



GROUNDWATER MODELLING

Assessment and management of groundwater

Groundwater professionals are frequently asked to predict groundwater behaviour. They may need to assess how much groundwater is present, by using *flow modelling*, or to predict the concentration of solutes contained within flowing groundwater, by using *contaminant transport modelling*. For the groundwater professionals at C. M. Jewell & Associates Pty Ltd (CMJA), groundwater modelling is a logical extension of hydrogeological and site contamination assessment.

Many of CMJA's investigations involve modelling – in a variety of formats, at various levels of resolution, and for a variety of objectives. Some models can be as simple as a one-dimensional analytical equation embedded in a spreadsheet program. Others can be highly complex, such as a multi-layered, time-variant numerical model intended to simulate subtle changes in groundwater movement within a complicated geological setting over a time scale of several decades.

At CMJA we have the experience and insight to make the critical choices in designing the model approach most appropriate to the application.

We use the latest analytical and numerical groundwater model codes and suites of integrated modelling software. The three main codes used are Visual MODFLOW, SEEP/W and SEEP 3D, described below.

Visual MODFLOW

Using the modular three-dimensional finite-difference flow model MODFLOW, together with the contaminant transport packages known as MODPATH and MT3D, we can extend modelling into complex contaminant transport simulations. The public domain model MODFLOW, universally recognised among scientists, is one of the most commonly used groundwater flow models. It utilises CAD and graphic-user-interface front-end software to accelerate and refine the modelling process. Much faster and more sophisticated than models of the past, it allows us to produce robust and accurate models in a matter of days.

SEEP/W

A two-dimensional, variably saturated, finite element code, which is particularly useful for sectional modelling of seepage through embankments and other geotechnical problems, but may also be used for 2-dimensional plan-form modelling with complex lateral boundaries.

SEEP 3D

An innovative, fully 3-dimensional (not layered) modelling code used to solve complex local (engineering scale) groundwater flow problems.

Other numerical groundwater modelling codes are used where appropriate, for individual projects. They include INTERSAT/INTERTRANS, FEMSEEP, TWODAN and PRINCE.

INTERSAT/INTERTRANS

Combined finite difference, groundwater flow/contaminant transport modelling software.

FEMSEEP

Finite-element flow and transport.

TWODAN

An analytical element code, TWODAN utilises sophisticated pre- and post-processing to underpin its highly flexible approach. Using TWODAN, effective two-dimensional groundwater flow models may be produced in a matter of hours.

PRINCE

A suite of analytical and semi-analytical compiled codes developed by Princeton University. Modern groundwater modelling software bears little resemblance to the cumbersome programs of the past. There has been a significant shift towards digital manipulation of environmental information, allowing computer-aided mapping and storage of virtually all baseline data.

CTRAN/W

A 2-dimensional finite-element transport model that is used in conjunction with SEEP/W.

MT3D / RT3D

3-dimensional mass transport and reactive transport modelling codes that are used in conjunction with MODFLOW.

HSSM

A one-dimensional code that is used to evaluate vertical migration of contamination through the vadose zone.

PREEQC

A complex geochemical speciation and one-dimensional transport code used for reactive transport and static evolution problems.

BIOSCEEN / BIOCLOR

Analytical codes used to assess natural attenuation or bioremediation of petroleum hydrocarbons and chlorinated solvents in groundwater.

BIOPLUME

A finite difference flow, transport and biodegradation modelling code.

To complement these models, we use the software packages described below.

Visual Groundwater

A three-dimensional sub-surface visualisation and imaging package used to depict surfaces such as geological formation boundaries or the envelopes of a contaminant plume. Geometric data can be shared with the integrated Visual MODFLOW package for modelling and visualisation of model results.

Mapinfo

A geographic information system for the storage and manipulation of large data sets.

Surfer

A computer-aided mapping and surface generation package that allows interpolation and contouring of distributed data and a variety of geo-statistical analyses.

CMJA has the necessary know-how and experience for the effective application of all these tools.

CMJA projects

The following CMJA projects have involved significant numerical modelling.

Eastern Distributor Motorway, Sydney, NSW

The motorway link from Woolloomooloo to Sydney Airport involved a tunnel through sandstone and a 'parkway' excavated below the water table in the Botany Sands aquifer. On behalf of the main contractor, Leighton, CMJA carried out a range of model studies, using analytical and numerical finite-element and finite-difference techniques. These were then used to assess regional and local impacts of construction dewatering and the permanent structure, and to optimise dewatering system design and the implementation of a re-injection system.

Woodend wastewater treatment facility, Central Victoria

When drawing up plans for another storage lagoon at this facility, Piper Associates asked us to assist with the design of the lagoon liner and under-drainage system. We were also asked to estimate leakage loss from the four existing storage lagoons, and to assess the impacts of the existing and proposed storage lagoons on local groundwater conditions.

A groundwater flow model, developed using Visual MODFLOW, was judged to be the only realistic and economically feasible means by which to simulate the spatially complex hydrogeological conditions at the site. Using this model, we could develop an understanding of the hydrogeological set-up, the role of different physical processes, and their influence on the groundwater system. This model was then used to simulate groundwater levels and lagoon leakages under various storage lagoon volumes. It also addressed the effects of variable under-drain spacings, and their ability to prevent leakage from reaching the water table.

CMJA also designed a two-dimensional cross-sectional finite-element model using the software SEEP/W, utilising parameters from the MODFLOW model. It confirmed the results obtained in the three-dimensional MODFLOW model, and also allowed seepage analysis of lagoon leakage and quantification of consequent water level mounding between the underlying drains.

Parkes water supply, NSW

The town of Parkes and the North Parkes Mine are supplied with groundwater by a borefield located in the Lachlan alluvial aquifer. This borefield was under stress, and experiencing a drawdown that greatly exceeded the predictions of the consultants who installed the boreholes. CMJA was engaged to review all data and prepare a numerical model of the borefield, to assess long-term sustained yield, and to help design a new pumping regime. A three-layer, transient groundwater flow model was developed, using Visual MODFLOW. Climate, irrigation abstraction, the town water supply abstraction, and the river water level fluctuation stresses were imposed in time-variant data sets in order to simulate the development of the decline in piezometric head as a result of over-abstraction at the Parkes Borefield.

Various model scenarios were developed, making it possible to assess the effect of a number of strategies intended to ameliorate the drawdown on the rest of the aquifer, and to achieve a more sustainable abstraction regime for Parkes Borefield.

Thredbo Landslide Inquiry, Snowy Mountains, south-eastern NSW

The NSW Police coronial inquiry into the Thredbo landslide disaster commissioned CMJA to investigate and provide expert testimony on the influence of groundwater seepage on factors contributing to the landslide. The geotechnical SEEP/W modelling code was used in verifying infiltration trials, in calculating seepage response to recharge, and in sensitivity analysis of seepage in landslide preconditions or triggers.

Off-stream water storage and irrigation, Bourke, NSW

For this project, CMJA investigated groundwater conditions and potential impacts of leakage from the large (20-GL) storage areas and from irrigation bypass flows. A numerical groundwater flow model – INTERSAT – was used as part of an extensive study that also included remote sensing, geophysical surveys and a drilling program. CMJA subsequently re-analysed the site for an alternative storage configuration, using Visual MODFLOW.

Beef cattle feedlot development, Forbes, NSW

Numerical groundwater-flow modelling (INTERSAT) was used to design a contaminant plume capture system in order to contain existing and potential groundwater contamination at this large export feedlot.

Leachate collection system, Homebush Bay, NSW

Analytical and numerical (FEMSEEP) modelling of the inflow to a leachate collection drain, to be constructed as part of the remediation of the former landfill sites at Homebush Bay, was carried out as part of detailed design and construction planning.

Environmental flows, Lower Darling River, NSW

The NSW Department of Water Resources asked CMJA to assess interrelationships between groundwater and surface water, and environmental flow requirements in the Darling River downstream of Menindee. FEMSEEP was used to model inflow along sections perpendicular to the river.

Damman aquifer model

This project, carried out by Groundwater Development Consultants International Ltd, involved creating an integrated finite-difference numerical model of the multi-layered Damman aquifer complex in eastern Saudi Arabia and Bahrain. Chris Jewell was responsible for program development, model calibration and operation, and presentation of results.

Oaklands Mine feasibility study, Oaklands, NSW

Water management aspects of a large open-cut coal mine development were studied. Work involved re-injecting large volumes of mine water into the Murray Basin aquifers, and included drilling and well testing, detailed field hydrochemical surveys, and modelling. Chris Jewell was responsible for formulation of model geometry and boundary conditions, and assessment of material properties.

Contaminant transport modelling, Blue Mountains, NSW

This project, relating to a former gasworks site in the upper Blue Mountains, involved modelling transport, natural attenuation, impacts on human and environmental receptors, and the feasibility of alternative remediation and containment options.

Open-cut Coal Mine, Hunter Valley, NSW

Finite-element modelling was used to assess the flow regime through a leaking saline water storage dam, and compare remedial alternatives.

Sandstone Quarry, Central Coast

SEEP 3D was used to assess the effect of expansion of a sandstone quarry on groundwater levels in the surrounding area, and on local groundwater users.

How CMJA can help you

We have the expert capability to deal with the complex issues and factors that are integral to groundwater flow modelling and contaminant transport modelling.

Whether you want us to design an efficient dewatering system or sustainable borefield, to assess transport times and the fate of contaminants in the groundwater system, or to make reliable predictions of groundwater impacts, our professional team can meet your needs.

We also offer a full-service consultancy in this field, from water sampling to expert testimony.