3D geological modelling: structural, facies, properties & conductivity

NATIONAL CENTRE FOR GROUNDWATER RESEARCH AND TRAINING

This resource describes 3D geological modelling for the development of conceptual site models. Having a geologically realistic conceptual site model is important for characterising hydraulic connectivity throughout aquifer systems, and modelling water transit times. It is designed for a technical audience.

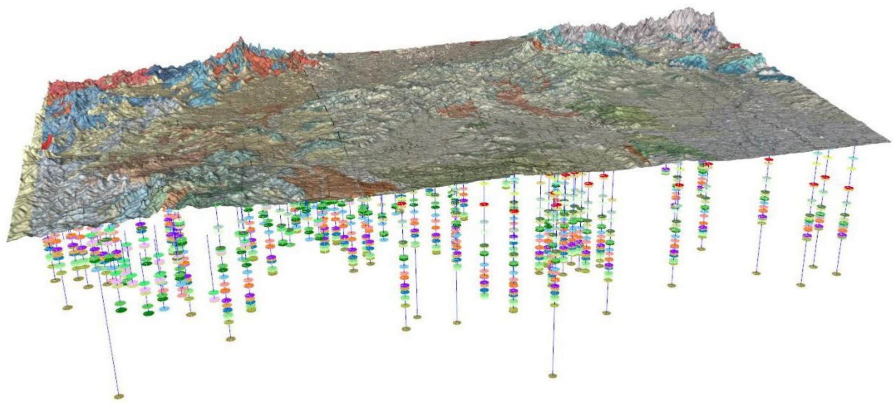
WHAT IS 3D GEOLOGICAL MODELLING?

Geological modelling uses integrated data sets to determine the geological framework that best represents the major geological features that should be incorporated into a representation of a region. These models can be built at any scale from global, country, catchment, mine site, to an urban block. To be reliable for use when making management decisions, groundwater flow models must accurately represent the distribution of hydraulic conductivity.

The scale of features incorporated into a model depends on the goals of the project. Data sets used to build 3D geological models include field mapping measurements of major structural features (fault and formation dip direction and azimuth), digital elevations models, aerial gravity and magnetic surveys, ground electrical and seismic surveys, borehole lithological logs, and borehole geophysical measurements.

Hydrogeologists use 3D geological modelling to:

- determine how many layers they need to incorporate into groundwater flow models
- estimate the facies between boreholes, and the distribution of porosity and hydraulic conductivity (permeability)
- map palaeo channels and belts (dominant pathways of connectivity)



- model fracture networks
- do kinematic reconstructions, to check that the geological model balances.

STRUCTURAL MODELLING

The first step in constructing a 3D geological model is to build the fault network and horizon top model.

Fault network and horizon tops

Modelling connectivity and flow through fractured rock is a difficult and critical problem to solve for many sectors. Underground mining has the potential to affect surface and groundwater supplies. Understanding flow through faults and joints is also important when tunnelling.

Throughout the world, fractured rock aquifers represent one of the largest potential supplies of groundwater. NCGRT researchers are extending the application of discrete fracture network and multiple point geostatistics to model 3D fracture networks.

Research is focused on developing methods to represent the 3D fractured rock framework for use in groundwater flow models.

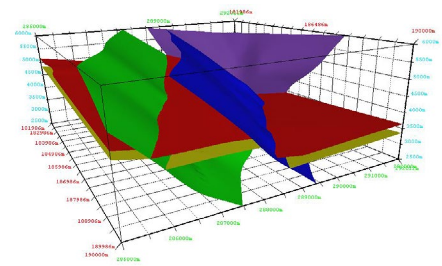


Figure 1: An example of a fault and horizon top model

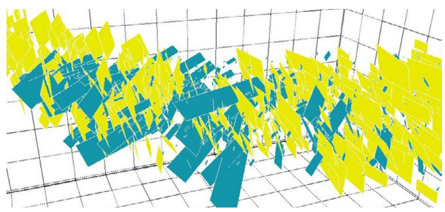


Figure 2: An example of a fracture network model

FACIES AND PROPERTY MODELLING

Predicting the distribution of geological facies in sedimentary environments from sparse well log data sets is one of the great challenges in hydrogeology.

Variogram-based kriging methods and transition probability algorithms have commonly been used to interpolate facies data. These methods are good at honouring the statistics, but often poor at replicating sedimentary bodies.

NCGRT researchers are developing and extending the application of multiple point geostatistics and stochastic process-based modelling. These two methods generate facies models that have realistic architecture. They better represent palaeochannels, sheet deposits and other depositional features. Once the distribution of the facies has been modelled it can be converted into porosity and hydraulic conductivity (permeability) models.

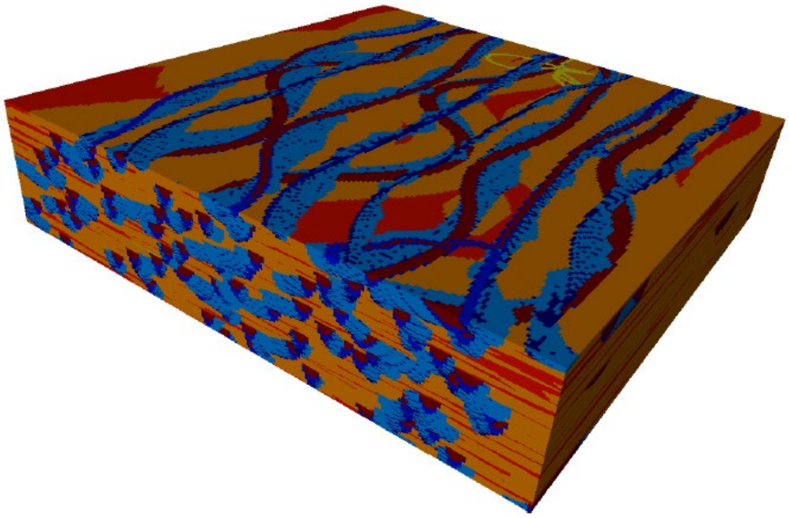
WHY IS CONCEPTUAL GEOLOGICAL MODELLING IMPORTANT?

Correctly representing aquifer architecture is important for modelling groundwater flow via preferential flow paths. Commonly, when groundwater models are calibrated the hydraulic conductivity is let float. The focus of model calibration is on matching the groundwater heads recorded in the monitoring boreholes.

In the post-auditing and validation of groundwater flow models it is rare to see cross checks against the geological reasonableness of the hydraulic conductivity distribution.

A well-calibrated groundwater model may not make geological sense. This applies not only to parameters like hydraulic conductivity, but also to the distribution of the permeable zones.

Having an accurate representation of the hydraulic conductivity distribution is particularly important for modelling pumping impacts where most groundwater flow is via the sands and gravels in palaeochannel belts. Accurately representing aquifer architecture is also needed when modelling residence times, or when modelling the migration of contaminated groundwater through heterogeneous sediments.



A stochastic process based model of a fluvial valley filling sequence, showing floodplain deposits (orange), mud fills (red), meandering channels (dark blue) and sand bar lateral accretions (light blue).

CASE STUDY

To validate the 3D geological modelling workflows and algorithms being developed within NCGRT we are testing them in the following geological settings.

Lower Namoi (NSW): This catchment consist of a 100 m thick valley-filling sequence that was deposited by high energy rivers at depth, through to low energy meandering rivers observable in modern landscapes. Groundwater has been extracted from this aquifer system to irrigate cotton and other crops since 1965. The facies models will assist with understanding flood recharge pathways and with evaluating the potential of managed aquifer recharge.

Maules Creek (NSW): Located at the foothills of the Nanderwar Range, this region has coal mining, dryland farming, and irrigation farming. Westerly following runoff from the mountain range deposited sediments orthogonally to the northerly flowing Namoi River that is located in the west of the region. Modelling these intersecting depositional systems will help us understand stream/aquifer interactions in the region.

Surat Basin / Condamine Alluvium (QLD): This region has seen the rapid expansion of the coal seam gas sector adjacent to irrigated farms. To model the future impacts of both sectors, we need better models of the alluvial sediments to manage the sustainable use of groundwater. We also need better facies models of the Walloon Coal Measures to model production and to quantify the impacts of coal seam gas developments.

CONTACT US
Call: 08 8201 2193
Fax: 08 8201 7906
Email: enquiries@groundwater.com.au
Web: www.groundwater.com.au
Mail: NCGRT, Flinders University, GPO Box 2100, Adelaide SA 5001

Australian Government
National Water Commission
Australian Research Council