Aupouri Aquifer Sustainable Yield Groundwater Modelling Study January 2000

For:
Northland Regional Council

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Executive Summary

At the request of Northland Regional Council (NRC), HydroGeo Solutions was commissioned to undertake a numerical modelling assessment of the hydrogeological conditions and sustainable yield of the Aupouri aquifer. The study was initiated as a result of noticeable groundwater depressurisations in NRC monitoring bores over the last decade, and concerns raised regarding the long-term sustainability of current groundwater allocations. The principle focus of the study was on two areas of high intensity horticulture at Houhora and Paparore-Sweetwaters, which have a heavy demand on groundwater resources during the summer growing season of November to April.

The Aupouri aquifer system is located north of Kaitaia within the relatively narrow stretch of land known as the Aupouri Peninsula, between Awanui and Ngataki. The sedimentary sequence of the aquifer consists of predominately clean fine aeolian sands in the west of the peninsula overlying older more consolidated silty sands. In the east the older sands are exposed at the surface and the occurrence of iron pans, and lenses of silt, clay and peat are more common. Underlying the sands is a high permeability coarse-grained shellbed that overlays basement rocks. The shellbed is up to 20 m thick in places and provides the highest groundwater yields.

The United State Geological Survey's finite-difference groundwater model MODFLOW was requested for the study. A dual-layer regional model consisting of 7,192 active cells and encompassing an area of approximately 430 square kilometres was developed. Conceptualisation of the model involved collation and review of previous reports and data provided by NRC. Data inadequacies encountered in some areas were resolved by making estimations based on sound hydrogeological principles. This necessitated simplification of the model over the regional scale.

The aquifer geometry utilised in the model was generated from lithological information from 38 bores that penetrate the shellbed. Sparse bore information in some locations meant that a high degree of interpolation was required.

The hydraulic property distribution in the model consisted of four zones in the upper model layer representing the progradation from west to east of clean to more silty sands, and a continuous distribution in the bottom layer representing the shellbed. The five hydraulic property zones in the model are summarised as follows:

- ***Zone 1 Dune Area*** – western peninsular and beachfront, relatively clean sands.
- ***Zone 2 Dune Area*** – eastern areas, older sands with higher proportion of silts.
- ***Zone 3 Plain Area*** – low lying areas in east, high proportion of surficial silts, clays and peat.
- ***Zone 4 Lake Area*** – wetlands and numerous clay sills (lakebeds).

- ***Zone 5 Shell bed*** – highly permeable shell deposits.

Vertical anisotropy is introduced into the hydraulic zones in the upper layer to attenuate groundwater percolation rates or leakage between layers, as indicated by bore hydrographic responses. The degree of anisotropy is more significant in eastern areas where a higher proportion of silt and clay occurs.

Three distinct groundwater recharge zones were identified based on borehole hydrographic responses, vegetation cover type, surface geology and topographic data. The characteristics of each zone are summarised below:

- ***Dune Zone*** - Surrounds the forest zone on the western and eastern side. Typically displays an assortment of vegetation types consisting of pasture, bush and orchards of low to medium height and density (moderate interception losses), smaller active root zone than forest (moderate interception and evapotranspiration (ET)), and high infiltration capacity (low surface runoff). The long term average water balance as a proportion of rainfall is; recharge 18.1%, ET 81.7%, runoff 0.2%.

- ***Forested Dune Zone*** – Corresponds to the Aupouri Forest and is located adjacent to Ninety Mile Beach on the western side of the Peninsula. Typically displays a high density of tall vegetation cover (high interception losses), has high soil moisture storage and infiltration capacity (low surface runoff), and a deep active root zone (high ET). Recharge 10.4%, ET 89.5%, runoff 0.1%.

- ***Plains Zone*** - Represents the low lying areas to the east which typically display low density vegetation (mostly pasture), higher proportions of silt, clay and peat within the surficial sediments to depths of up to approximately 20 mBGL (significant surface runoff), and numerous drainage features (draining of soil moisture). Recharge 12.0%, ET 64.2%, runoff 23.8%.

The model was calibrated to transient conditions from January 1987 to September 1999. Monthly groundwater observations from nine NRC monitoring bores were used for head matching purposes during the calibration. Aupouri forest rainfall for the corresponding period was utilised by a soil moisture water balance model (SMWBM) to generate a preconditioned groundwater recharge history for the groundwater model. The SMWBM calculates soil moisture, groundwater percolation and other water balance components on a daily basis using daily rainfall and mean-monthly pan evaporation data. It provides a more sophisticated method of calculating groundwater recharge because it accounts for antecedent soils moisture conditions and variable soil evaporation rates that depend on soil moisture status and time of year.

The calibrated model provides an acceptable approximation to measured field conditions over the simulation period. A sensitivity analysis of the model calibration was conducted to quantify uncertainty caused by limitations in model parameters. Root mean square (RMS) error was calculated for each observation bore at approximately twelve-month intervals. The average RMS error range during the calibration simulation was from 0.3 to 1.0 m, which equates to an error of approximately 3% to 10% of the average difference in groundwater elevation across

the aquifer. Analyses where model parameters were varied by plus and minus 30% reveal that the model is most sensitive to recharge and hydraulic conductivity and least sensitive to storage parameters.

Predictive simulations of the model were conducted to assess the performance of the aquifer under incrementally increasing groundwater abstraction rates in the two high abstraction areas, and hence the sustainable yields. Simulation involved 105 year runs utilising precondition groundwater recharge calculated from the longterm Kaitaia rainfall record from 1894 to 1967 and the Aupouri forest rainfall from 1967 to 1999. Five predictive model scenarios were simulated consisting of:

- Zero groundwater abstractions;
- 50% of currently allocated allowable abstraction;
- 100% of currently allocated allowable abstraction;
- 250% of currently allocated allowable abstraction; and
- 500% of currently allocated allowable abstraction.

Results from the predictive simulations indicate negligible difference in the response of the aquifer after 105 years between the zero abstraction and 100% abstraction scenarios. This would indicate that the aquifer is currently not over allocated. Results for the 500% abstraction scenario indicates localised depressurisation in the area of the pumping bores, but little difference elsewhere in the aquifer.

Groundwater throughflow rates were calculated by the model for each scenario along four kilometres of the west and east coasts, adjacent to the Hukatere-Houhora transect and the Paparore area, respectively. Throughflow rates at the Houhora transect vary during dry and wet periods from approximately 1,500 to 4,000 m^3/day/km on the west coast and between 1,000 to 3,000 m^3/day/km on the east coast, for the zero abstraction scenario. These rates were reduced with the 500% abstraction scenario by approximately 6–15% and 12–35% for the west and east coasts, respectively.

Throughflow rates for the Paparore area were estimated to vary from approximately 1,000 to 3,000 m^3/day/km at the west coast, compared with 300 to 700 m^3/day/km on the east coast. With the 500% abstraction scenario, these rates are reduced by approximately 7–20% and 21–50% for the west and east coasts, respectively.

This modelling study has provided council with a preliminary model that has increased the level of understanding of the aquifer flow system and will assist in formulation of future management policies and decision making. The model is limited in a number of areas as identified in the report, and will require refinement or redefinition when additional data becomes available if more detailed assessments are needed in the future.

1. Introduction

The Aupouri aquifer system is located north of Kaitaia within the relatively narrow stretch of land known as the Aupouri Peninsula, between Awanui and Ngataki (Figure 1). The aquifer coves an area of approximately 430 square kilometres and is bounded in the west by Ninety Mile Beach and in the east by Rangaunu Bay, and Rangaunu and Houhora Harbours.

Groundwater is the main source of horticultural irrigation and farm water on the Aupouri Peninsula. Since the 1980's development and landuse changes such as subdivision of farmland for orchards and market gardening, planting of exotic forest plantations and development of tourist resorts have resulted in increased demand on the groundwater resource.

Noticeable groundwater depressurisations in monitoring boreholes over the last decade along with concerns raised regarding the long-term sustainability of current groundwater allocations prompted Northland Regional Council (NRC) to seek tenders for a study to improve their understanding of the aquifer system. Two areas of high intensity horticulture at Houhora and Paparore-Sweetwaters, which have a heavy demand on groundwater during the summer growing season of November to April, were of particular concern.

In November 1999, HydroGeo Solutions was commissioned by NRC to conduct a study of the Aupouri aquifer. The objectives and broad methodology of the study were as follows:

- Review available hydrogeological and climate data.
- Conceptualise and develop a computer-based numerical groundwater flow model using the United States Geological Survey's MODFLOW code through the Visual MODFLOW interface.
- Provide an assessment of long-term average sustainable yields from the aquifer, and in particular from the two areas of intensive groundwater abstraction.

The developed model will provide a tool for increasing the level of understanding of the aquifer flow system, identify areas where additional data is required, allow preliminary assessments of the effects of increasing groundwater abstraction rates and aid in formulation of management policies and decision making. Future refinement of the model when additional data becomes available will enhance the accuracy of model predictions.

This report addresses the agreed scope of works, provides summary findings and identifies areas where additional research is required. The work has been undertaken in accordance with HydroGeo Solution's proposal dated 28th September 1999 and NRC's short form agreement for consultant engagement signed 9th November 1999.

This report has been prepared for the benefit of Northland Regional Council with respect to the particular brief given to HydroGeo Solutions and may not be relied upon in other contexts or for any other purposes without our prior review and approval.

2. Background Information

Baseline data for the study has been obtained from various sources. Where appropriate the data has been collated in digital form and installed in the appropriate spreadsheet or database. All relevant spatial data have been incorporated into the appropriate AutoCAD and SURFER grid files. Details of the available data are provided below.

Hydrogeology: NRC prepared a water resource assessment of the Aupouri Peninsula in 1991 (NRC, 1991). This report provides a comprehensive review of previous hydrogeological investigations and compiles all relevant supporting information available at the time of publication, including:

- Descriptions of the study area's physical features including topography, surface drainage, geology, soil types, vegetation, landuse and climate.
- Summaries of test pumping results and groundwater abstraction allocations.

The reader is referred to this report for a more detailed description of the study area.

In addition, NRC provided all relevant updated data from their respective databases including groundwater and lake monitoring data, drilled borehole and lithological log data, groundwater consent data, and test pump records.

Topographic & Regional Cadastral Data: The topography of the Aupouri Peninsula area has been mapped by the Department of Land and Survey and covers three NZMS 260 series 1:50,000 scale map sheets entitled Kaitaia O04, Ahipara N04 and Houhora N03. NRC supplied this data and additional cadastral information in digital format from their ArcView GIS database.

Rainfall and Pan Evaporation: Historical daily rainfall records of varying length have been supplied for four sites within the study area, which were subsequently processed and validated for completeness. A summary of this information is provided in Table 1.

Table 1. Summary of available daily rainfall records.

Station Name	Station ID	Approx. Easting	Approx. Northing	Start Date	End Date	Length (years)	Days Missing	Complete (%)
Kaitaia*	A53121	2534400	6676600	01/10/1893	30/09/1999	106	1595	95.88
Waiharara	A43921	2528700	6694800	01/06/1956	08/05/1994	37.9	244	98.24
Aupouri Forest*	NRC 530204	2528800	6687800	10/03/1967	31/08/1999	32.5	1020	91.40
Kaitaia – Weissing*	NRC 530205	2534500	6676500	02/12/1992	31/08/1990	6.9	1	99.96

* Still in operation.

Raised daily pan evaporation data has been obtained for the Kaitaia Observatory for the period 26 April 1985 to 28 October 1999.