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Review of 3D model development with application to groundwater studies in New Zealand 1996 - 2011.

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Aims

Three dimensional geological modelling techniques have been applied since 1996 with an aim to characterise the lithological and chronological units of New Zealand's many diverse aquifers. Models of property-scattered data have also been applied to assess physical properties of aquifers and the distribution of groundwater chemistry, including groundwater age, to inform an understanding of groundwater systems. These models, fundamental to understanding groundwater recharge, flow and discharge have found many uses as outlined in this paper

Methods

The procedure used to generate 3D models begins with review of published and unpublished information and data validation including assessment of well log quality. Then, assignment of lithological property codes, and creation of pseudo-logs, identifies lithological descriptions that are frequent in well logs throughout the dataset and characteristic of the general geological environment. Pseudo-logs, and key geological markers, are then used to generate 3D lithological property models making it possible to search for correlations between wells. Boundary surfaces for major geological units are then defined as a series of units (layers) and faulted blocks (if relevant) that are assembled with respect to their chronology and structural relationships. Three-dimensional property models are assembled from observations of groundwater chemistry, temperature and age by gridding observations within individual units, fault blocks, or regions.

Data and information relevant to model development include: digital terrain data, geological maps, geophysical surveys, reports, publications, well logs held by regional councils, groundwater chemistry and groundwater age data.

Results

Approximately 15 models have been developed throughout New Zealand for multiple applications, often as part of as sub-regional groundwater studies.

Groundwater allocation is a common application. These studies link 3D geological models with groundwater budgets, including groundwater use, to assess groundwater available for allocation. This approach has been used for three studies in the Bay of Plenty region (Western Bay of Bay of Plenty, Paengaroa-Matata and Rangitaiki Plains), Hauraki Plains and Horowhenua. For example the distribution of important ignimbrite aquifers is modelled in the Western Bay of Bay of Plenty. Groundwater flow in these aquifers is estimated as 6.5 m^3/s using a groundwater budget including: rainfall, rainfall recharge to groundwater and stream baseflow.

Land use and groundwater quality is another common application of these models. Geological models have been developed for this purpose in the Lake Rotorua catchment, Pukekohe, western Taupo and Upper Waikato. The model of geology in the Lake Rotorua catchment was used to assess groundwater flow paths between land use and the lake and to develop a groundwater flow model relevant for assessment of catchment water budgets and water quality. For example, approximately 24% of water, and 42% of the nitrate-nitrogen, entering the lake does so directly from the groundwater system and most water entering the lake travels through the groundwater system at some point in the flow path. This model has contributed to the identification of groundwater catchment boundaries which are crucial to the assessment of the effects of land use, nitrate-nitrogen inflows to Lake Rotorua and lake water quality.

Models have been developed to understand groundwater flows, combining geological models with hydrological and hydrogeological observations (Christchurch City and Waimea Plains). A geological model of Holocene sediments in the Christchurch City area identifies that gravel lobes, associated with deposition from the Waimakariri River, are interfingered with relatively impermeable marine and estuarine sediments deposited as sea level rose in the current interglacial period. Christchurch City streams are closely connected with these gravel lobes. For example, the Avon River is closely associated with the sub-surface Fendalton gravel lobe, deposited approximately 4000 years to 1600 years ago. This lobe is linked with the Harwood Floodway and the Waimakariri River, which provides most of the groundwater that flows from the Avon River.

Groundwater chemistry has been assessed with 3D models in Canterbury and Wairau Plain. Nitrate-nitrogen concentrations measured by Environment Canterbury, and 93 estimates of groundwater recharge year measured by the CFC techniques, were modelled in north Canterbury. Nitrate-nitrogen concentrations in older groundwaters are relatively low. Groundwaters with a recharge year later than 1980, and model nitrate-nitrogen concentration higher than 10 mg/L, occur west of Christchurch City and between the Rakaia and Ashburton rivers near the coast indicating the influence of land use on groundwater quality. Groundwaters with a recharge year later than 1980, and model nitrate-nitrogen concentration lower than 2.5 mg/L, are associated with recharge from surface water including the Ashley, Waimakariri, Selwyn and Rakaia rivers.

The integration of a 3D geological model, 3D models of nitrate distribution and multivariate statistical techniques identified the underlying physical and chemical processes that control the spatial distribution of groundwater chemistry patterns in the Wairau Plain, Marlborough. For example river recharge dominates groundwater inflow to the Rapaura Formation and land use is an important control on groundwater quality in the Speargrass Formation.

Currently, 3D models are used in the development of a web-based data access system under trial with Bay of Plenty Regional Council. This system could allow easy access to model information useful for groundwater managers, drillers, groundwater consent holders and the general public.

Conclusions

The period 1996 – 2011 has seen the application of 3D geological and property models to groundwater assessment in New Zealand. This paper demonstrates that these models have many uses including assessments of groundwater allocation, land use and groundwater quality, lake-water quality and groundwater chemistry. Expansion in the application of these models will continue in the future.