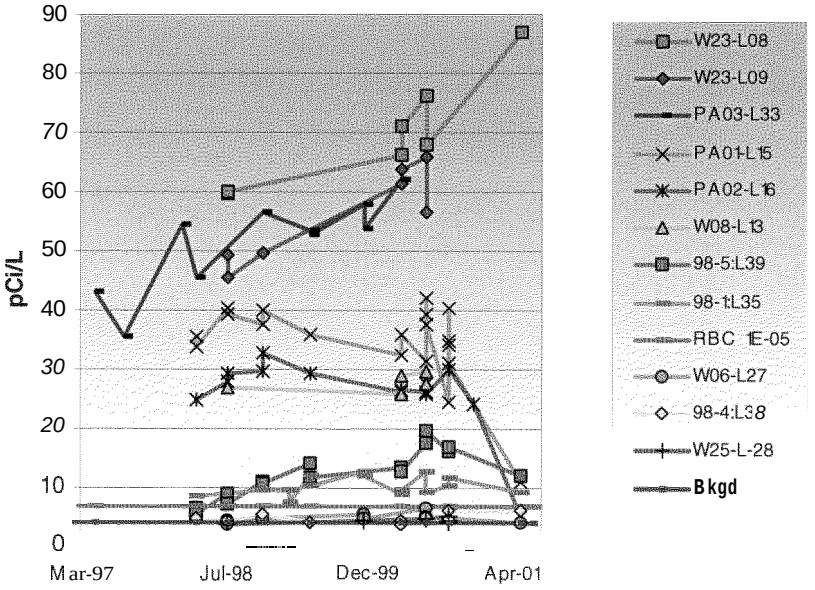

Figure 4-48. Soil moisture sample concentrations of uranium-233/234 in shallow lysimeters.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01-L15	PA02-L16	PA03-L33	W06-L27	W08-L13	W23-L08	W23-L09	W25-L28
1997	1											
	2						43.2					
	3						35.4					
	4											
1998	1						54.5					
	2	8.7	4.8	6.4	35.6	24.9	45.6					
	3		4.4	8.9	39.2	29.4		4.6	26.8	60.1	49.2	3.8
	4	9.6	5.7	11.1	40.0	32.8	56.5	4.9			49.7	
1999	1	9.7										
	2	12.2	4.3	14.0	35.7	29.4	53.4					
	3											
	4	12.9					57.9	5.6				4.6
2000	1	9.5	4.5	13.6	35.9	26.4	61.9		29.1	71.1	63.9	
	2	12.6	5.2	19.8	41.9	27.5		6.7	29.5	76.1	65.7	4.8
	3	11.7	6.1	16.9	40.3	29.9						5.2
	4					24.3						
2001	1											
	2	9.2	6.2	12.2	11.0	5.2		4.1		87.0		
	3											
	4											
Key			U-233/234 was analyzed for, but not detected.									
		x.xx	U-233/234 was detected at soil moisture background levels (3 pCi/L).									
			U-233/234 was detected above soil moisture background, but less than the risk-based concentration (6.7 pCi/L).									
			U-233/234 was detected above the risk-based concentration.									
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-49. Occurrence of uranium-233/234 detections at or near background (3 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in shallow lysimeters.

4.6.19.2.2.2 Uranium-235/236—A total of 122 lysimeter samples from shallow lysimeters in the SDA were analyzed for U-235/236, with 42 positive detections. Routine lysimeter monitoring began in 1997 in Well PA03; however, routine monitoring did not begin in the other lysimeter wells until 1998. The concentration trends are shown for each lysimeter in Figure 4-50. The occurrence of soil moisture detections of U-235/236 above background concentration in shallow lysimeters is depicted in Figure 4-51.

None of the detected concentrations in any of the shallow lysimeters exceeds the 1E-05 aquifer risk-based concentration for U-235 (6.63 pCi/L) or U-236 (7.11 pCi/L). Detected concentrations of U-235/236 ranged from 0.35 pCi/L (PA01-L15) to 4.40 pCi/L (W23-L09), with the majority of values between 1.0 and 2.6 pCi/L. In Well W23, U-235/236 was first detected just recently, with the last two sampling events yielding detectable U-235/236. The wells with the highest U-235/236 concentrations (Wells W23 and PA03) also show elevated concentrations and emerging trends of U-233/234; however, the data are insufficient to identify a significant correlation.

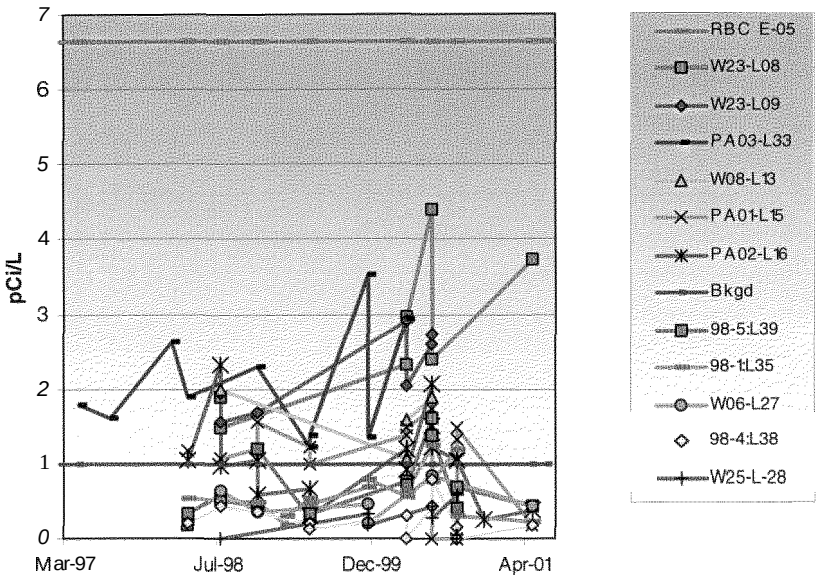

Figure 4-50. Soil moisture sample concentrations of uranium-235/236 in shallow lysimeters. (Note: Nondetected concentrations also are shown. Also see Figure 4-51, in which detected concentrations are identified for each well.)

Lysimeters W08-L 13 (near Acid Pit), W23-L08 and -L09 (west end of SDA), and PA03-L33 (near Pad A) show concentrations that are consistently greater than subsurface background levels. The last two sampling events out of W23-LO8 yielded samples with concentrations that were about four times higher than concentrations in other lysimeters. Uranium-233/234 was also elevated in W23 and PA03.

4.6.19.2.2.3 Uranium-238—A total of 122 shallow lysimeter samples were analyzed for U-238 between 1997 (beginning of uranium monitoring) and May 2001. 121 results contained detectable levels of U-238, ranging from 0.26 ± 0.06 pCi/L (98-4L38) to 53 ± 5 pCi/L (W23-L08), with the majority of values between about 3 and 28 pCi/L (Figure 4-52). One result contained a data qualifier flag. Results from PA03-L09, W23-L08, and W23-L09 are 10 pCi/L or more higher than all other samples in the latest round of sampling, and all three of these lysimeters exhibit increasing U-238 trends. The occurrence of the detections greater than the local soil moisture background and the detections above the risk-based concentrations are shown in Figure 4-53.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01-L15	PA02-L16	PA03-L33	W06-L27	W08-L13	W23-L08	W23-L09	W25-L28
1997	1											
	2						1.8					
	3						1.6					
	4											
1998	1						2.6					
	2						1.9					
	3				1.1	2.3			2.0			
	4	0.48	0.37	1.2	1.6	1.1	2.3	0.35			1.7	
1999	1											
	2				1.2							
	3											
	4						3.5					
2000	1											
	2	1.3	0.79	1.6	1.7	2.1			1.9	4.4	2.6	
	3											
	4											
2001	1											
	2									3.7		
	3											
	4											
Key			U-235/236 was analyzed for, but not detected.									
		x.xx	U-235/236 was detected at local soil moisture background levels (0.5 pCi/L).									
			U-235/236 was detected above local soil moisture background, but less than the risk-based concentration (6.6 pCi/L).									
			U-235/236 was detected above the risk-based concentration.									
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-51. Occurrence of uranium-235/236 nondetections, detections at or above background (0.5 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.6 pCi/L) in shallow lysimeters.

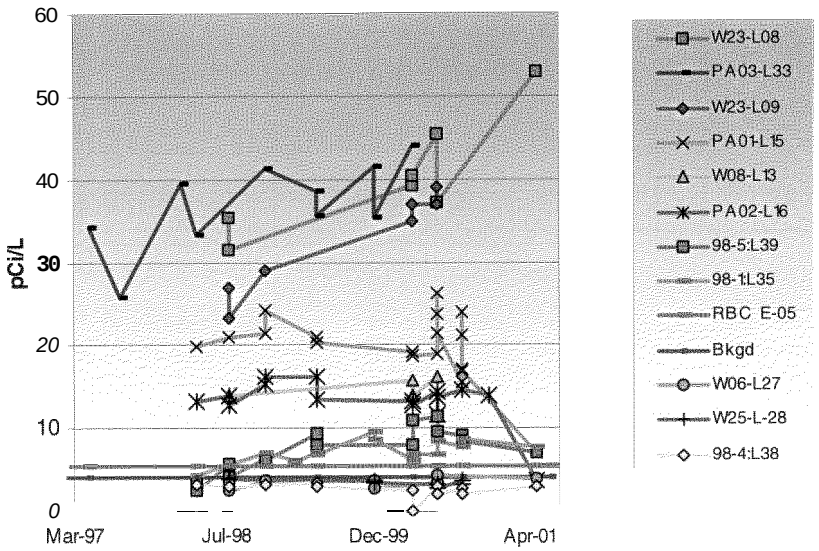

Figure 4-52. Soil moisture sample concentrations of uranium-238 in shallow lysimeters.

The wells with elevated uranium concentrations and noticeable trends are located at the west end of the SDA (W23) and near Pad A (PA03). As will be discussed later, the deeper lysimeter well samples (between 35 and 140 ft) also show elevated uranium concentrations and trends in these two locations.

Most of the samples consistently exceed the 1E-05 aquifer risk-based concentration for U-238 (5.47 pCi/L). The uranium data readily identify increasing uranium concentrations, but the source of uranium cannot be determined without additional data and further investigation.

4.6.19.2.2.4 Uranium Ratios in Shallow Lysimeter Samples—The atomic mass or activity ratios of U-234:U-238 can be used to evaluate whether it is likely that the uranium in a sample is natural uranium or uranium from waste, and whether the uranium from waste is enriched (higher U-233/234:U-238 ratio) or depleted (lower ratio) (see Section 4.6.16).

Uranium-233/234:U-238 ratios were evaluated for the routine shallow lysimeter well samples. All but one of the U-233/234:U-238 atomic mass ratios were between 5.31E-05 and 1.30E-04 (normal range), with the one outlier being 7.96E-04. attributable to a low concentration of U-238 (0.26 pCi/L).

The U-233/234:U-238 ratios for the W23-L09 and W23-L08 lysimeters decrease over time, suggesting the appearance of depleted uranium at both depth intervals in the soil moisture at the west end of the SDA (see Table 4-104). The U-233/234:U-238 atomic mass ratios associated with Lysimeter 98-5L39 also decreased from 1998 through March 2000, though, the June 2000 ratio increased.

Aside from the emerging trend toward depleted uranium in shallow lysimeter samples from Well W23, the current ratios for the shallow lysimeters are contradictory or unclear.

Year	Quarter	98-1 L35	984 L38	98-5 L39	PA01-L15	PA02-L16	PA03-L33	W06-L27	W08-L13	W23-L08	W23-L09	W25-L28
1997	1											
	2						34.2					
	3						25.7					
	4											
1998	1						39.5					
	2	4.4	3.3	3.5	19.9	13.2	33.4					
	3		2.9	5.6	21.1	13.9		3.3	14.0	35.4	26.9	3.9
	4	7.0	3.2	6.3	24.2	16.1	41.2	3.6			29.0	
1999	1	6.1										
	2	7.1	3.5	9.4	21.0	16.1	38.5					
	3											
	4	9.7					41.5	3.7				3.5
2000	1	6.9	2.6	11.0	19.1	13.3	44.0		15.7	40.4	37.0	
	2	8.4	3.0	11.5	26.3	14.3		4.3	16.2	45.5	39.0	3.3
	3	8.8	2.8	9.1	24.0	14.5						3.7
	4					13.9						
2001	1											
	2	7.7		7.2	7.1	3.6		3.9		53.0		
	3											
	4											
Key			U-238 was analyzed for, but not detected.									
		x.xx	U-238 was detected at local soil moisture background levels (1.5 pCi/L).									
			U-238 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (5.5 pCi/L).									
			U-238 was detected above the RBC.									
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-53. Occurrence of uranium-238 nondetections, detections at or above background (1.5 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (5.5 pCi/L) in shallow lysimeters.

In 1999, seven shallow lysimeter water samples were collected and sent for TIMS analysis. With the low-level analysis, it is possible to also evaluate the U-236 data, which is unique to anthropic uranium, and U-238:U-235 ratios. The samples were collected from the PA01-L15, PA02-L16, PA03-L33, W23-L08, 98-4L38, 98-5L39, and W25-L28 lysimeters. The water samples were filtered and both the filtrate and filtered material were analyzed for isotopic U-234, U-235, U-236, and U-238. None of the seven shallow lysimeters contained detectable U-236 (unique to man-made uranium) or had uranium ratios that confirmed the presence of anthropic uranium (Roback et al. 2000). However, the TIMS results suggested that the ratios for both water and filter samples from W23-L08 (11 A deep) and the water sample from 98-5L39 (10 ft deep) deviated somewhat from natural uranium.

4.6.19.2.3 Lysimeter Samples at Depths of 35 to 140 ft

4.6.19.2.3.1 Uranium-233/234—A total of 48 lysimeter samples collected from the B and C basalt flows and B-C interbed were analyzed for U-233/234 between 1997 (beginning of

uranium monitoring) and May 2001, with 37 detections. The U-233/234 soil moisture results ranged from 1.7 ± 0.3 pCi/L (D15-DL06) to 111 ± 10 pCi/L (D06-DL01). Concentration trends for each intermediate depth lysimeter are shown in Figure 4-54. The U-233/234 detections above the local soil moisture background (3 pCi/L) and above the 1E-05 aquifer risk-based concentration (6.7 pCi/L) are shown in Figure 4-55.

Uranium-233/234 results from D06 and TW1 consistently exceed the 1E-05 aquifer risk-based concentration for U-233 and U-234. Results from Well D06 near Pad **A** suggest that U-233/234 is leaching because there is a prominent increasing trend in the 88-ft lysimeter, and a constant, but high concentration in the 44-ft lysimeter. Concentrations in Well TW1 (located within the Pit 5 boundary) have always been relatively high (about 85 to 90 pCi/L), although the most recent sample contained a low concentration of U-233/234 (about 5 pCi/L), which is likely an unidentifiable sampling or analytical anomaly.

Lysimeter Well I-1S-DL09 (on the west end of the SDA) appears to have somewhat elevated concentrations of U-233/234, although not nearly as high as those from TW1 and D06.

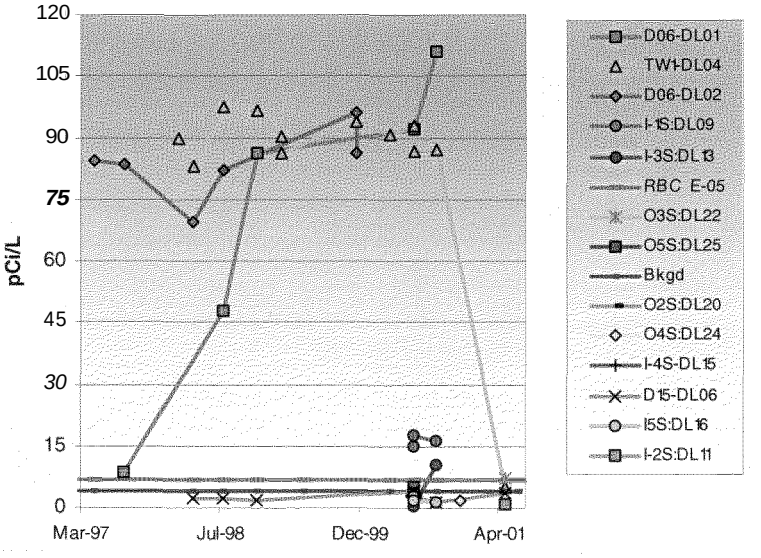

Figure 4-54. Soil moisture sample concentrations of uranium-233/234 in mid-depth lysimeters

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		84.4											
	3	8.5	83.5											
	4													
1998	1													90.0
	2		69.6	2.0										82.8
	3	47.9	82.3	2.4										97.4
	4	86.3		1.7										96.7
1999	1													90.2
	2													
	3													
	4		96.1											93.7
2000	1													90.6
	2	92.1		2.5	17.7				1.7				4.9	92.9
	3	111			16.1		10.4							87.0
	4											1.8		
2001	1													
	2			3.8							7.3			5.2
	3													
	4													
Key			U-233/234 was analyzed for, but not detected.											
		x.xx	U-233/234 was detected at local soil moisture background levels (3 pCi/L).											
			U-233/234 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (6.7 pCi/L).											
			U-233/234 was detected above the RBC.											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.												

Figure 4-55. Occurrence of uranium-233/234 nondetections, detections at or above background (3 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in mid-depth lysimeters.

4.6.19.2.3.2 Uranium-235/236—A total of 48 U-235/236 analyses were performed on lysimeter samples from the 35- to 140-ft depth interval within the SDA between 1997 (beginning of uranium monitoring) and May 2001, with 25 positive detections. One of the results (TW1-DL04) exceeded the E-05 risk-based concentration for the aquifer, used for comparison. Figure 4-56 shows the concentration trends in each of the intermediate depth lysimeters. Figure 4-57 shows the occurrence of the positive U-235/236 detections greater than local soil moisture background and greater than the 1E-05 aquifer risk-based concentration.

Though soil moisture results can be highly variable, a t-test shows that the U-235/236 concentrations from Lysimeter TW1-DL04 are significantly higher ($p<0.01$) than that in other lysimeters. Nine of 19 samples from TW1-DL04 yielded positive U-235/236 concentrations, and the TIMS analysis confirmed the presence of enriched uranium in TW1-DL04 samples.

There is a possible U-235/236 temporal trend in Lysimeter D06-DL01, which has relatively high concentrations, though the most recent data show a decline in the U-235/236 concentration, which may be attributable to natural variability, or an unidentifiable sampling or analytical anomaly.

Supporting TIMS data from Los Alamos confirm that anthropic uranium was present in a sample from TW1-DL04. Lysimeter D06-DL01 shows a possible trend of increasing U-235/236 over time, though the most recent data from that well suggest that the trend may be reversing or that the apparent trend could be attributable to natural variability.

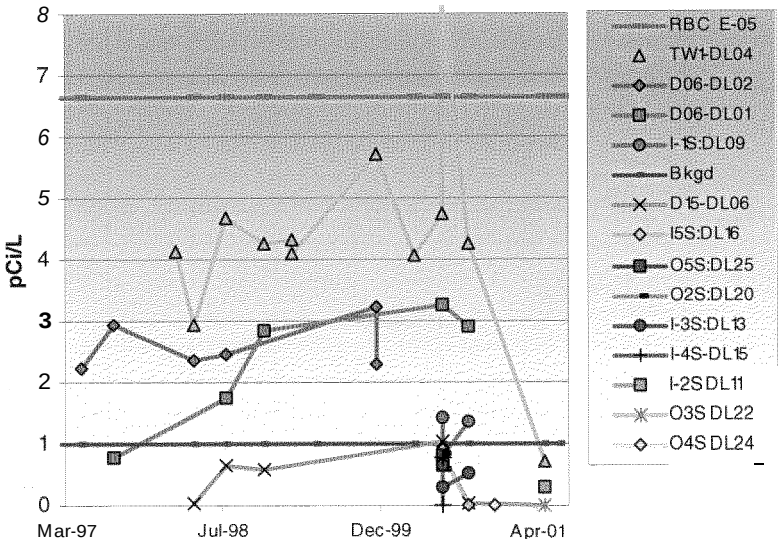

Figure 4-56. Soil moisture sample concentrations of uranium-235/236 measured in mid-depth lysimeters.

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		2.2											
	3		2.9											
	4													
1998	1													4.1
	2		2.4											2.9
	3	1.7	2.5											4.7
	4	2.8		0.59										4.3
1999	1													4.3
	2													
	3													
	4		3.2											5.7
2000	1													
	2	3.3		1.0	1.4			0.78	0.90				0.65	8.2
	3	2.9												4.3
	4													
2001	1													
	2													
	3													
	4													
Key			U-235/236 was analyzed for, but not detected.											
			U-235/236 was detected at local soil moisture background levels (0.5 pCi/L).											
			U-235/236 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (6.6 pCi/L).											
			U-235/236 was detected above the RBC.											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.												

Figure 4-57. Occurrence of uranium-235/236 nondetections, detections at or above background (0.5 pCi/L), and detections greater than the 1E-05 aquifer risk-based concentration of 6.6 pCi/L in mid-depth lysimeters.

4.6.19.2.3.3 Uranium-238—A total of 48 lysimeter U-238 analyses were performed on samples collected from the B and C basalt flows and B-C interbed between 1997 (beginning of uranium monitoring) and May 2001. Most of the lysimeters sampled have detectable levels of U-238. The positive results ranged from 0.7 ± 0.2 pCi/L (D15-DL06) to 52.6 ± 4.8 pCi/L (D06-DL01), with the majority of values between approximately 2 and 35 pCi/L. Figure 4-58 shows the U-238 concentration trends in each of the intermediate depth lysimeters. Figure 4-59 shows the occurrence of U-238 above background and above the 1E-05 risk-based concentration for U-238.

Samples from lysimeters D06-DL01 and D06-DL02 consistently contain U-238 above the 1E-05 risk-based concentration for U-238 used for comparison (Figure 4-58). There is a prominent trend in U-238 in D06-DL01 and a relatively stable but elevated concentration in D06-DL02, which is located in the same well (Figure 4-58). Lysimeter TW1-DL04 concentrations are considerably lower than the

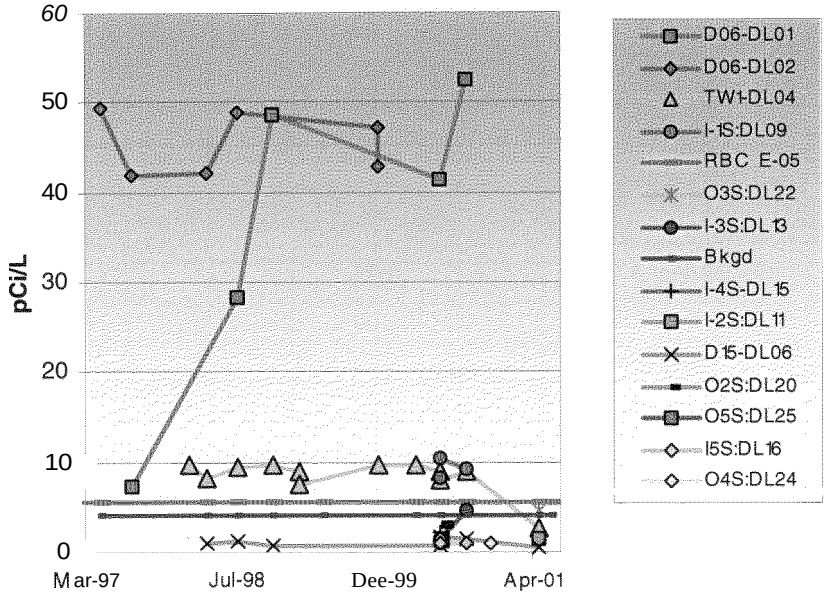

Figure 4-58. Soil moisture sample concentrations of uranium-238 measured in mid-depth lysimeters.

concentrations in the D06 lysimeters, but the uranium ratios U-233/234:U-238 and U-238:U-235/236 suggest the presence of enriched uranium (anthropic) in samples from that well.

4.6.19.2.4 Uranium Ratios in Mid-Depth Lysimeter Samples—Four lysimeter water samples (D06-DL01, D06-DL02, TW1-DL04, and D15-DL06) were collected from the B and C basalt flows and B-C interbed in 1999 and sent for TIMS analysis. The water samples were filtered and both the filtrate and filtered material were analyzed for isotopic U-234, U-235, U-236, and U-238. The filter sample from TW1-DL04 contained U-236 and had uranium isotopic ratios (i.e., U-234:U-238 and U-238:U-235) indicative of enriched uranium (Roback et al. 2000).

The INEEL routine monitoring data for U-235/236 from the lysimeters at this depth range are consistent with the TIMS results. The uranium data suggest increasing uranium concentrations, though the source of uranium in some cases cannot he determined without additional data and further investigation. The uranium atomic mass ratios for U-233/234:U-238 and U-238:U-235/236 in Lysimeter TW1-DL04 indicate anthropic uranium. The elevated U-234 results on the other three lysimeters and the trend data on D06-DL01 are inconclusive.

4.6.19.2.5 Deep Lysimeter and Perched Water Samples at Depths Greater than 140 ft

4.6.19.2.5.1 ***Uranium-233/234***—A total of 21 water samples (four lysimeter and 17 perched water) were analyzed for U-233/234 between 1998 and December 2000. There were nine positive detections of U-233/234, all from the perched water wells. Three of the positive detections met or exceeded the 1E-05 aquifer risk-based concentration of 6.7 pCi/L, used for comparison (Table 4-117).

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		49.4											
	3	7.2	41.9											
	4													
1998	1													9.8
	2		42.1											8.2
	3	28.4	48.9	1.2										9.5
	4	48.6		0.68										9.6
1999	1													9.1
	2													
	3													
	4		47.2											9.6
2000	1													9.6
	2	41.4		1.6	10.3		1.5	2.1		3.1				9.1
	3	52.6			9.3		4.5							8.9
	4											0.87		
2001	1													
	2										4.7			2.6
	3													
	4													
Key			U-238 was analyzed for, but not detected.											
		x.xx	U-238 was detected at local soil moisture background levels (1.5 pCi/L).											
			U-238 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (5.5 pCi/L).											
			U-238 was analyzed detected above the RBC (5.5 pCi/L).											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.												

Figure 4-59. Occurrence of uranium-238 nondetections, detections at or above background, and detections greater than the 1E-05 aquifer risk-based concentration in mid-depth lysimeter samples.