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Water Permit Application - Motutangi - Waiharara Water User Group (MWWUG), Aupouri Peninsula

1. Background

During 2016 Northland Regional Council (NRC) received multiple applications to abstract groundwater for irrigation of avocado orchards on the Aupouri Peninsula. After reviewing information provided to support the individual applications, NRC requested further information from each applicant under Section 92(1) of the Resource Management Act 1991 in order to adequately assess the effects of the proposed abstraction.

In response to the request for further information, a total of 17 parties formed the Motutangi-Waiharara Water User Group (MWWUG) to collectively advance the applications and engaged Williamson Water Advisory (WWA) to undertake appropriate analysis to respond to the initial NRC further information request. In June 2017, WWA lodged two documents with NRC on behalf of the MWWUG, comprising an assessment of environmental effects (AEE) and supporting technical assessment (comprising analysis of pumping scenarios undertaken using a numerical groundwater model developed for the portion of the Aupouri Peninsula subject to the applications).

Following a review of the information supplied to NRC¹, the Council requested further information from the applicant to enable assessment of potential effects on the environment. Information requested included:

- Further analysis of aquifer test results to improve characterisation of aquifer leakage in the Motutangi and Waiparera sub-zones;
- A comparison of modelled groundwater levels against measured static water levels, particularly in areas of the model domain where limited temporal groundwater level data is available;
- An evaluation of factors potentially contributing to apparent discrepancies between modelled and measured temporal groundwater level variations;

¹ LWP, 2017: Water Permit Application – *Motutangi-Waiharara Water User Group (MWWUG), Aupouri Peninsula*. Letter to Northland Regional Council, 22 June 2017.

- Further assessment of numerical model sensitivity and predictive uncertainty and discussion of relative changes in the modelled water budget under the various predictive scenarios with respect to the underlying conceptual model;
- Further analysis of potential local-scale and cumulative well interference effects, taking into account the nature of aquifer leakage calculated from aquifer test results;
- Re-assessment of potential saline intrusion risk in terms of static water levels at the coastal margin, and potential options for monitoring/managing saline intrusion risk;
- Assessment of potential water quality effects associated with the proposed use of water for orchard irrigation

The information sought was provided to NRC in an updated version of the AEE and supporting documentation in early September 2017. The following updated documents form the basis for this review:

- *Irrigation Water Supply Groundwater Take Consent Application*. Motutangi Waiharara Water User Group, WWA0026 | Final – Rev. 4, 30 August 2017²
- *Motutangi-Waiharara Groundwater Model Factual Technical Report - Modelling*. Motutangi Waiharara Water User Group, WWA0026 | Final – Rev. 9, 31 August 2017³

It is noted that the further information provided on behalf of the applicant includes some amendments to proposed irrigation areas and seasonal volumes for individual applications proposed in the original application.

The following report provides a technical review of information supplied to support the resource consent applications. In undertaking the review, reference has also been made to a number of previous hydrogeological investigations undertaken in the area including:

- Northland Regional Council, 1991: *Aupouri Peninsula Water Resources Assessment*
- HydroGeo Solutions, 2000; *Aupouri Aquifer Sustainable Yield Groundwater Modelling Study*, January 2000
- Lincoln Agritech, 2015; *Aupouri Aquifer Review*. Report prepared for Northland Regional Council, April 2015.

1.1 Proposed Activity

Table 1 provides a summary of the proposed groundwater abstraction for the MWWUG application which comprises 17 separate groundwater takes with a combined maximum abstraction rate of 380 L/s, 16,418 m³/day and 2,446,350 m³/year.

² Subsequently referred to as the “AEE”

³ Subsequently referred to as the “modelling report”

The proposed takes are distributed across the Waiparera (9,431 m³/day, 1,405,300 m³/year), Motutangi (6,137 m³/day, 914,400 m³/year) and Hohoura (850 m³/day, 126,650 m³/year) groundwater management zones defined by Lincoln Environmental (2015)⁴.

Table 1. Summary of proposed abstraction

Application	Name	Consent Status	Maximum Inst Rate (L/s)	Maximum Daily Volume (m ³)	Annual volume (m ³)
APP.038610.01.01	Mapua Avocados Ltd, C/o Murray Forlong	New	116	5,000	745,000
APP.038471.01.01	Honeytree Farms Limited, C/o Tony Hayward	New	81	3,500	521,500
APP.038410.01.01	Georgina Tui and Mate Nickolas Covich	New	35	1,500	223,500
APP.038420.01.01	Largus Orchard Ltd Partnership, C/o Murray Forlong	New	30	1,300	193,700
APP.038513.01.01	Te Runanga o Ngai Takoto, C/o Rangitane Marsden	New	30	1,300	193,700
APP.039332.01.01	Candy Corn Ltd, C/o Bryan Candy	New	12	537	80,000
APP.038454.01.01	Elbury Holdings Limited, C/o Kevin and Fiona King	New	18	763	113,700
APP.038328.01.01	Bernard Kim & Sheryl Dianne Shine	New	6	268	40,000
APP.027391.01.02	Ivan Anthony Stanisich	Increase	10	430	64,070
APP.39244.01.01	Kevin and Dani Thomas	New	9	400	59,600
APP.038589.01.01	Neil & Alma Violet Thompson and Steven & Josephine Suzanne Thompson	New	7	320	47,680
APP.038650.01.01	Tony and Diane Hewitt	New	6	270	40,230
APP.038591.01.01	Cypress Hills Ltd, C/o Alan Anderson & Carolyn Dawn Smith	New	7	280	41,720
APP.039345.01.01	Ian McLarnon & Jason McLarnon	New	5	200	29,800
APP.38732.01.01	Kathy Valadares	New	4	150	22,350
APP.038380.01.01	Daimen & Katherine Holloway	New	2	100	14,900

⁴ The groundwater management zones (and associated allocation limits) proposed by Lincoln Environmental (2015) have been incorporated as aquifer management units in the recently notified Proposed Regional Plan for Northland (pRPN).

Application	Name	Consent Status	Maximum Inst Rate (L/s)	Maximum Daily Volume (m ³)	Annual volume (m ³)
APP.039381.01.01	Johnno and Carol Brien (Lamb Road)	New	2	100	14,900
Total			380	16,418	2,446,350

2. Environmental Setting

The Aupouri Aquifer covers a land area of approximately 75,000 hectares 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.

The landform of the Aupouri Peninsula comprises a relatively thick sequence of sedimentary deposits which have formed as a tombolo (essentially a sand bar accumulated due to wave and current action) connecting outcrops of basement rocks at either end of Ninety Mile Beach. The subsurface geology of the area consists of Pleistocene and Holocene unconsolidated sedimentary materials deposited in beach and dune environments (abandoned shorelines and marine terraces) and associated alluvial, intertidal estuarine, shallow marine, lakebed and wetland environments. These deposits overlie Cretaceous basement rocks of the Mount Camel Terrain, which typically comprises hard grey to dark green / black igneous rocks described in Isaac (1996)⁵ as intercalated basalt and basaltic andesite lava, pillow lava, rhyolitic tuff, tuff-breccia, conglomerate, sandstone and mudstone

The unconsolidated sedimentary deposits of the Aupouri Peninsula host a spatially extensive unconfined aquifer system. As described in the AEE, the sedimentary deposits can be broadly classified into two hydrostratigraphic units:

- The upper part comprises 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 exhibit a higher degree of compaction and weathering compared to younger foredune sands at the coast. These shallower fine-sand dominated deposits host a low yielding unconfined aquifer.
- In many areas, the lower part of the sedimentary sequence (overlying the basement rocks) contains a high percentage of relatively coarse shell fragments. These deposits are commonly referred to as 'shellbeds' and exhibit significantly higher permeability than the overlying sands so are typically the target for larger scale groundwater development.

As noted by in both the AEE and Lincoln Environmental (2015) there does not appear to be a clear hydraulic boundary between the shellbeds and overlying sand deposits. In many cases this is due to

⁵ Isaac, M.J. (compiler), 1996: *Geology of the Kaitiaki area*. Institute of Geological & Nuclear Sciences 1:250 000 geological map 1. 1 sheet + 43 p. Lower Hutt, New Zealand. GNS Science.

the discontinuous nature of lower permeability layers (iron pans, peat and lignite layers) within the sand deposits. 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). However, as shown by aquifer testing undertaken on the Aupouri Peninsula, vertical leakage from the overlying fine sand deposits provides a significant storage buffer which increases the effective yield available from the shellbeds.

Appendix 1 of the modelling report outlines aquifer hydraulic properties derived from analysis of aquifer tests in the Aupouri Peninsula area. These data typically show transmissivity values of less than 100 m²/day in the sand deposits, increasing up to 500 m²/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).

Overall, aquifer system is unconfined at the surface but behaves in a manner that suggests a progressive degree of confinement with depth (leaky confinement). While there is no well-defined regionally extensive confining layer, 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 which varies spatially.

Groundwater underlying the Aupouri aquifer is recharged by infiltration of rainfall through the surficial sand deposits. Localised perched water tables occur in areas where infiltration is impeded by the accumulation of fine-grained sediments (typically silt or organic-rich sediments deposited in interdune areas). The rate of recharge may also be significantly influenced by overlying landcover, particular plantation forestry which reduces recharge due to canopy interception.

Groundwater flow within the unconfined aquifer is likely 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 to the Aupouri Peninsula, perpendicular to the coastline (HydroGeo Solutions, 2000). 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, areas such as Kaumaumau which extend laterally some distance from the central axis exhibit a low hydraulic gradient toward the eastern coastline.

As noted by Lincoln Environmental (2015), 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 also 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 sediments 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.

2.1 Assessment of aquifer sustainability

The Lincoln Environmental (2015) study collated available information on geology, hydrostratigraphy, hydraulic properties and spatial and temporal groundwater level variations to develop a regional-scale numerical groundwater model of the Aupouri Peninsula. The model was used to evaluate predictive scenarios and develop recommendations for the sustainable management of groundwater resources on the Aupouri Peninsula. These recommendations included allocation volumes for individual sub-zones of the wider groundwater system. These allocation volumes have been subsequently incorporated into the recently notified pRPN.

Aspects of the Lincoln Environmental (2015) relevant to consideration of the MWWUG application include:

- The conceptual model developed for the study divided the groundwater system into two hydraulic units: a shallow unconfined aquifer and a deeper leaky-confined aquifer system. These units were inferred to be separated by a laterally extensive low permeability horizon (comprising Holocene peat deposits) at approximately sea level which acts as a confining layer to deeper water-bearing intervals;
- Average recharge across the Aupouri aquifer was calculated to range between 160 and 840 mm/year, averaging 500 mm/year (or approximately 38% of rainfall). The average recharge volume for the entire aquifer area was estimated to be around 374 million m³/year
- The upper surface of the Cretaceous basement rocks (and corresponding thickness of the overlying sedimentary sequence) was interpreted from geophysical survey data to dip in a north-westerly direction from Rangaunu Harbour (<30 m bgl) toward the northern end of Ninety Mile Beach (>200 m bgl), with significant offset (up to 100m) occurring on the eastern side of a north-west to south-east trending fault extending from Waihuahua Swamp to a point on the western coast approximately 20 kilometres north-west of Hukatere;
- The Aupouri aquifer was subdivided into 9 aquifer sub-regions to assist management of groundwater allocation on the basis of criteria including the estimated position of the groundwater flow divide, cross boundary flows between zones, the location of existing and proposed monitoring sites and the clustering of groundwater consents and coastal domestic bores;
- Saline intrusion was identified as the primary constraint on groundwater availability with allocation limits recommended for each sub-region on the basis of estimated groundwater levels required to maintain the saline interface offshore at key coastal locations.

The Lincoln Agritech (2015) report acknowledged uncertainties associated with a lack of data in several geographic areas, including those sub-zones (Waiparera and Motutangi) where a majority of the proposed abstraction is located.

3. Information provided to support the MWWUG application

Hydrogeological investigations detailed in the WWA reports includes a range of information to improve characterisation of the regional and local hydrogeological setting, and assess the potential effects of the proposed abstraction. In part, this information builds on analysis undertaken by Lincoln Environmental (2015), but also includes analysis of additional data and re-interpretation of key aspects of the hydrogeological setting. The following section provides a technical review of the information provided.

3.1 Radon Isotope Survey

In order to characterise the potential interaction between deeper groundwater and the Kaimaumu wetland, a survey of radon concentrations was undertaken in groundwater and in surface waterways at representative points in, and around, the Kaimaumu wetland.

Radon (specifically the Rn-222 isotope) occurs naturally in groundwater as a result of the decay of uranium minerals present in almost all geological materials. This decay process leads to elevated Rn-222 concentrations in groundwater. However, where groundwater discharges to the surface environment, radon concentrations reduce relatively quickly due to degassing. The resulting contrast between concentrations in groundwater and surface water allows Radon to be used as an environmental tracer to identify areas where groundwater discharge exerts a significant influence on discharge in surface waterways.

The investigation involved measurement of Radon concentrations in samples collected from 8 surface water sites in and around the Kaimaumu wetland and a deep groundwater bore near Waiharara. Results indicate the Radon concentrations in deeper groundwater (6.3 BqL^{-1}) are significantly higher than in surface waters (0.1 to 2.7 BqL^{-1}). Lowest Radon concentrations were observed at sites in or immediately adjacent to the Kaimaumu wetland (Salles Drain, Pirini Stream), with more elevated concentrations observed in areas which are interpreted to receive local groundwater input from adjacent higher elevation sand dune areas (Selwyn Drain, Seymour Drain, Salles Drain downstream).

Overall, although not conclusive on its own, the Radon analysis does not indicate significant groundwater input into Kaimaumu wetland. This observation is consistent with the classification of the wetland as a bog (i.e. primarily recharged by rainfall and perched above the regional water table) where water levels, although varying locally, are largely maintained by a perched water table formed on sandstone hardpans (Hicks et.al., 2001). Springs observed in the wetland appear largely to result from lateral flow along hardpan deposits from higher elevation dune areas, rather than discharge from deeper groundwater underlying the Aupouri Peninsula (particularly given the relatively low hydraulic head in deeper groundwater in this area).

3.2 Aquifer Testing

The model report details three aquifer tests undertaken on proposed production bores, two located in the Waiparera sub-zone (Honeytree Farms and Stanisich) and one in the Motutangi sub-zone (de Bede Ltd). Analysis of these aquifer tests provided in Appendix D of the modelling report indicates

aquifer transmissivity values for the shellbed in the range of 360 to 780 m²/day, with storativity values between 0.004 and 0.0004.

Overall, aquifer testing undertaken appears to be of a suitable standard to characterise aquifer hydraulic properties in the vicinity of the bores tested. Results are generally consistent with data from previous aquifer tests undertaken in the area (outlined in Appendix 1 of the modelling report), although aquifer transmissivity values from the Honeytree Farms bore is at the upper end of the historical range⁶.

Of particular interest is the range of effective aquitard conductance (K'/B') values calculated from the aquifer tests which range from 1.9×10^{-3} at Stanisich to 1.6×10^{-5} at Honeytree Farm. Given this parameter is a key property influencing the overall rate of vertical leakage in response to pumping, the data (in combination with equivalent values listed in Table 2 of Lincoln Environmental (2015)) suggest significant spatial variability in the degree of hydraulic connection between the shellbed and overlying sand aquifer.

Overall, available aquifer test data indicate the shellbed layers occurring toward the base of the sedimentary sequence generally exhibit aquifer transmissivity values between 3 to 5 times higher than those occurring in the overlying fine sand deposits. The aquifer test data also indicate the extent of the hydraulic connection between the shellbed and the overlying sand aquifer varies spatially. In some locations the data indicate upper and lower hydraulic units exhibit a high degree of hydraulic connection (i.e. significant vertical leakage will occur in response to abstraction) while, in other areas, there may be greater resistance to vertical leakage (i.e. shellbed may be more well confined resulting in greater drawdown in the shellbed and less drawdown in the overlying land aquifer in response to abstraction).

3.3 Groundwater model

The WWA model report documents the conceptualisation and development of a sub-regional scale numerical groundwater model to enable assessment of potential cumulative effects of existing and proposed abstraction. The following comments on the set-up and application of the model generally follow the format (albeit somewhat simplified) outlined in Chapter 9 of the Australian Groundwater Model Guidelines⁷.

3.3.1 Model set-up and layer geometry

The model domain extends over an area of approximately 203 km² from Pukenui in the north to Waiharara in the south (including all proposed groundwater takes) using an unstructured grid to enable refinement of mesh size in the vicinity of proposed abstraction points and other points of

⁶ Possibly due to this bore being screened largely in the deeper shellbed layer which appears to exhibit higher transmissivity than the upper shellbed which a majority of historical tests are from

⁷ Sinclair Knight Merz and National Centre for Groundwater Research and Training, 2012; *Australian groundwater modelling guidelines*. Waterlines Report Series No. 82, June 2012.

interest. This area includes a large proportion of the Hohura, Motutangi and Waiparera sub-zones proposed by Lincoln Agritech (2015).

The sedimentary sequence of the Aupouri Peninsula was subdivided into four hydrostratigraphic units (comprising 6 layers) representing:

- *Unit 1*: a thick (40 to 70 m thick) sequence of unconsolidated fine sand interspersed with discontinuous layers of iron pan, silt and peat. This stratigraphic unit was represented in the model by three spatially variable layers reflecting the spatial and depth distribution and associated hydraulic properties of; coastal sand, weathered sand and low-lying peat deposits
- *Unit 2*: upper shell bed comprising the primary water-bearing interval targeted by historical drilling
- *Unit 3*: a sand layer of variable thickness separating the two shell bed layers
- *Unit 4*: a sequence of shellbeds exhibiting coarser texture than the upper shellbed unit

As noted in Section 2.2.1 of the modelling report, the discontinuous and irregular nature of the iron pans and other low permeability features within the sedimentary sequence represents a challenge for conceptualisation and representation of the aquifer system in the groundwater model:

“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 extensive confining layer but there are numerous low permeability layers (e.g. iron pan, brown (organic) sand, silt and peat) that vary in depth and thickness, which over multiple occurrences collectively provide a degree of confinement that leads to the development of vertical pressure gradients....”.

In the WWA model, the potential effects of such features on aquifer confinement were simulated by varying vertical anisotropy within the various model layers (ranging from 90 in weathered sand to 1 in the shellbeds). This approach differs from that utilised by Lincoln Agritech who utilised a specific layer in the model (layer 2) to represent a laterally continuous leaky confining layer between the shellbed and overlying sand aquifers.

Based on the documentation provided, the hydrostratigraphic subdivisions utilised within the model appear reasonable for a geologically complex area. The layers defined are broadly similar to those utilised for the Lincoln Agritech model, but reflect refinement of the conceptual model to account for geological variability in the upper sand layer and also include the deeper shellbed layer. Geometry assigned to the individual model layers was determined by kriging, based on interpretation of available geological logs. Hydrogeological cross sections presented in Figures 12 to 15 of the modelling report indicate a laterally continuous layer geometry consistent with the underlying conceptual model.

Both NRC (1991) and Lincoln Agritech (2015) identify a significant displacement in the basement structure, inferred to be associated with a NW-SE trending fault crossing the southern extent of the model domain. Section 3.3.2 of the model report addresses the potential influence of the inferred fault on the model and notes that there is a relatively high density of drill hole data in the northern

section of the model domain (Houhora-Hukatere) which provides confidence in interpolated basement elevations in this area, and does not indicate fault displacement is a major structural feature in this area. It is also noted that in the Kaimaumau swamp area in the south-eastern portion of the model domain, and upward displacement along the eastern side of the inferred fault would decrease the sensitivity to environmental effects (such as saline intrusion) compared to the geometry utilised in the WWA model⁸.

3.3.2 Hydraulic Properties

Initial aquifer hydraulic properties assigned to the model layers appear largely consistent with aquifer test results and values adopted by previous investigations (outlined in Appendix A and Appendix D of the model report). Although direct comparison is difficult due to differences in model configuration, it is noted that horizontal hydraulic conductivity values from the final model calibration (Table 7 of the modelling report) are within the range (albeit slightly higher than median values) determined by parameter optimisation reported for the Lincoln Agritech (2015) model.

3.3.3 Boundary Conditions

Boundary conditions were assigned as constant head, general head, drain and no-flow boundaries around or within the model domain. All boundaries appear to have been assigned in a manner consistent with the overall conceptual model.

3.3.4 Recharge

A land surface (rainfall) recharge time series was developed for the model using the Soil Moisture Water Balance Model (SMWBM) using a time series of climate data and various input parameters to represent the hydraulic characteristics of different soil materials in the model domain. Results of this assessment estimate groundwater recharge on average comprises 43% of rainfall in the coastal sand zone, 38% of rainfall in the weathered sand zone and 10% of rainfall in the plain zone (where surface runoff is appreciable higher).

As detailed in Section 2.4.1 of the modelling report, the calculated rainfall recharge estimates are consistent with previous calculations undertaken for the Aupouri Peninsula⁹ so would appear to provide a reasonable estimate of the timing and volume of the primary recharge component of the aquifer water balance.

3.3.5 Abstraction

A time series of water demand for irrigation was generated using the SMWBM for input into numerical model scenarios. Appendix C of the modelling report provides a comparison between estimated and

⁸ Due to a consequent reduction in aquifer saturated thickness

⁹ It is noted average recharge across the model domain is approximately 20% lower than the equivalent spatial average for the Lincoln Environmental (2015) model.

actual water use for an individual consent near Waiharara which indicates actual use is approximately 30% of the modelled demand. While there may be a range of operational reasons for the discrepancy between modelled and actual water use, it is likely that 'typical' irrigation water use may be significantly lower than the volumes modelled, other than in very dry years. It is therefore reasonable to assume that the pumping rates utilised in scenario modelling are likely to provide a suitably conservative (upper) estimate of the potential rate and volume of groundwater abstraction (and associated effects on the environment).

Further comments on the proposed rate and volume of abstraction for individual water permit applications are provided in Section 4.1 below.

3.3.6 Overall Model Conceptualisation

The overall conceptualisation of the groundwater system of the Aupouri Peninsula is outlined in Section 2 of the model report. The conceptual model is similar to that developed for previous investigations (e.g. Hydrogeo Solutions, 2001, Lincoln Agritech, 2015), with the water balance dominated by rainfall infiltration with groundwater water moving laterally from a flow divide along axis of the peninsula through a stratified aquifer system toward the coast.

Differences from previous investigations are relatively subtle, reflecting refinement of geological units in the upper sand layer, an alternative method for representing discontinuous low permeability layers within the sedimentary sequence and inclusion of the deeper shellbed unit, all of which appear supported by data available to characterise subsurface geology and hydraulic properties.

3.3.7 Steady-state calibration

Initial steady-state calibration of the model was undertaken to validate the model conceptualisation using water levels from 17 piezometers as the calibration target. Results indicate the steady-state model is capable of replicating overall spatial and depth variation in water levels, although significant discrepancies are noted for individual bores. In some cases (e.g. Wagenar and Game Club) these discrepancies may, in part, be related to intermittent abstraction from the monitoring bores.

3.3.8 Transient Calibration

Transient calibration of the model utilised a time series of recharge and water use data to represent a 70 year period (1956-2016)¹⁰. The simulation was divided into 442 stress periods of varying length with fixed intervals to represent the (nominal) start and end of the irrigation season. Overall, parameters controlling the transient simulation appear appropriate for a long-term sub-regional scale simulation of groundwater levels.

Calibration targets were established for the entire water level record from the 17 piezometers and goodness of fit to spatial and depth variation in temporal groundwater levels expressed both

¹⁰ It is assumed other environmental variables (such as surface water discharge) could not be utilised as calibration targets due to a lack of data.

quantitatively and qualitatively. The mean residual head and RMSE are within a range that can be considered to provide a reasonable calibration¹¹.

For individual monitoring locations, the model calibration data presented indicate a range of model errors. Some sites (e.g. Waterfront piezometers 1 and 2) show a good fit to the available groundwater levels records while others exhibit appreciable differences between measured and actual temporal groundwater level variations (e.g. Hukatere and Forest piezometers) or in terms of relative levels (e.g. Wagener). No consistent difference in model accuracy (in terms of absolute or temporal variation) is observed between shallow and deep piezometers.

Section 4.4.1 of the model report provides a summary of the model calibration to observed groundwater levels. The report identifies changes in land use and changes in land cover (particularly harvesting cycles for plantation forestry) as potentially contributing to the mismatch in calibration in inland piezometers. While it is uncertain if historical changes in land use fully account for all the observed variations, it is not unrealistic to infer that such changes could have a significant influence on the goodness of fit for the model calibration.

In response to initial technical comments, further verification of modelled water levels was undertaken by comparing modelled levels against relative groundwater levels measured in test pumping bores and comparing extrapolated water levels with those recorded in NRC monitoring bores (Ogle Drive and Paparore) located a relatively short distance south of the model domain. Results of this comparison again show indicate that modelled groundwater levels generally match the overall magnitude of observed groundwater levels. The report also identifies that some of the offset in measured and modelled groundwater levels in the test pumping bores may be associated with localised inaccuracies in the digital elevation model (DEM) used to reference groundwater levels to a common datum.

Overall, the numerical model exhibits a reasonable ability to simulate both temporal and depth variation in groundwater levels across the model domain. However, comparison of actual and modelled groundwater levels indicates localised variances between modelled and measured groundwater levels which may relate to temporal variations in calculated recharge (and associated lags) as well as localised variation associated with the heterogeneous geological environment. As a result, modelled groundwater levels are best considered to provide a generalised presentation of temporal and spatial piezometric variations, particularly with regard to relative difference between the individual pumping scenarios.

It is also noted that the calibrated model (i.e. used for Scenarios 1, 2 and 3) is likely to provide a conservative estimate of likely drawdown in the sand aquifer (and associated effects on hydraulically connected surface waterways) due to approach adopted to account for the spatial variability in vertical leakage (due to geological heterogeneity). Resulting uncertainties regarding the potential magnitude of drawdown in the shellbed aquifer are, in part, addressed by the lower leakage scenarios (4a, 4b and 4c) described in the following section (which assume lower rates of vertical leakage than utilised for Scenarios 1, 2 and 3).

¹¹ Sinclair Knight Merz and National Centre for Groundwater Research and Training, 2012; *Australian groundwater modelling guidelines*. Waterlines Report Series No. 82, June 2012.

3.3.9 Model predictive simulations

The calibrated numerical model was utilised to run a range of predictive scenarios representing existing, and potential future water use. The scenarios modelled include:

- *Scenario 1 - base case*: abstraction from existing groundwater consents (11,810 m³/day)
- *Scenario 2 - proposed abstraction*: existing abstraction plus the proposed MWWUG abstraction (i.e. 11,810 m³/day existing, plus 16,755 m³/day proposed)
- *Scenario 3a - future allocation*: existing and MWWUG proposed abstraction, plus an additional 20,000 m³/day abstraction from 'fictitious' bores distributed across the model domain
- *Scenario 3b - future allocation*: existing and MWWUG proposed abstraction, plus an additional 40,000 m³/day abstraction from 'fictitious' bores distributed across the model domain
- *Scenario 3c - future allocation*: existing and MWWUG proposed abstraction plus, an additional 80,000 m³/day abstraction from 'fictitious' bores distributed across the model domain

Each of the scenarios were run over the full climate record and provide a useful means to identify changes in model water budget in response to increasing abstraction.

3.3.10 Water Budget

Section 4.4.3 of the modelling report provides a long-term average water budget for the transient model calibration. The data presented indicate the water budget is dominated by rainfall recharge. The calculated recharge volume of 224,000 m³/year equates to an average recharge rate of 403 mm/year across the model domain (approximately 80 percent of the 500 mm/year recharge estimated by Lincoln Environmental). The data also indicate shallow coastal discharge is the major discharge mechanism, accounting for approximately 53 percent of the water budget, while deep coastal discharge accounts for approximately 7 percent of the water budget. The resulting ratio of shallow to deep coastal discharge is consistent with the conceptual understanding of the dynamics of groundwater flow outlined in Lincoln Environmental (2015). Discharge to surface waters (streams, drains and wetlands) collectively comprise 16 percent of the water budget, again consistent with the underlying conceptual model.

Section 5.2.1 of the model report provides a mass balance for each of the predictive scenarios. This provides a useful means to validate that the response of the model to variations in groundwater abstraction is consistent with the underlying hydrogeological conceptualisation. Comparison of water budget for Scenario 1 with that for the alternative pumping scenarios indicates a reduction in coastal discharge (both shallow and deep) with increased groundwater abstraction. The proportional reduction in deep coastal discharge is greater than the equivalent reduction in shallow coastal discharge indication greater sensitivity to seawater intrusion (due to lateral migration of the saline interface) in deeper water-bearing layers. The mass balance figures for the various pumping

scenarios also indicate that discharge to surface waterbodies (wetlands, drains and streams) is not particularly sensitive to significant increases in the volume of groundwater abstraction.

Overall the model water balance, including the calculated response to groundwater abstraction, is consistent with the underlying conceptualisation of the Aupouri aquifer system.

3.3.11 Model uncertainty analysis

In response to the initial technical review, additional sensitivity analysis was undertaken on Scenario 2 to address the acknowledged limitations with regard the ability of the model to simulate vertical leakage (and associated drawdown in the sand and shellbed aquifers). The analysis undertaken involved re-running the model with values of horizontal and vertical hydraulic conductivity in layer 2 reduced by one, two and three orders of magnitude (Scenario 4a, 4b and 4c respectively) to simulate response groundwater levels to varying levels of hydraulic connection between the sand and shellbed aquifers.

It is noted that the model was not recalibrated for the uncertainty runs so results provide information in terms of relative, rather than absolute, differences in calculated drawdown in the two water-bearing layers. However, the analysis provides a useful means to assess potential variability in aquifer response to abstraction for differing leakage scenarios. Further discussion of uncertainty modelling and its potential implications in terms of environmental effects is provided in Sections 4.3 and 4.4 below.

3.3.12 Model fitness for purpose

Overall, the numerical groundwater model described in the modelling report is appropriately constructed and provides a useful tool to assess potential effects associated with groundwater abstraction at a regional scale. The model does have some acknowledged limitations with regard to its ability to predict vertical leakage (and associated water level drawdown in shallow and deep groundwater) due to the irregular and discontinuous nature of iron pans and other low permeability horizons within the sedimentary sequence. However, such limitations are in part addressed by the uncertainty analysis undertaken in response to the Council further information request.

4. Potential effects on the environment

4.1 Reasonable and efficient water use

Some minor amendments to the irrigated area and/or seasonal volumes for individual water permit applications have occurred since the original MWWUG application was lodged. Table 2 below provides a summary of the updated figures, along with the corresponding maximum daily and seasonal irrigation application rates. Based on the figures provided, the proposed maximum daily application rate varies between 1.9 and 5.0 mm/day (equivalent to 19 and 50 m³/ha/day respectively), while the proposed seasonal application depths for individual applications range from 279 to 530 mm/year (equivalent to 2,790 and 5,300 m³/ha/year respectively).

Table 2. *Irrigated area, maximum abstraction rate, seasonal volume and irrigation depth for the MWWUG application*

Application	Name	Irrigated Area (Ha)	Maximum Daily Volume (m ³)	Maximum Daily Application Rate (mm)	Annual volume (m ³)	Seasonal Application Depth (mm)
APP.038610.01.01	Mapua Avocados Ltd, C/o Murray Forlong	160	5,000	3.1	745,000	466
APP.038471.01.01	Honeytree Farms Limited, C/o Tony Hayward	110	3,500	3.2	521,500	474
APP.038410.01.01	Georgina Tui and Mate Nickolas Covich	70	1,500	2.1	223,500	319
APP.038420.01.01	Largus Orchard Ltd Partnership, C/o Murray Forlong	60	1,300	2.2	193,700	323
APP.038513.01.01	Te Runanga o Ngai Takoto, C/o Rangitane Marsden	60	1,300	2.2	193,700	323
APP.039332.01.01	Candy Corn Ltd, C/o Bryan Candy	20	540	2.7	80,000	400
APP.038454.01.01	Elbury Holdings Limited, C/o Kevin and Fiona King	30	760	2.5	113,700	379
APP.038328.01.01	Bernard Kim & Sheryl Dianne Shine	10	500	5.0	40,000	400
APP.027391.01.02	Ivan Anthony Stanisich	17	430	2.5	64,070	377
APP.39244.01.01	Kevin and Dani Thomas	16	400	2.5	59,600	373
APP.038589.01.01	Neil & Alma Violet Thompson and Steven & Josephine Suzanne Thompson	9	320	3.6	47,680	530
APP.038650.01.01	Tony and Diane Hewitt	10	270	2.7	40,230	402
APP.038591.01.01	Cypress Hills Ltd, C/o Alan Anderson & Carolyn Dawn Smith	9	280	3.1	41,720	464
APP.039345.01.01	Ian McLarnon & Jason McLarnon	6	200	3.3	29,800	497
APP.38732.01.01	Kathy Valadares	8	150	1.9	22,350	279
APP.039381.01.01	Johno and Carol Brien (Hukatere Road)		125		18,625	
APP.038380.01.01	Daimen & Katherine Holloway	4	100	2.5	14,900	373
APP.039381.01.01	Johno and Carol Brien (Lamb Road)	4	100	2.5	14,900	373

The proposed seasonal allocation volumes were assessed by NRC using the Councils SPASMO irrigation calculator. This assessment assumed Te Kopuru Sand as a representative soil type across

the proposed irrigation area. Te Kopuru Sand is classified as a Humis-pan densipan podzol which comprises grey loamy sand which exhibits low soil water holding capacity, overlying a sandy subsoil which typically contains a hard shallow pan that restricts rooting depth and drainage. The calculated 1 in 10 year (i.e. 90% reliability) high irrigation demand on this soil type was calculated at 310 mm/year. Allowing for 80% irrigation efficiency, the SPASMO calculation indicates a maximum seasonal irrigation requirement for avocados on the Aupouri Peninsula of 372 mm/year.

Comparison of the annual irrigation requirement calculated by SPASMO against the figures listed in Table 2 indicates 10 of the 18 individual applications are seeking seasonal volumes in excess of the estimated 1 in 10 year irrigation demand, with five applications (APP.038591.01.01, APP038610.01.01, APP038471.01.01, APP039345.01.01, APP038589.01.01) seeking annual volumes significantly higher (>90mm) higher than that calculated by SPASMO.

However, as an alternative, Figure 1 shows a screenshot of irrigation water requirements calculated for a sandy soil at a representative site in the Waiharara area (at the corner of Kaimaumau and Far North Road) using the Irrigation New Zealand Irrigation Reasonable Use Database¹². This assessment utilises the Irricalc application to calculate irrigation water demand based local climate data and an assumed soil water holding capacity (in this case 60 mm) for an avocado crop irrigated by micro/drip irrigation. Results of this assessment indicate a maximum daily irrigation demand for avocados of 5.0 mm/day (equivalent to 50 m³/ha/day) and a 90 percentile (i.e. 1 in 10 year maximum) irrigation demand of 441 mm/year (equivalent to 4,410 m³/ha).

Compared to the figures listed in Table 2, all applications have a maximum daily application rates less than that the maximum calculated 1 in 10 year demand. However, five applications (APP.038591.01.01, APP038610.01.01, APP038471.01.01, APP039345.01.01, APP038589.01.01) are seeking annual volumes in excess of the 1 in 10 year maximum annual demand.

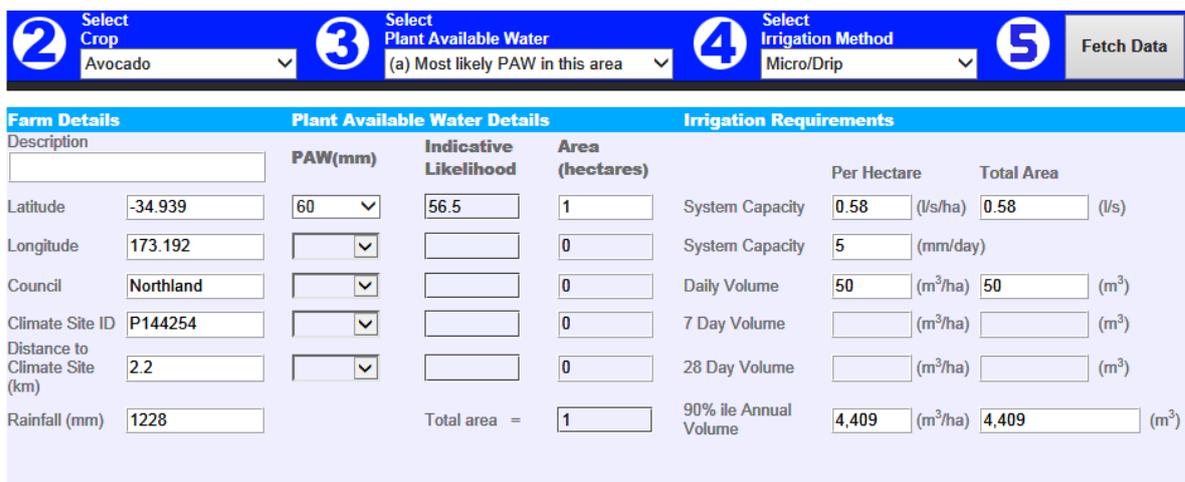


Figure 1. Irrigation water requirements for avocados on the Aupouri Peninsula calculated using the Irrigation New Zealand Reasonable Use Database

¹² <http://mycatchment.info/>

Based on the varying estimates of irrigation water use for avocados¹³, the Council may wish to consider if the proposed annual volumes for individual water permits represent reasonable and efficient water use, particularly those which are seeking volumes equivalent to seasonal irrigation depths in excess of 450 mm/year.

In addition, it is understood that the updated irrigation areas listed in Table 2 relate to land parcels outside of those identified in Table 2 of the AEE for a subset of applications. The council may therefore also wish to consider if it is appropriate to grant water permits for seasonal volumes based on proposed irrigation areas which include land to which applicants may not currently have legal access. Such consideration may need to balance commercial considerations (i.e. the costs involved to secure access to land without guaranteed access to water) against the potential for 'water banking' (i.e. securing larger volumes than required on a 'speculative' basis, potentially denying alternative users access to the resource). A possible option to address this issue could be via consent conditions which relate specific allocation volumes to individual land parcels.

4.2 Effects on surface waterbodies

Section 3.3.1 of the AEE summarises analysis of the potential effect of the proposed abstraction of cumulative drain flows within the model domain. This analysis involved calculating drain flow annual minima from the 70 year simulation for the various predictive scenarios, compared to the base case (existing allocation). Results suggest that the proposed allocation has the potential to reduce annual minimum cumulative drain flows by approximately 5% (406 to 386 L/s) and the 5-year low flow by 7 percent (303 to 281 L/s).

Potential effects on the Kaimaumau wetland were assessed in a similar manner by comparing changes in annual minima discharge calculated from the 70 year record for the different predictive scenarios. Results of this analysis suggested a maximum reduction of 7% in annual minima discharge and an 11% reduction in the 5-year low flow discharge.

The assessment notes that, due to the over-prediction of drawdown in shallow groundwater, the calculated effect on drain flows and the Kaimaumau wetland simulated in Scenario 2 and 3a (i.e. current and proposed abstraction) is likely to represent a conservative upper estimate of the potential magnitude of effect¹⁴.

Overall, as discussed in Section 3 above, the degree of hydraulic connection between deeper groundwater and the Kaimaumau wetland assumed in the calibrated model is likely to result in an over-estimation of the potential magnitude of effect in hydraulically connected surface waterways. In particular, while the model assumes a degree of hydraulic connection between the sand aquifer and

¹³ Including Section 1.2 of the AEE which refers to an average daily water requirement equivalent to 25 m³/day/ha, based on historical water use.

¹⁴ It is noted that water balances for the reduced vertical leakage scenarios (4a, 4b and 4c) were not calculated as the model was not recalibrated for each of these alternative scenarios (which were primarily targeted at exploring variations in drawdown in the shellbed aquifer in response to lower leakage).

the Kaimaumau wetland, this waterbody is typically classified as being perched, with recharge predominantly sourced from rainfall (Hicks et.al., 2001). As a consequence, it is reasonable to conclude the modelled effects will represent the upper bound of potential effects. Similarly, due to the acknowledged difficulty in appropriately representing the degree of confinement of deeper groundwater due to discontinuous iron pans it is not unreasonable to conclude the assessed impact on drain flows represents a conservative (upper) estimate of the actual magnitude of effect.

The AEE does not provide any assessment of the potential ecological significance of the calculated reduction in surface water discharge other than noting the calculated reduction in surface water discharge comprise a small proportion (<10%) of natural discharge.

4.3 Effects on existing groundwater users

The potential for well interference (drawdown) resulting from the proposed abstraction to adversely affect existing groundwater users is addressed in Section 3.2.2 of the AEE. This assessment utilised the various groundwater model predictive scenarios to calculate the maximum drawdown likely to occur in response to abstraction in a total of 34 existing groundwater takes within the model domain.

Results of the well interference assessment outlined in Table 5 of the AEE indicate a maximum drawdown of less than 0.7 metres in all neighbouring wells screened in the Shellbed aquifer under Scenario 2 (i.e. proposed abstraction, high vertical leakage), increasing to 2.1 metres under the low vertical leakage scenario (Scenario 4c).

The assessment concludes that, due to the large drawdown available (typically of the order of 100 metres in bores adequately constructed to utilise the full available saturated thickness in the Shellbed aquifer) in properly constructed bores, well interference effects resulting from the proposed abstraction will be no more than minor. The assessment also indicates that in areas where vertical leakage is reduced (i.e. where low permeability layers may be more prevalent), well interference effects remain minor (<5%) in the context of available drawdown in the Shellbed aquifer.

Results of the well interference assessment are consistent with the conceptual hydrogeological model of the aquifer system. While the Shellbed aquifer exhibits moderate permeability and has a limited saturated thickness, vertical leakage from the overlying sand aquifer provides a large storage volume which acts to offset drawdown. Even under the lower leakage scenarios (4a, 4b and 4c), drawdown in the shellbed aquifer is limited due to the leakage contribution. This observation is consistent with available aquifer test data (summarised in Appendix A and Appendix D of the modelling report). While bores screened in the sand aquifer have less available drawdown, the magnitude of drawdown occurring in response to the proposed abstraction is also significantly reduced compared to that occurring in the Shellbed aquifer.

Overall, based on both physical observations (aquifer test results) and modelled pumping scenarios it is reasonable to conclude the proposed abstraction is unlikely to result in more than minor well interference effects on existing groundwater users, provided bores are constructed in a manner consistent with Policy 10.5 of the Water and Soil Regional Plan.

4.4 Effects on Saltwater Intrusion

Along the coastal margin, fresh groundwater flowing from inland areas meets with saline water from the sea resulting in a natural transition from fresh to brackish to saline with distance offshore. Under natural conditions, the hydraulic gradient from inland recharge results in seepage of fresh groundwater out into the sea at, and off-shore of, the coastal margin. In shallow unconfined aquifers the fresh groundwater at the water table and sea water form an interface close to the coastal margin. However, at greater depths, the location and geometry of the interface between the fresh groundwater and the sea water is largely determined by the hydraulic gradients in the aquifer and the density difference between fresh and saline water (with groundwater typically becoming more brackish with depth).

Saline intrusion (i.e. displacement of freshwater by brackish/saline water) can result from two different processes as a result of groundwater abstraction. Firstly, a reduction in the head of freshwater in an aquifer can allow saline water at depth to move upwards in an aquifer (a process termed *upconing*). A reduction in groundwater head can also allow the saline interface at depth to migrate further inland (referred to as *lateral migration*).

4.4.1 Unconing

The AEE provides an assessment of potential upconing resulting from the proposed abstraction based on the Ghyben-Herzberg relation. 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. The assessment of potential upconing calculated the depth of freshwater along a number of section lines across and along the Aupouri Peninsula, based on modelled groundwater levels calculated from the various pumping scenarios. Results of this assessment show that sufficient head will be maintained in the aquifer to maintain the depth to the saline interface in excess of 100 metres below the base of the shellbed aquifer across the entire model domain.

Given the geology of the basement rocks underlying the Quaternary sediments comprises low permeability sediments and volcanics (assumed to be a no flow boundary in the groundwater model) it is uncertain if upconing is a plausible scenario for saltwater intrusion on the Aupouri Peninsula. However, if the basement sediments were to sufficiently permeable and contain saline or brackish water, the analysis confirms that there is limited potential for depressurisation occurring in the shellbed and overlying sand aquifers to result in adverse effects on water quality within the overlying Quaternary sediments via this mechanism.

4.4.2 Lateral migration

Further information provided by the applicant addresses the potential for the inland movement of the saline interface within the shellbed aquifer (i.e. along contact between the Quaternary sediments and underlying basement rocks).

The Lincoln Agritech (2015) report identified lateral migration of the saline interface as the primary constraint on sustainable groundwater allocation on the Aupouri Peninsula. The report recommended

provisional allocation limits for various groundwater management sub-zones 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). It is noted the recommended allocation limits have been incorporated into Policy D.4.17 of the Proposed Regional Plan notified in early September 2017.

Table 3, provides a comparison of current and proposed allocation against the sub-zone allocation limits recommended by Lincoln Agritech (2015). These figures indicate that, if granted, the current applications would increase allocation in the Motutangi and Waiparera sub-zones to 122 and 81 percent of the recommended limits respectively. Allocation in the Hohoura sub-zone would increase to 58 percent of the recommended allocation limit.

Table 3. Cumulative allocation (existing and proposed) compared to allocation limits recommended by Lincoln Agritech (2015)

Sub - Zone	Current Allocation (m ³ /year) ^a	Proposed Allocation (m ³ /year)	Cumulative Allocation (m ³ /year)	Recommended allocation limit (m ³ /year)	% of recommended allocation
Hohoura	1,124,844	126,650	1,251,494	2,141,300	58.4
Motutangi	389,692	914,400	1,304,092	1,069,600	121.9
Waiparera	327,949	1,405,300	1,733,249	2,312,200	81.1

^a Susie Osbaldiston *pers comm.*, 18 September 2017

It is noted that the Lincoln Environmental (2015) states that:

“It is important to recognise that we can only have confidence in the model’s predictions in areas where data is available to constrain the calibration. For five of the groundwater zones [including the Motutangi and Waiparera zones] we consider the model to be poorly constrained due to a lack of available data, and we do not recommend that the model be used for predictive purposes within these zones”.

It is therefore reasonable to conclude there is some uncertainty regarding the allocation limits proposed for some of the areas in which the proposed abstractions are located. With regard to the Motutangi sub-zone, the Lincoln Environmental (2015) report further observes that:

Groundwater levels also remain above the thresholds calculated by the Ghyben-Herzberg approximation with the exception of Motutangi. This area has a low hydraulic gradient, and the projected deep aquifer base in this area gives a high sea water intrusion threshold level using the Ghyben-Herzberg approximation. As a result, groundwater levels at the recommended Motutangi monitoring site do not meet the threshold groundwater water levels during model calibration. We interpret this to be an artefact of the model since there is insufficient information to constrain the aquifer structure and hydraulic properties, or to characterise groundwater levels in this area. While the low predicted water levels are not a cause for immediate concern, the relatively flat hydraulic gradient and deep aquifer base do indicate that the Motutangi area is an area of potential risk for seawater

intrusion. It is recommended that further investigations be carried out prior to further allocation in the Motutangi sub-region.

As described in Section 2 of the modelling report, the numerical model constructed by WWA goes some way to addressing uncertainties identified by Lincoln Environmental (2015) by incorporating the results of additional hydrogeological investigations as well as a re-analysis of the geological and hydrogeological setting. The potential for lateral migration of the saline interface in response to the proposed abstraction was re-analysed using the Ghyben-Herzberg relation to estimate the minimum hydraulic head required (referred to in the AEE as the 'required head') to maintain the saline interface below the shellbed aquifer, based on the estimated depth to basement rock at a total of 85 points distributed evenly around the coastal margin of the model domain. For example, based on the Ghyden-Herzberg relation, if the interpolated layer geometry in the model indicated basement occurs at a depth of 80 m bgl at a particular point along the coastline, a required head of 2 metres was calculated for that location.

The various pumping scenarios were run (i.e. Scenario 2, 3a, 3b, 3c, 4a, 4b and 4c) and a timeseries of calculated heads extracted for each of the 85 nominated coastal locations. The modelled heads were then compared to the required head at each location, based on a 90 day moving average. Provided the minimum 90 day moving average head from the 60 year simulation remained above the required head, the potential for saline intrusion was assessed as no more than minor.

Figure 1 below shows a plot of the calculated residual head (i.e. the difference between the minimum 90 day average modelled head and the estimated required head) for Scenario 2. As illustrated, model results indicate that groundwater levels remain above the required head at all coastal locations indicating the saline interface will be maintained offshore around the entire model domain under the proposed abstraction throughout the 1956 to 2017 simulation period.

Base on the assessment of coastal drawdown calculated for the Scenario 2, the AEE concludes that the potential for saline intrusion to result from the proposed abstraction is no more than minor.

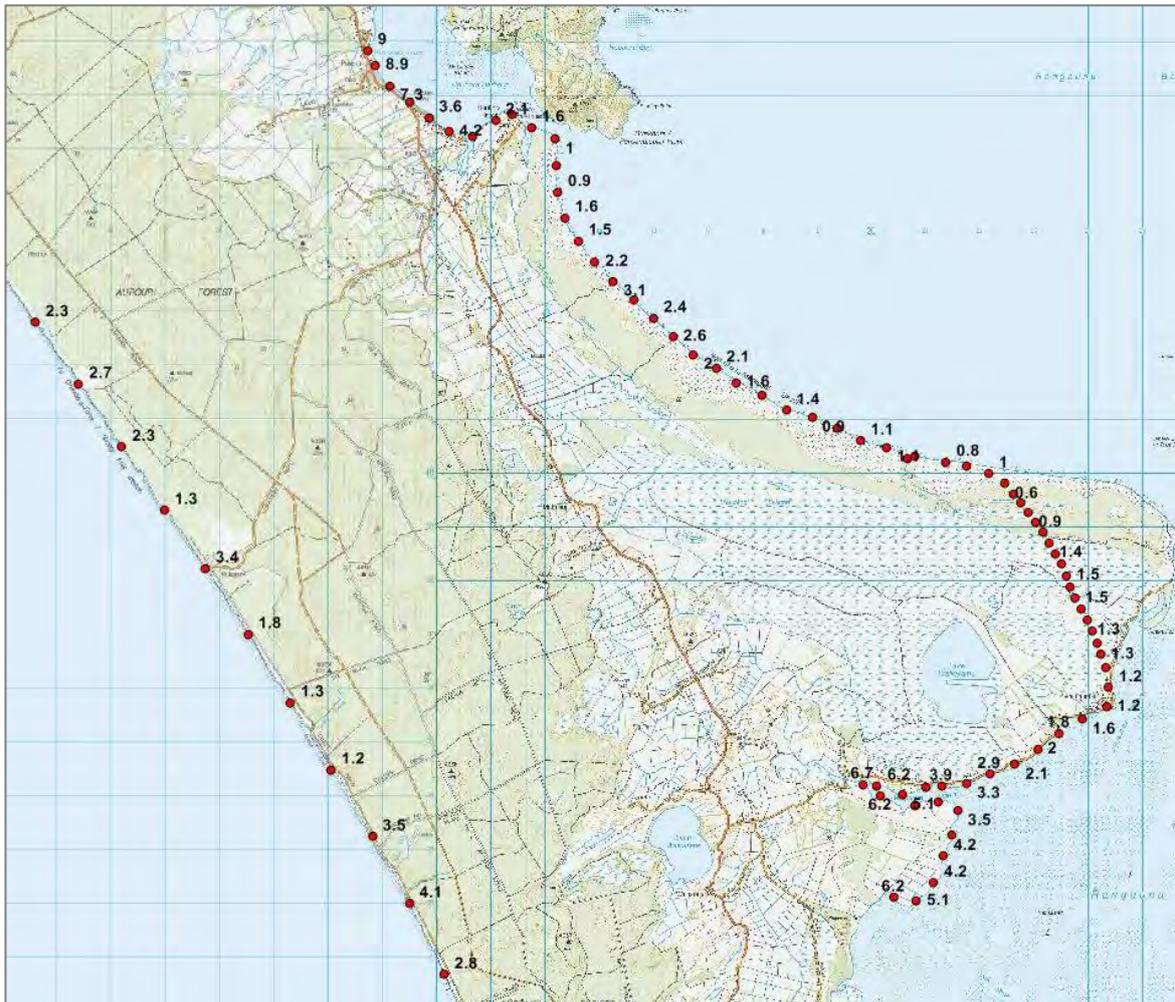


Figure 2. Residual head (i.e. difference between minimum 90 day average modelled head and the estimated required head) calculated for Scenario 2

In response to Councils request for further information, Scenarios 4a, 4b and 4c (which assume lower vertical leakage) were evaluated over the 60 year simulation period. Results of these scenarios exhibit progressively lower residual head around the coastal margin (due to increased drawdown simulated in the shellbed aquifer). Under Scenarios 4a and 4b modelled heads are maintained above the required head at all points around the model domain. Under Scenario 4c (which assumes vertical hydraulic conductivity is reduced by three orders of magnitude), the minimum calculated head falls below the required head along the middle section of East Beach¹⁵.

¹⁵ Spatial variability in the sensitivity to saline intrusion is also illustrated on Figures 43 and 44 of the modelling report which show modelled heads are closest to minimum required head (i.e. the potential for saline intrusion is highest) immediately south of Houhora Heads (due to the concentration of abstraction in this area) and

While aquifer test data indicate spatial variability in aquifer leakage, due to the overall heterogeneity of the geological environment, it is likely that the lower leakage conditions simulated by Scenarios 4a, 4b and 4c are more reflective of local-scale geological variability rather aquifer response at a sub-regional to regional scale. However, results of these scenarios illustrate the sensitivity of coastal drawdown to assumed aquifer leakage and provide a useful conservative (upper) estimate of potential drawdown occurring around the coastal margin (and hence the potential for saline intrusion), which indicates localised risk only for the lowest assume aquifer leakage.

It is noted that the assessment of saline intrusion risk associated with lateral migration of the saline interface outlined in the AEE utilises a 90-day moving average to represent groundwater levels over the medium-term rather than the minimum groundwater level calculated for individual model time steps. This approach is justified on the basis that saline intrusion is a slow process and any management triggers need to be cognisant of the timescale over which effects are likely to occur. As illustrated on Figures 45 and 46 of the modelling report, use of the 90-day moving average smoothes the calculated seasonal variation (which reflects temporal variation in aquifer recharge and abstraction) and reduces the overall magnitude of drawdown by less than 0.1 metre. Given the relatively modest rate at which saline intrusion effects are likely to develop and the limited sensitivity to small changes in groundwater level¹⁶, I consider the 90-day moving average statistic provides an appropriate measure to evaluate regional-scale saline intrusion risk.

Overall, I consider the AEE provides a suitable assessment of the potential for saline intrusion to result from the proposed abstraction which can be used to justify allocation in the Motutangi sub-zone in excess of the volume recommended by Lincoln Environmental (2015). Results of the assessment indicate there is limited potential for saline intrusion to occur as a result of the proposed abstraction (and therefore effects will be less than minor).

However, due to the overall heterogeneity of the geological environment and the limited data available to characterise the hydrogeological environment, there is inevitably uncertainty associated with any regional-scale assessment of saline intrusion risk. As further discussed in Section 5 below, the applicant proposes to address this uncertainty through development of a monitoring and response framework for managing saline intrusion risk. I consider this an appropriate means to address uncertainties in the modelling undertaken, and ensure the proposed abstraction does not result in adverse effects on water quality.

It is also noted that areas where the risk of saline intrusion is estimated to be greatest (i.e. the coastal margin east of Kaimaumau Wetland) also correspond to areas where there is little, if any, existing development of the groundwater resource. As a result, localised saline intrusion along the coastal margin in this area presents a low risk to existing groundwater users. Council may therefore wish to

approximately half way along East Beach between Houhora Heads and Otiaia Point (due to the flat hydraulic gradient in this area).

¹⁶ Particularly given the relative magnitude and timing of natural tidal variations in both groundwater and the marine environment which vary on both a diurnal and monthly basis

consider if future groundwater development in this area is a relevant consideration for overall assessment of saline intrusion risk¹⁷.

4.5 Effects on long-term aquifer storage

Section 3.2.3 of the AEE assesses the potential effect on the proposed abstraction on groundwater availability. This assessment identifies that the proposed cumulative volume of groundwater abstraction (current and proposed) represents less than 2 percent of total recharge to the groundwater system within the model domain and concludes that potential effects of the proposed abstraction on groundwater storage are likely to be no more than minor.

Policy 10.5.1 of the Water and Soil Regional Plan seeks to “..ensure the sustainable use of groundwater resources, by avoiding groundwater takes that exceed recharge...” and result in specified adverse effects on the environment. Based on the modelled water budget, it is reasonable to conclude that the proposed abstraction only represents a minor component of the overall aquifer water budget. This observation is also supported by modelling undertaken by Lincoln Environmental (2015) which assumed an annual recharge volume approximately 20% higher per unit area than the figure utilised in the WWA modelling¹⁸.

It is therefore reasonable to assume the proposed abstraction is unlikely to result in any long-term adverse effects on aquifer storage.

4.6 Effects on Land Subsidence

In sedimentary aquifers, aquifer compaction may occur as a result of dewatering and compression of fine-grained sediments (typically fine sands, silts and clays). As these fine-grained materials are dewatered, the resulting reduction in fluid pressure increases the effective stress associated with the weight of the overlying geological materials. This process can result in a rearrangement of grains within the geological media to balance the increased effective stress which can alter the hydrodynamics of the aquifer materials due to a reduction in porosity and/or permeability, and can also result in subsidence of the land surface as underlying sediments undergo compaction.

With regard to potential land subsidence, the AEE refers to a geotechnical modelling assessment undertaken using a finite element model for a previous resource consent application (King Avocado Orchard). This study concluded that subsidence effects resulting from groundwater abstraction would be no more than minor, with a total subsidence of 50 mm assessed as unlikely to adversely impact on

¹⁷ Particularly given the saline interface may naturally occur close to, or inland of the coastal margin toward Otiaia Point, where the hydraulic gradient is flat and the land is essentially surrounded by seawater.

¹⁸ It is further noted that the proposed allocation (equivalent to no more than 2 percent of estimated annual recharge) is consistent with Policy D.4.17 of the Proposed Regional Plan which established a default allocation limit not exceeding 10 percent of annual recharge for coastal aquifers.

built structures in the rural environment. Given the similarity of the geology setting and magnitude of groundwater level drawdown predicted, the AEE concludes that the potential for land subsidence to result from the proposed abstraction is less than minor.

Based on the assessment provided, I consider it reasonable to conclude subsidence effects associated with the proposed abstraction are likely to be no more than minor.

4.7 Effects on Groundwater Quality

Section 3.6.2 of the AEE provides a brief assessment of potential effects of the proposed water use on shallow groundwater quality. The assessment notes that avocado orchardists tend to apply fertiliser via fertigation due to the nature of the dominant soil conditions (high permeability, low water holding capacity and limited organic matter). This enables targeted application of fertiliser at rates similar to that at which nutrients can be taken up by the plants. Combined with efficient irrigation water use, this reduced the potential for nutrient losses from the root zone into shallow groundwater.

In addition, as described in Lincoln Environmental (2015), groundwater in the Aupouri Aquifer typically exhibit reducing (anoxic) geochemical conditions (illustrated by elevated concentrations of iron and manganese) due to the abundance of organic material (peat and lignite) within the sand deposits. Under these conditions it is reasonable to assume that any losses of nitrogen to the saturated zone will be assimilated by denitrification occurring in shallow groundwater.

Overall, due to the nature of water use and the geochemical conditions prevalent in the groundwater receiving environment, it is reasonable to conclude the proposed use of water for irrigation is unlikely to result in more than minor effects on groundwater quality.

5. Proposed Monitoring Conditions

Section 4 of the AEE acknowledges that, due to the nature of the geological/hydrogeological setting of the Aupouri aquifer system, there will always remain an element of uncertainty regarding the potential for adverse environmental effects to result from the proposed abstraction. The AEE proposes to address this uncertainty by the development of a Groundwater Monitoring and Contingency Plan (GMCP) which would outline specific requirements for environmental monitoring and establish a framework identifying and mitigating potential adverse effects on the environment. Rather than imposing monitoring through conditions on individual water permits (aside from water use and possibly groundwater level), the GMCP would be implemented through the establishment of monitoring at an aquifer scale.

The AEE identifies the potential for saline intrusion as the key environmental effect associated with the proposed abstraction. As described in Section 4.2.2 above, the most likely mechanism for saline intrusion to occur on the Aupouri Peninsula is via the landward migration of the saline interface due to depressurisation in response to groundwater abstraction. Given the inland location of a majority of the proposed abstraction, such effects take some time to reach individual production bores, by which time groundwater quality across a significant portion of the aquifer may be adversely affected. As a result, monitoring of individual production bores is unlikely to provide an effective means of identifying and, if required, mitigating effects associated with saline intrusion.

The proposed GMCP would require monitoring of groundwater levels and quality¹⁹ in specified monitoring (sentinel) bores located at key locations along the coastline. Nominated trigger levels for groundwater level and electrical conductivity would be established at each monitoring location. Any exceedance of the trigger levels would initiate a sequence of actions which, depending on the potential duration and significance of the trigger level exceedance, could range from increased monitoring to a reduction in the cumulative rate and volume of groundwater abstraction. The overall premise of the GMCP is that the proposed groundwater abstraction would be subject to maintenance of aquifer storage (i.e. groundwater levels) and groundwater quality above nominated thresholds that ensure there are no long-term adverse effects on the groundwater resource.

Overall, although specific details of would require agreement between the NRC and applicant(s), I consider development of the proposed GMCP has the potential to provide a pragmatic framework for monitoring and managing effects on the environment resulting from the proposed abstraction in a manner that:

- Recognises the potential for effects to occur at a regional (aquifer) scale, rather than on a localised basis, by establishing monitoring at the most sensitive location (i.e. along the coastal margin);
- Provides more effective and timely monitoring of potential saline intrusion than would be achieved by placing specific monitoring conditions on individual water permits located some distance inland from the coast;
- Effectively establishes a minimum threshold for groundwater quality and levels to ensure groundwater abstraction is sustainable on a long-term basis;
- Provides certainty regarding procedures that would be implemented (including mitigation through a reduction in the cumulative rate and volume of pumping) should monitoring indicate that abstraction was resulting in adverse effects on aquifer storage or groundwater quality.

6. Summary

The application by Motutangi-Waiharara Water User Group seeks authorisation for a total of 17 water permits for groundwater abstraction on the Aupouri Peninsula, up to a cumulative volume of 16,775 m³/day and 2,446,350 m³/year. The proposed abstraction will be sourced from a semi-confined aquifer system hosted in shellbed layers located at the base of a sequence of unconsolidated sedimentary materials (primarily comprising fine-grained sands, interspersed with sporadic iron pan, peat, lignite, silt, gravel) which overlie low permeability basement rocks.

The modelling report and AEE prepared by WAA provide a description of hydrogeological investigations and analysis undertaken to support the applications, as well as an assessment of potential effects on the environment. The majority of the assessment is undertaken using a numerical groundwater model described in the modelling report. This model provides a useful tool to

¹⁹ Electrical conductivity (EC) is proposed as an indicator of any water quality changes associated with ingress of saline water into the aquifer

characterise how the groundwater system is likely to respond to the proposed abstraction. However, the calibrated model does have some acknowledged limitations due to the challenge of representing the influence of the heterogeneous geological environment on aquifer hydrogeology at a local scale. The potential influence of this heterogeneity is accounted for in model scenarios which assume varying levels of confinement of the primary water-bearing layers (i.e. the shellbed aquifer).

Lincoln Environmental (2015) identified the potential for saline intrusion along the coastal margin as the primary constraint on aquifer sustainability in the Aupouri aquifer system, and recommended allocation limits for various aquifer sub-zones which have subsequently been incorporated into the pRPN. In combination with existing allocation, the proposed allocation would exceed the proposed allocation limit for the Motutangi sub-zone.

Information and analysis provided by the applicant builds on analysis undertaken by Lincoln Environmental (2015), and includes analysis of additional data and re-interpretation of key aspects of the hydrogeological setting. Based on this information, the AEE provides an assessment of the potential for saline intrusion which indicates the potential for saline intrusion to result from the proposed abstraction is low. Other potential effects including effects on existing groundwater users and hydraulically connected water resources are assessed as no more than minor. The applicant also proposes to address any residual uncertainties regarding the potential effects on the environment through development of a Groundwater Monitoring and Contingency Plan (GMCP) which would outline specific requirements for environmental monitoring and establish a framework identifying and mitigating potential adverse effects on the environment.

Overall, I consider the AEE provides an appropriate assessment of the potential for saline intrusion to result from the proposed abstraction which supports allocation in the Motutangi sub-zone in excess of the volume recommended by Lincoln Environmental (2015). However, due to the complex nature of the hydrogeological setting, I also consider that development and implementation of an appropriate monitoring and response framework (such as the proposed GMCP) is required to provide confidence that the proposed abstraction will not result in adverse effects on the environment.

The proposed rates and volume of abstraction for water permits comprising the collective MWWUG application exhibit a degree of variability between individual sites. The Council may therefore wish to consider appropriate seasonal volumes for horticultural irrigation on the Aupouri Peninsula, possibly with regard to historical water use for similar enterprises. It is noted that any reduction in the cumulative rate and volume of abstraction will provide increased confidence that the analysis provided in the AEE provides a suitable conservative assessment of potential effects on the environment.

Yours Sincerely



Brydon Hughes
Hydrogeologist