

Daniel Feinstein

D. Feinstein has worked in the field of quantitative hydrogeology for 30 years. He studied groundwater modeling at the New Mexico Institute of Mining and Technology and at the University of Wisconsin-Madison before working as a consultant on remediation projects for Papadopulos & Associates and Geraghty & Miller. In 1997 Mr. Feinstein joined the USGS where he specializes in interpretive studies involving regional groundwater modeling, simulation of groundwater/surface-water interactions, and contaminant transport. He recently headed up a pilot modeling study of the Lake Michigan Basin as part of a USGS program to determine the status, trends, and prospects of water availability in the United States. His current research interests include statistical models which emulate process-driven simulations of groundwater age and stream depletion by wells, and transport models which forecast heat flow under climate change. Mr. Feinstein is an adjunct professor at the Geosciences Department of the University of Wisconsin-Milwaukee and teaches modeling courses in Italy.

Course programme

Lesson 1 (60 min of lecture)

MODFLOW history: from the original version through MODFLOW-2000, MODFLOW-2005, MODFLOW-NWT and MODFLOW-6

As computers became increasingly powerful and widely available in the 1960s and 1970s, the need to include boundary conditions and aquifer geometries other than "perfectly flat", led many hydrologists to turn from analogue to digital, or numerical, groundwater modelling. By the early 1980s a number of programs were available to model typical conditions in a variety of aquifer systems. Differences in computer architecture and programming languages, variations in input-output data formats, however, complicated the attempts to share programs and adapt them to new applications. In 1983 the USGS released a modular three-dimensional finite-difference groundwater flow model, or MODFLOW (McDonald and Harbaugh, 1984) designed with a modular structure to facilitate the addition of new capabilities. In time, MODFLOW evolved into the most widely used groundwater modelling program in the world. Graphical User Interfaces were first developed at the end of the 90s, sensibly increasing the spread of MODFLOW among professionals and researchers with no programming skills. Since then, the capabilities of the MODFLOW family of codes have grown rapidly.

Lesson 2 (60 min lecture+2-4 hrs of workshops)

Introduction to Groundwater Vistas 7/8:
Overview of GUI

Workshop 1: Development of an example model with GWV

- How to enter in GWV
- Grid of "Granta model"
- Aquifer parameters
- Boundary Conditions
- Introduction of a hydraulic stress
- Creation of input files
- Visualization and analysis of model results
- Use of the model in transient regime
- 3-D flow simulation with MODFLOW

Workshop 1a (optional): Pumping test simulation with GWV to estimate parameters

Workshop 1b (optional): Preparation of an autonomous model to optimize a remediation design

Importance of mass balance analysis

Workshop 2: Sources of water to pumping wells

- General context and bibliography
 - Application examples – Granta model and (optional) advanced model
-

Lesson 3 (45 min + 1.5 hrs)

MODFLOW-NWT: a powerful solver

- Motivation: ability to model the shallow part of the groundwater system
- Newton-Raphson solver theory
- Advantages of the method: comparison with PCG to overcome dry cell problems
- Introduction to example model

Workshop 3: Example model with MODFLOW-NWT and GWV7:

- NWT solver settings
 - Sensitivity of the solution to NWT parameters
-

Lesson 4 (45 min + 1 hr)

Multi-Node Well (MNW) package

- Motivation: a better way to handle pumping in 3D models
- Theoretical basis
- Package options and practical applications
- MNW1 vs MNW2
- Application of MNW2 to pumping test simulation

Workshop 4: Example model with MNW:

- Conversion from WEL to MNW package
 - GWV6/7 options and simulation
 - Analysis of output for pumped and unpumped well
 - Sensitivity of results to borehole radius and "skin" effect
 - Conversion to MNW2
-

Lesson 5 (45 min + 1.5 hrs)

Simulation of exchanges between surface water and groundwater with MODFLOW-2000, MODFLOW-2005 and GWV7

- Groundwater-surface water interactions - introduction
- "Stream routing" concept
- Experimental methods to determine baseflow for calibration purposes
- STR and LAK packages

Workshop 5a: Conjunctive management of water bodies and groundwater

- Setting boundary conditions for surface water features: RIV-STR
- Link of STR package to the LAK package
- New MODFLOW-2005 options: SFR2 package

Workshop 5b: STR-SFR2

- Simulation of water body stages and flows under influence of wells
-

Interlude - A talk by Randall Hunt

Common modelling errors

Lesson 6 (60 min + 1.5 hrs)

Particles Tracking with MODPATH-5 and -7

- Analysis of the advection process: tracing of flow lines and delimitation of catchment areas
- MODPATH software

Workshop 6: MODPATH capability

- Visualization of flow lines with MODPATH in GWV environment
- Comparison between "backward" and "forward" particle lines
- "Endpoint" analysis
- Comparison between "weak sink" and "strong sink"

Workshop 6a: Exercise version with MODPATH7/MODFLOW-NWT/GWV8

- Discussion of the IFACE option to overcome the "weak sink" problem for external boundary conditions
-

Lesson 7 (75 min + 1.5 hrs)

- Contaminant transport in aquifers: physical and chemical mechanisms
- Effect of source behavior
- Effect of average velocity
- Effect of dispersivity
- Effect of exchange with the solid matrix
- Effect of decay

Introduction to MT3DMS

- Resolving the advective-dispersive equation
- Five MT3DMS packages
- Interface with MODFLOW

Workshop 7: Development of an example transport model

- Examination of an existing 3D flow model
 - Input of transport parameters in MT3D
 - Use of the model for risk evaluation
-

Overview of advanced options in MT3D-USGS (recently released)

Lesson 8 (45 min+2 hrs)

SEAWAT code: Introduction to modelling of variable density and saltwater intrusion

- Case studies
- Mathematical treatment of variable density

Workshop 8: Conversion of MT3DMS model to SEAWAT model via GWV7

- Hints for building a robust variable density model
 - Construction of a saltwater intrusion model to simulate effects of pumping
 - Calibration of variable density model
 - Use of model in forecasting
 - Optimization of a pumping center in the presence of deep brackish water
-

Lesson 9 (30 min+2.5 hrs)

SEAWAT2005: Heat transport, with consideration of temperature and viscosity as well as variable density

Workshop 9a: SEAWAT2005 functionalities – advanced exercise

Workshop 8b: Heat transport in closed-loop geothermal system; comparison between MT3DMS and SEAWAT.

Lesson 10 (60 min+2 hrs)

MODFLOW-6 overview: a new architecture, new options, and a new solution strategy

- Changes to input format
- New architecture: Multiple strongly-coupled models
- Elimination of “pinched” cells
- Design of unstructured/nested grids
- Transfer of water between packages (WATERMOVER)
- Revised NWT solver
- Transport package (2021)
- Integration with GWV7 and GWV8

Workshop 10a: Conversion from MODFLOW-NWT to MODFLOW-6, for GWV7 and GWV8

Workshop 10b: Elimination of pinched cells, for GWV7 and GWV8

Workshop 10c: Water transfer between packages, for GWV7 and GWV8

Workshop 10d (optional): Construction of unstructured grid via MODFLOW-USG and MODFLOW-6, application of particle tracking, for GWV7

Preview of topics to be presented in SYMPLE Module 4

- Optimization of groundwater resource management with **MODFLOW GWM** package;
- Simulation of unsaturated flow, recharge to water table, and seepage to land surface with **MODFLOW UZF** package;
- Application of advanced options in **MT3D-USGS** for contaminant transport: non-point transport of nitrate from land surface, degradation behavior of benzene, techniques for remediating TCE.