4.6 Soil and Vegetation Surveillance

B. L. Tiller and B. G. Fritz

Soil surveillance provides information on long-term contamination trends and baseline environmental radionuclide concentrations at undisturbed locations (DOE/RL-91-50). Surveillance of perennial vegetation provides information on atmospheric deposition of radioactive materials in uncultivated areas and at onsite locations adjacent to potential sources of manmade radioactivity. Accordingly, radionuclide concentrations in soil and perennial vegetation provide a baseline against which unplanned releases can be compared.

Soil and perennial vegetation samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large database exists that thoroughly documents onsite and offsite levels of manmade radionuclides in soil and perennial vegetation at specific locations. Routine radiological surveillance of soil and vegetation on and around Hanford was last conducted in 1998 (Section 4.6 in PNNL-12088). In 2001, thirteen vegetation samples and 38 soil samples were collected (Figure 4.6.1).

4.6.1 Soil Sampling

In 2001, soil samples were collected at the locations shown in Figure 4.6.1. Samples were organized into four distinct groups: (1) onsite, (2) the Fitzner/Eberhardt Arid Lands Ecology Reserve, (3) perimeter, and (4) distant. Onsite sampling locations were collected at undisturbed locations around industrial development on the site. Two samples were collected on the Fitzner/Eberhardt Arid Lands Ecology Reserve on the northeastern side of Rattlesnake Mountain. Perimeter samples were collected at the edge of the Hanford Site and at downwind locations in Franklin County. Distant samples were collected at McNary Dam, Sunnyside, Toppenish, Walla Walla, and Washtucna.

Soil samples consisted of five plugs, each 2.54 centimeters (1 inch) deep and 10.2 centimeters (4 inches) in diameter that were collected within 10 meters (33 feet) of one another and combined into one bulk sample. Soil samples were dried to remove residual moisture and sieved at the laboratory prior to analysis to remove rocks and plant debris.

All samples were analyzed for gamma-emitting radionuclides, strontium-90, uranium-234, -235, -238, and plutonium-238, -239/240. Selected samples were analyzed for americium-241 (Table 4.6.1). The 2001 analytical results were compared to results from 1993, 1994, and 1998 (Table 4.6.2). In 1996, results of an assessment of Hanford background radionuclide concentrations in soils were published (DOE/RL-96-12). These assessment results provided comparison values (median and 95th percentile[a] concentrations) for radionuclides that are routinely monitored on the Hanford Site.

In 2001, observed mean radionuclide concentrations in onsite soil samples analyzed for plutonium isotopes, strontium-90, cesium-137, uranium-238, and americium-241 were at or below their respective averages from 1993, 1994, and 1998 (see Table 4.6.2). This indicated that there has been no appreciable increase in radionuclide concentrations in onsite soil in the last several years. There were also no increases in soil concentrations of any measured radionuclide at distant or perimeter locations. The onsite average soil concentrations in 2001 were higher than at site perimeter or distant locations for the radionuclides measured (see Table 4.6.2). This was consistent with historical data and reflected the higher onsite soil concentrations associated with years of nuclear materials production. The

(a) The percentile is a statistical grouping of values, 95% of all values fall below the 95th percentile; hence, the 95th percentile is used as an estimate of the upper bound.

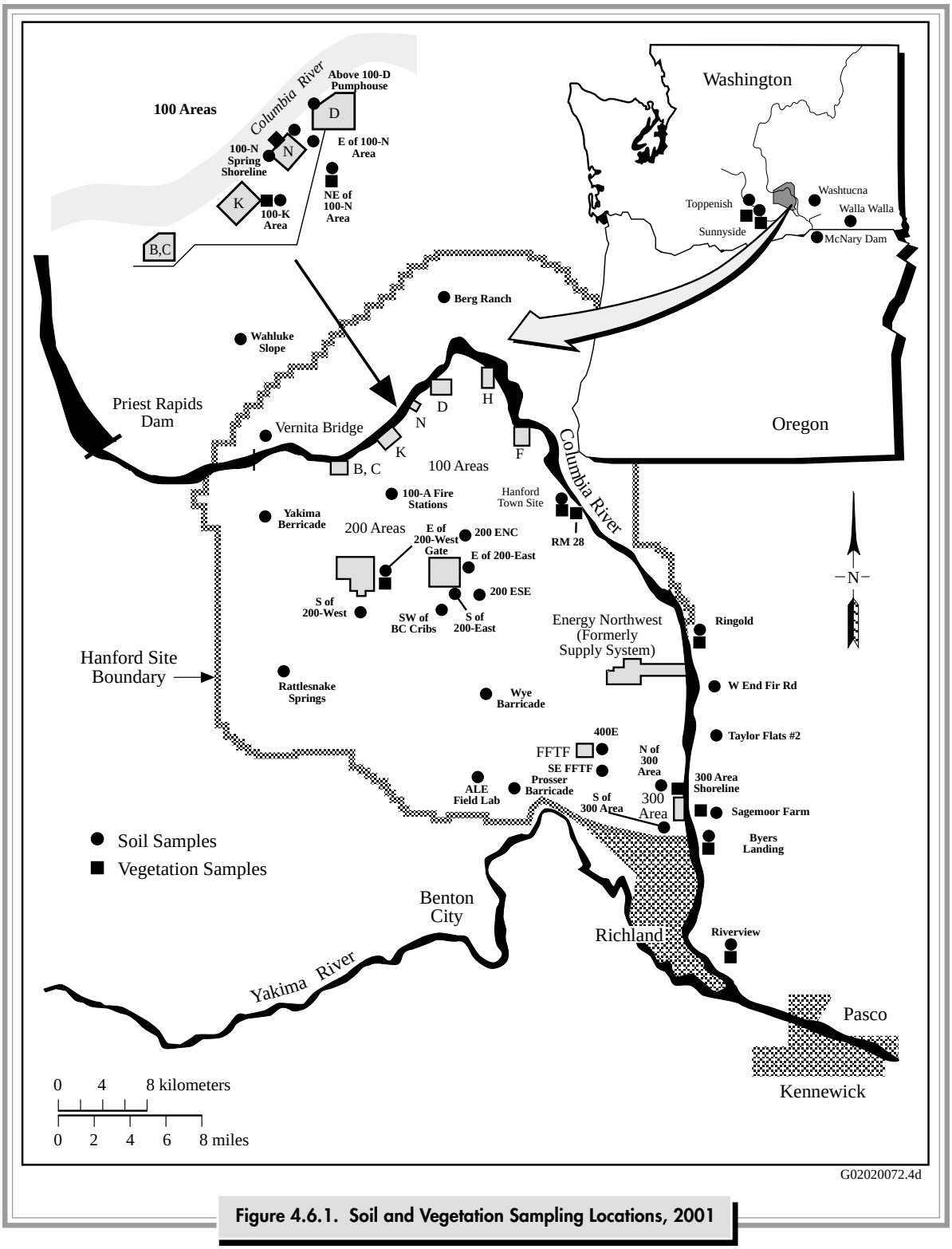

Figure 4.6.1. Soil and Vegetation Sampling Locations, 2001

Table 4.6.1. Routine Soil and Vegetation Samples Collected and Analyzed, 2001

Location	No. of Samples	Frequency	Analytes[a]
Soil			
Onsite[b]	20	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu,[c] ^{241}Am
ALE[d]	2	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu, ^{241}Am
Perimeter	11	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu, ^{241}Am
Distant	5	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu, ^{241}Am
Vegetation			
Onsite	4	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu
Perimeter	4	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu
Shoreline	3	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu
Distant	2	Annual to once every 5 yr	Gamma, ^{90}Sr, U_{iso}, Pu

(a) Not all analytes are analyzed for at each location.
(b) Onsite denotes sample locations designated as "onsite." Some perimeter samples are collected inside the Hanford Site boundary.
(c) Plutonium-238 and plutonium-239/240.
(d) Fitzner-Eberhardt Arid Lands Ecology Reserve.

sampling location east of the 200-West gate (see Figure 4.6.1) had the highest observed concentrations of any sampling location. This was consistent with historical results.

Maximum soil concentrations of several radionuclides at various distance classes were higher in 2001 than in previous years. Maximum concentrations of strontium-90 and uranium-238 on the site were higher in 2001 than maximums observed since 1993 (Figure 4.6.2 and Table 4.6.2). At the site perimeter, the plutonium-239/240 maximum concentration was slightly higher than in recent years. Uranium-238 maximum concentrations at perimeter and distant locations were also higher in 2001 than in the last 8 years, but the differences were not statistically significant.

In the past, soil samples from the Fitzner/Eberhardt Arid Lands Ecology Reserve were included in the perimeter grouping. After the transfer of management of this reserve to the U.S. Fish and Wildlife Service in 1997, results from the Rattlesnake Springs and Arid Lands Ecology Field Laboratory stations were reported separately. Results for some radionuclides measured at these locations in 2001 were elevated compared to results from 1993 and 1998 (Table 4.6.3).

Concentrations of plutonium-239/240 in soil samples from the Fitzner/Eberhardt Arid Lands Ecology Reserve in 2001 had statistically significant increases ($\alpha = 0.05$) in concentrations from samples analyzed from recent years. In 1993 and 1998, plutonium-239/240 samples from the reserve had an average concentration of 0.0054 ± 0.0062 pCi/g (0.20 ± 0.23 mBq/g) (see Table 4.6.3). In 2001, the two samples collected on the reserve had an average plutonium-239/240 concentration of 0.012 pCi/g (0.44 mBq/g). The maximum plutonium-239/240 value reported on the reserve in 2001 exceeded the maximum plutonium-239/240 concentration from 1993 and 1998 by a factor of two. However, concentrations of plutonium-239/240 in 2001 were not elevated relative to results from the last 18 years (Figure 4.6.3). While the changes in radionuclide concentrations in soil onsite and near the perimeter are noted, effective doses received by members of the public from these levels are small (see Section 5.0).

The median background concentration and the 95th percentile background concentration of uranium-238 near and on the Hanford Site have been reported as 0.76 and 1.18 pCi/g (0.028 and 0.044 Bq/g), respectively (DOE/RL-95-55). These background concentrations were based primarily on low-energy photon spectrometry. Low-energy photon spectrometry results for uranium-238 are generally higher than alpha spectrometry results; however, the degree of difference varies, depending on the soil type and particle-size distribution. Maximum uranium-238 concentrations measured in soil on and around the Hanford Site in 2001 by alpha spectrometry were below the reported median background level.

Table 4.6.2. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Soil, 2001 Compared to Previous Years

		2001				1993, 1994, and 1998			
Location	Radionuclide	No. of Samples	No. Detected[b]	Mean[c]	Maximum[d]	No. of Samples	No. Detected[b]	Mean[c]	Maximum[d]
Onsite	^{241}Am	3	3	0.0060 ± 0.013	0.013 ± 0.0029	10	7	0.038 ± 0.15	2.4 ± 0.14
	$^{239/240}Pu$	20	20	0.028 ± 0.068	0.13 ± 0.019	48	47	0.034 ± 0.20	0.53 ± 0.058
	^{238}Pu	20	18	0.00079 ± 0.0029	0.0068 ± 0.0012	48	33	0.00060 ± 0.0026	0.0081 ± 0.0013
	^{137}Cs	20	20	1.0 ± 5.1	12 ± 1.4	48	46	0.90 ± 4.6	12 ± 1.3
	^{90}Sr	20	15	0.25 ± 1.3	3.1 ± 0.70	48	48	0.15 ± 0.30	0.70 ± 0.13
	$^{238}U_{leps}$[e]					35	35	0.67 ± 0.47	1.5 ± 0.29
	$^{238}U_{iso}$[f]	20	20	0.15 ± 0.21	0.57 ± 0.11	13	13	0.15 ± 0.085	0.25 ± 0.042
ALE[g]	$^{239/240}Pu$	2	2	0.012 ± 0.0066	0.014 ± 0.0026	2	2	0.0054 ± 0.0062	0.0076 ± 0.0012
	^{238}Pu	2	2	0.00038 ± 0.00020	0.00045 ± 0.00033	2	2	0.00018 ± 0.00033	0.00036 ± 0.00020
	^{137}Cs	2	2	0.26 ± 0.034	0.27 ± 0.039	2	2	0.18 ± 0.23	0.29 ± 0.039
	^{90}Sr	2	2	0.077 ± 0.018	0.084 ± 0.035	2	2	0.068 ± 0.079	0.11 ± 0.022
	$^{238}U_{leps}$[e]					2	2	0.76 ± 0.71	1.0 ± 0.50
	$^{238}U_{iso}$[f]	2	2	0.13 ± 0.021	0.13 ± 0.033	2	2	0.16 ± 0.14	0.21 ± 0.029
Perimeter	^{241}Am	1	0		0.00014 ± 0.00019	3	2	0.0021 ± 0.0031	0.0030 ± 0.0015
	$^{239/240}Pu$	11	11	0.0085 ± 0.016	0.030 ± 0.0044	19	19	0.0070 ± 0.0079	0.013 ± 0.0021
	^{238}Pu	11	7	0.00026 ± 0.00036	0.00051 ± 0.00023	19	14	0.00029 ± 0.00067	0.00083 ± 0.00050
	^{137}Cs	11	11	0.22 ± 0.31	0.48 ± 0.064	19	18	0.28 ± 0.34	0.62 ± 0.073
	^{90}Sr	11	7	0.049 ± 0.071	0.11 ± 0.041	19	19	0.069 ± 0.068	0.15 ± 0.029
	$^{238}U_{leps}$[e]					15	13	0.68 ± 0.54	1.1 ± 0.51
	$^{238}U_{iso}$[f]	11	11	0.16 ± 0.19	0.38 ± 0.078	4	4	0.19 ± 0.15	0.30 ± 0.045
Distant	^{241}Am	1	1		0.0043 ± 0.00090	2	2	0.0055 ± 0.0033	0.0066 ± 0.0024
	$^{239/240}Pu$	5	5	0.0055 ± 0.012	0.014 ± 0.0022	4	4	0.0090 ± 0.013	0.017 ± 0.0021
	^{238}Pu	5	3	0.00021 ± 0.0029	0.00047 ± 0.00019	4	3	0.00037 ± 0.00039	0.00059 ± 0.00025
	^{137}Cs	5	5	0.15 ± 0.32	0.39 ± 0.053	4	4	0.47 ± 0.46	0.74 ± 0.083
	^{90}Sr	5	2	0.052 ± 0.11	0.14 ± 0.046	4	4	0.13 ± 0.15	0.24 ± 0.055
	$^{238}U_{leps}$[e]					3	2	0.74 ± 0.15	0.81 ± 1.1
	$^{238}U_{iso}$[f]	5	5	0.15 ± 0.11	0.24 ± 0.051	1	1		0.10 ± 0.022

(a) 1 pCi = 0.037 Bq.
(b) Detection is defined as a value reported above the minimum detectable activity or above the total analytical uncertainty. A detection for gamma-emitting radionuclides is defined as a value above the minimum detectable activity.
(c) Reported mean values ±2 standard deviations.
(d) Reported maximum values ± the total analytical uncertainty.
(e) Samples analyzed by low-energy photon system.
(f) Isotopic uranium.
(g) Fitzner/Eberhardt Arid Lands Ecology Reserve Unit.

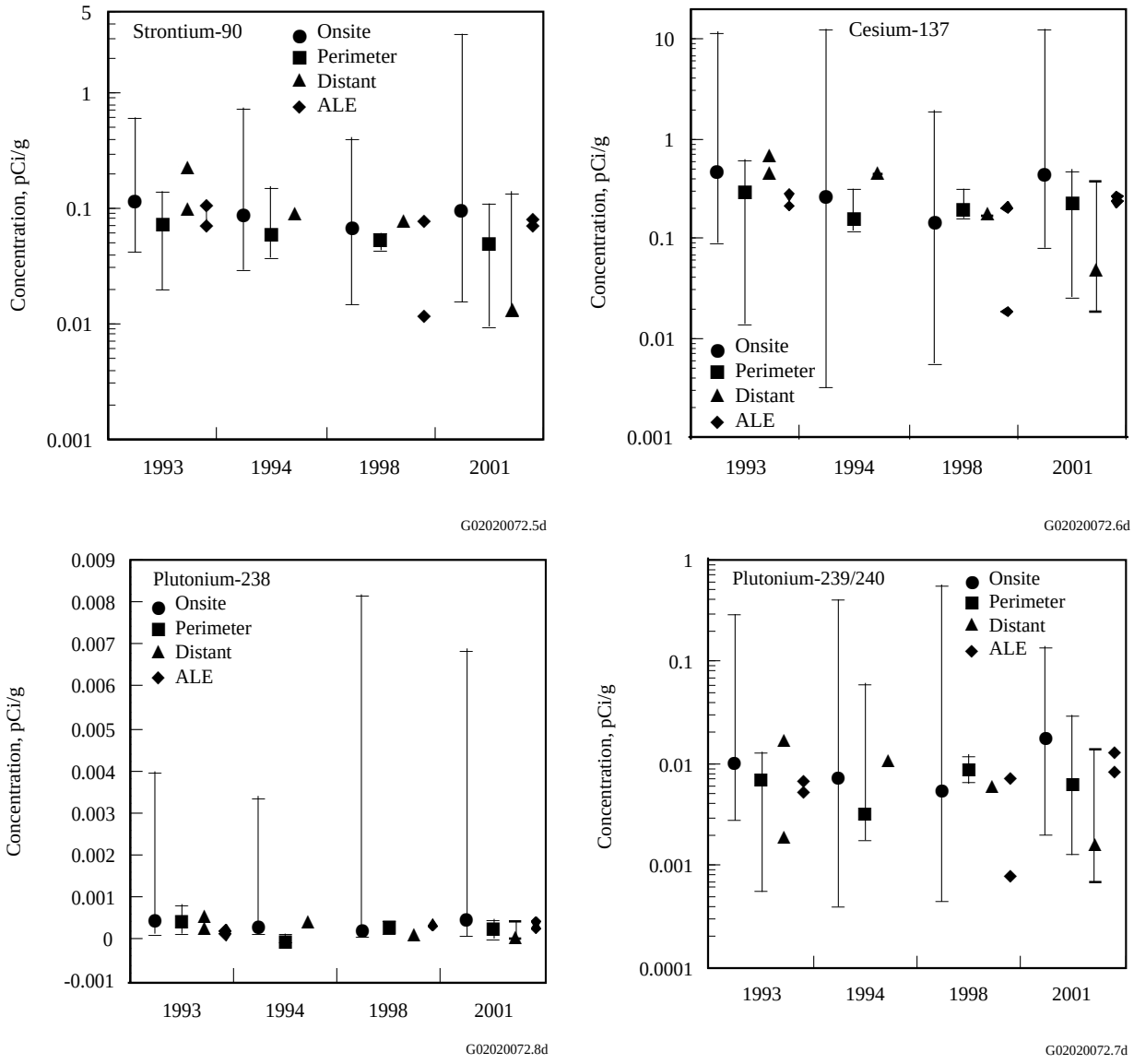

Figure 4.6.2. Median, Maximum, and Minimum Radionuclide Concentrations of Strontium-90, Cesium-137, Plutonium-238, and Plutonium-239/240 in Soil (pCi/g dry wt.), 1993 through 2001 (ALE = Fitzner/ Eberhardt Arid Lands Ecology Reserve) (1 pCi = 0.037 Bq)

4.6.2 Vegetation Sampling

Vegetation samples were collected at 13 locations on and around the Hanford Site in 2001 (see Figure 4.6.1). Samples were organized into four distinct groups: (1) onsite, (2) perimeter, (3) Columbia River shoreline, and (4) distant upwind (see Table 4.6.1). Onsite sampling locations were generally selected in areas around industrial development on the site. The downwind perimeter locations were Ringold, Byers Landing, Sagemoor, and Riverview (see Figure 4.6.1). These four locations lie generally east and southeast of the site. They are expected to be in areas of highest offsite accumulation of contaminants from site stack emissions.

Perennial vegetation samples consisted of the current year's growth of leaves, stems, and new branches collected from sagebrush and rabbitbrush. Sample vegetation was dried before analyses, and analytical results were reported on a dry weight basis. Shoreline vegetation samples were usually taken from a predominant species at the sampling location. A contaminant was detected if

Table 4.6.3. Radionuclide Concentrations (pCi/g dry wt.)[a] in Soil Collected from the Fitzner/Eberhardt Arid Lands Ecology Reserve

Location[b]	Radionuclide	1993[c]	1998[d]	2001
Rattlesnake Springs	Strontium-90	0.07 ± 0.02	0.08 ± 0.02	0.084 ± 0.035
	Cesium-137	0.29 ± 0.04	0.21 ± 0.03	0.24 ± 0.035
	Uranium-238[d]	0.51 ± 0.39	0.11 ± 0.02	0.13 ± 0.033
	Plutonium-238	0.0002 ± 0.0001	0.0004 ± 0.0002	0.00031 ± 0.00024
	Plutonium-239/240	0.007 ± 0.001	0.008 ± 0.001	0.014 ± 0.0015
Arid Lands Ecology Reserve Field Laboratory	Strontium-90	0.11 ± 0.02	0.012 ± 0.004	0.078 ± 0.033
	Cesium-137	0.22 ± 0.04	0.02 ± 0.01	0.27 ± 0.039
	Uranium-238[d]	1.01 ± 0.50	0.21 ± 0.04	0.19 ± 0.028
	Plutonium-238	0.0002 ± 0.0002	ND[e]	0.00045 ± 0.00033
	Plutonium-239/240	0.006 ± 0.001	0.0009 ± 0.0005	0.0093 ± 0.0020

(a) 1 pCi = 0.037 Bq.
(b) See Figure 4.6.1.
(c) ± total analytical uncertainty.
(d) 1993 uranium-238 was determined by low-energy photon analysis; 1998 and 2001 determined by alpha spectrometry.
(e) ND = Not detected.

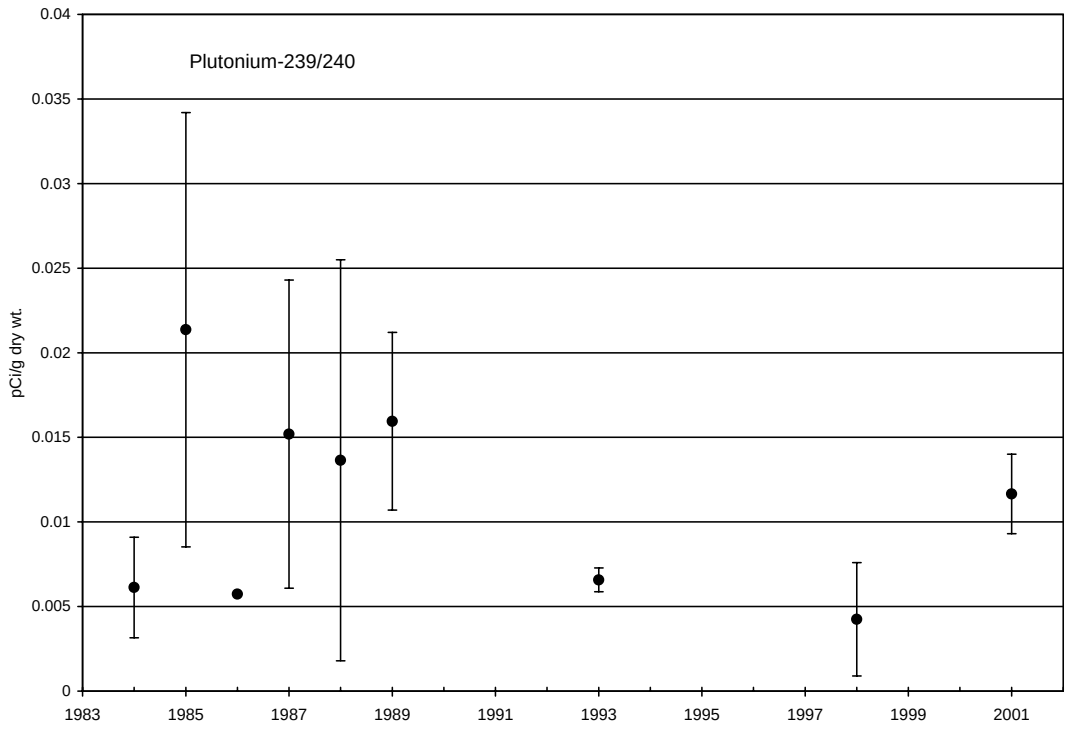

Figure 4.6.3. Mean, Maximum, and Minimum Concentrations of Plutonium-239/240 in Soil on the Fitzner/Eberhardt Arid Lands Ecology Reserve, 1984 through 2001 (1 pCi = 0.037 Bq)

the analytical result was greater than the minimum detectable concentration, and was larger than the total analytical uncertainty.

Vegetation sampling results in 2001 generally confirmed observations from past sampling efforts. Strontium-90, cesium-137, plutonium-238, and uranium-238 concentrations were all below nominal detection limits at distant and shoreline locations (Table 4.6.4), as were cesium-137 and strontium-90 concentrations at perimeter locations. Nominal detection limits for strontium-90, cesium-137, plutonium-238, and uranium-238 were 0.14, 0.03, 0.0002, and 0.005 pCi/g (5.2, 1.1, 0.0074, and 0.19 mBq/g), respectively. Uranium-238 was detected in three of four perimeter samples collected. These three samples were from Franklin County, across the eastern boundary of the Hanford Site. The maximum uranium-238 concentration measured in vegetation during 2001 was collected at Byers Landing (0.016 ± 0.0094 pCi/g [0.60 ± 0.35 mBq/g]). This result was higher than the maximum onsite uranium-238 concentration measured in 2001. The average uranium-238 concentration at perimeter locations was similar to the average of samples collected in 1993, 1994, and 1998.

Concentrations of plutonium-238 and uranium-238 in onsite samples were all less than the detection limit. Cesium-137 and strontium-90 were each measured in one sample, and results were similar to those from past years (see Table 4.6.4).

The percentage of samples collected in 2001 with measurable plutonium-239/240 concentrations increased relative to those samples collected in 1993, 1994, and 1998. Between 1993 and 1998, >40% of the vegetation samples analyzed had detectable concentrations of plutonium-239/240. In 2001, plutonium-239/240 was detected in all vegetation samples collected and analyzed. The 2001 average concentrations for all distance classes increased relative to the average concentration measured during the past 8 years (see Table 4.6.4).

4.6.3 Cross Media Comparison

In 2001, slightly increased plutonium-239/240 concentrations were detected in soil, vegetation, and air samples on and near the Hanford Site. In general, the increases were only apparent on a relatively short time scale. Figure 4.6.4 illustrates annual average plutonium-239/240 concentrations over an 18-year period at onsite and perimeter locations for vegetation and air, and onsite and Fitzner/Eberhardt Arid Lands Ecology Reserve locations for soil. For some distance class/media combinations, 2001 indicated an increase in plutonium-239/240 concentration relative to the past several sampling periods. This included onsite and perimeter vegetation, Fitzner/Eberhardt Arid Lands Ecology Reserve soil, and onsite atmospheric particulates. With the exception of perimeter vegetation, all of the 2001 averages were below levels measured in the previous 17 years. It is possible that the increase in plutonium-239/240 observed in 2001 was related to the 24 Command Hanford fire of 2000. It is likely that the increases were not a result of additional contamination, but rather the movement of contaminants already present in soil no longer held in place by vegetative cover. This conclusion is based on the following facts. The increase of plutonium-239/240 detected in the Fitzner/Eberhardt Arid Lands Ecology Reserve soil was small and could be the result of random variation. There was significant wind erosion of soil in the burned area after the fire (PNNL-13487) and significant particulate transport in 2001 (see Section 4.1.3). Plutonium is tightly bound to soil and uptake by plants is generally minimal (Eisenbud 1987), so increases in plutonium-239/240 in new vegetative growth is likely due to atmospheric particles deposited onto plant foliage.

Table 4.6.4. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Vegetation, 2001 Compared to Previous Years

		2001				1993, 1994, and 1998			
Location	Radionuclide	No. of Samples	No. Detected[b]	Mean[c]	Maximum[d]	No. of Samples	No. Detected[b]	Mean[c]	Maximum[d]
Onsite	$^{239/240}Pu$	4	4	0.0026 ± 0.0058	0.0069 ± 0.0014	13	6	0.00099 ± 0.0040	0.0066 ± 0.0011
	^{238}Pu	4	0	0.000029 ± 0.000077	0.000074 ± 0.000086	13	1	0.00058 ± 0.0041	0.0073 ± 0.0012
	^{137}Cs	4	1	0.022 ± 0.047	0.055 ± 0.029	13	3	0.0057 ± 0.031	0.027 ± 0.021
	^{90}Sr	4	1	0.029 ± 0.11	0.094 ± 0.061	13	11	0.20 ± 1.2	2.2 ± 0.39
	$^{238}U_{NAT}$[d]					6	3	0.0025 ± 0.0041	0.0065 ± 0.0029
	$^{238}U_{iso}$[e]	4	1	0.0043 ± 0.0060	0.0062 ± 0.0068	7	0	-0.00031 ± 0.0093	0.0063 ± 0.0074
Perimeter	$^{239/240}Pu$	4	4	0.00094 ± 0.00062	0.0012 ± 0.00048	12	6	0.00019 ± 0.00024	0.00038 ± 0.00031
	^{238}Pu	4	1	0.000092 ± 0.00026	0.00027 ± 0.00023	12	0	0.000065 ± 0.00043	0.00064 ± 0.0010
	^{137}Cs	4	0	0.0092 ± 0.0072	0.014 ± 0.013	12	0	0.0087 ± 0.018	0.027 ± 0.018
	^{90}Sr	4	0	0.040 ± 0.042	0.060 ± 0.11	12	12	0.028 ± 0.037	0.069 ± 0.016
	$^{238}U_{NAT}$[d]					4	3	0.0038 ± 0.0051	0.0061 ± 0.0041
	$^{238}U_{iso}$[e]	4	3	0.0099 ± 0.0090	0.016 ± 0.0094	8	4	0.011 ± 0.018	0.029 ± 0.0080
Shoreline	$^{239/240}Pu$	3	3	0.0016 ± 0.0036	0.0037 ± 0.00069	7	1	0.00090 ± 0.0044	0.0059 ± 0.0014
	^{238}Pu	3	0	0.000013 ± 0.000027	0.000029 ± 0.000056	7	0	-0.000021 ± 0.00057	0.00026 ± 0.00027
	^{137}Cs	3	0	-0.0038 ± 0.018	0.0059 ± 0.021	7	4	0.057 ± 0.18	0.25 ± 0.033
	^{90}Sr	3	0	0.039 ± 0.027	0.053 ± 0.072	7	7	0.21 ± 0.45	0.54 ± 0.10
	$^{238}U_{NAT}$[e]					1	0		0.00034 ± 0.0016
	$^{238}U_{iso}$[f]	3	0	0.0010 ± 0.0071	0.0051 ± 0.0064	6	1	0.11 ± 0.52	0.64 ± 0.073
Distant	$^{239/240}Pu$	2	2	0.00078 ± 0.0016	0.0013 ± 0.00046	5	1	0.000068 ± 0.00016	0.0018 ± 0.00014
	^{238}Pu	2	0	0.000016 ± 0.000022	0.000024 ± 0.000065	5	0	0.0000041 ± 0.000047	0.000045 ± 0.000079
	^{137}Cs	2	0	0.0022 ± 0.034	0.014 ± 0.013	5	1	0.016 ± 0.027	0.032 ± 0.025
	^{90}Sr	2	0	0.066 ± 0.059	0.087 ± 0.10	5	5	0.020 ± 0.028	0.045 ± 0.012
	$^{238}U_{NAT}$[d]					3	2	0.0030 ± 0.0038	0.0051 ± 0.0031
	$^{238}U_{iso}$[e]	2	0	0.0059 ± 0.0058	0.0079 ± 0.0084	2	0	-0.0041 ± 0.0055	-0.0002 ± 0.0056

(a) 1 pCi = 0.037 Bq.
(b) Detection is defined as a value reported above the minimum detectable activity or above the total analytical uncertainty. A detection for gamma-emitting radionuclides is defined as a value above the minimum detectable activity.
(c) Reported mean values ±2 standard deviations.
(d) Reported maximum values ± total analytical uncertainty.
(e) U_{NAT} is a chemical analysis not used since 1994.
(f) Isotopic uranium.

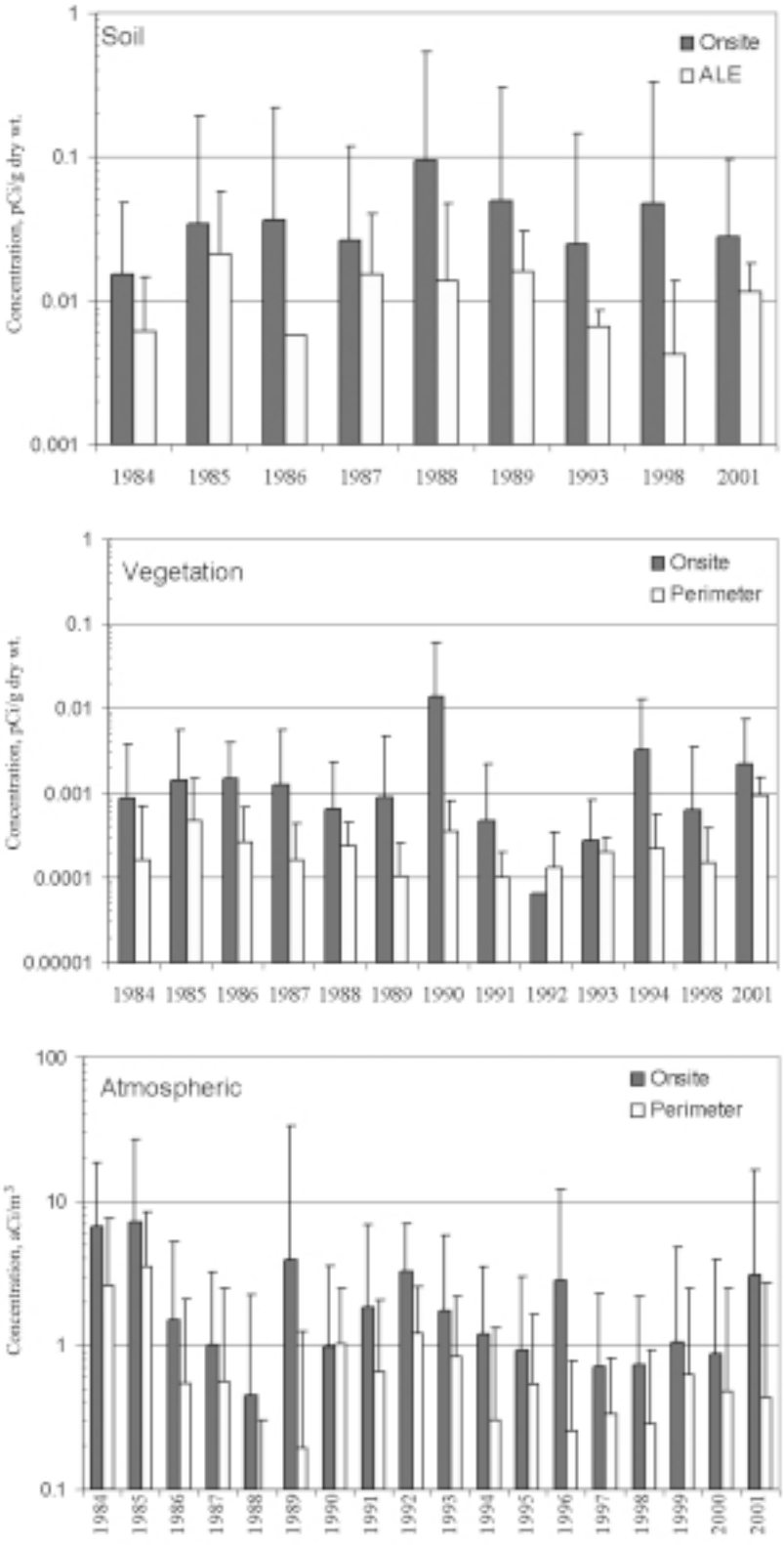

Figure 4.6.4. Annual Average Plutonium-239/240 Concentrations (+2 standard deviations) in Soil, Vegetation, and Air from 1984 through 2001 (ALE = Fitzner/Eberhardt Arid Lands Ecology Reserve)