



中國地質大學
China University of Geosciences

艰苦朴素 求真务实

温家宝

地下水模拟软件调研 Groundwater Model

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中国地质大学

China University of Geosciences

艰苦朴素 求真务实

地下水

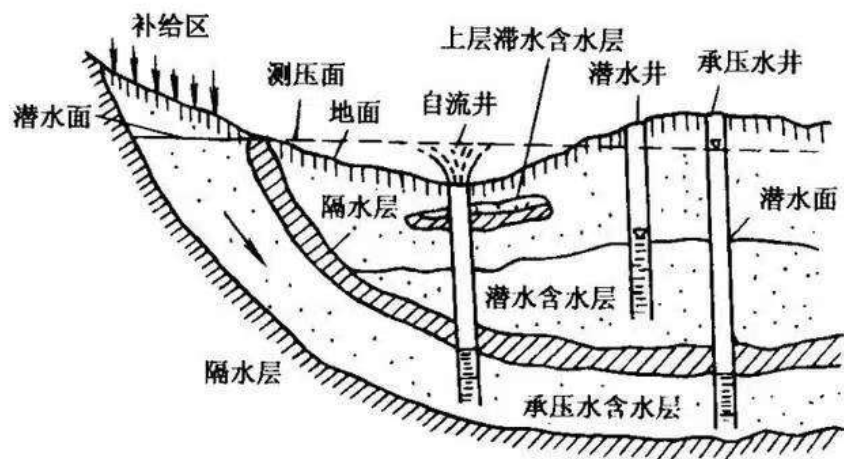
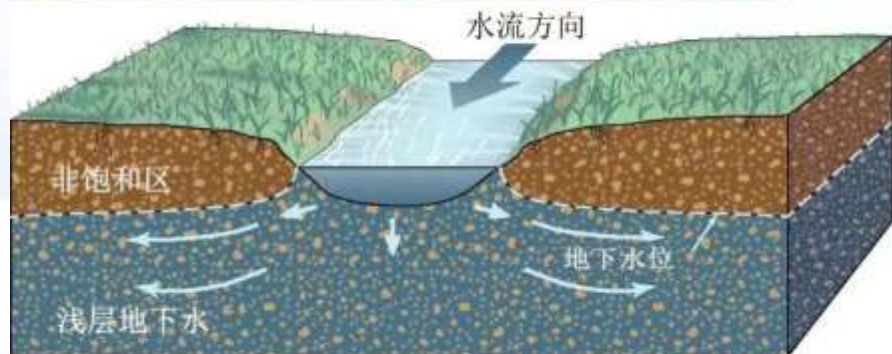
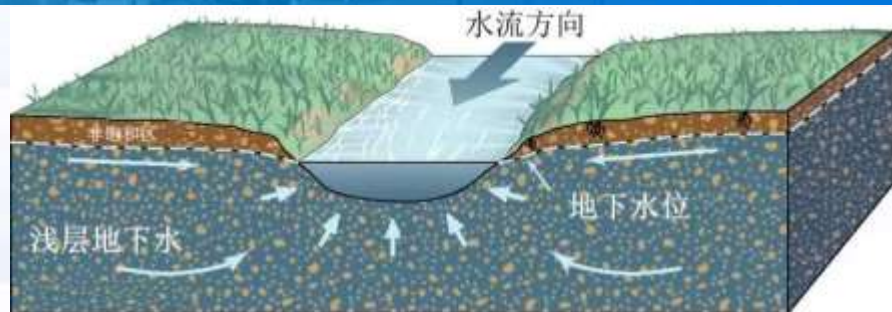
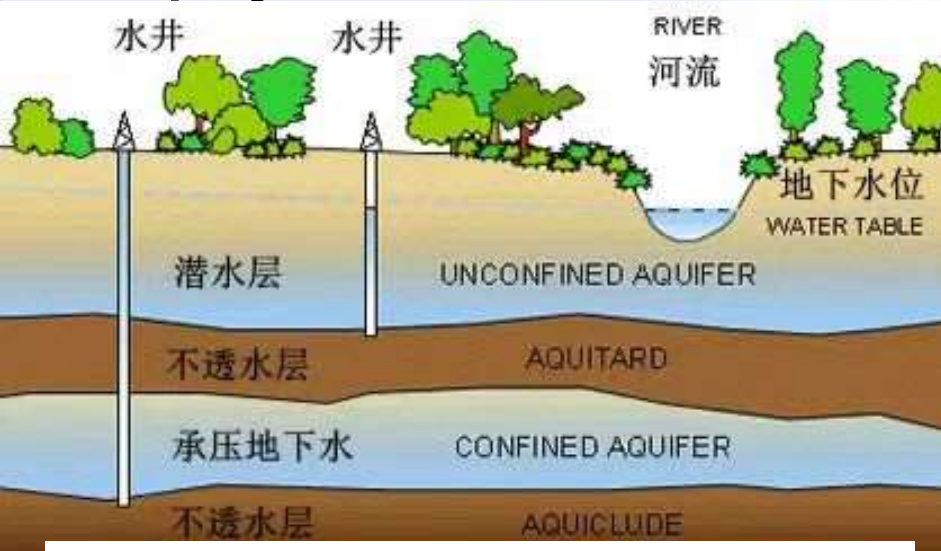
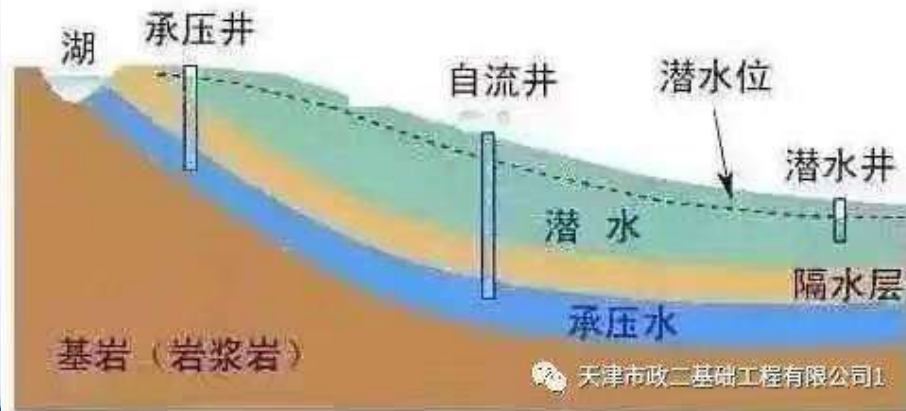


图 7-5 潜水、承压水及上层滞水含水层



天津市政二基础工程有限公司



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MODFLOW

MODFLOW现在常用的是MODFLOW-2005（结构网格）、MODFLOW-USG（非结构网格）与MODFLOW6（统一模型框架，最新）。

MODFLOW-2005已有OpenMP与CUDA并行化的线性方程组求解器。

MODFLOW-USG只有串行版本。

MODFLOW6已实现MPI并行化。

MODFLOW-USG可使用嵌套网格(nested grid)、四叉树网格(quadtree)；而

MODFLOW6可使用结构网格、MODFLOW-USG的网格以及**DISV三角形网格**。

Gridgen（**不是Pointwise Gridgen**）可作为MODFLOW-USG的quadtree网格生成程序，导出ASCII格式的MODFLOW-USG的网格输入文件。

flop是MODFLOW系列软件的后处理程序。



Visual Modflow

Visual Modflow由加拿大Waterloo Hydrogeologic公司 开发。

Comprehensive Groundwater Modeling

With Visual MODFLOW Flex you have a comprehensive set of tools necessary for addressing water quality, groundwater supply, and source water protection initiatives, including:

MODFLOW-2000, 2005, NWT	The world standard for groundwater flow modeling
MODFLOW-USG	A finite volume version of MODFLOW that uses unstructured grids. Learn more
MODFLOW-LGR	Shared-node local grid refinement (LGR) for regional-local scale simulations
MODFLOW-SURFACT	Enhanced simulations of complex saturated/unsaturated subsurface flow and transport processes
MT3DMS	The standard package for multi-species contaminant transport simulations
SEAWAT	The model for variable-density groundwater flow coupled with multi-species solute and heat transport
RT3D	Advanced and specialized multi-species reactive contaminant transport simulations
MODPATH	The standard package for forward and reverse particle tracking
MOD-PATH3DU	An advanced package for forward and reverse particle tracking supporting unstructured grids
Zone Budget	A package for sub-regional water budget calculations
PEST v.12.3	Automated calibration and sensitivity analysis with support for pilot points



Visual Modflow

Visual MODFLOW Flex supported Grid types:

Uniform Grid

Non-Uniform Grid

Finite Element Mesh

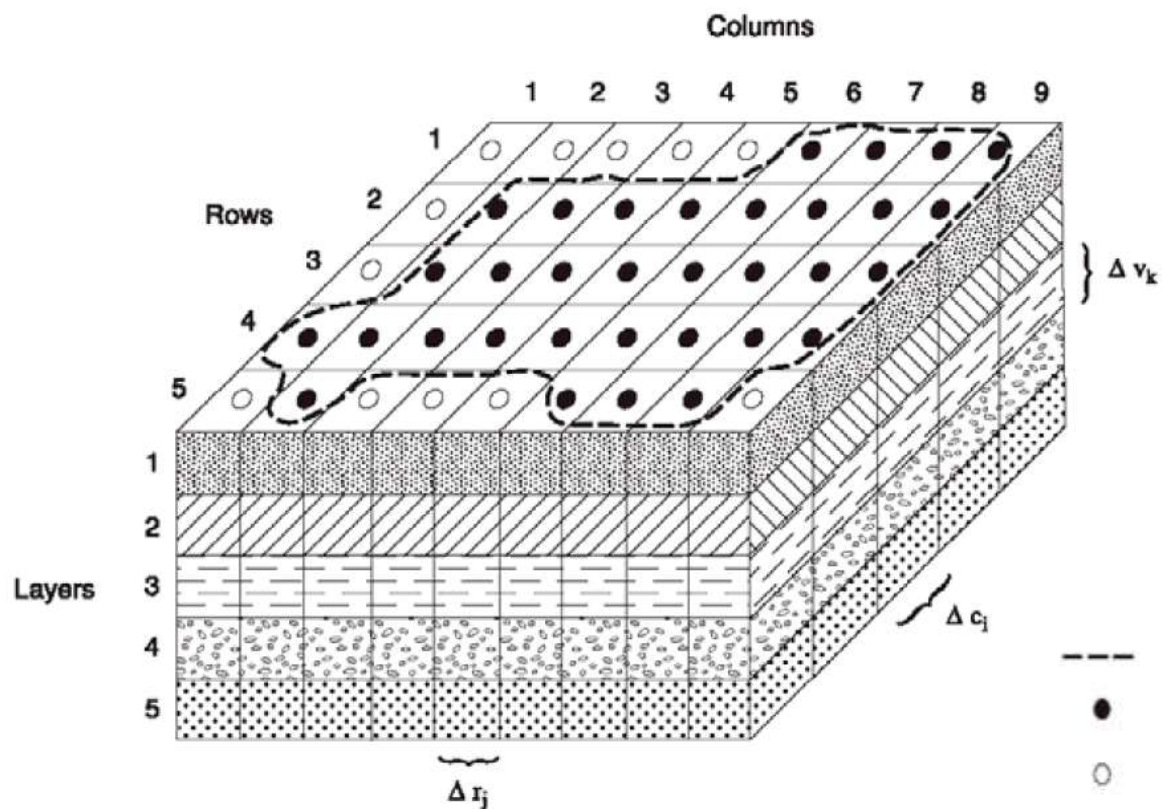
Localized Child Grids (MODFLOW-LGR)

Unstructured Grids (MODFLOW-USG)



MODFLOW-2005

空间离散方法见
手册P50
TM6A16.pdf



EXPLANATION

- AQUIFER BOUNDARY
- ACTIVE CELL
- INACTIVE CELL
- Δr_j DIMENSION OF CELL ALONG THE ROW DIRECTION—
Subscript (j) indicates the number of the column
- Δc_l DIMENSION OF CELL ALONG THE COLUMN DIRECTION—
Subscript (l) indicates the number of the row
- Δv_k DIMENSION OF CELL ALONG THE VERTICAL DIRECTION—
Subscript (k) indicates the number of the layer

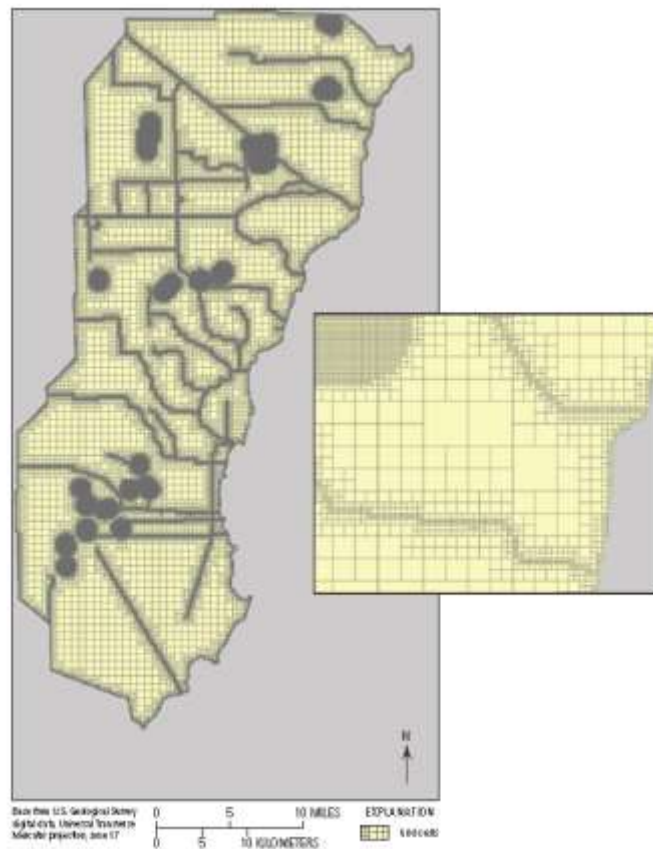
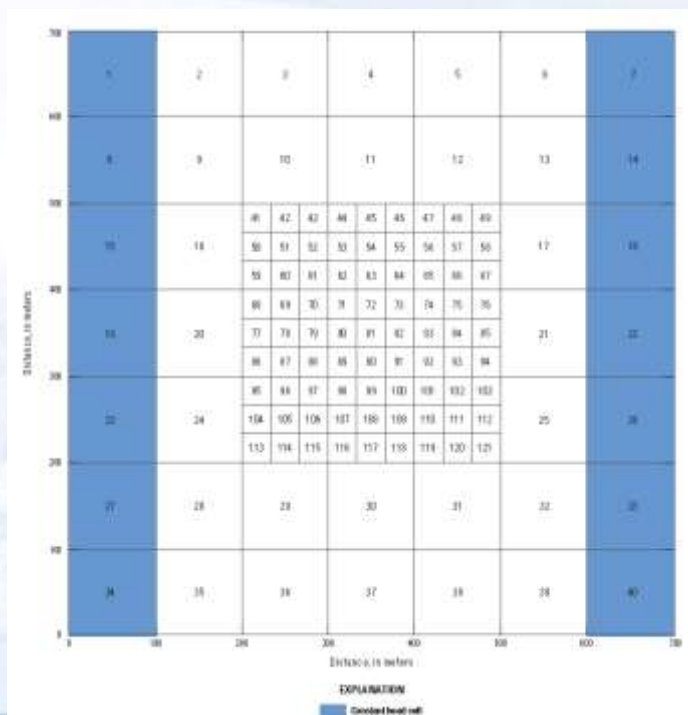
结构网格与有限差分法



MODFLOW-USG 尚未见到使用DISV的三角形非结构的算例

MODFLOW-USG的水平网格，目前使用：

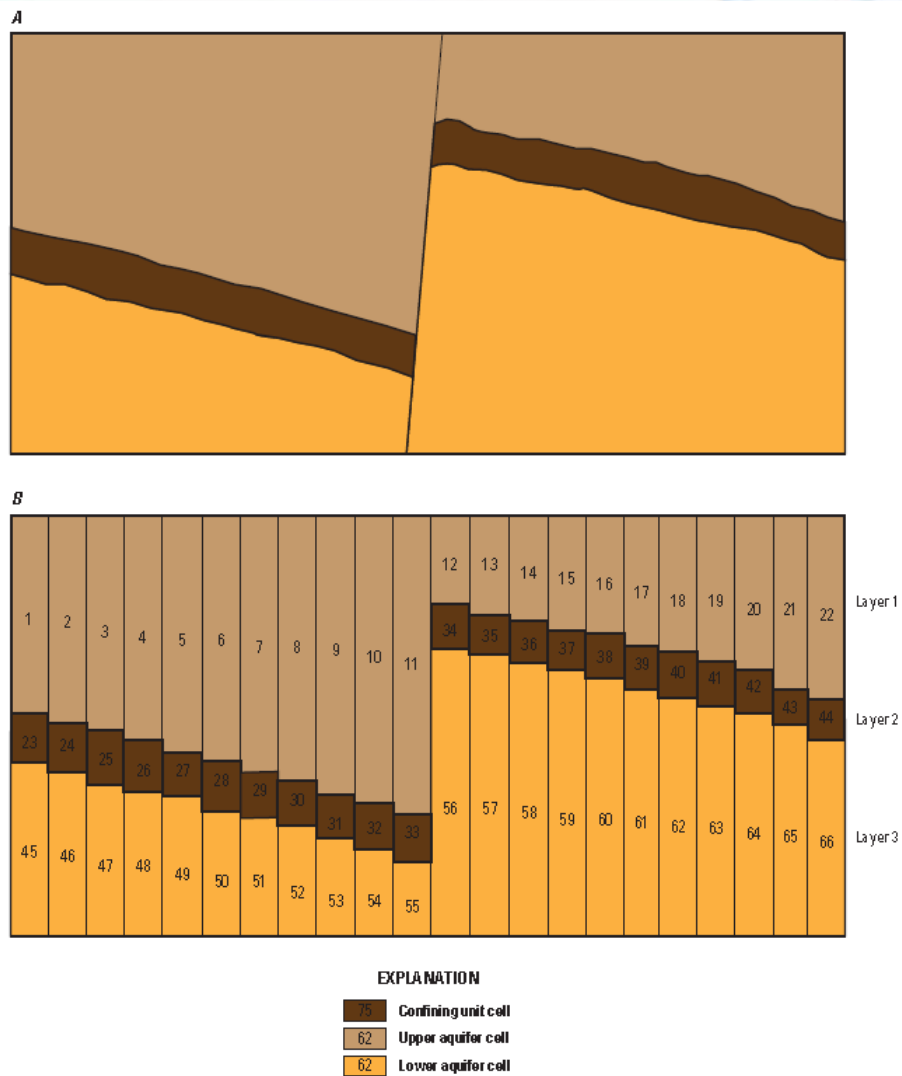
- ✓ nested grid (LGR—Local grid refined)
- ✓ quadtree grid





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MODFLOW-USG

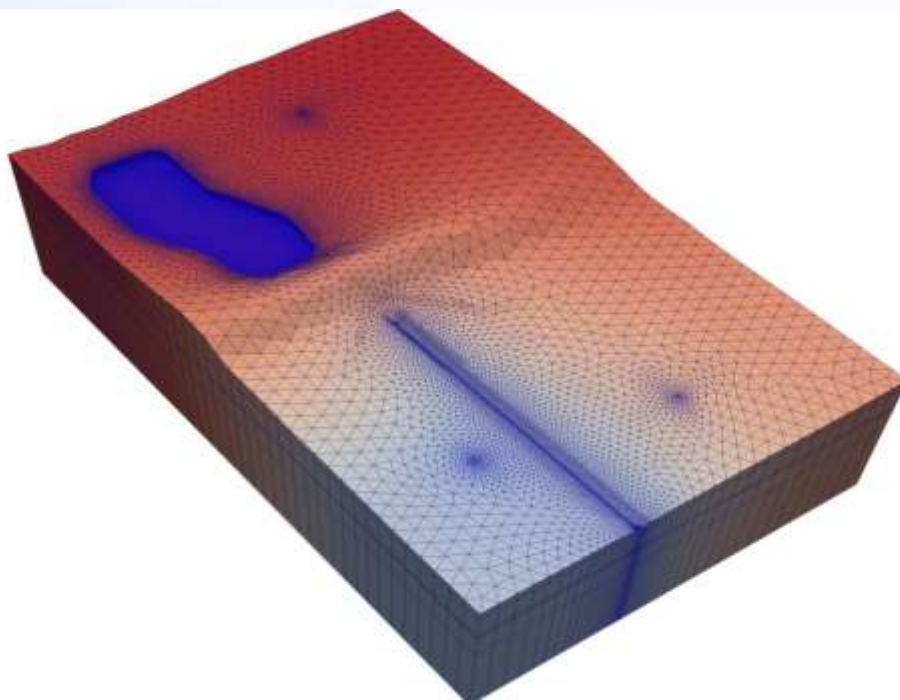


水力分层的垂向网格分层描述

断层的垂向网格分层描述



MODFLOW-6



DISV水平网格

1. a regular MODFLOW grid consisting of layers, rows, and columns,
2. a layered grid defined by (x, y) vertex pairs, or
3. a general unstructured grid based on concepts developed for [MODFLOW-USG](#).



FEFLOW-DHI

Hans-Jorg G. Diersch 在1979年开始研发，在德国柏林科学研究院，开发至1990年代。FEFLOW持续研发，拓展至一个商业模拟软件
2007年，被丹麦DHI收购。

Why use FEFLOW?

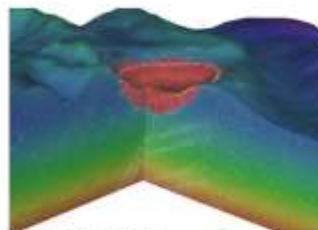
For over 40 years, groundwater modellers have relied on FEFLOW to simulate flow, mass and heat transport processes in the subsurface. Primarily, FEFLOW enables users to:

- Analyse interactions below the land surface by including underground structures, tunnels and faults
- Predict potential water quality issues in groundwater and provide remediation strategies
- Model geothermal installations at any scale and depth
- Investigate groundwater-surface water interaction by coupling FEFLOW to other MI
- Estimate ground subsidence and predict pumping rates and stability issues in geotechnical engineering

Mining & Metals

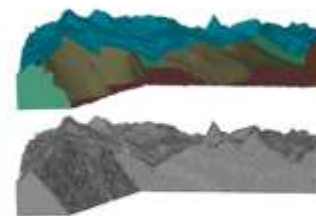
Key Features

Case Stories



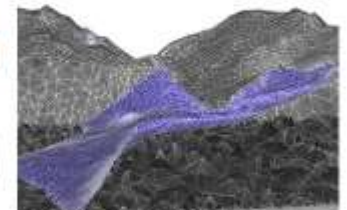
Flexible 3D meshing

Accurately represent complex structures, typically found in mining hydrogeology, for more robust and spatially detailed results.



Geological model integration

Build your geologic model in GeoModeller 3D, GOCAD or Leapfrog Hydro and transfer it to FEFLOW with ease



Fractured media representation

Identify flow paths by accounting for faulting and fractures typical of mining.



GMS (Aquavo 公司): Groundwater Modeling System 另一个SMS (Surfacewater Modelling System)

The screenshot shows the GMS website interface. At the top is a red navigation bar with links: Introduction, MODFLOW Modeling, Transport Modeling, Models & Utilities, Learning, Free Trial, and What's New. Below the navigation bar is the FEFLOW logo and the title "Finite Element Groundwater Flow & Transport in GMS". The main content area is divided into two columns. The left column contains application details: Application (Groundwater Flow & Transport Modeling), Method (Finite Element), Model Type (3D), and Developer (DHI-WASY GmbH). Below this are two buttons: "Try GMS Free for 14 Days" and "Purchase GMS". The right column features a 3D visualization of a groundwater model and a list of "GMS Supported Models" including MODFLOW, MODFLOW-USG, MODFLOW-LGR, MODPATH, MT3DMS, PHT3D, SEAWAT, RT3D, SEAM3D, MODAEM, UTEXAS, SEEP2D, FEMWATER, FEFLOW, and TOUGH2. At the bottom right, there is a section for "GMS Supported Utilities" listing PEST & Parallel PEST, T-PROGS, and SAMG Solver.

FEFLOW
Finite Element Groundwater Flow & Transport in GMS

Application: Groundwater Flow & Transport Modeling
Method: Finite Element
Model Type: 3D
Developer: DHI-WASY GmbH

[Try GMS Free for 14 Days](#) [Purchase GMS](#)

FEFLOW Description:
Import and export 2D and 3D finite element meshes into and out of GMS using the FEFLOW ASCII Model File Format (*.fem). This makes it possible to build a mesh in GMS and export it so it can be used to build a model in FEFLOW. Also, the mesh from a FEFLOW model can be exported from FEFLOW and imported into GMS for viewing, examination and post-processing.

In order to use all the capabilities in GMS related to FEFLOW, your license will need to include the Mesh and Subsurface modules.

GMS Supported Models

- MODFLOW
- MODFLOW-USG
- MODFLOW-LGR
- MODPATH
- MT3DMS
- PHT3D
- SEAWAT
- RT3D
- SEAM3D
- MODAEM
- UTEXAS
- SEEP2D
- FEMWATER
- FEFLOW
- TOUGH2

GMS Supported Utilities

- PEST & Parallel PEST
- T-PROGS
- SAMG Solver

GMS囊括了很多主流的地下水模型，包括MODFLOW，FEFLOW，TOUGH2等
界面化，交互操作



总结

- 1、FEFLOW, GMS 为商业软件, 需要许可证; 界面化很好, 计算性能不足 (面向工作站的HPC)。
- 2、MODFLOW系列, 开源FORTRAN, MODFLOW6在2020年实现MPI并行化 (开发中)。
- 3、地下水模型很多, 缺少统一开发框架。DuMu^x基于DUNE框架开发, 是一个很好的开端。