

TABLE 5.1
Average Monthly Precipitation

MONTH	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	AVERAGE
January	0.5	1.3	0.9	0.0	0.0	1.2	1.0	2.9	0.0	2.2	1.3	1.0
February	4.0	0.5	0.8	1.2	1.1	4.0	1.0	8.8	0.8	2.7	0.2	2.3
March	1.3	4.1	2.0	3.1	1.7	3.6	4.2	8.5	0.4	5.0	3.8	3.4
April	2.1	4.1	5.8	0.3	2.4	2.9	2.7	5.9	3.6	0.9	5.0	3.2
May	11.4	6.5	9.8	4.4	13.4	6.5	2.4	2.9	5.9	7.5	0.8	6.5
June	7.2	3.9	3.6	7.6	6.2	5.5	4.7	6.0	4.0	4.6	3.2	5.1
July	2.3	1.9	0.0	5.6	0.8	1.4	0.2	4.8	2.3	5.6	1.7	2.4
August	2.5	4.8	0.3	5.5	1.5	2.6	2.5	2.6	3.5	2.5	2.5	2.8
September	3.9	8.4	1.6	2.7	0.7	1.1	1.4	6.5	9.9	5.1	7.5	4.4
October	0.6	0.9	1.7	3.6	0.5	8.1	4.0	6.4	12.8	0.1	2.4	3.7
November	5.0	3.2	0.3	1.9	2.7	2.0	2.9	2.7	2.6	2.8	4.2	2.7
December	0.0	1.6	2.0	0.6	1.2	0.4	4.8	0.2	3.2	2.6	0.5	1.5
Totals	40.7	41.1	28.6	36.2	32.0	39.1	31.7	58.1	48.9	41.5	32.9	39.2

6. SITE-SPECIFIC PARAMETER ANALYSIS

6.1 Site Ground-Water Analyses

Ground-water samples were collected and analyzed for specific parameters which potentially are related to facility production and decommissioning activities. The parameters include fluoride, nitrate, TOC and TOX, gross alpha and beta activity, Pu-239, Ra-228, Ra-226, Th-232, Th-228, U-238, U-235, and U-234. Each of these parameters are discussed in the following sections.

6.1.1 Fluoride and Nitrate.

Fluoride and nitrate were present in the wastewater stream discharged from production operations. The presence of these ions at concentrations above background could be an indication of facility effects. Figure 6.1 shows the concentrations of fluoride in ground-water samples from around the site. Figure 6.2 shows the concentrations of nitrate in ground water.

Fluoride

The background concentration of fluoride is interpreted to be approximately 1 milligram per liter (mg/l) or less. Twenty of the twenty-four wells had concentrations less than 1 mg/l. Well 1332 had a fluoride concentration of 1.30 mg/l.

In the March, 1989 data, three wells had fluoride concentrations significantly higher than the background value. These wells and the fluoride concentrations were: Well 1312 - 50 mg/l; Well 1313 - 140 mg/l; and Well 1336 - 17 mg/l. These wells all are completed in Sandstone A, the shallowest water-bearing stratum.

These three wells contain levels of fluoride in excess of the EPA Maximum Contaminant Level (MCL) of 4.0 mg/L. These wells are down-gradient from the two closed wastewater ponds. The ground-water monitoring results from the annual sampling of these wells indicates that the concentration of fluoride is decreasing. The results of the annual sampling are tabulated in Table 6.1.

The proximity of Wells 1312, 1313, and 1336 to the two wastewater retention ponds indicates that the ponds had been sources of fluoride. The ponds have since been closed, back-filled, and reclaimed, and the detections at the monitoring wells reflects residual amounts of fluoride remaining in the unsaturated zone or in the water-bearing stratum.

Nitrate

The average nitrate concentration reported by Carr and Havens (1976) for wells completed in the Garber/Wellington aquifer is 12 mg/l, which is probably representative of regional background in the Cimarron facility area. Wells at the site which are located in areas up-gradient of plant facilities, including Wells 1324, 1325, and 1335, show nitrate concentrations between 13 and 22 mg/l. The nitrate concentrations depicted in Figure 6.2 indicate that twelve of the twenty-four wells show nitrate concentrations above the MCL of 10 mg/l. Local nitrate background is higher than the MCL.

Only five monitoring wells have concentrations greater than 22 mg/l; four of these wells have concentrations greater than 100 mg/l. All five of these higher concentration wells are completed in the shallowest water-bearing stratum, Sandstone A. Wells 1311, 1312, 1313, and 1336 show concentrations of 66 mg/l, 1020 mg/l, 720 mg/l, and 1260 mg/l, respectively. Well 1311 is up-gradient, but near, closed wastewater pond #1. The three remaining wells are down-gradient from closed wastewater ponds #1 or #2.

The nitrate concentration at Well 1330 was 172 mg/l. This well is located near the edge of a cultivated wheat field. The location is also adjacent to a small drainage that begins in the uranium plant areas. Surface runoff from part of the plant area drains toward the well location. A significant portion of the runoff comes from cultivated fields and is believed reflect the application of nitrogen-based fertilizers.

6.1.2 TOC and TOX.

Total organic carbon (TOC) and total organic halide (TOX) analyses were performed on four ground-water samples. These organic species parameters are general indicators of ground-water quality. Three wells near the facility production operations and one well near the designated landfill area were tested. These all are Sandstone A wells and include Well 1322 between the uranium and plutonium plants, Well 1326 east of the uranium plant, Well 1329 south of the uranium plant and near the former solvent extraction area, and Well 1325 south of the designated landfill area. Well 1325 was chosen to provide background data.

Only the background well, Well 1325, showed a TOC concentration above the laboratory detection limit of 10 mg/L. The source or type of organic compounds responsible for the 12 mg/l concentration at the background well is not known but probably is related to natural causes.

The total organic halide concentrations ranged from 62 ug/l in Well 1329 to 130 ug/l in Well 1325. 130 ug/l is probably representative of local background. The TOX results do not indicate that organic constituents used during facility production operations have impacted the shallow ground-water quality.

6.1.3 Radionuclides.

The ground-water samples also were analyzed for gross alpha and beta activity, Pu-239, Ra-226, Ra-228, Th-232, Th-228, U-238, U-235, and U-234. These results are presented in Table 3.4. Figure 6.3 shows alpha activity in ground water; Figure 6.4 shows beta activity; Figure 6.5 shows total uranium activity; and Figure 6.6 shows total radium activity. Plutonium and thorium activities are not indicated on separate figures because the ground-water analyses indicate they are not present in quantities above background.

6.1.3.1 Gross Alpha Activity.

Figure 6.3 shows four areas where ground water shows gross alpha activity greater than 50 picoCuries per liter (pCi/l). These are the two closed wastewater ponds, the former burial ground, and an area down-gradient from the uranium plant.

- o Down-gradient from waste water ponds #1 and 2: Well 1312, 59 pCi/l, and Well 1313, 260 pCi/l, are down-gradient from pond 1. Well 1336, 140 pCi/l is down-gradient from pond #2. These wells are completed in Sandstone A.
- o Down-gradient from former burial area: Wells 1315, 1316, and 1317 had gross alpha levels of 6440 pCi/l, 331 pCi/l, and 66 pCi/l, respectively. These wells are completed in Sandstone A.
- o Down-gradient from the uranium plant: Well 1331, 190 pCi/l, and Well 1323, 51 pCi/l. Well 1331 is completed in Sandstone A and Well 1323 is completed in Sandstone C.

At four locations, wells completed in Sandstone A are paired with wells completed in the deeper Sandstone C. At three of these locations, the deep well has higher gross alpha activity levels than the shallow well. These data are summarized below:

Well	Completion	Gross Alpha Concentration
1320	A	<10 pCi/l
1321	C	18 pCi/l
1322	A	15 pCi/l
1323	C	51 pCi/l
1329	A	12 pCi/l
1328	C	29 pCi/l
1333	A	47 pCi/l
1332	C	23 pCi/l

The generally higher activity levels in the deeper, Sandstone C wells reflect higher natural background level in the confined sandstone. The Sandstone C data are not interpreted to reflect effects of the plant since several significant confining layers separate Sandstone C from the most shallow stratum.

The MCL for gross alpha excluding uranium and radon is 15 pCi/l. Fourteen of the twenty-four wells sampled had values greater than 15 pCi/l. These wells generally are located in one of the areas previously identified as locally impacted.

6.1.3.2 Gross Beta Activity.

Thirteen of the twenty-four wells sampled had gross beta activity levels less than the detection limit of 20 pCi/l, and five more wells had values between 20 and 26 pCi/l. These data suggest that background levels are generally comparable to these values. The EPA has not published guidelines or standards for beta activity in ground water.

Figure 6.4 depicts gross beta activity in ground water. The map shows that the highest gross beta concentrations occur down-gradient from the two closed wastewater ponds and the former burial ground, and in the surface-water drainage feature north and down-gradient from the uranium building.

The six wells with gross beta values of 50 pCi/l or more are summarized below.

- o Down-gradient from waste water pond #1: Wells 1312, 2370 pCi/l and 1313, 2200 pCi/l. These wells are completed in Sandstone A.
- o Down-gradient from waste water pond #2: Well 1336, 4970 pCi/l. This well is completed in Sandstone A.

- o Down-gradient from former burial area: Wells 1315, 660 pCi/l and 1316, 100 pCi/l. These wells are completed in Sandstone A.
- o Southwest and down-stream (surface water) from the uranium building: Well 1330, 62 pCi/l. This well is completed in Sandstone A.

Gross beta values do not exceed background in shallow or deep wells at any of the locations of paired Sandstone A and C wells.

6.1.3.3 Uranium.

The EPA has not yet established specific guidelines or limits on uranium activity in drinking water; however the proposed rules governing uranium in drinking water supplies will be announced in the summer of 1990. It is anticipated that the MCL for uranium will be in the 20 to 40 pCi/l range (Mr. Bob Clement, U.S. EPA Drinking Water Section, Denver, personal communication).

Figure 6.5 shows total uranium (U-238 + U-235 + U-234) activity at the facility. The distribution of uranium activity levels is comparable to the gross alpha activity levels shown in Figure 6.3. Figure 6.5 also suggests that four site-activity related sources for uranium are present. Locations and wells where uranium levels exceed 30 pCi/l are summarized below.

- o Down-gradient from waste water ponds #1 and 2: Well 1312, 58 pCi/l, and Well 1313, 117 pCi/l, are down-gradient from closed wastewater pond #1. Well 1336, 101 pCi/l is down-gradient from closed wastewater pond #2. These wells are completed in Sandstone A.
- o Down-gradient from former burial area: Wells 1315, 5230 pCi/l, and 1316, 287 pCi/l. These wells are completed in Sandstone A.
- o Down-gradient from the uranium plant: Well 1331, 165 pCi/l. This well is completed in Sandstone A.

At three of the four locations where paired Sandstone A and C wells were completed, the deep well has higher uranium levels than the shallow well. These data are summarized below:

Well	Completion	Total Uranium Concentration
1320	A	8.85 pCi/l
1321	C	10.97 pCi/l
1322	A	12.23 pCi/l
1323	C	27.22 pCi/l
1329	A	7.43 pCi/l
1328	C	27.66 pCi/l
1333	A	24.91 pCi/l
1332	C	20.42 pCi/l

These wells show the same pattern as described for gross alpha activity levels. The slightly higher uranium activity levels in the deep wells is representative of regional background values.

6.1.3.4 Radium.

Figure 6.6 shows areal variations in total radium activity (Ra-228 + Ra-226) in the ground-water samples. The analyses are tabulated in Table 3.4. Radium sources were not used at the facility, and concentrations detected in the ground-water samples represent naturally-occurring levels. Table 6.2 presents the radium analyses in order of increasing concentration. Statistical analyses of the radium data were performed to determine background levels and the statistical significance of any variations.

A visual inspection of Table 6.2 indicates that two populations of radium values may exist. Nineteen of the twenty-four wells have values less than 0.5 pCi/l, four of the twenty-four lie between 1.1 and 2.9 pCi/l, and Well 1336 showed a concentration of 9.78 pCi/l. A histogram and probability distribution were constructed to determine how the data are distributed.

Figure 6.7 is a histogram of the natural logarithm of radium concentrations in ground water, which shows a log-normal distribution skewed to the right. A second population may be indicated by the increased number of observations in the last three classes.

Figure 6.8 is a probability plot of the log-transformed radium values. The majority of values in Figure 6.8 generally lie along a straight line, confirming the data are log-normally distributed (EPA, 1989). Two populations and an outlier are suggested in Figure 6.8.

A t-test was performed to determine the statistical significance of the radium values greater than 1 pCi/l. The calculations were performed in accordance with the procedures presented in 40 CFR Part 264, Appendix IV. The outlier, 9.78 pCi/l, was not included in the calculations.

The t-test assumed the data represents one population (all background) and the statistical significance of the values lying above 1 pCi/l compared to the population mean was calculated. The test conducted in this manner is more likely to fail to recognize a statistical difference in the larger values. Statistical significance was determined by calculating a t-statistic at the 0.05 level of significance and comparing it to a comparison t-statistic (40 CFR, Part 264, Appendix IV).

The t-statistic, t^* , is calculated to be 3.72. The comparison t-statistic, t_c , is calculated to be 2.26. Since t^* is greater than t_c , the group of values lying between 1.1 and 2.9 pCi/l represent a significant increase compared to background (40 CFR, Part 264, Appendix IV).

Since nineteen of the twenty-four wells had total radium concentrations less than 0.5 pCi/l and the log-transformed probability plot of radium concentrations suggests two populations are present, background is believed to be represented by the group of values below 0.5 pCi/l. The background mean is 0.155 pCi/l with a standard deviation of 0.141 and a variance of 0.020. Values above 1 pCi/l lie greater than six standard deviations from the background mean. The locations and wells where radium values elevated above background were reported are summarized below.

- o Down-gradient from waste water ponds #1 and 2: Well 1312, 1.83 pCi/l, and Well 1313, 2.83 pCi/l, are down-gradient from pond 1. Well 1336, 9.78 pCi/l is down-gradient from pond #2. These wells are completed in Sandstone A.
- o Down-gradient from former burial area: Well 1315, 1.61 pCi/l. This well is completed in Sandstone A.
- o Well 1332: Well 1332 with a level of 1.18 pCi/l is a deep Sandstone C well northwest of the sewage lagoons. The shallower Sandstone A wells in the area do not exhibit radium levels above background.

Since no sources of radium were managed at the facility, the elevated radium cannot result from leaching of waste materials. Changes in ground-water chemistry from natural background near the wastewater ponds and the former burial location could be responsible for the slightly elevated values. The wastewater disposed in the now-closed ponds may have altered the ground-water chemistry sufficiently to elute naturally occurring radium from the aquifer matrix.

The maximum contaminant level (MCL) for combined Ra-228 and Ra-226 in community water supplies is 5 pCi/l. Only Well 1336, down-gradient from wastewater pond #2, exceeds this standard.

6.1.4 Facility Impacted Areas.

The ground-water analyses indicate that there are four likely sources of site-related activity impacts. These include the closed wastewater ponds #1 and #2, the former burial ground, and the uranium plant areas. Elevated fluoride, nitrate, uranium, and gross alpha and beta activities were detected near the wastewater ponds. Elevated uranium, and alpha and beta activity were detected near the former burial location. Elevated nitrate and uranium concentrations, and alpha activity were detected near the uranium plant.

6.2 Site Soil and Rock Analyses

Selected soil and rock samples were submitted to the Kerr-McGee Technical Center laboratory for fluoride, nitrate, TOC, gross alpha and beta activity, Pu-239, Ra-228, Ra-226, Th-232, Th-228, U-238, and U-234 analyses. The samples selected were representative of the various strata encountered in the shallow subsurface, and emphasize those intervals that may be the host for the contaminants and retarding medium for the vertical and horizontal movement of contaminants. Before the samples were shipped to the laboratory, the uranium activity in each sample was measured by Cimarron personnel by gamma spectrometry. The results of the analyses are summarized below.

6.2.1 Fluoride and Nitrate.

Fluoride and nitrate were detected in all selected soil and rock samples submitted to the laboratory. Fluoride concentrations ranged from 18 ppm to 640 ppm and are comparable to the average naturally-occurring crustal abundance of fluoride in sedimentary rocks reported by Levinson (1980) and Mason (1966), which ranges up to 740 ppm. Although Figure 6.9 shows a positive correlation between fluoride and uranium, neither set of values are above

natural background levels and may not be directly related to past activities at the facility.

Nitrate concentrations ranged from 2 ppm to 130 ppm and show no apparent correlation with the other parameters analyzed.

6.2.2 Total Organic Carbon.

Total organic carbon (TOC) was analyzed to determine if organic materials in the subsurface adsorbed uranium. TOC in the soil and rock samples ranged from less than the detection limit of 10 ppm to 3110 ppm. The highest value occurred at Well 1326 in soil from the two to four feet deep interval. Organic carbon does not appear to have adsorbed uranium as no correlation between TOC and uranium concentrations was determined.

6.2.3 Radionuclides.

Site soil and rock samples were analyzed for gross alpha and beta activity, Pu-239, Ra-228, Ra-226, U-238, U-234, Th-232, and Th-228. The laboratory analyses are tabulated in Table 3.5.

6.2.3.1 Alpha and Beta Activity.

Gross alpha activity values ranged from less than the detection limit of 10 pCi/g to 38 pCi/g. The higher values were all associated with mudstone samples. No sandstone samples had gross alpha values higher than 12 pCi/g. Alpha activity is probably related to naturally-occurring isotopes and the higher concentrations detected in the mudstones samples reflects adsorption on the clay-rich mudstone matrix.

None of the samples submitted had values for gross beta activity greater than the detection limit of 20 pCi/g.

6.2.3.2 Plutonium.

No plutonium above background was detected in any samples submitted. Reported values range from 0.001 to 0.006 pCi/g, which are representative of background values. The precision of these analyses is 0.001 pCi/g.

6.2.3.3 Uranium.

Uranium-238 ranged from 0.16 to 0.84 pCi/g. Uranium-234 ranged from 0.21 to 0.73 pCi/g. The higher concentrations for both isotopes were associated with mudstone samples. There is no apparent correlation with proximity to facility components and is therefore attributed to be representative of naturally-occurring uranium rather than an impact from plant activities. A greater concentration in the higher surface area mudstone matrix is to be expected as it provides an active adsorption environment.

6.2.3.4 Radium.

Radium-228 ranged from 0 to 1.9 pCi/g. Radium-226 ranged from 0 to 0.77 pCi/g. As was reflected in the uranium values, the higher radium values are associated with mudstone samples. These values represent naturally-occurring radium and do not indicate an impact from plant activities. Radium was not used in the production processes. The facility processed high purity enriched uranium isotopes.

6.2.3.5 Thorium.

Thorium was present at the site either as drummed waste buried at the former burial location or as contamination on equipment from the Cushing facility which was stored at the uranium plant yard. The drums and equipment were removed and disposed in an off-site licensed commercial disposal facility. No thorium was processed at the facility and its presence in the subsurface is attributed to naturally-occurring isotopes.

6.2.4 Correlation with Field-Measured Gamma Activity.

A comparison of laboratory measured values for uranium-238 and the borehole gamma probe measurements was made and is presented in Figure 6.10. Although the data does not show a strong correlation the method does provide a gross evaluation tool to distinguish between naturally occurring background gamma activity and that resulting from plant activities.

A threshold count is apparent (see Figure 6.10) at approximately 27,000 to 30,000 counts/minute. Below that threshold, uranium activities are typically less than 1 pCi/g. Above the threshold, uranium activities significantly greater than 1 pCi/g are apparent. This threshold is believed to represent the division between natural background gamma activities and facility related impacts.

6.3 Uranium Mobility

The mobility of uranium at the site depends upon the chemistry of the ground water and the soil and rock chemistry. The stability and mobility of particular species in the subsurface depends primarily on active matrix adsorption sites, ligands available for complexation, pH, and Eh of the ground water. Uranium has limited solubility in the slightly alkaline and oxidizing ground water typical of the site. The solubility is higher near the ponds because of the altered ground-water chemistry in these areas and the presence of complexing agents, e.g. fluoride and nitrate.

The dominant uranium species in the natural environment are uranyl complexes. Uranium exists in the hexavalent state as the uranyl ion UO_2^{+2} in this environment (Levinson, 1980). The solubility of uranium is limited by precipitation and adsorption on the aquifer matrix. Uranyl hydroxide and uranium trioxide will precipitate from slightly alkaline and oxidizing ground water. These compounds are relatively insoluble. Uranyl ions in solution also will be sorbed onto the aquifer matrix.

The distribution coefficient analyses described in Section 3.2.8.5 indicate that the equilibrium concentration of uranium in ground water should be less than 10 pCi/l. The tests performed on five representative samples of aquifer material yielded final concentrations of uranium in test solutions less than 10 pCi/l and relatively large equilibrium distribution coefficients. The ground-water analyses from most of the monitoring wells showed similar values.

Concentrations of uranium above the typical equilibrium level were detected in some monitoring wells. These wells generally were located down-gradient from the closed wastewater ponds and former burial area. Materials stored in these areas could cause changes in the chemistry of the ground water near the facilities. The process wastewater discharged to the ponds contained dissolved uranium and was significantly different chemically from the natural ground water (Wayne Norwood, personal communication, 1989). The difference is responsible for the higher uranium concentrations near the ponds. Likewise, leaching of materials stored at the former burial location would alter the ground-water chemistry in that area.

Uranium concentrations decreased rapidly to background levels with distance from the sources, as is discussed in Section 7.3.

TABLE 6.1

Annual Ground-Water Sampling Results

Date	Alpha pCi/L	Beta pCi/L	NO3 mg/L	F mg/L	U-238 pCi/L	Pu-239 pCi/L	Ra-224 pCi/L	Ra-226 pCi/L
WELL No. 1311								
06/21/85	10.0	31.0	57.0	< 0.2	< 0.7	0.015	NR	NR
06/26/86	<10.0	< 20.0	87.0	0.4	1.0	< 0.100	NR	NR
06/16/87	<10.0	< 20.0	34.0	0.4	1.7	0.010	0.081	0.3
06/28/88	<10.0	< 20.0	38.0	< 1.0	1.7	0.008	0.040	0.2
03/21/89	<10.0	23.0	66.0	< 0.2	0.8	0.002	NR	0.2
WELL NO. 1312								
06/21/85	2200.0	8275.0	< 20.0	83.0	86.0	0.020	NR	NR
06/28/86	94.0	7300.0	1310.0	59.0	5.6	< 0.100	NR	NR
06/16/87	41.0	65.0	620.0	18.0	15.0	0.002	0.290	0.6
06/30/88	90.0	231.0	480.0	22.0	48.0	0.012	0.410	1.1
03/21/89	59.0	2370.0	1020.0	50.0	15.3	0.003	NR	0.5
WELL NO. 1313								
06/21/85	453.0	1512.0	< 5.0	120.0	23.0	0.003	NR	NR
06/28/86	230.0	3000.0	690.0	157.0	25.4	< 0.100	NR	NR
06/16/87	84.0	25.0	450.0	120.0	26.0	0.004	0.350	0.2
06/28/88	61.0	24.0	570.0	3.1	42.0	0.006	0.120	0.3
03/21/89	260.0	2200.0	720.0	140.0	30.0	0.003	NR	0.5
WELL NO. 1314								
07/02/85	< 10.0	< 20.0	2.0	0.4	< 0.7	0.007	NR	NR
06/26/86	< 10.0	< 20.0	9.0	1.5	0.7	< 0.100	NR	NR
06/15/87	< 10.0	< 20.0	4.8	1.3	1.7	0.027	0.057	0.2
06/29/88	< 10.0	< 20.0	12.0	1.8	2.3	0.002	0.070	0.2
03/21/89	< 10.0	< 20.0	0.4	< 0.2	0.3	0.003	NR	0.1
WELL NO. 1315								
07/02/85	3125.0	189.0	11.0	< 0.2	1800.0	0.019	NR	NR
06/26/86	5400.0	740.0	5.0	0.5	2310.0	< 0.100	NR	NR
06/16/87	3850.0	2450.0	6.7	0.6	1600.0	0.005	0.036	0.1
06/27/88	3800.0	989.0	< 2.0	< 1.0	1590.0	0.002	0.210	0.2
09/13/88	3560.0	240.0	< 10.0	< 1.0	1340.0	NR	0.000	1.9
03/21/89	6440.0	660.0	13.0	0.2	1550.0	0.003	NR	0.0
WELL NO. 1316								
07/02/85	200.0	< 20.0	11.0	< 0.2	63.0	0.020	NR	NR
06/26/86	608.0	140.0	4.0	0.8	530.0	< 0.100	NR	NR
06/15/87	420.0	300.0	4.6	0.6	180.0	0.002	0.100	0.1
06/29/88	378.0	116.0	12.0	< 1.0	99.0	0.012	0.060	0.1
03/21/89	331.0	100.0	16.0	< 0.2	67.0	0.003	NR	0.0
WELL NO. 1317								
07/02/85	20.0	27.0	25.0	< 0.2	< 0.7	0.003	NR	NR
06/26/86	< 10.0	21.0	8.0	0.4	7.0	< 0.100	NR	NR
06/15/87	13.0	< 20.0	2.2	0.3	3.3	0.002	0.100	0.2
06/29/88	105.0	< 20.0	< 1.0	< 1.0	42.0	0.002	0.030	0.1
03/21/89	66.0	26.0	0.4	< 0.2	8.1	0.003	NR	0.0

NOTE: NR means result not reported

TABLE 6.2

Radium Concentrations in Ground Water

Well No.	TOTAL RADIUM pCi/l	ln(Ra)	Frequency	i	Cumulative Frequency
1331	0.000		2	2	8.00
1335	0.000				
1321	0.021	-3.86	1	3	12.00
1329	0.030	-3.51	1	4	16.00
1328	0.054	-2.92	1	5	20.00
1323	0.058	-2.85	1	6	24.00
1324	0.059	-2.83	1	7	28.00
1327-B	0.061	-2.80	1	8	32.00
1330	0.088	-2.43	1	9	36.00
1317	0.100	-2.30	1	10	40.00
1314	0.110	-2.21	1	11	44.00
1326	0.150	-1.90	1	12	48.00
1334	0.229	-1.47	1	13	52.00
1333	0.240	-1.43	1	14	56.00
1322	0.258	-1.35	1	15	60.00
1311	0.262	-1.34	1	16	64.00
1325	0.346	-1.06	1	17	68.00
1320	0.400	-0.92	1	18	72.00
1316	0.470	-0.76	1	19	76.00
1332	1.180	0.17	1	20	80.00
1315	1.610	0.48	1	21	84.00
1312	1.830	0.60	1	22	88.00
1313	2.830	1.04	1	23	92.00
1336	9.780	2.28	1	24	96.00

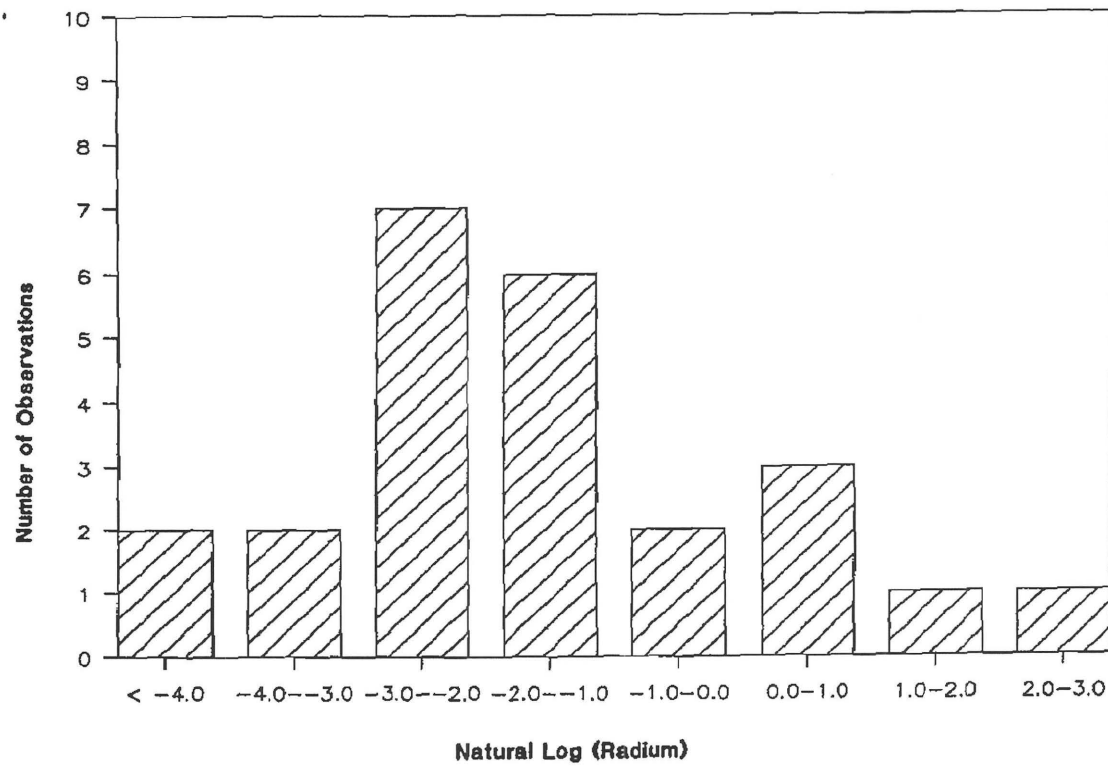


FIGURE 6.7

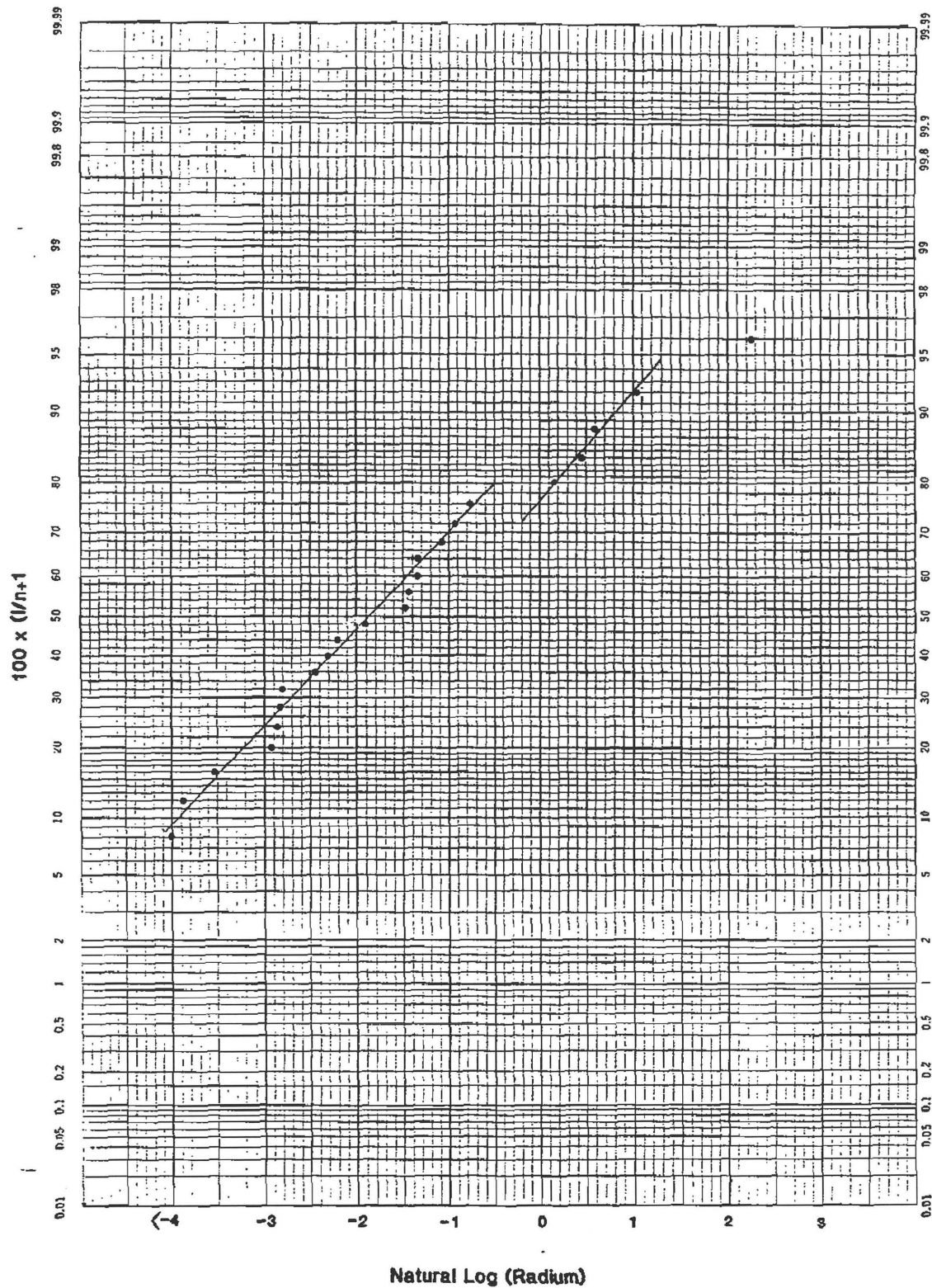
HISTOGRAM OF RADIUM CONCENTRATIONS
IN GROUND WATER



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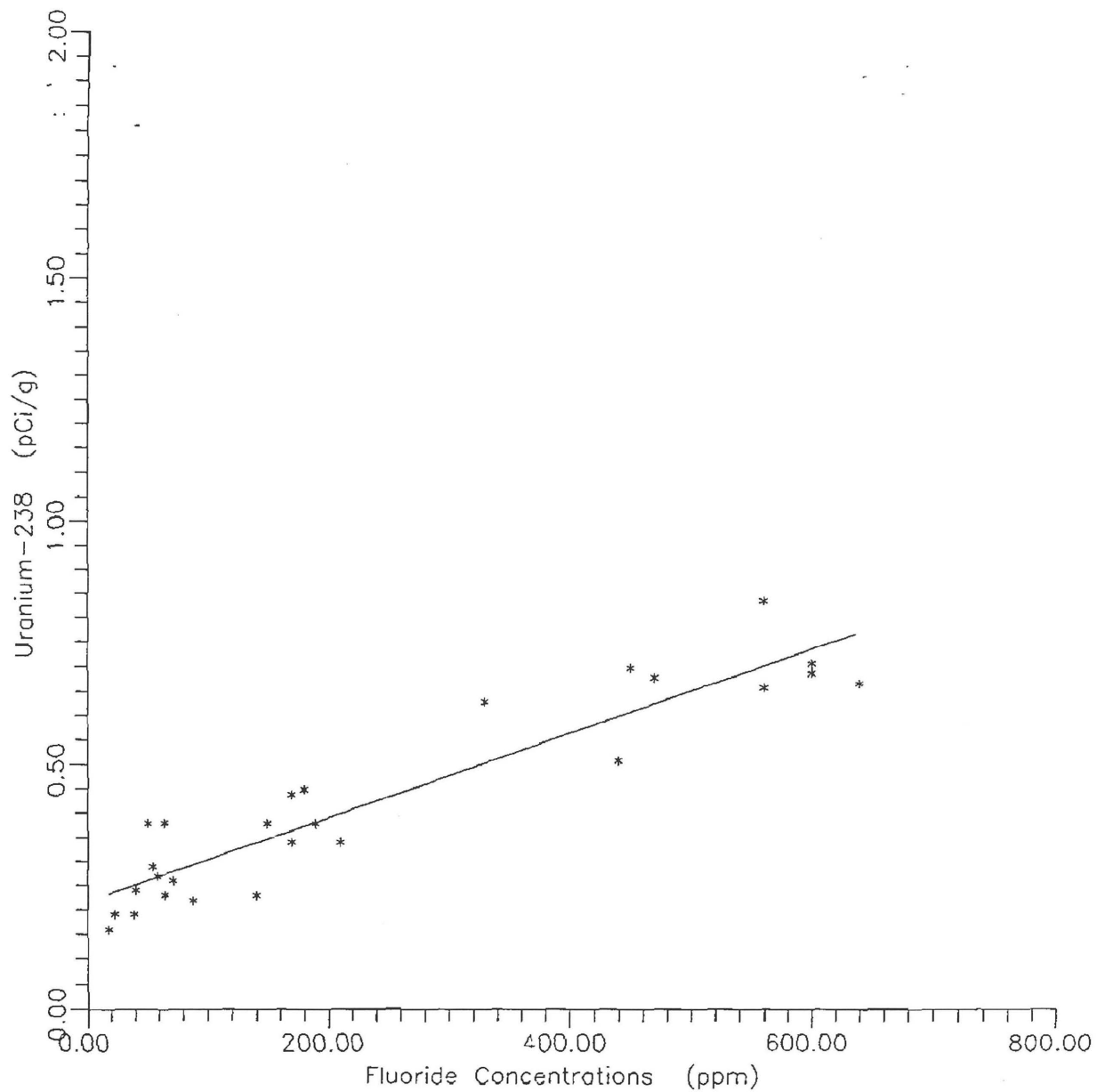
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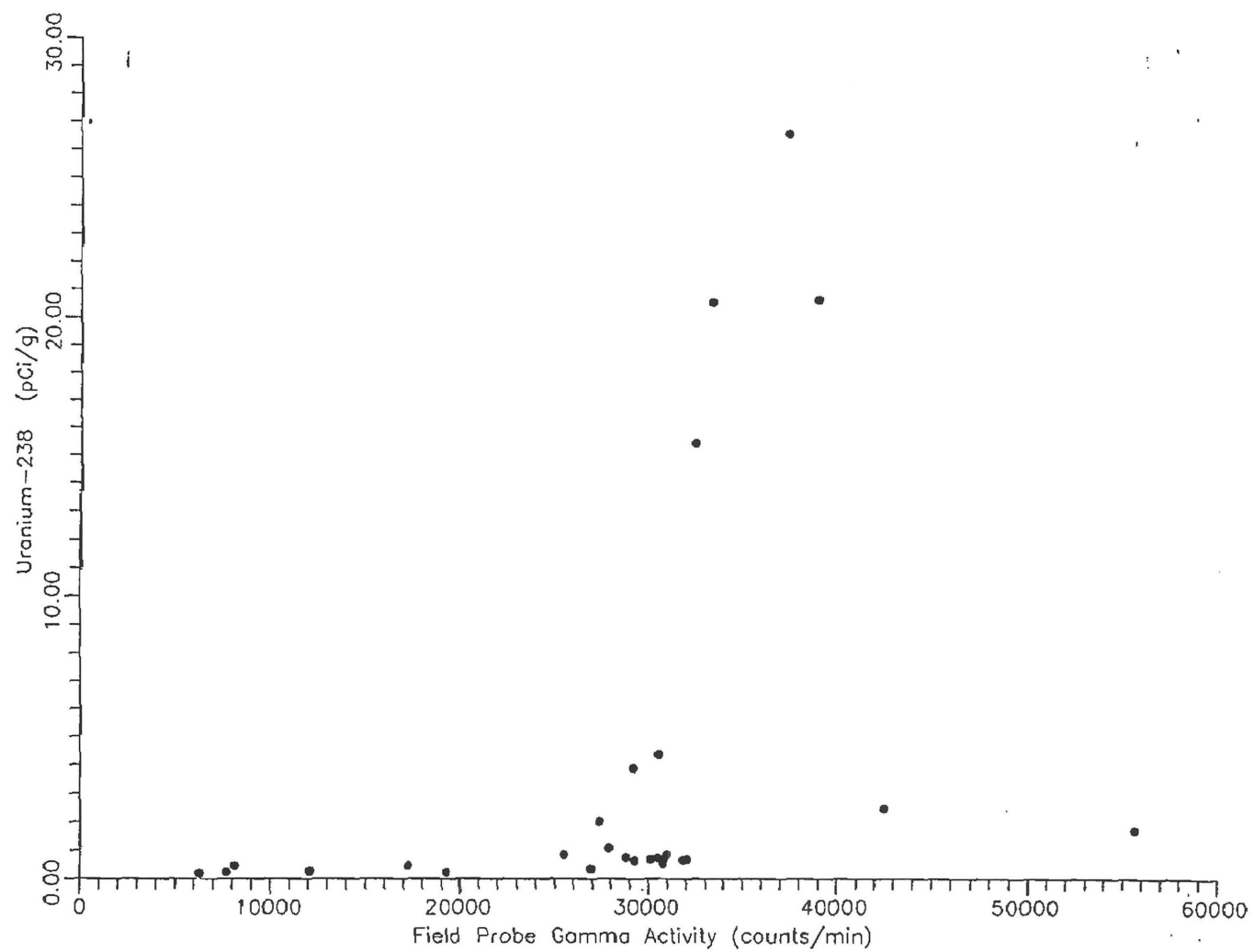
FIGURE 6.8

**LOG-TRANSFORMED PROBABILITY PLOT
 OF RADIUM IN GROUND WATER**



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FIGURE 6.9
FLUORIDE VERSUS U-238
IN SOIL AND ROCK



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FIGURE 6.10
FIELD PROBE GAMMA ACTIVITY
VERSUS U-238

7. MOBILITY AND MATRIX RETENTION OF RADIONUCLIDES

This section describes the solubility and mobility of radionuclides in the subsurface at the Cimarron site. The discussion presents estimates of natural rainfall infiltration and percolation through the proposed landfill. Elemental partition coefficients are used to describe the solubility of the radionuclides in the undisturbed soil and in the proposed landfill. The percolation estimates are used to assess the rate and quantity of radionuclides that might leach from the soils.

The potential impacts of these radionuclides on ground-water and surface-water quality are discussed. The calculations in this section demonstrate that the materials which will remain at the site after decommissioning will not represent a real or potential threat to ground-water or surface-water use in the surrounding area.

7.1 Infiltration

7.1.1 Methods of Analysis.

The HELP model (Schroeder et.al., 1984; Schroeder, 1988) was used to develop estimates of potential infiltration through a natural soil profile and through the cover of the proposed landfill. The HELP model is a water balance model developed by the U.S. EPA to calculate infiltration and percolation into and through solid waste disposal facilities. The program is a quasi-two-dimensional, deterministic model adapted from an earlier EPA model, HSSWDS, and the U.S. Department of Agriculture CREAMS model.

The HELP model uses the Soil Conservation Service runoff curve number method to calculate storm-water runoff. Evapotranspiration is calculated using a modified Penman method. Percolation is calculated using a modification of Darcy's law. The program provides default and synthetically-derived climatic data, and default soil properties. Default or site-specific properties can be used in the analysis.

The program allows layered profiles comprising vertical percolation layers, lateral drainage layers, and hydraulic barriers. The program uses daily climatic data to calculate daily, monthly, and annual water budgets at critical points in the soil profile. The simulations performed are included in Appendix I.

7.1.1.1 Data.

The HELP model requires climatic data, soil properties, and the soil profile to be specified for each water budget simulation. Synthetically-generated 20-year records were used for Cimarron analyses. The records were generated using climatic data for Oklahoma City contained within the HELP model. Soil properties were developed from laboratory measurements of density, porosity, saturated hydraulic conductivity, and matric potential described in Section 2 of this report. Values appropriate for site soils were tabulated and matched with similar default values provided within the HELP database. The soil properties used in the analyses are summarized in Table 7.1. Hydraulic conductivity and porosity values are shown for "loose" and "dense" soil conditions. Surficial soil layers were assumed to be loose, and compacted layers were assumed to be dense.

Soil texture descriptions were used to estimate soil hydraulic classifications and to determine curve numbers for the surficial soils. An hydraulic group C was determined appropriate for the surficial site soils. Assuming a "fair" grass cover, a curve number of 65 for antecedent moisture condition II was obtained from standard references. This curve number was used for all soil analyses. The curve number is at the lower range of appropriate values for the site soils and is therefore conservative. Larger curve numbers would increase surface runoff and decrease infiltration estimates, although this effect would be relatively small within the range of realistic curve numbers.

7.1.1.2 Calculations.

Calculations were made for a range of profiles described in Table 7.2. These profiles consist of differing arrangements of the two basic soil types identified in the laboratory testing program on site generated samples. The different arrangements were analyzed to determine the sensitivity of the percolation estimates to variations in the soil profile. The results of the calculations are summarized in Table 7.3. Table 7.4 presents average monthly water balances for the cases analyzed.

Estimates of natural percolation range from 5.3 inches per year for the more-permeable surface soil to 3.8 inches per year for the less-permeable soil. These differences reflect the differences in water-holding capacity of the two soils. These numbers are comparable to the infiltration estimates that range up to 3.5 inches per year presented by Bingham and Moore (1975).

Estimates of percolation through the landfill cover ranged from 0.14 inches to 4.9 inches per year. The percolation estimates for cases LF1, LF3, and LF4 are nearly equal to the saturated hydraulic conductivity of the barrier layer, indicating that percolation is limited by the capacity of the barrier to transmit water in these cases. The percolation estimate for case LF2 is significantly less than the saturated hydraulic conductivity of the barrier, indicating that percolation through this cover is limited by evapotranspiration demands in the vegetative layer. The latter value essentially is equal to the estimates of percolation through the natural profile.

The sensitivity analyses can be summarized by noting that for barrier layer hydraulic conductivities larger than about 5×10^{-7} cm/sec, percolation will be limited by evapotranspiration at a constant value of about 5 inches per year. For smaller barrier layer hydraulic conductivities, percolation will be limited by the barrier layer, and will be essentially equal to the hydraulic conductivity of the barrier layer.

7.2 Leachability

The radionuclide analyses and distribution coefficient (Kd) analyses indicate that uranium has limited solubility and mobility in the ground water beneath the Cimarron facility. The Kd analyses show equilibrium concentrations of uranium of about 10 pCi/l or less. Kd values obtained from the tests are high. The measured Kd values range from about 300 to 3000 ml/g.

Concentrations of dissolved uranium in the test solutions after soil contact were less than 10 pCi/l. These concentrations are typical of uranium concentrations in the site monitoring wells, where corresponding uranium concentrations on the soil are smaller than those in the laboratory tests. The larger distribution coefficients in the laboratory tests are believed reflective of the influence of solubility upon the calculated value of Kd. In other words, a larger source of uranium does not create higher concentrations of uranium in solution, but, because of the insolubility of the uranium, results in a larger apparent Kd. As described in Section 3.2.8.5, the amount of uranium used in the Kd laboratory tests was equivalent to 3 pCi/g and 17 pCi/g of soil for the two test conditions.

The uranium concentrations in the test fluids are consistent with the concentrations of uranium measured in the natural site ground water. Samples of ground water from twenty-four wells were tested to determine the concentration of U-238. Eighteen of the samples had concentrations less than 10 pCi/l. The six wells where U-238 concentrations were higher are located near the wastewater ponds and the former burial area, facility components

where the natural chemistry of the ground water has been altered due to seepage. Samples from wells down-gradient from these facilities show that the U-238 concentrations decrease to background levels away from these facilities where natural background conditions are again prevalent.

Soils which will be buried in the proposed landfill will contain soluble and insoluble uranium compounds in concentrations less than those prescribed in the NRC Branch Technical Position Option 2. The Option 2 concentration limit for soluble uranium is 100 pCi/g. Materials with soluble concentrations between 30 and 100 pCi/g will be placed in the landfill. Some materials placed in the landfill may have concentrations of soluble uranium less than 30 pCi/g. This point is important since the concentrations of uranium in the landfill soils is of the same order of magnitude as the concentration used in the laboratory Kd tests.

The materials to be placed in the proposed landfill are soils identical to the soils encountered during the site investigation. Leaching of these materials will not alter the chemistry of the leachate appreciably. Leachate chemistry will therefore reflect the chemistry of the unaltered ground water beneath the site. Under these conditions, leaching of the uranium from the landfill will be controlled by equilibrium established between the leachate and the soil matrix. The concentration of uranium in the leachate will be related to the concentration of uranium on the soil by the relation (Isherwood, 1981)

$$C_w = C_s \cdot n / (\rho \cdot K_d)$$

Where

C_w is the concentration of uranium
in the leachate (pCi/ml)
 C_s is the concentration of uranium
on the soil (pCi/g)
 n is the porosity of the soil in the landfill
 ρ is the bulk density of the soil
in the landfill, and
 K_d is the equilibrium distribution coefficient
of uranium in the soil/leachate system.

For typical values of porosity and bulk density of the soil in the landfill of about 0.4 and 1.6 respectively, the concentration of uranium in the leachate will range from about 0.00008 to 0.00083 times the concentration of uranium in the soil. In units of pCi/l, the concentration of uranium in the leachate will range from about 0.08 to 0.83 times the concentration of uranium in the soil in units of pCi/g.

7.3 Potential for Migration

The mobility of dissolved uranium in the ground water is limited by solubility constraints and the affinity of uranium for site soils. The results of the Kd tests indicate that distribution coefficients of uranium in the natural ground-water system at the Cimarron facility range between 300 and 3000 ml/g. Estimates of Kd values from site well data indicate that the Kd of uranium may be on the order of 10 to 200 ml/g at low uranium concentrations. Even these smaller values are representative of immobile materials. With a Kd of ten, dissolved uranium will move about 40 times slower than water in the ground-water system. With a Kd of 200, the uranium will move about 800 times slower than ground water.

Site water-quality data reflect the immobility of uranium in the subsurface. Figure 7.1 is a plot of U-238 concentrations in water from wells near the former burial ground. Wastes were buried in this facility and later exhumed and disposed off-site. The concentration of uranium in well 1315, located within the burial ground, and well 1316, located near well 1315, increase during the year 1986. This temporary increase may be related to abnormally high rainfall during 1985. The peak concentration of uranium in well 1315 is about 2300 pCi/l, and the peak concentration in well 1316 is about 530 pCi/l. An increase in concentration is observed in well 1317 in 1988, two years after the increase in the wells nearer the former burial ground. The peak concentration in well 1317 is 42 pCi/l, or about 12 times less than well 1316.

The changes in U-238 concentrations with distance from the former burial ground are illustrated in Figure 7.2. Up-gradient well 1314 shows background U-238 concentrations of about one to two pCi/l. Concentrations are increased to as much as about 2300 pCi/l across the former burial area, and decrease rapidly with distance down-gradient of the area. Migration around this area reflects the influence of the leachate chemistry upon uranium Kd's. Within the former burial area, Kd's probably are much smaller than in the natural system. The Kd's increase with distance from the facility as the ground-water chemistry approaches that of the native ground water.

Migration from the proposed landfill will be much less pronounced than from the former burial ground because the landfill will not influence ground-water chemistry, and because only soils with low levels of uranium will be buried in the landfill. Leaching of the uranium will be limited by solubility and by sorptive processes in the landfill. Migration of uranium that does leach will be limited by the sorption of the material in the subsurface.

7.4 Computer Simulation of Leaching and Migration

Leaching and subsurface migration of uranium from the Option 2 limit soils disposed at the proposed landfill was simulated using the TRANSS model (Simmons et.al., 1986). The TRANSS model is a one-dimensional, convective, dispersive transport program based on Van Genuchten analytical solutions, modified to include the simultaneous decay of the source and released radionuclides. The program can model concentration or solubility limited releases, adsorption (K_d) limited releases, or diffusion beneath a barrier to the water table.

Simulations of distribution coefficient-limited releases were performed to predict uranium migration through the unsaturated zone to the water table, and through the saturated zone to the Cimarron River alluvium.

7.4.1 K_d limited release simulation - Vadose zone.

Two simulations of uranium leaching and migration to the water table directly below the proposed landfill were performed using K_d values representative of the range of aquifer matrix materials. K_d values of 2000 ml/g and 300 ml/g were used. K_d is entered into the model through the retardation factor, R , which is related to K_d by the relation:

$$R = 1 + \rho / (\theta * K_d)$$

where ρ = dry bulk density of material (1.6 g/cc)
 θ = moisture content (0.3)
 K_d = distribution coefficient

The source term used in the simulations is calculated to be 1.81 Curies, based upon a total of 14,800 cubic yards soil disposed at the Option 2 Limit of 100 pCi/g soluble uranium. The leachate velocity through the unsaturated zone is low, and dispersion will be negligible. Leachate velocity is calculated from the infiltration rate and soil field capacity calculated for the HELP model described in Section 7.1. The parameters used in the simulations are listed in Table 7.5, and the output generated is included in Appendix J.

Both simulations show that very little uranium will leach and enter the water table. For a distribution coefficient of 2000 ml/g, a maximum leachate concentration of about 10 pCi/l is estimated to arrive at the water table in approximately 170,000 years. Figure 7.3 shows leachate concentration with time at the water table directly under the landfill for $K_d=2000$ ml/g simulation.

A distribution coefficient of 300 ml/g results in a maximum leachate concentration of about 67 pCi/l arriving at the water table in approximately 27,000 years. Figure 7.4 shows leachate concentration with time for the $K_d=300$ simulation.

7.4.2 K_d limited release simulation - Saturated zone.

Two simulations of leaching and migration of uranium from the landfill to the Cimarron River alluvium were performed using K_d values of 2000 and 300 ml/g. The pathline selected for the simulation is indicated on Figure 7.5. A length of 1000 feet, width of 360 feet, and thickness of 10 feet was estimated for the flowtube. Transport was modeled in the first saturated sandstone, which is approximately 10 feet thick, for a flowtube cross-sectional area of 3600 square feet. The same initial source concentration of uranium was modeled. The input parameters are listed in Table 7.5. The simulation output is included in Appendix J.

With a K_d of 2000 ml/g, a maximum leachate concentration of about 4 pCi/l is seen at the end of the flowtube in approximately 237,000 years. Figure 7.6 shows leachate concentration with time for the $K_d=2000$ ml/g simulation.

A K_d of 300 ml/g produces a maximum leachate concentration of about 27 pCi/l at the end of the flowtube in approximately 36,000 years. Figure 7.7 shows leachate concentration with time for this simulation.

7.4.3 Discussion of Results.

The results of the TRANSS model simulations support interpretations that leaching and migration of uranium in the subsurface of the Cimarron facility will be limited. The simulations show that the combined effects of precipitation, adsorption and dilution of uranyl complexes will prevent significant migration of uranium from the proposed landfill site.

7.5 Migration of Uranium Left In-Situ

The TRANSS model simulations also indicate that migration of radionuclides from soils left in place at the facility will be negligible. The simulations of leaching through the proposed landfill represent a case where soils containing the maximum permissible concentration of soluble uranium under the NRC Branch Technical Position Option 2 criterion are confined in a small area. Since the uranium concentration in soils left in place will be less than those disposed in the proposed landfill and are

present over a greater area, the concentration of uranium in ground water that leached from the in-situ soils will be considerably less than that predicted for the landfill.

Subsurface conditions are essentially identical to those under the landfill and Kd values up to 2000 ml/g are expected. The concentration of uranium in ground water resulting from leaching of soils left in place is not anticipated to exceed the estimated equilibrium concentration of 10 pCi/l described in Section 3.2.8.5.

TABLE 7.1

Assumed Soil Properties
for HELP model simulations

	Sand	Clay
Porosity (loose)	0.42	0.42
(dense)	0.33	0.33
Field Capacity	0.24	0.29
Wilting Point	0.104	0.187
K (cm/sec) (loose)	1×10^{-4}	5×10^{-5}
(dense)	1×10^{-6}	1×10^{-7}

TABLE 7.2

Cover Profiles Analyzed
for HELP model simulations

Profile	Upper Layer		Barrier Layer	
	Material	Thickness (inches)	Material	Thickness (inches)
LF1	Sa	24	Cl	12
LF2	Sa	24	Sa	12
LF3	Cl	24	Cl	12
LF4	Sa	24	Cl*	12
NA1	Sa	36	--**	12
NA2	Cl	36	--**	12

Notes: Soil types correspond to those in Table 7.1

* Hydraulic conductivity = 1×10^{-8} cm/sec.

** Hydraulic conductivity = 1×10^{-6} cm/sec.

TABLE 7.3

Summary of Percolation Calculations
for HELP model simulations

CASE	AVERAGE PERCOLATION (inches/yr)	STD.DEV.	SOIL PROFILE
LF1	1.32	0.55	Sa/Cl
LF2	4.87	2.62	Sa/Sa
LF3	1.24	0.51	Cl/Cl
LF4	0.14	0.06	Sa/Cl*
NA1	5.27	2.92	Sa**
NA2	3.77	2.17	Cl**

* Hydraulic conductivity of Clay = 1×10^{-8} cm/sec.

** Hydraulic conductivity of underlying soil = 1×10^{-6} cm/sec.

TABLE 7.4

Average Monthly Water Balances
for HELP model simulations
(inches)

	LF1					
	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87	1.25	2.09	3.04	4.85	3.03
	2.88	2.27	4.40	3.27	1.77	1.13
RUNOFF	0.011	0.012	0.045	0.357	0.883	0.039
	0.010	0.000	0.013	0.120	0.159	0.039
EVAPOTRANSPIRATION	0.790	0.882	1.456	1.789	3.284	6.254
	4.491	2.456	2.689	1.727	1.044	0.857
PERCOLATION	0.1267	0.1199	0.1494	0.1771	0.2237	0.1723
	0.0440	0.0000	0.0049	0.0652	0.1075	0.1332
LF2						
	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87	1.25	2.09	3.04	4.85	3.03
	2.88	2.27	4.40	3.27	1.77	1.13
RUNOFF	0.000	0.000	0.000	0.051	0.234	0.000
	0.010	0.000	0.012	0.121	0.057	0.000
EVAPOTRANSPIRATION	0.781	0.885	1.459	1.803	3.306	5.454
	3.007	2.449	2.691	1.745	1.037	0.858
PERCOLATION	0.2337	0.2089	0.3218	0.6076	1.0633	0.5912
	0.0348	0.0000	0.0447	0.5105	0.6927	0.5559
LF3						
	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87	1.25	2.09	3.04	4.85	3.03
	2.88	2.27	4.40	3.27	1.77	1.13
RUNOFF	0.009	0.000	0.063	0.467	1.109	0.085
	0.124	0.034	0.305	0.407	0.188	0.030
EVAPOTRANSPIRATION	0.836	0.947	1.532	1.900	3.498	5.878
	3.092	2.388	2.741	1.844	1.094	0.925
PERCOLATION	0.1247	0.1184	0.1476	0.1765	0.2169	0.1328
	0.0093	0.0000	0.0050	0.0621	0.1110	0.1387

Average Monthly Water Balances (continued)

LF4

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87 2.88	1.25 2.27	2.09 4.40	3.04 3.27	4.85 1.77	3.03 1.13
RUNOFF	0.032 0.010	0.076 0.000	0.224 0.013	0.543 0.127	1.168 0.176	0.075 0.063
EVAPOTRANSPIRATION	0.789 4.833	0.887 2.458	1.461 2.690	1.788 1.722	3.221 1.043	6.315 0.859
PERCOLATION	0.0137 0.0057	0.0132 0.0000	0.0164 0.0005	0.0189 0.0066	0.0235 0.0111	0.0185 0.0140

NA1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87 2.88	1.25 2.27	2.09 4.40	3.04 3.27	4.85 1.77	3.03 1.13
RUNOFF	0.000 0.010	0.000 0.000	0.000 0.012	0.051 0.121	0.152 0.012	0.000 0.000
EVAPOTRANSPIRATION	0.780 2.914	0.885 2.449	1.459 2.698	1.803 1.741	3.306 1.039	5.253 0.866
PERCOLATION	0.2733 0.2592	0.2087 0.0077	0.3131 0.0369	0.5762 0.4647	1.0641 0.6638	0.7856 0.6193

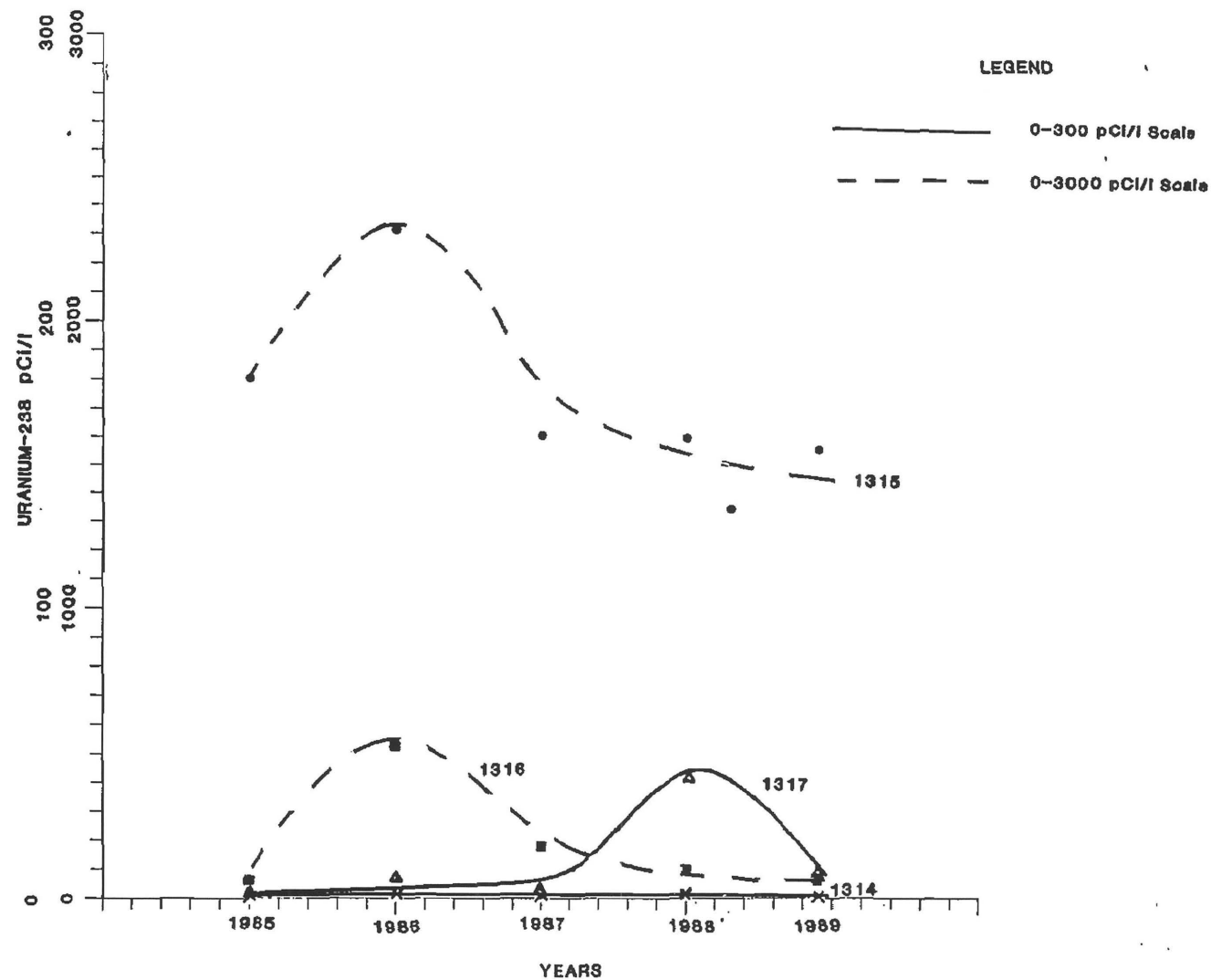
NA2

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.87 2.88	1.25 2.27	2.09 4.40	3.04 3.27	4.85 1.77	3.03 1.13
RUNOFF	0.000 0.125	0.000 0.034	0.014 0.306	0.189 0.397	0.577 0.082	0.035 0.000
EVAPOTRANSPIRATION	0.834 2.697	0.948 2.387	1.540 2.735	1.906 1.834	3.542 1.102	4.823 0.923
PERCOLATION	0.1773 0.0295	0.1476 0.0000	0.2632 0.0339	0.4975 0.3759	0.8370 0.5397	0.4777 0.3885

Note: All values in inches

TABLE 7.5
Hydrologic Parameters used in TRANSS Model

Parameter	Kd Limited	Kd Limited
	Vadose Zone Simulation	Saturated Zone Simulation
Dispersion Coefficient	1.0 sq ft/yr	1.0 sq ft/yr
Retardation Factor: Kd=2000	10600	10600
Kd=300	1600	1600
Radionuclide Inventory	1.81 Ci	1.81 Ci
Pathline Length	20 ft	1000 ft
Travel Time in Unsat. Zone	14.5 years	14.5 years
Effective Porosity	0.30	0.30
Flowtube Area	80,000 sq ft	3,600 sq ft
Depth of Source Distribution	10 ft	10 ft
Infiltration Flux	0.3 ft/yr	0.3 ft/yr



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FIGURE 7.1

ANNUAL URANIUM CONCENTRATIONS: 1985-1989
AT THE FORMER BURIAL LOCATION

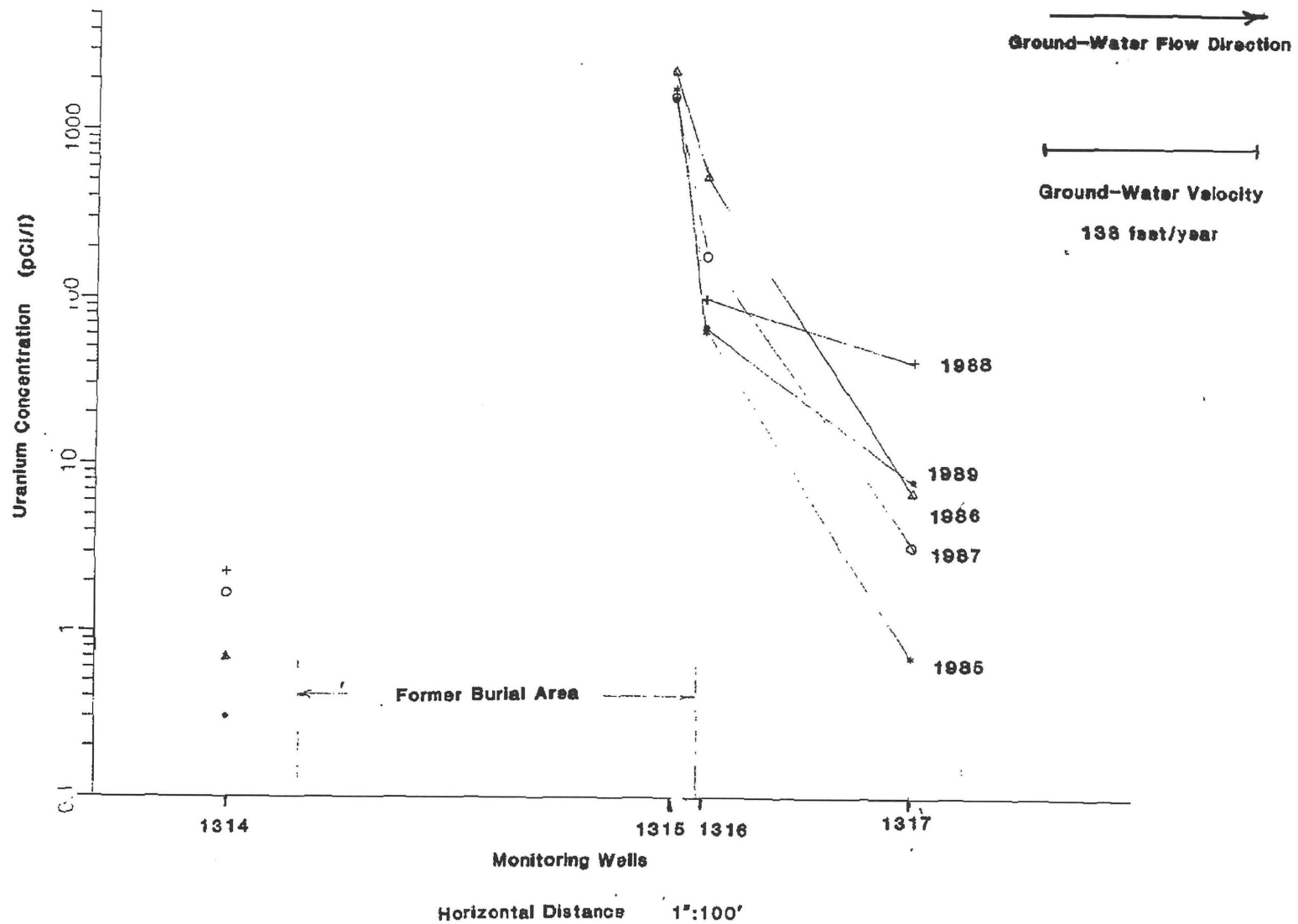
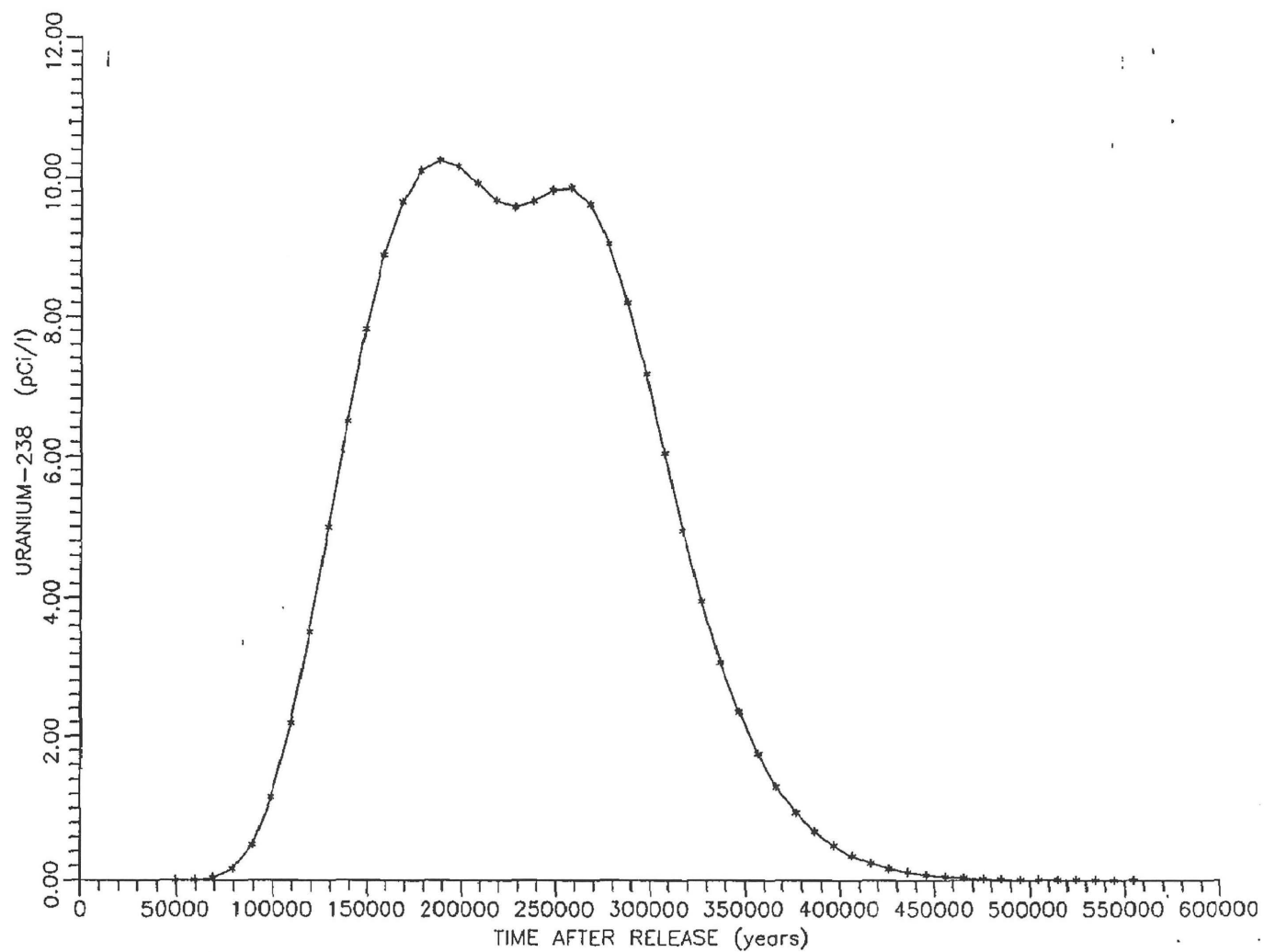


FIGURE 7.2

URANIUM CONCENTRATIONS IN GROUND WATER
AT THE FORMER BURIAL LOCATION



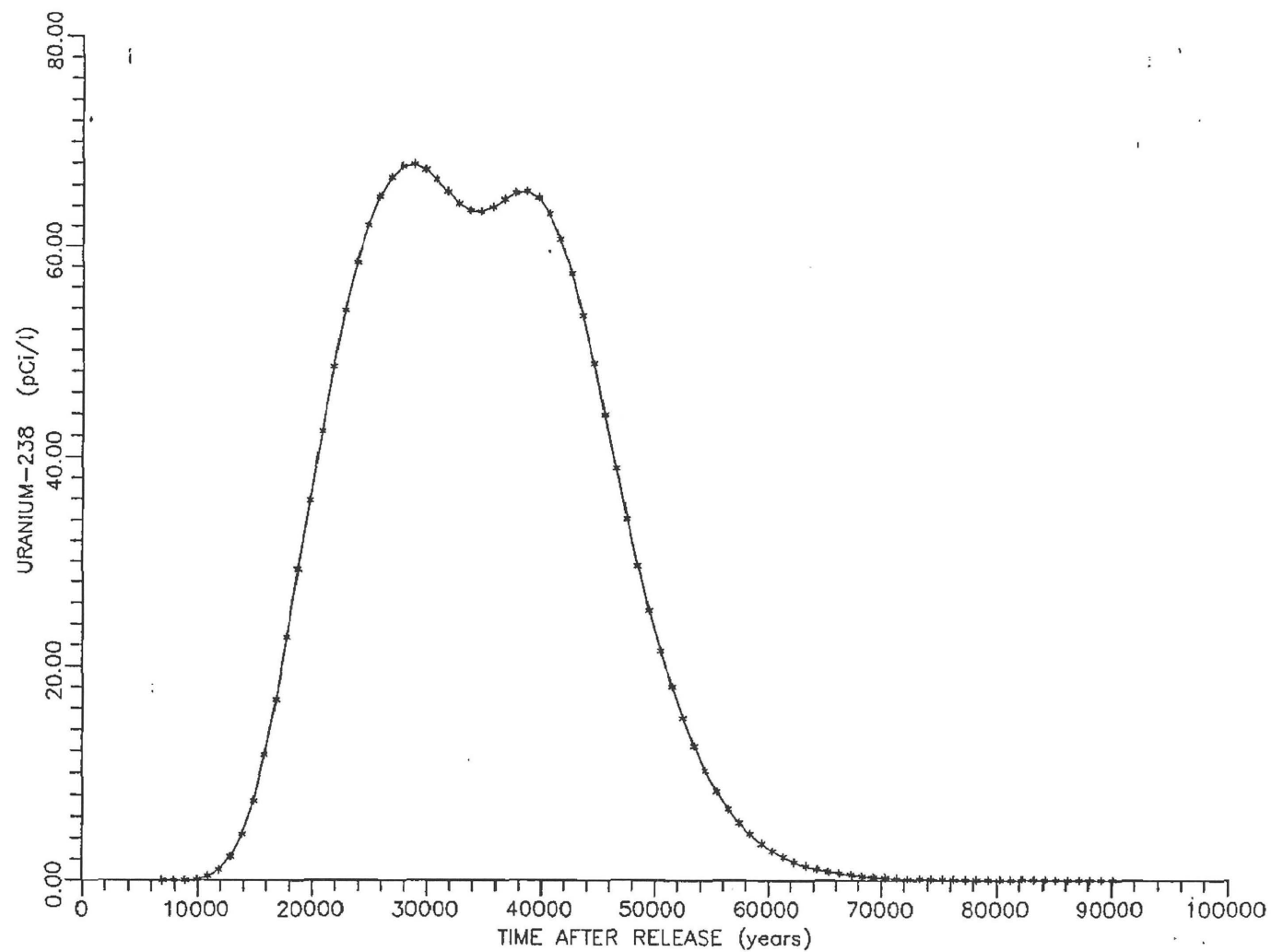
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FIGURE 7.3

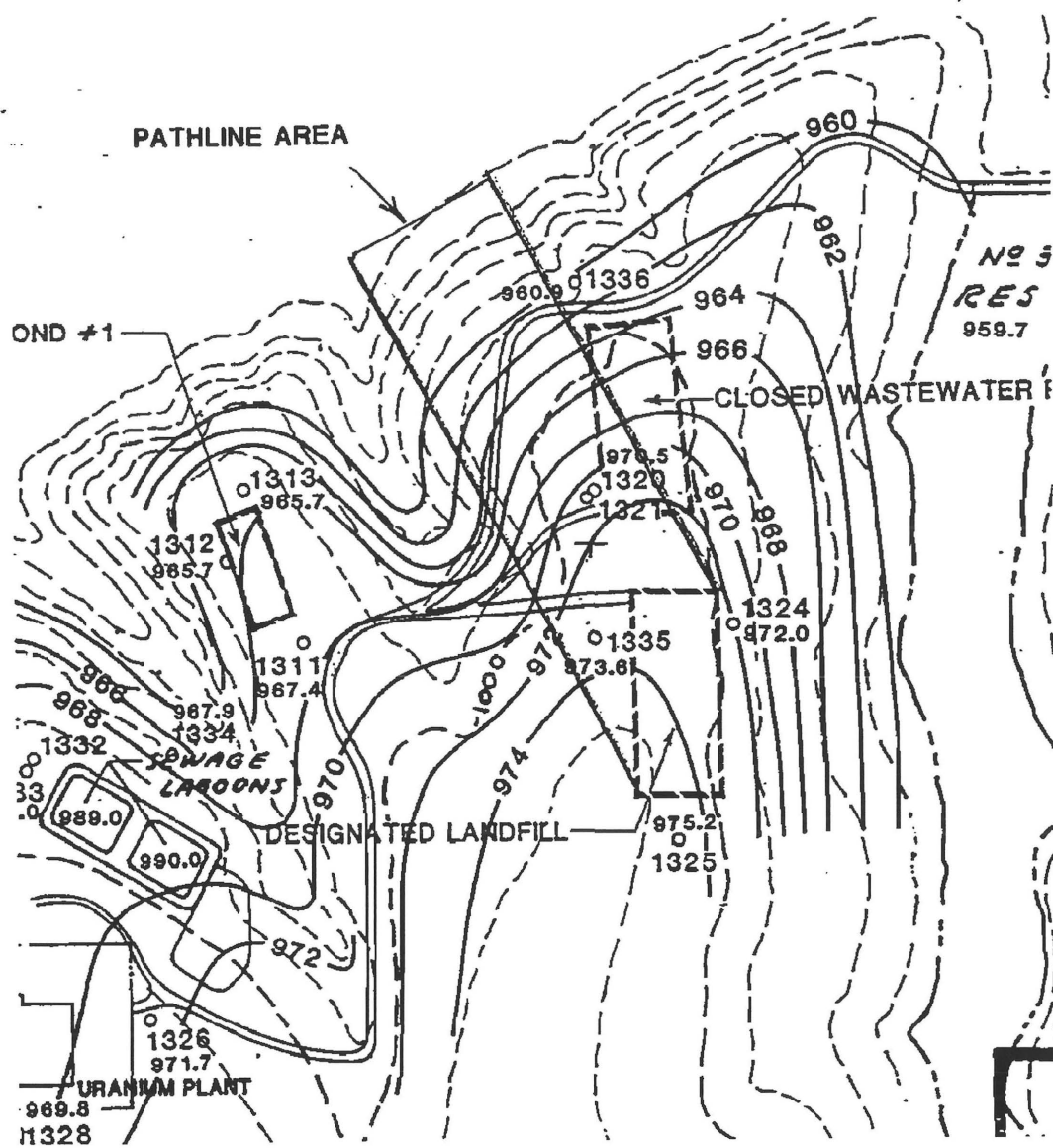
LEACHATE CONCENTRATION WITH TIME
VADOSE ZONE: $K_d=2000$



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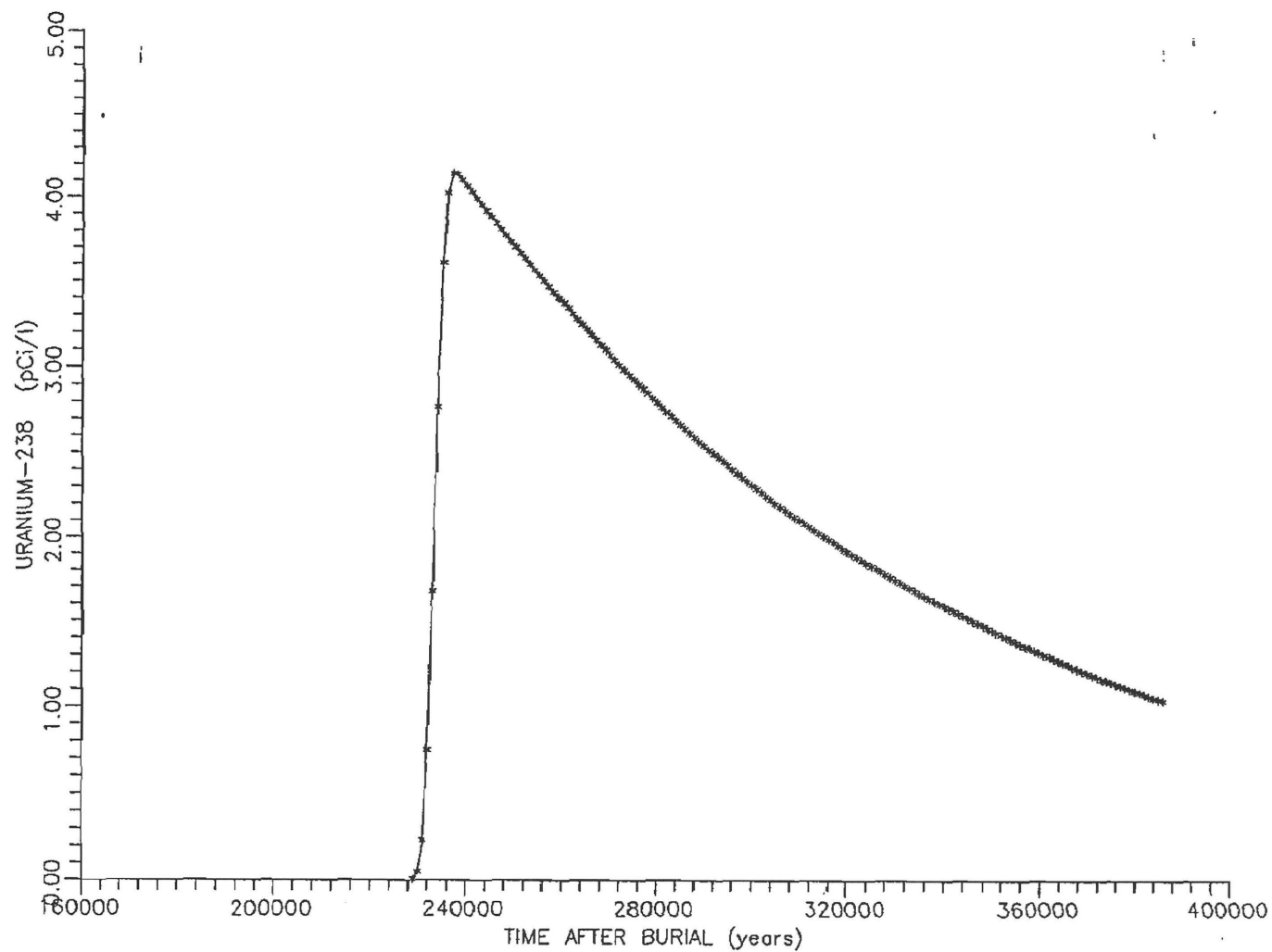
FIGURE 7.4

LEACHATE CONCENTRATION WITH TIME
VADOSE ZONE: $K_d = 300$



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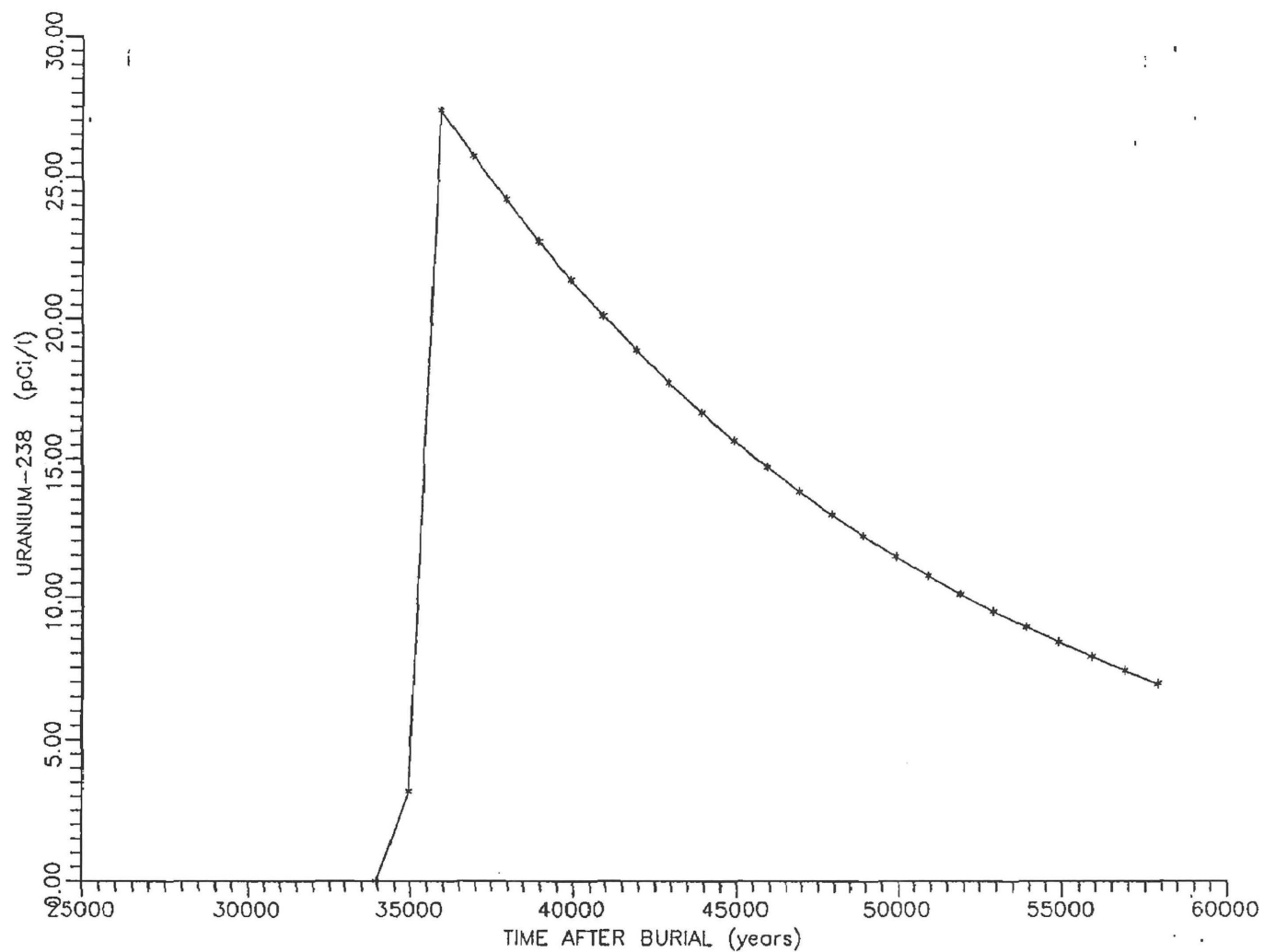
FIGURE 7.5
PATHLINE
FOR SATURATED ZONE SIMULATIONS



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FIGURE 7.6

LEACHATE CONCENTRATION WITH TIME
SATURATED ZONE: $K_d = 2000$



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FIGURE 7.7

LEACHATE CONCENTRATION WITH TIME
SATURATED ZONE: $K_d = 300$

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APPENDIX A
WORK PLAN FOR SITE INVESTIGATION PROGRAM

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WORK PLAN
FOR
SITE INVESTIGATION PROGRAM
CIMARRON CORPORATION FACILITY
LOGAN COUNTY, OKLAHOMA

Submitted to
Kerr-McGee Corporation
and
Cimarron Corporation
Oklahoma City, Oklahoma

Prepared By
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Denver, Colorado
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WORK PLAN
FOR
SITE INVESTIGATION PROGRAM

Cimarron Facility
Logan County, Oklahoma

1. INTRODUCTION

1.1 Project Information

1.1.1 Facility Information.

Cimarron Corporation (Cimarron), a wholly-owned subsidiary of Kerr-McGee Corporation (Kerr-McGee), operates the Cimarron Facility in Logan County, Oklahoma. The principal operation at the plant involved the fabrication of fuel elements from plutonium and enriched uranium. Cimarron is decommissioning the facilities. Certain materials associated with the decommissioning activities will be left on-site, either in a designated area or in-situ, in accordance with the Nuclear Regulatory Commission's (NRC) Branch Technical Position (46 Federal Register 52061, October 23, 1981). The soils contain uranium and thorium that meet the Branch Technical Position Options 1 and 2 concentration limits and conditions for disposal.

1.1.2 Investigations.

Cimarron has been conducting an extensive and continuous environmental monitoring program at the facility to determine the impacts of facility activities on the environment. This program consists of routinely collecting and analyzing air, surface water, ground water, soil and vegetation samples from the site and adjacent areas.

A number of monitoring wells have been installed throughout the facility area for collection of ground water samples from the unconfined aquifer which occurs at depths less than 50 feet below ground surface. Significant areas of radiological contamination of the ground water are not present; however, elevated levels of uranium and gross alpha and beta have been detected in soils near the uranium plant yard. Elevated concentrations of nitrate (NO₃) and fluoride (F) have been detected in ground water near the closed wastewater disposal ponds. Figure 1.1 shows the location of these facility components.

Cimarron has conducted a detailed soil sampling program to quantify the extent and concentration of uranium in the shallow subsurface. The survey consisted of lowering a calibrated sodium iodide (NaI) probe into borings and measuring gamma radiation at one-foot intervals. The quantities of soils meeting the Option 1 and 2 disposal criteria have been estimated from the survey. A large quantity of soil has been identified as containing levels of uranium that pose no threat to human health and will be left in place.

1.2 Site Hydrogeology

1.2.1 Geology.

The Cimarron Facility is located in the Central Lowlands region of the Great Plains physiographic province. Bedrock in the region are Permian-aged clastic formations, which dip gently to the west-southwest at about 30 feet per mile into the Anadarko Basin. The formations of principal interest are the Hennessey Shale and the Garber Sandstone. Overlying the Hennessey is an unconformity upon which Quaternary terrace deposits and alluvium have been deposited in the vicinity of the Cimarron River.

The Garber group is mostly composed of orange to red brown fine-grained sandstones, interbedded with siltstones, shales and local chert and mudstone conglomerate. The Pleistocene terrace deposits are lenticular sands, silts, clays and gravels and represent glacial outwash. They lie predominantly north of the Cimarron River. Recent alluvium is restricted to the Cimarron River flood plain, with minor development in the intermittent drainages.

Ground water at the facility occurs in a shallow, unconfined aquifer and in a deeper, confined aquifer within the Garber Sandstone. The unconfined aquifer water table occurs at depths ranging from 15 to 40 feet below land surface. Ground water in the unconfined aquifer at the site is estimated to flow to the north-northwest under a gradient of 90 to 120 feet per mile, and contribute to the base flow of the Cimarron River. Local flow direction is influenced by topography. The hydraulic conductivity has been measured and ranges from 1×10^{-4} to 6×10^{-4} centimeters per second.

The deeper, confined aquifer in the Garber sandstone is found at depths greater than 100 feet below ground surface. The piezometric surface is substantially below the water table found in the unconfined aquifer. A fresh water/salt water transition is found in the confined aquifer at a depth of approximately 200'. Flow direction in the confined aquifer is likely to be more

influenced by regional dip than the unconfined aquifer. It is anticipated that the flow direction will be toward the west. Hydraulic conductivities of the deeper Garber aquifer in the region have been estimated at 9×10^{-4} to 2×10^{-3} centimeters per second.

1.3 Proposed Work Plan

1.3.1 Proposed Scope of Work.

To more fully understand and determine the impact of facility activities on the environment, additional data will be collected to characterize the hydrogeologic regime and complement the on-going environmental monitoring program conducted by Cimarron. Data also will be collected to determine the geotechnical properties of site soils, particularly in the vicinity of the planned NRC Branch Technical Position Option 2 landfill.

This work plan describes the procedures which will be used to:

- o obtain lithologic and hydrologic data for the soils and the Garber Sandstone aquifers,
- o install ground-water monitoring wells in the Garber aquifers,
- o determine ground-water flow direction, gradient and other hydraulic properties of the aquifers,
- o sample and analyze site soils for engineering behavior, mineralogy, uranium, plutonium, NO₃ and F,
- o sample and analyze ground water from the aquifers for uranium, plutonium, gross alpha and beta activity, NO₃ and F, and
- o prepare a report summarizing these data.

1.3.2 Areas of Investigation.

The areas at the Cimarron Facility to be investigated include the uranium plant yard, the closed wastewater disposal ponds, the sanitary lagoons, and the NRC Branch Technical Position Option 2 landfill site. The possibility of off-site sources of NO₃- will be investigated by sampling ground water from background wells. The facility components to be investigated are identified on Figure 1.1.

1.3.3 Investigation Team.

The team which will perform the investigation and analyses described in this program will consist of personnel from James L. Grant and Associates (JLGA), Cimarron Corporation and Kerr-McGee. The investigation team will be competent in the disciplines and skills required to complete their respective project assignments. Training will be required only in the program-specific aspects of the investigation.

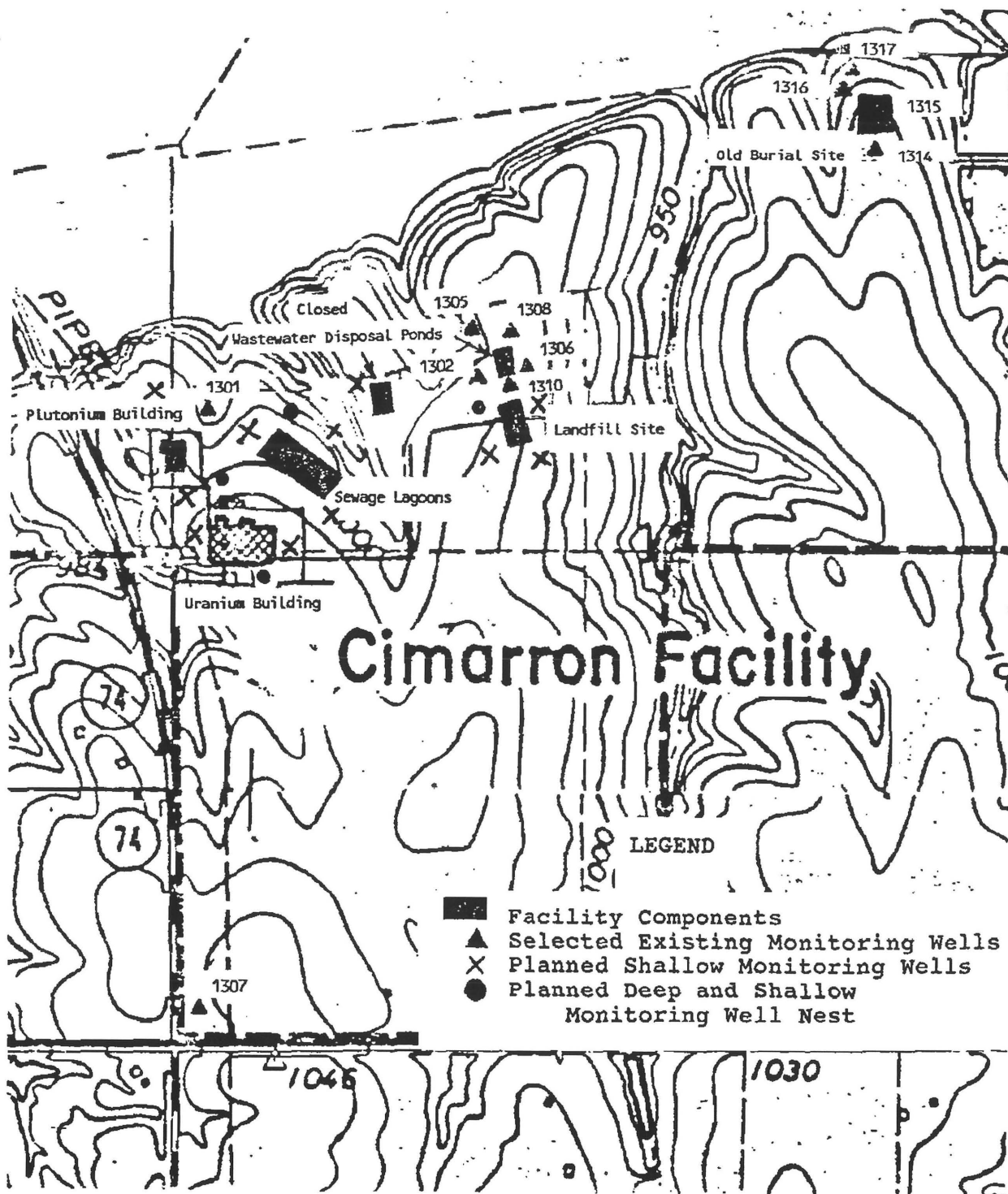
The field data acquisition team, including professional and support personnel, will be trained in the specific project activities to which they are assigned. Professional personnel will be trained in program-specific activities required for drilling and well installation, soil and ground-water sampling. Drilling support personnel will be trained in program-specific requirements for equipment operation and drilling, soil sampling, and well installation. All on-site personnel will have completed safety training required for their specific work assignments.

The personnel performing the laboratory analyses will be trained for the program-specific aspects of the analyses to be performed. Proper quality assurance/quality control procedures will be followed to ensure the integrity of results.

1.3.4 Health and Safety.

The investigative activities described in this Work Plan will be conducted under the Cimarron facility Health and Safety Plan. This program includes provisions for training, site access control, personnel monitoring, and other measures necessary or prudent to protect the health and safety of site personnel. It is anticipated that this work will be conducted with modified-level D protective measures. These measures include standard safety equipment such as hard hat, safety glasses, hard toe/shank boots, and coveralls for splash protection.

No individual will be allowed on-site unless he is familiar with the provisions of the Health and Safety Plan. The Cimarron Health and Safety Officer will be responsible for instructing individuals in the requirements and contents of the Health and Safety Plan prior to the commencement of program activities. The Health and Safety Officer also will be responsible for verifying and maintaining records that site personnel have received the proper Health and Safety training.



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FIGURE 1.1
 Facility Components
 and Monitoring Well Locations