A Review of Finite Difference Grid Types

Introduction

This document contains details on types of Finite-Difference grid types that can be designed and simulated in VMOD Flex and the advantages/disadvantages of each.

Background

The Finite difference grid used by MODFLOW has several restrictions:

- The model layers cannot be zero thickness
- Model layers must be continuous across the domain

When designing the vertical numerical grid, several approaches can be used:

- Uniform model layers (a rectilinear grid)
- Deformed model layers
- Semi-uniform layers (deformed on top and bottom, with uniformly thick layers in between)

Using VMOD Flex, it is possible to define multiple numerical grids, of different types, and create a numerical model from this grid, based on your conceptual model. This makes it possible to easily choose the most appropriate grid for your project, and generate the numerical model files in minutes.

Deformed Grid

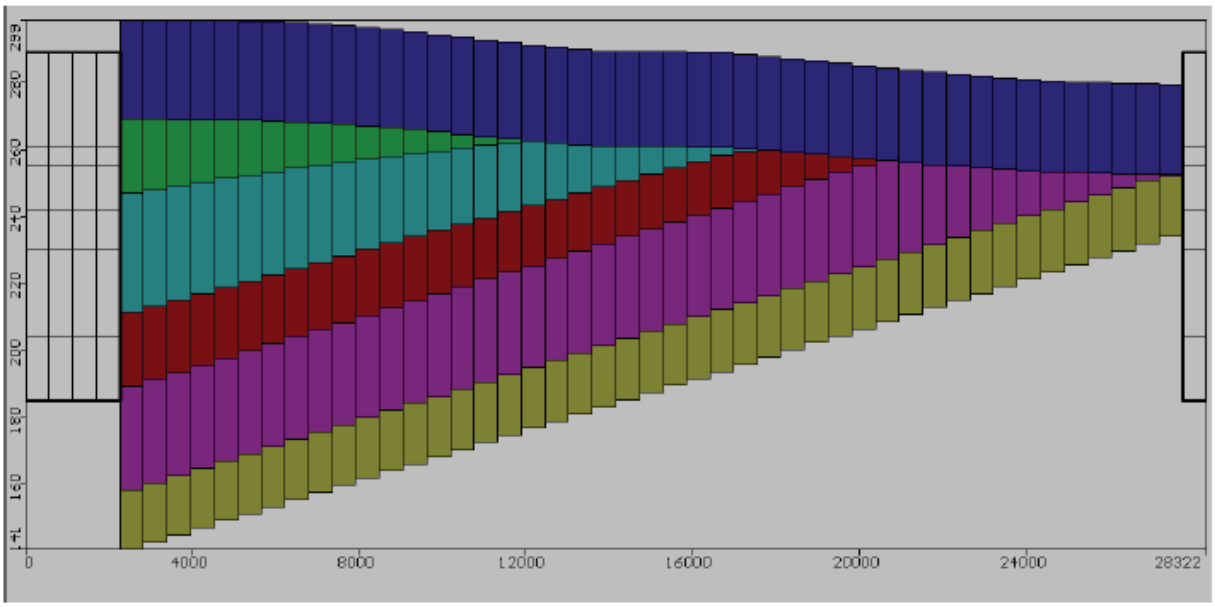
In a deformed grid, the tops and bottoms of the model layers follow the horizons elevations (the geological layers). Each model layer corresponds to a hydrogeological unit. Property parameters are applied to the full layer thickness. You can refine the model layers, by dividing the zones into proportionately thick layers.

Advantages:

- requires a smaller number of layers
- easy to design and construct

Disadvantages:

- potential inaccuracy problems
- pinch out layers, requires you to manually change the properties in these areas



Cross-section of MODFLOW Properties with Deformed Grid

Uniform Grid

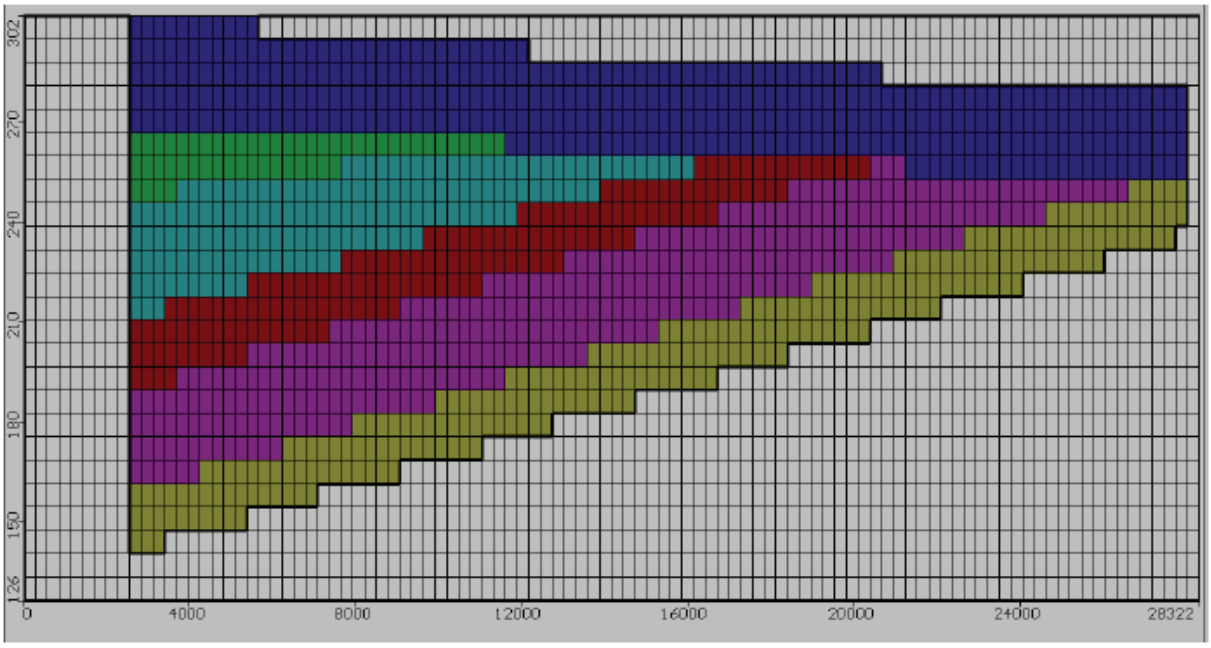
In a uniform grid, a number of layers with uniform thickness will be created. At the time of translating the conceptual model to the numerical model, the properties will be assigned to the appropriate grid cells to represent the geological structure. Grid cells above the topmost geological layer (and below the bottommost layer) are set as inactive.
This grid is useful for transport or density-dependent simulations, where it is desirable to have fine vertical discretization.

Advantages:

- fully respects the finite-difference assumptions
- less disconnected grid cells

Disadvantages:

- requires larger number of cells
- time consuming to define manually (requires you to assign the correct properties to the appropriate grid cells, individually)



Cross-section of MODFLOW Properties with Uniform Grid

Semi-Uniform Grid

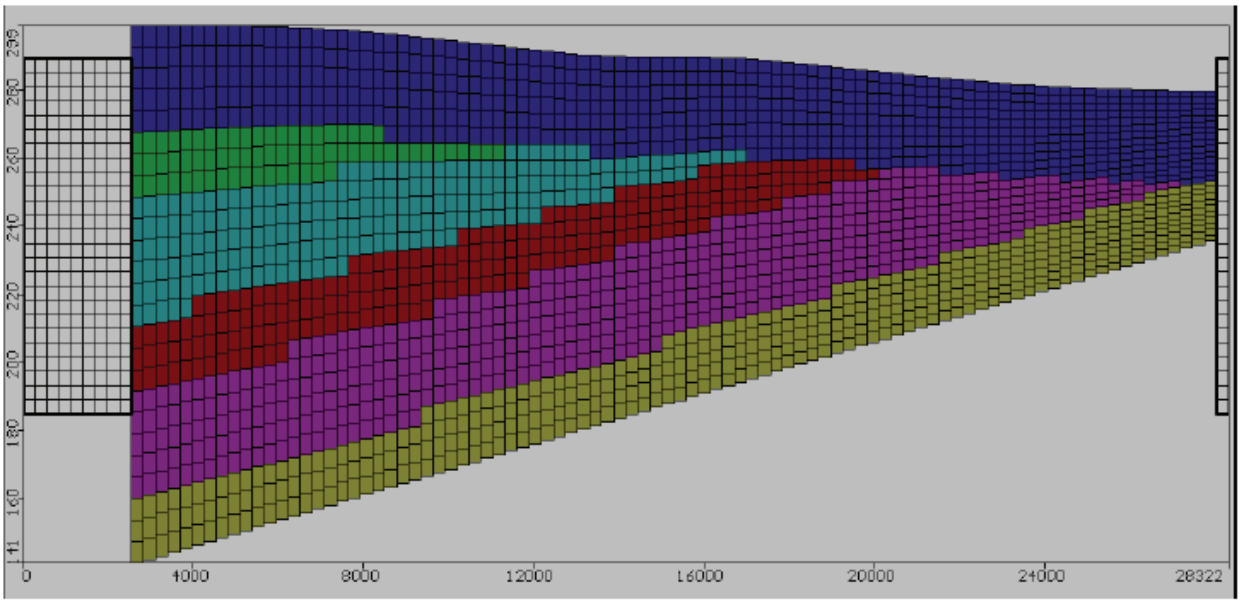
In a semi-uniform grid, the top and bottom of the grid are deformed, following the top-most and bottom-most horizons respectively; in between, a set of uniformly thick layers will be generated. At the time of translating the conceptual model to the numerical model, the properties will be assigned to the appropriate grid cells to represent the geological structure. This grid is useful where you have discontinuous layers

Advantages:

- Almost fully respects the finite-difference assumptions
- Less disconnected grid cells
- Could be more stable for layers that pinch-out
- Top and bottom layers deform

Disadvantages:

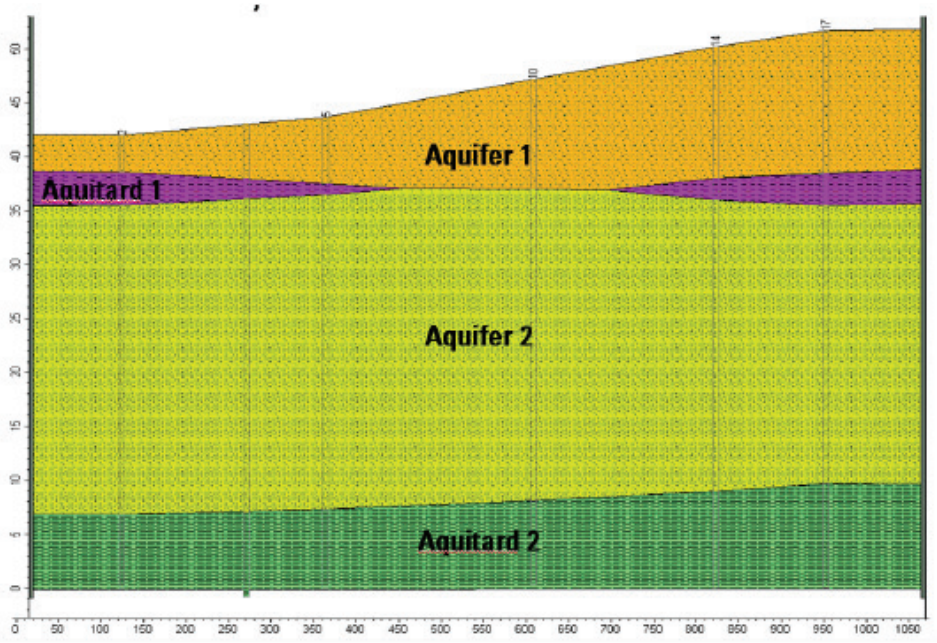
- requires larger number of cells
- time consuming to define manually (requires you to assign the correct properties to the appropriate grid cells, individually)



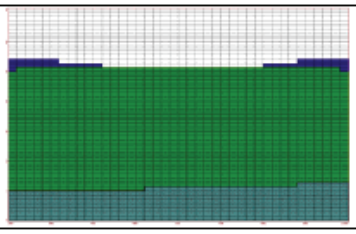
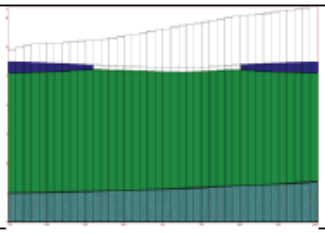
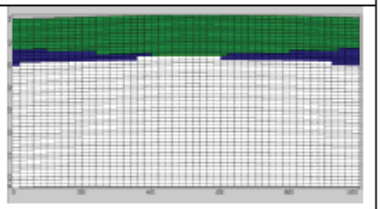
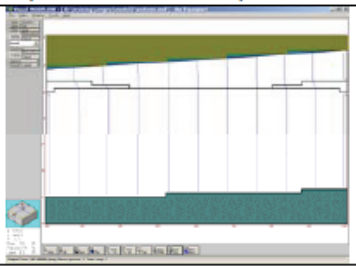
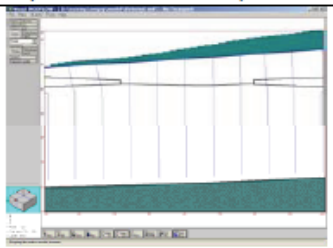
Cross-section of MODFLOW Properties with Semi-Uniform Grid

Example

An example was prepared based on the simple geological setting shown below:



Three Visual MODFLOW models were built, with different grid types. The results are summarized below.

	Uniform Grid	Deformed Grid	Semi-Uniform
Property distribution on the grid			
# Layers	50 model layers (each 1.0 m thick)	3 model layers	50 model layers (each approx 0.7 m thick)
# Cells	100,000 cells	6,000 cells	100,000 cells
Mass Balance	Mass Balance = 1.1 E-5 = (0.18 / 15887.78)	Mass Balance = 1.3 E-6 = (0.02 / 15880.36)	N/A
Cross-section showing calculated heads			N/A

Conclusions

The appropriate grid type should be chosen based on your project objectives. In some cases, it is more suitable to use a uniform grid, however, due to the practical limitations of designing and populating this grid, it is not commonly used. As illustrated above, it can take several hours to construct a property model with this approach.

Using VMOD Flex, a numerical model with any of the grids above can be quickly constructed from your conceptual model. Since the property zones in your conceptual model are grid-independent, you can change your grid type and quickly design and populate multiple numerical models, and select the most appropriate one. You are no longer restricted to using the deformed grid type. Designing and populating a uniform or semi-uniform grid can be done in minutes, as opposed to hours.