

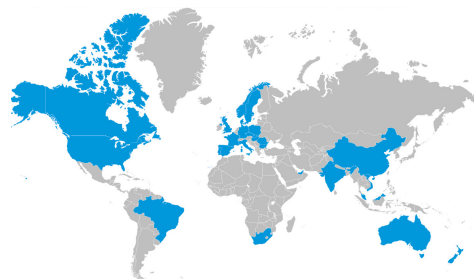
DHI WASY Software Training

Groundwater Modelling with FEFLOW 7.1



DHI Group

- Independent, self-governing not-for-profit research and consultancy organization
- Builds competence and promotes technological development relevant to water environments
- Total staff about 1200



DHI WASY

- Formerly
 - WASY
Gesellschaft für Wasserwirtschaftliche
Planung und Systemforschung mbH,
founded in 1990
 - DHI Wasser und Umwelt GmbH, German
branch of DHI Group, founded 2004
- Merged into DHI WASY GmbH in 2007
- About 85 permanent staff members in:
Berlin (headquarter), Bremen, Hamburg,
Munich
- Areas
 - Consulting
 - Software Solutions
 - Software Products



Headquarters Berlin-Adlershof

© DHI



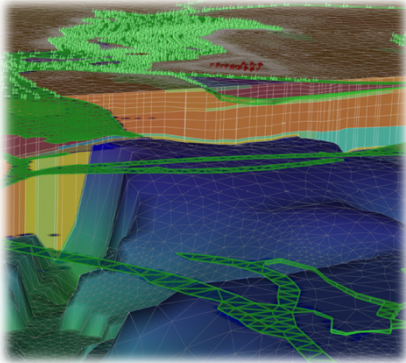
Groundwater Modelling Centre

- Specialized porous media simulation expertise within the DHI Group
- Staff: 10 people
- Three closely integrated main activities:
 - FEFLOW Development
 - FEFLOW Services
 - Groundwater Consulting

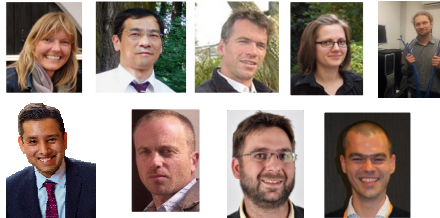
© DHI



GMC – Groundwater Modelling Centre



“Internationally renowned scientists, software specialists and consulting professionals: The DHI Groundwater Modelling Centre (GMC) is designed to take up groundwater-modelling projects beyond the average — in all environments, in all countries”



© DHI-WASY



Consultants GMC



Anna Zabel



Katja Eulitz



Peter Schätzl



Bertram Monnikhoff



Junfeng Luo



Alex Renz

Abr.	Name	Remark
JLU	Junfeng Luo	Senior hydrogeologist, FEFLOW since more than 25 years, expert for density dependent flow, mining, capture zone analyses, Chinese
KEU	Katja Eulitz	Senior hydrogeologist, Groundwater modelling since 2001, expert for geological structural models, mining, groundwater flooding, capture zone analyses, Russian moderate
AKZ	Anna Zabel	Project Manager, experience in FEFLOW since 2011, Support and ACADEMY experience, also surface water capabilities, Portuguese, Spanish moderate
PSC	Peter Schätzl	Global BAM porous media, geothermal applications, plug-in solutions, training, Spanish moderate
BMO	Bertram Monnikhoff	Senior Civil Engineer, BAM Groundwater Germany, FEFLOW since 1996, expert for coupled systems, plug-in solutions, Dutch
ARE	Alex Renz	Senior Engineer, expert for mine water management, stochastic and data-driven modelling, uncertainty analysis and machine learning. FEFLOW since more than 10 years.

© DHI-WASY



Additional Experts GMC



Björn Kaiser



Carlos Rivera



Fabien Cornaton



Julia Mayer



Patrick Keilholz

Abr.	Name	Remark
BOK	Björn Kaiser	Support Team, density-dependent flow, geothermal applications, training, visualization
CVI	Carlos Rivera	Head of Support Team, automatic calibration and uncertainty analysis (PEST), unsaturated flow, mining, reactive transport, training, plug-in solutions, Spanish
PAK	Patrick Keilholz	BD-Team, expert for integrated water management, MIKE SHE, expert for arid regions
FJC	Fabien Cornaton	Head of FEFLOW development, coupled interfaces, French, Spanish
JMR	Julia Mayer	Director Sales & Support, Head of ACADEMY, unsaturated flow, French / Hebrew moderate

FEFLOW – More than Groundwater

More than „just“ groundwater:

- Subsurface Flow and Transport

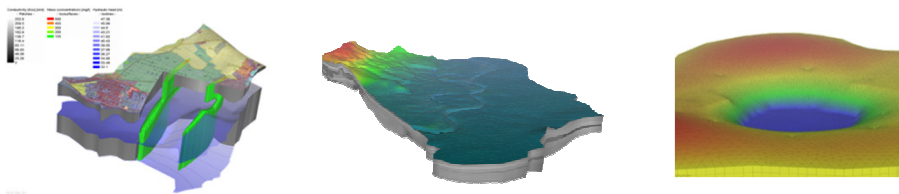
FEFLOW handles groundwater flow and related processes in one software environment and one simulation model:

- Variably saturated flow
- Contaminant transport
- Heat transport
- Density-affected flow
- Chemical reactions
- And more...

FEFLOW – More than Groundwater

The software must be ...

- Easy-to-use and intuitive to quickly master everyday groundwater projects
- Powerful and comprehensive to model complex subsurface processes

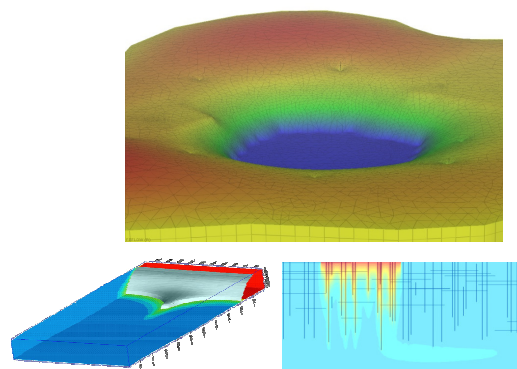


© DHI



Fields of Application

- Regional groundwater management
- Mine-water management
- Simulation of open-pit progress
- Groundwater management in construction and tunneling
- Geothermal energy (deep and near surface, both open-loop and closed-loop systems)
- Remediation / natural attenuation
- Seepage through dams and levees
- Groundwater – surface water interaction
- Capture-zone delineation and risk assessment
- Saltwater intrusion



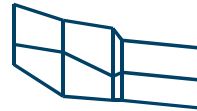
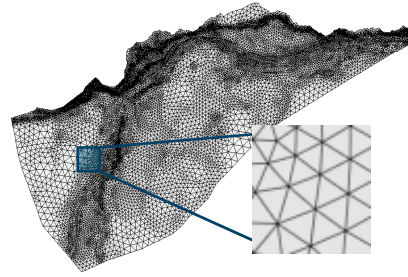
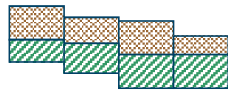
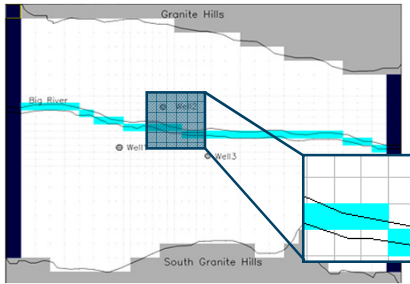
- Industrial porous materials
- ... and many more

© DHI



Flexible Meshes

- Finite Differences vs. Finite Elements

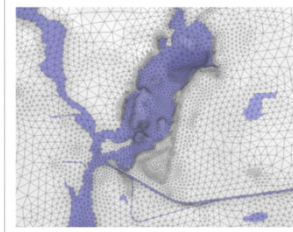
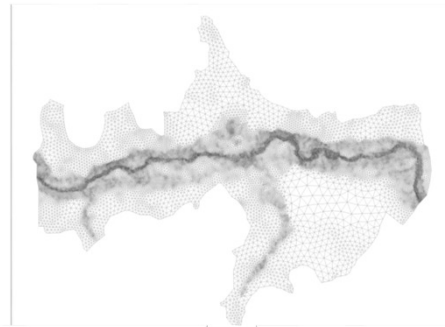


© DHI



Flexible Meshing

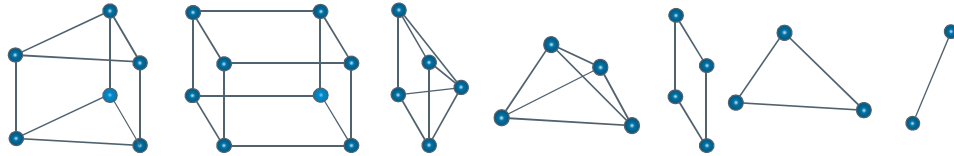
- Triangular or quad elements (2D)
- Prisms, cuboids, tetrahedron (3D)
- 3D or 2D horizontal / vertical / axisymmetric projection
- 1D and 2D for fracture / pipe / borehole flow



© DHI



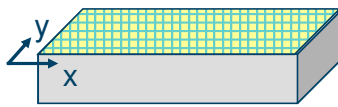
Finite-Element Mesh Type Library



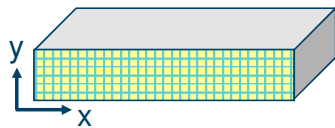
© DHI



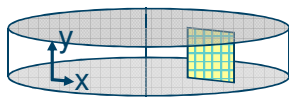
2D Model Projections



Horizontal projection



Vertical projection



Axisymmetric projection

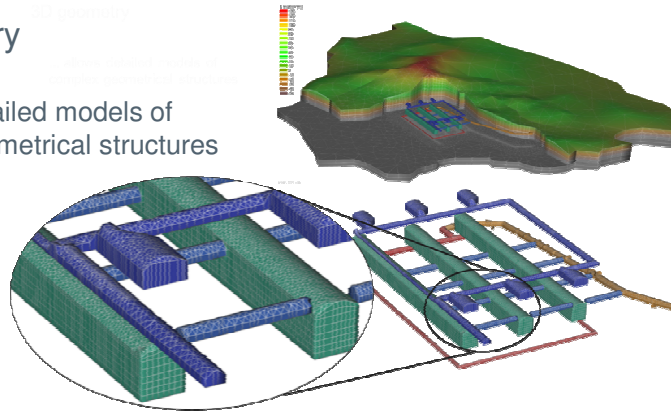
© DHI



Flexible Meshing

3D Geometry

...allows detailed models of complex geometrical structures

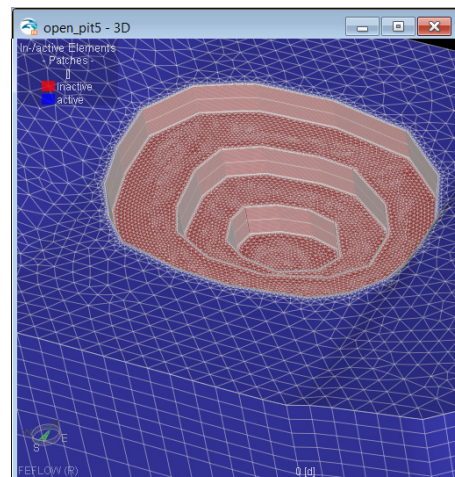


© DHI



Temporal Element Deactivation

- Elements of the finite-element mesh can be temporarily deactivated and reactivated.
- Simulation of time-varying model domain geometry (e.g. open-pit simulation projects, long-term morphological changes, etc.).



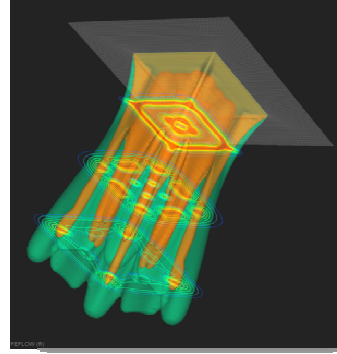
© DHI



Physics

Groundwater and vadose-zone flow

- Saturated flow (Darcy law)
- Unconfined conditions (different approaches)
- Unsaturated / variably saturated flow (Richards equation)
- Fracture flow
- Density- and viscosity-dependent flow



Physics

Transport

- Heat transport (advection-conduction equation)
- Solute transport (advection-diffusion equation)
- Groundwater age
- Combined solute/heat/age transport
- Sorption, decay
- Multispecies simulation
- Kinetic reaction systems

FEFLOW Problem Settings

Problem Class: Simulation Time Control

Chemical Species

Each species is associated with either the fluid or the solid phase

Name	Phase	Definition
1 PCE	Fluid	User-defined
2 TCE	Fluid	User-defined
3 DCE	Fluid	User-defined
4 VC	Fluid	User-defined
5 O2	Fluid	User-defined
6 NO3-	Fluid	User-defined
7 Cl-	Fluid	User-defined

FEFLOW Reaction Kinetics - Expression Editor

$$R_{p1} = \frac{0.204 \cdot C_{p1} \cdot \text{Rate}_{p1} \cdot \text{PORO}_{p1} + 0.262 \cdot C_{p2} \cdot \text{Rate}_{p2} \cdot \text{PORO}_{p2} + 0.356 \cdot C_{p3} \cdot \text{Rate}_{p3} \cdot \text{PORO}_{p3}}{1.008 \cdot C_{p1} \cdot \text{Rate}_{p1} \cdot \text{PORO}_{p1} + 0.2312 \cdot C_{p2} \cdot \text{Rate}_{p2} \cdot \text{PORO}_{p2} + 0.552 \cdot C_{p3} \cdot \text{Rate}_{p3} \cdot \text{PORO}_{p3} + C_{p4}} \text{ if } C_{p1} < 0.1$$

Other species: all species with...

Boundary Conditions (BC): Material Properties, General Parameters, Calculation Parameters, Reference Constants, Auxiliary Data, Mesh

Please note: Due to inevitable round-off, an exact comparison of floating-point numbers is not guaranteed to give the expected result. For example, the value for system error is often less than 1e-14.

Ease of Use

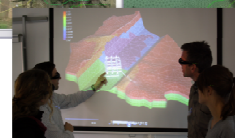
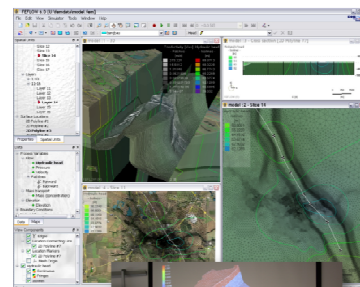
- User interface for preprocessing, simulation, and postprocessing
- GIS/CAD/ASCII/Excel/Access interfaces for import and export
- 2D/3D map support
- Database support (ESRI, Oracle, PostgreSQL)
- Geological models (LeapFrog, GeoModeller, GOCAD)
- Advanced computational methods
 - Powerful mesh generators
 - Automatic time-stepping scheme
 - Algebraic multigrid solver
 - Parallelization

• ...
© DHI



Visualization

- 2D top / cross-section / data-trace views
- 3D views
- 2D / 3D map support
- 3D clipping and carving
- Live, interactive visualization during simulation run
- Hardware acceleration via OpenGL
- 3D stereoscopic display/projector support

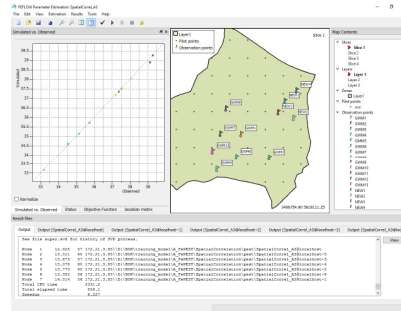


© DHI



FePEST: Parameter Estimation with PEST

- Interface between FEFLOW and PEST
- Part of FEFLOW installation
- Calibration, optimisation, predictive analysis and sensitivity analysis
- Latest versions of PEST.exe and PLPROC.exe accessible
- Features:
 - Pilot-point method
 - Constant values within specified zones
 - 2D and 3D models
 - Steady state and transient models Tikhonov regularization, SVD, SVD-Assist
 - Parallel optimisation (BeoPEST)



© DHI



Corporate Licenses

- Arbitrary number of FEFLOW instances possible for the same model (identical mesh and problem class) with only one license seat
- Running FEFLOW on remote servers
- Licenses accessible via network
- Benefits:
 - No additional costs for optimization / sensitivity analysis
 - Simultaneous editing of multiple scenarios of the same model

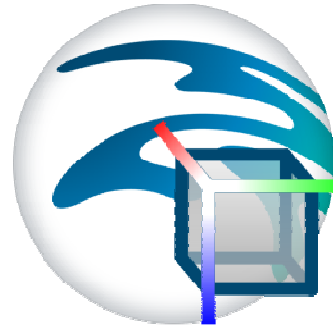
Corporate	Subscription	Personal
Fully featured, fully flexible software	Fully featured, fully flexible software	Fully featured software
Unlimited users	Unlimited users	One user per licence
Floating (network) licences	Floating (network) licences	Single user licence
World-wide training through The Academy	World-wide training through The Academy	World-wide training through The Academy
Additional seats with growing discount	Additional seats with growing discount	Additional licences available
Flexible rental with discounts	Flexible rental with discounts	Rental licences available
First year Service and Maintenance included	Service and Maintenance included	First year Service and Maintenance included
Service and Maintenance with volume discounts	Service and Maintenance with volume discounts	Service and Maintenance available world-wide
Parallel optimisation / sensitivity analysis with one seat		

© DHI



FEFLOW Viewer

- Free (no license required)
- Works with existing FEFLOW models
- Model and results files
- Visualization and analysis
- Export of figures and animations
- Use by modeler
 - No license necessary for postprocessing
 - Share your model with colleagues even if licenses are limited
- Use by consulting clients
 - No need to purchase an additional license
 - Deliver viewable model files to customers



© DHI



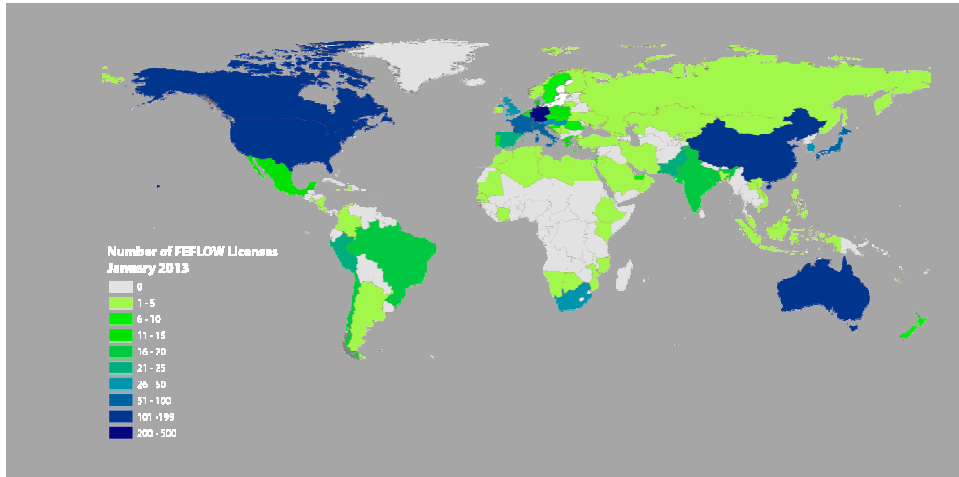
Extensibility

- Open programming interface
 - Documented API interface
 - User can develop plug-ins for
 - Additional functionality
 - Workflow automation
- Application Examples
 - Groundwater / surface-water coupling
 - Integration of technical installations in geothermal modeling
 - Import of model properties
 - Export of model results
- Development Services
 - Plug-in development as a consulting service

© DHI



FEFLOW Community



© DHI



FEFLOW Community

MIKE by DHI DHI - The expert in WATER ENVIRONMENTS

Home Help Search Admin Moderate Profile My Messages Calendar Members Logout

MIKEbyDHI Forum » Groundwater & Porous Media » FEFLOW

Child Boards

<p>Plug-in Development Programming for the FEFLOW Interface Manager IFM</p>	<p>173 Posts 55 Topics</p>	<p>Last post by Blair in Re: About simulation? on December 06, 2012, 09:36:29 AM</p>
<p>Announcements DHI-WASY for example announces the latest FEFLOW patch releases here!</p>	<p>38 Posts 38 Topics</p>	<p>Last post by Julia Meyer in FEFLOW 6.100 and New LIC... on January 05, 2013, 05:01:16 PM</p>
<p>Suggestions Wishes for additional functionality in FEFLOW.</p>	<p>227 Posts 108 Topics</p>	<p>Last post by hidromatrix in Re: Ability to import/ex... on November 25, 2012, 04:44:23 AM</p>

Pages: [1] 2 3 ... 39

Subject / Started by	Replies / Views	Last post
EXPORT NODES WITH COORDINATES Started by CÉSAR CONDÍA	1 Replies 91 Views	January 07, 2013, 09:34:27 PM by Christian Tomsau
How to import solute into model through rainfall Started by Jiale Wang	0 Replies 38 Views	January 03, 2013, 03:37:36 PM by Jiale Wang
<Too many open dongle features> Started by Blair	0 Replies 32 Views	January 02, 2013, 09:25:04 AM by Blair
How to Calculate Evaporation of Groundwater in FEFLOW Started by Jiale Wang	1 Replies 194 Views	December 17, 2012, 05:24:25 AM by Jags
Geometrical flexibility of Feflow Started by Iesthesa	0 Replies 96 Views	December 14, 2012, 10:23:45 AM by Iesthesa
Keep nodes on polygon boundaries and lines UNMOVED when smoothing the mesh Started by cuqiang	2 Replies 118 Views	December 14, 2012, 01:43:34 AM by cuqiang
"Free & movable" VS "Pneatic" Started by Jiale Wang	4 Replies 181 Views	December 12, 2012, 04:03:36 PM by Jiale Wang

forum.MIKEbyDHI.com

© DHI



User Support

- We help by
 - Giving advice on FEFLOW modeling
 - Analyzing possible model improvements
 - Explaining theoretical background and functionality
- In addition, we offer:
 - Training courses
 - Solutions
 - Software customization
 - Consulting in modeling projects
 - Model reviews

FEFLOW Services

Support
Training
Plug-in solutions



Dr. Dipl.-Ing. (FH)
Carlos Andres
Rivera Villarreyes



Dr. Dipl.-Ing. (FH)
Björn Onno Kaiser



M.Sc. Geol.
Jintao Liu

Why FEFLOW

- Highly scalable software package
 - Different feature levels available
- Commercial software
 - DHI guarantees consistent services
 - Close contact to support staff
 - Software performance benchmarked and documented
 - Quality assurance
 - Ongoing development

Documentation

- Installation Guide and Demonstration Exercise
- User Manual
- FEFLOW Book
- White Papers Vol. I-V
- [Help System](#)



All manuals are available as pdf on the FEFLOW DVD (*.pdf) or for download on www.feflow.com.

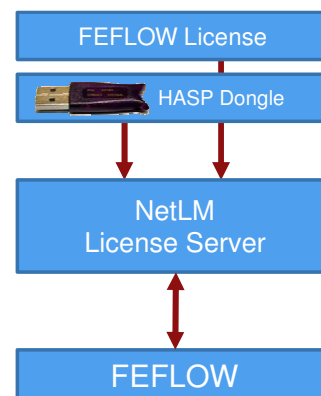
© DHI



Licensing and Maintenance

Licensed via HASP hardware dongle and license manager software NetLM

- License types:
 - F2 2D flow
 - FM2 2D flow, mass and age transport
 - F3 2D/3D flow
 - FM3 2D/3D flow, mass and age transport
 - FH3 2D/3D flow and heat transport
 - FMH3 2D/3D flow, mass, age and heat transport
- Personal, Corporate or Subscription licenses
- License includes 1 year maintenance
- Research discounts and lab kits available



© DHI

