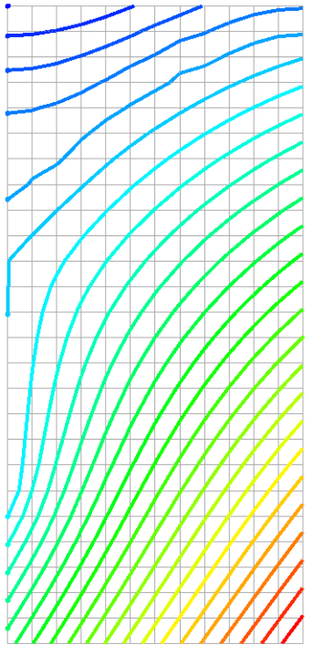
Tutorial

Seepage Face



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Outline

1 Description

This tutorial presents a groundwater flow analysis. It describes the determination of a seepage face by means of a nonlinear steady state analysis. The model is a rectangular vertical cross-section of 1.62 × 3.50 m [Fig. 1]. At side BC there is a potential height of 3.22 m and at side AD a potential height of 0.84 m. It is expected that a seepage point will occur somewhere at side AD. The material has a saturated hydraulic conductivity of 1e-6 m/s. A theoretical solution for this problem has been given by Muskat (1937)[1]: a seepage point at 2.06 m above point A.

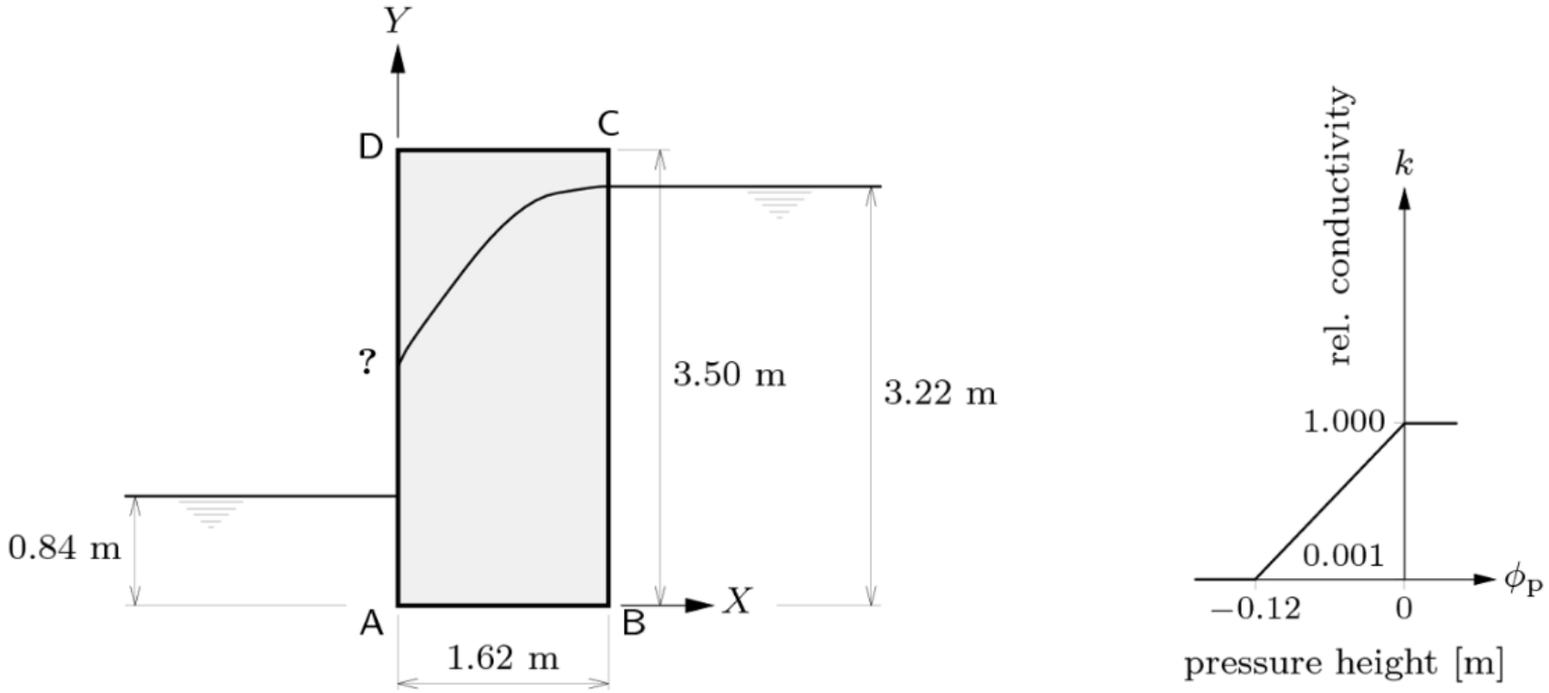

Figure 1: Geometry and characteristics of the model

[1] Muskat, *The Flow of Homogeneous Fluids Trough Porous Media*, 1937

2 Finite Element Model

We start a new project for a groundwater flow analysis with plane strain. The model thickness is 1m and the model size is set to 100 m. We use default units Figure 4.

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Main menu → File → New [Fig. 2]
Geometry browser → Reference system → Units [Fig. 3]
Property Panel [Fig. 4]

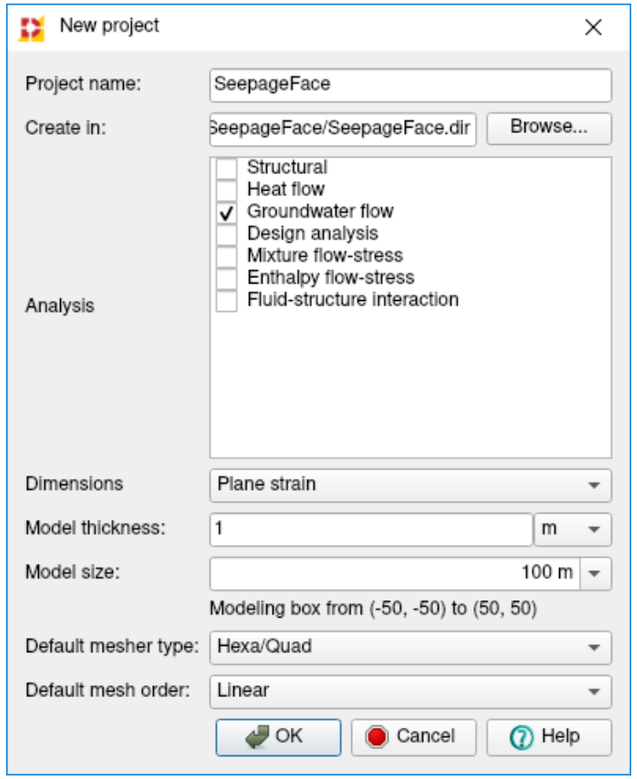

Figure 2: New project dialog

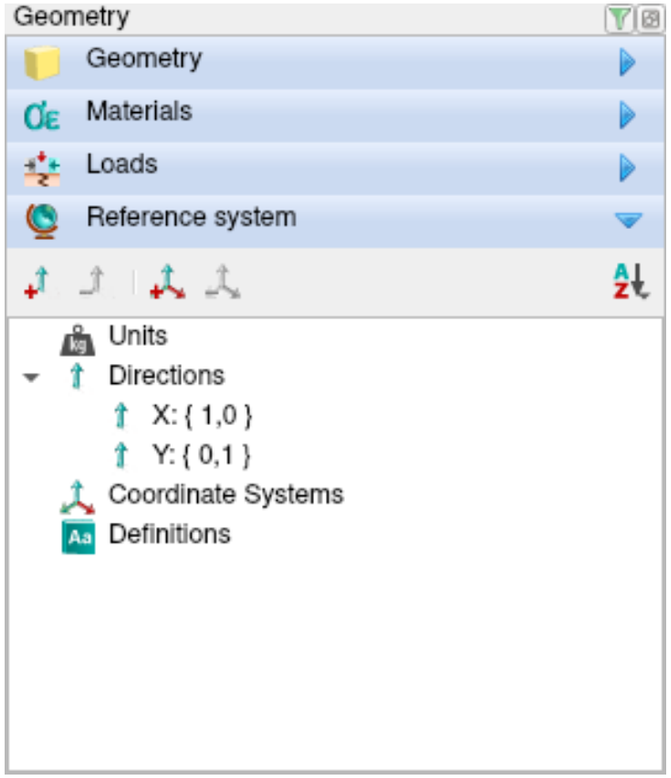

Figure 3: Geometry browser - units

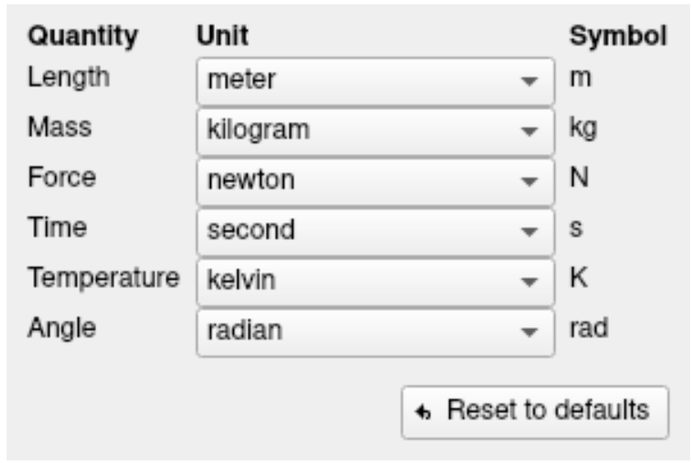

Figure 4: Property panel - units

2.1 Geometry

The geometry of the model consists of a rectangular sheet with corner points A, B, C, D respectively. An additional point is added on the right side at the location of the fixed potential height. The XY coordinates are: (0, 0), (1.62, 0), (1.62, 3.22), (1.62, 3.5), (0, 3.5).

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Main menu → Geometry → Create → Polygon sheet [Fig. 5]

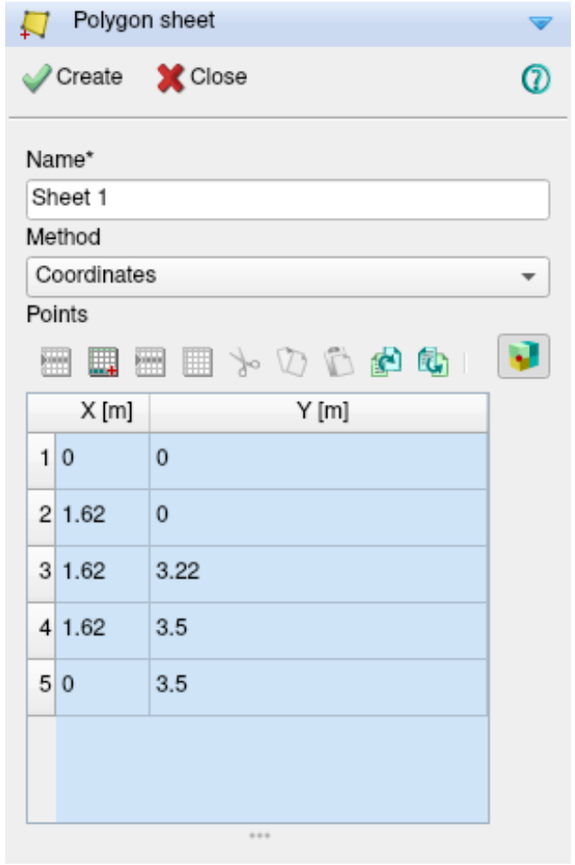

Figure 5: Create polygon sheet

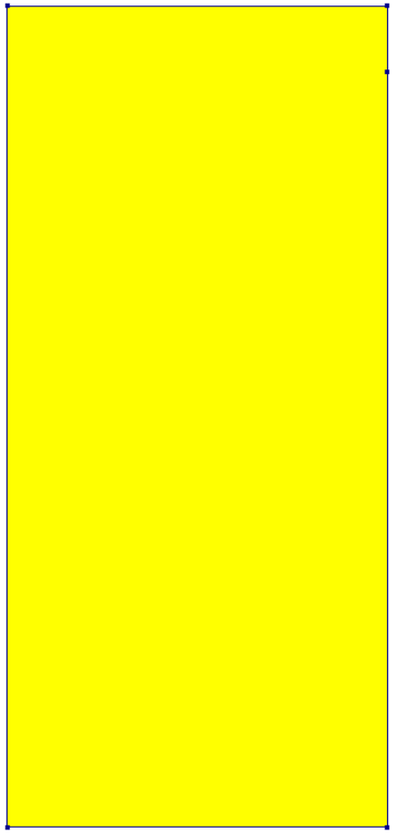

Figure 6: Polygon sheet

3 Properties

We define groundwater flow properties to the seepage face. Using the button, we can enter the tabular properties of the hydraulic conductivity.

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Main menu → Geometry → Assign → Shape properties [Fig. 7]
Shape properties → Material → Add material [Fig. 8] → Edit material [Fig. 9]

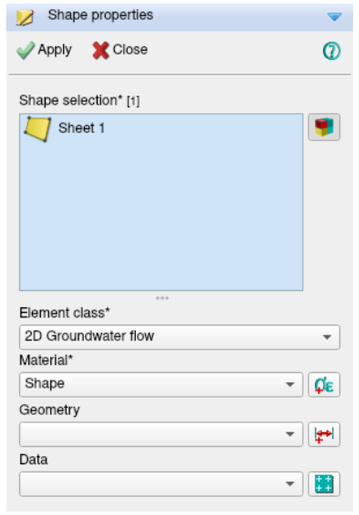

Figure 7: Property assignments seepage face

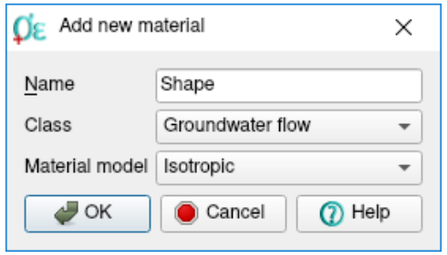

Figure 8: Add new material

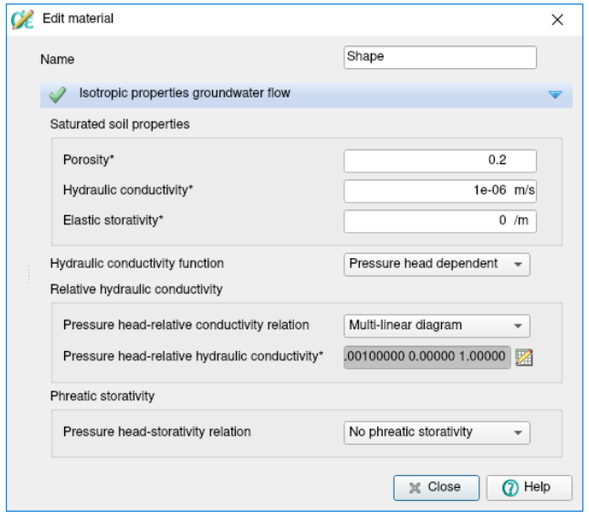

Figure 9: Edit material

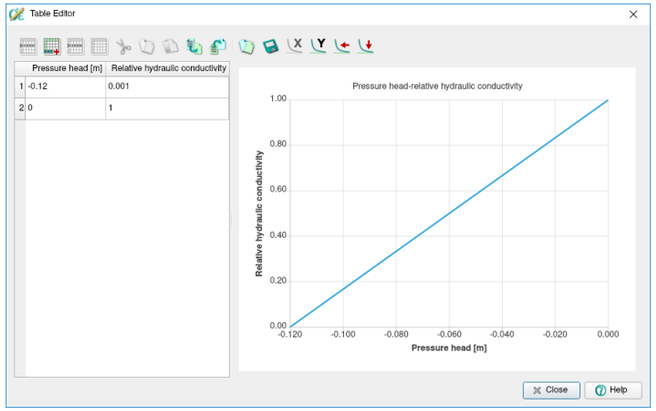

Figure 10: Edit conductivity properties

3.1 Boundary Conditions

3.1.1 Prescribed head

We apply a constant pressure head of 3.22 m at the right side of the model. For that, we need to fix the potential head on this edge.

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Main menu → Geometry → Assign → Groundwater boundary conditions [Fig. 12]

Edit groundwater conditions → Fixed head → Edit fixed heads [Fig. 11]

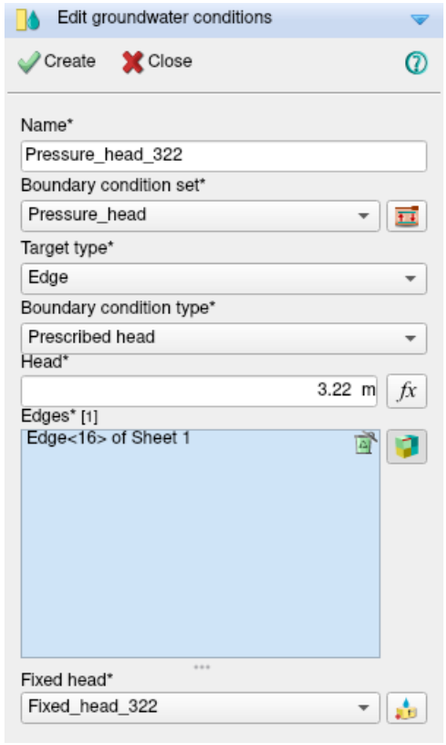

Figure 11: Create groundwater boundary condition

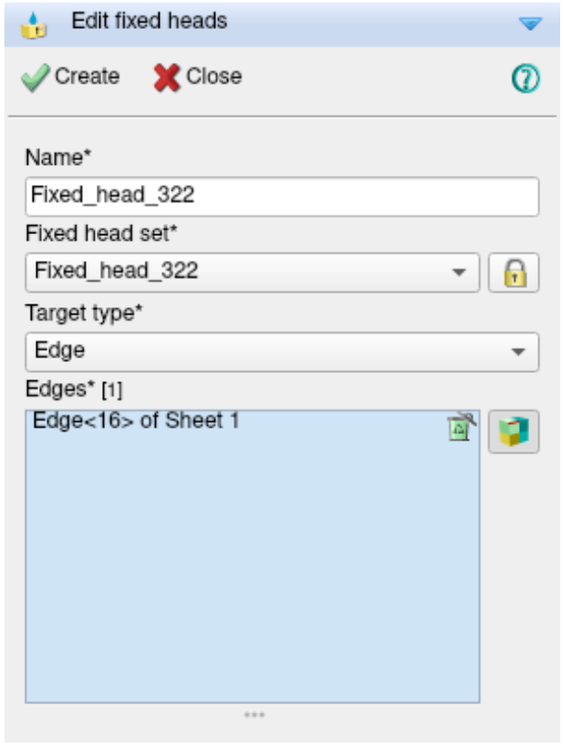

Figure 12: Create fixed head

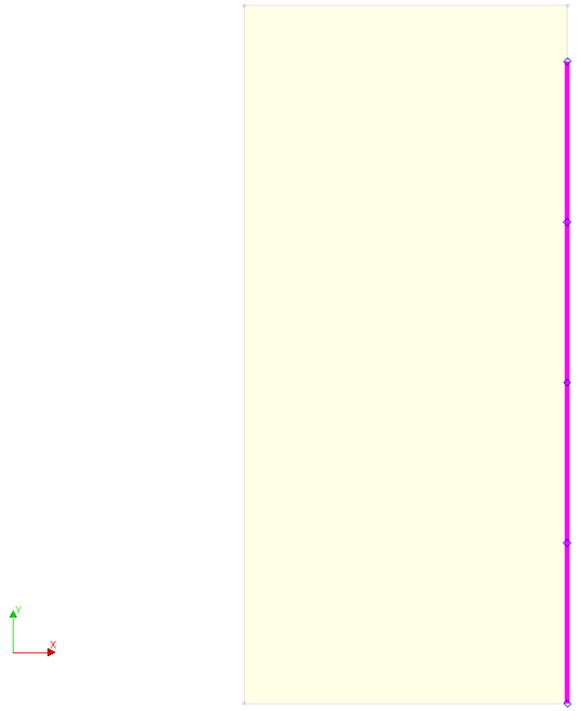

Figure 13: Boundary conditions on right side

3.1.2 External head

We create a groundwater flow boundary interface on the left side of the model. We create a new material model for groundwater flow boundary elements.
Before we define the boundary condition at the left-hand side we define the boundary interface connection dependent on these. It is also necessary to define the material and geometry properties for this connection.

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Main menu → Geometry → Assign → Connections [Fig. 14]
Edit connections → Material → Add material [Fig. 15] → Edit material [Fig. 16]

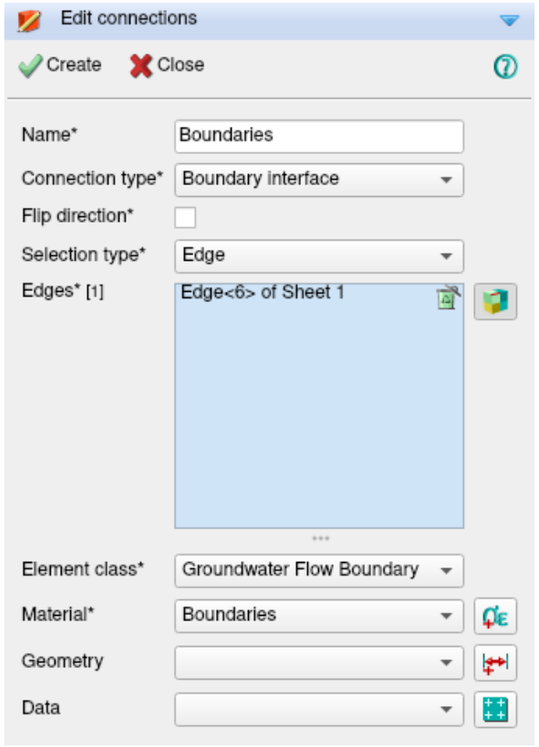

Figure 14: Connection property assignments

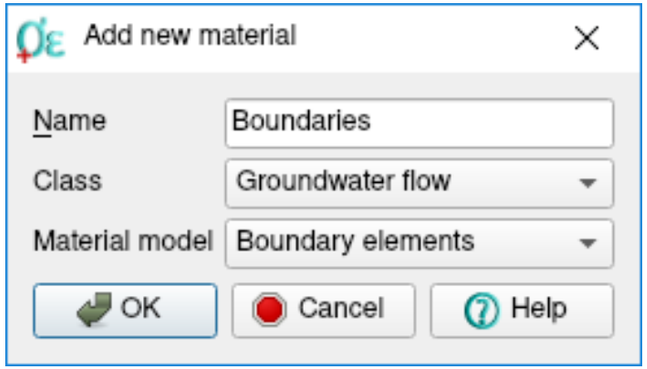

Figure 15: Add material: Boundaries

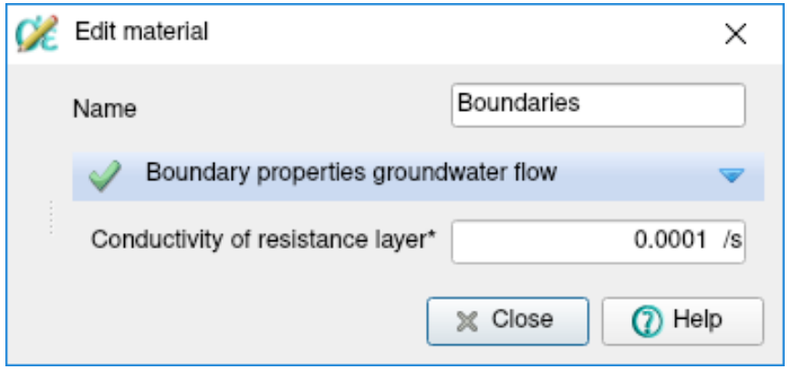

Figure 16: Edit material: Boundaries

We attach an external head of 0.84 m to the groundwater flow boundary interface.

Main menu → Geometry → Assign → Groundwater boundary conditions [Fig. 17]

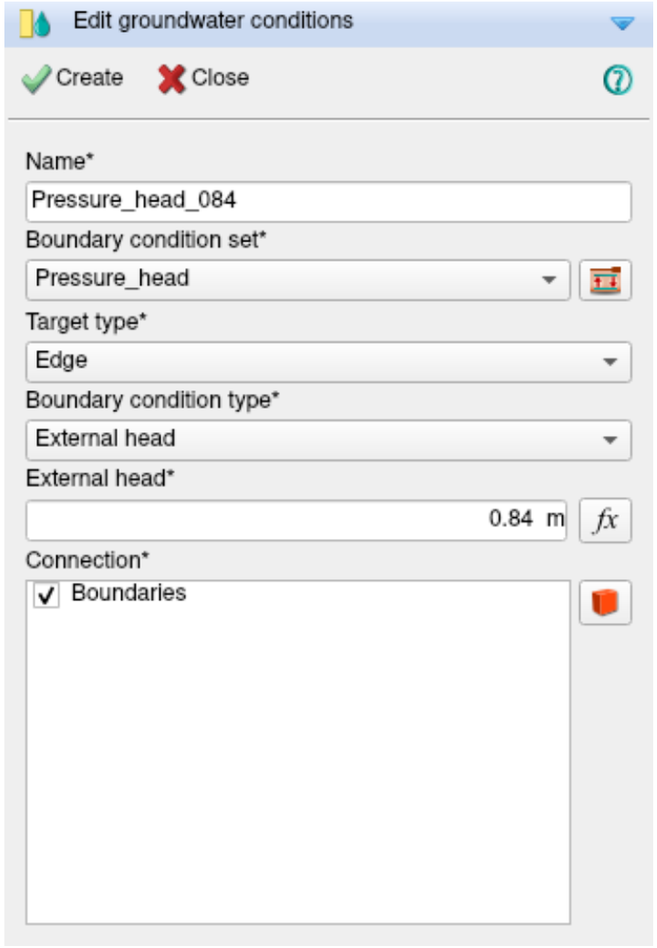

Figure 17: Attach boundary condition

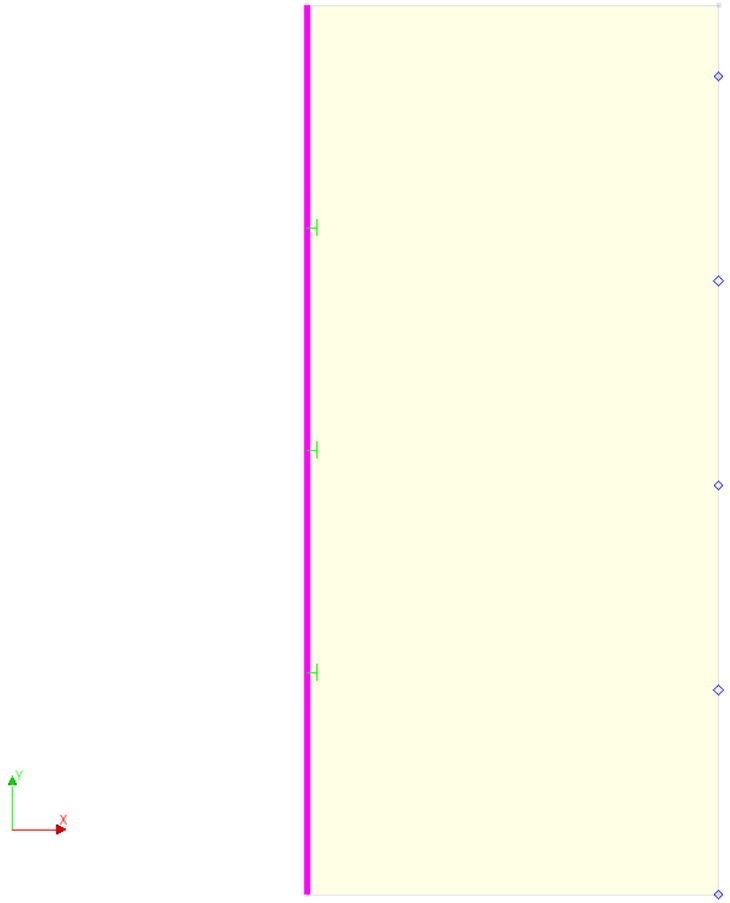

Figure 18: Connection properties on the left side

3.2 Mesh

We create a mesh with a desired element size of 0.14 m and we generate the mesh.

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Main menu → Geometry → Mesh → Mesh properties [Fig. 19]

Main menu → Geometry → Mesh → Generate mesh [Fig. 20]

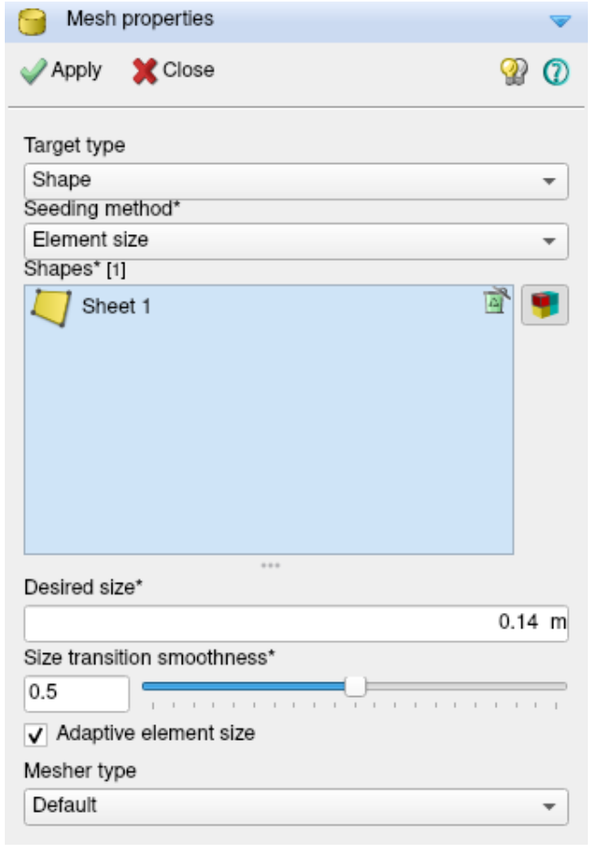

Figure 19: Mesh properties

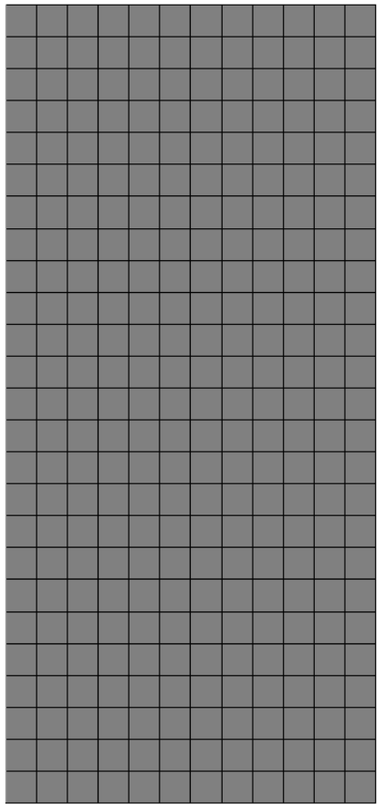

Figure 20: Finite element mesh

4 Nonlinear Steady State Groundwater Flow

4.1 Commands

We perform a nonlinear steady state groundwater flow analysis. For that we add a new analysis and a command for steady state groundwater flow. In the execute properties we consider the nonlinear analysis type.

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Main menu → Analysis → Add analysis [Fig. 21]

Analysis browser → Analysis → Add command → Steady state ground water flow [Fig. 22]

Analysis browser → Analysis → Steady state ground water flow → Execute groundwater flow analysis → Edit properties [Fig. 23]

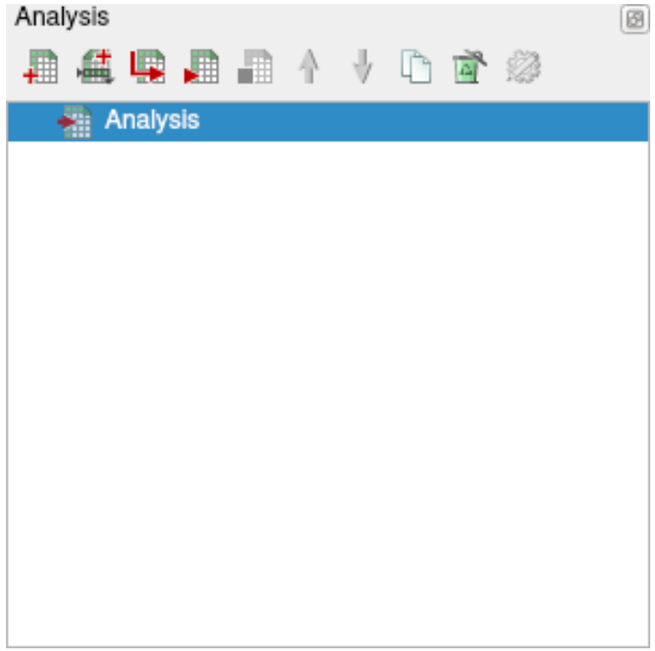

Figure 21: Analysis browser

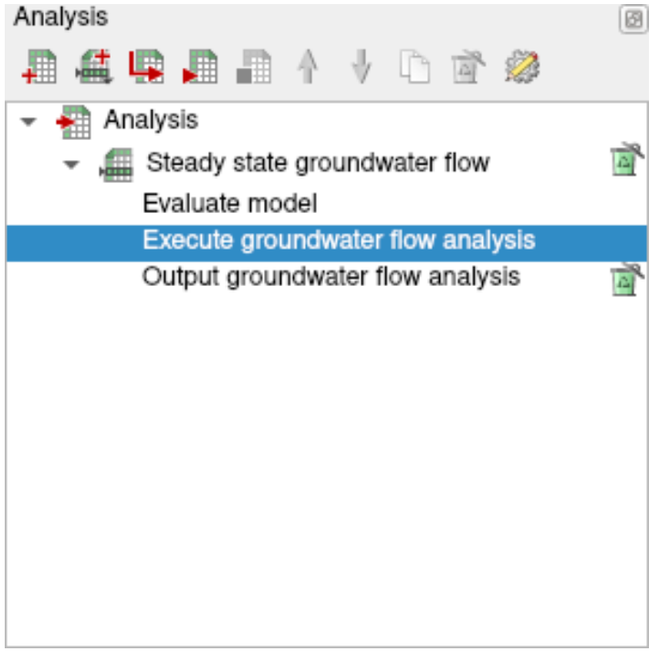

Figure 22: Analysis browser

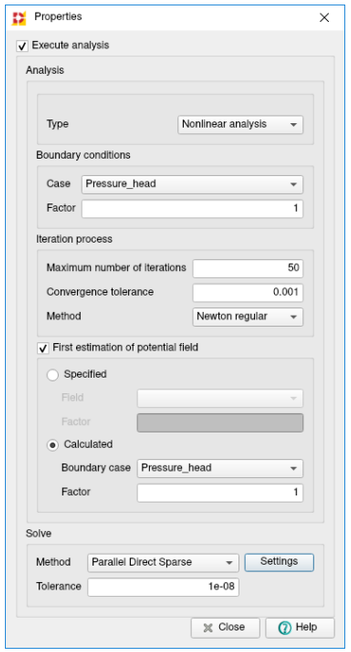

Figure 23: Nonlinear properties

In the output properties we select the results for total heads, pressure heads and fluxes. For the fluxes (FLUX TOTAL GLOBAL) we specify the location in the integration points. Finally, we run the analysis.

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Analysis browser → Analysis → Steady state ground water flow → Output groundwater flow analysis → Edit properties [Fig. 24] – [Fig. 27]

Main menu → Analysis → Run selected analysis

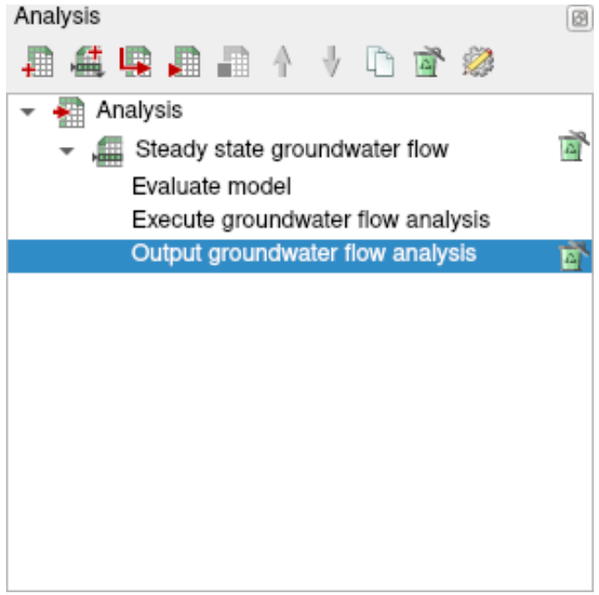

Figure 24: Analysis browser

Figure 25: Output properties

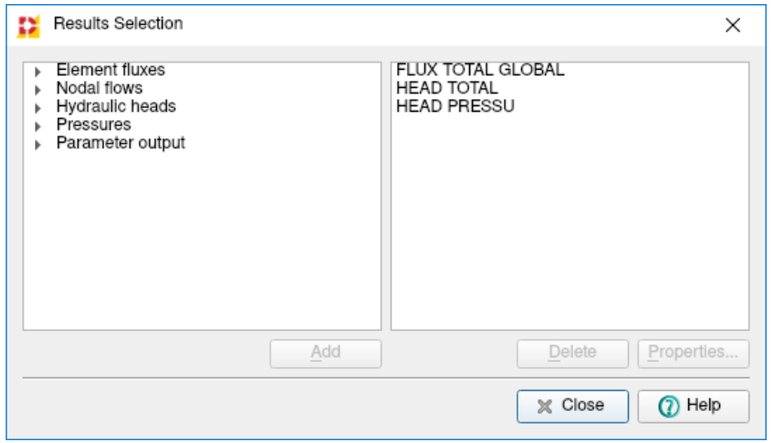

Figure 26: Results selection

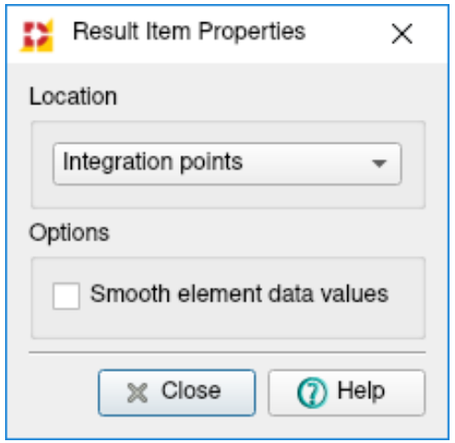

Figure 27: Results location

4.2 Results

We present the contour plot of the pressure head [Fig. 28]. In the view settings panel we set the contour levels to equidistant levels and specify the number of contour levels to 25 [Fig. 29]. Also the vector plot of the groundwater flux is presented [Fig. 30].

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Results browser → Analysis → Output groundwater flow analysis → Nodal results → Pressure Head → HP → Show contours

Graphics window → Show view settings

Results browser → Analysis → Output groundwater flow analysis → Element results → Groundwater Flux → FLXYZ → Show vectors

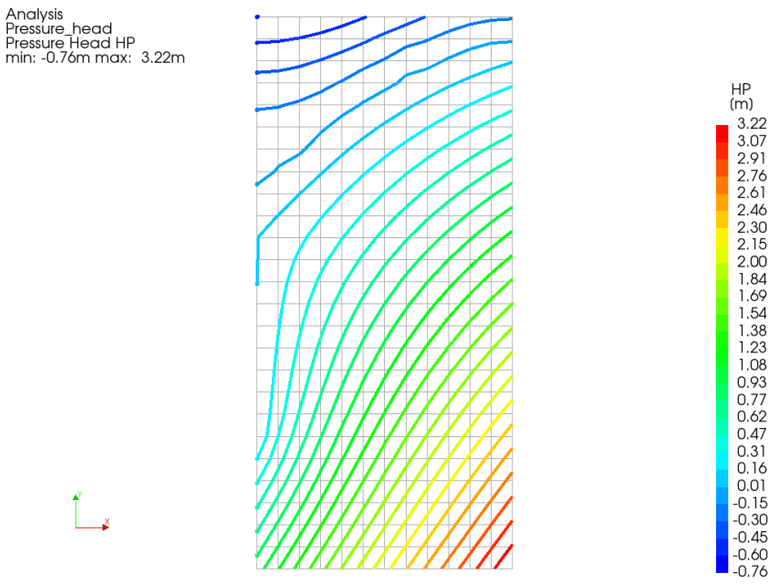

Figure 28: Pressure head - nonlinear analysis

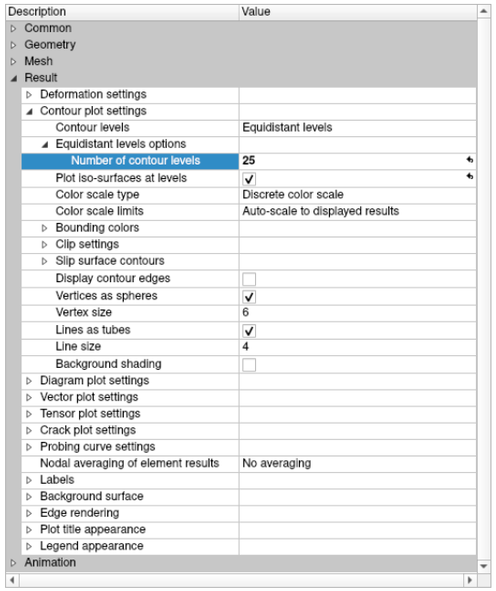

Figure 29: View settings panel

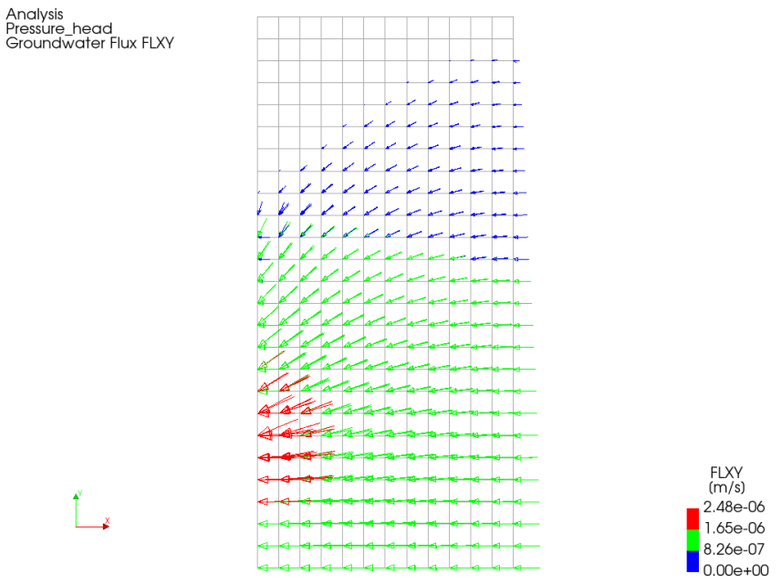

Figure 30: Groundwater flux - nonlinear analysis

Finally, we plot the phreatic line [Fig. 31] to get the seepage point. We do this in the same manner as done for the linear steady state groundwater flow analysis [Fig. 32]. With the we can measure the distance between point A and the seepage point (see Figure 1).

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Results browser → Analysis → Output groundwater flow analysis → Nodal results → Pressure Head → HP → Show contours

Graphics window → Show view settings

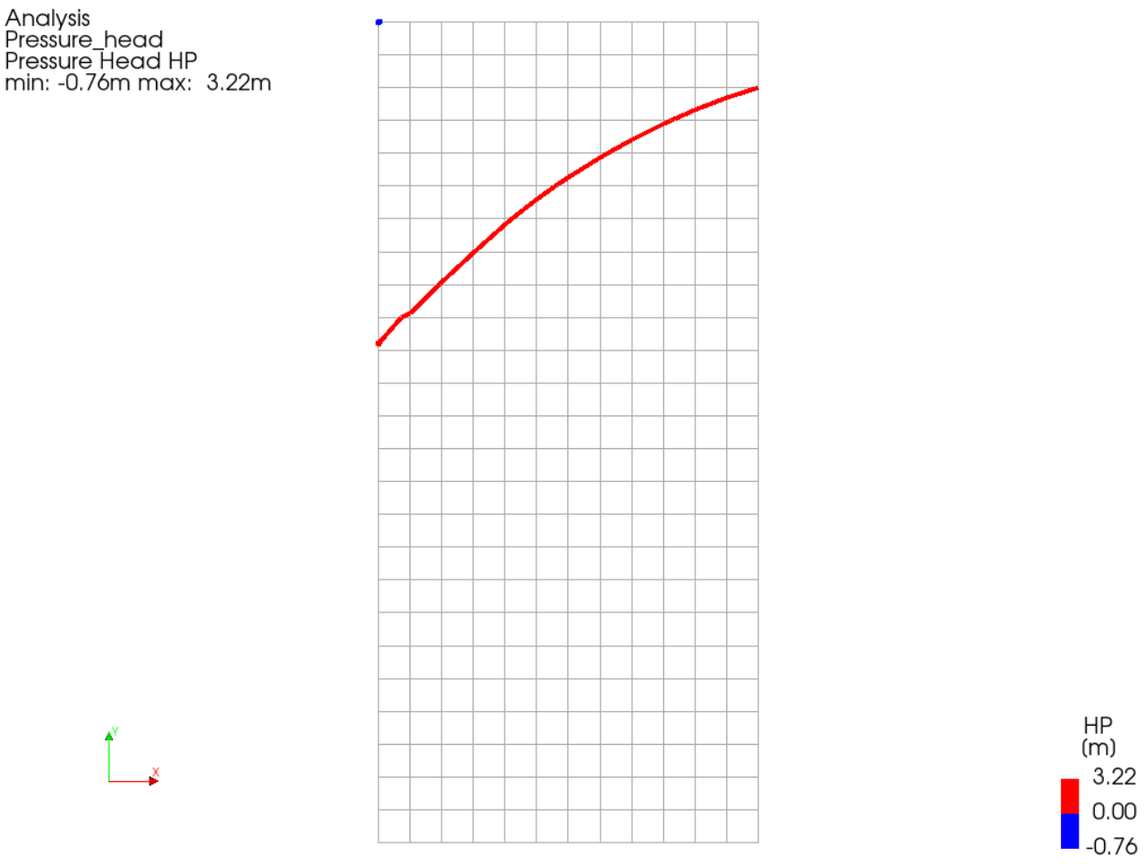

Figure 31: Phreatic line non-linear steady state groundwater flow analysis

Description	Value
▷ Common	
▷ Geometry	
▷ Mesh	
◢ Result	
▷ Deformation settings	
◢ Contour plot settings	
Contour levels	**At specific values**
◢ Specified values options	
value	0.00000
Plot iso-surfaces at levels	☑
Color scale type	Discrete color scale
Color scale limits	Auto-scale to displayed results
▷ Bounding colors	
▷ Clip settings	
▷ Slip surface contours	
Display contour edges	☐
Vertices as spheres	☑
Vertex size	6
Lines as tubes	☑
Line size	4
Background shading	☐
▷ Diagram plot settings	
▷ Vector plot settings	
▷ Tensor plot settings	
▷ Crack plot settings	
▷ Probing curve settings	
Nodal averaging of element results	No averaging
▷ Labels	
▷ Background surface	
▷ Edge rendering	
▷ Plot title appearance	
▷ Legend appearance	
▷ Animation	

Figure 32: View settings phreatic line

5 Verification

The theoretical solution given by Muskat (1937)[1] is a seepage point of 2.06 m above the bottom of the model. From the plot of the phreatic line we can determine that the phreatic line reaches the left side of the model (the seepage point) at 2.129 m above the bottom, which seems to be quite accurate.
The theoretical solution assumes a perfect separation between saturated and unsaturated areas but in reality, and also in this DianaIE analysis, a partly saturated area will occur just above the phreatic line. Due to this partly saturated area the seepage point will be situated at a bit higher level.

Appendix A Additional Information

Folder: Tutorials/SeepageFace

Number of elements ≈ 300

Keywords:
ANALYS: flow growa nonlin steady.
CONSTR: head.
ELEMEN: b2gw flow ground q4gw.
LOAD: elemen head node.
MATERI: hydcnd isotro permea porosi.
OPTION: direct.
POST: binary ndiana.
PRE: dianai.
RESULT: flux head pressu total.

References:

[1] M. Muskat. *The Flow of Homogeneous Fluids Trough Porous Media*. McGraw-Hill, 1937.

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