

POLLUTE

Version 8

Example 6: Fractured Layer and Sorption



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Description

This example illustrates the use of the program for the case where one of the layers are fractured and there is adsorption of the contaminant species. The “barrier” consists of a 1 m thick compacted clay layer overlying a 3 m thick fractured till. A reactive species (i.e., one that will sorb on to the clay) is modelled in this case. The same finite mass source and leachate collection system is used as in the previous examples. A Darcy velocity (v_a) of 0.02 m/a through the deposit and an infiltration through the cover (q_o) of 0.3 m/a are assumed. The Volume of Leachate Collected (Q_c) is then given by:

$$Q_c = q_o - v_a = 0.3 - 0.02 = 0.28 \text{ m/a}$$

As in the previous examples the inflow in the aquifer at the up gradient edge of the landfill is 4 m/a. The outflow (v_b) at the down gradient edge of the landfill is then:

$$v_b = 4 + 200 \times 0.02 = 8 \text{ m/a}$$

The following parameters are defined for this example:

Property	Symbol	Value	Units
Darcy Velocity	v_a	0.02	m/a
Diffusion Coefficient	D	0.01	m ² /a
Distribution Coefficient	K_d	1.5	cm ³ /g
Soil Porosity	n	0.4	-
Dry Density		2	g/cm ³
Soil Liner Thickness	H_L	1	m
Number of Sub-layers		1	-
Fractured Till Thickness	H_T	3	m
Number of Sub-layers		1	-
Fracture spacing in x direction	$2H_1$	1	m
Fracture opening in x	$2h_1$	10	μm
Fracture spacing in y direction	$2H_2$	1	m
Fracture opening in y	$2h_2$	10	μm
Dispersion along fractures	D_f	0.06	m ² /a
Fracture Distribution Coefficient	K_f	0	cm ³ /g
Matrix Diffusion Coefficient	D_m	0.01	m ² /a
Matrix Distribution Coefficient	K_m	1.5	cm ³ /g
Matrix Porosity	n_m	0.4	-
Dry Density of Matrix		2	g/cm ³
Source Concentration	c_o	1000	mg/L
Rate of Increase in c_o	c_r	0	mg/L/a
Ref. Height of Leachate	H_r	7.5	m
Volume Collected	Q_c	0.28	m/a
Landfill Length	L	200	m
Landfill Width	W	1	m
Thickness of Aquifer	h	1	m
Porosity of Aquifer	n_b	0.35	
Base Outflow Velocity	v_b	8	m/a
Lower and Upper Time Limits		20, 300	a

Data Entry

Open the Examples project and open Case 6.

General Tab

The screenshot displays the 'General' tab of a software interface. At the top, there is a toolbar with icons for 'Run', 'Auto', 'On', 'Off', 'Save', and 'Save As'. Below the toolbar are tabs for 'General', 'Layers', 'Boundaries', 'Special Features', and 'Subsurface Model'. The 'General' tab is active and contains several sections:

- General Information:** Includes a text field for 'Model Title' (Case 6: Fractured layer and sorption), a 'Maximum Depth' field (5 m), and a 'Darcy Velocity' field (0.02 m/year).
- Laplace Transform Parameters:** Includes input fields for 'TAU' (7), 'N' (20), 'SIG' (0), and 'RNU' (2).
- Run Parameters:** Includes a sub-section for 'Output Units' with dropdowns for 'Time Units' (yr), 'Depth Units' (m), and 'Concentration Units' (mg/L). Below this are radio buttons for 'All Depths' (selected), 'Specified Depths', 'Concentrations at Specified Times', and 'Maximum Concentrations'. The 'Maximum Concentrations' section includes fields for 'Search Depth' (4), 'Accuracy (%)' (0.01), 'Number of Iterations' (25), 'Lower Time Limit' (20), and 'Upper Time Limit' (300).

On the General tab the Darcy velocity of 0.02 m/a can be specified. The run parameters for this model are specified at the bottom of this tab where the parameters for searching for the maximum concentration can be specified.

Layers Tab

Run

Auto

On

Off

Save

Save As

General

Layers

Boundaries

Special Features

Subsurface Model

+ Add

X Delete

Copy

Paste

↓ Move Down

↑ Move Up

Name	Sublayers	Thickness	Thickness Units	Dry Density	Density Units	Porosity	Hydrodynamic Dispersion Coefficient	Dispersion Units	Distribution Coefficient	Distribution Units	Fractures	Symbol
Compacted Clay	1	1	m	2	g/cm³	0.4	0.01	m²/a	1.5	cm³/g	None	
Fractured Till	1	3	m	2	g/cm³	0.4	0.01	m²/a	1.5	cm³/g	2	

The layer data for the two layers can be specified on the Layers tab. The first layer in this model is a compacted clay with no fractures. The second layer is a fractured till with 2 dimensional fractures. When this layer is selected the parameters for the two sets of fractures can be specified. The x and y directions for a 2-dimensional fracture system refer to two sets of vertical fractures which are approximately perpendicular to each other. Fracture opening size is the gap between the walls of the fractures in m for metric units.

Boundaries Tab

Run	Auto	On	Off	Save	Save As		
General	Layers	Boundaries	Special Features	Subsurface Model			

Top Boundary

☐ Zero Flux
☐ Constant Concentration
☒ Finite Mass

Initial Source Concentration:

Rate of Concentration Increase:

Volume of Leachate Collected:

Specify

☒ Reference Height of Leachate ☐ Waste Properties

Reference Height of Leachate:

Bottom Boundary

☐ Zero Flux
☐ Constant Concentration
☒ Fixed Outflow Velocity
☐ Infinite Thickness

Landfill Length:

Landfill Width:

Base Thickness:

Base Porosity:

Base Outflow Velocity:

Base Symbol 

The boundary conditions for the model can be specified on the Boundaries tab. In this example, the top boundary has a finite mass and the bottom boundary is represented as an aquifer

with a fixed outflow velocity.

Model Execution



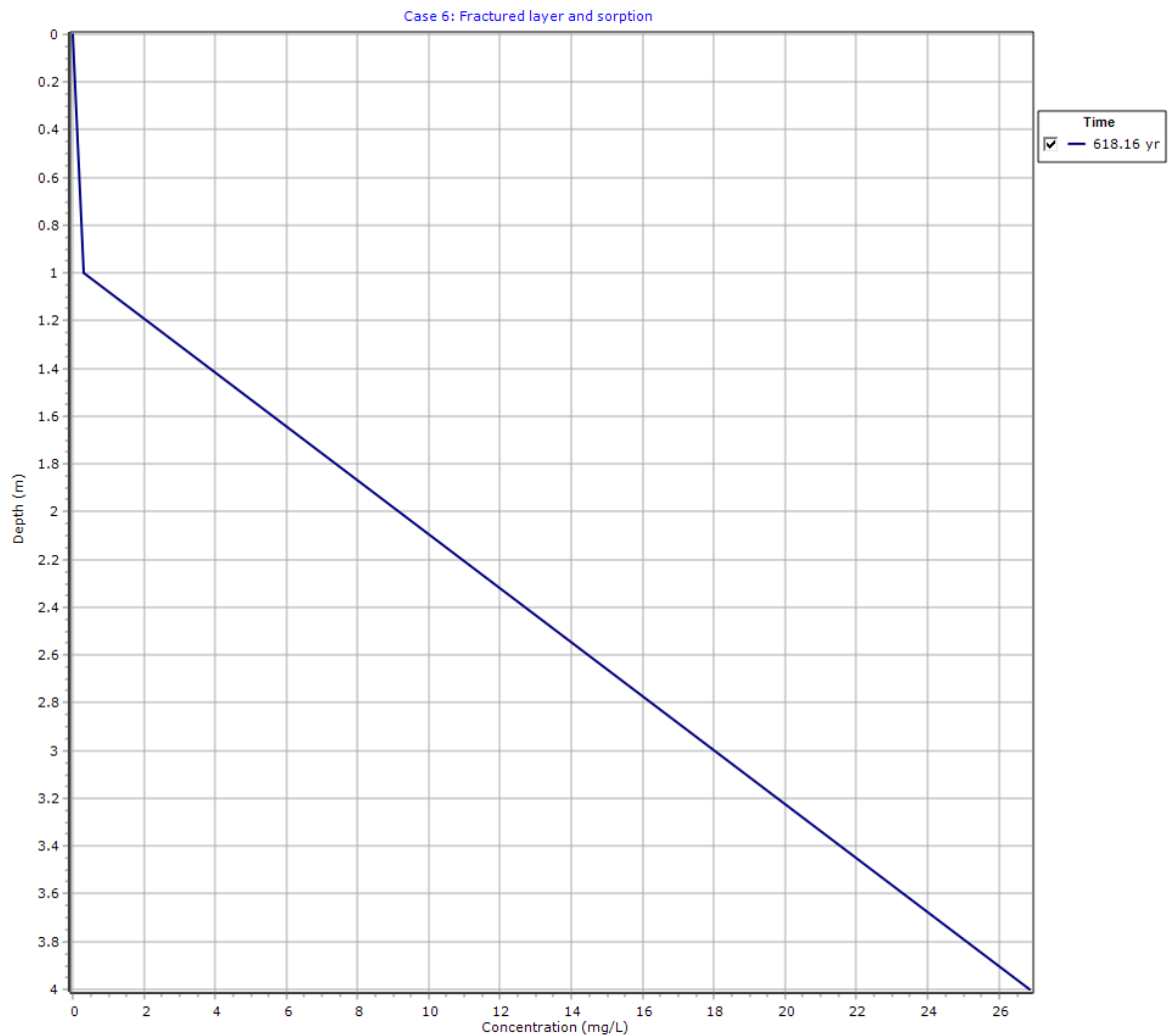
To run the model and calculate the concentrations press the Run button on the toolbar.

Model Output

After the model has been executed, the output for the model will be displayed.

Depth vs Concentration

The Depth vs Concentration chart can be displayed by selecting the Depth vs Concentration item for the Chart Type.



Output Listing

To display the output as a text listing that will show the calculated concentrations as numbers, click on the List tab. The peak concentration occurred at 618 years, which is outside the lower and upper time limits specified. In this example the program was able to find the peak since the bounds were reasonably close to the peak time of occurrence.

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Case 6: Fractured layer and sorption

THE DARCY VELOCITY (Flux) THROUGH THE LAYERS $V_a = 0.02$ m/year

Layer Properties

Layer	Fracture Spacing 1	Opening Size 1	Number 1	Fracture Spacing 2	Opening Size 2	Number 2	Fracture Spacing 3	Opening Size 3	Number 3
Fractured Till	1	1E-5	10	1	1E-5	10			

Layer	Dispersion Coefficient in Fractures	Distribution Coefficient in Fractures	Fracture Porosity	Retardation Coefficient in Matrix
Fractured Till	0.06	0	2.0000E-05	8.5000E+00

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distribution Coefficient	Dry Density
Compacted Clay	1 m	1	0.01 m ² /a	0.4	1.5 cm ³ /g	2 g/cm ³
Fractured Till	3 m	1	0.01 m ² /a	0.4	1.5 cm ³ /g	2 g/cm ³

Boundary Conditions**Finite Mass Top Boundary**

Initial Concentration = 1000 mg/L
 Rate of Increase = 0 mg/L/yr
 Volume of Leachate Collected = 0.28 m/a
 Thickness of Waste = 0 m
 Waste Density = 0 kg/m³
 Proportion of Mass = 0
 Volumetric Water Content = 0
 Conversion Rate Half Life = 0 year
 Reference Height of Leachate = 7.5 m

Fixed Outflow Bottom Boundary

Landfill Length = 200 m
 Landfill Width = 1 m
 Base Thickness = 1 m
 Base Porosity = 0.35
 Base Outflow Velocity = 8 m/a

Laplace Transform Parameters

TAU = 7 N = 20 SIG = 0 RNU = 2

Maximum Base Concentration Parameters

Depth to Search = 4 Search
 Lower Time Limit = 20 Lower
 Upper Time Limit = 300 Upper
 Base Concentration Accuracy = 0.01
 Maximum Search Attempts = 25

Maximum Base Concentration and Time of Occurrence

Time yr	Depth m	Concentration mg/L	Preceding Time	Preceding Concentration	Exceeding Time	Exceeding Concentration
6.1816E+02	0.0000E+00	1.7644E-03				

	1.0000E+00	2.9323E-01				
	4.0000E+00	2.6868E+01	6.1770E+02	2.6868E+01	6.1861E+02	2.6869E+01

Number of Search Attempts = 10

NOTICE

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