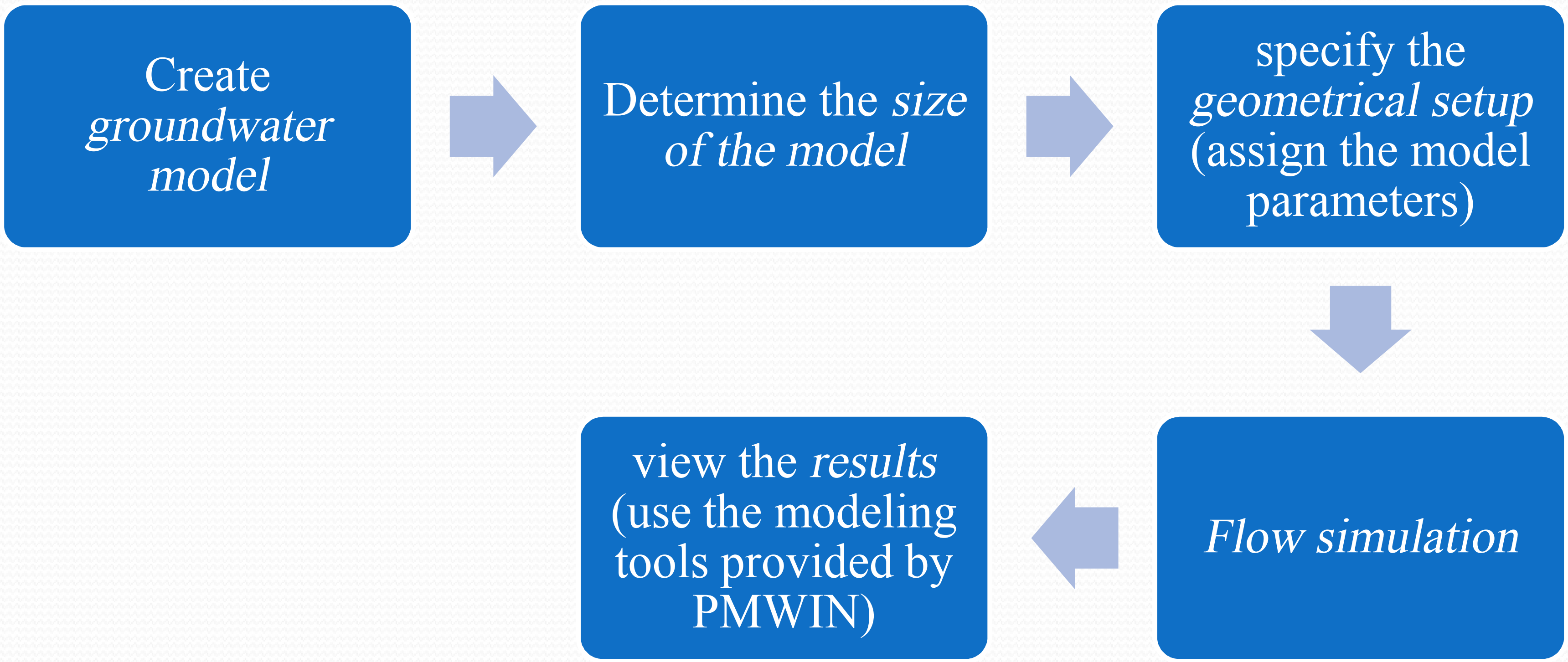
PMWIN

- Processing Modflow for Windows (PMWIN) is a simulation system for modeling groundwater with:
  - **MODFLOW**: modular three-dimensional finite-difference groundwater model (simulate the effects of wells, rivers, drains, head dependent boundaries, recharge and evapotranspiration)
  - **PMPATH**: the particle tracking model (for showing and shows pathlines or flowlines and travel time. It provides various on-screen graphical options including head contours, drawdown contours and velocity vectors.)

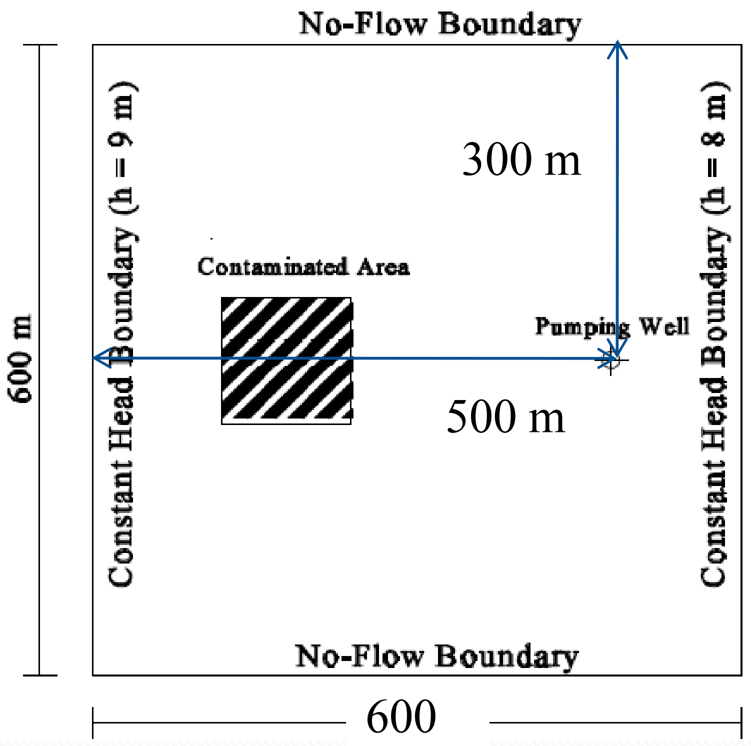
PMWIN

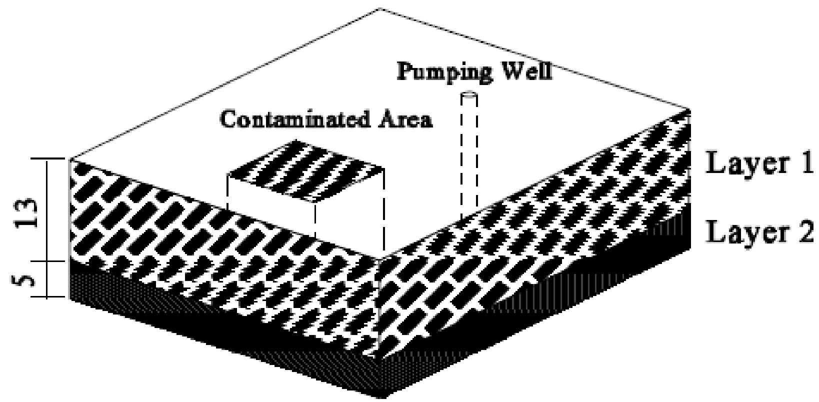
- Processing Modflow for Windows (PMWIN) is a simulation system for modeling groundwater with:
  - **MT3D**: The solute transport model which uses a mixed Eulerian-Lagrangian approach to the solution of the three-dimensional advective dispersive-reactive transport equation
  - **PEST:** The parameter estimation program .If there are field or laboratory measurements, PEST can adjust model parameters and/or excitation data

Steps to model groundwater system

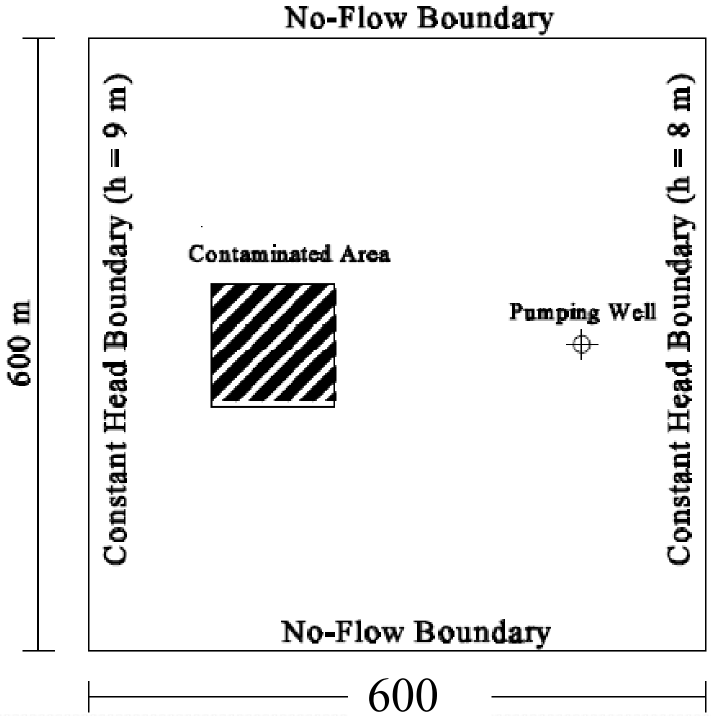


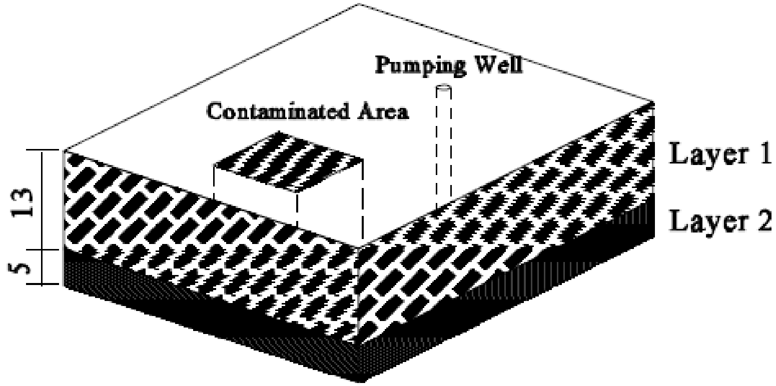
Example



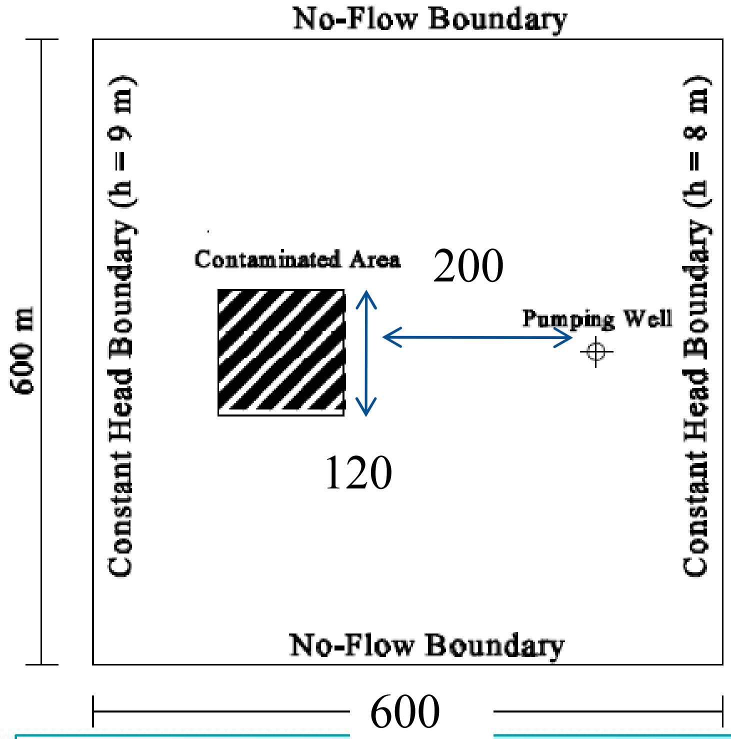


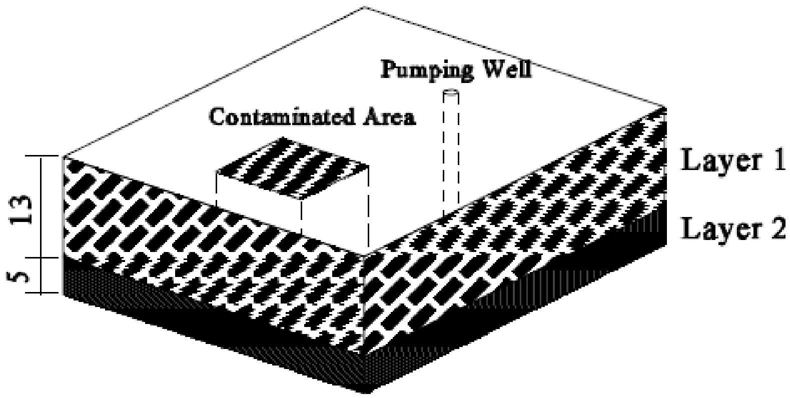
- ✓No- flow boundaries on the north and south sides
- ✓The west and east sides are constant-head boundaries
- ✓The hydraulic heads on the west and east boundaries are 9 m and 8 m
- ✓Initial hydraulic head= 8 m





- The aquifer consists of two layers. The **first layer is unconfined** and the **second layer is confined**.
  - Horizontal **hydraulic conductivities** of the first and second layers are **0.005** m/s and **0.001** m/s
  - Vertical hydraulic conductivity of both layers **is about 10 percent** of the horizontal hydraulic conductivity.
- The effective porosity is approximately 25 percent





✓The **elevation** of the top of the first layer is **10m**. The **thickness** of the first layer and the second layer is **13** m and **5**.

A contaminated area lies in the first layer next to the west boundary. To clean up the aquifer, a fully penetrating pumping well is located next to the east boundary.

A numerical model has to be developed for this site to calculate the required pumping rate of a well. The pumping rate must be large enough, so that the contaminated area lies within the capture zone of the pumping well

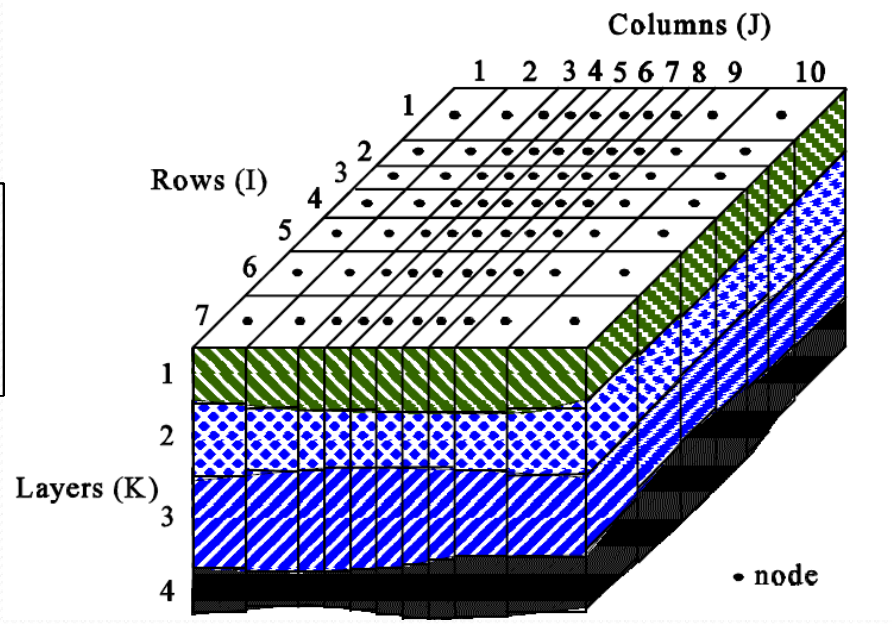
Steps:

- 1- create a flow model
- 2- Assign model data
  - Generate the model grid (mesh),
  - Specify boundary conditions, and
  - Assign model parameters to the model grid
- 3- Perform the flow simulation
- 4- Check simulation results and produce output

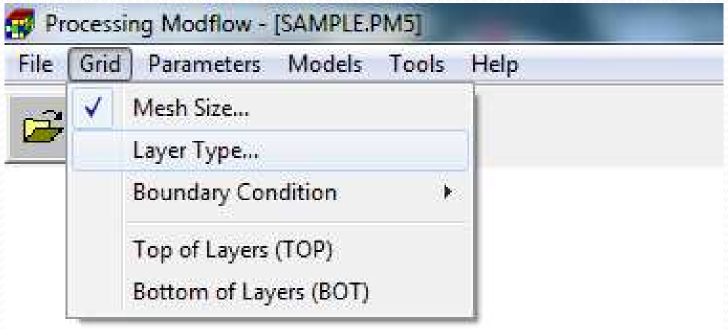
Assign model data

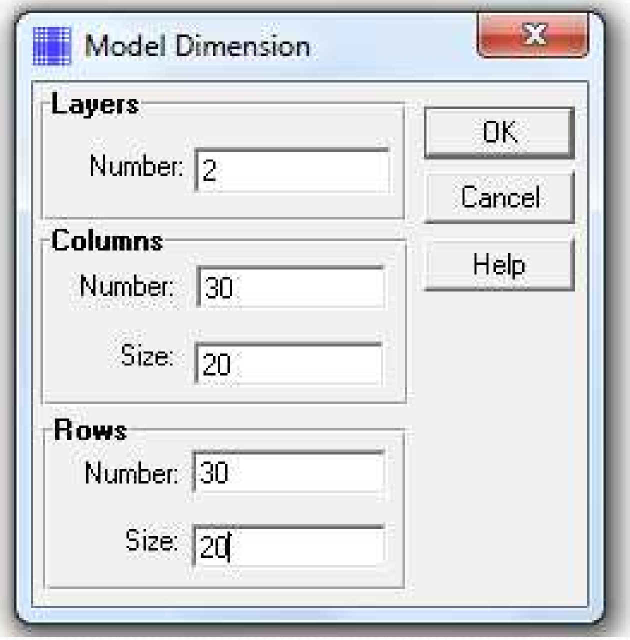
- An aquifer system is replaced by a discretized domain consisting of an array of nodes and associated finite difference blocks (cells).
- The locations of cells are described in terms of columns, rows, and layers.

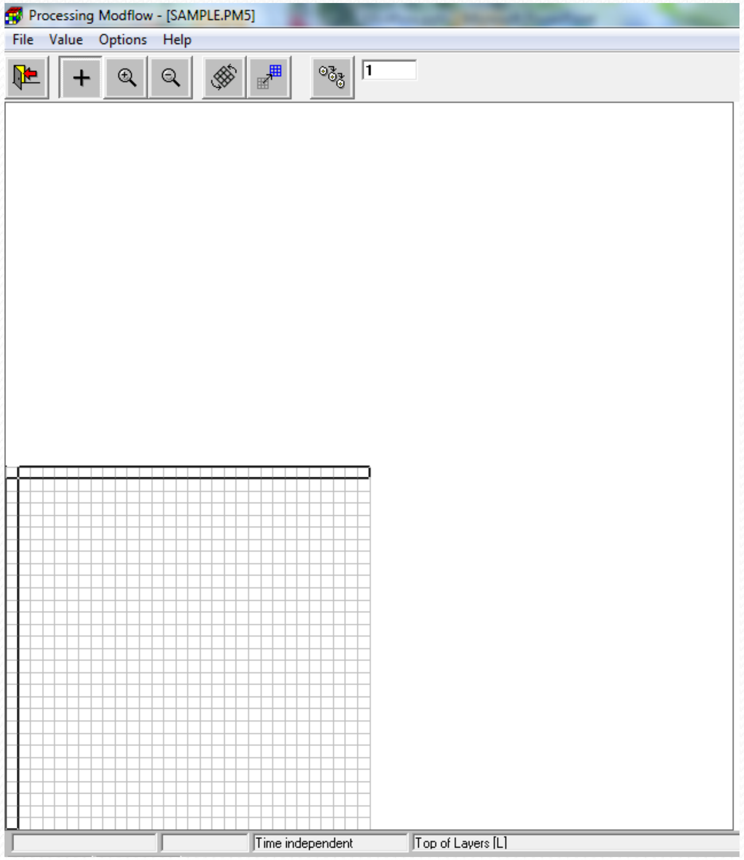
✓The cell located in the 2nd column, 6th row, and the first layer is denoted by [2, 6, 1]



Assign the type of layers

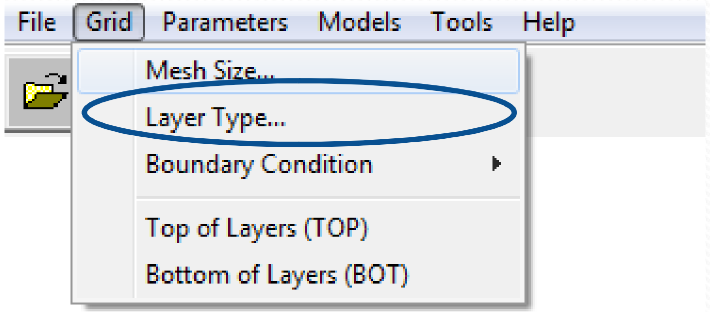


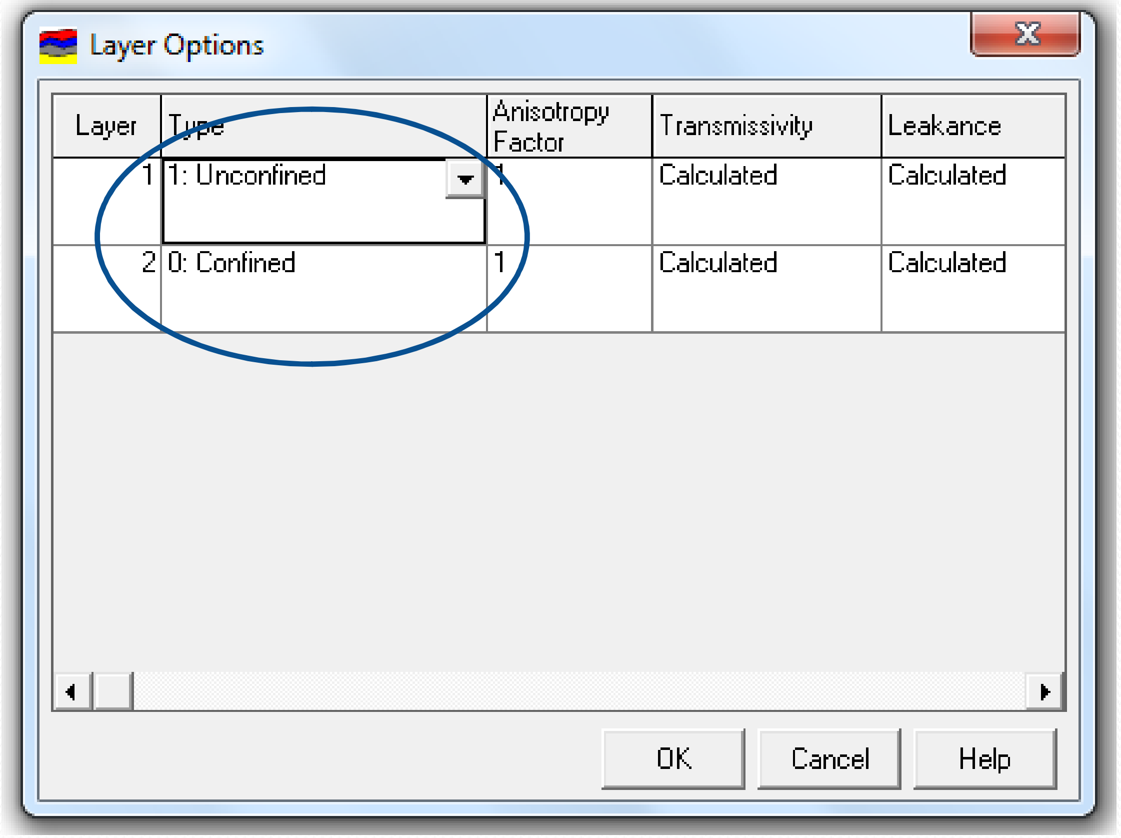




Choose Leave editor

Assign model data





Specify boundary conditions

Using IBOUND array

➢This array contains a code for each model cell which indicates whether

✓(1) the hydraulic head is computed (active variable-head cell or active cell),

✓(2) the hydraulic head is kept fixed at a given value (constant-head cell or time-varying specified-head cell), or

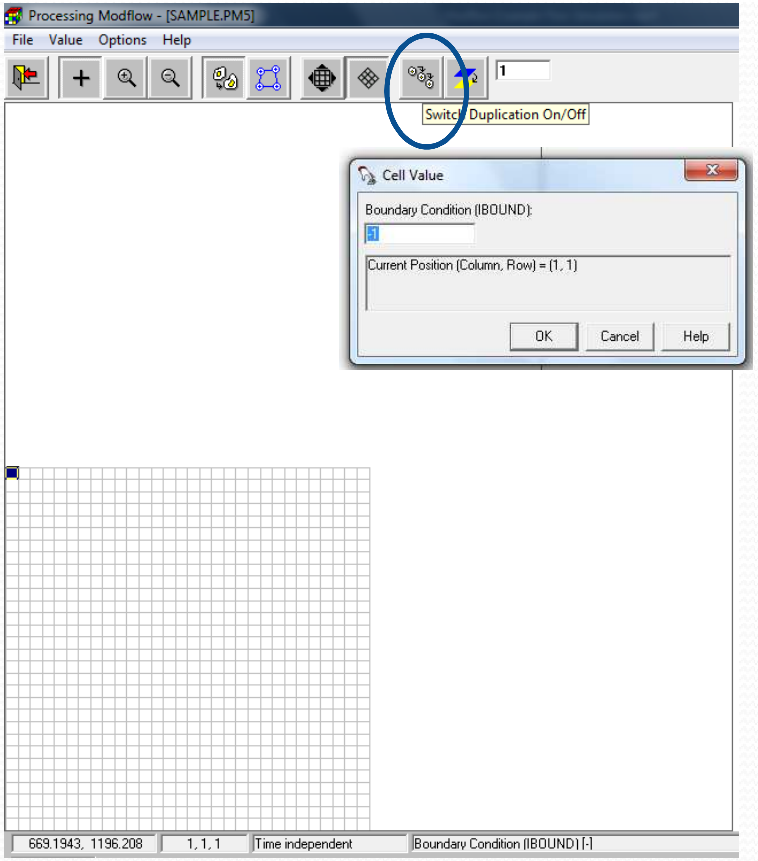
✓(3) no flow takes place within the cell (inactive cell).

➢It is suggested to use 1 for an active cell, -1 for a constant-head cell, and 0 for an inactive cell.

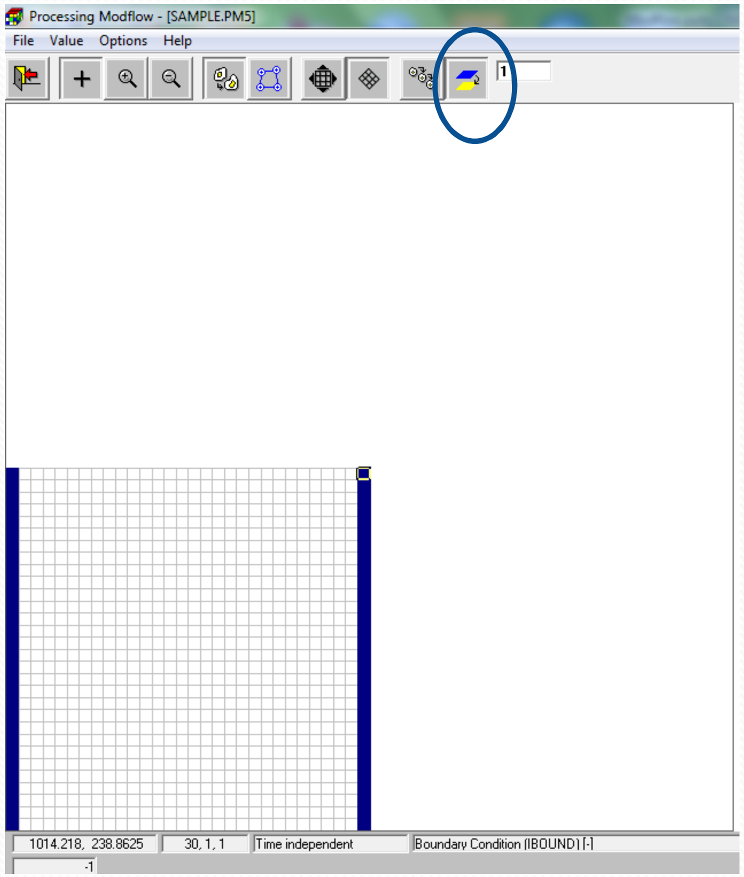
❖For the sample problem, we need to **assign -1 to the cells on the west and east boundaries and 1 to all other cells**.

Specify boundary conditions

Clicking the Duplication icon

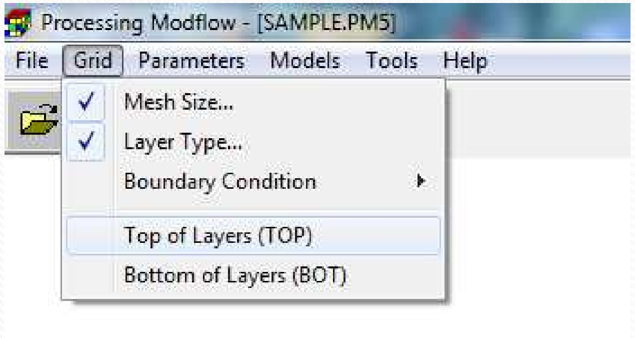


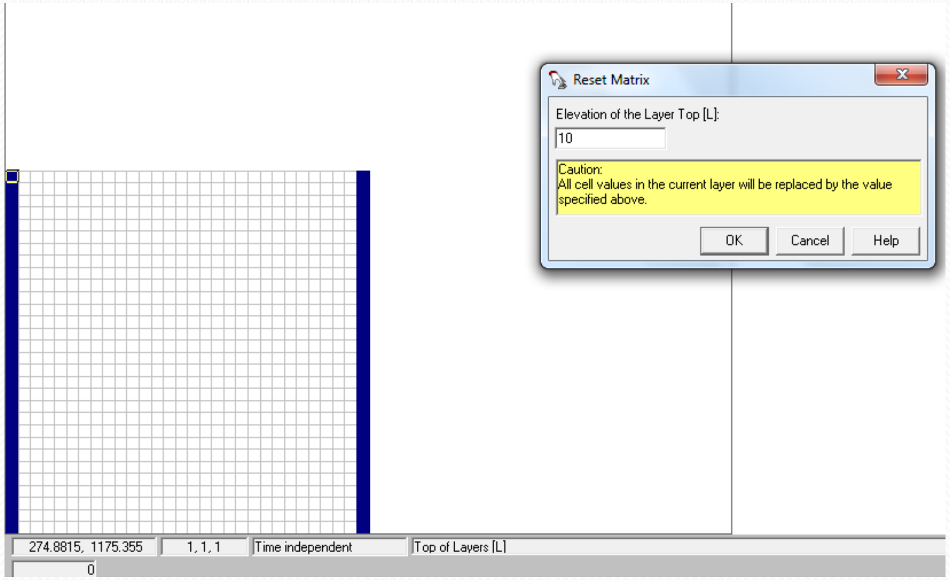
Turn Copy Layer on



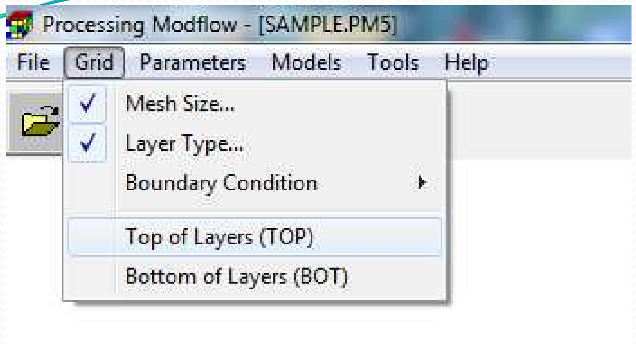
Specify the geometrical setup of the model

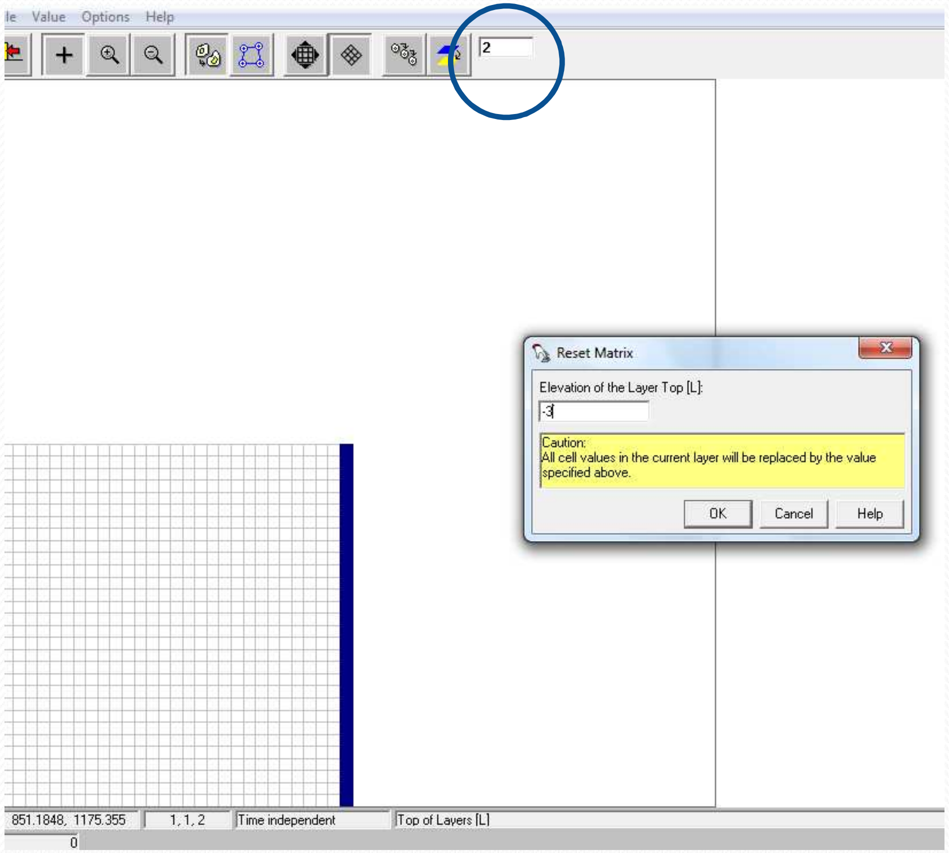
I) Specify the elevation of the top of model layers





First Layer (Value=10)

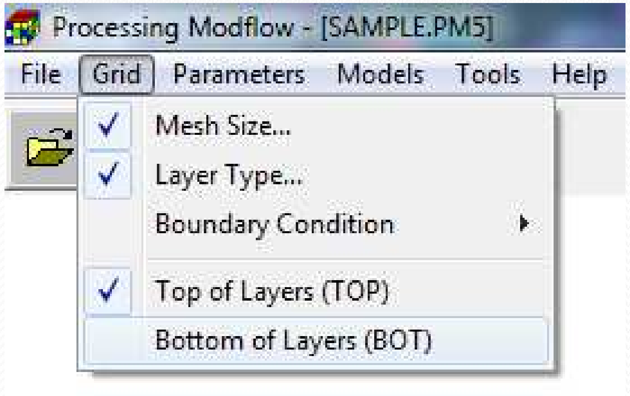


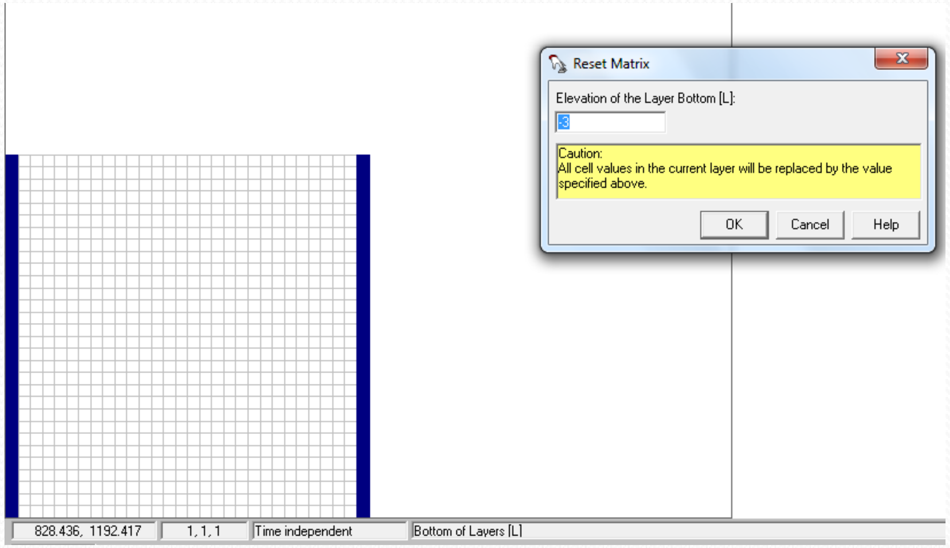


Second Layer (Value=-3)

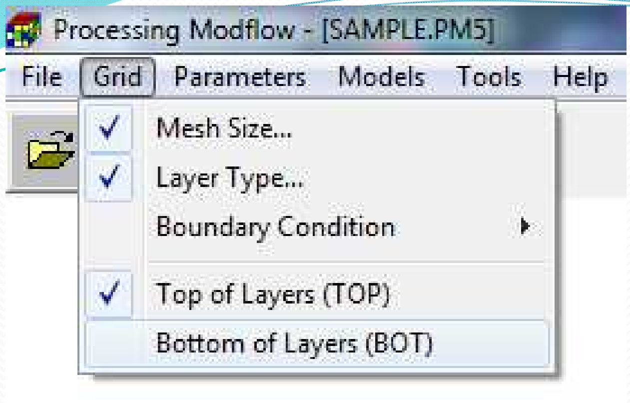
Specify the geometrical setup of the model

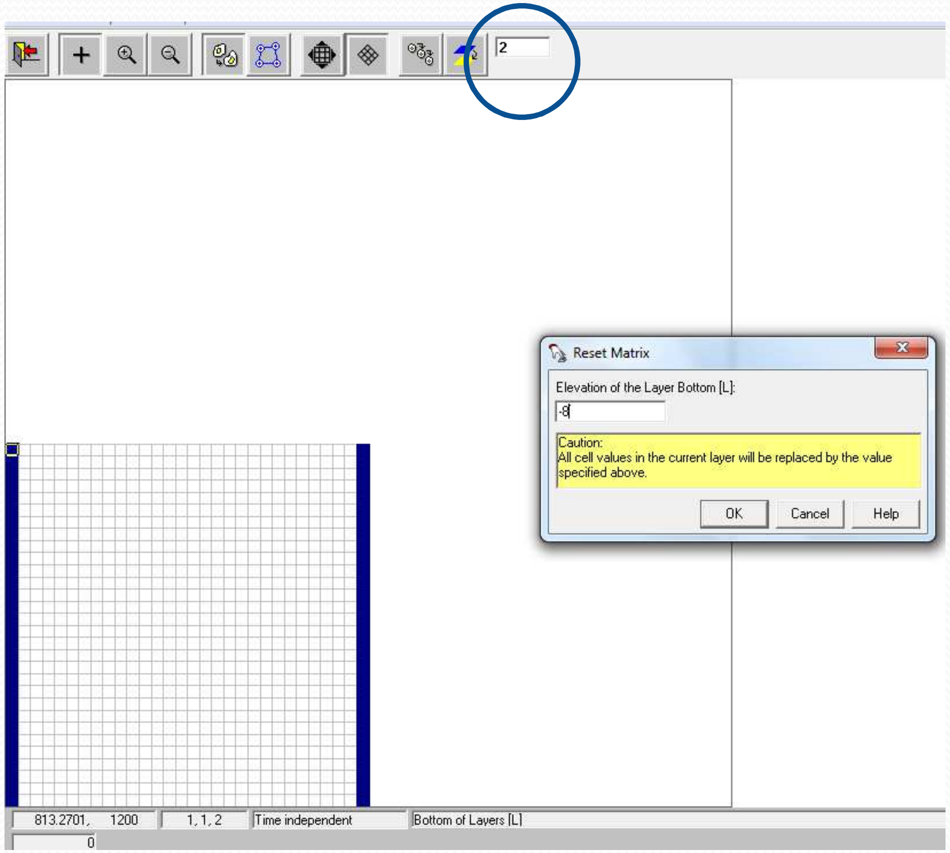
I) Specify the elevation of the bottom of model layers





First Layer (Value=-3)





Second Layer (Value=-8)

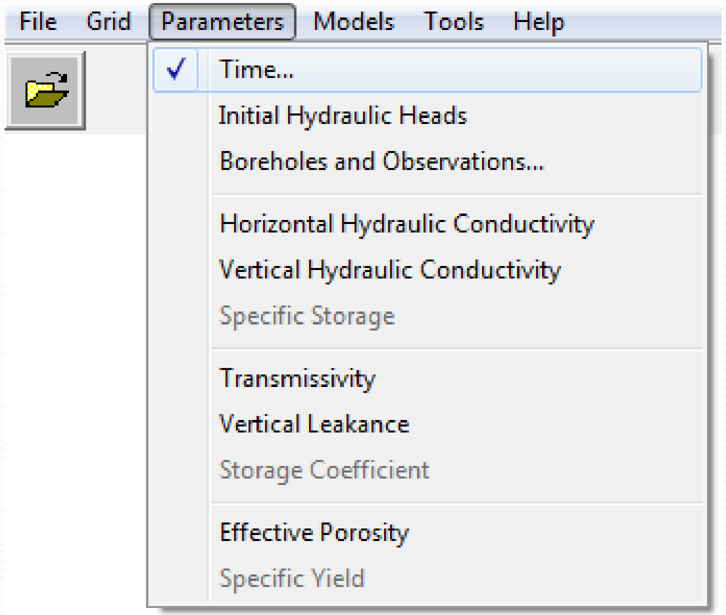
- **The next step is to specify the temporal and spatial parameters of the model. For the sample problem, spatial parameters include the starting hydraulic head, horizontal and vertical hydraulic conductivities, and effective porosity.**

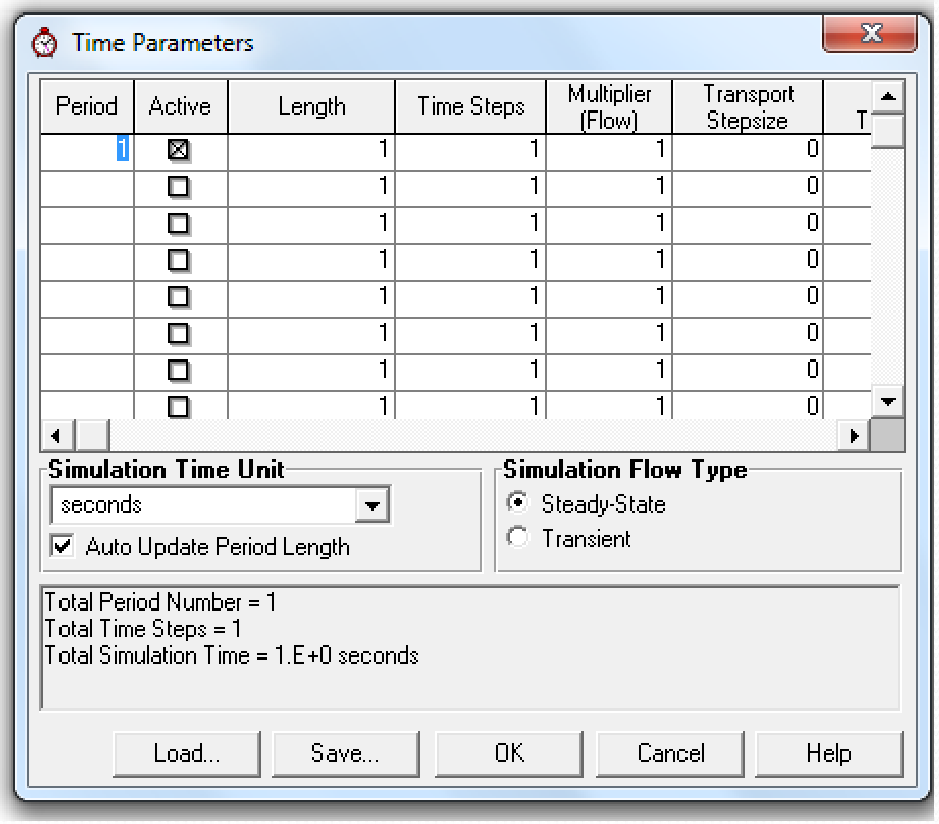
Specify the Temporal Parameters

- time unit and the numbers of stress periods,
- time steps and
-transport steps.

In MODFLOW, the simulation time is divided into **stress periods** - i.e., time intervals during which all external excitations or stresses are constant - which are, in turn, divided into **time steps**. In the MT3D model, each time step is further divided into smaller time increments, called **transport steps**. The length of stress periods is not relevant to a steady state flow simulation. However, if you want to perform contaminant transport simulation with MT3D at a later time, you must specify the actual time length in the table.

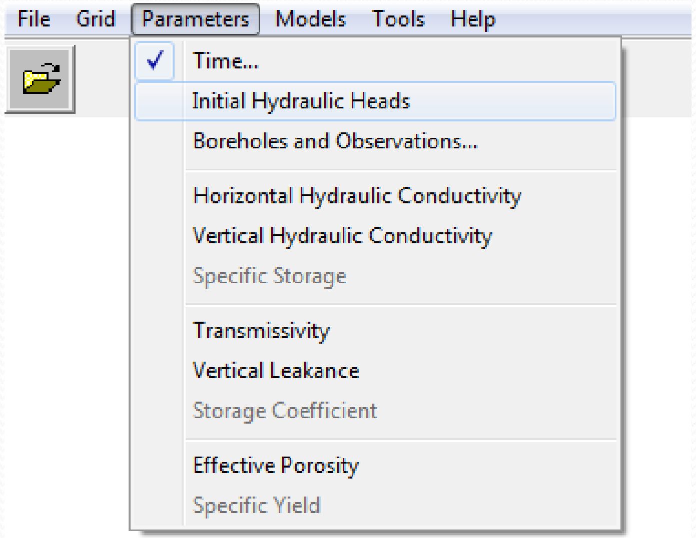
Specify the Temporal Parameters

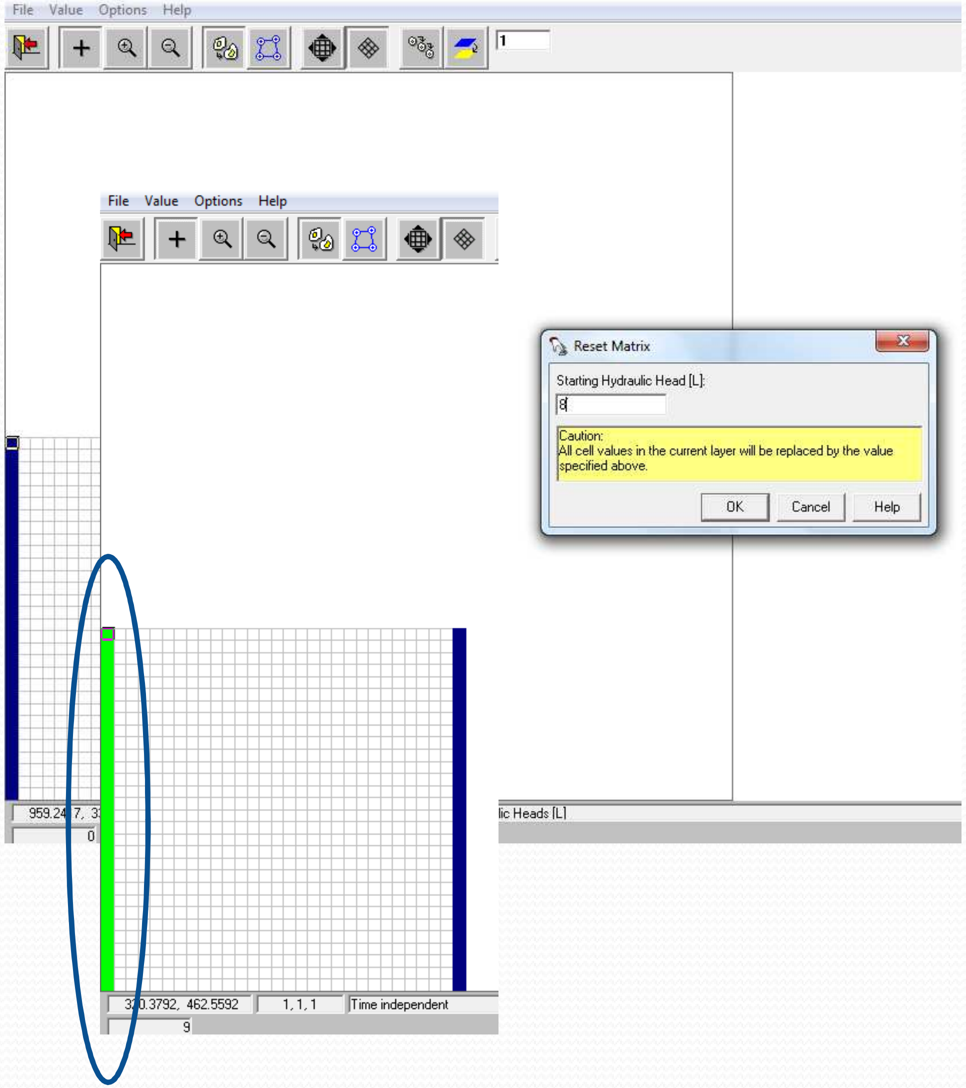




We used default values

Specify the initial hydraulic head



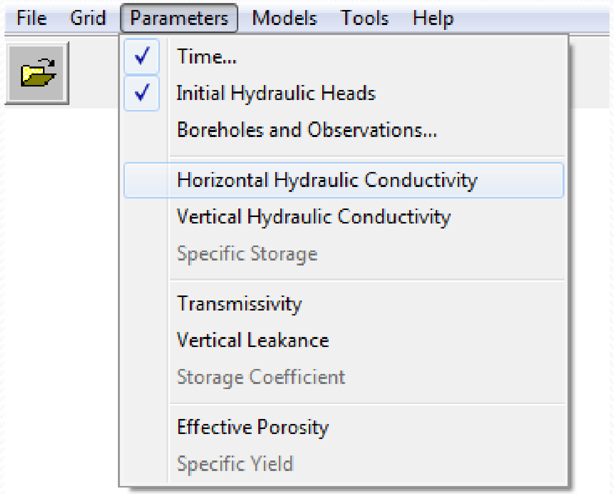


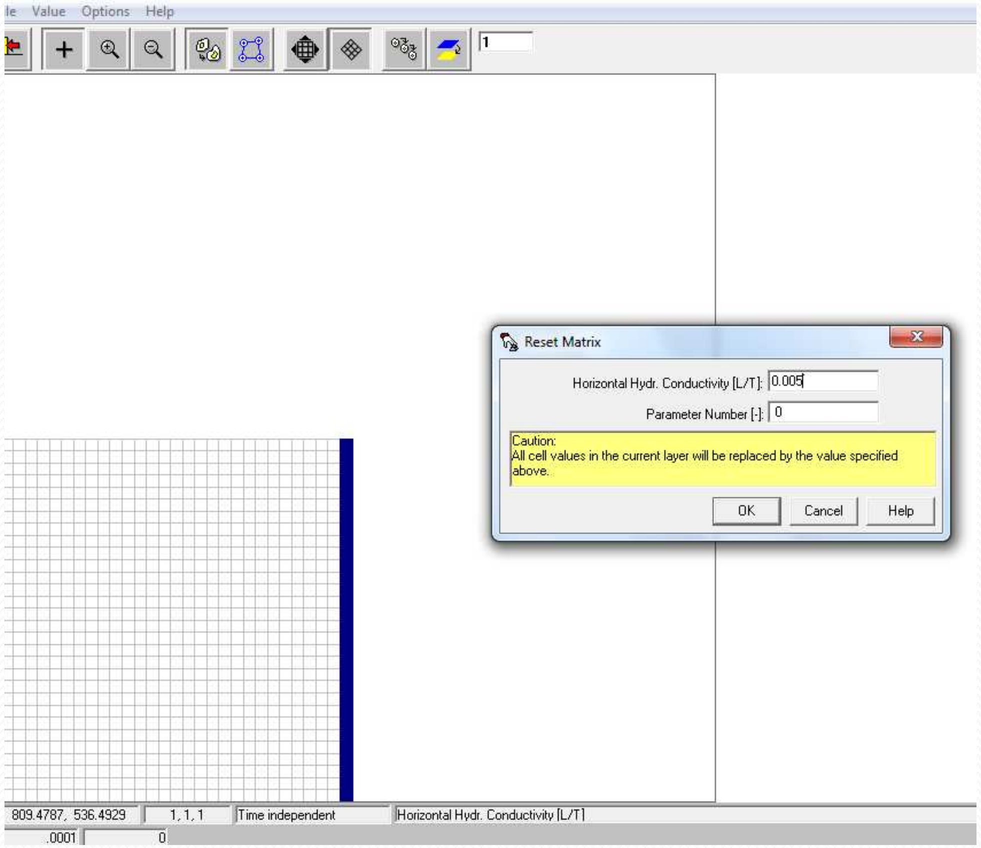
Initial head every where= 8 m

The left cells= 9 m (with Duplication icon)

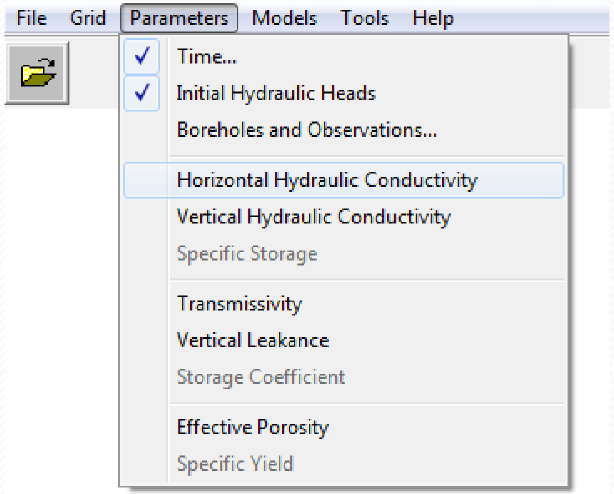
Turn on layer Copy icon

Specify the horizontal hydraulic conductivity

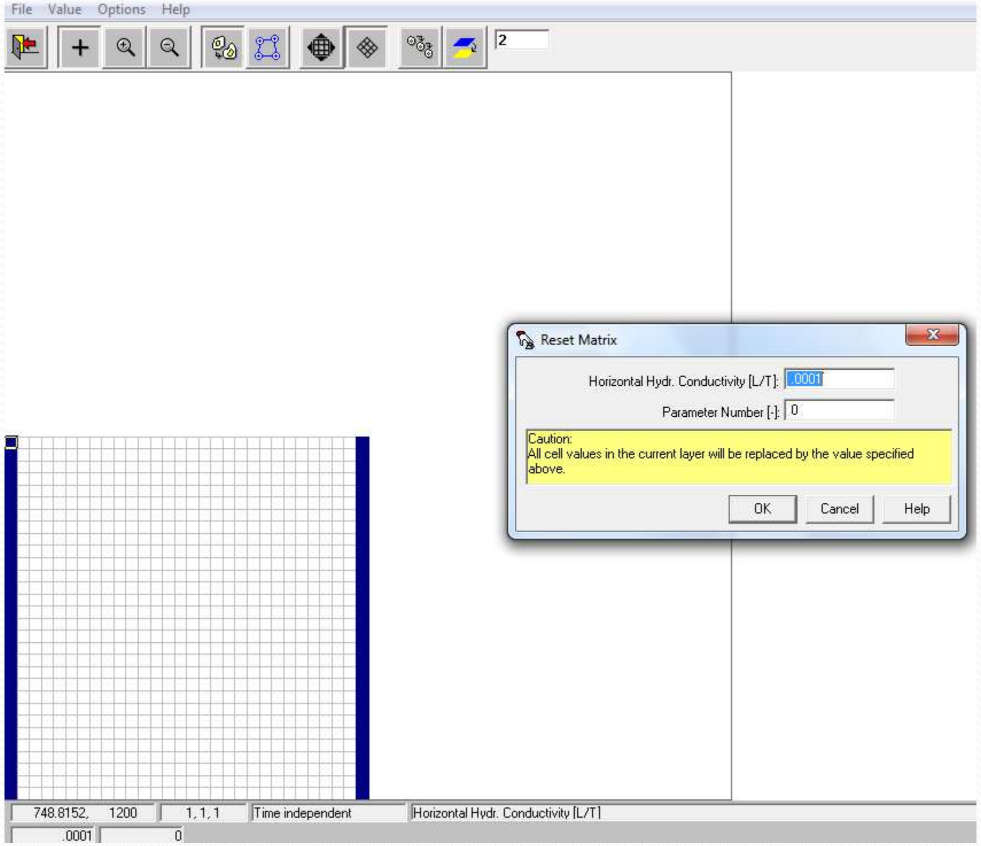




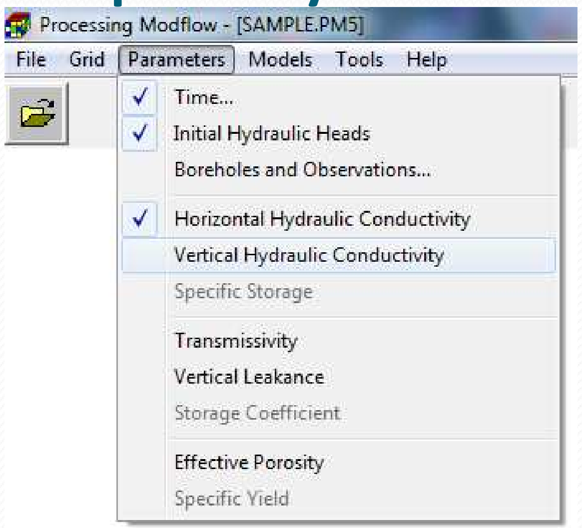
First Layer = 0.005

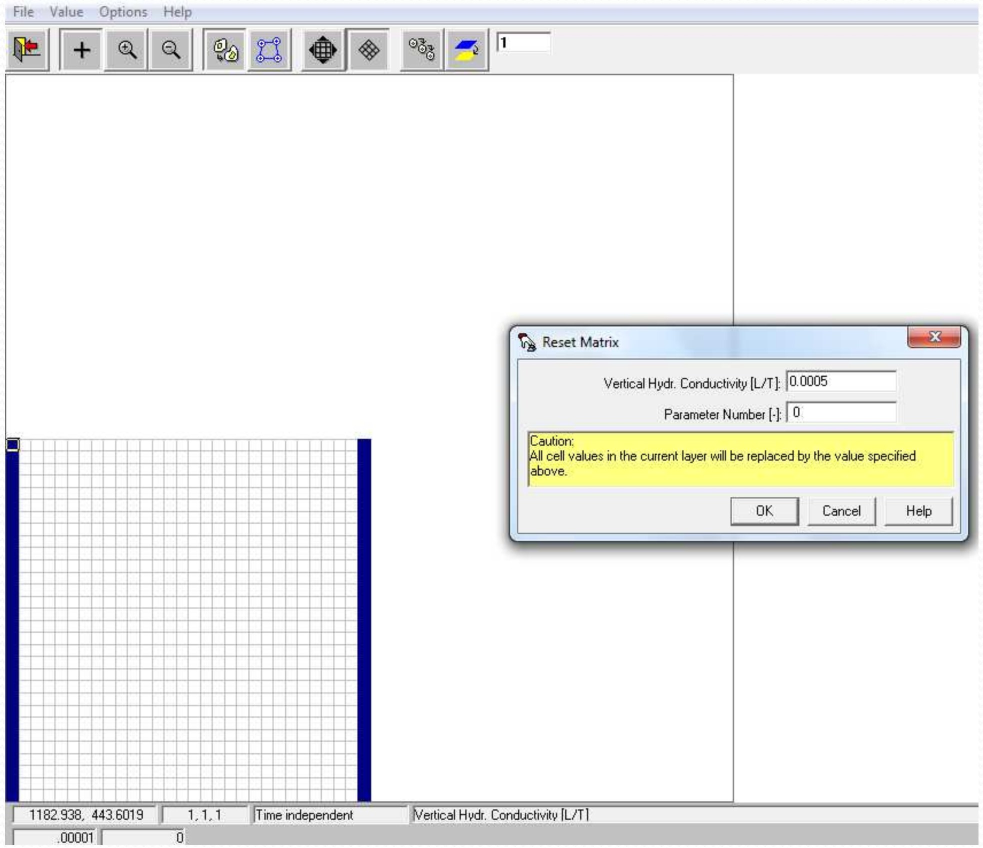


Second Layer = 0.001

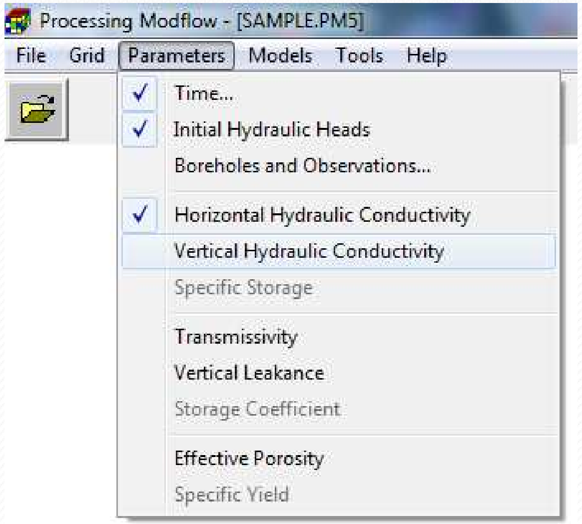


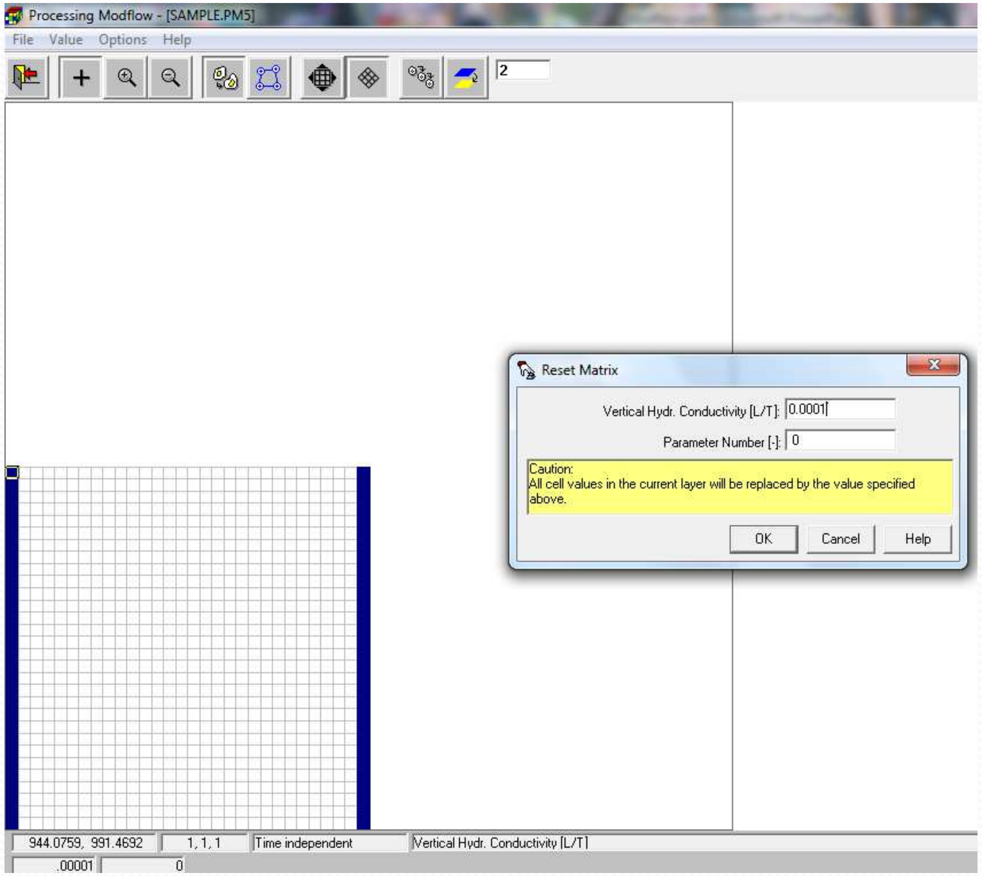
Specify the vertical hydraulic conductivity





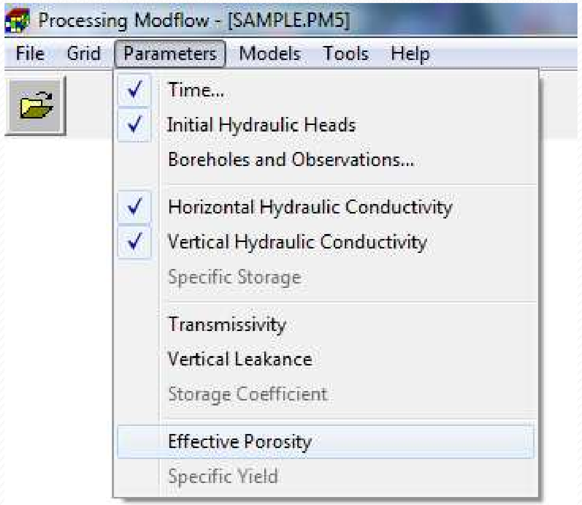
First Layer = 0.0005

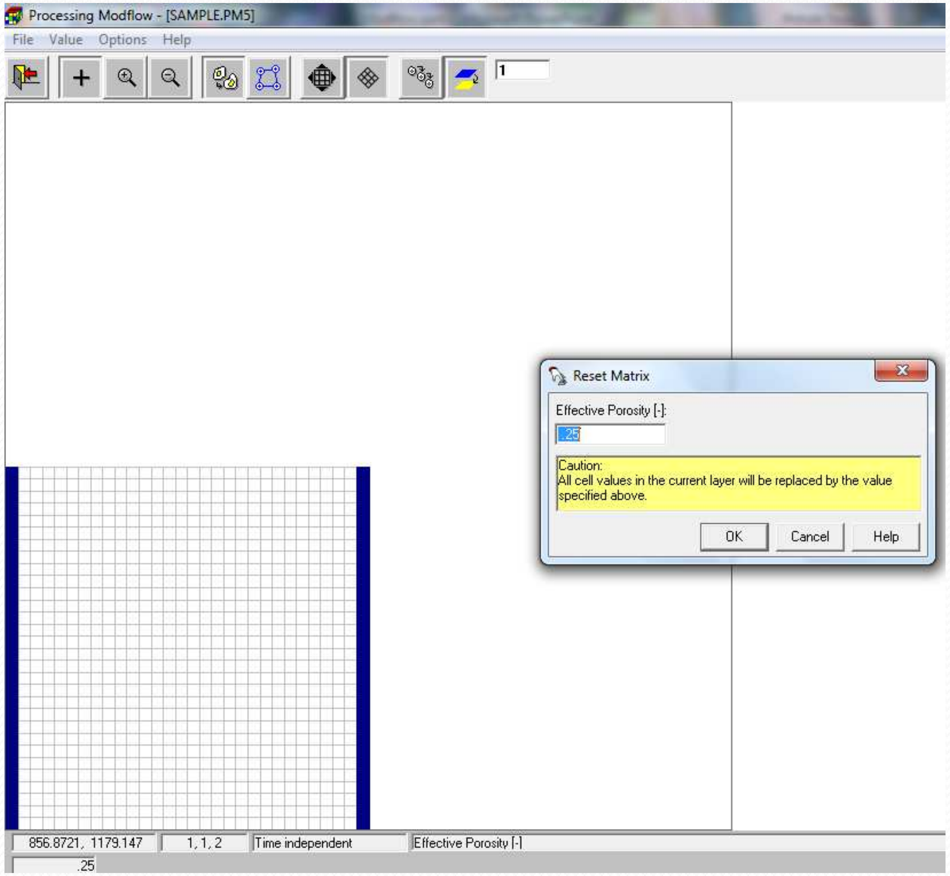




Second Layer = 0.0001

Specify the effective porosity



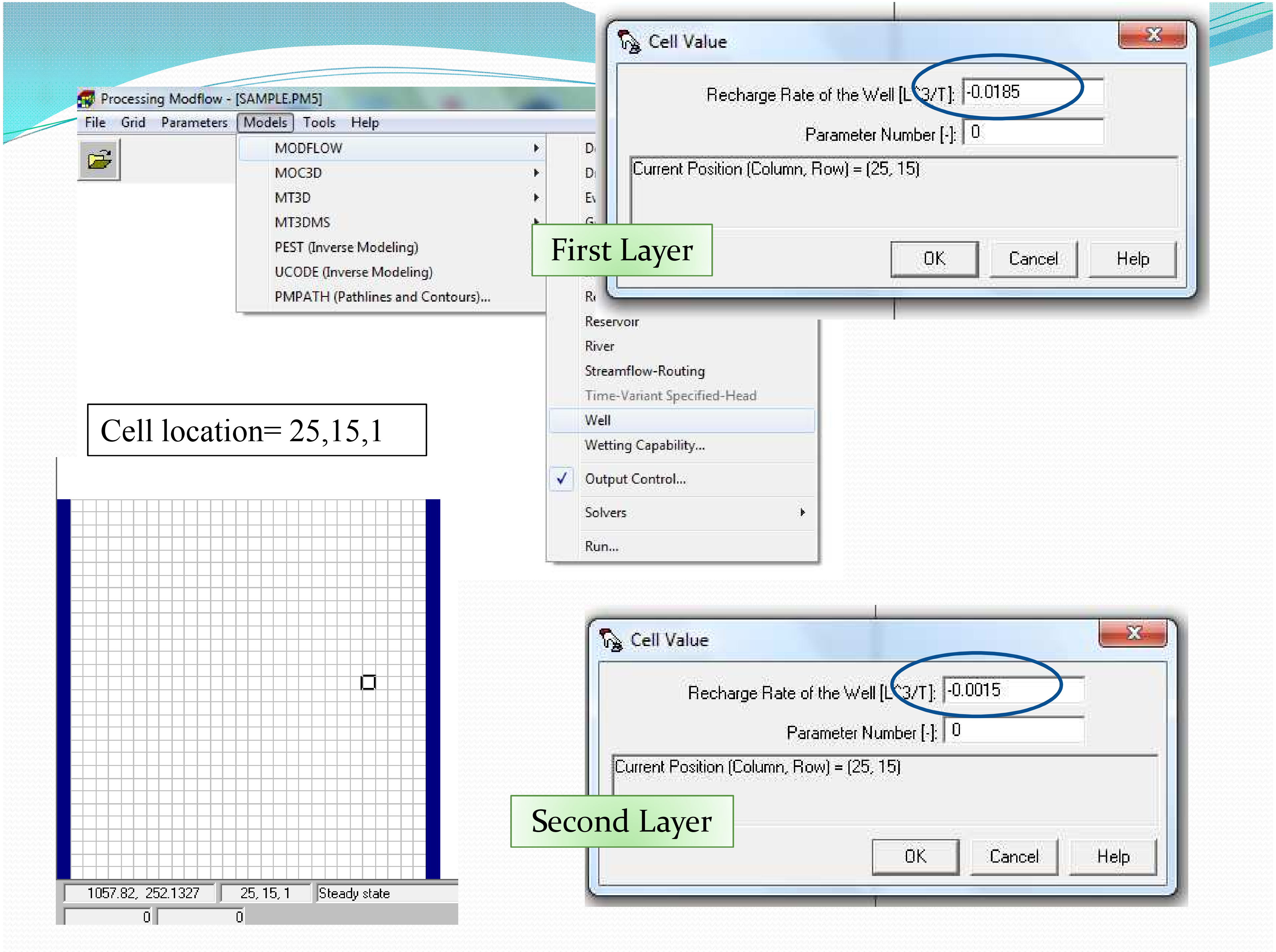


Both Layers = 0.25

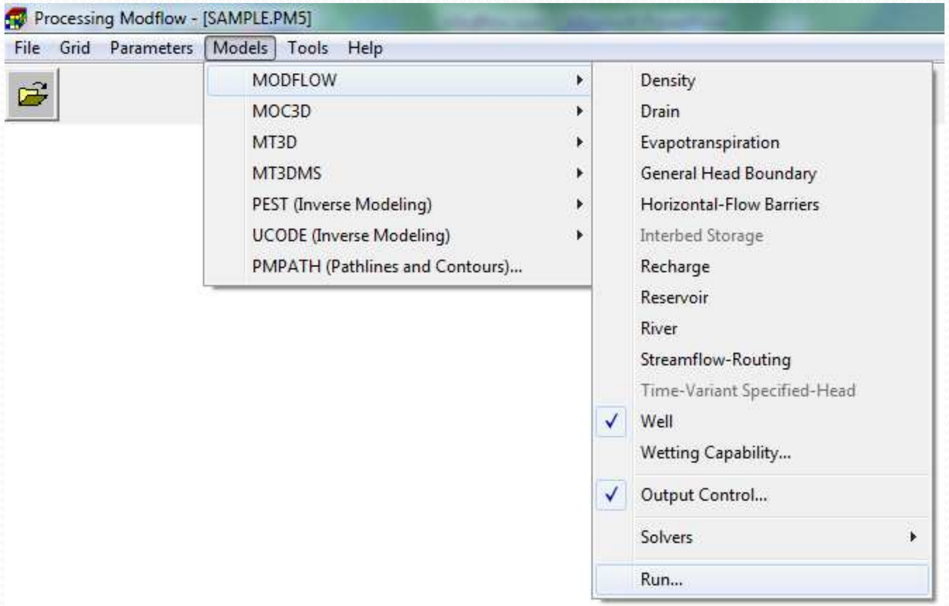
- The final step before simulation is to specify the location of the pumping well and its pumping rate
- The total pumping rate for the multilayer well is equal to the sum of the pumping rates from the individual layers. The pumping rate for each layer (Qk) can be approximately calculated by dividing the total pumping rate (Qtotal) in proportion to the layer transmissivities

$$Q_k = Q_{total} \frac{T_k}{\Sigma T}$$

As we do not know the required pumping rate for capturing the contaminated area, we will try a total pumping rate of 0.02 m3/s. By above equation, the pumping rates are 0.0185 m3/s and 0.0015 m3/s in the first and second layer, respectively.


Processing Modflow - [SAMPLE.PM5]
File Grid Parameters Models Tools Help
MODFLOW
MOC3D
MT3D
MT3DMS
PEST (Inverse Modeling)
UCODE (Inverse Modeling)
PMPATH (Pathlines and Contours)...
Reservoir
River
Streamflow-Routing
Time-Variant Specified-Head
Well
Wetting Capability...
Output Control...
Solvers
Run...
Cell Value
Recharge Rate of the Well [L^3/T]: -0.0185
Parameter Number [-]: 0
Current Position (Column, Row) = (25, 15)
OK Cancel Help
First Layer
Cell location= 25,15,1
1057.82, 252.1327
25, 15, 1
Steady state
Cell Value
Recharge Rate of the Well [L^3/T]: -0.0015
Parameter Number [-]: 0
Current Position (Column, Row) = (25, 15)
OK Cancel Help
Second Layer

Flow Simulation



File	Contents
path\OUTPUT.DAT	Detailed run record and simulation report
path\HEADS.DAT	Hydraulic heads
path\DDOWN.DAT	Drawdowns, the difference between the starting heads and the calculated hydraulic heads.
path\BUDGET.DAT	Cell-by-Cell flow terms
path\INTERBED.DAT	Subsidence of the entire aquifer and compaction and preconsolidation heads in individual layers.

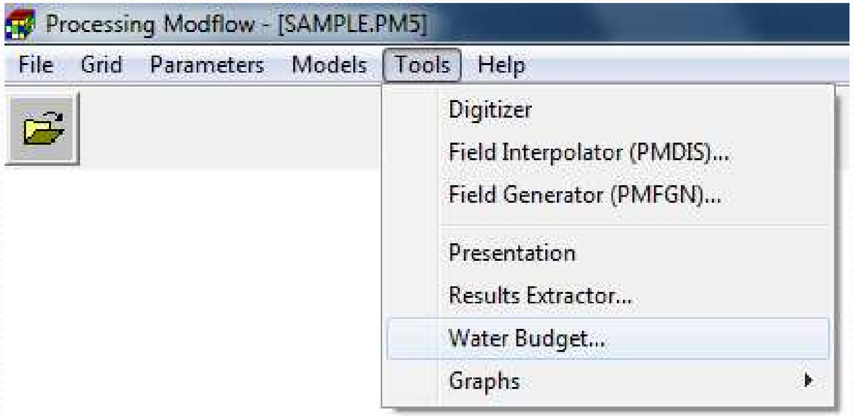
- **Volumetric water budget**: provides an indication of the overall acceptability of the numerical solution. In numerical solution techniques, the system of equations solved by a model actually consists of a flow continuity statement for each model cell. Continuity should also exist for the total flows into and out of the entire model or a sub-region.

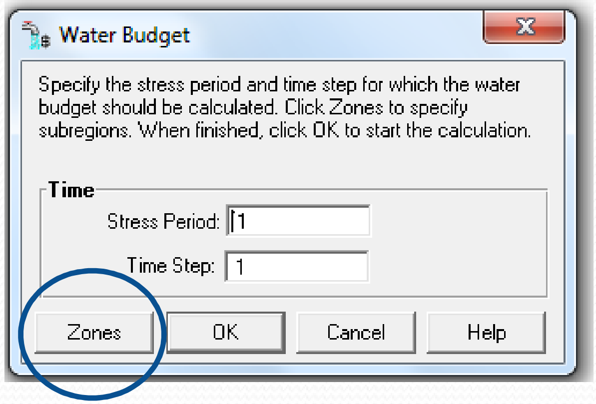
```
             VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
             ------------------------------------------------------------------------------
CUMULATIVE VOLUMES    L**3/T                              RATES FOR THIS TIME STEP   L**3/T
      ------------------                                        ------------------------

            IN:                                                         IN:
            ---                                                         ---
      STORAGE =    0.00000                                        STORAGE =    0.00000
CONSTANT HEAD =    0.68083E-01                              CONSTANT HEAD =    0.68083E-01
        WELLS =    0.00000                                          WELLS =    0.00000
     TOTAL IN =    0.68083E-01                                   TOTAL IN =    0.68083E-01

           OUT:                                                        OUT:
           ----                                                        ----
      STORAGE =    0.00000                                        STORAGE =    0.00000
CONSTANT HEAD =    0.48096E-01                              CONSTANT HEAD =    0.48096E-01
        WELLS =    0.2E-01                                          WELLS =    0.20000E-01
    TOTAL OUT =    0.68096E-01                                  TOTAL OUT =    0.68096E-01
     IN - OUT =   -0.13150E-04                                   IN - OUT =   -0.13150E-04

PERCENT DISCREPANCY =    -0.02                                PERCENT DISCREPANCY = -0.02
```

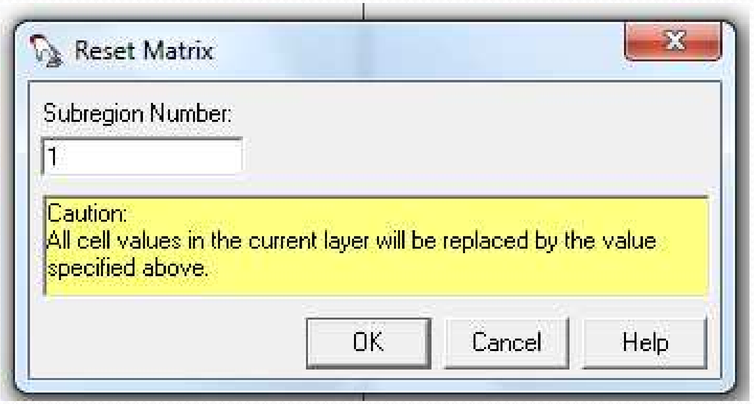
Results Presentation

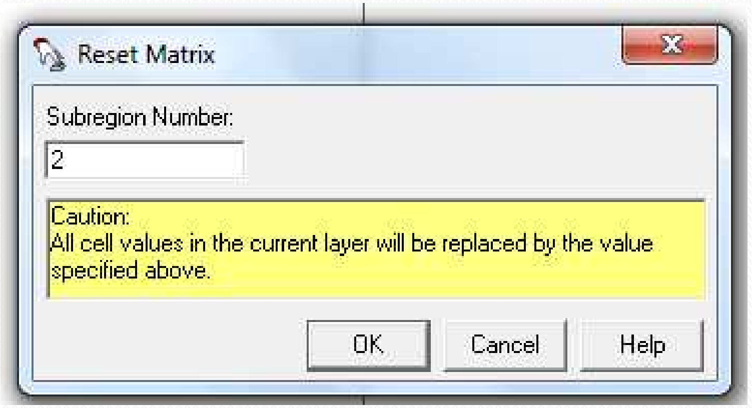
1. Use the **Water Budget** Calculator to compute water budgets of each layer and the entire model
2. Use the Result Extractor to read and save the **calculated hydraulic heads** of each layer.
3. Generate **contour maps** based on the calculated hydraulic heads saved in step 2.
4. Create a **solid fill plot** based on the calculated hydraulic heads saved in step 2 and add contours to the plot.
5. Use PMPATH to produce **pathlines** as well as the **capture zone** of the pumping well.

Water Budget Calculator









First Layer

Second Layer

Water Budget Calculator

```
WATER BUDGET OF SELECTED ZONES:

                              IN              OUT           IN-OUT
       ZONE(  1):  6.2989511E-02  6.2958285E-02  3.1225383E-05
       ZONE(  2):  5.6107184E-03  5.6550838E-03 -4.4365413E-05
```

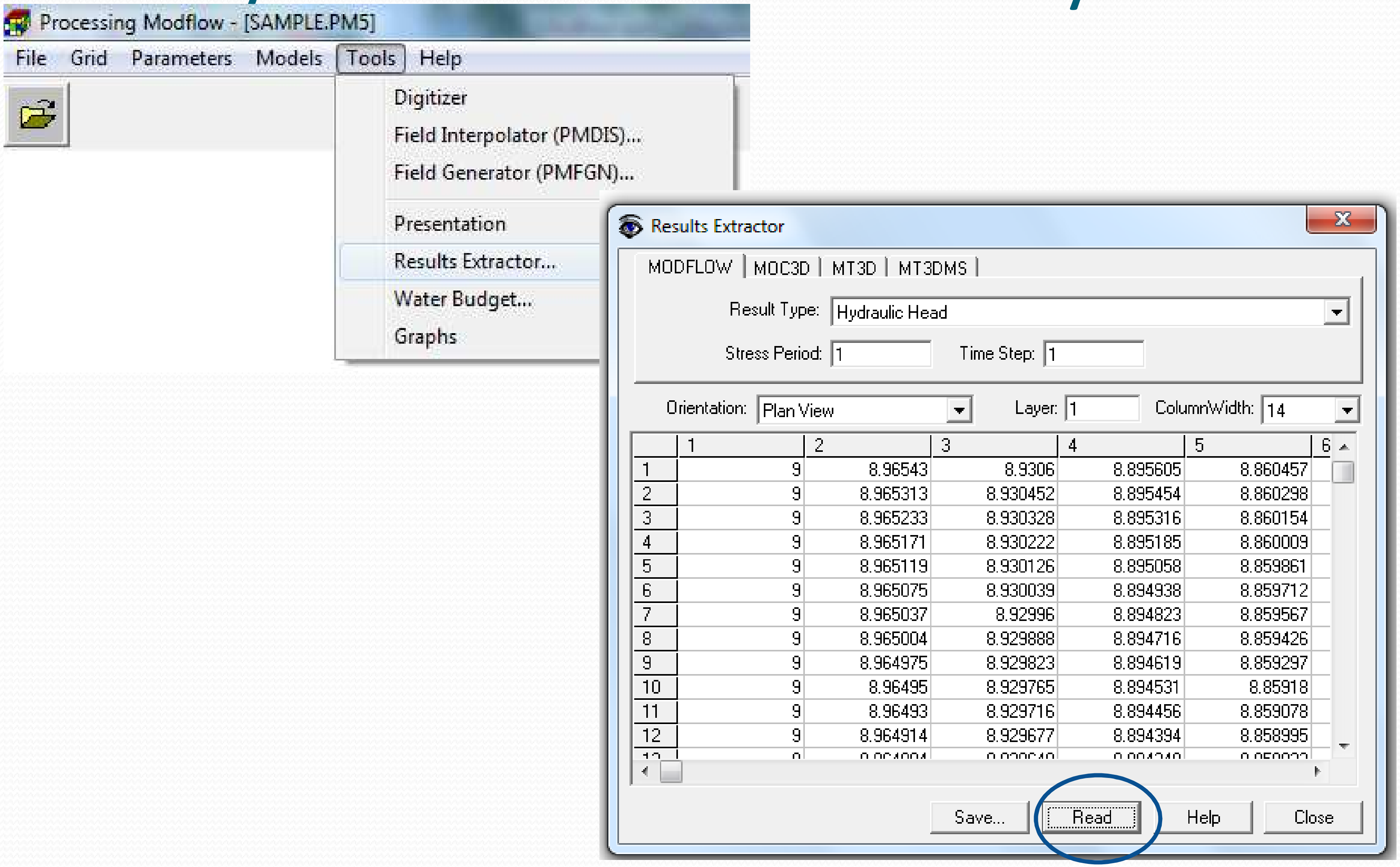
```
======================================================================
FLOW RATES BETWEEN ZONES
======================================================================
```

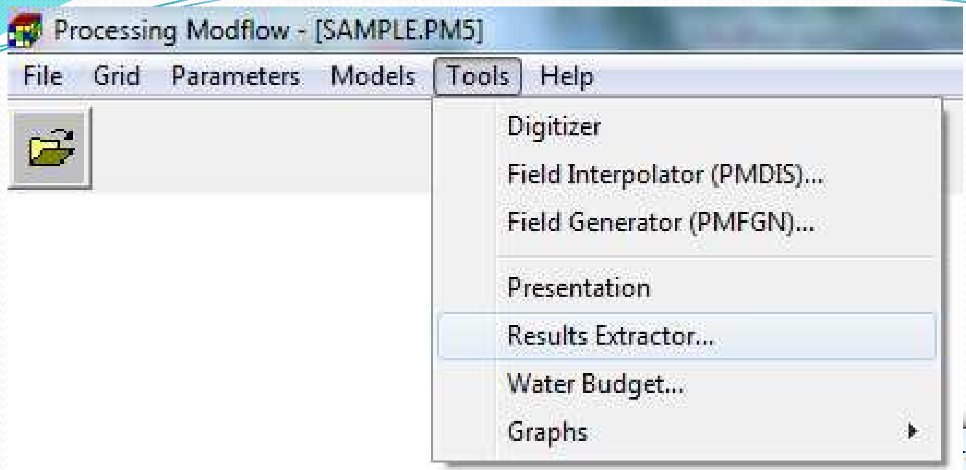
The value of the element (i,j) of the following flow matrix gives the flow rate from the i-th zone to the j-th zone. Where i is the column index and j is the row index.

FLOW MATRIX:

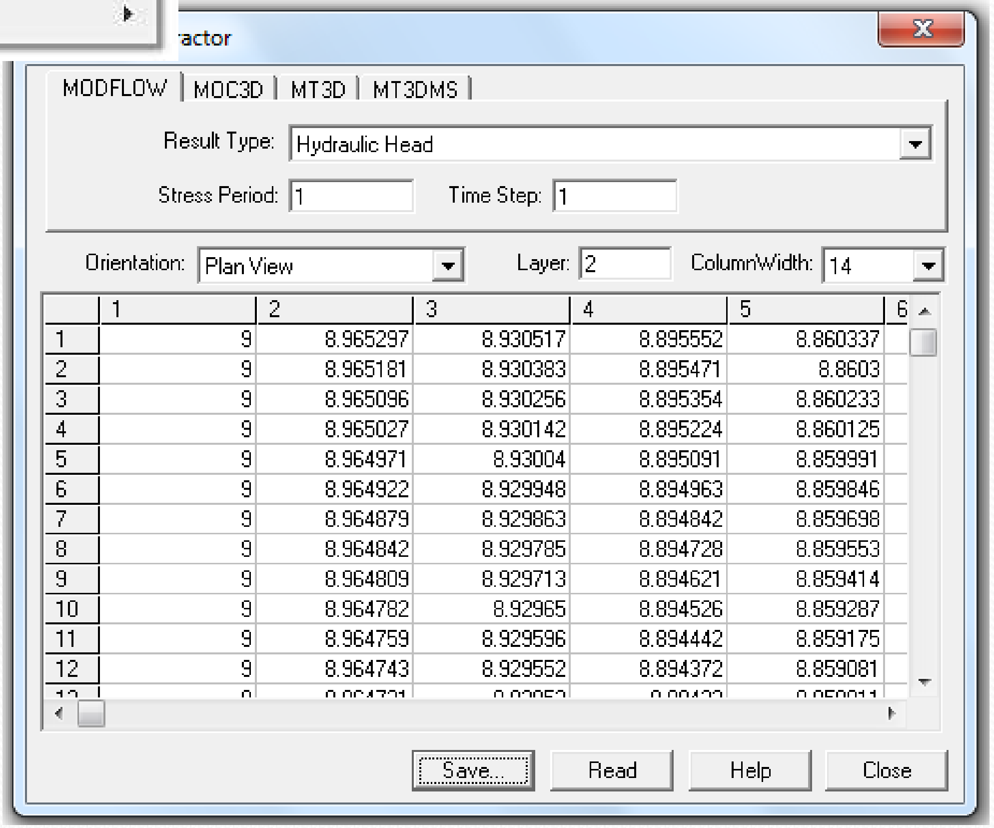
		1	2
0	1	0.000	3.5598E-04
0	2	5.6373E-04	0.000

Hydraulic heads of each layer



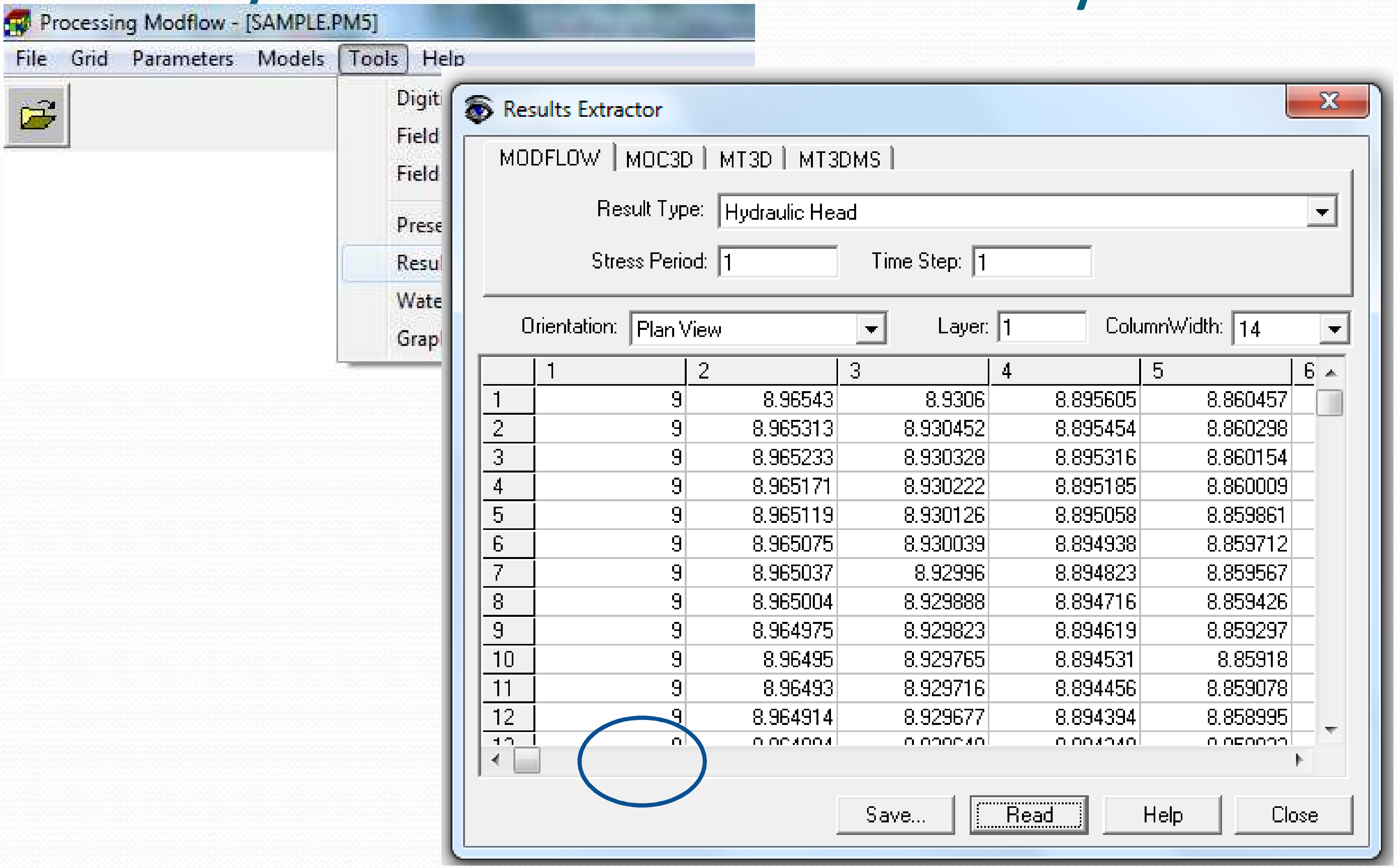


Processing Modflow - [SAMPLE.PM5]
File
Grid
Parameters
Models
Tools
Help
Digitizer
Field Interpolator (PMDIS)...
Field Generator (PMFGN)...
Presentation
Results Extractor...
Water Budget...
Graphs

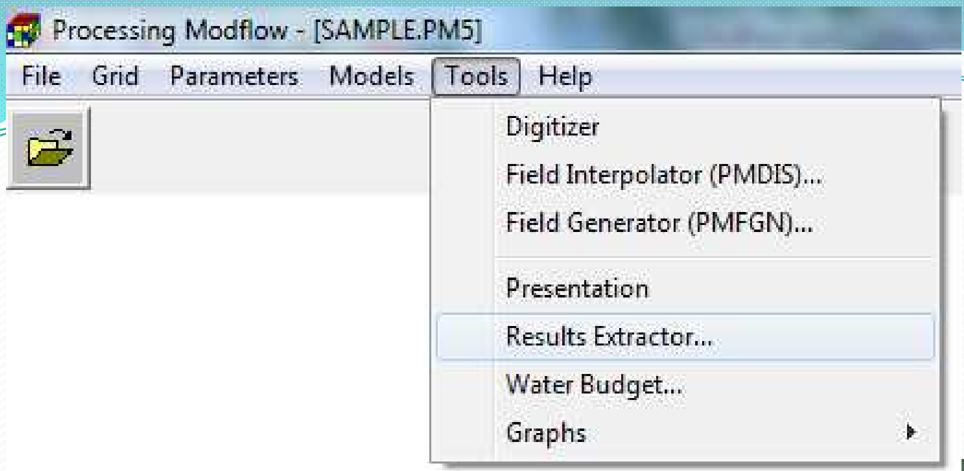


ractor
MODFLOW
MOC3D
MT3D
MT3DMS
Result Type: Hydraulic Head
Stress Period: 1
Time Step: 1
Orientation: Plan View
Layer: 2
ColumnWidth: 14
1 2 3 4 5 6
1 9 8.965297 8.930517 8.895552 8.860337
2 9 8.965181 8.930383 8.895471 8.8603
3 9 8.965096 8.930256 8.895354 8.860233
4 9 8.965027 8.930142 8.895224 8.860125
5 9 8.964971 8.93004 8.895091 8.859991
6 9 8.964922 8.929948 8.894963 8.859846
7 9 8.964879 8.929863 8.894842 8.859698
8 9 8.964842 8.929785 8.894728 8.859553
9 9 8.964809 8.929713 8.894621 8.859414
10 9 8.964782 8.92965 8.894526 8.859287
11 9 8.964759 8.929596 8.894442 8.859175
12 9 8.964743 8.929552 8.894372 8.859081
Save...
Read
Help
Close

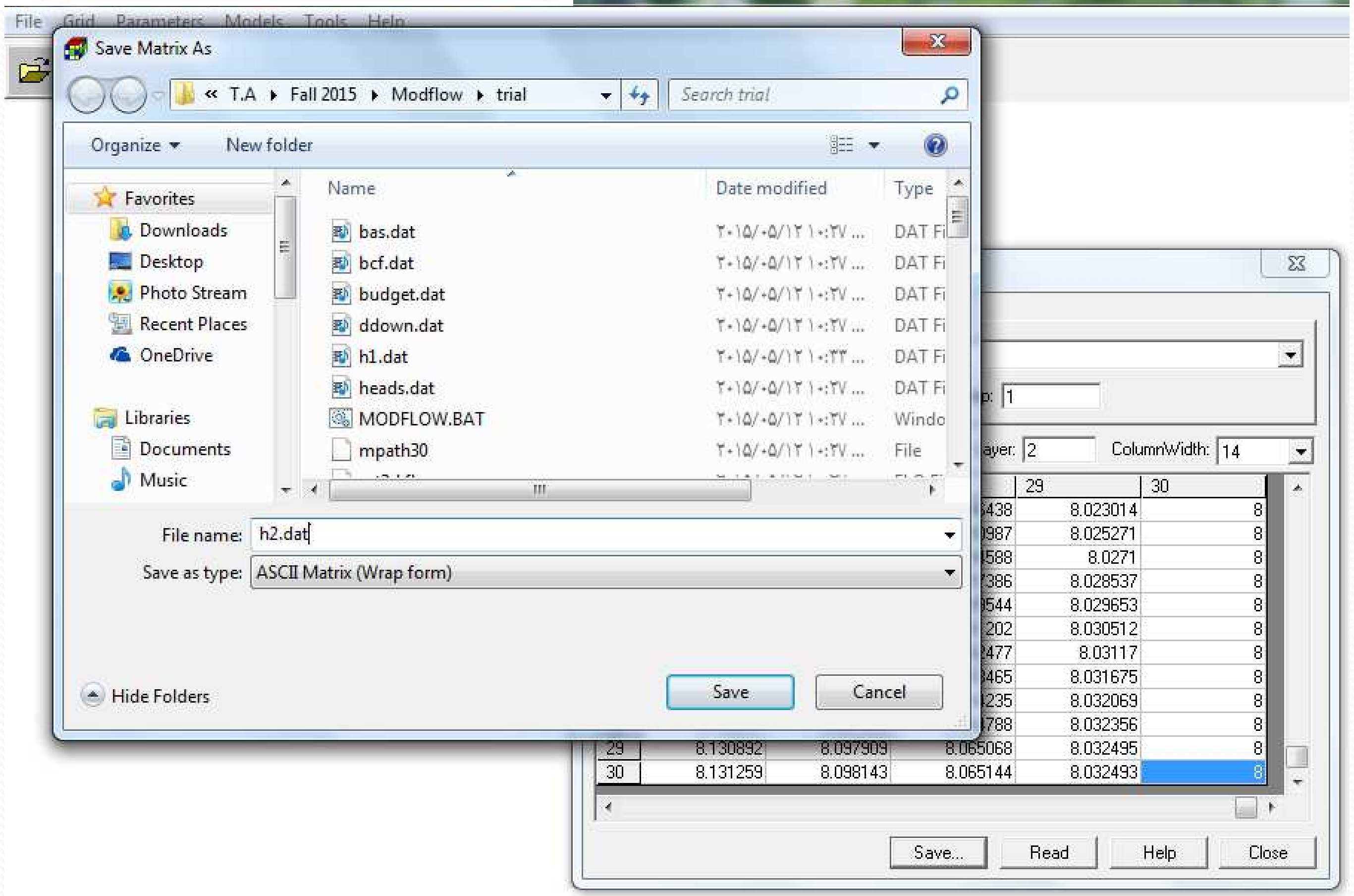
Hydraulic heads of each layer



	1	2	3	4	5
1	9	8.96543	8.9306	8.895605	8.860457
2	9	8.965313	8.930452	8.895454	8.860298
3	9	8.965233	8.930328	8.895316	8.860154
4	9	8.965171	8.930222	8.895185	8.860009
5	9	8.965119	8.930126	8.895058	8.859861
6	9	8.965075	8.930039	8.894938	8.859712
7	9	8.965037	8.92996	8.894823	8.859567
8	9	8.965004	8.929888	8.894716	8.859426
9	9	8.964975	8.929823	8.894619	8.859297
10	9	8.96495	8.929765	8.894531	8.85918
11	9	8.96493	8.929716	8.894456	8.859078
12	9	8.964914	8.929677	8.894394	8.858995

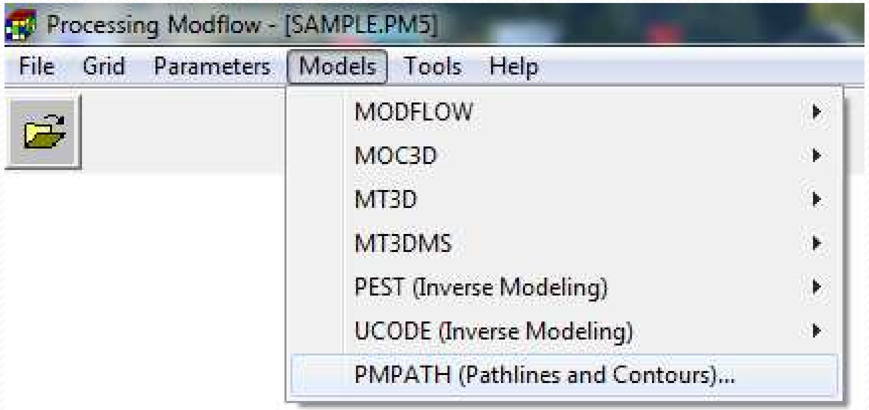


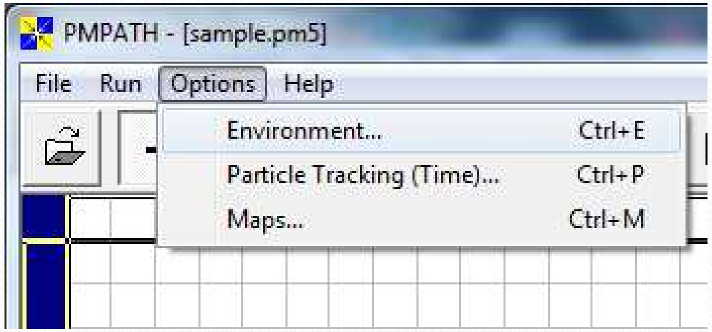
Processing Modflow - [SAMPLE.PM5]
File Grid Parameters Models Tools Help
Digitizer
Field Interpolator (PMDIS)...
Field Generator (PMFGN)...
Presentation
Results Extractor...
Water Budget...
Graphs

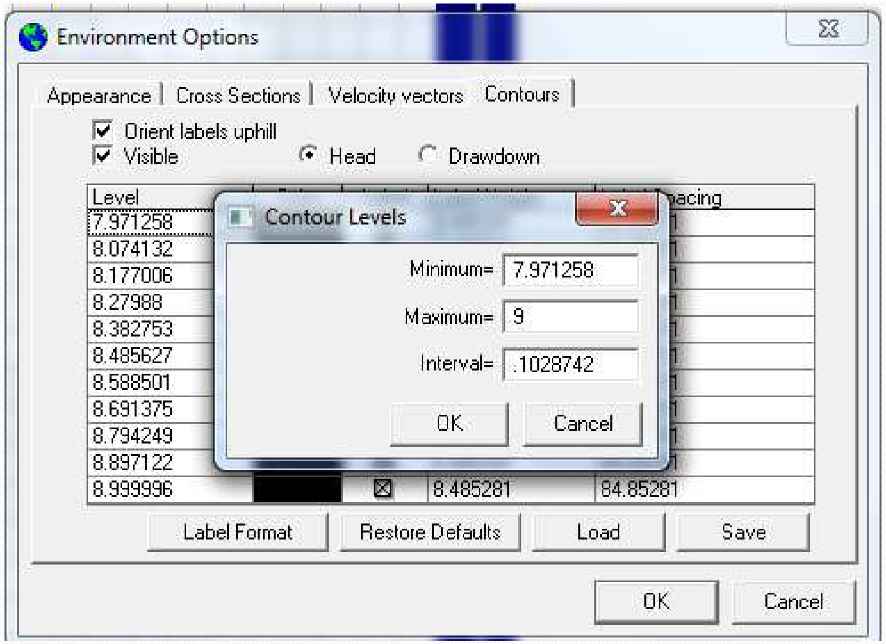


Save Matrix As
« T.A ▸ Fall 2015 ▸ Modflow ▸ trial
Search trial
Organize
New folder
Favorites
Downloads
Desktop
Photo Stream
Recent Places
OneDrive
Libraries
Documents
Music
Name
Date modified
Type
bas.dat
bcf.dat
budget.dat
ddown.dat
h1.dat
heads.dat
MODFLOW.BAT
mpath30
File name: h2.dat
Save as type: ASCII Matrix (Wrap form)
Hide Folders
Save
Cancel
ColumnWidth: 14
Save...
Read
Help
Close

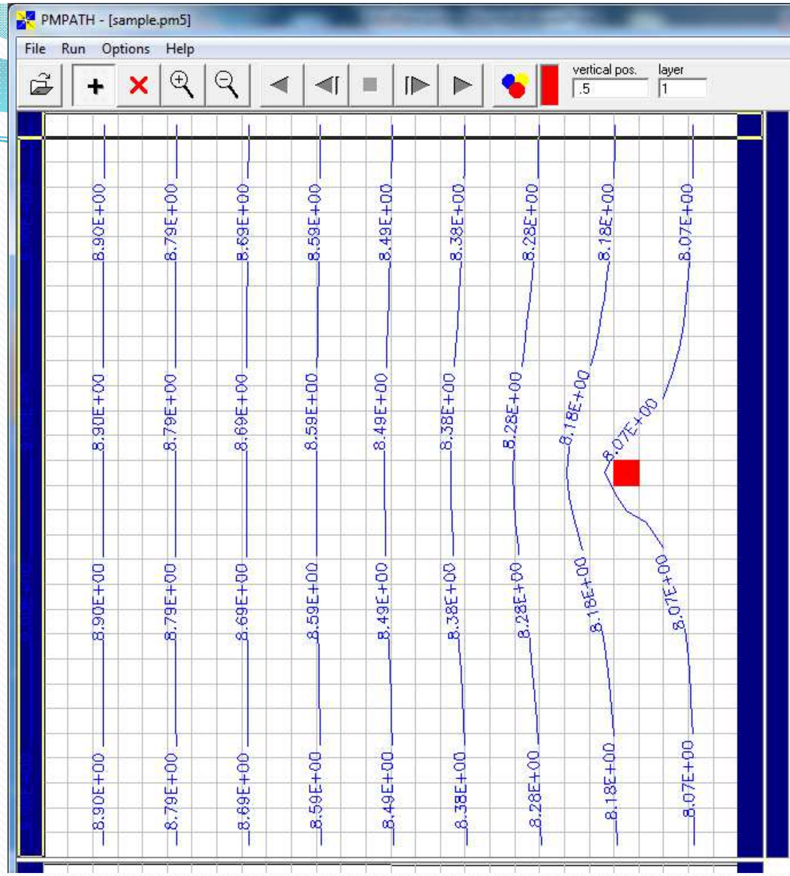
Contour maps of the calculated heads

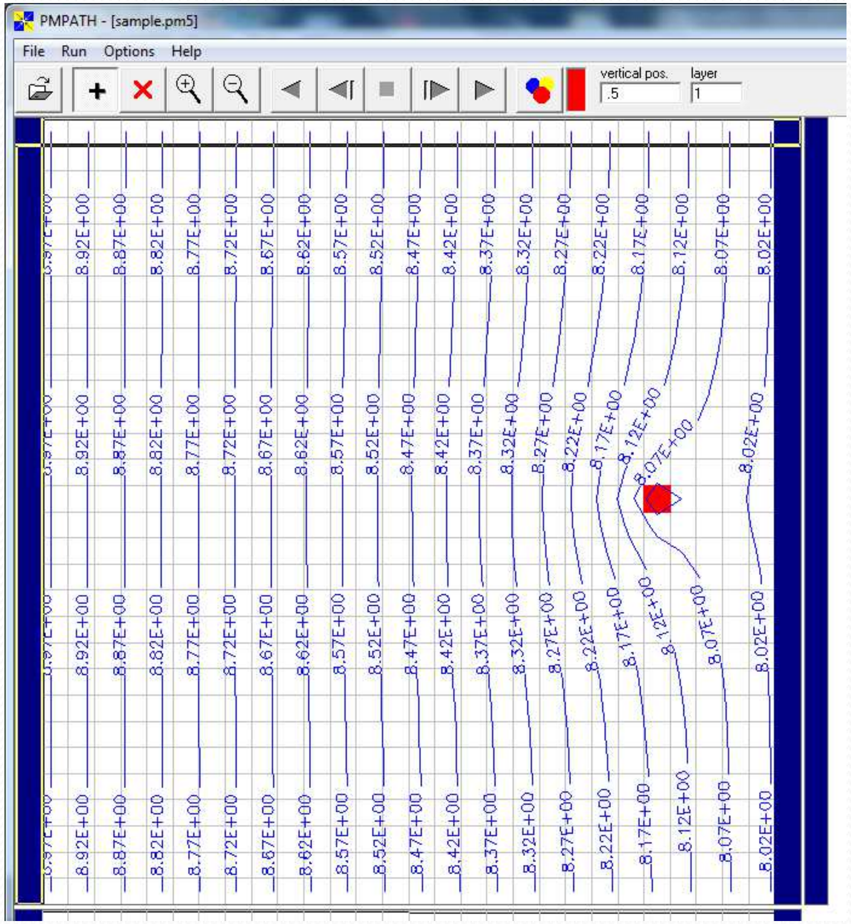






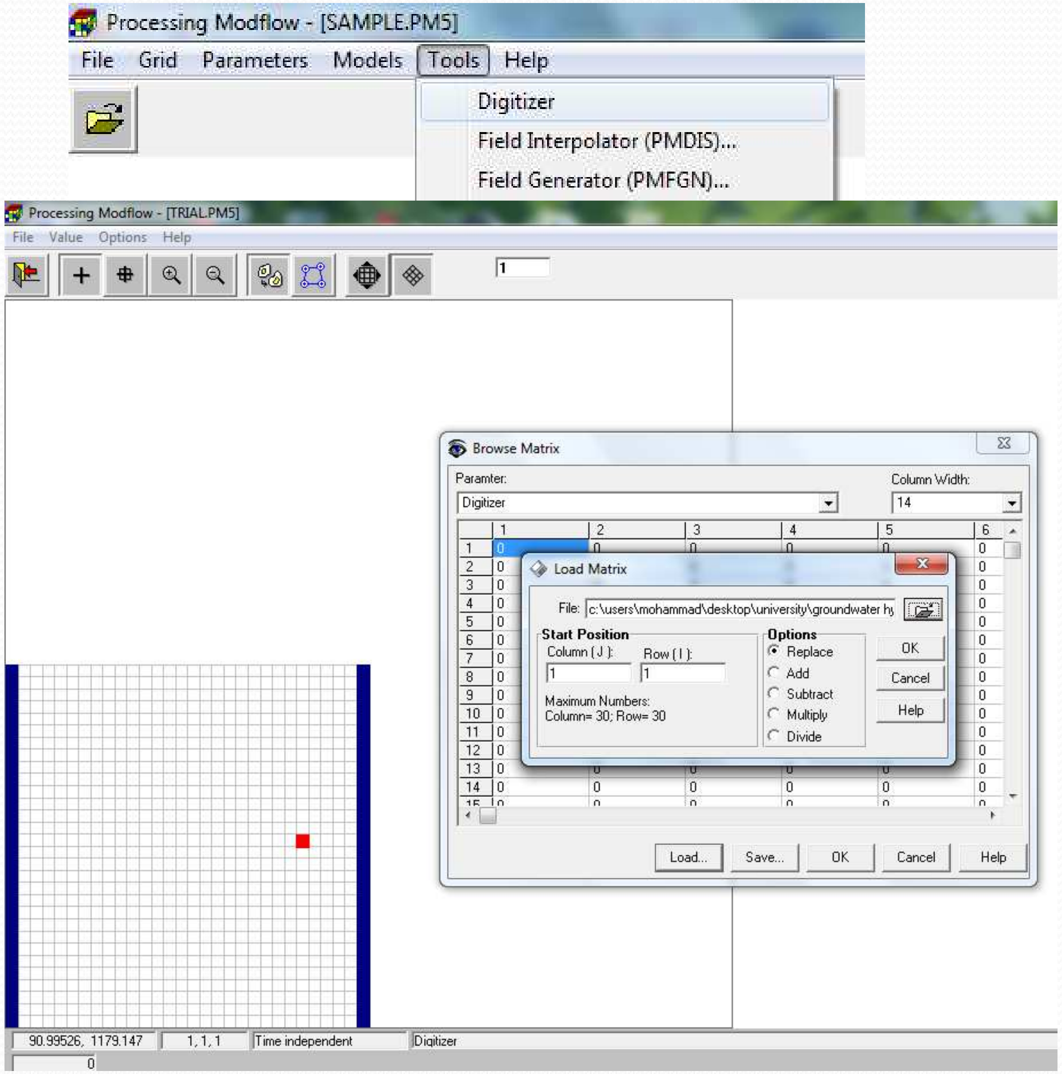
Interval= 0.1

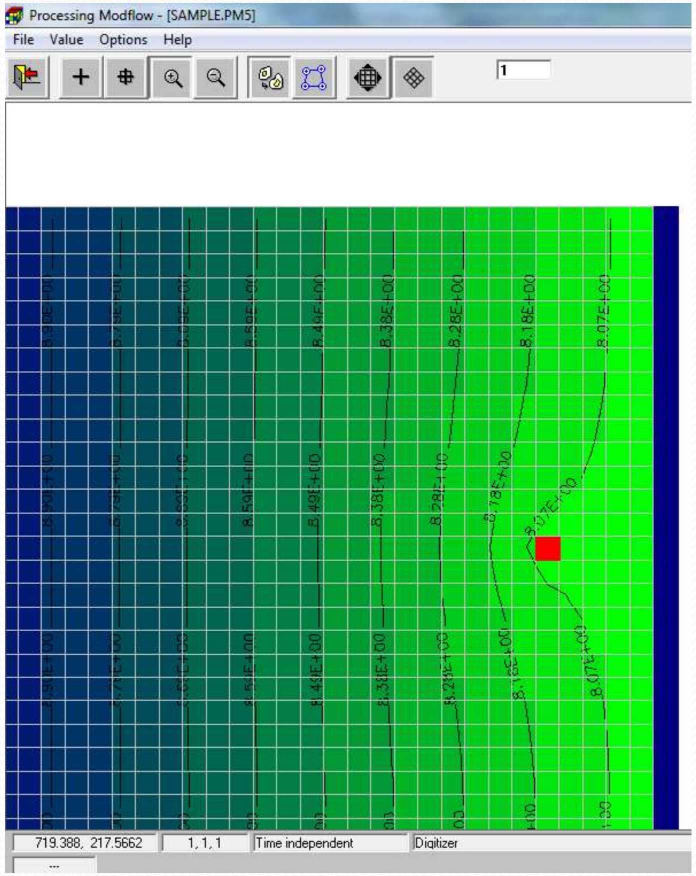




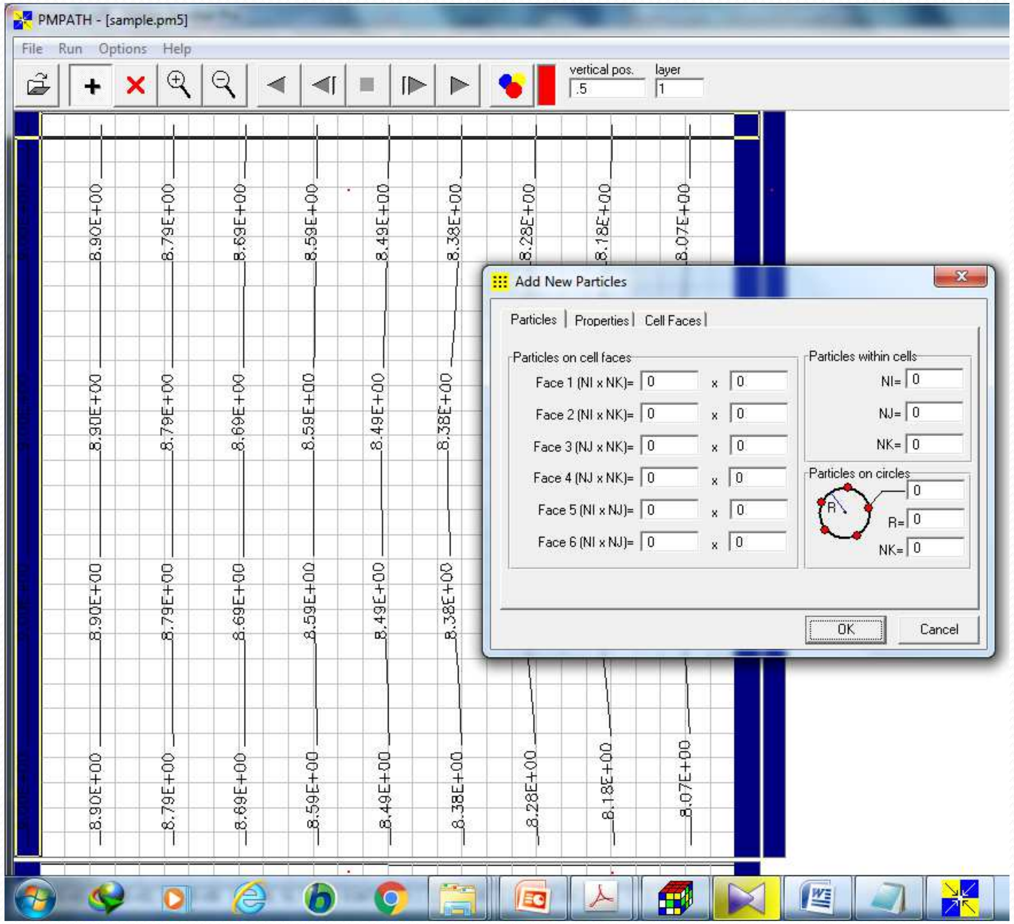
Interval= 0.05

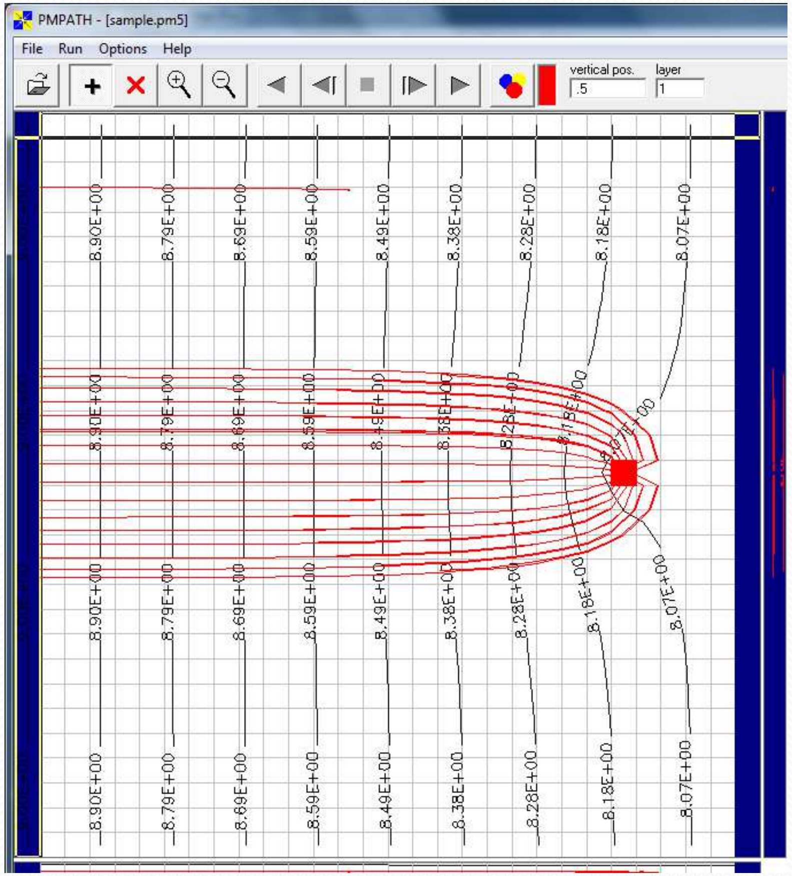
Solid fills of the calculated heads



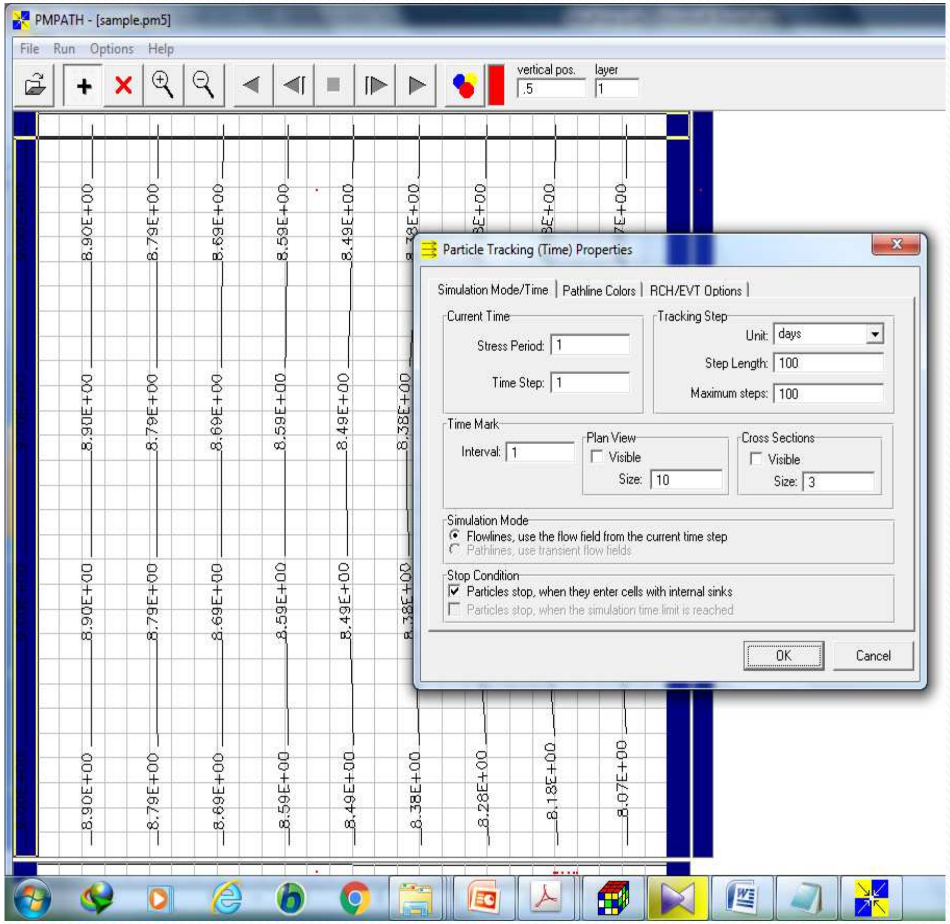


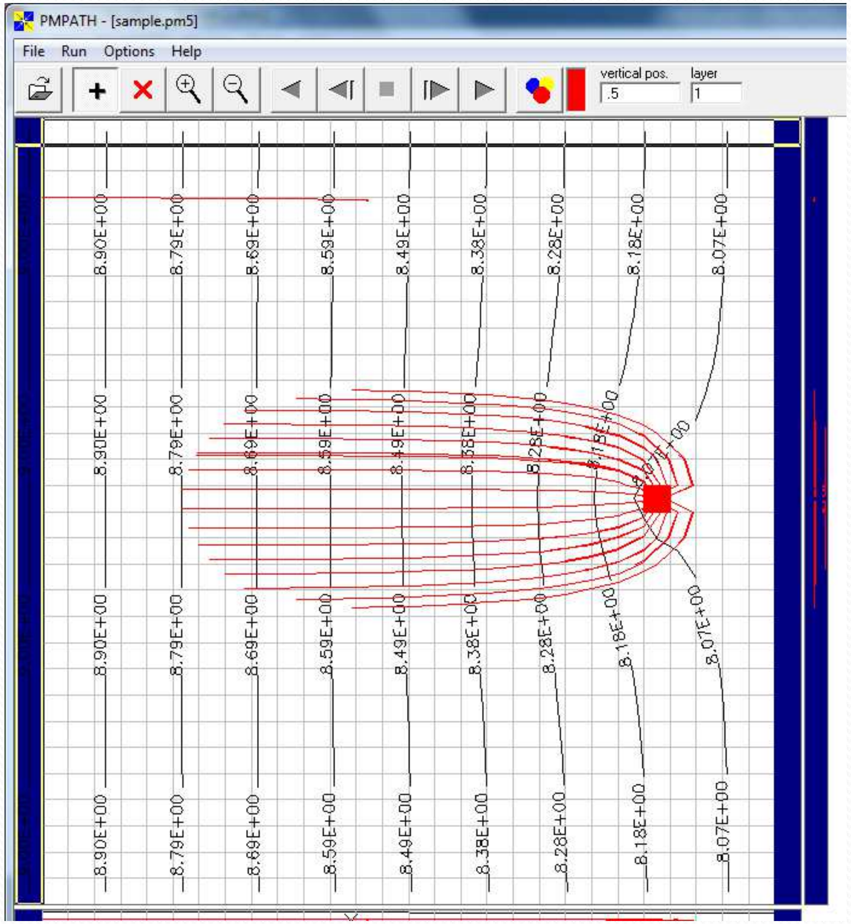
Capture zone of the pumping well





100-days-capture zone calculated by PMPATH





Thanks for your attention