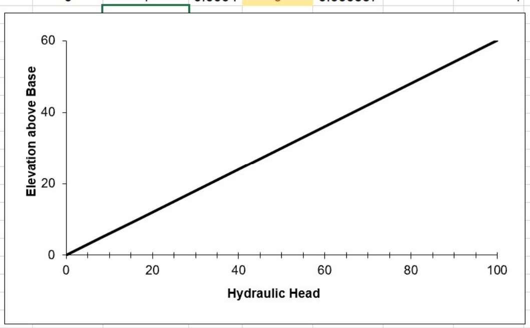
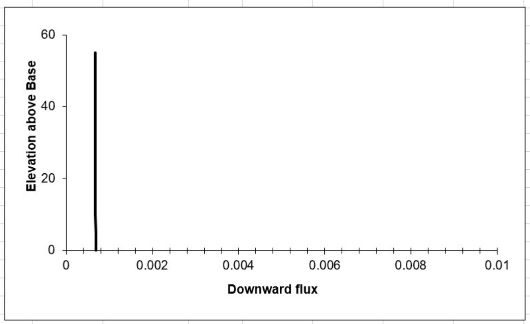
Direct solution for flux		
	K	num cells
zone 1	0.0004	12
zone 2	0.01	0
zone 3	0.0001	0
Keq	0.0004	
q	0.000667	

z	K zone cell	K cell	H	q	zone 1	zone 2	zone 3
60	1	0.0004	100		1	0	0
55	1	0.0004	91.67083	0.000666	1	0	0
50	1	0.0004	83.34111	0.000666	1	0	0
45	1	0.0004	75.01062	0.000666	1	0	0
40	1	0.0004	66.67923	0.000667	1	0	0
35	1	0.0004	58.34687	0.000667	1	0	0
30	1	0.0004	50.01354	0.000667	1	0	0
25	1	0.0004	41.6793	0.000667	1	0	0
20	1	0.0004	33.34427	0.000667	1	0	0
15	1	0.0004	25.00863	0.000667	1	0	0
10	1	0.0004	16.67256	0.000667	1	0	0
5	1	0.0004	8.33628	0.000667	1	0	0
0	1	0.0004	0	0.000667	1	0	0

Map of node and cell numbers			
	node	cell	
1	-		1
2	-		2
3	-		3
4	-		4
5	-		5
6	-		6
7	-		7
8	-		8
9	-		9
10	-		10
11	-		11
12	-		12
13	-		13





The Challenge:

Create a 1D, vertical steady state model with constant head top and bottom boundaries.

Show, based on the flux with depth, that the model is steady state.
Repeat this for a homogeneous and for a heterogeneous column.

Show that the steady state flux agrees with the direct calculation based on the harmonic mean average K.

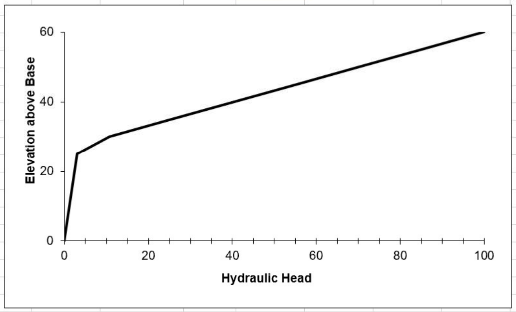
Show the steady state head profile for a column with approximately equal-thickness layers with different K values.
Use this profile to explain why the equivalent hydraulic conductivity, Keq, is closer to the lower of the K values.

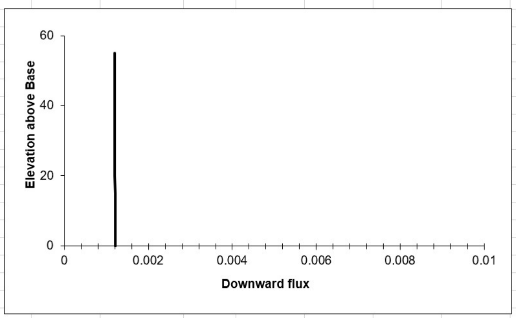
Figure 1: Homogenous Column @ Steady State

Direct solution for flux		
	K	num cells
zone 1	0.0004	6.5
zone 2	0.01	5.5
zone 3	0.0001	0
Keq	0.000714	
q	0.00119	

z	K zone cell	K cell	H	q	zone 1	zone 2	zone 3
60	1	0.0004	100		1	0	0
55	1	0.0004	85.11905	0.00119	1	0	0
50	1	0.0004	70.2381	0.00119	1	0	0
45	1	0.0004	55.35716	0.00119	1	0	0
40	1	0.0004	40.4762	0.00119	1	0	0
35	1	0.0004	25.59525	0.00119	1	0	0
30	1	0.0004	10.7143	0.00119	1	0	0
25	2	0.01	2.976202	0.00119	0	1	0
20	2	0.01	2.380962	0.00119	0	1	0
15	2	0.01	1.785722	0.00119	0	1	0
10	2	0.01	1.190482	0.00119	0	1	0
5	2	0.01	0.595241	0.00119	0	1	0
0	2	0.01	0	0.00119	0	1	0

Map of node and cell numbers			
	node	cell	
1	-		1
2	-		2
3	-		3
4	-		4
5	-		5
6	-		6
7	-		7
8	-		8
9	-		9
10	-		10
11	-		11
12	-		12
13	-		13





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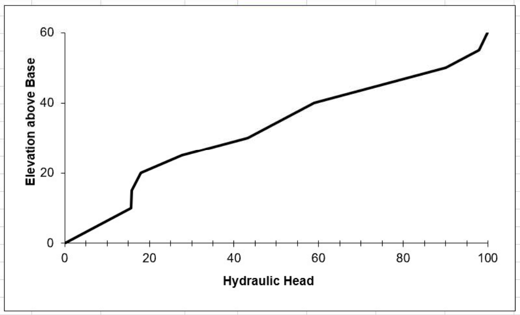
q	0.00119
Keq	0.000714
q = Keq * dh/dL	0.00119
dh	100
dL	60

Figure 2: Heterogenous column with ~ equal thickness layers

Direct solution for flux		
	K	num cells
zone 1	0.0004	1.5
zone 2	0.01	4.5
zone 3	0.0001	6
Keq	0.000187	
q	0.000312	

z	K zone cell	K cell	H	q	zone 1	zone 2	zone 3
60	1	0.0004	100		1	0	0
55	2	0.01	97.97508	0.000312	0	1	0
50	3	0.0001	90.10903	0.000312	0	0	1
45	3	0.0001	74.53271	0.000312	0	0	1
40	3	0.0001	58.95639	0.000312	0	0	1
35	2	0.01	51.09034	0.000312	0	1	0
30	3	0.0001	43.2243	0.000312	0	0	1
25	3	0.0001	27.64797	0.000312	0	0	1
20	1	0.0004	17.91277	0.000312	1	0	0
15	2	0.01	15.88785	0.000312	0	1	0
10	2	0.01	15.73209	0.000312	0	1	0
5	3	0.0001	7.866043	0.000312	0	0	1
0	2	0.01	0	0.000312	0	1	0

Map of node and cell numbers				
	node	cell		RAND K
1	-		1	2
2	-		2	1
3	-		3	3
4	-		4	2
5	-		5	1
6	-		6	1
7	-		7	1
8	-		8	2
9	-		9	2
10	-		10	1
11	-		11	3
12	-		12	2
13	-		13	3



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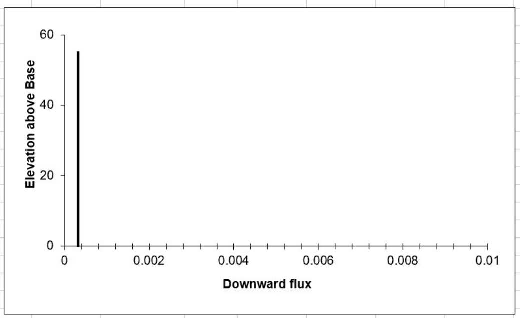


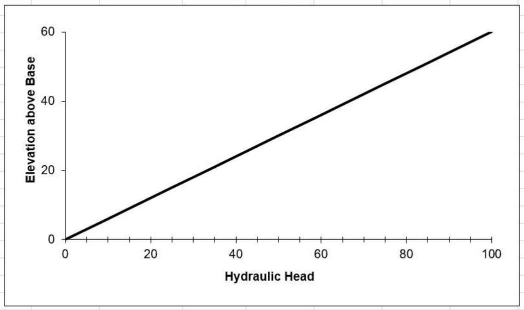
q	0.000312
Keq	0.000187
q = Keq * dh/dL	0.000312
dh	100
dL	60

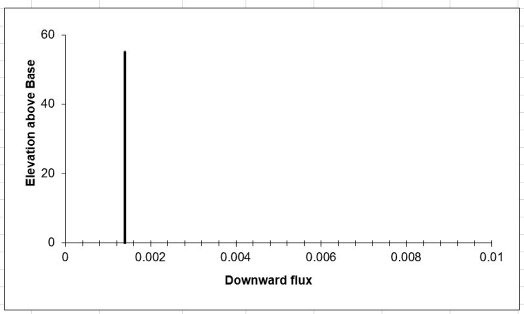
Figure 3: Randomly heterogenous column, for fun.

Direct solution for flux		
	K	num cells
zone 1	0.0004	5.5
zone 2	0.01	6.5
zone 3	0.0001	0
Keq	0.000833	
q	0.001389	

z	K zone cell	K cell	H	q	zone 1	zone 2	zone 3
60	1	0.000833	100		1	0	0
55	1	0.000833	91.66667	0.001389	1	0	0
50	1	0.000833	83.33333	0.001389	1	0	0
45	1	0.000833	75	0.001389	1	0	0
40	1	0.000833	66.66667	0.001389	1	0	0
35	1	0.000833	58.33333	0.001389	1	0	0
30	2	0.000833	50	0.001389	0	1	0
25	2	0.000833	41.66667	0.001389	0	1	0
20	2	0.000833	33.33333	0.001389	0	1	0
15	2	0.000833	25	0.001389	0	1	0
10	2	0.000833	16.66667	0.001389	0	1	0
5	2	0.000833	8.333333	0.001389	0	1	0
0	2	0.000833	0	0.001389	0	1	0

Map of node and cell numbers			
	node	cell	
1	-		1
2	-		2
3	-		3
4	-		4
5	-		5
6	-		6
7	-		7
8	-		8
9	-		9
10	-		10
11	-		11
12	-		12
13	-		13





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Use this profile to explain why the equivalent hydraulic conductivity, Keq, is closer to the lower of the K values.

q	0.001389
Keq	0.000833
q = Keq * dh/dL	0.001389
dh	100
dL	60

Figure 4: Homogenous column utilizing the Keq from the heterogenous column with equal thickness.