POLLUTE

Version 8

Example 15: Leachate Collection with Failure

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Version 8

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Description

This example is similar to case 14 except the failure of the primary leachate collection system is also modelled using the Variable Properties special feature. Prior to the failure of the primary leachate collection system there is a downward Darcy velocity of 0.01 m/a between the landfill and the secondary leachate collection system. The primary leachate collection system is assumed to fail between 20 and 30 years, causing the leachate mound in the landfill to rise resulting in an increase in the Darcy velocity. After 30 years the collection system has completely failed and the Darcy velocity is now assumed to be 0.1 m/a.

As in case 14 the landfill contains a finite mass of a conservative species, and is underlain by an aquifer with fixed outflow. A passive sink is used to model the secondary leachate collection system, which is assumed to be composed of a 0.3 m thick granular layer. The Darcy velocity is assumed to be initially 0.01 m/a downward from the landfill to the secondary leachate collection system, and 0.0 m/a between the secondary leachate collection system and the aquifer (i.e., the water table is assumed to be at the base of the secondary leachate collection system).

The analysis starts at time zero which corresponds to the completion of the landfill and the development of a peak leachate concentration (co) of 1000 mg/L. As in example 14 the Reference Height of Leachate is 7.5 m, and the Rate of Increase in Concentration is zero.

The average infiltration through the cover (q_o) is assumed to be 0.3 m/a. If the average exfiltration through the base of the landfill v_a (which varies with time), then the Volume of Leachate Collected is:

$$Q_c = q_o - v_a = 0.3 - v_a$$

The strata beneath the landfill, landfill dimensions, and aquifer characteristics are the same as in example 14.

Passive sink layers are divided the same as in example 14, except that the Darcy velocity in the first layer and the outflow in the second layer will be variable. The Darcy velocity in the first layer will be 0.01 m/a between 0 and 20 years, then will increase linearly between 20 and 30 years to 0.1 m/a, and then will be 0.1 m/a. In the second layer the horizontal outflow is equal to the difference in Darcy velocity between the layers above and below, multiplied by the landfill length and divided by the layer thickness, viz:

$$v_s = (v_{a2} - v_{a1}) * 200/0.3 \text{ m/a}$$

In the third layer there is no vertical or horizontal advective flow, there will however still be diffusive flow. When using the Variable Properties special feature with the Passive special feature it is possible to specify the Darcy velocities in both features. The Darcy velocity used by POLLUTE will be the result from the multiplication of the two velocities. For most practical applications, it is recommended that the Darcy velocity be entered as 1.0 in one of the features, and then the actual value entered in the other feature. In
this example the Darcy velocity is entered as 1.0 in the Variable Properties special feature, and the actual values are entered in the Passive Sink special feature.

Using the Variable Properties special feature the dispersivity can also be specified, in this example it is assumed to be 0.4 since there is outward flow from the landfill.

Following are the parameters used in this example:

Property	Symbol	Value	Units
Darcy Velocity	v_a	variable	m/a

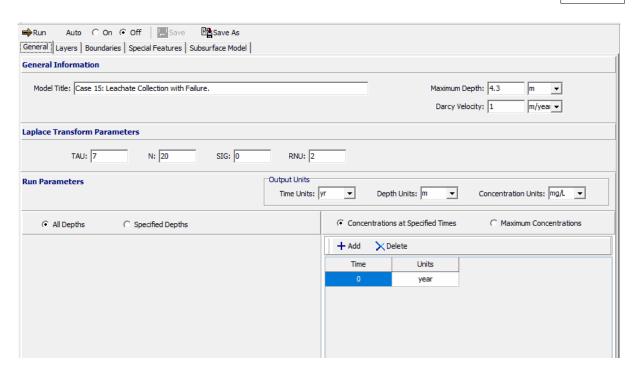|			
Sink Outflow Velocity	v_s	variable	m/a
Diffusion Coefficient	D	0.02	m²/a
Dispersivity		0.4	m
Distribution Coefficient	K_d	0.0	cm³/g
Soil Porosity	n	0.4	-
Granular Layer Porosity	n	0.3	-
Dry Density		1.5	g/cm³
Layer 1 Thickness	H	1	m
Layer 2 Thickness	H	0.3	m
Layer 3 Thickness	H	2	m
Source Concentration	c_0	1000	mg/L
Ref. Height of Leachate	H_r	7.5	m
Vol. of Leachate Collected	Q_c	variable	m/a
Landfill Length	L	200	m
Landfill Width	W	1	m
Aquifer Thickness	h	1	m
Aquifer Porosity	n	0.3	-
Aquifer Outflow Velocity	v_b	4	m/a

When using the Variable Properties special feature the accuracy of the results is dependent on the number of sublayers used.

This example is for a hypothetical landfill and is used to illustrate how to prepare an input file and run an analysis using the Variable Properties and Passive Sink option. The example is not a prescription for modeling contaminant migration during operation of a landfill. Each landfill has its own unique characteristics and no general prescription can be made. These options should only by used by someone with the hydrogeologic and engineering background necessary to appreciate the subtleties associated with the physical situation and the steps necessary for appropriate modeling of this physical situation.
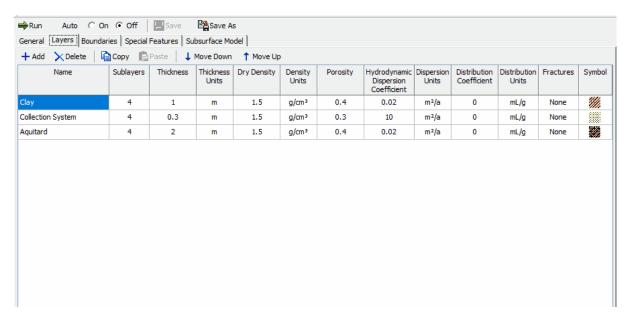
Data Entry

Open the Examples project and open Case 15.

General Tab

The general data for this example is the same as for Case 14, except that the title is different.

Layers Tab

The layer data for this example is the same as for Case 14

Boundaries Tab

The boundary conditions for this example is the same as for Case 14.

Special Features

The time-varying data and passive sink data for this model can be entered using the Time-varying Properties option in the Special Features tab. When both of these are options are selected the passive sink data is entered as part of the time varying properties.

Time Varying Properties

To specify the time-varying properties, check the Time-Varying Properties box on the Special Features tab. The Time-Varying Data sub-tab is used to specify the time period data and whether there are variable layer properties and variable decay. In this example there are 5 time periods.

In the first time period, specifying only one time increment means that the concentrations will only be calculated at the end time (i.e., 20 years). The Darcy velocity is set to one here and will be entered in the Passive Sink property on the left. Since this is the first time period the primary leachate collection system is still functioning and there is no increase in any of the above parameters.

The data for the second time period, from 20 to 30 years, can be specified by pressing the Next arrow. The increment in the Leachate collected results from the increasing Darcy velocity during this period. This increase in Darcy velocity will be taken into account in the Passive Sink property on the left side.

Next the data for time period three from 30 to 50 years can be entered.. Two increments are used to calculate the concentrations at 40 and 50 years. At this point the primary leachate collection system has completely failed and there is no further increase in the Darcy velocity. The Volume of Leachate collected is now equal to the infiltration through the cover 0.3 m/a minus the final Darcy velocity 0.1 m/a.

The data for time period four should can be entered by clicking on the next arrow. Five increments are used to calculate the concentrations at 60, 70, 80, 90, and 100 years.

Finally the data for time period five is entered.. Five increments are used to calculate the

concentrations at 120, 140, 160, 180, and 200 years.

Model Execution

⇨Run

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.

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Output Listing

To display the output as a text listing that will show the calculated concentrations as numbers, click on the List tab.

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THE VARIABLE VELOCITY AND/OR CONCENTRATION OPTION HAS BEEN USED. NOTE THAT THE ACCURACY OF THE CALCULATIONS WITH THIS OPTION WILL DEPEND ON THE NUMBER OF SUBLAYERS USED.

THE PASSIVE SINK OPTION HAS BEEN USED. NOTE THE USER IS RESPONSIBLE FOR ENSURING THAT VELOCITY CHANGES ARE CONSISTENT WITH THE PASSIVE SINK.

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Clay	1 m	4	0.02 m²/a	0.4	0 mL/g	1.5 g/cm³
Collection System	0.3 m	4	10 m²/a	0.3	0 mL/g	1.5 g/cm³
Aquitard	2 m	4	0.02 m²/a	0.4	0 mL/g	1.5 g/cm³

Boundary Conditions

Finite Mass Top Boundary

Fixed Outflow Bottom Boundary

Landfill Length = 200 m
Landfill Width = 1 m
Base Thickness = 1 m
Base Porosity = 0.3

Variation in Properties with Time

Time Periods with the same Source and Velocity

Period	Start Time	No. of Steps	Time Step	Source Conc	Rate of Change	Height of Leachate	Volume Collected
1	0 yr	1	20 yr	1000 mg/L	0	7.5 m	0.29 m/a
2	20 yr	5	2 yr	-1 mg/L	0	7.5 m	0.2 m/a
3	30 yr	2	10 yr	-1 mg/L	0	7.5 m	0.2 m/a
4	50 yr	5	10 yr	-1 mg/L	0	7.5 m	0.2 m/a
5	100 yr	5	20 yr	-1 mg/L	0	7.5 m	0.2 m/a

Period	Start Time	End Time	Proportion Mass	Dispersivity	Base Velocity
1	0 yr	20 yr	1 m/a	0.4 m	4 m/a
2	20 yr	30 yr	1 m/a	0.4 m	4 m/a
3	30 yr	50 yr	1 m/a	0.4 m	4 m/a
4	50 yr	100 yr	1 m/a	0.4 m	4 m/a
5	100 yr	200 yr	1 m/a	0.4 m	4 m/a

Velocity and Sink Profile

Time Period	Minimum Depth	Maximum Depth	Vertical Velocity	Horizontal Outflow
1 / 1	0 m	1 m	0.01 m/a	0 m/a
	1 m	1.3 m	0.01 m/a	6.67 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
2 / 1	0 m	1 m	0.028 m/a	0 m/a
	1 m	1.3 m	0.028 m/a	18.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
2 / 2	0 m	1 m	0.046 m/a	0 m/a
	1 m	1.3 m	0.046 m/a	30.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
2 / 3	0 m	1 m	0.064 m/a	0 m/a

	1 m	1.3 m	0.064 m/a	42.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
2 / 4	0 m	1 m	0.082 m/a	0 m/a
	1 m	1.3 m	0.082 m/a	54.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
2 / 5	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
3 / 1	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
3 / 2	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
4 / 1	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
4 / 2	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
4 / 3	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
4 / 4	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
4 / 5	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
5 / 1	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
5 / 2	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
5 / 3	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
5 / 4	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a
5 / 5	0 m	1 m	0.1 m/a	0 m/a
	1 m	1.3 m	0.1 m/a	66.7 m/a
	1.3 m	3.3 m	0 m/a	0 m/a

Laplace Transform Parameters

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

Calculated Concentrations at Selected Times and Depths

Time yr	Depth m	Concentration mg/L
20	0.000E+00	4.395E+02
	2.500E-01	4.454E+02
	5.000E-01	4.211E+02
	7.500E-01	3.712E+02
	1.000E+00	3.033E+02
	1.075E+00	3.033E+02
	1.150E+00	3.032E+02
	1.225E+00	3.032E+02
	1.300E+00	3.032E+02
	1.800E+00	1.307E+02
	2.300E+00	4.108E+01
	2.800E+00	9.391E+00
	3.300E+00	7.095E-01
22	0.000E+00	4.137E+02
	2.500E-01	4.158E+02
	5.000E-01	4.017E+02
	7.500E-01	3.701E+02
	1.000E+00	3.224E+02
	1.075E+00	3.223E+02
	1.150E+00	3.223E+02
	1.225E+00	3.224E+02
	1.300E+00	3.225E+02
	1.800E+00	1.411E+02
	2.300E+00	4.899E+01
	2.800E+00	1.236E+01
	3.300E+00	1.062E+00
24	0.000E+00	3.895E+02
	2.500E-01	3.927E+02
	5.000E-01	3.861E+02
	7.500E-01	3.679E+02
	1.000E+00	3.372E+02
	1.075E+00	3.371E+02
	1.150E+00	3.372E+02
	1.225E+00	3.373E+02
	1.300E+00	3.376E+02
	1.800E+00	1.530E+02
	2.300E+00	5.647E+01
	2.800E+00	1.551E+01
	3.300E+00	1.518E+00
26	0.000E+00	3.667E+02
	2.500E-01	3.717E+02
	5.000E-01	3.705E+02
	7.500E-01	3.614E+02
	1.000E+00	3.426E+02
	1.075E+00	3.426E+02
	1.150E+00	3.427E+02
	1.225E+00	3.430E+02
	1.300E+00	3.434E+02

	1.800E+00	1.645E+02
	2.300E+00	6.390E+01
	2.800E+00	1.875E+01
	3.300E+00	2.077E+00
28	0.000E+00	3.454E+02
	2.500E-01	3.512E+02
	5.000E-01	3.531E+02
	7.500E-01	3.497E+02
	1.000E+00	3.388E+02
	1.075E+00	3.388E+02
	1.150E+00	3.390E+02
	1.225E+00	3.394E+02
	1.300E+00	3.399E+02
	1.800E+00	1.741E+02
	2.300E+00	7.118E+01
	2.800E+00	2.208E+01
	3.300E+00	2.737E+00
30	0.000E+00	3.253E+02
	2.500E-01	3.312E+02
	5.000E-01	3.345E+02
	7.500E-01	3.341E+02
	1.000E+00	3.282E+02
	1.075E+00	3.282E+02
	1.150E+00	3.285E+02
	1.225E+00	3.289E+02
	1.300E+00	3.296E+02
	1.800E+00	1.808E+02
	2.300E+00	7.803E+01
	2.800E+00	2.547E+01
	3.300E+00	3.490E+00
40	0.000E+00	2.199E+02
	2.500E-01	2.276E+02
	5.000E-01	2.345E+02
	7.500E-01	2.401E+02
	1.000E+00	2.437E+02
	1.075E+00	2.437E+02
	1.150E+00	2.440E+02
	1.225E+00	2.443E+02
	1.300E+00	2.449E+02
	1.800E+00	1.881E+02
	2.300E+00	1.076E+02
	2.800E+00	4.712E+01
	3.300E+00	1.035E+01
50	0.000E+00	1.488E+02
	2.500E-01	1.546E+02
	5.000E-01	1.602E+02
	7.500E-01	1.656E+02
	1.000E+00	1.704E+02
	1.075E+00	1.705E+02
	1.150E+00	1.706E+02

	1.225E+00	1.709E+02
	1.300E+00	1.713E+02
	1.800E+00	1.603E+02
	2.300E+00	1.120E+02
	2.800E+00	5.985E+01
	3.300E+00	1.789E+01
60	0.000E+00	1.008E+02
	2.500E-01	1.050E+02
	5.000E-01	1.093E+02
	7.500E-01	1.138E+02
	1.000E+00	1.183E+02
	1.075E+00	1.184E+02
	1.150E+00	1.185E+02
	1.225E+00	1.187E+02
	1.300E+00	1.190E+02
	1.800E+00	1.282E+02
	2.300E+00	1.023E+02
	2.800E+00	6.254E+01
	3.300E+00	2.307E+01
70	0.000E+00	6.828E+01
	2.500E-01	7.132E+01
	5.000E-01	7.456E+01
	7.500E-01	7.808E+01
	1.000E+00	8.201E+01
	1.075E+00	8.206E+01
	1.150E+00	8.215E+01
	1.225E+00	8.230E+01
	1.300E+00	8.249E+01
	1.800E+00	9.970E+01
	2.300E+00	8.728E+01
	2.800E+00	5.698E+01
	3.300E+00	1.817E+01
80	0.000E+00	4.629E+01
	2.500E-01	4.847E+01
	5.000E-01	5.087E+01
	7.500E-01	5.358E+01
	1.000E+00	5.679E+01
	1.075E+00	5.682E+01
	1.150E+00	5.689E+01
	1.225E+00	5.699E+01
	1.300E+00	5.713E+01
	1.800E+00	7.584E+01
	2.300E+00	7.026E+01
	2.800E+00	4.642E+01
	3.300E+00	1.154E+01
90	0.000E+00	3.140E+01
	2.500E-01	3.295E+01
	5.000E-01	3.470E+01
	7.500E-01	3.674E+01
	1.000E+00	3.925E+01

	1.075E+00	3.927E+01
	1.150E+00	3.932E+01
	1.225E+00	3.939E+01
	1.300E+00	3.949E+01
	1.800E+00	5.637E+01
	2.300E+00	5.393E+01
	2.800E+00	3.537E+01
	3.300E+00	6.863E+00
100	0.000E+00	2.130E+01
	2.500E-01	2.240E+01
	5.000E-01	2.366E+01
	7.500E-01	2.516E+01
	1.000E+00	2.705E+01
	1.075E+00	2.707E+01
	1.150E+00	2.710E+01
	1.225E+00	2.715E+01
	1.300E+00	2.722E+01
	1.800E+00	4.101E+01
	2.300E+00	4.000E+01
	2.800E+00	2.597E+01
	3.300E+00	4.082E+00
120	0.000E+00	9.819E+00
	2.500E-01	1.037E+01
	5.000E-01	1.101E+01
	7.500E-01	1.182E+01
	1.000E+00	1.287E+01
	1.075E+00	1.288E+01
	1.150E+00	1.290E+01
	1.225E+00	1.293E+01
	1.300E+00	1.296E+01
	1.800E+00	2.176E+01
	2.300E+00	2.284E+01
	2.800E+00	1.723E+01
	3.300E+00	8.038E+00
140	0.000E+00	4.534E+00
	2.500E-01	4.811E+00
	5.000E-01	5.153E+00
	7.500E-01	5.595E+00
	1.000E+00	6.199E+00
	1.075E+00	6.204E+00
	1.150E+00	6.213E+00
	1.225E+00	6.226E+00
	1.300E+00	6.243E+00
	1.800E+00	1.201E+01
	2.300E+00	1.374E+01
	2.800E+00	1.149E+01
	3.300E+00	6.350E+00
160	0.000E+00	2.099E+00
	2.500E-01	2.243E+00
	5.000E-01	2.428E+00

	7.500E-01	2.677E+00
	1.000E+00	3.030E+00
	1.075E+00	3.033E+00
	1.150E+00	3.038E+00
	1.225E+00	3.044E+00
	1.300E+00	3.052E+00
	1.800E+00	6.754E+00
	2.300E+00	8.230E+00
	2.800E+00	7.255E+00
	3.300E+00	4.279E+00
180	0.000E+00	9.745E-01
	2.500E-01	1.050E+00
	5.000E-01	1.151E+00
	7.500E-01	1.292E+00
	1.000E+00	1.498E+00
	1.075E+00	1.500E+00
	1.150E+00	1.502E+00
	1.225E+00	1.505E+00
	1.300E+00	1.510E+00
	1.800E+00	3.809E+00
	2.300E+00	4.858E+00
	2.800E+00	4.426E+00
	3.300E+00	2.701E+00
200	0.000E+00	4.542E-01
	2.500E-01	4.945E-01
	5.000E-01	5.499E-01
	7.500E-01	6.294E-01
	1.000E+00	7.481E-01
	1.075E+00	7.490E-01
	1.150E+00	7.503E-01
	1.225E+00	7.522E-01
	1.300E+00	7.544E-01
	1.800E+00	2.144E+00
	2.300E+00	2.830E+00
	2.800E+00	2.637E+00
	3.300E+00	1.644E+00

NOTICE