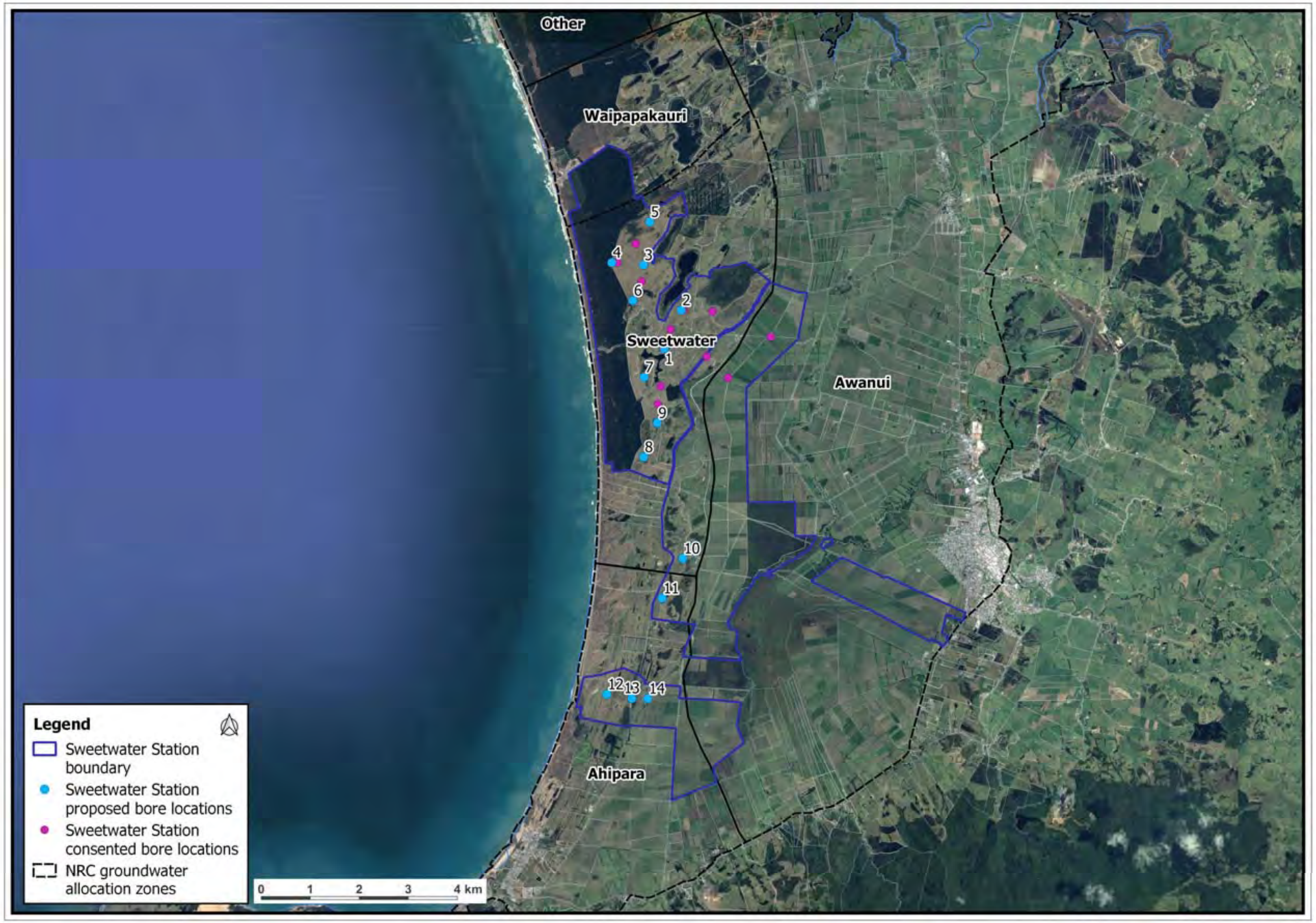

Figure 2. Location of consented and proposed bores

2.2 Allocation Availability

The Aupouri Peninsula Aquifer is divided into different allocation zones for management purposes. The Sweetwater Farms property sits within the Aupouri-Sweetwater, Aupouri-Awanui, and Aupouri-Ahipara allocation zones (**Figure 2**). The current consent for Sweetwater Station is granted for up to 13 bores, 11 of which are in the Aupouri-Sweetwater sub-aquifer manage zone while the other 2 are in the Aupouri-Awanui management zone. The distribution of pumping among the permitted bore locations is at the discretion of Sweetwater Station. All current groundwater extraction occurs at 2 bores that are within the Aupouri-Sweetwater management zone. The allocation limit, current level of allocation and the level of allocation should this consent (along with other pending consents) be granted, are shown in **Table 2** and **Table 3**.

The allocation limit for the Aupouri-Sweetwater zone is calculated as 35% of mean annual recharge, and the Aupouri-Ahipara is calculated as 15% of mean annual recharge as recommended in Osbaldiston (2017).

Table 2 shows that the Aupouri-Sweetwater management zone is currently 88% allocated and granting the proposed Sweetwater Farms groundwater take (216,000 m^3/yr) will account for an additional 4.6% of the allocation limit. If the other current proposals are granted (Elbury Holdings) the total allocation status for the Aupouri-Sweetwater zone will increase to 97%.

Table 3 shows that the Aupouri-Ahipara management zone is currently 9% allocated and granting the proposed Sweetwater Farms groundwater take (a combined 560,000 m^3/yr) will increase the total allocation status for the Aupouri-Ahipara zone will increase to 57%.

Table 2. Aupouri-Sweetwater Aquifer Limits[1] and Allocation Status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)[A.]		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (216,000), Elbury Holdings (200,000)	
	m^3/year	% mean annual recharge	Allocated groundwater (m^3/year)	% of allocation limit	Allocated groundwater (m^3/year)	% of allocation limit
Aupouri - Sweetwater	4,675,000	35	4,124,480	88%	4,540,480	97%

Notes:

A. Includes currently consented Sweetwater Farms take (2,317,000 m^3/yr)

Table 3. Aupouri-Sweetwater Aquifer Limits[2] and Allocation Status.

Sub-aquifer Management Zone	Allocation Limit		Allocation Status (Current)		Allocation Status Including Proposed Groundwater Takes: Sweetwater Farms (560,000)	
	m^3/year	% mean annual recharge	Allocated groundwater (m^3/year)	% of allocation limit	Allocated groundwater (m^3/year)	% of allocation limit
Aupouri - Ahipara	922,500	15	100,202	11%	660,202	72%

[1] According to NRC's allocation maps at http://gis.nrc.govt.nz/LocalMaps-Viewer/?map=895e0785f7054d47b10a72edc38022dc
[2] According to NRC's allocation maps at http://gis.nrc.govt.nz/LocalMaps-Viewer/?map=895e0785f7054d47b10a72edc38022dc

3. Background Information

3.1 Site Conditions

3.1.1 Soils

There is no Landcare Research S-map soil data available for this site, however there is Fundamental Soil Layer information, pre-dating S-Map, which describes the soil around the property as having typic sandy brown soils[3], which occur in areas where summer drought and winter waterlogging do not generally occur. These soils display the following properties:

- ***Physical properties*** - Brown soils are relatively stable topsoils with a well-developed structure, with sandy brown soils dominated by coastal and loamy sand.
- ***Chemical properties*** - Brown soils have low to moderate base saturation.
- ***Biological properties*** - Brown soils are associated with high biological activity (earthworms are prominent).

3.1.2 Geology

The property is underlain by the Aupouri Aquifer – an extensive sequence of sand, peat and shellbed that covers an area of approximately 79,000 ha extending from Ahipara in the south to Ngataki in the north. The aquifer is underlain by older low permeability Cenozoic and Mesozoic age basement rocks.

Fine sand is the dominant sediment within the Aupouri Aquifer, which vary in thickness from a few meters near the hard rock boundaries to over 100 m in some places. The sand sequence is interspersed with multiple discontinuous layers of alternating iron pan (sandstone), clay and peat, which reside across the entire peninsula typically in the upper portion of the aquifer. These deposits are associated with ancient wetlands.

The aquifer is underlain to the east by volcanic basement rocks that outcrop forming Mount Camel. These rocks most likely extend to some depth across the subsurface of the Aupouri Peninsula together with greywacke, argillite and indurated conglomerate deposits of the same age.

3.1.3 Hydrogeological Interpretation

The surficial sand deposits generally become progressively younger, unconsolidated and mobile towards the west. These younger sands have higher permeability than the sands in the east, which tend to be more weathered and contain cemented iron pans close to the surface.

With increasing depth, the presence of shell-rich sands increases, which is important from a water yield perspective as the shellbeds typically have significantly higher hydraulic conductivity (ability to transmit water) than the finer sands. The shellbed is the target aquifer for orchard irrigation water and typically resides at depths from 70 – 140 m below ground level.

All the basement rocks in the area are known to be low permeability.

3.2 Neighbouring Bore Information

There are 59 bores registered within the NRC database within a 2 km radius of the 14 proposed Sweetwater bores (**Figure 3**). The database also describes the activity status of the bores. Statistics on the 59 bores are as follows:

- 56 are active and three are inactive;
- Bore depth is provided for 55 bores and ranges from 3.3 m to 108 m, with an average depth of 54 m;

[3] https://soils.landcareresearch.co.nz/describing-soils/nzsc/soil-order/brown-soils/

- 47 bores have information attached in terms of the purpose of the bores, among these:
  - Twelve are for monitoring;
  - Nine are for domestic;
  - Seven are for exploration;
  - Six are for stock;
  - Five are for irrigation;
  - Five are for domestic and stock;
  - Three are for public water supply.

Figure 3. Neighbouring bores within 2 km radius.

4. Numerical Modelling Analysis

4.1 Groundwater Model Overview

The MODFLOW Unstructured Grid (MODFLOW-USG) developed by the United States Geological Survey (USGS) was utilised within the GMS10.2 modelling platform to construct a groundwater flow model to represent the Aupouri Aquifer. The resulting numerical model is referred to as the Aupouri Aquifer Groundwater Model (AAGWM).

The AAGWM domain represents the area occupied by the Aupouri Shellbed Aquifer which occurs from Ahipara to Ngataki, an area of 535 km^2 and is shown in **Figure 4**. Model grid spacing ranges from 40 m at the highest resolution, centred around large groundwater extraction points, to 1,000 m in the northwest portion of the model area where high resolution is unnecessary.

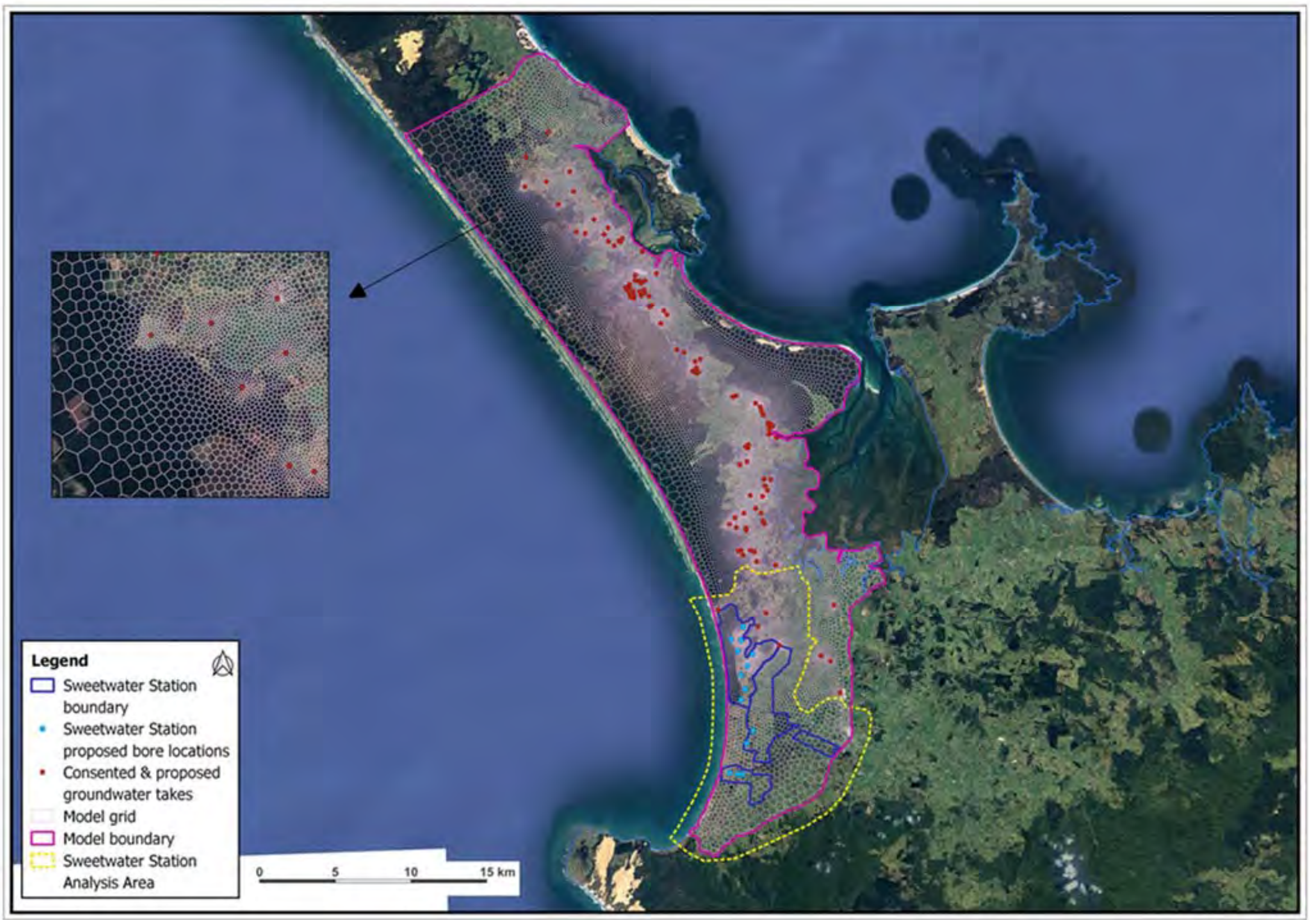

Figure 4. Aupouri Aquifer Model Domain.

The model was constructed based on six layers representing the primary geologic strata that occur within the model domain which are described below:

- ***Layer 1 – Sand / Silt.*** A sequence of predominately unconsolidated fine sand interspersed with discontinuous layers of alternating iron pan, silt and peat. The layer varies in thickness from approximately 45 m to 110 m with the thickest regions located around the model area peak elevations.
- ***Layer 2 – Upper Shellbed.*** A sequence of shellbeds comprising medium to coarse shell with some fine sand in the matrix. The proportion of shell typically varies from 30% to 90%. The layer is typically encountered at a depth of 60 - 110 mBGL and varies in thickness from typically 5 m - 15 m.
- ***Layer 3 – Sand.*** A thin layer of finer sediment separating the upper and lower shellbed.
- ***Layer 4 – Lower Shellbed.*** A sequence of shellbeds typically comprising a higher proportion of shell with coarser grain size than the upper shellbed. In some locales, the shell is more consolidated and described by drillers as shell rock. Drillers also report circulation losses when drilling this formation. The layer is typically encountered at depths of 80 - 145 mBGL and varies in thickness from typically 5 m - 30 m.

Details of the groundwater model development and calibration are provided in a separate report (WWLA, 2019), while the scope of this report is limited to the application of the calibrated model for the purpose of assessing the proposed groundwater take for Sweetwater Farms.

4.2 Predictive Simulations

The proposed takes for Sweetwater Farms (776,000 m^3/year) was evaluated using the AAGWM. The Base Case Scenario (Scenario 1) for evaluating the proposed groundwater take at Sweetwater Farms included all currently consented groundwater takes and pending applications. The Proposed Pumping Scenario (Scenario 2) was then developed by adding the proposed groundwater takes for Sweetwater Farms to the Base Case Scenario. The results of the two scenarios were compared to assess cumulative effect of the proposed groundwater take with regard to the AEE criteria.

This assessment also included a sensitivity analysis (Scenario 3). In the sensitivity analysis, connectivity between the surface conditions and the deep aquifer was significantly reduced while boundary and source/sink conditions remained the same as in the baseline model. The model was not calibrated to the conditions applied in Scenario 3, therefore Scenario 3 results are only referenced to illustrate relative (rather than absolute) changes in simulated groundwater levels.

The sensitivity analysis was undertaken because the calibrated groundwater model errs on the side of over simulation of vertical leakage. This was deliberately built into the model in the absence of a single well-defined low permeability horizon in the field, but rather a series of multi-layered and discontinuous iron pans and other low permeability horizons within the sedimentary sequence that in combination act as a flow barrier between the deeper groundwater system and the surface drains and wetlands. As a result, the model exaggerates the effects of the proposed abstraction on the groundwater levels in the shallow aquifer and at the surface. Conversely, the model under-predicts the local-scale drawdown in the deeper aquifer.

The numerical simulation was run for a 58-year time period using historic climate records and groundwater pumping data. In effect, the climatic conditions of the last 58-years have been utilised to simulate conditions that may occur in the next 58-years.

The three predictive model scenarios can be summarized as follows:

- ***Scenario 1: Base Case*** – the calibration model which includes all currently consented groundwater takes at a total peak annual abstraction rate of 11,606,251 m^3/year. This represents the permitted baseline for groundwater extraction.
- ***Scenario 2: Proposed Extraction*** – includes current and proposed groundwater extraction totalling a combined peak annual rate of 12,382,251 m^3/year.

- ***Scenario 3: Low Permeability-Proposed Extraction*** – Groundwater extraction is the same as in Scenario 2 with horizontal hydraulic conductivity of Layer 2 was decreased to $1x10^{-7}$ m/s in both the coastal sands and weathered sand regions to simulate a hard pan extending over the model area.

From an assessment of effects perspective, it is important to focus on annual volumes. However, simulated pumping in the model is premised on peak daily rates (consented or proposed) pumped until the annual volume is reached (cap). However, due to variable stress period length ranging from a minimum of 13 days to a maximum of 185 days, the average pumping rate reported from the model is always less than the peak rate due to days within the stress period where pumping was not required. Historical dates where the maximum annual volume (consented or proposed) was simulated included 1964, 1974, 1983, 1991, and 2010.

4.3 Mass Balance Results

The end of the 2010 irrigation season (30 April 2010) was selected for impact analysis as this date represents the end time of the driest period within the historical record, and the greatest simulated seasonal irrigation pumping requirement. Simulation results were evaluated for the drainages within and around Sweetwater Station in order to assess potential effects from proposed pumping in the area most likely to be impacted. This area is referred to in this report as the Sweetwater Station Analysis Area which is included in **Figure 4**.

A comparison of the model flow budget during the peak pumping period within the 2009-2010 irrigation season for all three scenarios is provided in **Table 4**, which in the model corresponds to 24 December 2009. The peak pumping period in the model occurred at this date (as opposed to later in the season) due to the model stress period configuration. During the stress period ending 24 December irrigation occurred on 40 out of the proceeding 43 days, whereas during the following stress period (24 December to 30 April 2010) simulated pumping was cut-off after a further 69 days pumping due to the annual volume limit being reached, hence irrigation was required on only 114 out of 127 days in the later stress period. The pumping rates and irrigation demand requirements for these two model stress periods are exemplified in **Figure 5.**

Table 4. Simulated Sweetwater Station Analysis Area groundwater budget for peak pumping period in 2010 irrigation season

Sweetwater Station Analysis Area					
Mass balance	**Components**	**Scenario 1: Base Case**		**Scenario 2: Proposed GW Extraction**	
		Flow (m^3/d)	**Percentage of Flow (%)**	**Flow (m^3/d)**	**Percentage of Flow (%)**
Inflow	Storage	57,793	31.3	62,238	32.9
	CH	0	0.0	0	0.0
	Recharge	117,605	63.7	117,605	62.2
	Lakes	71	0.0	71	0.0
	Cross Boundary	9,137	4.9	9,134	4.8
	Total inflow	**184,606**	**100**	**189,048**	**100**
Outflow	Storage	1,359	0.7	1,036	0.5
	Shallow Coastal Discharge (CH)	73,477	39.8	71,845	38.0
	Wells	34,259	18.6	40,685	21.5
	Drains/Wetlands (DC)	62,944	34.1	63,000	33.3
	Deep Coastal Discharge (GHB)	4,682	2.5	4,580	2.4
	Cross Boundary	7,876	4.3	7,882	4.2
	Total outflow	**184,597**	**100**	**189,027**	**100**
Percentage discrepancy		0.00%		0.01%	

Note: CH = constant head; GHB = general head boundary; DC = drain cells. Changes in storage are due to the difference in climatic and hence water table conditions between the start and the end of the model run.

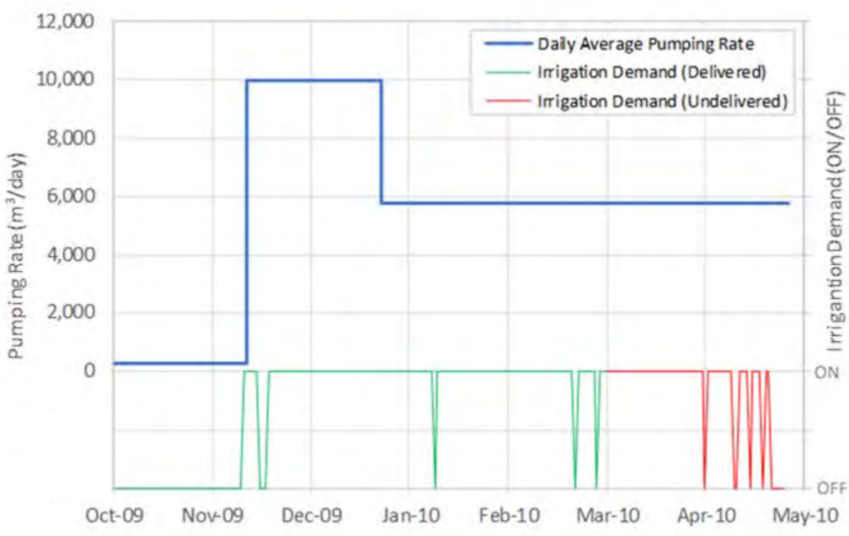

Figure 5. Model pumping rates during the 2009-2010 irrigation season.

Comparison between Scenario 1 and Scenario 2 from an environmental impact perspective of key water budget components in **Table 4** indicates the following:

- Groundwater extraction in the Base Case scenario is predicted to be approximately 18.6% of the water budget in the Sweetwater Station analysis area for this time period. The additional proposed pumping, approximately 15,000 m³/day, is predicted to increase groundwater extraction to 21.5% of the groundwater budget for the Sweetwater Station Analysis Area, an increase of 2.9%.
- Groundwater discharge to surface water, primarily occurring as drain flows is predicted to decline by 0.8 % in the total groundwater budget with the increase in groundwater extraction.
- The portion of the groundwater budget that goes to shallow coastal discharge adjacent to Sweetwater Station is predicted to decline by 1.8% as water is diverted for groundwater pumping.
- Deeper coastal discharge adjacent to Sweetwater Station is predicted to remain stable.
- During the peak irrigation season, the majority of groundwater pumping demand is drawn from aquifer storage. With the increased groundwater take at Sweetwater Station this is predicted to increase by 1.6% of the groundwater budget (approximately 8,000 m³/day).

For comparison the mean groundwater budget for the Sweetwater Station Analysis Area over the entire 58 year simulation period is provided in **Table 5.** Several differences in the groundwater budget emerge when year-round conditions are taken into account:

- Inflow and outflow from groundwater storage are more in balance in both scenarios, accounting for about 16% of both inflows and outflows.
- Increased recharge relative to the peak irrigation as higher rainfall typically occurs during non-irrigation season.
- The portion of the groundwater extracted by pumping for irrigation in the Base Case scenario is only 4.1% of the annual groundwater budget, increasing to 4.8% with proposed pumping included. This indicates that the proposed groundwater takes will comprise 0.7% of the annual groundwater budget in the Sweetwater Station Analysis Area should the consent be granted.
- Coastal groundwater discharge and lateral groundwater flow into adjacent areas (cross boundary flow) are minimally affected by the proposed pumping.

Table 5. Average groundwater budget for Sweetwater Station Analysis Area for 58 year simulation period

Sweetwater Station Analysis Area					
Mass balance	**Components**	**Scenario 1: Base Case**		**Scenario 2: Proposed GW Extraction**	
		Flow (m^3/d)	**Percentage of Flow (%)**	**Flow (m^3/d)**	**Percentage of Flow (%)**
Inflow	Storage	26,832	16.0	27,322	16.3
	CH	0	0.0	0	0.0
	Recharge	131,226	78.4	131,226	78.2
	Lakes	74	0.0	74	0.0
	Cross Boundary	9,253	5.5	9,271	5.5
	Total inflow	167,385	100	167,893	100
Outflow	Storage	26,763	16.0	27,233	16.2
	Shallow Coastal Discharge (CH)	68,638	41.0	67,530	40.2
	Wells	6,815	4.1	8,093	4.8
	Drains/Wetlands (DC)	53,320	31.9	53,252	31.7
	Deep Coastal Discharge (GHB)	4,410	2.6	4,350	2.6
	Cross Boundary	7,438	4.4	7,435	4.4
	Total outflow	167,385	100	167,892	100
Percentage discrepancy		0.00%		0.00%	
Note: CH = constant head; GHB = general head boundary; DC = drain cells. Changes in storage are due to the difference in climatic and hence water table conditions between the start and the end of the model run.					

5. Assessment of Environmental Effects

The simulation scenario results were evaluated with regard to the applicable criteria for an assessment of effects for a groundwater take as described in the Resource Management Act Section 104 (1)(b).

Based on the rainfall record and simulated groundwater response in the base model, the end time of a dry period with maximum water use was selected for impact analysis. The selected date was April 30, 2010, corresponding to the period of maximum irrigation over the simulation period.

Model results for the Proposed Extraction Scenario were considered relative to the permitted baseline groundwater extraction represented in the Base Case Scenario.

5.1 Drain Flows

An analysis of the impact on flows including discharge to surface streams and farm drains was undertaken for low-flow situations. The annual minima in daily flow was obtained from the flow budget for all drain boundary cells combined for each time step exported from the model. Annual recurrence intervals were calculated from this table of data for each scenario, and the resulting data is presented in **Table 6** and **Figure 6**.

A comparison of the drain flows with proposed groundwater takes (Scenario 2) against the base case scenario indicates that low flows for recurrence interval from 1 to 100 years are effectively unchanged by the proposed groundwater extraction. The greatest predicted impact is on the mean annual low flow (1-year recurrence interval), which is only predicted to decline by 0.4%. As stated in WWA (2018) the model errs on the side of exaggerating groundwater level reduction in the shallow aquifer and at the surface because of the lack of hard pans in the model. In this regard, this can thus be considered a conservative estimate.

The impact on surface water resources due to proposed take will therefore be less than minor.

Table 6. Low-flow analysis of surface discharge and percentage reduction in flow from base case.

Recurrence Interval	Scenario 1: Baseline	Scenario 2: Proposed GW Extraction	
(years)	(L/s)	(L/s)	(%)
1	686	683	-0.4%
2	515	515	0.1%
5	438	438	0.1%
10	420	419	-0.2%
25	404	404	0.1%
50	399	399	-0.1%
100	382	382	-0.1%

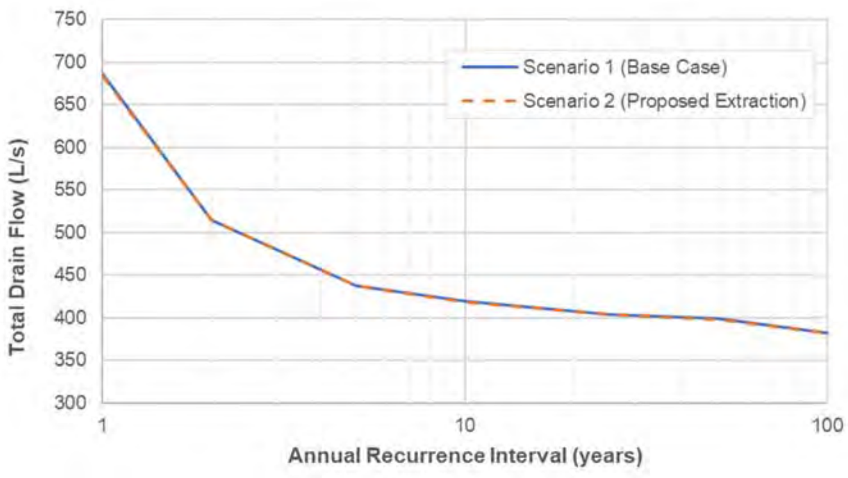

Figure 6. Surface drainage low flow analysis for model predictive scenarios.

5.2 Pumping Interference Effects

Simulation results for 30/4/2010 were evaluated within and around Sweetwater Station in order to assess potential effects from proposed pumping in the area most likely to be impacted.

Drawdown Effects

The simulated groundwater level for the end of 2010 irrigation season for Scenarios 2 and 3 were subtracted from the head simulated at the corresponding time from the Base Case Model in the case of Scenario 2, and a revised version of the Base Case Model with low permeability in Layer 2 for Scenario 3, to produce regional drawdown maps (**Figure 7** and **Figure 8**). The resulting drawdown predictions are used to evaluate the magnitude and extent of potential impacts resulting from the proposed pumping on both the shallow and deep aquifers for both scenario conditions.

Deep aquifer

The predicted drawdown in the deep aquifer for Scenario 2 is shown in **Figure 7**. In Scenario 2 the maximum predicted drawdown was 1.4 m at the proposed Sweetwater-13 bore location. The predicted drawdown at Sweetwater-13 reflects the proximity of two other proposed pumping bores Sweetwater-12 and Sweetwater-14. The extent of significant drawdown, typically considered to be the 0.6 m contour, was almost entirely within the Sweetwater Station property boundary. The exceptions were an area extending 150 m west from the proposed Sweetwater-10 groundwater take, an area extending 70 m west from the Sweetwater-11 groundwater take, and an area extending 125 m north from the proposed Sweetwater-14 groundwater take.

In Scenario 3, the low permeability of model Layer 2 limited leakage from the overlying layers thereby magnifying the impact of pumping on groundwater levels. The maximum drawdown predicted in Scenario 3 was 1.8 m at the proposed Sweetwater-13 pumping location (**Figure 8**). The 0.6 m drawdown contour did not extend beyond the Sweetwater Station property boundary to the east, however it did encompass most of the area west of Sweetwater Station up to the coast.

This proposal entails both a new consent for taking groundwater and a change in pumping locations for the existing consent. Therefore, the proposed groundwater take scenarios assume the relocation of some bores resulting in a shift in drawdown; with increased pumping in the west and south portions of Sweetwater Station, and less pumping in the northeast portion of the property. In areas where currently consented bores are relocated, predicted groundwater levels in Scenario 2 are up to 1.2 m higher than the baseline established in Scenario 1 (currently permitted baseline). The groundwater levels in these areas are up to 1.4 m higher in Scenario 3 relative to Scenario 1. Negative drawdown values and green shaded contours in **Figure 7** and

Figure 8 indicate areas where groundwater levels are predicted to be higher in the proposed extraction scenarios due to the relocation of currently permitted bores.

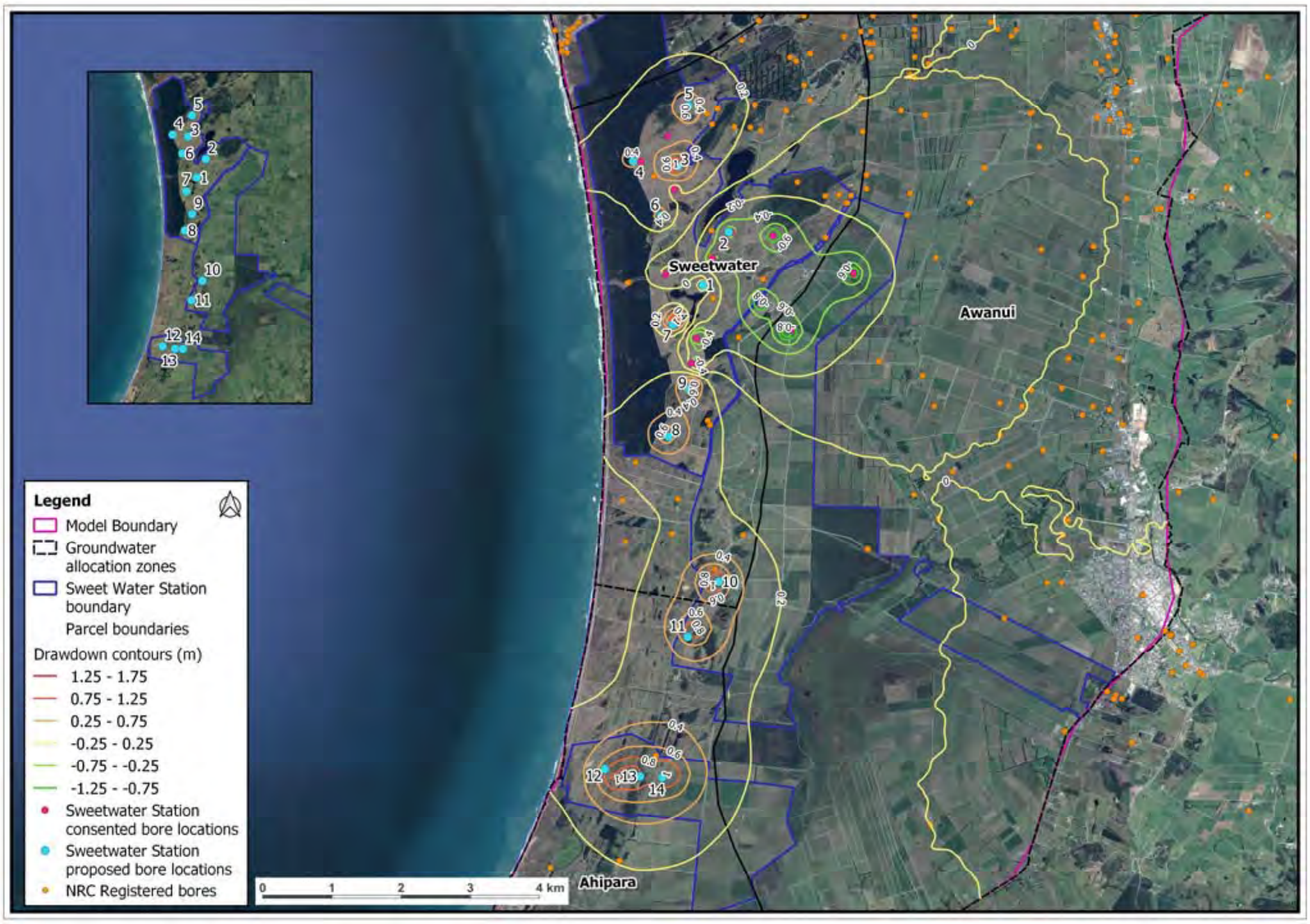

Figure 7. Simulated drawdown of deep aquifer (Scenario 2). Proposed bore locations are labelled on inset.

Figure 8. Simulated drawdown of deep aquifer (Scenario 3). Proposed bore locations are labelled on inset.

Shallow aquifer

The maximum drawdown predicted in the shallow aquifer for the proposed extraction scenario (Scenario 2) was 0.4 m (**Figure 9**). The greatest level of drawdown extent beyond the Sweetwater Station property boundary was approximately 0.35 m which was predicted north of the proposed Sweetwater-14 groundwater take. As with the deep aquifer, groundwater levels in the north-eastern portion of Sweetwater Station were predicted to be higher with the proposed extraction relative to the permitted baseline because of the relocation of some of the permitted bores.

In Scenario 3, no shallow aquifer drawdown was predicted due to increased groundwater pumping because of the disconnection of the upper and lower portions of the aquifer.

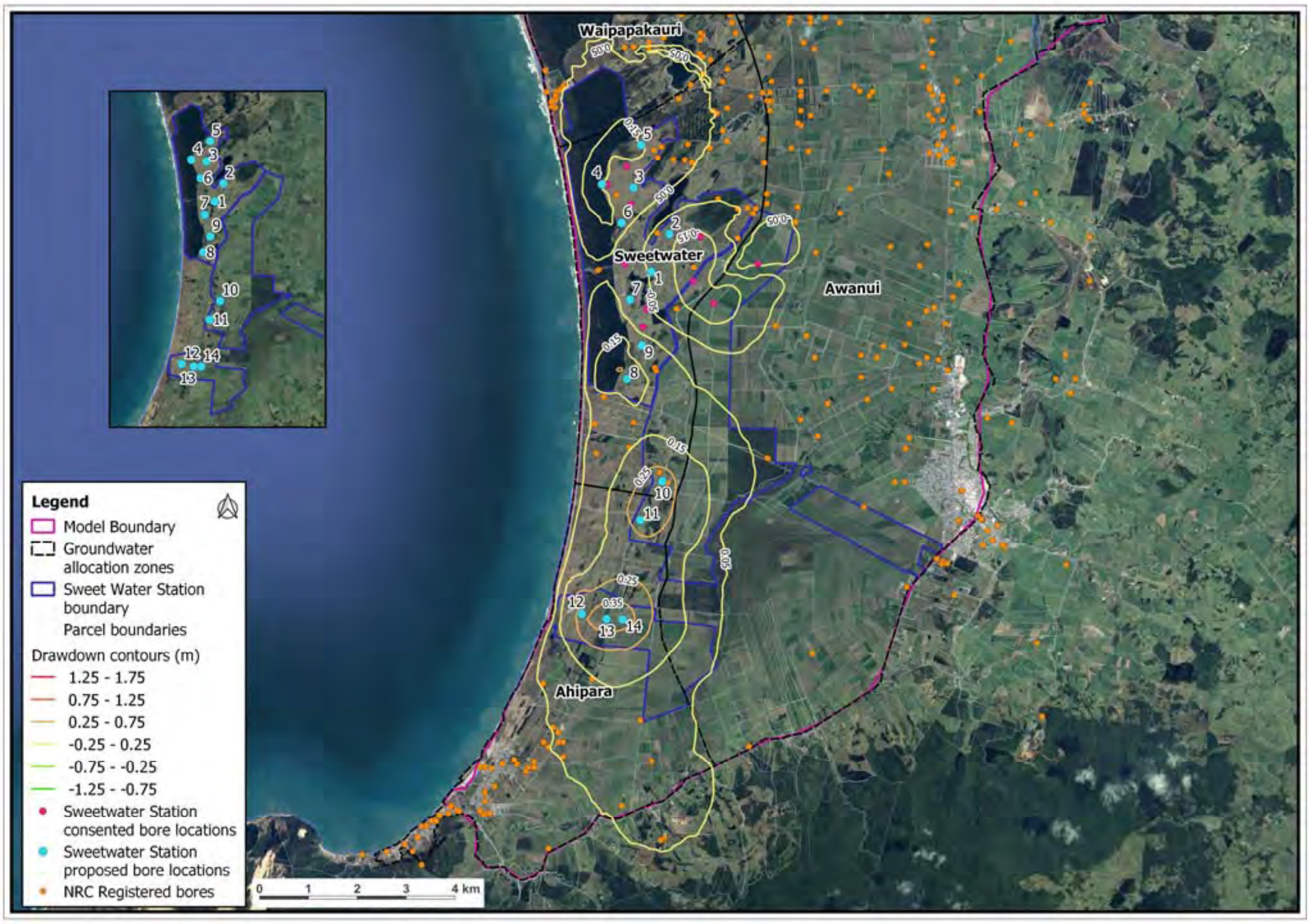

Figure 9. Simulated drawdown of shallow aquifer (Scenario 2). Proposed bore locations are labelled on inset.

Existing bores

The drawdown induced by the groundwater take applied in each scenario was calculated and plotted similarly at 59 existing bores within 2 km of the proposed groundwater takes (**Figure 3**) as a boxplot, with the maximum and minimum drawdown shown in **Figure 10**. Of these bores, 28 are within the Sweetwater Station property boundary and 31 are not.

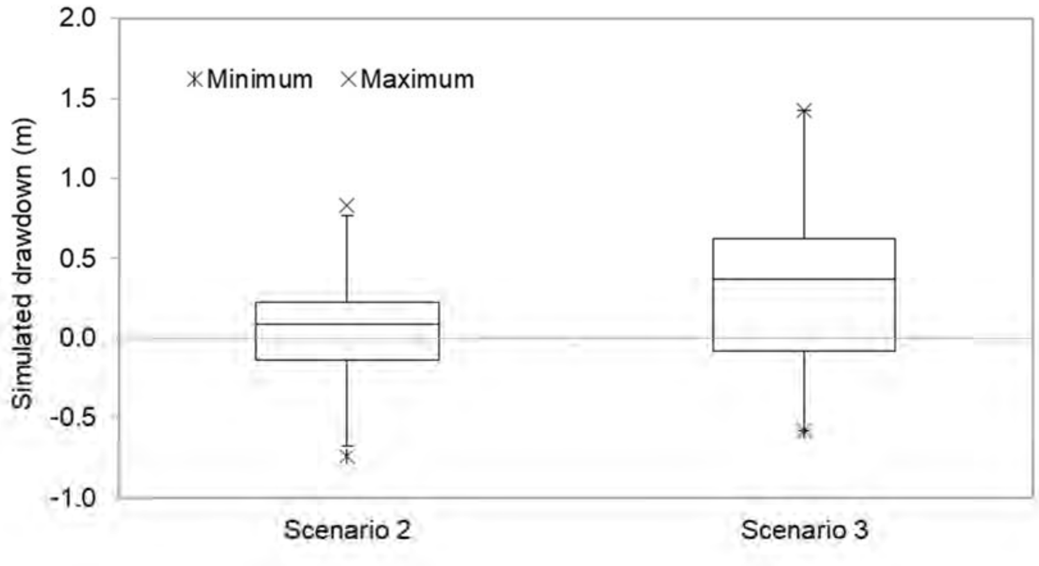

Figure 10. Drawdown observed at existing bores at the observation time step for each scenario.

The drawdown at the existing bores predicted in Scenario 2 is largely affected by their distance to the proposed locations for groundwater takes or conversely, their proximity to currently consented groundwater takes that are displaced in the new groundwater pumping scheme. At the time of maximum pumping (30/04/2010), the simulated change in water level in Scenario 2 ranges between a 0.83 m drawdown to a 0.74 m increase due to bore relocation. Many of the bores with the greatest predicted drawdown were within the Sweetwater Station property. Of bores not on the Sweetwater Station property the maximum drawdown predicted to occur in Scenario 2 was 0.33 m at the Lake Heather 1 observation bore registered as LOC.200226, which is located approximately 425 m southeast of the proposed Sweetwater-5 groundwater take. In Scenario 3, the maximum drawdown predicted was 0.79 m at LOC.209638, a stock bore approximately 950 m northwest of the proposed Sweetwater-10 bore location.

Appendix A provides a table specifying predicted drawdown at all NRC registered bores within 2 km of Sweetwater Station proposed groundwater takes.

Given that the available drawdown in the Aupouri aquifer is typically 70 to 100 m in most shellbed bores, and no neighbouring bore is predicted to see more than 0.79 m of additional drawdown under the most conservative conditions, the interference effects on existing groundwater users is considered <u>less than minor</u>.

5.3 Saltwater Intrusion

Saltwater intrusion under the hydrogeological conditions in the Sweetwater Station area, and specifically into the shellbed aquifer has been evaluated using the method of *Lateral Migration Analysis*. Lateral migration along the aquifer/bedrock interface considers the material under the aquifer impermeable where inland migration of salinity occurs via the permeable sediments along the lower boundary of the aquifer. This mechanism assumes that the pressure at the coastal margin is relevant to maintaining an offshore position of the saline interface.

The shellbed aquifer in the Sweetwater Station groundwater investigation area is underlain by relatively impermeable basement rock and is well represented by this conceptual approach.

5.3.1 Lateral Migration Analysis

Based on the estimated depth to the basement rock at the coastal margins, the Ghyben-Herzberg relation was used to back-calculate the minimum hydraulic head required to maintain the saline interface below the shellbed aquifer (i.e. the lateral migration "Trigger Level"). This calculation was performed at approximately 200 m intervals along the coastal margin of the western model boundary, adjacent to the Sweetwater Station Analysis Area where saline intrusion would be most likely to occur due to pumping at Sweetwater Station. The analysis was not performed for the east coast or northern half of the west coast because these locations were beyond the extent of predicted drawdown. The point locations used for lateral migration analysis are shown in **Figure 11**. Simulated layer 6 groundwater levels from the Base Case and Proposed Extraction scenarios were extracted at these points for analysis.

Saltwater intrusion is not an instantaneous response to the lowered water table - it is a gradual process requiring prolonged reduction in groundwater level below a critical level to initiate the landward migration of the saline interface. A 90-day rolling average (RA) was calculated from the simulated groundwater level to reflect this slow process. The simulated groundwater levels were then compared against the Trigger Level at the model time 13/03/1994, which corresponds to the lowest groundwater level over the simulation period.

Figure 11. Location of the selected points for lateral migration analysis

The hydraulic heads in the deep shellbed at the selected time step (13/03/1994) were, on average, 2.0 and 2.1 m greater than the pressure required to maintain the saline interface below the shellbed aquifer at the selected points in Scenario 2 and Scenario 3, respectively.

The greatest difference in groundwater elevation at the coast between the two scenarios, 0.27 m, was predicted to occur at sampling point 61, adjacent to the proposed Sweetwater-12 groundwater take. The predicted groundwater level at this location at the lowest point of the simulation period was 1.3 m above the head required to prevent saline intrusion under proposed pumping conditions. Based on this result the predicted drawdown resulting from proposed extraction at Sweetwater Station is not a risk to induce saline intrusion along the west coast (Figure 12).

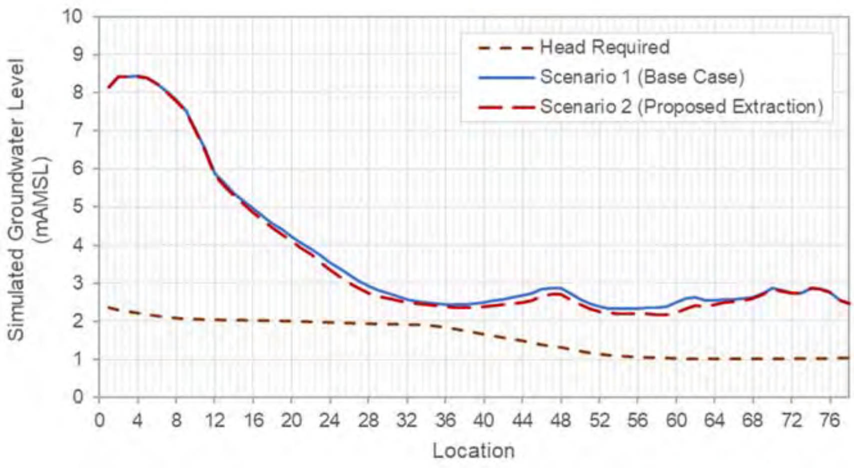

Figure 12. Simulated minimum groundwater level between 1960 and 2080 in Layer 6. Corresponding point locations are shown in Figure 13.

It can be concluded that saltwater inland migration along the basement contact is unlikely to increase in response to the proposed groundwater extraction at Sweetwater Station and the predicted impact in terms of saline intrusion is <u>less than minor</u>.

5.4 Land Settlement

Land subsidence due to groundwater extraction at the maximum rate in the simulation, 30/4/2010, was calculated using the Bouwer (1977)[4] equation:

$$S_u = (P_{i2} - P_{i1})\frac{Z_1}{E}$$

where S_u = vertical subsidence (m)
$P_{i2} - P_{i1}$ = Increase in intergranular pressure due to drop of the water table
Z_1 = layer thickness
E = modulus of elasticity of the soil

The following characteristics were assumed for the aquifer:

- Porosity = 0.30
- Unsaturated water content = 0.08
- Specific weight of aquifer material (consolidated silty sand) = 20 kN/m^3 (Silty sand density ranges between 1,410 kg/m^3 and 2,275 kg/m^3 (http://structx.com/Soil_Properties_002.html), corresponding to specific weight of 14 kN/m^3 and 22 kN/m^3)
- Specific weight of water = 9.81 kN/m^3.

The deep shellbed material is denser and less compressible compared to the mixture of sand, silt and peat overlying above. The subsidence analysis was conducted using three separate layers representing the conceptual hydrogeological units of the sub-surface environment, and the parameter values used were based on Bouwer (1977).

The potential maximum ground settlement was estimated at the proposed Sweetwater bores based on the maximum simulated drawdown in the Base Case Scenario, as summarised in **Section 5.2**. The results are presented in **Table 7**.

Predicted settlement at the 14 bores ranges from 0.00 to 0.02 m with the maximum settlement predicted to occur at the proposed Sweetwater-7 bore while no settlement was predicted at Sweetwater-2 because this location is the location of a currently operating production bore. In a rural setting, settlement effects of this magnitude are less than minor for the following reasons:

- there is no sensitive urban infrastructure such as water or wastewater mains or high-rise buildings to rupture or crack; and
- the changes in land surface due to farm machinery (e.g. rotary hoeing) would likely mask impacts of this magnitude (<0.05 m) if materialised.

Table 7. Predicted subsidence at proposed Sweetwater Station bores

Bore ID	Subsidence (m)	
	Scenario 2-Proposed extraction	**Scenario 3-Proposed extraction, low permeability**
Sweetwater-1	0.01	0.01
Sweetwater-2	0.00	0.00
Sweetwater-3	0.02	0.02
Sweetwater-4	0.01	0.01
Sweetwater-5	0.01	0.01
Sweetwater-6	0.01	0.01
Sweetwater-7	0.02	0.02
Sweetwater-8	0.01	0.01
Sweetwater-9	0.01	0.01
Sweetwater-10	0.01	0.01
Sweetwater-11	0.01	0.01
Sweetwater-12	0.01	0.01
Sweetwater-13	0.02	0.02
Sweetwater-14	0.01	0.01

6. Conclusions

Sweetwater Station is seeking to increase and amend an existing consent to use groundwater for irrigation purposes. The current consent authorises the take and use of 2,317,000 m^3/year sourced from up to 13 bores in the Aupouri aquifer, located within the Sweetwater and Awanui sub-aquifer management zones. Currently two production bores are operating under this consent in the Sweetwater management zone.

The proposed groundwater take would increase the level of extraction authorised under the existing consent by 776,000 m^3/year for a total of 3,093,000 m^3/year. The proposed groundwater take would also change the location of some of the production bores to reflect an improved understanding of the future land development relative to when the consent was initially granted under previous ownership. With these changes, 9 bores would be in the Aupouri-Sweetwater allocation zone and 5 bores would be in the Aupouri-Ahipara allocation zone. The proposed increase in groundwater pumping in the Aupouri-Sweetwater allocation zone would be 216,000 m^3/year bringing the total amount of consented groundwater extraction to 97% of the allocation limit within that zone. The proposed increase in groundwater pumping in the Aupouri-Ahipara allocation zone would be 560,000 m^3/year bringing the total amount of consented groundwater extraction to 72% of the allocation limit within that zone.

A numerical groundwater flow model, the AAGWM, was developed for the Aupouri aquifer to be used to assess groundwater resources at the basin scale in the context of historic, present and future conditions. The model was intended to determine the potential impact from the proposed groundwater abstraction on the regional aquifer system and the hydrological condition of relevant surface water. In particular, the model was used to inform an assessment of effects with regard to seasonal pumping on the aquifer system water budget, aquifer groundwater levels, surface water drain flows, saline intrusion, and land settlement.

A baseline model was calibrated to current conditions and used to develop a Base Case Scenario where all consented groundwater takes are included, and a Proposed Extraction Scenario that added the proposed Sweetwater Station groundwater takes and applied the proposed bore relocations. An alternate version of these scenarios was also run with reduced connection between the surface and the deep shell bed aquifer to test model sensitivity to variable conditions as may occur in areas where hard pans layers are present in the relatively shallow subsurface.

Model results were assessed for an area delineated by the surface water catchments within and around the Sweetwater Station property in order to focus analysis on the area most likely to be impacted by the proposed activities. This area was referred to herein as the Sweetwater Station Analysis Area.

Water Budget

At the time of peak irrigation total groundwater abstraction under current conditions in the Sweetwater Station area accounts for 18.6% of the groundwater budget, increasing to 21.5% of the water budget with the proposed groundwater takes, which represents an increase of 2.9%. The increase in groundwater abstraction is balanced by a corresponding decrease in discharge to drains and a decrease in groundwater discharge at the coast.

Drain Flows

The impact of proposed groundwater extraction at Sweetwater Station has potential to lower groundwater levels in the shallow aquifer and in turn reduce discharge to drains and streams. However, the simulated impact on drain flows with a leaky aquifer model configuration (conservative scenario) was negligible, with the predicted impact on annual low flows being a reduction of approximately 0.4%.

Drawdown from Pumping

The proposed abstraction has potential to change groundwater levels in both the deep and the shallow aquifer, particularly during dry times, but the aquifers respond quickly to wetter climate following the irrigation season.

Predicted drawdown at existing bores was primarily governed by their distance to the proposed groundwater takes. At the time of maximum irrigation, 30/04/1994, the maximum simulated drawdown at a bore outside of the Sweetwater Station property was 0.78 m, considerably less than the 70 to 100 m of drawdown typically available in Aupouri aquifer. This result occurred under Scenario 3 (low leakage) conditions, the greatest drawdown at a neighbouring bore in Scenario 2 (proposed extraction) was 0.33 m.

In the shallow aquifer minimum drawdown was predicted with the greatest impact on a neighbouring bore being 0.15 m. No drawdown was predicted in the shallow aquifer in the Scenario 3 due to the disconnection between the shallow aquifer and the deeper pumping layer.

Saline Interface

Groundwater depressurisation at the coast margin has the potential to induce the landward migration of saline groundwater. The model was used to assess potential saline intrusion by the process of lateral migration of the saline/fresh water interface. Simulation results showed saline intrusion along the west coast is unlikely in the Sweetwater Station Analysis Area and that the maximum impact on groundwater levels along the coast was 0.27 m. Proposed groundwater extraction at Sweetwater station had no impact on groundwater levels along the east coast.

Land Settlement

Potential land subsidence as a result of proposed groundwater extraction at Sweetwater Station was assessed based on predicted drawdown at the proposed pumping bores. Results indicated that the maximum amount of settlement was likely to be 0.02 m, a negligible value that would not impact anything in the rural area where the settlement would likely occur.

7. References

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p

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Osbaldiston (2017). Approach Used to Determine Freshwater Allocation in Northland: Freshwater Quantity Accounting System. *Northland Regional Council*

WWA *see Williamson Water Advisory*

WWLA *see Williamson Water & Land Advisory*

Williamson Water Advisory (2018). Sweetwater Farms PB2 Test Pumping Report. Consultancy Report prepared for Sweetwater Farms Limited.

Williamson Water & Land Advisory (2019). Aupouri Aquifer Groundwater Model-Factual Technical Report. Consultancy report prepared for interested parties and the public.

Appendix A. Impact on Existing Bores

Predicted drawdown on bores over 50 m deep that are included in the NRC database:

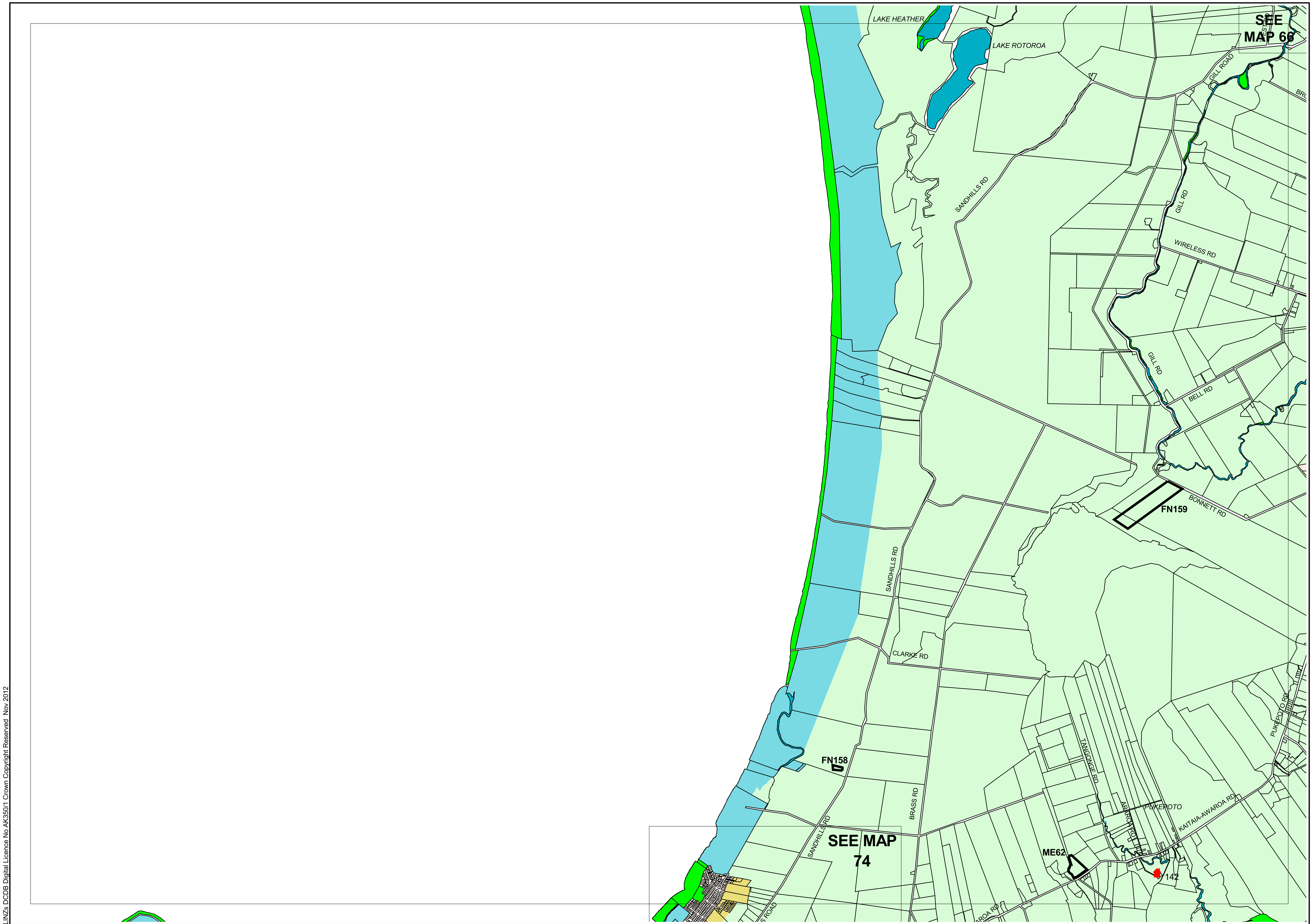
IRISID	Within Sweetwater Property Boundary	X	Y	Purpose	Depth of Bore (m)	Scenario 3 Drawdown: Deep Aquifer (m)
LOC.209575	yes	1616796	6112205	Stock	51.5	1.43
LOC.209759	yes	1617644	6114898	Monitoring	61	1.31
LOC.209757	yes	1617067	6118436	Monitoring	89	0.92
LOC.314089	yes	1617450	6119000	Irrigation	95	0.82
LOC.209638	no	1617022	6115406	Stock	62	0.79
LOC.210270	no	1616501	6116438	Domestic and stock	65	0.76
LOC.210376	no	1616313	6115888	Domestic and stock	67	0.74
LOC.209620	no	1617112	6115915	Domestic and Stock	71	0.73
LOC.209754	yes	1616759	6120571	Monitoring	99	0.72
LOC.201579	yes	1618054	6115390	Exploration	56	0.65
LOC.209758	yes	1617576	6116979	Monitoring	76	0.62
LOC.200226	no	1617605	6121325	Not Specified	105.5	0.61
LOC.210514	no	1617927	6121289	Monitoring	101	0.47
LOC.210233	no	1615512	6122353	Not Specified	Not Specified	0.40
LOC.209753	yes	1616404	6119040	Monitoring	92	0.40
LOC.210305	no	1615513	6122512	Domestic	84	0.39
LOC.210513	no	1618159	6121280	Public Water Supply	95.6	0.39
LOC.210433	no	1618225	6121604	Exploration	99	0.37
LOC.210432	no	1618225	6121604	Public Water Supply	97.5	0.37
LOC.201288	no	1615677	6122797	Private Water Supply	108	0.36
LOC.209511	no	1618033	6122535	Domestic	101	0.35
LOC.210515	no	1618308	6121233	Monitoring	100.3	0.32
LOC.201267	no	1617431	6123583	Domestic	60	0.27
LOC.311405	no	1618539	6123040	Domestic	101.5	0.25
LOC.201424	no	1618734	6122288	Irrigation	82	0.24
LOC.209710	no	1619026	6122344	Domestic	78	0.20
LOC.209755	no	1617597	6119793	Monitoring	98	-0.06
LOC.201010	yes	1618839	6120489	Not Specified	Not Specified	-0.10
LOC.201011	yes	1619239	6120290	Not Specified	Not Specified	-0.23
LOC.201606	yes	1619617	6120296	Stock	64.45	-0.24
LOC.201607	yes	1619560	6120189	Stock	65.45	-0.26
LOC.201581	yes	1619560	6120189	Domestic	65	-0.26
LOC.201012	yes	1619539	6120191	Not Specified	Not Specified	-0.26
LOC.209756	yes	1617594	6119410	Monitoring	93	-0.36
LOC.201580	yes	1618343	6119088	Exploration	72.45	-0.49

IRISID	Within Sweetwater Property Boundary	X	Y	Purpose	Depth of Bore (m)	Scenario 3 Drawdown: Deep Aquifer (m)
LOC.210522	yes	1617851	6119772	Irrigation	91	-0.58

Appendix F
Plan Maps

Appendix F Plan Maps

Appendix F



Zone

- Conservation
- Coastal Living
- Coastal Residential
- General Coastal
- Lakes and Rivers
- Residential
- Recreational Activities
- Rural Production
- Road
- Coastal Marine
- Designations
- Historic Site

Note :-
Roads carry the same zoning as the adjoining land. If a boundary between zones follows a road, the zone boundary is located on the centreline of the formed road, or where unformed, the centreline of the legal road

13	14	15
18	19	20
24	25	26

Map Index

Map 18

Far North District Plan - Zone Maps

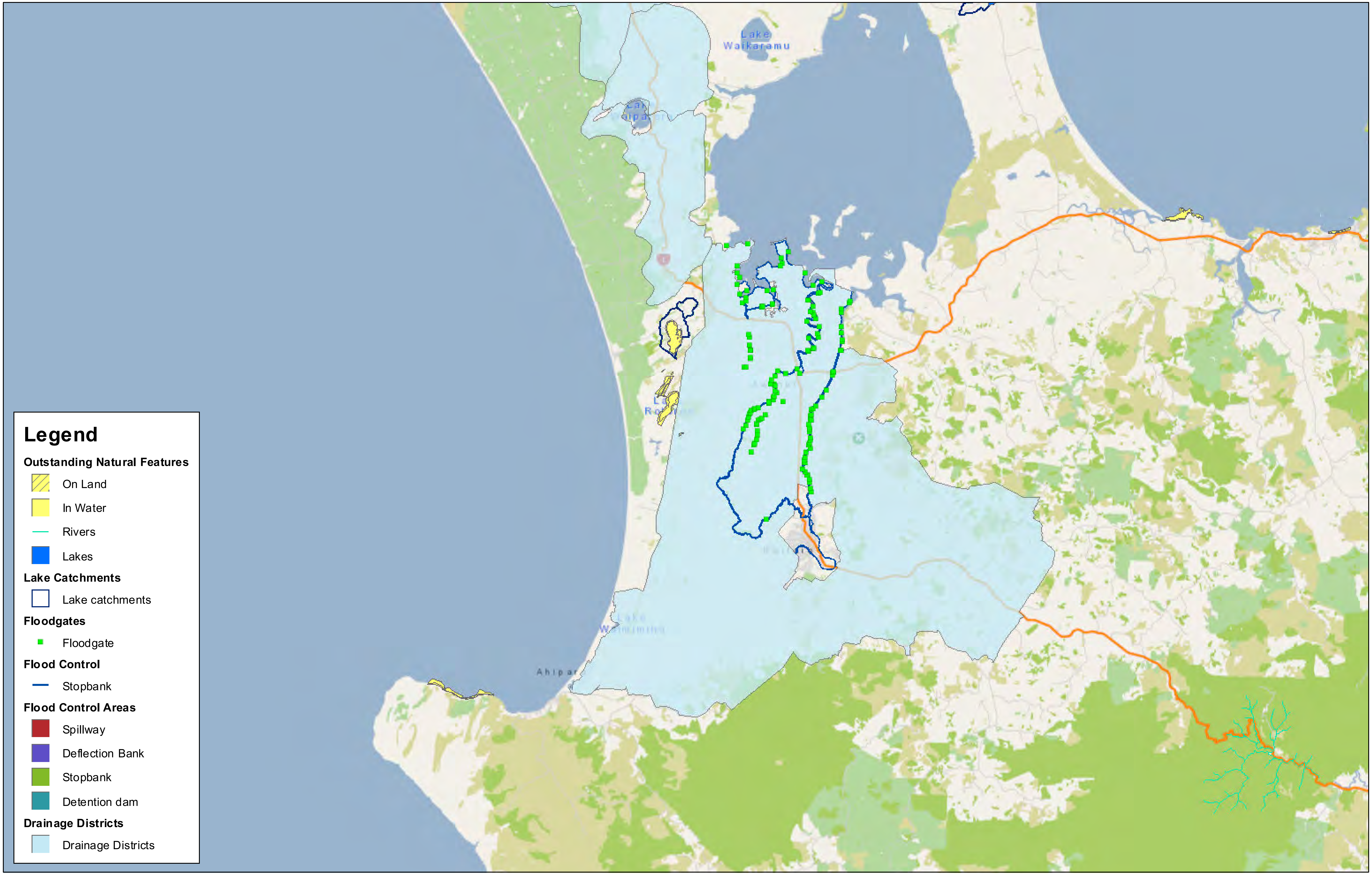
N

0 1 2 3 Km

Scale 1:50,000

DISCLAIMER

Considerable care has been taken to avoid errors and omissions, and the latest information has been included in these District Plan maps. However, even with the greatest care inaccuracies may occur and therefore the Far North District Council cannot accept any responsibility for such errors and omissions.



Northland REGIONAL COUNCIL

Proposed Regional Plan for Northland 2017 (decisions version)

Projection NZTM. Datum NZTM2000.

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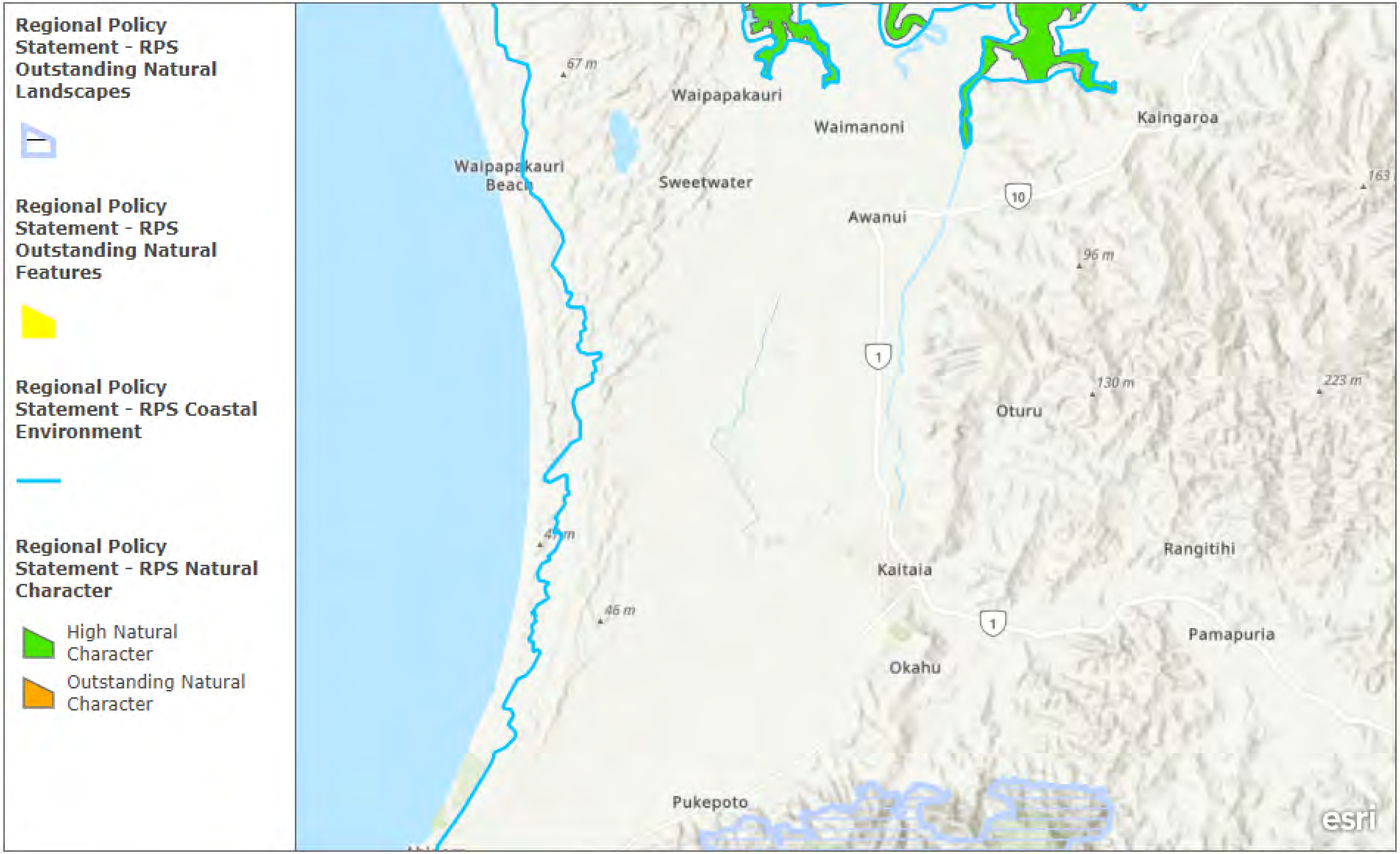

Regional Policy Statement for Northland 2016 – Map Sheet Layers wsp | OPUS

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