Getting Out of Squaresville: MODFLOW USG Tools for ArcGIS

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Why Use ArcGIS for Hydrologic Modeling?

1) Access map-base and data
Why Use ArcGIS for Hydrologic Modeling?

2) Flexibility to meet new classes of problems

Use well known MODFLOW input output patterns and model concepts and flexibly apply geo-spatially aware scripting tools to achieve novel analysis and visualizations of hydrologic model and related data.
Why Use ArcGIS for Hydrologic Modeling?

3) Results look like Hydrogeology.
What is MODFLOW-USG?

“A new version of MODFLOW, called MODFLOW-USG (for UnStructured Grid), was developed to support a wide variety of structured and unstructured grid types, including nested grids and grids based on prismatic triangles, rectangles, hexagons, and other cell shapes. Flexibility in grid design can be used to focus resolution along rivers and around wells, for example, or to subdiscretize individual layers to better represent hydrostratigraphic units.”
Background: Finite Element Models in ArcGIS
Background: Integrated Finite Difference in MODFLOW-88 and ArcGIS

Implementation: Toolset and Schema
Implementation: Code (ArcPy + Python)
Implementation: Use

```python
for w in range(1):
    for line in open("NewUnitTopz.dat", "r"):
        cellStack.deposition(1, 3, TotalTHK)
        cellStack.deposition(2, 2, QVTHK)
        cellStack.deposition(1, 1, QvTHK)
        cellStack.wedge(118)
        grid.addStack(cellStack)
        grid.numberByLNM(1, 23)
        grid.createTopology(True)
        print "Save"
        saveGeoCellStackContainer(grid, "C:\\GoogleDrive\\USGTools\\Tools\\make814.py")
        grid.print()
        grid.print("read")
        grid = readGeoCellStackContainer("C:\\GoogleDrive\\USGTools\\Tools\\make814.py")
        print "done"
        grid.writeDisc("", 33)
        print "Done"
        LPTDDict = {}
        LPTDDict[1] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[2] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[3] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[4] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[5] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[6] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[7] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        LPTDDict[8] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        grid.writeLFPF("GRID", LPTDDict, 33)
        print "CDP"
        CNDDict = {}
        CNDDict[1] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[2] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[3] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[4] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[5] = [10.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[6] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[7] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        CNDDict[8] = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
        grid.writeCDN("GRID", CNDDict, 33)
        grid.writeTopCellSet()"
“The term “unstructured grid” simply means that the number of connections may be variable for each cell. For example, with mesh-centered triangular finite-elements, a node may be common to several elements, and this connectivity may vary for each node. This variability results in an unstructured system of equations. Similarly, in CVFD schemes the connectivity of a cell depends on the number of shared faces, which may vary for each cell.”

USGS Techniques and Methods 6–A45 pg. 8
Grids and Meshes: Tools

Grid:
Creates a feature class grid with regular rows and columns.
Mesh tool utilizes Gmsh:
Grids and Meshes: Grid
Grids and Meshes: Grid with Irregular Domain
Grids and Meshes: Grid with Quad-Tree Refinement
Grids and Meshes: Grid with Sub-Grids
Grids and Meshes: Triangular Mesh
Grids and Meshes: Quadrilateral Mesh
Grids and Meshes: Triangular Mesh With Embedded Polyline
Grids and Meshes: Quadrilateral Transfinite Mesh
Geo-Cellular Model
Geo-Cellular Model
Geo-Cellular Model
Building Grid Topology: Lateral Connections
Building Grid Topology: Lateral Connections
1) Lateral Connections and flow area by geometric intersection

Layer 3
Layer 10
Layer 11
Layer 12

Layers 10, 11, and 12 connect to layer 3.

2) Lateral Connections by layer, flow area by layer geometry

Layer 3
Layer 12

Layers 12 ends (pinches out), no connection to layer 3.
Interaction with MODFLOW-USG

1) Write discretization package arrays
2) Write LPF/UPW arrays
3) Write starting head
4) Return number of cell in each layer
5) Return top most active cells
6) Return edge cells
7) Write constant head package
8) Write RIV1 and ET packages
9) Create polygon FC from geo-cells
10) Create cross section
11) Read MF-USG solution head file and create water-table grid and saturated outcrop.
Example
Next Steps?

1) Ghost Node Placement and Calculation

2) Connected Linear Network Support

3) Transient stress packages