

SEEP2D & GMS:

Simple Tools for Solving a Variety of Seepage Problems

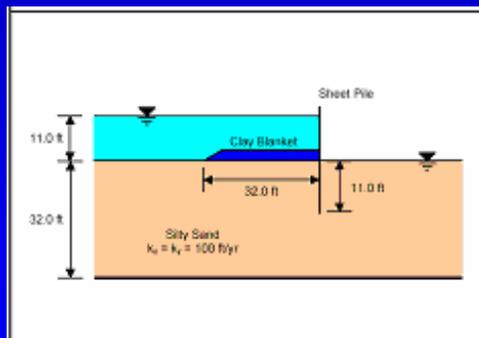
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Eileen Glynn, ERDC-GSL

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Earl Edris, ERDC-CHL



SEEP2D

- 2-D finite element seepage model
- Written by Fred Tracy, USACE-ERDC-ITL, published 1973
- Late 1970s – Dr. Tracy published groundbreaking work on visualization and pre- and post-processing for FEM models.
- Simple, mesh-based interface for SEEP2D first included in GMS v2.1, 1998.
- **NEW!** GMS v6.0 (2005) has a newly updated map-based interface



SEEP2D Applications

- **Isotropic/anisotropic soil properties**
- **Confined/unconfined profile models**
- **Saturated/unsaturated flow for unconfined profile models**
- **Confined flow for plan (areal) models**
- **Flow simulation in the saturated and unsaturated zones**
- **Heterogeneous soil conditions**
- **Axisymmetric models such as flow from a well**
- **Drains**



SEEP2D cannot simulate...

- **Transient or time varying problems**
- **Unconfined plan (areal) models**



Governing Equation

$$\nabla \cdot (K \cdot \nabla h) = 0$$



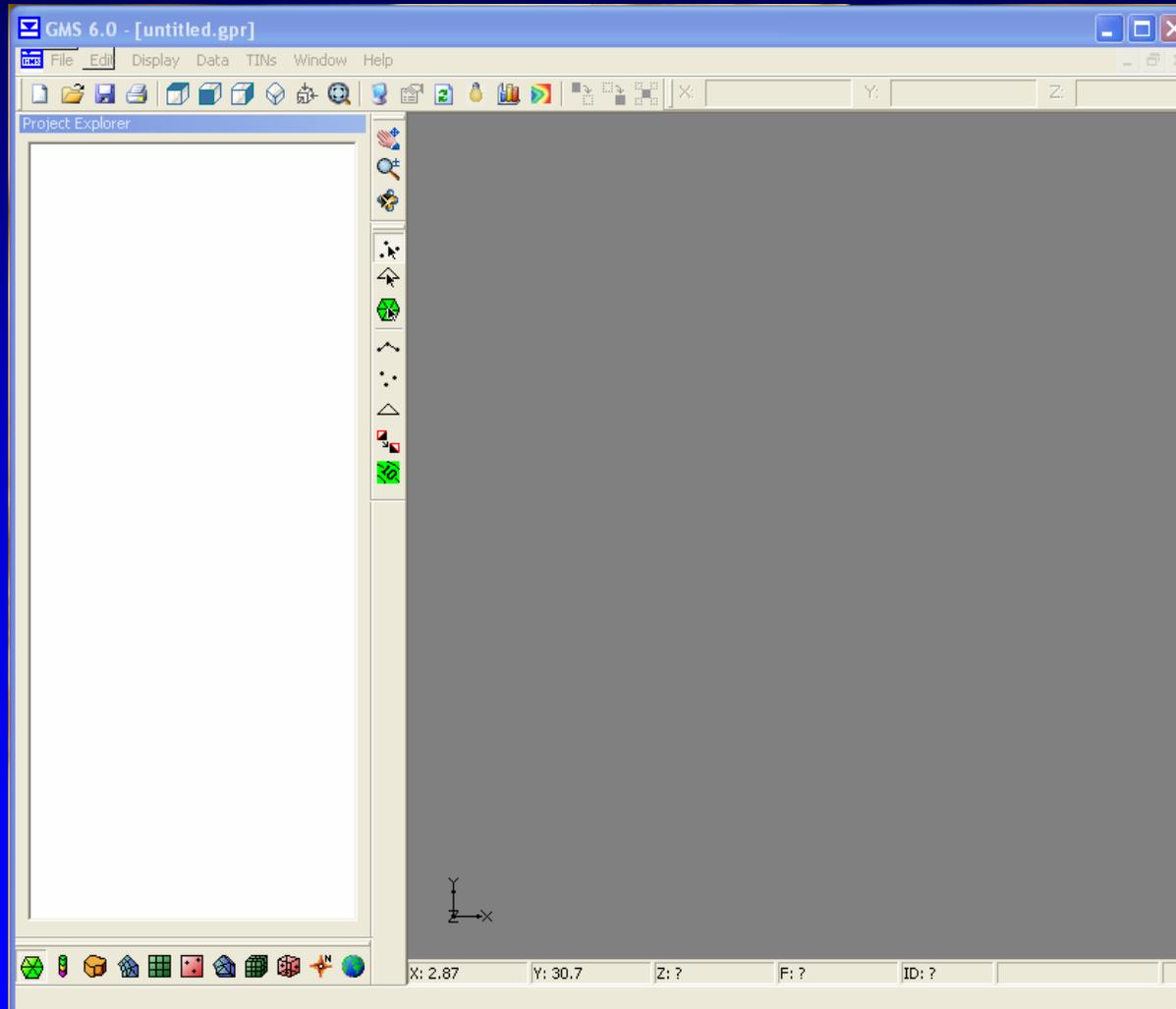
$$\frac{\partial}{\partial x} \left(K_{xx} \frac{\partial h}{\partial x} + K_{xy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial y} \left(K_{yy} \frac{\partial h}{\partial y} + K_{yx} \frac{\partial h}{\partial x} \right) = 0$$

h = total head (elevation + pressure head)

K = hydraulic conductivity



Department of Defense Groundwater Modeling System (GMS)

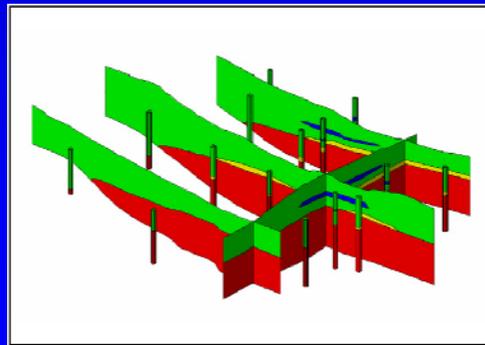


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Groundwater Modeling System (GMS)

- 3D sub-surface characterization for groundwater modeling
- Supports 2D and 3D FEM, FDM, and analytic codes
- Incorporates advanced 3D post-processing visualization tools
- Supported Models
 - MODFLOW2000
 - MODPATH
 - FEMWATER
 - WASH123D
 - ADH
 - **SEEP2D**
 - ART3D
 - SEAM3D
 - MT3DMS
 - RT3D
 - UTCHEM
 - MODAEM





GMS Quick Facts

- **First version released late 1994**
- **Current version is v6.0**
- **Developed by consortium of federal, academic & private concerns**
- **Graphical interface by EMRL at BYU**
- **Over 700 Fed Gov't users and thousands more in over 90 countries**



Obtaining GMS

- Employees of DoD, DoE, NRC, EPA and their on-site contractors can obtain free licenses for GMS at <http://chl.erd.c.usace.army.mil/gms>.
- Groundwater Modeling Technical Support Center at ERDC handles GMS user support and training.
- Others can purchase licenses by contacting EMS-I at <http://www.ems-i.com>.



The GMS download comes with the SEEP2D executable and source code, two SEEP2D tutorials and the SEEP2D documentation.

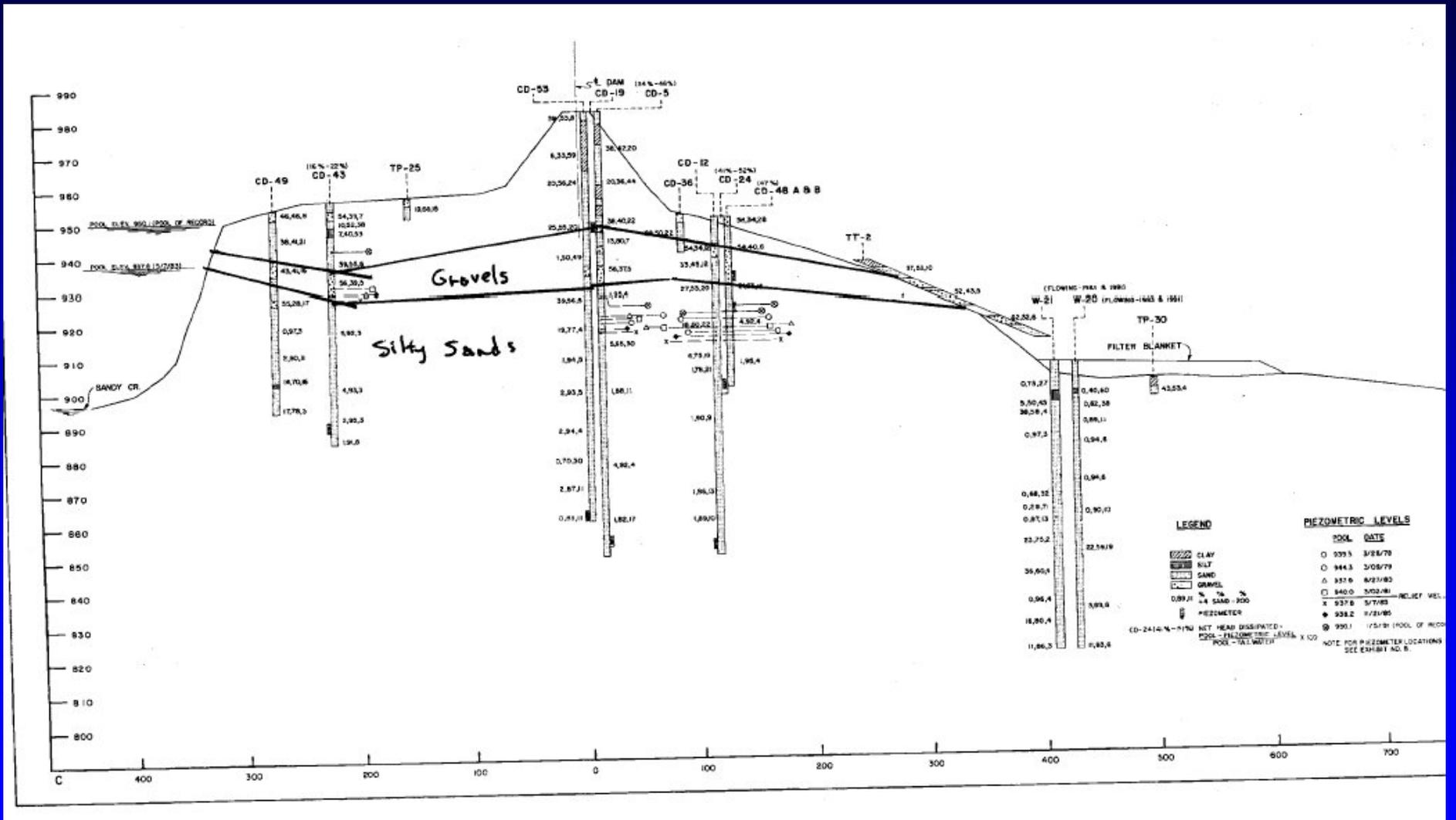


Setting Up a SEEP2D Simulation in GMS

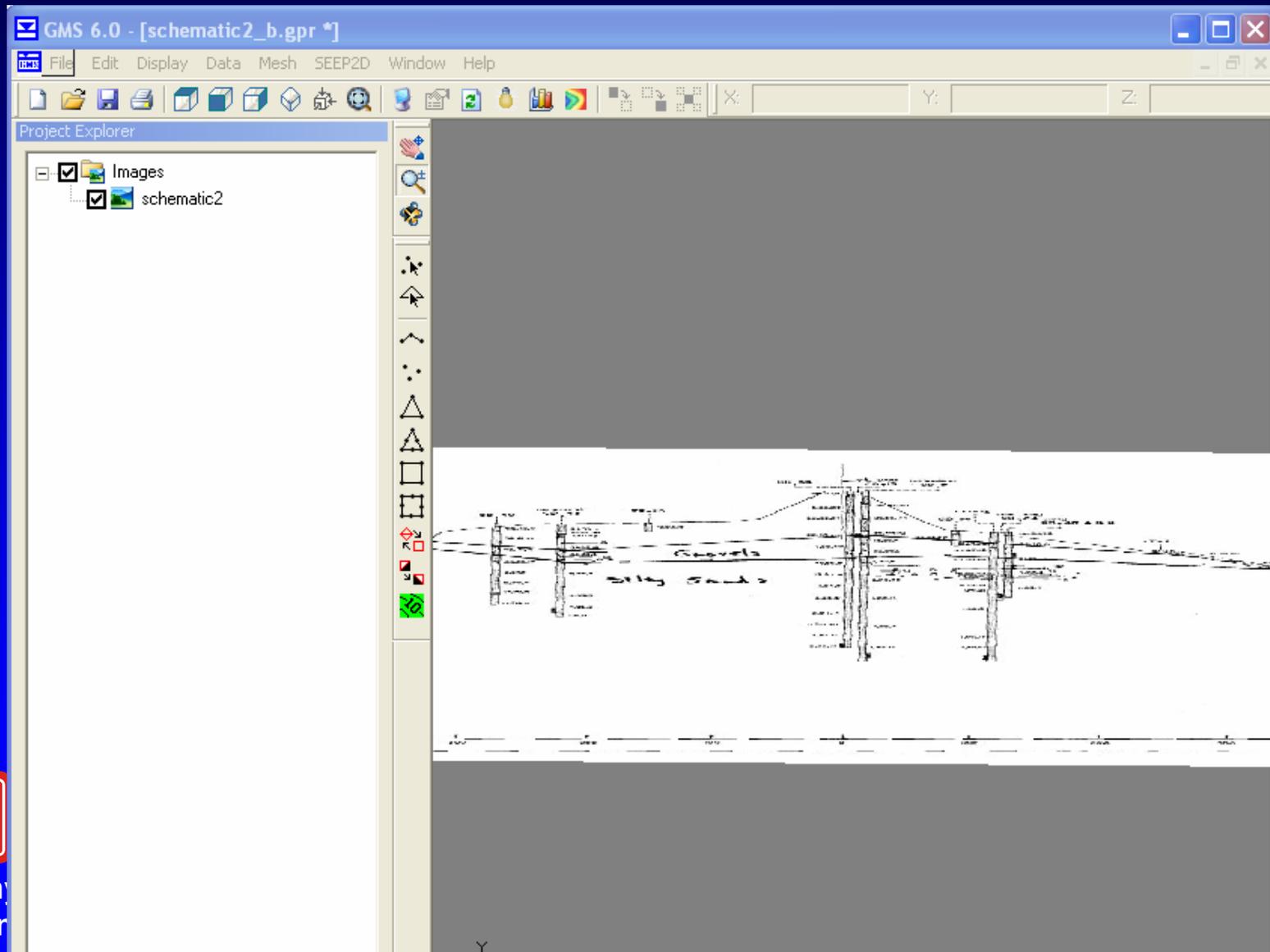
- 1. Set up Conceptual Model**
 - a) Set up domain**
 - b) Assign soil properties**
 - c) Redistribute vertices**
 - d) Assign boundary conditions**
- 2. Build Computational Mesh**
- 3. Map Boundary Conditions**
- 4. Run**
- 5. View Results**



Sample Problem



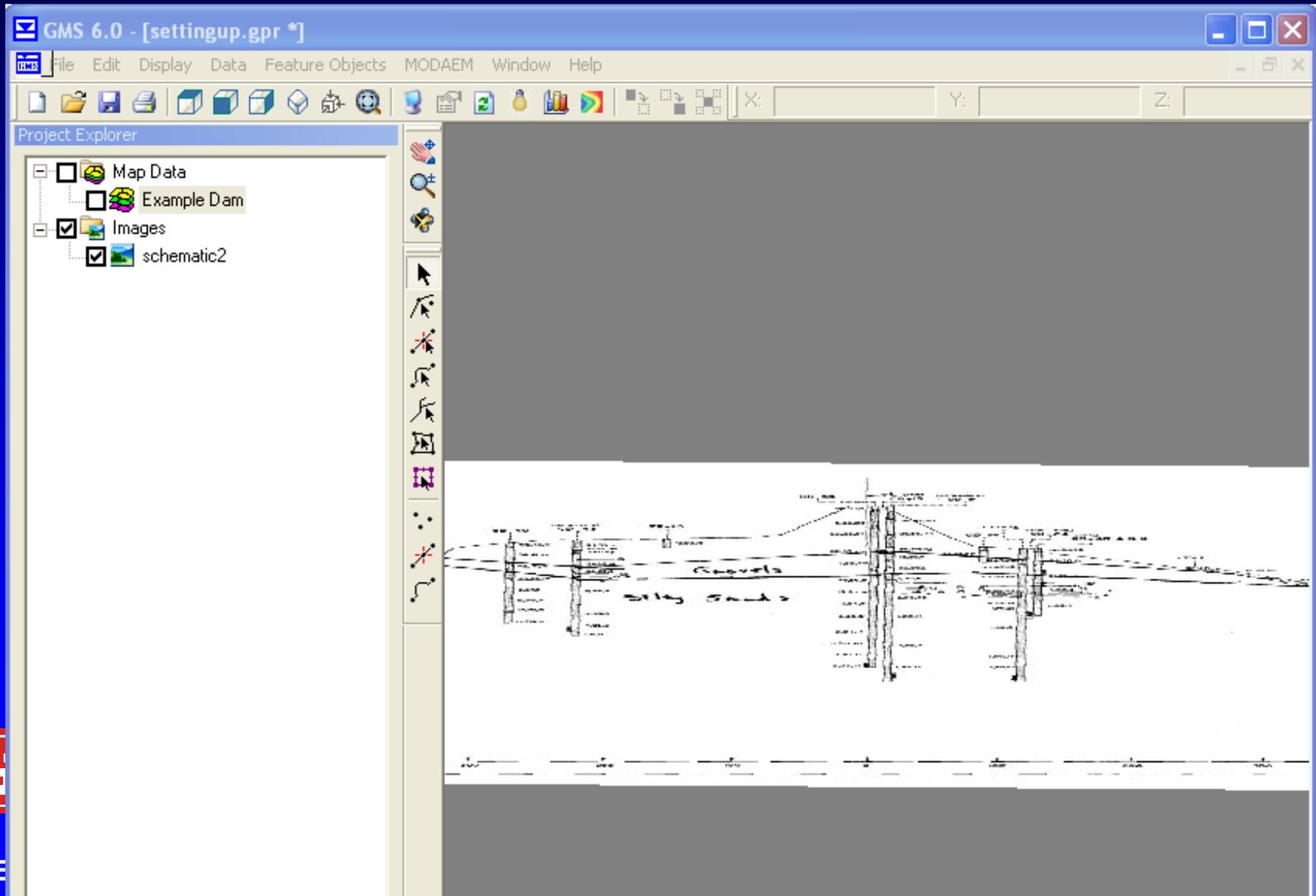
Import Image



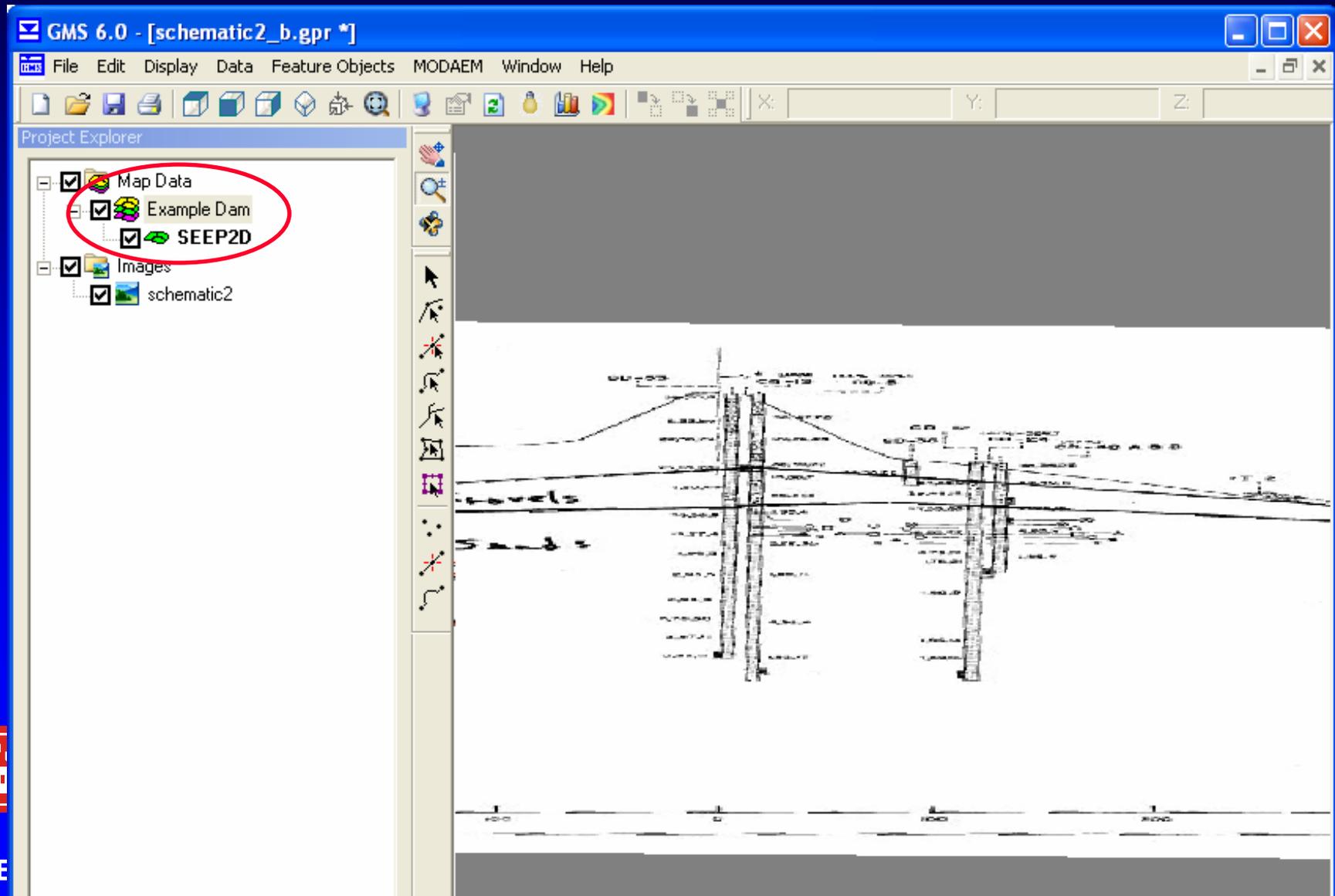
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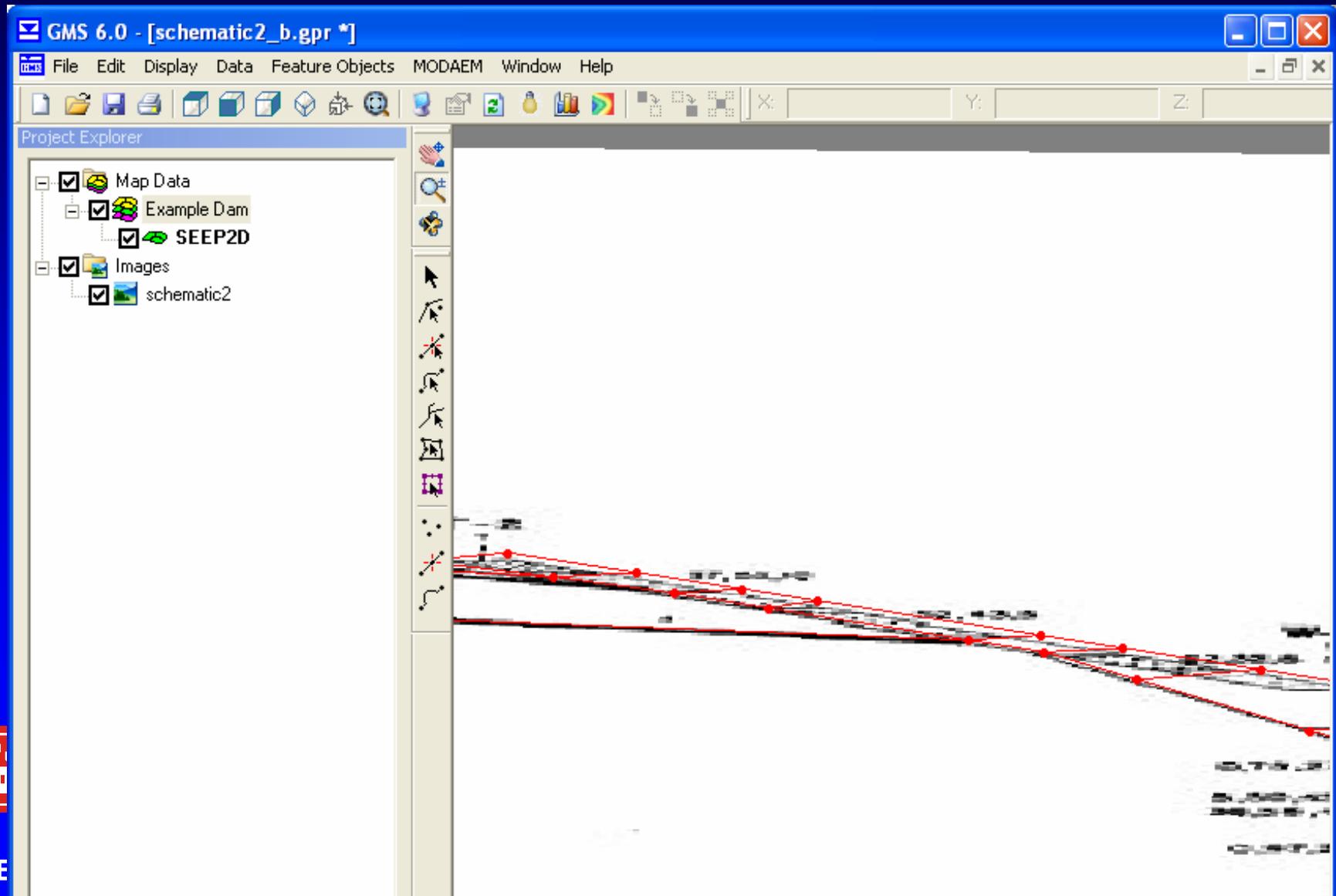
Create Conceptual Model



Create Coverage



Set Up Domain



Create Material Types

The screenshot shows the GMS 6.0 interface with the 'Material Properties' dialog box open. The dialog is titled 'Material Properties' and has a close button (X) in the top right corner. It is divided into two tabs: 'MODFLOW' and 'SEEP2D', with 'SEEP2D' currently selected. On the left side of the dialog, there is a table listing material types:

Name	Id
clay	1
gravel	2
siltsand	3
filter_blanket	4

Below the table are buttons for 'New', 'Delete', and 'Copy', and 'Move Up' and 'Move Down'. There is also a 'Global options' section with a 'Material color / pattern' dropdown (set to a blue square) and a 'Pattern scale' input field (set to 50). A checkbox for 'Display material legend' is present and unchecked. The right side of the dialog contains several parameter groups:

- Soil Coefficients:** k1: 1.0 (ft/d), k2: 1.0 (ft/d), Angle: 0.0
- Van Genuchten saturated/unsaturated parameters:** Van Genuchten alpha: 0.0 (1/ft), Van Genuchten n-value: 0.0
- Saturated/Unsaturated modeling with linear front:** ho value: -1.0 (ft), kro value: 0.01

A context menu is open over the 'Materials...' option in the left sidebar, showing options like 'Delete', 'Select All', 'Unselect All', 'Select With Poly', 'Select From List', 'Properties...', 'Materials...', 'Units...', 'Coordinate System...', 'Coordinate Transfo...', 'Single Point Transfo...', 'Preferences...', 'Screen Capture', and 'Paste Text'. A mouse cursor is pointing at the 'filter_blanket' material in the table.



Assign Material Properties

The screenshot shows the GMS 6.0 interface with the 'Material Properties' dialog box open. The 'Materials' list in the dialog is circled in red, and the 'Materials...' menu option in the main application is highlighted. The dialog box contains the following information:

Name	Id
clay	1
gravel	2
siltsand	3
filter blanket	4

Global options:

- Material color / pattern:
- Pattern scale: 50
- Display material legend

MODFLOW SEEP2D

Soil Coefficients:

- k1: 90.0 (ft/d)
- k2: 90.0 (ft/d)
- Angle: 0.0

Van Genuchten saturated/unsaturated parameters:

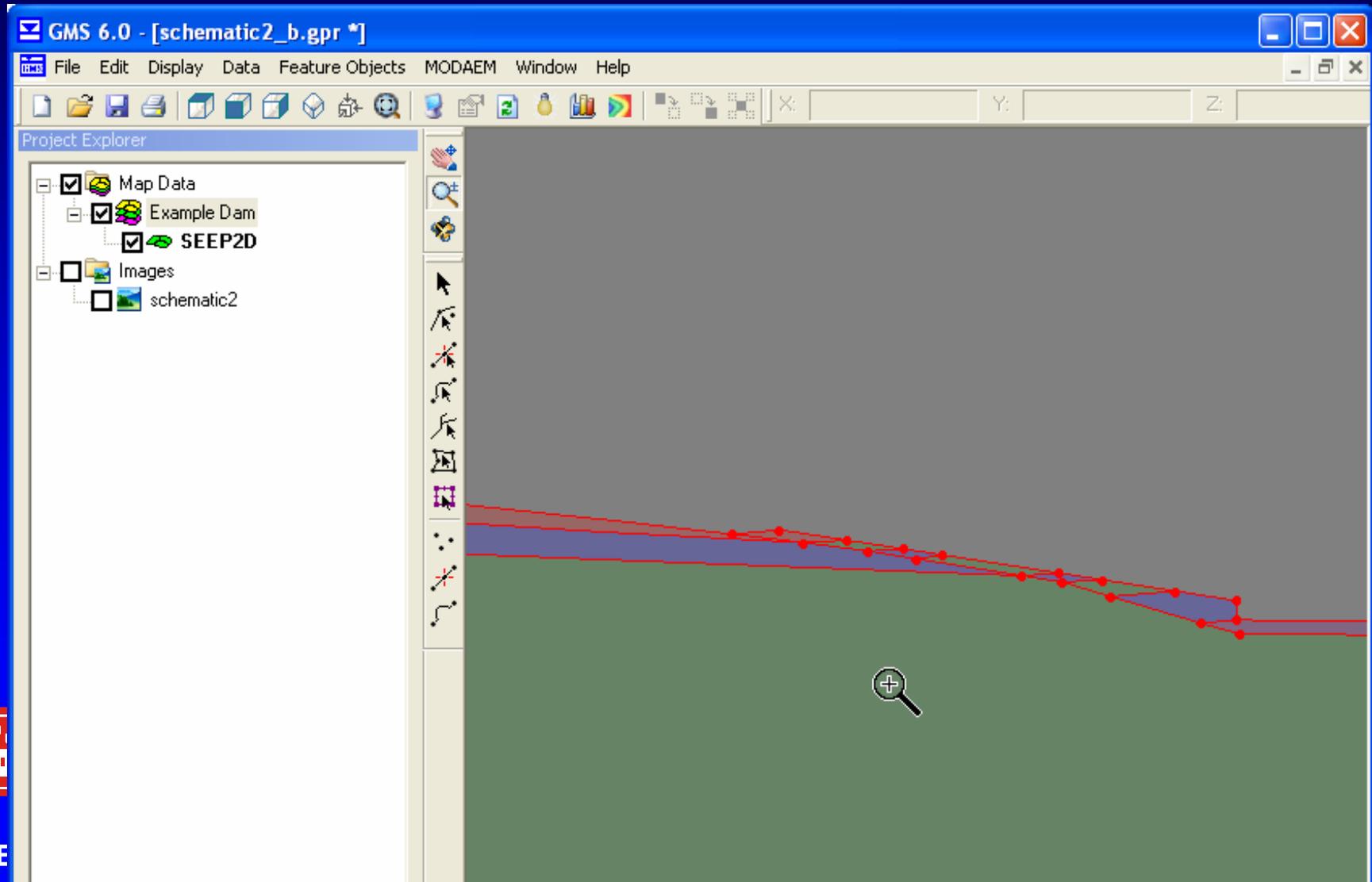
- Van Genuchten alpha: 4.42 (1/ft)
- Van Genuchten n-value: 2.68

Saturated/Unsaturated modeling with linear front:

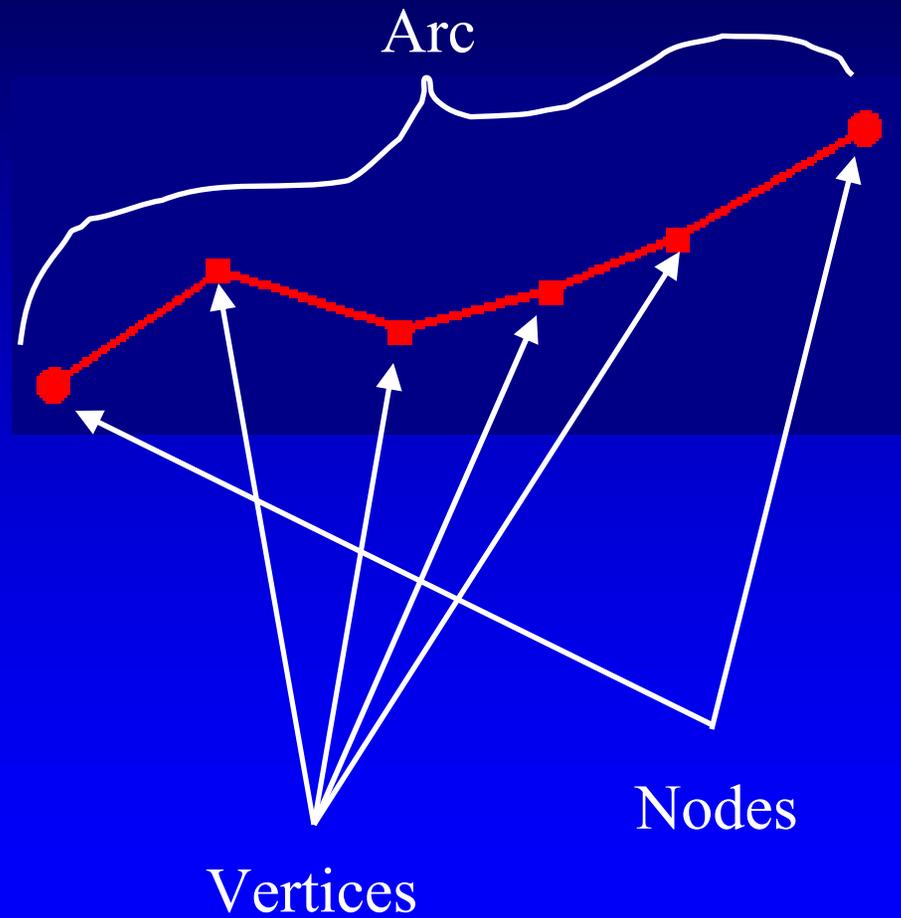
- ho value: -0.39 (ft)
- kro value: 0.001



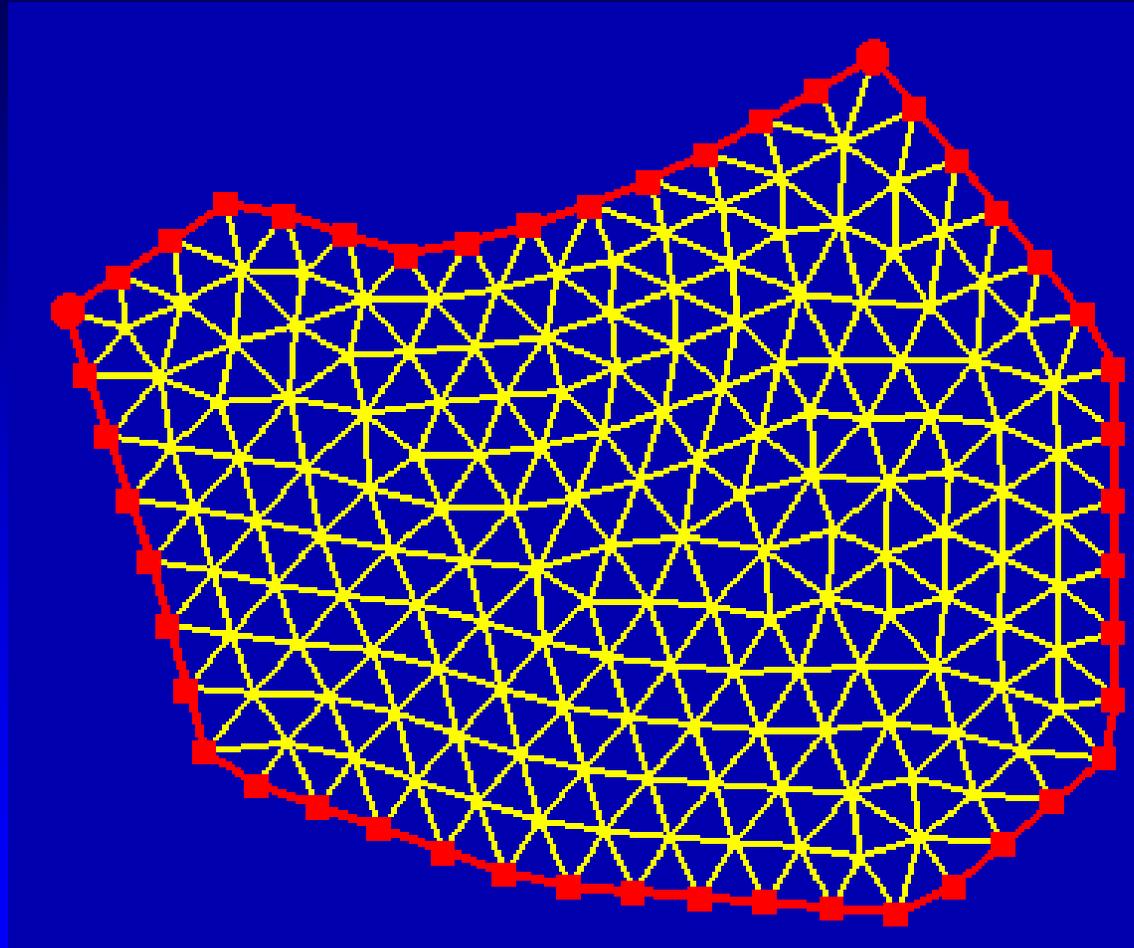
Assign Materials to Polygons



Redistribute Vertices



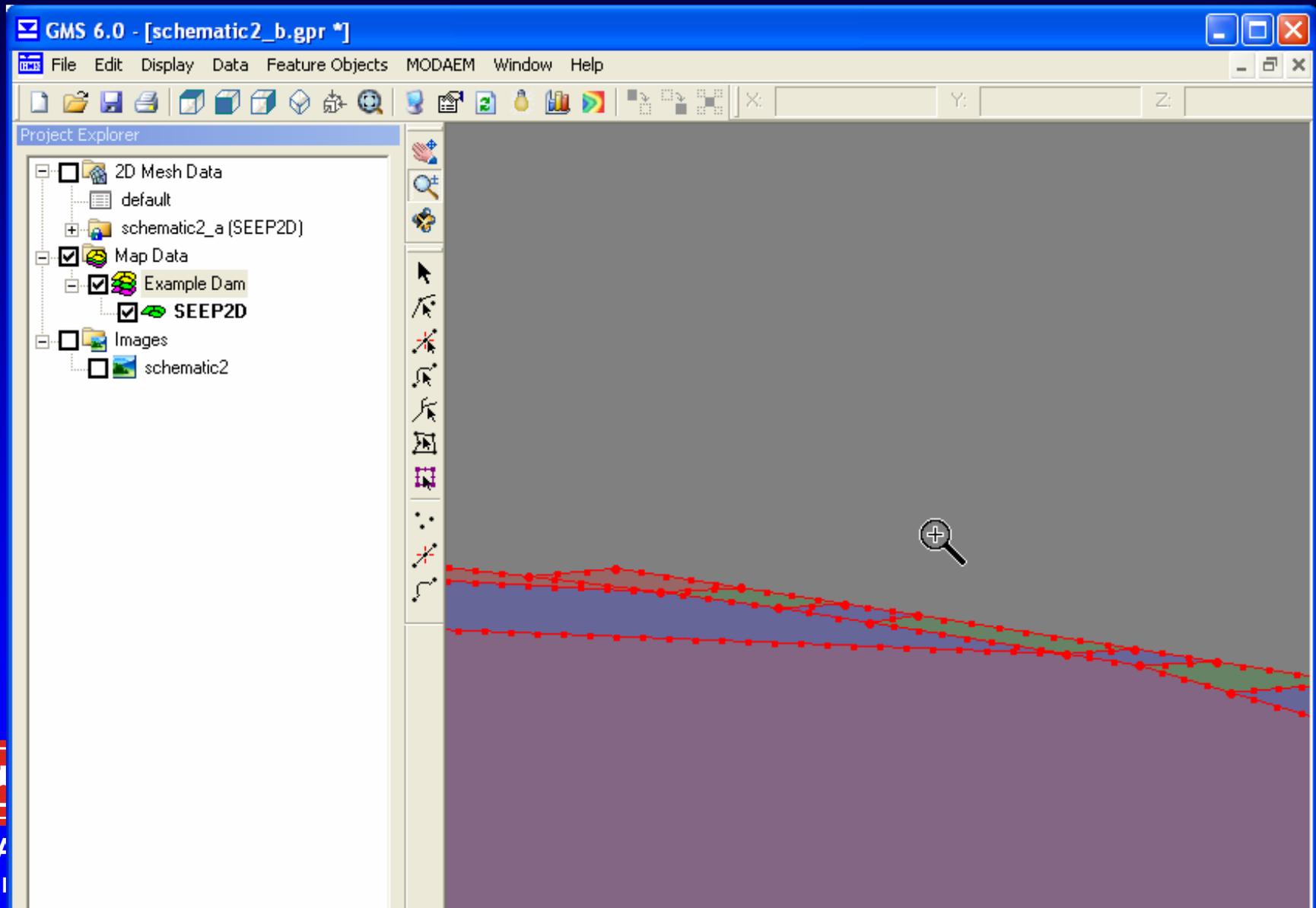
Redistribute Vertices



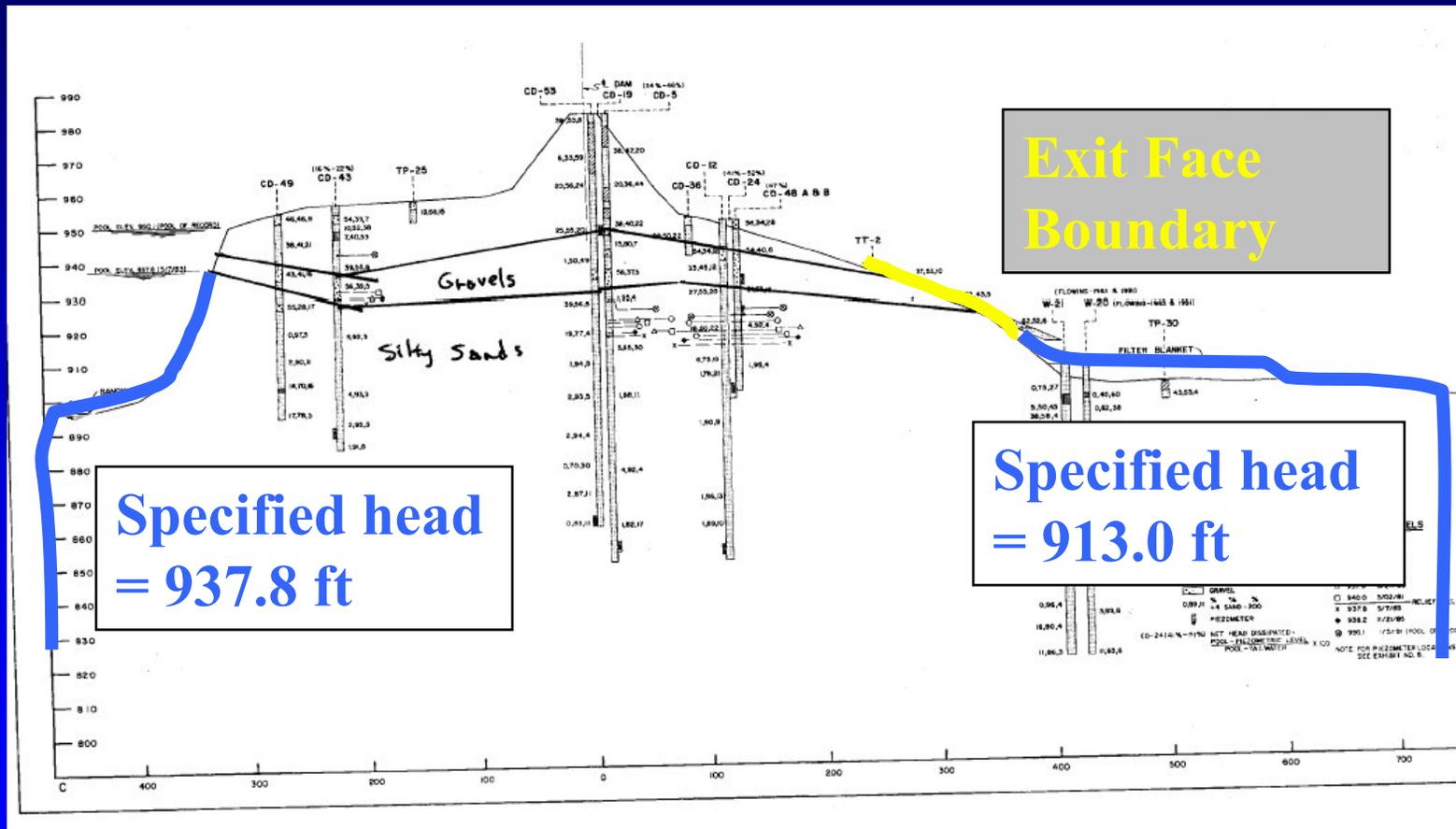
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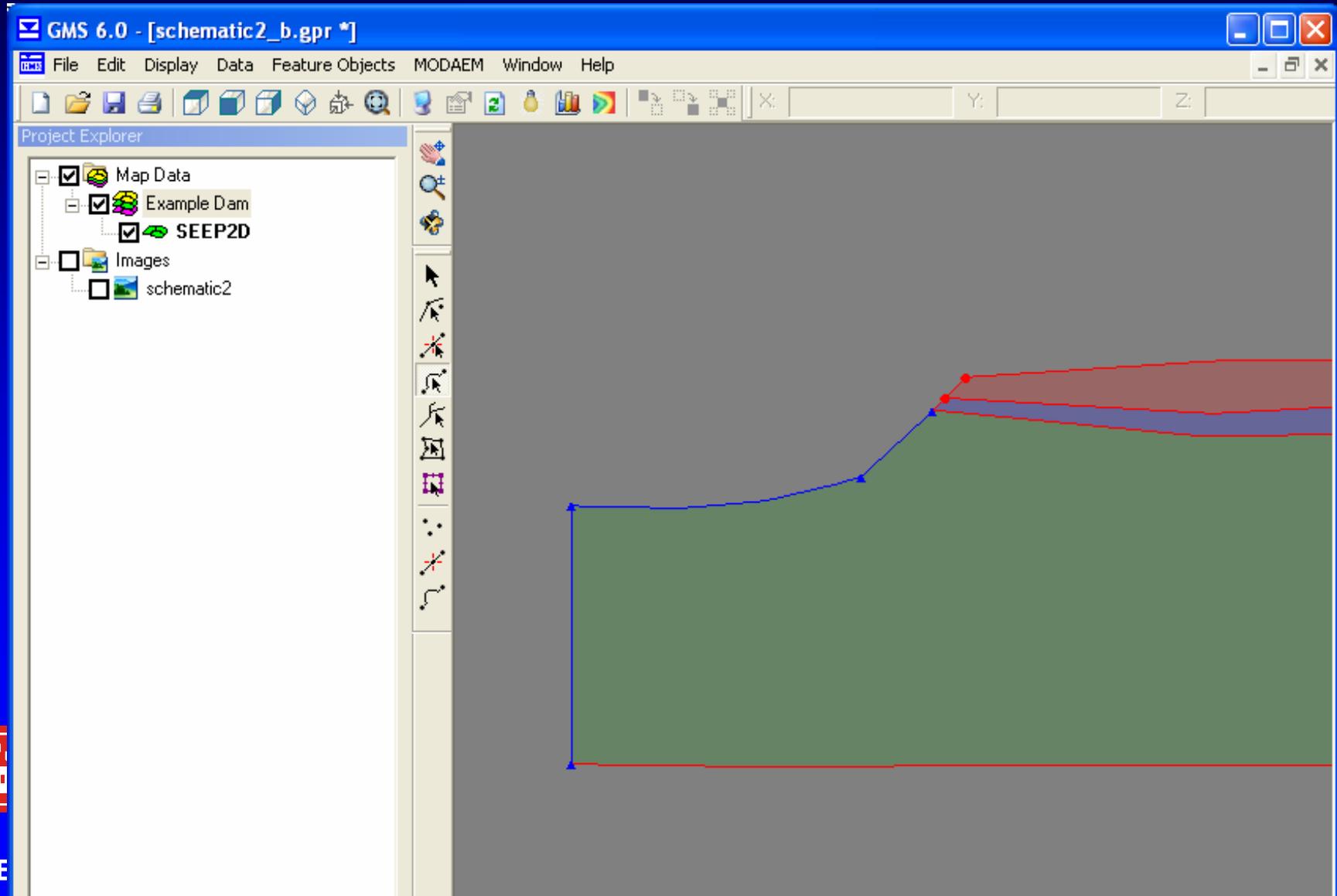
Redistribute Vertices



Assign Boundary Conditions



Assign Boundary Conditions



Assign Boundary Conditions

The screenshot displays the GMS 6.0 interface with a schematic model open. The Project Explorer on the left shows a tree structure with 'Map Data', 'Example Dam', 'SEEP2D', 'Images', and 'schematic2'. The main window shows a 3D schematic of a dam cross-section with various layers and boundary conditions. A 'Properties' dialog box is open, showing the 'Nodes' feature type and a table of node properties.

Feature type: Nodes Show: Selected BC type:

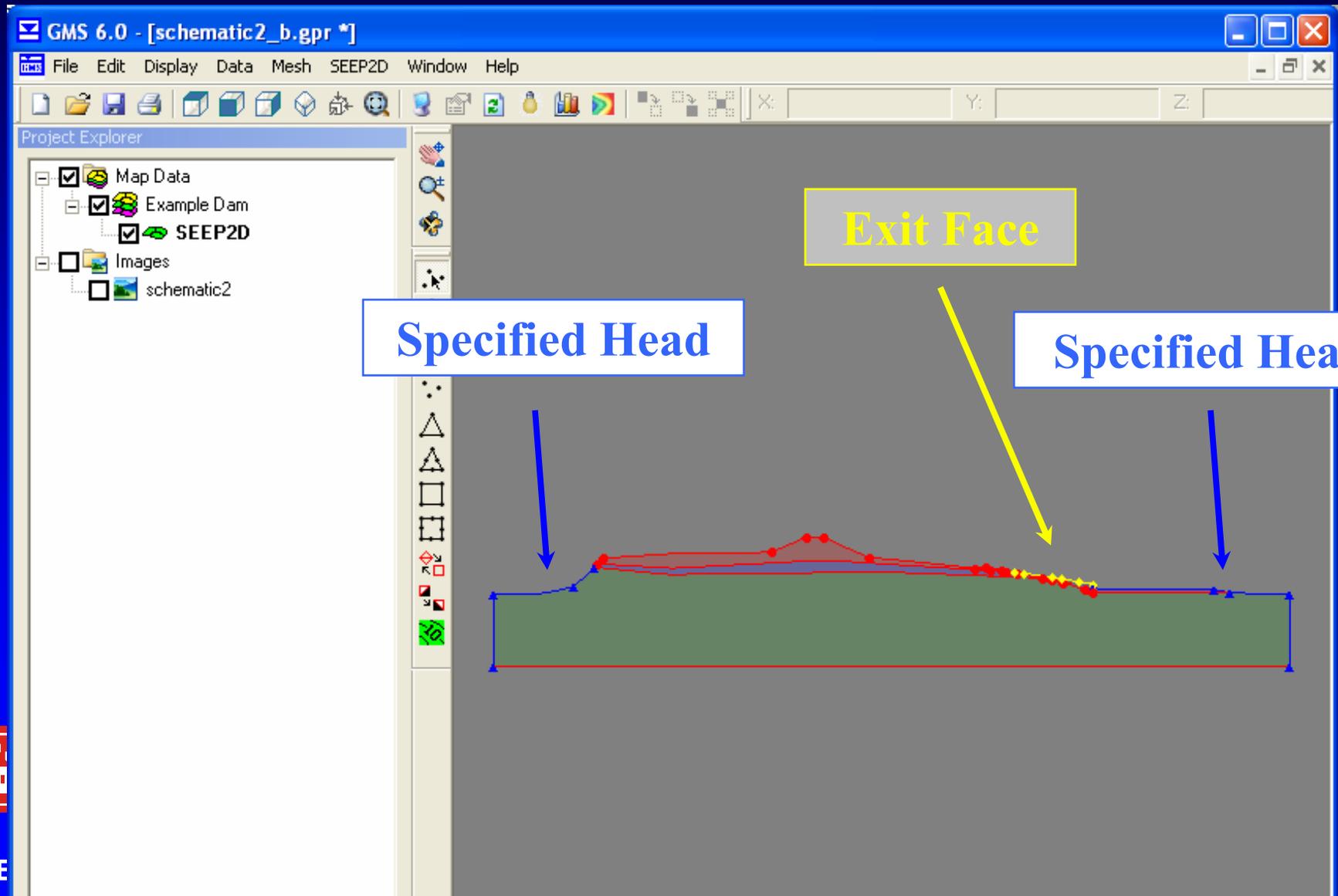
Show point coordinates

ID	Type	Head (ft)
All		973.8
18	head	973.8
19	head	973.8
31	head	973.8
35	head	973.8

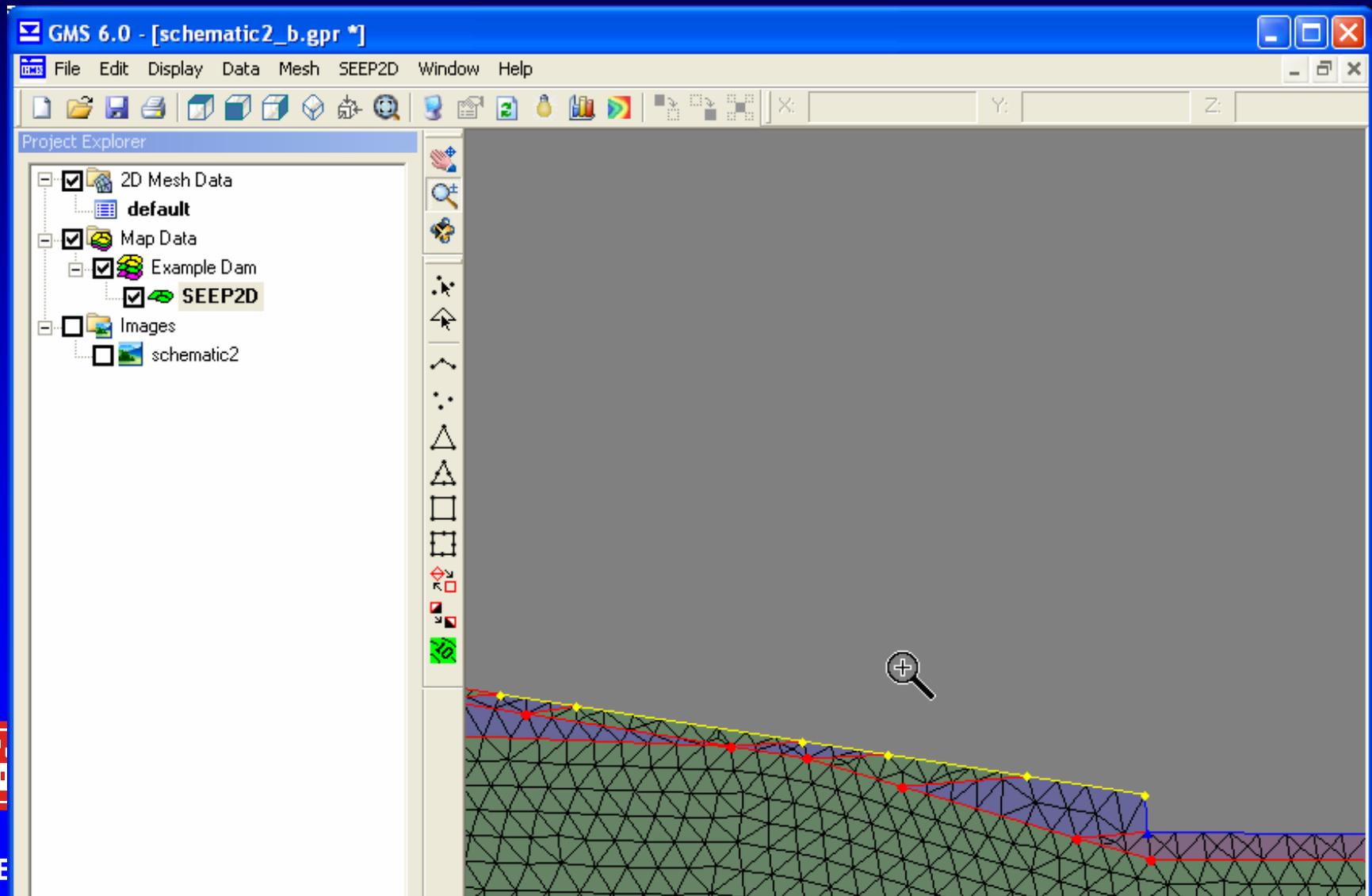
Buttons: Help... Add Point Delete Point OK Cancel



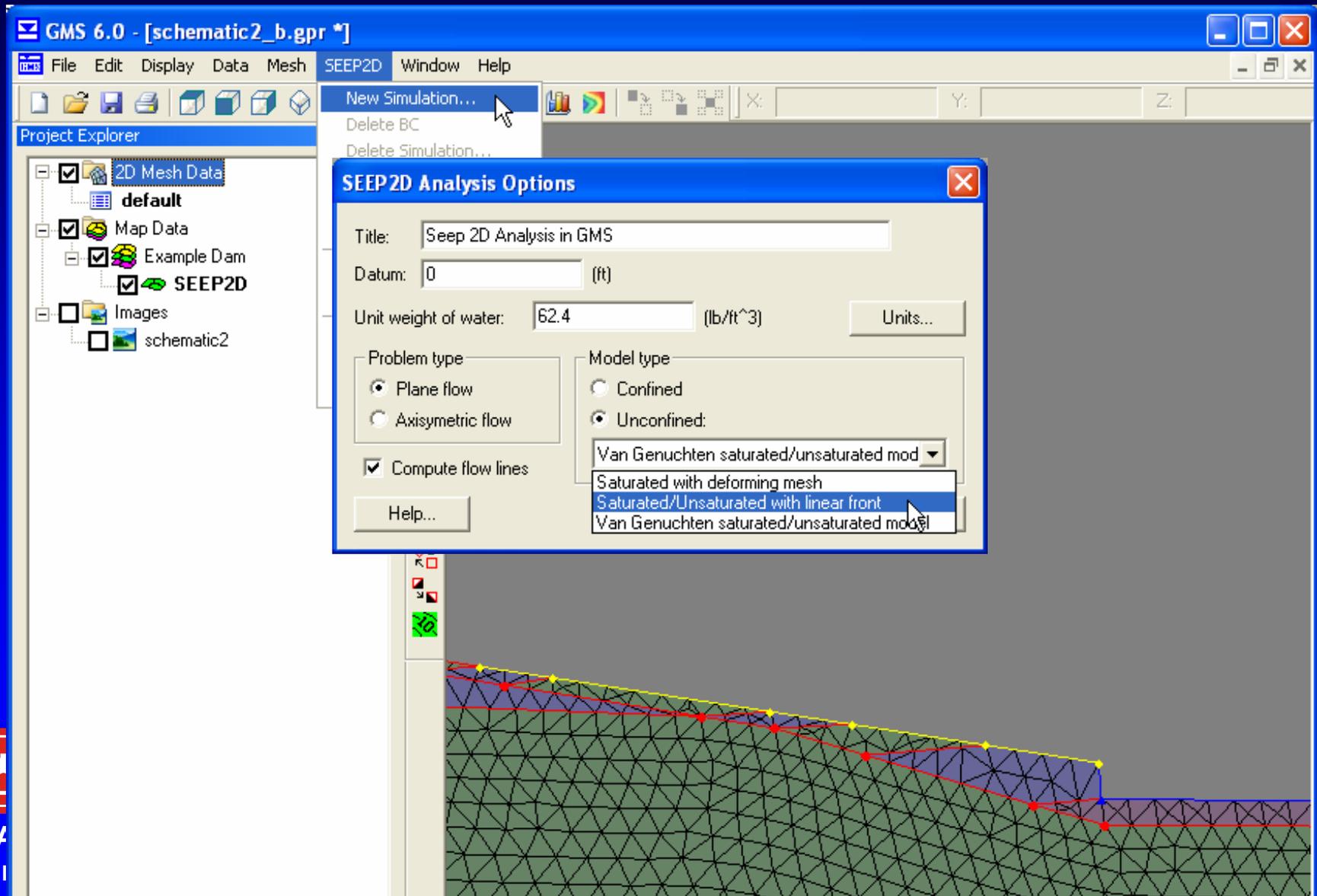
Assign Boundary Conditions



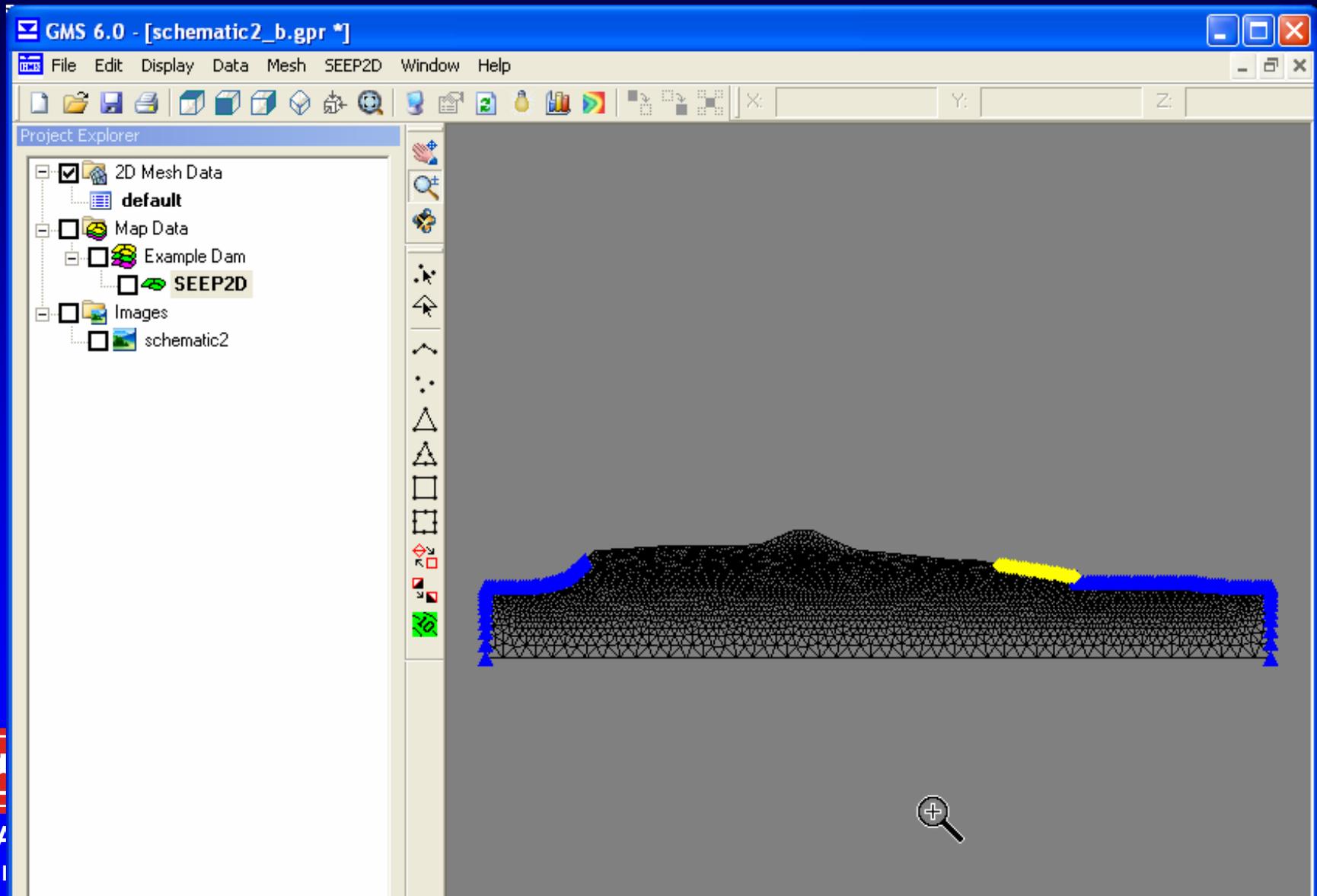
Build Computational Mesh



Initialize SEEP2D Simulation

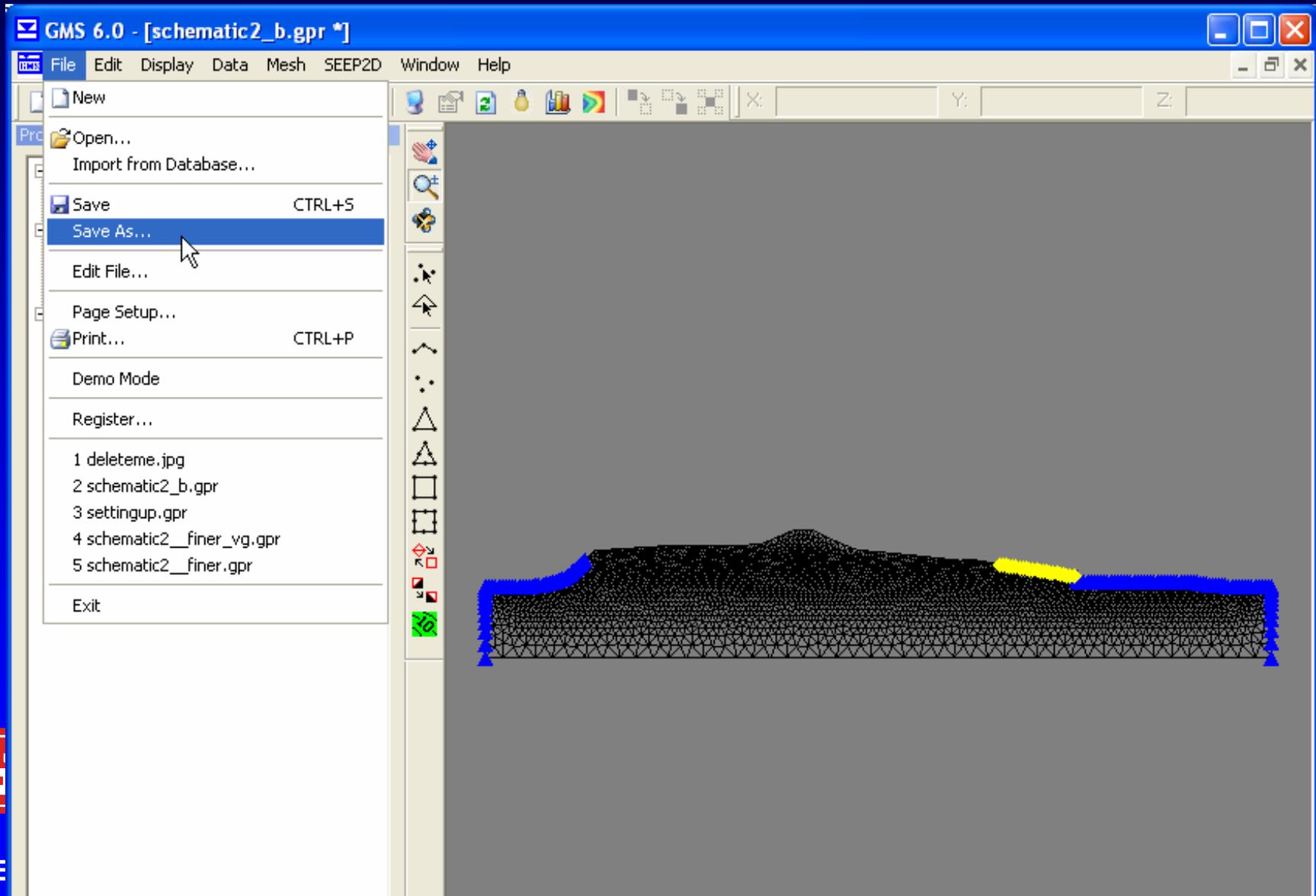


Map Boundary Conditions



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Save the Simulation



Run SEEP2D

GMS 6.0 - [schematic2_c.gpr]

File Edit Display Data Mesh SEEP2D Window Help

Project Explorer

- 2D Mesh Data
- default
- Map Data
- Example Dam
 - SEEP2D
- Images
- schematic2

Seep2d

C:\Program Files\GMS51_4_05b\models\seep2d.exe
C:\Projects\seep2d\schematic2_c_SEEP2D\schematic2_c.sps

Finished
Elapsed Time: 0 hrs 0 min 14 sec

```
Executable started

Entering seepage analysis
Reading nodes
Reading elements
Solving for heads
Iteration no. =      1   Delta h max. =  1.0000000000000000E+030
Iteration no. =      2   Delta h max. =  0.525265736743108
Iteration no. =      3   Delta h max. =  0.204127342383913
Iteration no. =      4   Delta h max. =  7.486838260069817E-002
Iteration no. =      5   Delta h max. =  4.411613342019336E-002
Iteration no. =      6   Delta h max. =  8.470116502962810E-003
Iteration no. =      7   Delta h max. =  3.670492603646380E-003
Solving for flow lines
Seep2D terminated successfully

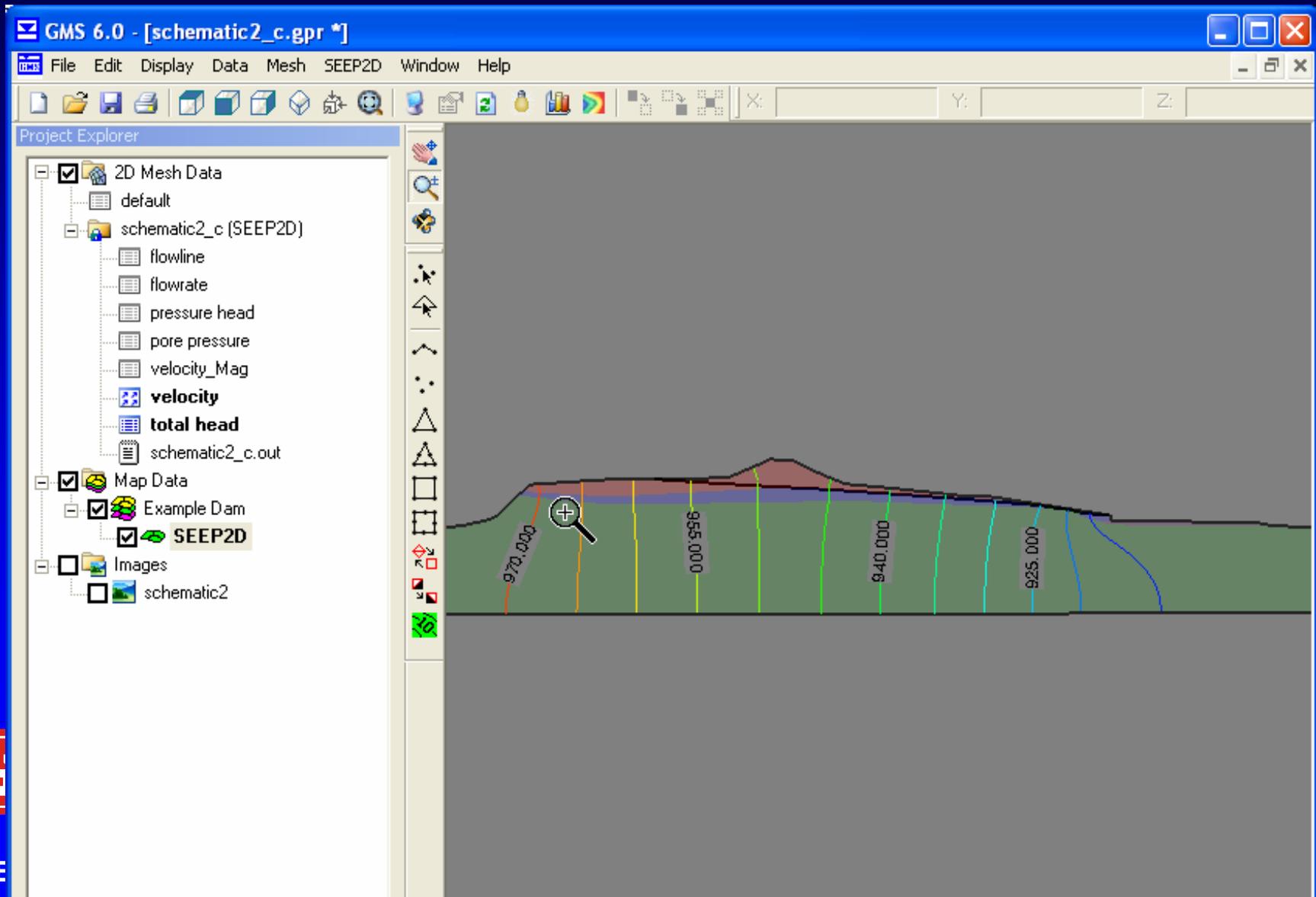
Seep2d finished.
```

Read solution on exit

Help... Close

US of E

View Results



Conclusion

- **SEEP2D is a fast, simple tool for seepage analysis.**
- **GMS provides a nice interface for setting up the problem and assigning boundary conditions.**
- **GMS also provides multiple options for viewing and analyzing the results.**
- **Best of all... SEEP2D and GMS are free for federal employees (DoD, DoE, EPA, NRC)**

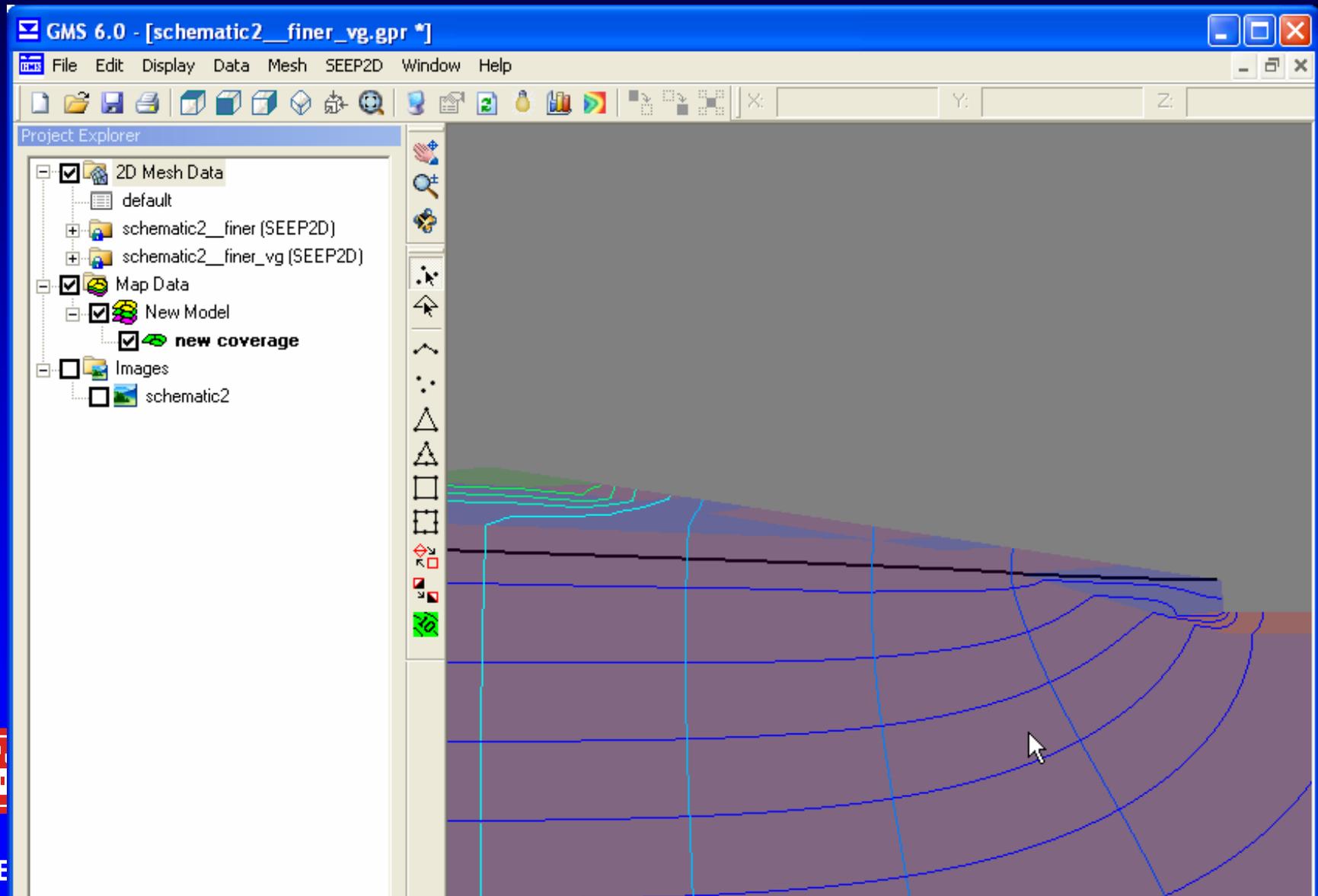


Issues to Consider:

- **Mesh resolution**
- **How to handle the unsaturated zone:**
 - **Linear Front**
 - **Van Genuchten parameters**



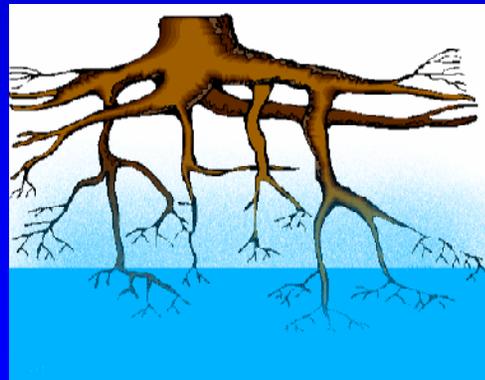
Mesh Resolution



Unsaturated Zone Flow

- Conductivities are lower than the saturated value and can be tied to the pressure head.
- SEEP2D calculates K_r , relative conductivity, and uses the following equation to determine the conductivity at each node having a negative pressure head:

$$- K = K_{\text{sat}} * K_r$$

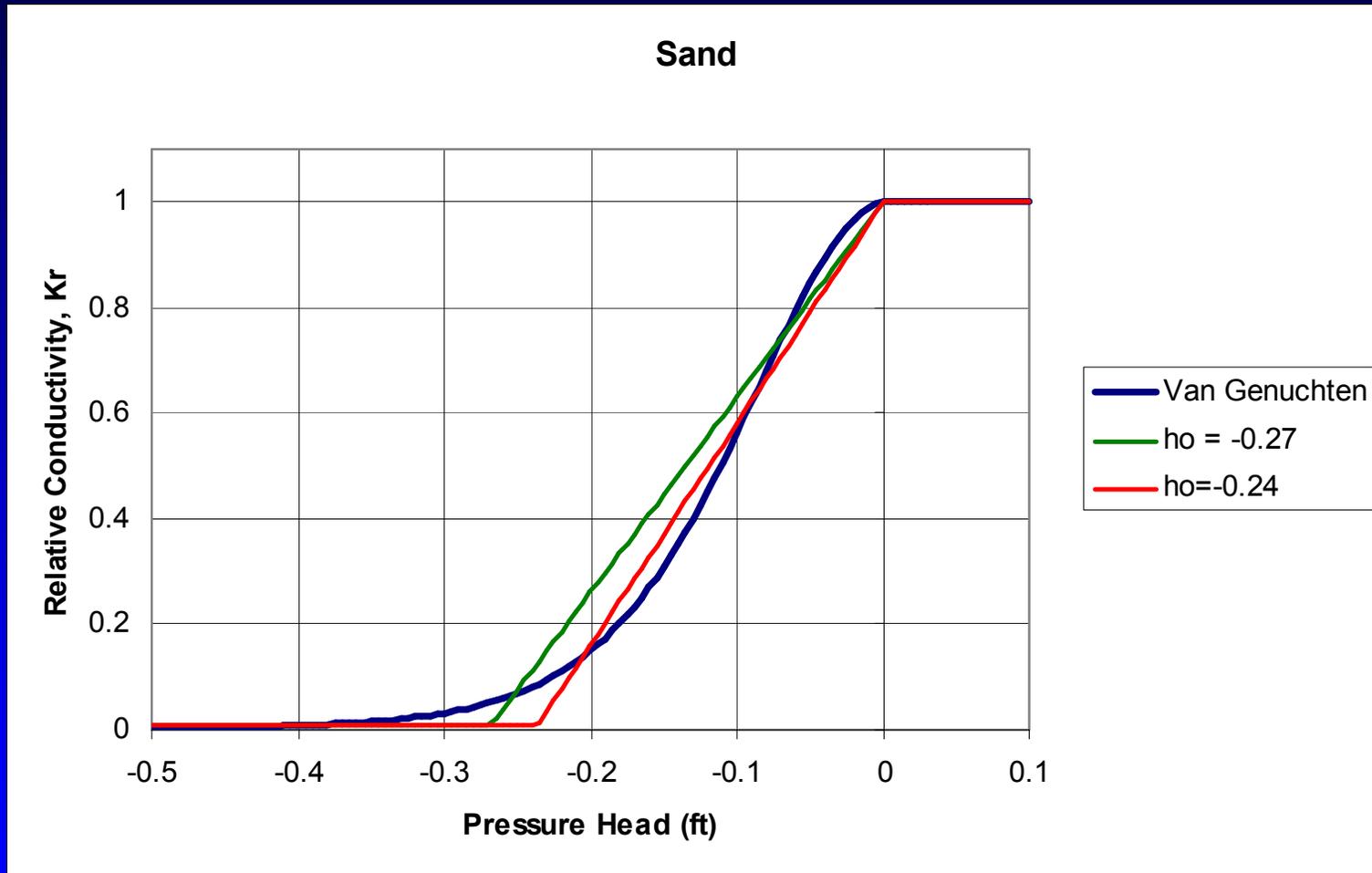


Unsaturated Zone Flow

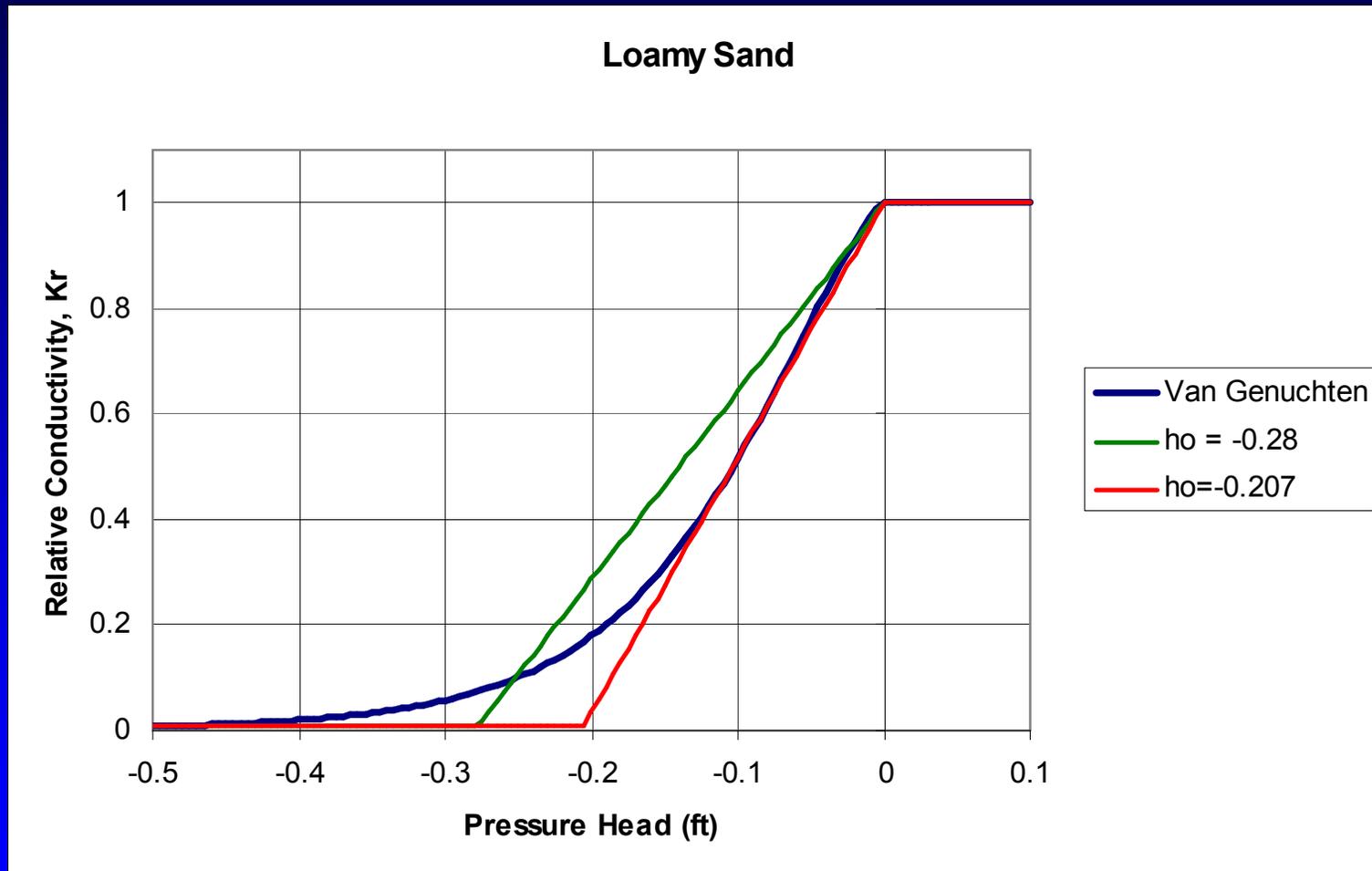
- Two ways to determine K_r :
 - Van Genuchten Parameters
 - User supplies α , n .
 - Estimated for several soil types in:
 - Carsel, F. F. and R. S. Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. *Water Resources Research* 24, no. 5:755-69.
 - Linear Approximation
 - User supplies h_o , K_{ro}



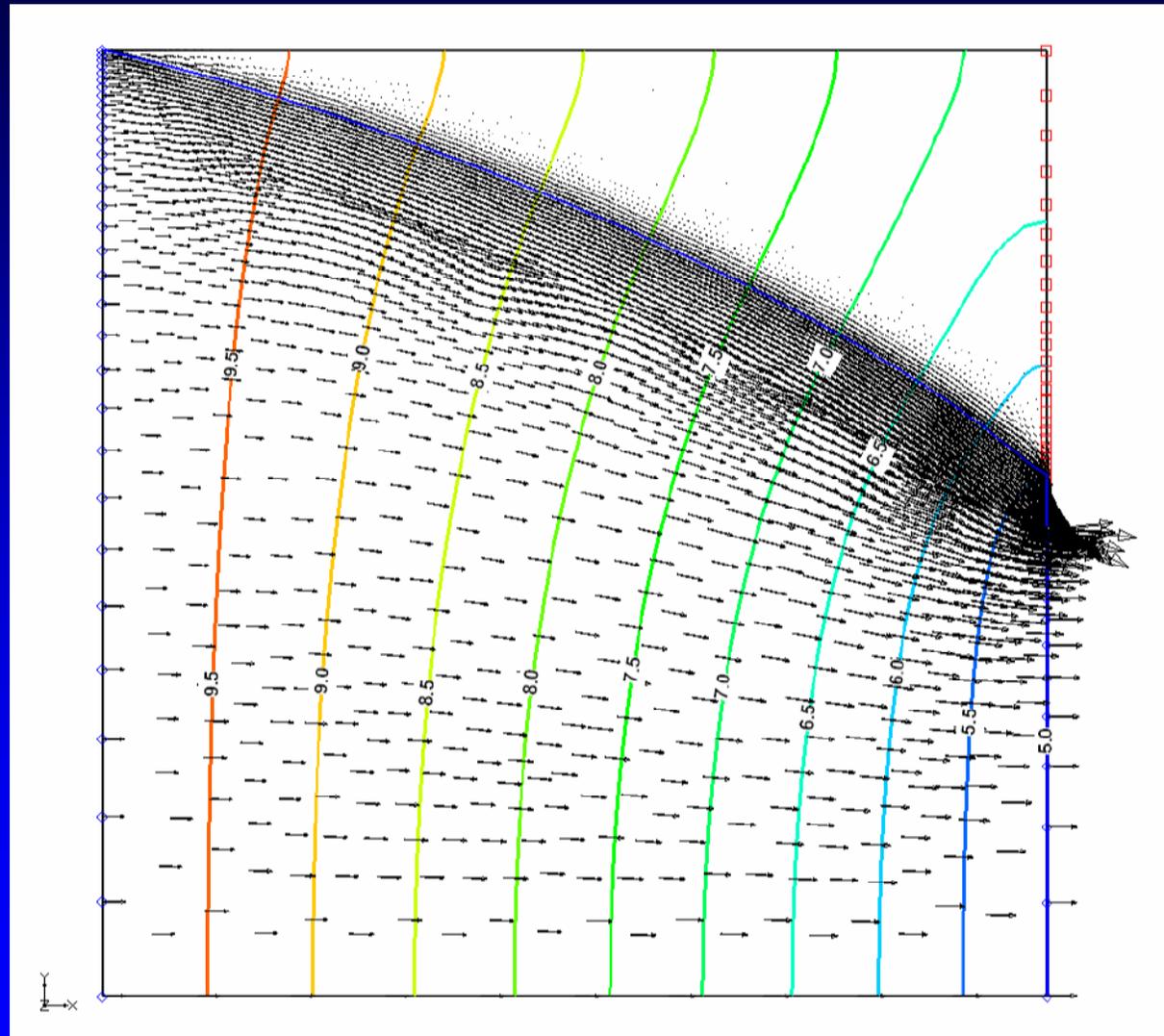
Unsaturated Zone Flow



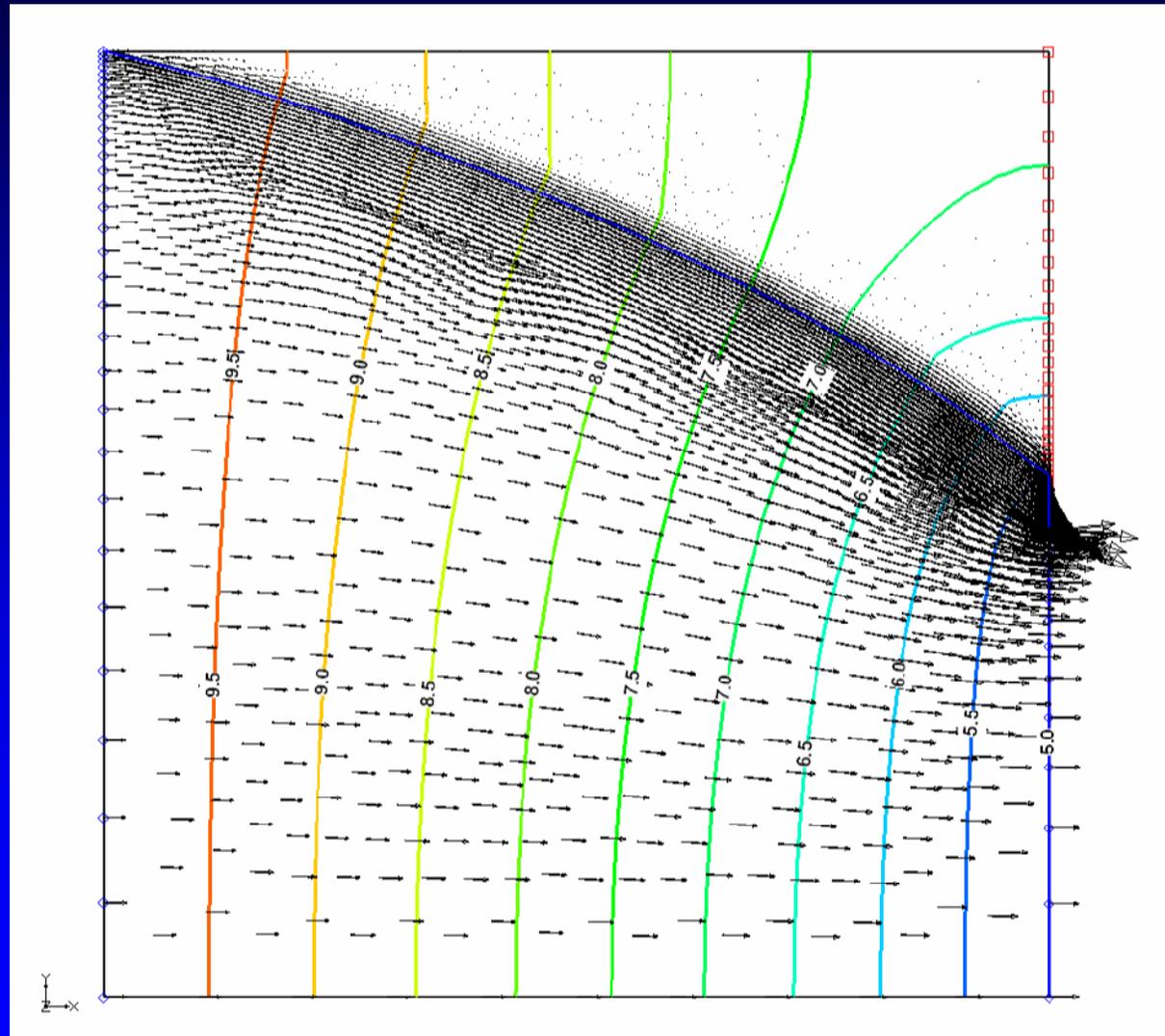
Unsaturated Zone Flow



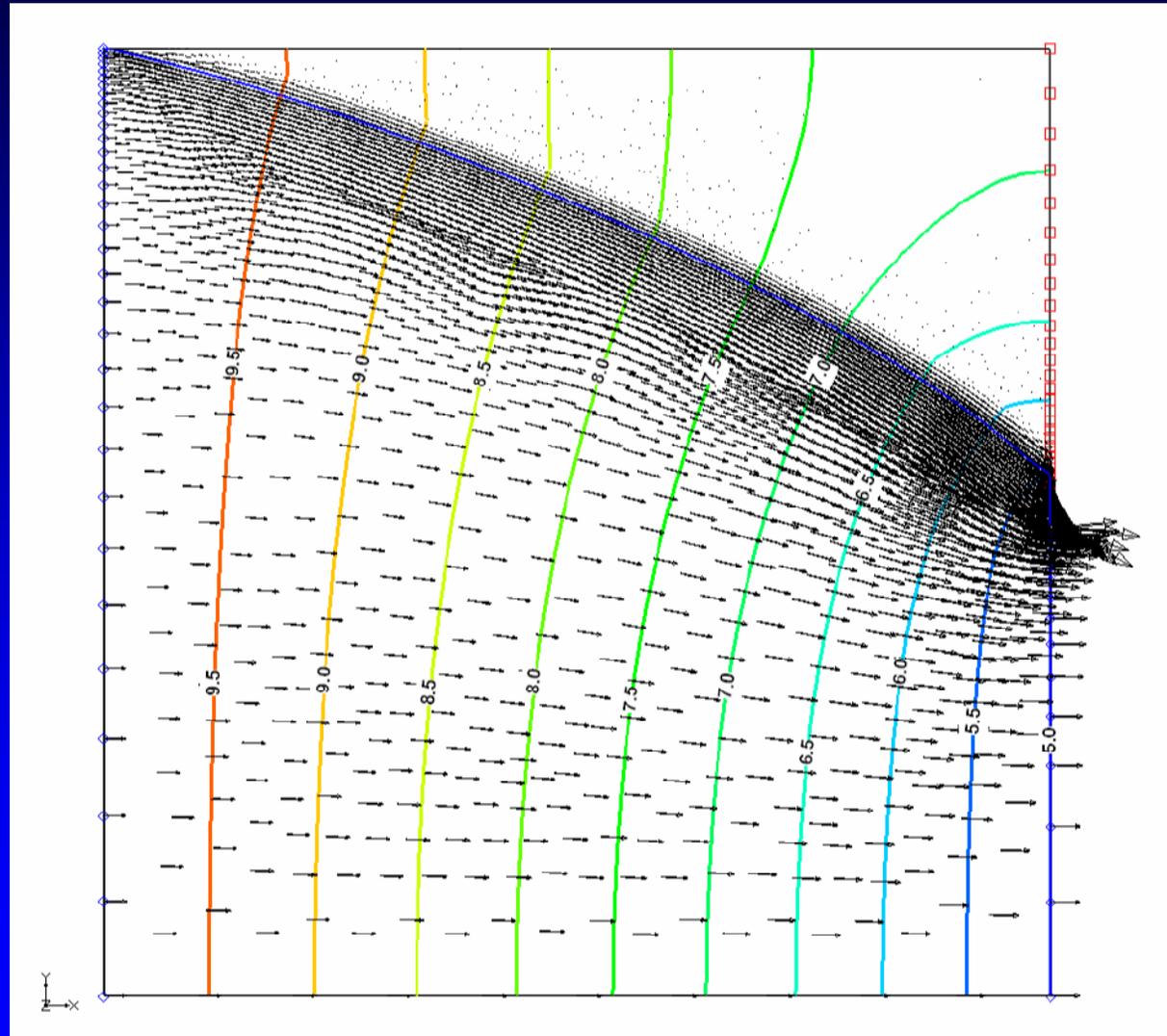
Loamy Sand – Van Genuchten



Loamy Sand – Linear, $h_o = -0.28$



Loamy Sand – Linear, $h_o = -0.207$



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