NOTICE

All drawings located at the end of the document.

RF/RMRS-96-0053.UN

1995 ANNUAL RCRA GROUNDWATER MONITORING REPORT

FO

ROCKY FLATS I Y SITE

Combo

SW-A-004867

1/193

TABLE OF CONTENTS

2

LIST OF TABLES

Table

3

LIST OF TABLES (CONTINUED)

Table

4

APPENDICES

Appendix A: Appended 1995 Database (on diskette)

Appendix B: Fourth-Quarter Analytical Data

5

Appendix B: Fourth-Quarter Analytical Data (Continued)

Appendix C: Output from Statistical Testing (on diskette)

6

EXECUTIVE SUMMARY

The purpose of the Resource Conservation and Recovery Act (RCRA) groundwater-monitoring program at the Rocky Flats Environmental Technology Site (Rocky Flats) is to assess the impact of waste-management activities on groundwater quality in the upper hydrostratigraphic unit (UHSU) beneath and hydraulically downgradient of the RCRA units. In compliance with Colorado Hazardous Waste Act Regulations 6 CCR 1007-3, Subpart F, sec. 265.94 for interim-status waste-management units, this addendum to the *1995 Annual RCRA Groundwater Monitoring Report* (DOE, 1996) presents final results of the 1995 quarterly sampling and analysis of groundwater from the three regulated, interim-status units (West Spray Field, Solar Evaporation Ponds, Present Sanitary Landfill) at Rocky Flats.

The assessment for the 1995 RCRA Addendum has been conducted by statistically comparing chemical data for upgradient groundwater to data for downgradient groundwater. Methods of statistical comparisons for groundwater data are based on guidance from the U.S. Environmental Protection Agency (EPA, 1989; 1992a) and are discussed Section 1.4.6 of the 1995 Annual RCRA Report. The results of the statistical comparisons made for each RCRA unit are presented and discussed in Sections 2, 3, and 4 of this report.

Revisions to the 1995 Annual Report include addition to and revision of the analytical databases, an update of tables of infrequently detected analytes in downgradient monitoring wells, and an update of results of statistical comparisons of groundwater quality upgradient and downgradient of the RCRA-regulated units. At the time of this addendum, data for 1995 included 12,854 analytical records for the West Spray Field (51.4 percent validated), 8,680 analytical records for the Present Landfill (64.3 percent validated), and 13,823 analytical records for the Solar Evaporation Ponds (46.5 percent validated).

The addition of new fourth-quarter data resulted in a few changes in the outcome of the statistical comparisons; however, the descriptions of groundwater quality and interpretations of contaminant migration at the RCRA units did not change significantly. Tables in this RCRA Addendum indicate which analytes showed a difference from the results presented in the 1995 Annual RCRA Report. Descriptions of the impacts to groundwater were not changed from those presented in the 1995 Annual RCRA Report.

7

1.0 INTRODUCTION

The purpose of the Resource Conservation and Recovery Act (RCRA) groundwater monitoring program at the Rocky Flats Environmental Technology Site (Rocky Flats) is to assess the impact of contaminants released from regulated units to groundwater contained in the uppermost "aquifer" beneath the units. The state standards for groundwater monitoring at RCRA interim-status units require that at least three monitoring wells be installed hydraulically downgradient at the limit of the RCRA-regulated unit [6 CCR 1007-3, 265.91(a)(2)].

This addendum to the *1995 Annual RCRA Groundwater Monitoring Report at Rocky Flats* (DOE, 1996) completes the information required under Colorado Hazardous Waste Act Regulations 6 CCR 1007-3, Subpart F, sec. 265.94, for interim-status waste-management units. Data presented in this addendum include additional results for organic and inorganic analytes in groundwater at the three regulated units (Present Landfill, Solar Evaporation Ponds, and West Spray Field) at Rocky Flats. These fourth-quarter data were not yet available during preparation of the 1995 Annual RCRA Report.

A total of 3,221 records for real data, as well as 375 additional records for quality control (QC) samples, were added to the original database used to produce the 1995 Annual RCRA Report. The appended database includes all data for groundwater samples collected during 1995 at the RCRA-regulated units and is provided on diskette in Appendix A.

Revisions to the 1995 Annual RCRA Report include the amended and revised analytical data files, updated tables of infrequently detected analytes, and updated results of statistical comparisons of groundwater quality at upgradient and downgradient monitoring wells.

8

2.0 GROUNDWATER MONITORING AT THE SOLAR EVAPORATION PONDS

Additional analytical results for fourth-quarter samples were incorporated into the existing database for the Solar Evaporation Ponds. The statistical analyses discussed in Section 1.4.6 of the 1995 Annual RCRA Report (DOE, 1996) were performed again using the updated database. The tables of analytical data for the fourth quarter (Appendix B) supplement the existing maps of the 1995 RCRA Annual Report, and were used to update the discussion of groundwater quality at the Solar Evaporation Ponds. Groundwater from UHSU alluvium and groundwater from UHSU bedrock were evaluated separately for the Solar Ponds unit.

2.1 Infrequently Detected Analytes

Those analytes detected in less than 50 percent of the samples collected from the RCRA unit are designated as infrequently detected analytes. Statistical comparisons were not performed for analytes with less than 50-percent quantifiable results or less than two detects. Most major anions and other water-quality parameters were detected at greater than 50-percent frequency. Several organic compounds had detection rates greater than 50 percent. Analytes for which there were more than two detections and greater than 50-percent detections were statistically tested using the appropriate analysis of variance (ANOVA) test, the results of which are discussed in Section 2.2

2.1.1 UHSU Alluvial Groundwater

During 1995, in UHSU alluvial groundwater, acetone was detected once (9.00 µg/L) in upgradient well 05293, carbon tetrachloride was detected in downgradient wells 3887 (1.00 µg/L) and P207889 (0.20 µg/L) and in upgradient well P209289 (450.0 µg/L), chloroform was detected in upgradient well P209289 (170.0 µg/L) and downgradient wells 3887 (0.50 µg/L) and P207389 (0.20 µg/L), and di-n-butyl phthalate was detected in downgradient wells 05093 and 05193 (3.00 and 2.00 µg/L, respectively) (Tables 2-1 and 2-2).

Dissolved aluminum, antimony, arsenic, beryllium, chromium, cyanide, iron, silver, tin, vanadium, and zinc (Table 2-3), as well as dissolved cesium-134, cesium-137, and total plutonium-238 were each detected at least once throughout the year (Table 2-4). Infrequently detected water-quality parameters included cyanide and alkalinity as $CaCO_3$ (Table 2-5).

The presence of substantially higher concentrations of some volatile organic compounds (VOCs) in groundwater upgradient of the RCRA unit clearly indicates a non-RCRA, upgradient source of contaminants. Well P209289 intersects the plume of VOC contamination, which is migrating into and through the Solar Ponds area; however, upgradient well P209289 was sampled only once (7-31-95) during 1995 and showed carbon tetrachloride (450 µg/L) and chloroform (170 µg/L) contamination (see Table 2-1).

2.1.2 UHSU Bedrock Groundwater

In groundwater from UHSU bedrock, upgradient well P209389 exhibited detections of 1,1,1-trichloroethane (1,1,1-TCA); 1,2-dichloroethane; naphthalene (0.10 µg/L); and methylene chloride (0.20 µg/L) (Table 2-6). Methylene chloride was also found in downgradient wells 05393 (0.53 µg/L), P209489 (0.60 µg/L), and P209589 (0.70 µg/L). Benzene was detected once (0.90 µg/L) in downgradient well P209689, toluene was detected twice in downgradient well P209589 (0.30 µg/L each), and vinyl chloride was detected once (0.84 µg/L) in downgradient well P209489 (Table 2-7).

Dissolved aluminum, antimony, arsenic, cadmium, cesium, cobalt, copper, cyanide, lead, manganese, mercury, molybdenum, nickel, thallium, vanadium, and zinc were infrequently detected in downgradient groundwater in UHSU bedrock (Table 2-8). Dissolved cesium, antimony, cobalt, manganese, thallium, and zinc were also infrequently detected in upgradient groundwater (see Table 2-6).

Dissolved cesium-134, cesium-137, and total plutonium-238 were each detected at least once in UHSU bedrock groundwater (Table 2-9). Each of these three radionuclides was also detected at least once in upgradient groundwater in UHSU bedrock (see Table 2-6).

Water-quality parameters infrequently detected in downgradient groundwater in UHSU bedrock included ammonia, carbonate as $CaCO_3$, chemical oxygen demand (COD), and total organic carbon (TOC) (Table 2-10). In upgradient groundwater, alkalinity as $CaCO_3$ and carbonate as $CaCO_3$ were each reported once (see Table 2-6).

The upgradient VOC plume also appears to have impacted UHSU bedrock groundwater. Upgradient well P209389 intersects the plume of VOC contamination, which is moving into and through the Solar Ponds area. This well showed multiple detections of 1,1,1-trichloroethane; 1,1,-dichloroethene; and 1,2-dichloroethane, as well as one detection each of methylene chloride and naphthalene (see Table 2-6).

2.2 ANOVA Comparisons

Statistical comparisons of upgradient versus downgradient groundwater were performed for the UHSU alluvium and for UHSU bedrock, using the updated database for 1995. Distributional testing was performed prior to the analysis of variance (ANOVA) testing. Analytes were classified as normal, lognormal, or unknown distributions; nonparametric ANOVA was used to evaluate the latter.

The output of statistical tests (Appendix C) gives a probability value (p) for each analyte, which indicates the probability (1-p) that the differences in analyte concentrations are statistically significant. Therefore, taken at the 95-percent confidence limit, any p-value less than 0.05 indicates a significant difference between the two populations compared.

2.2.1 UHSU Alluvial Groundwater

Additional detections for dissolved cesium, cobalt, copper, manganese, mercury, molybdenum, nickel, selenium, thallium, ammonia, chemical oxygen demand (COD), and total organic carbon (TOC) moved these analytes into the category of greater than 50-percent detections for UHSU alluvial groundwater. Dissolved barium, magnesium, sodium, radium-226, uranium-233+234, and uranium-238, as well as bicarbonate, chloride, nitrate/nitrite, specific conductivity, and total dissolved solids (TDS) continued to show significant differences between upgradient and downgradient UHSU groundwater (Table 2-11).

Dissolved calcium, lithium, potassium, silicon, fluoride, gross alpha, gross beta, strontium-89+90 and uranium-235, as well as tritium, tetrachloroethene (PCE), and trichloroethene (TCE) were analytes that did not previously show a significant difference, but which do when the fourth-quarter data are added to the database. Dissolved strontium and total suspended solids (TSS) no longer showed significant differences after the addition of fourth-quarter data to the database.

2.2.2 UHSU Bedrock Groundwater

For UHSU bedrock groundwater, comparative statistics show that dissolved barium, calcium, lithium, magnesium, potassium, selenium, sodium, strontium, tin, gross alpha, gross beta, radium-226, radium-228, strontium-89+90, uranium-233+234, uranium-235, and uranium-238, as well as bicarbonate, chloride, nitrate/nitrite, specific conductivity, sulfate, TDS, and tritium reflect significant differences at the 5-percent confidence level (Table 2-12). Tin, sulfate, radium-228, and strontium-89+90 did not previously show a significant difference.

The most notable difference in the results of statistical comparisons was for the organic analytes in UHSU bedrock groundwater. Like UHSU alluvial groundwater, PCE and TCE showed a significant difference between concentrations in upgradient and downgradient UHSU bedrock groundwater. In addition, significant differences were seen for carbon tetrachloride, chloroform, and cis-1,2-dichloroethene (cis-1,2-DCE) in UHSU bedrock groundwater.

The volatile organic compounds (VOCs) detected in UHSU bedrock groundwater at the Solar Evaporation Ponds are of interest because the detected concentrations of 1,1,1-TCA; 1,1-DCA; 1,1-DCE; carbon tetrachloride; chloroform; methylene chloride; PCE; TCE; and cis-1,2-DCE are found in samples collected from upgradient well P209389. The statistically significant differences found for some of these analytes indicate contamination in the upgradient groundwater, relative to the downgradient groundwater.

2.3 Groundwater Quality

Overall, there were few changes in groundwater quality, as indicated by the addition of fourth-quarter data. The fourth-quarter data are listed in **Appendix B**, and can be reviewed in conjunction with Figures 3-4 to 3-25 in the 1995 Annual RCRA Report. The inclusion of fourth-quarter data did not alter any previous conclusions regarding the distribution of contaminants at the Solar Evaporation Ponds.

3.0 GROUNDWATER MONITORING AT THE PRESENT LANDFILL

Additional analytical results for fourth-quarter samples were incorporated into the existing database for the Present Landfill. The statistical analyses discussed in Section 1.4.6 of the 1995 Annual RCRA Report were performed again using the updated database. The tables of analytical data for the fourth quarter (Appendix B) supplement the existing maps of the 1995 RCRA Annual Report, and were used to update the discussion of groundwater quality at the Present Landfill. Groundwater from UHSU bedrock and groundwater from the total UHSU (bedrock + alluvium) were evaluated separately.

3.1 Infrequently Detected Analytes

Those analytes detected in less than 50 percent of the samples collected from the RCRA unit are designated as infrequently detected analytes. In the appended database, most anions/water-quality parameters were detected at greater than 50-percent frequency. No organic compound had a detection rate greater than 50 percent. A number of dissolved metals were detected infrequently in UHSU groundwater at the Present Landfill. Only one sample was collected for total metals; these results are not included here.

3.1.1 Total UHSU Groundwater (Alluvium + Bedrock)

In the amended database for total UHSU groundwater at the Present Landfill, 1,1,1-trichloroethane (1,1,1-TCA) was detected at least once in five upgradient wells (Table 3-1). 1,1-DCA; 1,1-DCE; 1,2,3-trichlorobenzene; benzene; carbon tetrachloride; chloroform; hexachlorodibenzo-p-dioxin; PCE; total xylenes; TCE; total xylenes, and cis-1,2-DCE were all detected at least once, in upgradient wells only (see Table 3-1). None of these organic compounds were included in the ANOVA testing. Methylene chloride was detected once (2.0 µg/L, B-qualified, in well B206989) (Table 3-2).

Infrequently detected metals in total UHSU groundwater from upgradient locations included dissolved aluminum, antimony, cesium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Dissolved antimony, cadmium, copper, iron, manganese, selenium, thallium, tin, and vanadium were infrequently detected in downgradient groundwater from the total UHSU (see Table 3-2). There was one sample analyzed for total metals (upgradient well 70393) (see Table 3-3).

Other infrequently detected analytes in downgradient groundwater from the UHSU included dissolved cesium-134, cesium-137, americium-241, plutonium-239+240, radium-228, and total plutonium-238 (Table 3-4). Dissolved

13

cesium-134, cesium-137, and total plutonium-238 were each detected once in downgradient well B207089 (see Table 3-2).

Ammonia and pH were infrequently reported for upgradient groundwater in the total UHSU (Table 3-5). In downgradient groundwater, ammonia, cyanide, and pH were infrequently detected (see Table 3-2).

3.1.2 UHSU Bedrock Groundwater

In UHSU bedrock groundwater at the Present Landfill, 1,1,1-TCA in upgradient wells 70193 (0.10 μg/L), 70493 (0.60 μg/L), and 70693 (110.0 μg/L); 1,1-DCE and carbon tetrachloride in upgradient well 70693 (50.0 μg/L and 3.80 μg/L, respectively); chloroform in upgradient wells 70193 (0.70 μg/L) and 70693 (0.95 μg/L); and PCE and TCE in upgradient wells 70493 (0.72 μg/L, 0.80 μg/L) and 70693 (4.40 μg/L, 18.00 μg/L) were detected infrequently throughout the year (Table 3-6). Methylene chloride was detected in downgradient well B206989 (2.00 μg/L, B-qualified result) (Table 3-7).

Infrequently detected metals in upgradient groundwater from UHSU bedrock included dissolved cesium, copper, iron, manganese, mercury, selenium, vanadium, and zinc (see Table 3-6). In downgradient groundwater from the UHSU bedrock, dissolved antimony, copper, iron, manganese, selenium, thallium, tin, and vanadium were each detected once in well B207089 (see Table 3-7).

Dissolved americium-241, plutonium-239+240, radium-228, and total plutonium-238 were detected in upgradient groundwater, although many of the reported results are given as zero (see Table 3-6). Dissolved cesium-134, cesium-137, and total plutonium-238 were detected once in downgradient groundwater from the UHSU bedrock (see Table 3-7).

Ammonia, COD, and pH were reported infrequently in upgradient groundwater (see Table 3-6). In downgradient groundwater from the UHSU bedrock . COD, cyanide, and pH were each detected once (see Table 3-7).

3.2 ANOVA Comparisons

Analytes for which there were more than two detections and greater than 50-percent detections were statistically tested using the appropriate ANOVA test. Statistical comparisons of upgradient versus downgradient groundwater were performed for the total UHSU (bedrock + alluvium) and for UHSU bedrock, using the updated database for 1995. Distributional testing was performed prior to the ANOVA testing. Analytes were classified as normal, lognormal, or unknown distributions; nonparametric ANOVA was used to evaluate the latter.

The output of the statistical tests (Appendix C) gives a probability value (p), which indicates the probability (1-p) that the differences in analyte concentrations are statistically significant. Therefore, taken at the 95-percent confidence limit, any p-value less than 0.05 indicates a significant difference between the two populations compared.

3.2.1 Total UHSU Groundwater (Alluvium + Bedrock)

Additional detections for dissolved potassium, COD, and radium-226 moved these analytes into the category of greater than 50-percent detections for total UHSU groundwater. Dissolved barium, calcium, lithium, magnesium, silicon, sodium, strontium, gross alpha, gross beta, uranium-233+234, bicarbonate, chloride, nitrate/nitrite, specific conductivity, sulfate, TDS, and TSS continued to show significant differences between upgradient and downgradient UHSU groundwater (Table 3-8). Potassium and radium-226 were the only analytes that did not previously show a significant difference, but which do when the fourth-quarter data are added to the database.

3.2.2 UHSU Bedrock Groundwater

For the UHSU bedrock, comparative statistics indicated that dissolved barium, calcium, lithium, magnesium, potassium, silicon, sodium, strontium, and uranium-233+234, as well as bicarbonate, chloride, nitrate/nitrite, specific conductivity, sulfate, TDS, and TSS were significantly different at the 5-percent confidence level (Table 3-9). Only TSS and uranium-233+234 did not previously show a significant difference.

3.3 Groundwater Quality

Overall, there were few changes in groundwater quality, as indicated by the addition of fourth-quarter data. These data are listed in Appendix B, and can be reviewed in conjunction with Figures 4-4 to 4-16 in the 1995 Annual RCRA Report. The entire, appended database for 1995 is provided on diskette in Appendix A. The inclusion of fourth-quarter data did not alter any previous conclusions regarding the distribution of contaminants at the Present Landfill.

4.0 GROUNDWATER MONITORING AT THE WEST SPRAY FIELD

Additional analytical results for fourth-quarter samples were incorporated into the existing database for the West Spray Field. The statistical analyses discussed in Section 1.4.6 of the 1995 Annual RCRA Report were performed again using the updated database. Analytical data for the fourth quarter (Appendix B) were used to update the discussion of groundwater quality at the West Spray Field. Only groundwater from UHSU alluvium was evaluated.

4.1 Infrequently Detected Analytes

As noted in Section 1.4.6 of the 1995 Annual RCRA Report, statistical comparisons were not performed for analytes with less than 50-percent quantifiable results or fewer than two detections for the wells used in the statistical comparisons. The concentrations of infrequently detected analytes in groundwater upgradient and downgradient of the RCRA unit are reported and discussed below.

In the appended database for the West Spray Field, methylene chloride was detected at low levels (0.2 - 0.80 μg/L) in one upgradient well (46192, 0.30 μg/L) (Table 4-1) and in five downgradient wells (5086, B110989, B111189, B410589, B410789) (Table 4-2). All of these results are J or B-qualified, indicating estimated concentrations (J) or that the chemical was detected in the blank (B). Chloroform was detected in downgradient well 51194 (0.91 μg/L) and naphthalene was detected once in well B111189 (1.10 μg/L) (see Table 4-2). Unless verified by subsequent analyses, these infrequently detected VOCs are not considered indicative of contamination.

Dissolved metals that were infrequently detected in upgradient groundwater in UHSU alluvium included aluminum, antimony, arsenic, beryllium, cesium, copper, iron, lead, lithium, manganese, mercury, molybdenum, selenium, silver, thallium, tin, vanadium, and zinc (Table 4-3). Dissolved antimony, cadmium, iron, lead, lithium, manganese, silver, thallium, tin, and zinc were also infrequently detected in upgradient groundwater at the West Spray Field (see Table 4-1).

Dissolved americium-241, plutonium-238, and plutonium-239+240 were the only radionuclides detected infrequently in downgradient groundwater (Table 4-4), although all results were reported as zero. These same radionuclides were detected once in upgradient groundwater (see Table 4-1), but again, the reported results are zero.

Other infrequently detected inorganic analytes reported for downgradient UHSU groundwater included alkalinity as $CaCO_3$, ammonia, COD, cyanide, and TOC (Table 4-5). Cyanide and orthophosphate were each reported once in upgradient UHSU groundwater (see Table 4-1).

17

4.2 ANOVA Comparisons

Statistical comparisons of upgradient versus downgradient groundwater were performed for UHSU alluvium, using the updated database for 1995. Distributional testing was performed prior to the ANOVA testing. Analytes were classified as normal, lognormal, or unknown distributions; nonparametric ANOVA was used to evaluate the latter.

The output of the statistical tests (Appendix C) gives a probability value (p), which indicates the probability (1-p) that the differences in analyte concentrations are statistically significant. Therefore, taken at the 95-percent confidence limit, any p-value less than 0.05 indicates a significant difference between the two populations compared.

With the addition of fourth-quarter data, the results of statistical tests showed that dissolved potassium and TSS no longer exhibited a significant difference between upgradient and downgradient groundwater (Table 4-6). Conversely, sulfate and nitrate/nitrite, which were not significant in the 1995 Annual RCRA Report, showed significant differences after the addition of the fourth-quarter data. Dissolved cesium-134 and cesium-137, and total plutonium-238 were added to the list of analytes having greater than 50-percent detections; however, none of these three radionuclides exhibited a significant difference between upgradient and downgradient groundwater (see Table 4-6).

4.3 Groundwater Quality

The inclusion of fourth-quarter data resulted in only minor changes in the list of significantly different analytes. Two analytes dropped below significance (potassium and TSS), whereas two analytes gained significance (nitrate/nitrite and sulfate) in the statistical tests. Otherwise there were no significant alterations to the conclusions on groundwater quality, as presented in the 1995 Annual RCRA Report.

5.0 REFERENCES

DOE, 1996, 1995 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Environmental Technology Site. Final Draft. Rocky Mountain Remediation Services, Inc. L.L.C., Golden Colorado, February, 1996.

EPA, 1989. Interim Final Guidance on Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Office of Solid Waste, Waste management Division, U.S. Environmental Protection Agency, EPA/530-SW-89-026.

EPA, 1992. Statistical Analysis of Groundwater Monitoring Data At RCRA Facilities. Draft Addendum to Interim Final Guidance. U.S. Environmental Protection Agency, Office of Solid Waste Permits and State Programs Division, Washington, D.C. July, 1992.

19

TABLES

TABLE 2-1 Infrequently Detected Analytes in Upgradient UHSU Alluvial Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
2486	UP	4/11/95	DSMETCLP	CHROMIUM	3.40	UG/L	B	3
P209289	UP	7/31/95	VOA524.2	CARBON TETRACHLORIDE	450.00	UG/L		0.5
P209289	UP	7/31/95	VOA524.2	CHLOROFORM	170.00	UG/L		0.5
5293	UP	8/7/95	VOACLP	ACETONE	9.00	UG/L	J	10

TABLE 2-2 Infrequently Detected Organic Compounds in Downgradient UHSU Alluvial Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
5093	DN	4/24/95	BNACLP	DI-n-BUTYL PHTHALATE	3.00	UG/L	BJ	10
5193	DN	4/25/95	BNACLP	DI-n-BUTYL PHTHALATE	2.00	UG/L	BJ	10
3887	DN	7/31/95	VOA524.2	CARBON TETRACHLORIDE	1.00	UG/L		0.5
P207889	DN	7/31/95	VOA524.2	CARBON TETRACHLORIDE	0.20	UG/L	J	0.5
3887	DN	7/31/95	VOA524.2	CHLOROFORM	0.50	UG/L	J	0.5
P207689	DN	10/25/95	VOA524.2	CHLOROFORM	0.20	UG/L	J	1

TABLE 2-3 Infrequently Detected Dissolved Metals in Downgradient UHSU Alluvial Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
5093	DN	2/6/95	DSMETCLP	ALUMINUM	17.60	UG/L	B	12
5093	DN	7/21/95	DSMETCLP	ALUMINUM	20.10	UG/L	J	200
5093	DN	4/24/95	DSMETCLP	ANTIMONY	2.30	UG/L	B	2
5193	DN	4/25/95	DSMETCLP	ANTIMONY	3.30	UG/L	B	2
5093	DN	4/24/95	DSMETCLP	ARSENIC	7.20	UG/L	B	3
5193	DN	4/25/95	DSMETCLP	ARSENIC	5.80	UG/L	B	3
P207889	DN	7/31/95	DSMETCLP	BERYLLIUM	0.57	UG/L	B	5
P209789	DN	4/28/95	DSMETCLP	BERYLLIUM	1.20	UG/L	B	5
P207889	DN	7/31/95	DSMETCLP	IRON	37.90	UG/L	B	100
P209789	DN	4/28/95	DSMETCLP	IRON	43.50	UG/L	B	100
5193	DN	4/25/95	DSMETCLP	SILVER	5.00	UG/L	B	3
5093	DN	4/24/95	DMETADD	TIN	40.10	UG/L	B	24
5193	DN	1/19/95	DMETADD	TIN	45.80	UG/L	B	24
5193	DN	4/25/95	DMETADD	TIN	72.00	UG/L	B	24
2686	DN	7/12/95	DMETADD	TIN	98.20	UG/L	J	200
P209789	DN	7/13/95	DMETADD	TIN	58.80	UG/L	J	200
5093	DN	2/6/95	DSMETCLP	VANADIUM	2.00	UG/L	B	1.5
5193	DN	1/19/95	DSMETCLP	VANADIUM	3.30	UG/L	B	3
P207689	DN	1/13/95	DSMETCLP	VANADIUM	4.44	UG/L	B	3
P207689	DN	7/27/95	DSMETCLP	VANADIUM	3.60	UG/L	J	50
P207889	DN	7/31/95	DSMETCLP	VANADIUM	19.90	UG/L	B	50
P209789	DN	4/28/95	DSMETCLP	VANADIUM	16.70	UG/L	B	50
5093	DN	4/24/95	DSMETCLP	ZINC	5.70	UG/L	B	3
5093	DN	7/21/95	DSMETCLP	ZINC	14.70	UG/L	J	20
5193	DN	4/25/95	DSMETCLP	ZINC	3.00	UG/L	B	3
P207689	DN	1/13/95	DSMETCLP	ZINC	2.63	UG/L	B	2
P207689	DN	7/27/95	DSMETCLP	ZINC	4.40	UG/L	J	20
P207889	DN	7/31/95	DSMETCLP	ZINC	12.20	UG/L	B	20
P209789	DN	4/28/95	DSMETCLP	ZINC	24.50	UG/L		20

TABLE 2-4 Infrequently Detected Dissolved and Total Radionuclides in Downgradient UHSU Alluvial Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
5093	DN	7/21/95	DRADS	CESIUM-134	0.73	PCI/L	J	2.27
5193	DN	7/21/95	DRADS	CESIUM-134	-0.39	PCI/L	J	1.01
P207689	DN	7/27/95	DRADS	CESIUM-134	-0.32	PCI/L	J	1.1
P207889	DN	7/31/95	DRADS	CESIUM-134	-0.34	PCI/L	J	1.09
P209789	DN	7/13/95	DRADS	CESIUM-134	0.00	PCI/L	J	1
5093	DN	7/21/95	DRADS	CESIUM-137	-0.39	PCI/L	J	2.31
5193	DN	7/21/95	DRADS	CESIUM-137	0.18	PCI/L	J	1.12
P207689	DN	7/27/95	DRADS	CESIUM-137	0.18	PCI/L	J	1.2
P207889	DN	7/31/95	DRADS	CESIUM-137	-0.16	PCI/L	J	1.14
P209789	DN	7/13/95	DRADS	CESIUM-137	0.29	PCI/L	J	1.1
5093	DN	7/21/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
5193	DN	7/21/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
P207689	DN	7/27/95	TRADS	PLUTONIUM-238	0.01	PCI/L		0.01
P207689	DN	10/25/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
P207889	DN	7/31/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
P209789	DN	7/13/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.02
P209789	DN	10/24/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01

TABLE 2-5 Infrequently Detected Anions/Water-Quality Parameters in Downgradient UHSU Alluvial Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE		RESULT	UNITS	QUAL	DETECT
5093	DN	2/6/95	WQPL	ALKALINITY AS CACO3	51	3900.00	UG/L	1	0
P209789	DN	4/28/95	WQPL	ALKALINITY AS CACO3	27	6000.00	UG/L	1	0
5093	DN	7/21/95	WQPL	CYANIDE		2.80	UG/L	J	50
5193	DN	7/21/95	WQPL	CYANIDE		1.50	UG/L	J	50
P207689	DN	7/27/95	WQPL	CYANIDE		3.60	UG/L	J	50

TABLE 2-6 Infrequently Detected Analytes in Upgradient UHSU Bedrock Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
P209389	UP	4/12/95	DMETADD	CESIUM	40.00	UG/L	B	24
P209389	UP	4/12/95	DSMETCLP	ANTIMONY	3.10	UG/L	B	2
P207389	UP	7/21/95	DSMETCLP	COBALT	3.30	UG/L	J	50
P207389	UP	2/1/95	DSMETCLP	MANGANESE	1.35	UG/L	B	1
P207389	UP	5/2/95	DSMETCLP	THALLIUM	14.60	UG/L		10
P207389	UP	7/21/95	DSMETCLP	THALLIUM	11.00	UG/L		10
P209389	UP	7/20/95	DSMETCLP	THALLIUM	11.60	UG/L		6.9
P209389	UP	4/12/95	DSMETCLP	ZINC	5.60	UG/L	B	3
P207389	UP	7/21/95	DRADS	CESIUM-134	0.15	PCI/L	J	1.11
P209389	UP	7/20/95	DRADS	CESIUM-134	-0.32	PCI/L	J	0.96
P207389	UP	7/21/95	DRADS	CESIUM-137	0.83	PCI/L	J	1.21
P209389	UP	7/20/95	DRADS	CESIUM-137	0.09	PCI/L	J	1.04
P207389	UP	7/21/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
P207389	UP	12/7/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
P209389	UP	7/17/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
P209389	UP	11/13/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
P209389	UP	1/26/95	VOA524.2	1,1,1-TRICHLOROETHANE	1.50	UG/L		0.5
P209389	UP	4/12/95	VOA524.2	1,1,1-TRICHLOROETHANE	1.52	UG/L		0.5
P209389	UP	7/17/95	VOA524.2	1,1,1-TRICHLOROETHANE	1.00	UG/L		1
P209389	UP	11/13/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.80	UG/L		0.5
P209389	UP	1/26/95	VOA524.2	1,1-DICHLOROETHENE	44.00	UG/L	E	0.5
P209389	UP	4/12/95	VOA524.2	1,1-DICHLOROETHENE	49.60	UG/L	E	0.5
P209389	UP	7/17/95	VOA524.2	1,1-DICHLOROETHENE	38.00	UG/L		1
P209389	UP	11/13/95	VOA524.2	1,1-DICHLOROETHENE	28.00	UG/L	E	0.5
P209389	UP	1/26/95	VOA524.2	1,2-DICHLOROETHANE	0.62	UG/L		0.5
P209389	UP	7/17/95	VOA524.2	1,2-DICHLOROETHANE	0.50	UG/L	J	1
P209389	UP	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	BJ	1
P209389	UP	7/17/95	VOA524.2	NAPHTHALENE	0.10	UG/L	J	1
P207389	UP	2/1/95	WQPL	ALKALINITY AS CACO3	294800.00	UG/L		10000
P207389	UP	2/1/95	WQPL	CARBONATE AS CACO3	32470.00	UG/L		10000

TABLE 2-7 Infrequently Detected Organic Compounds in Downgradient UHSU Bedrock Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
P209489	DN	1/26/95	VOA524.2	1,1-DICHLOROETHENE	0.57	UG/L		0.5
P209489	DN	7/13/95	VOA524.2	1,1-DICHLOROETHENE	0.20	UG/L	J	2
P209689	DN	8/1/95	VOA524.2	BENZENE	0.90	UG/L		0.5
5393	DN	7/24/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	J	1
P209489	DN	1/26/95	VOA524.2	METHYLENE CHLORIDE	0.53	UG/L		0.5
P209489	DN	7/13/95	VOA524.2	METHYLENE CHLORIDE	0.60	UG/L	J	2
P209589	DN	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.70	UG/L	BJ	1
P209589	DN	8/7/95	VOA524.2	TOLUENE	0.30	UG/L	J	0.5
P209589	DN	11/13/95	VOA524.2	TOLUENE	0.30	UG/L	J	0.5
P209489	DN	1/26/95	VOA524.2	VINYL CHLORIDE	0.84	UG/L		0.5

TABLE 2-8 Infrequently Detected Dissolved Metals in Downgradient UHSU Bedrock Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
3086	DN	5/8/95	DMETADD	CESIUM	63.00	UG/L	B	24
P208989	DN	1/23/95	DMETADD	CESIUM	36.00	UG/L	B	22
P209489	DN	4/13/95	DMETADD	CESIUM	46.00	UG/L	B	24
P209889	DN	4/20/95	DMETADD	CESIUM	59.00	UG/L	B	24
5393	DN	7/24/95	DMETADD	MOLYBDENUM	11.00	UG/L	J	200
3086	DN	7/21/95	DMETADD	MOLYBDENUM	9.50	UG/L	J	200
P209889	DN	7/26/95	DSMETCLP	ALUMINUM	55.10	UG/L	J	400
3086	DN	5/8/95	DSMETCLP	ANTIMONY	9.50	UG/L	B	2
P209489	DN	4/13/95	DSMETCLP	ANTIMONY	4.30	UG/L	B	2
3086	DN	5/8/95	DSMETCLP	ARSENIC	37.00	UG/L		3
P209889	DN	4/20/95	DSMETCLP	ARSENIC	5.80	UG/L	B	3
P209889	DN	1/16/95	DSMETCLP	CADMIUM	3.80	UG/L	B	3
3086	DN	7/21/95	DSMETCLP	COBALT	3.40	UG/L	J	50
P209889	DN	4/20/95	DSMETCLP	COBALT	12.80	UG/L	B	6
P209889	DN	7/26/95	DSMETCLP	COBALT	8.30	UG/L	J	100
3086	DN	5/8/95	DSMETCLP	COPPER	5.30	UG/L	B	2
3086	DN	7/21/95	DSMETCLP	COPPER	5.30	UG/L	J	25
3086	DN	7/21/95	DSMETCLP	LEAD	4.70	UG/L		3
P209489	DN	1/26/95	DSMETCLP	MANGANESE	39.20	UG/L		1
P209489	DN	4/13/95	DSMETCLP	MANGANESE	26.70	UG/L		2
5393	DN	7/24/95	DSMETCLP	MERCURY	0.07	UG/L	J	0.2
3086	DN	5/8/95	DSMETCLP	MERCURY	0.23	UG/L		0.2
P208989	DN	7/27/95	DSMETCLP	MERCURY	0.12	UG/L	J	0.2
P209489	DN	4/13/95	DSMETCLP	MERCURY	0.24	UG/L		[illegible]
P209489	DN	7/13/95	DSMETCLP	MERCURY	0.53	UG/L		0.2
3086	DN	5/8/95	DSMETCLP	NICKEL	18.00	UG/L	B	12
P208989	DN	1/23/95	DSMETCLP	NICKEL	27.90	UG/L	B	12
P209489	DN	4/13/95	DSMETCLP	NICKEL	13.10	UG/L	B	12
P209889	DN	1/16/95	DSMETCLP	NICKEL	32.40	UG/L	B	12
P209889	DN	4/20/95	DSMETCLP	NICKEL	17.90	UG/L	B	12
P209889	DN	7/26/95	DSMETCLP	NICKEL	19.80	UG/L	J	80
5393	DN	7/24/95	DSMETCLP	THALLIUM	15.20	UG/L		10
3086	DN	7/21/95	DSMETCLP	THALLIUM	7.60	UG/L	J	10
P208989	DN	5/4/95	DSMETCLP	THALLIUM	26.10	UG/L		10
P209489	DN	7/13/95	DSMETCLP	THALLIUM	11.00	UG/L		10
P209889	DN	7/26/95	DSMETCLP	THALLIUM	18.30	UG/L	J	20
P208989	DN	1/23/95	DSMETCLP	VANADIUM	3.80	UG/L	B	3
P209889	DN	4/20/95	DSMETCLP	VANADIUM	4.90	UG/L	B	3
3086	DN	5/8/95	DSMETCLP	ZINC	10.80	UG/L	B	3
P209489	DN	4/13/95	DSMETCLP	ZINC	6.20	UG/L	B	3
P209889	DN	4/20/95	DSMETCLP	ZINC	7.50	UG/L	B	3

28

TABLE 2-9 Infrequently Detected Dissolved and Total Radionuclides in Downgradient UHSU Bedrock Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
3086	DN	7/21/95	DRADS	CESIUM-134	-0.81	PCI/L	J	1.1
P208989	DN	7/27/95	DRADS	CESIUM-134	0.61	PCI/L	J	1.09
P209489	DN	7/13/95	DRADS	CESIUM-134	-0.45	PCI/L	J	1.1
P209889	DN	7/26/95	DRADS	CESIUM-134	-0.38	PCI/L	J	1.15
3086	DN	7/21/95	DRADS	CESIUM-137	0.06	PCI/L	J	1.1
P208989	DN	7/27/95	DRADS	CESIUM-137	-0.60	PCI/L	J	1.21
P209489	DN	7/13/95	DRADS	CESIUM-137	-0.14	PCI/L	J	1.18
P209889	DN	7/26/95	DRADS	CESIUM-137	0.69	PCI/L	J	1.29
3086	DN	7/21/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
P208989	DN	7/27/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
P209489	DN	7/13/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0
P209889	DN	7/26/95	TRADS	PLUTONIUM-238	0.01	PCI/L		0

TABLE 2-10 Infrequently Detected Anions/Water-Quality Parameters in Downgradient UHSU Bedrock Groundwater, Solar Evaporation Ponds

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
3086	DN	1/18/95	WQPL	AMMONIA	137.00	UG/L		50
P208989	DN	5/4/95	WQPL	AMMONIA	74.00	UG/L	J	100
P209489	DN	1/26/95	WQPL	AMMONIA	92.00	UG/L		50
P209589	DN	1/13/95	WQPL	AMMONIA	557.00	UG/L		50
P209589	DN	4/17/95	WQPL	AMMONIA	161.00	UG/L		50
P209689	DN	1/30/95	WQPL	AMMONIA	4037.00	UG/L	N	50
3086	DN	5/8/95	WQPL	CARBONATE AS CACO3	2380.00	UG/L	B	10000
P209889	DN	4/20/95	WQPL	CARBONATE AS CACO3	691.00	UG/L	B	10000
5393	DN	7/24/95	WQPL	CHEMICAL OXYGEN DEMAND	70000.00	UG/L		20000
P207989	DN	8/7/95	WQPL	CHEMICAL OXYGEN DEMAND	21500.00	UG/L		10000
5393	DN	7/24/95	WQPL	TOTAL ORGANIC CARBON	30700.00	UG/L		1000
P207989	DN	8/7/95	WQPL	TOTAL ORGANIC CARBON	4300.00	UG/L		1000
P208989	DN	7/27/95	WQPL	TOTAL ORGANIC CARBON	4400.00	UG/L		1000
P209889	DN	7/26/95	WQPL	TOTAL ORGANIC CARBON	7700.00	UG/L		1000

30

Table 2-11

Results of ANOVA Testing for UHSU Alluvial Groundwater, Solar Evaporation Ponds

UHSU Alluvium	Normal	Lognormal	Nonparametric	Significant ?	
Dissolved Metals					
Barium	0.0001			YES	
Calcium			0.0079	YES	X
Cesium	0.8175			No	
Cobalt	0.3324			No	
Copper	0.5053			No	
Lithium			0.0112	YES	X
Magnesium			0.0222	YES	
Manganese			0.1194	No	
Mercury	0.1879			No	
Molybdenum	0.5748			No	
Nickel	0.3251			No	
Potassium			0.0071	YES	X
Selenium	0.3932			No	
Silicon	0.0062			YES	X
Sodium			0.0065	YES	
Strontium			0.0502	No	X
Thallium	0.7649			No	
Water Quality/Anions					
Ammonia		0.0617		No	
Bicarbonate as CaCO3	0.0045			YES	
COD	0.4429			No	
Chloride			0.0225	YES	
Fluoride	0.0072			YES	X
Nitrate/Nitrite			0.0326	YES	
Specific Conductivity			0.0147	YES	
Sulfate			0.0538	No	
TDS			0.0161	YES	
TOC	0.1444			No	
Di TSS			0.0583	No	X
Dissolved Radionuclides					
Gross alpha			0.0159	YES	X
Gross beta		0.0001		YES	X
Radium-226		0.0063		YES	
Strontium-89+90	0.0388			YES	X
Total Radiocesium	0.0847			No	
Uranium-233+234		0.0001		YES	
Uranium-235		0.0001		YES	X
Uranium-238		0.0001		YES	

Table 2-11 (Continued)

Results of ANOVA Testing for UHSU Alluvial Groundwater, Solar Evaporation Ponds

UHSU Alluvium (cont')	Normal	Lognormal	Nonparametric	Significant ?	
Total Radionuclides					
Americium-241			0.1229	No	
Plutonium-239+240			0.1404	No	
Tritium		0.0001		YES	X
VOCs/SVOCs					
Tetrachloroethene, PCE	0.0418			YES	X
Trichloroethene, TCE	0.0175			YES	X

Significance is at the 5-percent level; therefore, any p-value result less than 0.05 indicates a significant difference between upgradient and downgradient groundwater. An "X" indicates a change from the statistical results presented in the 1995 Annual RCRA Report. Note that analytes must have a detection rate equal to or greater than 50 percent, and 2 or more detects to be included in the statistical analysis. Results of statistical tests are provided on diskette in Appendix B.

Table 2-12

Results of ANOVA Testing for UHSU Bedrock Groundwater, Solar Evaporation Ponds

UHSU Bedrock	Normal	Lognormal	Nonparametric	Significant ?	
Dissolved Metals					
Barium	0.0001			YES	
Calcium			0.0029	YES	
Cyanide			0.9705	No	
Lithium			0.0021	YES	
Magnesium			0.0021	YES	
Potassium			0.0077	YES	
Selenium			0.0096	YES	
Silicon	0.0731			No	
Sodium			0.0024	YES	
Strontium			0.0029	YES	
Tin			0.0482	YES	X
Water Quality/Anions					
Bicarbonate as CaCO3			0.0176	YES	
Chloride			0.0034	YES	
Fluoride			0.0854	No	
Nitrate/Nitrite			0.0007	YES	
Specific Conductivity			0.0259	YES	
Sulfate			0.0129	YES	X
TDS		0.0001		YES	
TSS			0.4185	No	
Dissolved Radionuclides					
Gross alpha			0.0087	YES	
Gross beta			0.0043	YES	
Radium-226			0.0148	YES	
Radium-228	0.0341			YES	X
Strontium-89+90		0.0211		YES	X
Total Radiocesium			0.1553	No	
Uranium-233+234			0.0026	YES	
Uranium-235			0.0028	YES	
Uranium-238			0.0034	YES	
Total Radionuclides					
Americium-241		0.0879		No	
Plutonium-239+240			0.1528	No	
Tritium			0.0001	YES	

Table 2-12 (Continued)
Results of ANOVA Testing for UHSU Bedrock Groundwater, Solar Evaporation Ponds

UHSU Bedrock (cont')	Normal	Lognormal	Nonparametric	Significant ?	
VOCs/SVOCs					
1,1-Dichloroethane			0.9090	No	
1,1-Dichloroethene			0.1373	No	
Carbon tetrachloride	0.0001			YES	X
Chloroform			0.0212	YES	X
Tetrachloroethene, PCE		0.0061		YES	X
Trichloroethene, TCE		0.0001		YES	X
cis-1,2-DCE		0.0001		YES	X

Significance is at the 5-percent level; therefore, any p-value result less than 0.05 indicates a significant difference between upgradient and downgradient groundwater. An "X" indicates a change from the statistical results presented in the 1995 Annual RCRA Report. Note that analytes must have a detection rate equal to or greater than 50 percent, and 2 or more detects to be included in the statistical analysis. Results of statistical tests are provided on diskette in Appendix B.

TABLE 3-1 Infrequently Detected Organic Compounds in Upgradient Total UHSU Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
1086	UP	7/31/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.20	UG/L	J	0.5
70093	UP	2/13/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.85	UG/L		0.5
70093	UP	11/9/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.70	UG/L		0.5
70193	UP	12/18/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.10	UG/L	J	1
70393	UP	2/14/95	VOA524.2	1,1,1-TRICHLOROETHANE	51.00	UG/L		0.2
70393	UP	11/21/95	VOA524.2	1,1,1-TRICHLOROETHANE	43.00	UG/L		1
70493	UP	11/22/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.60	UG/L	J	1
70693	UP	2/17/95	VOA524.2	1,1,1-TRICHLOROETHANE	110.00	UG/L	E	0.5
70393	UP	2/14/95	VOA524.2	1,1-DICHLOROETHANE	1.00	UG/L		0.2
70393	UP	11/21/95	VOA524.2	1,1-DICHLOROETHANE	1.00	UG/L		1
70393	UP	2/14/95	VOA524.2	1,1-DICHLOROETHENE	11.00	UG/L		0.2
70393	UP	11/21/95	VOA524.2	1,1-DICHLOROETHENE	13.00	UG/L		1
70693	UP	2/17/95	VOA524.2	1,1-DICHLOROETHENE	50.00	UG/L	E	0.5
1086	UP	7/31/95	VOA524.2	1,2,3-TRICHLOROBENZE	0.40	UG/L	BJ	0.5
1086	UP	7/31/95	VOA524.2	BENZENE	0.20	UG/L	J	0.5
6087	UP	8/3/95	VOA524.2	BENZENE	2.00	UG/L		0.5
6087	UP	8/3/95	VOA524.2	BENZENE	0.50	UG/L	J	0.5
70393	UP	2/14/95	VOA524.2	CARBON TETRACHLORIDE	0.80	UG/L		0.3
70693	UP	2/17/95	VOA524.2	CARBON TETRACHLORIDE	3.80	UG/L		0.5
70193	UP	12/18/95	VOA524.2	CHLOROFORM	0.70	UG/L	J	1
70393	UP	2/14/95	VOA524.2	CHLOROFORM	0.30	UG/L	J	0.2
70393	UP	11/21/95	VOA524.2	CHLOROFORM	0.30	UG/L	J	1
70693	UP	2/17/95	VOA524.2	CHLOROFORM	0.95	UG/L		0.5
6087	UP	5/17/95	DIOX8280	HEXACHLORODIBENZO-p-DIOXIN	0.00	UG/L		0.001
70393	UP	2/14/95	VOA524.2	TETRACHLOROETHENE	5.00	UG/L		0.2
70393	UP	11/21/95	VOA524.2	TETRACHLOROETHENE	6.00	UG/L		1
70493	UP	2/9/95	VOA524.2	TETRACHLOROETHENE	0.72	UG/L		0.5
70693	UP	2/17/95	VOA524.2	TETRACHLOROETHENE	4.40	UG/L		0.5
70093	UP	11/9/95	VOA524.2	TOTAL XYLENES	0.30	UG/L	J	0.5
5887	UP	1/12/95	VOA524.2	TRICHLOROETHENE	1.10	UG/L		0.5
5887	UP	8/3/95	VOA524.2	TRICHLOROETHENE	0.50	UG/L		0.5
5887	UP	10/23/95	VOA524.2	TRICHLOROETHENE	0.80	UG/L	J	1
70393	UP	2/14/95	VOA524.2	TRICHLOROETHENE	23.00	UG/L		0.2
70393	UP	11/21/95	VOA524.2	TRICHLOROETHENE	23.00	UG/L		1
70493	UP	11/22/95	VOA524.2	TRICHLOROETHENE	0.80	UG/L	J	1
70693	UP	2/17/95	VOA524.2	TRICHLOROETHENE	18.00	UG/L		0.5
70393	UP	2/14/95	VOA524.2	cis-1,2-DICHLOROETHENE	0.40	UG/L		0.2
70393	UP	11/21/95	VOA524.2	cis-1,2-DICHLOROETHENE	0.40	UG/L	J	1

TABLE 3-2 Infrequently Detected Analytes in Downgradient Total UHSU Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
B207089	DN	1/11/95	DSMETCLP	ANTIMONY	2.30	UG/L	B	2
4087	DN	5/15/95	DSMETCLP	CADMIUM	2.20	UG/L		1.9
4087	DN	5/15/95	DSMETCLP	COPPER	4.60	UG/L		1.8
B207089	DN	5/11/95	DSMETCLP	COPPER	3.60	UG/L		1.8
4087	DN	5/15/95	DSMETCLP	IRON	8.30	UG/L		3.9
B207089	DN	5/11/95	DSMETCLP	IRON	5.40	UG/L		3.9
4087	DN	5/15/95	DSMETCLP	MANGANESE	2.20	UG/L		1.7
B207089	DN	5/11/95	DSMETCLP	MANGANESE	9.10	UG/L		1.7
4087	DN	5/15/95	DSMETCLP	SELENIUM	4.50	UG/L		1.8
B207089	DN	1/11/95	DSMETCLP	SELENIUM	8.50	UG/L		3
B207089	DN	7/20/95	DSMETCLP	THALLIUM	12.80	UG/L		10
B207089	DN	5/11/95	DMETADD	TIN	17.10	UG/L		16.6
4087	DN	5/15/95	DSMETCLP	VANADIUM	3.90	UG/L		2
B207089	DN	5/11/95	DSMETCLP	VANADIUM	2.40	UG/L		2
B207089	DN	7/20/95	DRADS	CESIUM-134	-0.56	PCI/L	J	1.13
B207089	DN	7/20/95	DRADS	CESIUM-137	0.35	PCI/L	J	1.16
B207089	DN	7/20/95	TRADS	PLUTONIUM-238	0.00	PCI/L		0.003
B206989	DN	11/6/95	VOA524.2	METHYLENE CHLORIDE	2.00	UG/L	B	1
4087	DN	7/24/95	WQPL	AMMONIA	78.00	UG/L	J	100
B207089	DN	7/20/95	WQPL	CYANIDE	1.60	UG/L	J	50
4087	DN	5/15/95	WQPL	pH	7.60	PH		0 2
B207089	DN	5/11/95	WQPL	pH	7.40	PH		0 2

TABLE 3-3 Infrequently Detected Dissolved Metals in Upgradient Total UHSU Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
1086	UP	5/9/95	DSMETCLP	ALUMINUM	29.50	UG/L		21.2
5887	UP	1/12/95	DSMETCLP	ANTIMONY	4.20	UG/L	B	2
70693	UP	2/17/95	DMETADD	CESIUM	43.00	UG/L	B	22
5887	UP	8/3/95	DSMETCLP	CHROMIUM	2.80	UG/L	B	10
1086	UP	5/9/95	DSMETCLP	COPPER	2.50	UG/L		1.8
1086	UP	7/31/95	DSMETCLP	COPPER	9.80	UG/L	B	25
5887	UP	1/12/95	DSMETCLP	COPPER	6.20	UG/L	B	3
5887	UP	5/4/95	DSMETCLP	COPPER	2.90	UG/L		1.8
5887	UP	8/3/95	DSMETCLP	COPPER	15.90	UG/L	B	25
6087	UP	5/17/95	DSMETCLP	COPPER	2.90	UG/L		1.8
6087	UP	8/3/95	DSMETCLP	COPPER	15.00	UG/L	B	25
70093	UP	5/5/95	DSMETCLP	COPPER	2.00	UG/L		1.8
70193	UP	5/17/95	DSMETCLP	COPPER	2.10	UG/L		1.8
1086	UP	5/9/95	DSMETCLP	IRON	25.60	UG/L		3.9
1086	UP	7/31/95	DSMETCLP	IRON	20.20	UG/L	B	100
5887	UP	8/3/95	DSMETCLP	IRON	22.00	UG/L	B	100
6087	UP	5/17/95	DSMETCLP	IRON	17.30	UG/L		3.9
6087	UP	8/3/95	DSMETCLP	IRON	24.80	UG/L	B	100
70093	UP	5/5/95	DSMETCLP	IRON	7.90	UG/L		3.9
70393	UP	5/18/95	DSMETCLP	IRON	4.30	UG/L		3.9
70693	UP	5/4/95	DSMETCLP	IRON	4.50	UG/L		3.9
5887	UP	5/4/95	DSMETCLP	LEAD	3.00	UG/L		0.8
1086	UP	5/9/95	DSMETCLP	MANGANESE	3.40	UG/L		1.7
1086	UP	7/31/95	DSMETCLP	MANGANESE	4.20	UG/L	B	15
5887	UP	8/3/95	DSMETCLP	MANGANESE	5.50	UG/L	B	15
6087	UP	8/3/95	DSMETCLP	MANGANESE	4.90	UG/L	B	15
70093	UP	2/13/95	DSMETCLP	MANGANESE	32.00	UG/L		1
70093	UP	5/5/95	DSMETCLP	MANGANESE	11.00	UG/L		1.7
70193	UP	2/14/95	DSMETCLP	MANGANESE	24.60	UG/L		1
70393	UP	5/18/95	DSMETCLP	MANGANESE	14.00	UG/L		1.7
70693	UP	2/17/95	DSMETCLP	MANGANESE	6.42	UG/L	B	1
70693	UP	5/4/95	DSMETCLP	MANGANESE	3.40	UG/L		1.7
70193	UP	2/14/95	DSMETCLP	MERCURY	0.36	UG/L		0
70093	UP	11/9/95	DMETSOW	NICKEL	13.30	UG/L	B	40
1086	UP	1/10/95	DSMETCLP	SELENIUM	3.10	UG/L	B	3
5887	UP	5/4/95	DSMETCLP	SELENIUM	2.00	UG/L		1.8
5887	UP	10/23/95	DMETSOW	SELENIUM	7.30	UG/L		5
70093	UP	5/5/95	DSMETCLP	SELENIUM	1.80	UG/L		1.8
70093	UP	11/9/95	DMETSOW	SELENIUM	6.20	UG/L		5
70193	UP	2/14/95	DSMETCLP	SELENIUM	3.30	UG/L	B	3
70393	UP	11/21/95	DMETSOW	SELENIUM	6.90	UG/L		5
70493	UP	11/22/95	DMETSOW	SELENIUM	16.50	UG/L		5
5887	UP	1/12/95	DSMETCLP	SILVER	4.50	UG/L	B	4
1086	UP	7/31/95	DSMETCLP	THALLIUM	6.20	UG/L	B	10
1086	UP	7/31/95	DSMETCLP	VANADIUM	7.10	UG/L	B	50
5887	UP	8/3/95	DSMETCLP	VANADIUM	10.40	UG/L	B	50
6087	UP	5/17/95	DSMETCLP	VANADIUM	4.20	UG/L		2
6087	UP	8/3/95	DSMETCLP	VANADIUM	11.40	UG/L	B	50
70393	UP	5/18/95	DSMETCLP	VANADIUM	3.30	UG/L		2
70493	UP	5/15/95	DSMETCLP	VANADIUM	2.90	UG/L		2
1086	UP	5/9/95	DSMETCLP	ZINC	6.70	UG/L		6

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETEC
1086	UP	7/31/95	DSMETCLP	ZINC	11.80	UG/L	B	20
5887	UP	1/12/95	DSMETCLP	ZINC	19.40	UG/L	B	2
5887	UP	5/4/95	DSMETCLP	ZINC	9.60	UG/L		6
5887	UP	8/3/95	DSMETCLP	ZINC	19.20	UG/L	B	20
6087	UP	5/17/95	DSMETCLP	ZINC	7.20	UG/L		6
6087	UP	8/3/95	DSMETCLP	ZINC	12.40	UG/L	B	20
70093	UP	2/13/95	DSMETCLP	ZINC	3.40	UG/L	B	2
70193	UP	5/17/95	DSMETCLP	ZINC	6.00	UG/L		6
70693	UP	2/17/95	DSMETCLP	ZINC	2.85	UG/L	B	2
70693	UP	5/4/95	DSMETCLP	ZINC	9.50	UG/L		6
70393	UP	2/14/95	SMETCLP	ALUMINUM	16500.00	UG/L	N	12
70393	UP	2/14/95	SMETCLP	ARSENIC	3.60	UG/L	B	1.4
70393	UP	2/14/95	SMETCLP	BERYLLIUM	1.30	UG/L	B	0.2
70393	UP	2/14/95	SMETCLP	CHROMIUM	15.80	UG/L		1.8
70393	UP	2/14/95	SMETCLP	COBALT	7.10	UG/L	B	1.4
70393	UP	2/14/95	SMETCLP	COPPER	11.90	UG/L	B	1.1
70393	UP	2/14/95	SMETCLP	IRON	16800.00	UG/L	N	7.3
70393	UP	2/14/95	SMETCLP	LEAD	13.50	UG/L		0.9
70393	UP	2/14/95	SMETCLP	MANGANESE	201.00	UG/L		0.5
70393	UP	2/14/95	SMETCLP	NICKEL	10.80	UG/L	B	3.7
70393	UP	2/14/95	SMETCLP	VANADIUM	25.80	UG/L	B	1.5
70393	UP	2/14/95	SMETCLP	ZINC	51.20	UG/L		1.1

TABLE 3-4 Infrequently Detected Dissolved and Total Radionuclides in Upgradient Total UHSU Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
1086	UP	7/31/95	DRADS	CESIUM-134	0.61	PCI/L	J	1.14
5887	UP	8/3/95	DRADS	CESIUM-134	0.25	PCI/L	J	1.22
6087	UP	8/3/95	DRADS	CESIUM-134	-1.06	PCI/L	J	2.35
6087	UP	8/3/95	DRADS	CESIUM-134	-0.43	PCI/L	J	1.07
1086	UP	7/31/95	DRADS	CESIUM-137	-0.28	PCI/L	J	1.05
5887	UP	8/3/95	DRADS	CESIUM-137	0.62	PCI/L	J	1.27
6087	UP	8/3/95	DRADS	CESIUM-137	-0.71	PCI/L	J	2.38
6087	UP	8/3/95	DRADS	CESIUM-137	0.08	PCI/L	J	1.24
70093	UP	2/13/95	DRADS	AMERICIUM-241	0.01	PCI/L		0.011
70193	UP	2/14/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.007
70393	UP	2/14/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.012
70493	UP	2/9/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.008
70693	UP	2/17/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.022
70093	UP	2/13/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.011
70193	UP	2/14/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.014
70393	UP	2/14/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.005
70493	UP	2/9/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.005
70693	UP	2/17/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.016
5887	UP	10/23/95	DRADS	RADIUM-228	0.40	PCI/L		0.335
70093	UP	11/9/95	DRADS	RADIUM-228	0.45	PCI/L		0.402
70193	UP	12/18/95	DRADS	RADIUM-228	0.67	PCI/L		0.455
70393	UP	11/21/95	DRADS	RADIUM-228	0.25	PCI/L	J	0.399
70493	UP	11/22/95	DRADS	RADIUM-228	0.56	PCI/L		0.404
1086	UP	7/31/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.003
5887	UP	8/3/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.009
5887	UP	10/23/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.003
6087	UP	8/3/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.006
6087	UP	8/3/95	TRADS	PLUTONIUM-238	0.01	PCI/L	J	0.008
70093	UP	11/9/95	TRADS	PLUTONIUM-238	1.02	PCI/L		0.011
70193	UP	12/18/95	TRADS	PLUTONIUM-238	0.00	PCI/L		0.003
70393	UP	11/21/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.017
70493	UP	11/22/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.006

TABLE 3-5 Infrequently Detected Anions/Water-Quality Parameters in Upgradient Total UHSU Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
70093	UP	5/5/95	WQPL	AMMONIA	230.00	UG/L		200
70193	UP	2/14/95	WQPL	AMMONIA	37.00	UG/L	B	50
70693	UP	5/4/95	WQPL	AMMONIA	270.00	UG/L		200
1086	UP	5/9/95	WQPL	pH	6.50	PH		0.2
5887	UP	5/4/95	WQPL	pH	6.40	PH		0.2
6087	UP	5/17/95	WQPL	pH	7.00	PH		0.2
70093	UP	5/5/95	WQPL	pH	6.00	PH		0.2
70193	UP	5/17/95	WQPL	pH	7.00	PH		0.2
70393	UP	5/18/95	WQPL	pH	7.60	PH		0.2
70493	UP	5/15/95	WQPL	pH	7.50	PH		0.2
70693	UP	5/4/95	WQPL	pH	6.30	PH		0.2

TABLE 3-6 Infrequently Detected Analytes in Upgradient UHSU Bedrock Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
70693	UP	2/17/95	DMETADD	CESIUM	43.00	UG/L	B	22
70493	UP	11/22/95	DMETSOW	SELENIUM	16.50	UG/L		5
70193	UP	5/17/95	DSMETCLP	COPPER	2.10	UG/L		1.8
70693	UP	5/4/95	DSMETCLP	IRON	4.50	UG/L		3.9
70193	UP	2/14/95	DSMETCLP	MANGANESE	24.60	UG/L		1
70693	UP	2/17/95	DSMETCLP	MANGANESE	6.42	UG/L	B	1
70693	UP	5/4/95	DSMETCLP	MANGANESE	3.40	UG/L		1.7
70193	UP	2/14/95	DSMETCLP	MERCURY	0.36	UG/L		0
70193	UP	2/14/95	DSMETCLP	SELENIUM	3.30	UG/L	B	3
70493	UP	5/15/95	DSMETCLP	VANADIUM	2.90	UG/L		2
70193	UP	5/17/95	DSMETCLP	ZINC	6.00	UG/L		6
70693	UP	2/17/95	DSMETCLP	ZINC	2.85	UG/L	B	2
70693	UP	5/4/95	DSMETCLP	ZINC	9.50	UG/L		6
70193	UP	2/14/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.01
70493	UP	2/9/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.01
70693	UP	2/17/95	DRADS	AMERICIUM-241	0.00	PCI/L		0.02
70193	UP	2/14/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.01
70493	UP	2/9/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.01
70693	UP	2/17/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L		0.02
70193	UP	12/18/95	DRADS	RADIUM-228	0.67	PCI/L		0.46
70493	UP	11/22/95	DRADS	RADIUM-228	0.56	PCI/L		0.4
70193	UP	12/18/95	TRADS	PLUTONIUM-238	0.00	PCI/L		0
70493	UP	11/22/95	TRADS	PLUTONIUM-238	0.00	PCI/L	J	0.01
70193	UP	12/18/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.10	UG/L	J	1
70493	UP	11/22/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.60	UG/L	J	1
70693	UP	2/17/95	VOA524.2	1,1,1-TRICHLOROETHANE	110.00	UG/L	E	0 5
70693	UP	2/17/95	VOA524.2	1,1-DICHLOROETHENE	50.00	UG/L	E	0 5
70693	UP	2/17/95	VOA524.2	CARBON TETRACHLORIDE	3.80	UG/L		0 5
70193	UP	12/18/95	VOA524.2	CHLOROFORM	0.70	UG/L	J	1
70693	UP	2/17/95	VOA524.2	CHLOROFORM	0.95	UG/L		0 5
70493	UP	2/9/95	VOA524.2	TETRACHLOROETHENE	0.72	UG/L		0 5
70693	UP	2/17/95	VOA524.2	TETRACHLOROETHENE	4.40	UG/L		0 5
70493	UP	11/22/95	VOA524.2	TRICHLOROETHENE	0.80	UG/L	J	1
70693	UP	2/17/95	VOA524.2	TRICHLOROETHENE	18.00	UG/L		0.5
70193	UP	2/14/95	WQPL	AMMONIA	37.00	UG/L	B	50
70693	UP	5/4/95	WQPL	AMMONIA	270.00	UG/L		200
70693	UP	5/4/95	WQPL	CHEMICAL OXYGEN DEMAND	8000.00	UG/L		5000
70193	UP	5/17/95	WQPL	pH	7.00	PH		0.2
70493	UP	5/15/95	WQPL	pH	7.50	PH		0.2
70693	UP	5/4/95	WQPL	pH	6.30	PH		0.2

TABLE 3-7 Infrequently Detected Analytes in Downgradient UHSU Bedrock Groundwater, Present Landfill

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
B207089	DN	1/11/95	DSMETCLP	ANTIMONY	2.30	UG/L	B	2
B207089	DN	5/11/95	DSMETCLP	COPPER	3.60	UG/L		1.8
B207089	DN	5/11/95	DSMETCLP	IRON	5.40	UG/L		3.9
B207089	DN	5/11/95	DSMETCLP	MANGANESE	9.10	UG/L		1.7
B207089	DN	1/11/95	DSMETCLP	SELENIUM	8.50	UG/L		3
B207089	DN	7/20/95	DSMETCLP	THALLIUM	12.80	UG/L		10
B207089	DN	5/11/95	DMETADD	TIN	17.10	UG/L		16.6
B207089	DN	5/11/95	DSMETCLP	VANADIUM	2.40	UG/L		2
B207089	DN	7/20/95	DRADS	CESIUM-134	-0.56	PCI/L	J	1.13
B207089	DN	7/20/95	DRADS	CESIUM-137	0.35	PCI/L	J	1.16
B207089	DN	7/20/95	TRADS	PLUTONIUM-238	0.00	PCI/L		0
B206989	DN	11/6/95	VOA524.2	METHYLENE CHLORIDE	2.00	UG/L	B	1
B207089	DN	5/11/95	WQPL	CHEMICAL OXYGEN DEMAND	8000.00	UG/L		5000
B207089	DN	7/20/95	WQPL	CYANIDE	1.60	UG/L	J	50
B207089	DN	5/11/95	WQPL	pH	7.40	PH		0.2

Table 3-8

Results of ANOVA Testing for Total UHSU Groundwater, Present Landfill

Total UHSU	Normal	Lognormal	Nonparametric	Significant ?	
Dissolved Metals					
Barium		0.0002		YES	
Calcium	0.0001			YES	
Lithium			0.0052	YES	
Magnesium			0.0058	YES	
Potassium			0.0054	YES	X
Silicon	0.0001			YES	
Sodium		0.0001		YES	
Strontium	0.0001			YES	
Water-Quality/Anions					
Bicarbonate as CaCO3			0.0024	YES	
COD			0.0545	No	
Chloride			0.0023	YES	
Fluoride			0.0601	No	
Nitrate/Nitrite			0.0023	YES	
Specific Conductivity			0.0027	YES	
Sulfate		0.0001		YES	
TDS			0.0023	YES	
TOC			0.0517	No	
TSS		0.0001		YES	
Dissolved Radionuclides					
Gross alpha			0.0181	YES	
Gross beta		0.0017		YES	
Radium-226	0.0285			YES	
Strontium-89+90		0.7428		No	
Total Radiocesium		0.3533		No	
Uranium-233+234			0.0128	YES	
Uranium-235		0.1651		No	
Uranium-238			0.0809	No	
Total Radionuclides					
Americium-241		0.9077		No	
Plutonium-239+240			0.6309	No	
Tritium		0.1799		No	

Significance is at the 5-percent level; therefore, any p-value result less than 0.05 indicates a significant difference between upgradient and downgradient groundwater. An "X" indicates a change from the statistical results presented in the 1995 Annual RCRA Report. Note that analytes must have a detection rate equal to or greater than 50 percent, and 2 or more detects to be included in the statistical analysis. Results of statistical tests are provided on diskette in Appendix B.

Table 3-9

Results of ANOVA Testing for UHSU Bedrock Groundwater, Present Landfill

UHSU Bedrock	Normal	Lognormal	Nonparametric	Significant ?	
Dissolved Metals					
Barium			0.0167	YES	
Calcium	0.0001			YES	
Lithium	0.0001			YES	
Magnesium	0.0001			YES	
Potassium			0.0164	YES	
Silicon	0.0001			YES	
Sodium			0.0167	YES	
Strontium	0.0001			YES	
Water-Quality/Anions					
Bicarbonate as CaCO3			0.0167	YES	
Chloride			0.0167	YES	
Fluoride	0.6071			No	
Nitrate/Nitrite		0.0165		YES	
Specific Conductivity	0.0001			YES	
Sulfate			0.0167	YES	
TDS	0.0001			YES	
TOC			0.4367	No	
TSS			0.0201	YES	X
Dissolved Radionuclides					
Gross alpha			0.1530	No	
Gross beta		0.1125		No	
Radium-226	0.1815			No	
Strontium-89+90	0.0670			No	
Total Radiocesium	0.4109			No	
Uranium-233+234	0.0218			YES	X
Uranium-235			0.1530	No	
Uranium-238			0.4142	No	
Total Radionuclides					
Americium-241	0.4183			No	
Plutonium-239+240			0.8808	No	
Tritium	0.3132			No	

Significance is at the 5-percent level; therefore, any p-value result less than 0.05 indicates a significant difference between upgradient and downgradient groundwater. An "X" indicates a change from the statistical results presented in the 1995 Annual RCRA Report. Note that analytes must have a detection rate equal to or greater than 50 percent, and 2 or more detects to be included in the statistical analysis. Results of statistical tests are provided on diskette in Appendix B.

TABLE 4-1 Infrequently Detected Analytes in Upgradient Alluvial Groundwater West Spray Field

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
50294	UP	5/8/95	DSMETCLP	ANTIMONY	50.40	UG/L	B	60
5186	UP	1/13/95	DSMETCLP	ANTIMONY	3.60	UG/L	B	2
50294	UP	5/8/95	DSMETCLP	CADMIUM	2.70	UG/L	B	5
50294	UP	5/8/95	DSMETCLP	IRON	33.80	UG/L	B	100
46192	UP	4/12/95	DSMETCLP	LEAD	2.00	UG/L	B	0.7
5186	UP	4/12/95	DSMETCLP	LEAD	1.20	UG/L	B	0.7
46192	UP	7/13/95	DMETADD	LITHIUM	6.50	UG/L	J	100
46192	UP	4/12/95	DSMETCLP	MANGANESE	0.69	UG/L	B	0.6
50294	UP	5/8/95	DSMETCLP	MANGANESE	6.70	UG/L	B	15
5186	UP	1/13/95	DSMETCLP	SILVER	5.40	UG/L	B	4
46192	UP	7/13/95	DSMETCLP	THALLIUM	9.30	UG/L	J	10
50294	UP	5/8/95	DSMETCLP	THALLIUM	3.20	UG/L	B	10
46192	UP	4/12/95	DMETADD	TIN	7.60	UG/L	B	7.3
50294	UP	5/8/95	DMETADD	TIN	73.40	UG/L	B	200
50294	UP	5/8/95	DSMETCLP	ZINC	15.60	UG/L	B	20
50294	UP	5/8/95	DRADS	AMERICIUM-241	0.00	PCI/L	J	0.01
50294	UP	5/8/95	DRADS	PLUTONIUM-238	0.00	PCI/L	J	0
50294	UP	5/8/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L	J	0
46192	UP	7/13/95	VOA524.2	METHYLENE CHLORIDE	0.30	UG/L	J	1
46192	UP	7/13/95	WQPL	CYANIDE	1.40	UG/L	J	50
50294	UP	5/8/95	DWQPL	ORTHOPHOSPHATE	56.10	UG/L		50

TABLE 4-2 Infrequently Detected Organic Compounds in Downgradient Alluvial Groundwater, West Spray Field

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
51194	DN	2/8/95	VOA524.2	CHLOROFORM	0.91	UG/L		0.5
5086	DN	8/14/95	VOA524.2	METHYLENE CHLORIDE	0.80	UG/L		0.5
B110989	DN	9/25/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	JB	1
B111189	DN	8/24/95	VOA524.2	METHYLENE CHLORIDE	0.50	UG/L	BJ	1
B410589	DN	7/13/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	J	1
B410789	DN	9/25/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	JB	1
B111189	DN	1/20/95	VOA524.2	NAPHTHALENE	1.10	UG/L		0.5

TABLE 4-3 Infrequently Detected Dissolved Metals in Downgradient Alluvial Groundwater, West Spray Field

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
51194	DN	5/8/95	DSMETCLP	ALUMINUM	28.90	UG/L	B	200
B110889	DN	7/20/95	DSMETCLP	ALUMINUM	77.30	UG/L	J	200
B111189	DN	4/19/95	DSMETCLP	ALUMINUM	45.10	UG/L	B	33
B410789	DN	4/28/95	DSMETCLP	ALUMINUM	29.00	UG/L	B	200
5086	DN	8/14/95	DSMETCLP	ANTIMONY	15.40	UG/L	B	14.8
B110989	DN	5/10/95	DSMETCLP	ANTIMONY	3.90	UG/L	B	2
B110989	DN	9/25/95	DSMETCLP	ANTIMONY	21.40	UG/L	J	60
B111189	DN	4/19/95	DSMETCLP	ANTIMONY	2.50	UG/L	B	2
B410689	DN	4/13/95	DSMETCLP	ANTIMONY	2.80	UG/L	B	2
B410789	DN	1/25/95	DSMETCLP	ANTIMONY	50.70	UG/L	B	45
B410789	DN	9/25/95	DSMETCLP	ANTIMONY	18.90	UG/L	J	60
5086	DN	8/14/95	DSMETCLP	ARSENIC	1.60	UG/L		1.3
B110989	DN	5/10/95	DSMETCLP	ARSENIC	6.03	UG/L	B	3
B110989	DN	5/10/95	DSMETCLP	ARSENIC	5.90	UG/L	B	3
B110989	DN	9/25/95	DSMETCLP	BERYLLIUM	0.74	UG/L	J	5
B410789	DN	9/25/95	DSMETCLP	BERYLLIUM	0.74	UG/L	J	5
51194	DN	5/8/95	DMETADD	CESIUM	63.00	UG/L	B	1000
B110989	DN	5/10/95	DMETADD	CESIUM	72.00	UG/L	B	24
B111189	DN	4/19/95	DMETADD	CESIUM	58.00	UG/L	B	24
B410689	DN	4/13/95	DMETADD	CESIUM	35.00	UG/L	B	24
B410789	DN	4/28/95	DMETADD	CESIUM	85.00	UG/L	B	1000
B110989	DN	5/10/95	DSMETCLP	COPPER	2.00	UG/L	B	2
B110989	DN	9/25/95	DSMETCLP	COPPER	3.80	UG/L	J	25
B410789	DN	4/28/95	DSMETCLP	COPPER	9.90	UG/L	B	25
5086	DN	8/14/95	DSMETCLP	IRON	4.60	UG/L	B	3.4
51194	DN	5/8/95	DSMETCLP	IRON	185.00	UG/L		100
B111189	DN	1/20/95	DSMETCLP	IRON	7.91	UG/L	B	6
B111189	DN	4/19/95	DSMETCLP	IRON	20.80	UG/L	B	12
B410789	DN	4/28/95	DSMETCLP	IRON	21.70	UG/L	B	100
B410589	DN	4/12/95	DSMETCLP	LEAD	1.10	UG/L	B	0.7
5086	DN	8/14/95	DMETADD	LITHIUM	6.00	UG/L	B	1
B110889	DN	7/20/95	DMETADD	LITHIUM	4.50	UG/L	J	100
B110989	DN	9/25/95	DMETADD	LITHIUM	3.80	UG/L	J	100
B110989	DN	9/25/95	DMETADD	LITHIUM	3.80	UG/L	J	100
B410589	DN	7/13/95	DMETADD	LITHIUM	5.90	UG/L	J	100
B410689	DN	7/13/95	DMETADD	LITHIUM	6.20	UG/L	J	100
B410789	DN	9/25/95	DMETADD	LITHIUM	4.10	UG/L	J	100
5086	DN	8/14/95	DSMETCLP	MANGANESE	0.80	UG/L		0.5
51194	DN	5/8/95	DSMETCLP	MANGANESE	902.00	UG/L		15
B410589	DN	1/25/95	DSMETCLP	MANGANESE	13.80	UG/L	B	1
B410589	DN	4/12/95	DSMETCLP	MANGANESE	3.10	UG/L	B	0.6
B410789	DN	4/28/95	DSMETCLP	MANGANESE	3.20	UG/L	B	15
B110889	DN	7/20/95	DSMETCLP	MERCURY	0.05	UG/L	J	0.2
51194	DN	5/8/95	DMETADD	MOLYBDENUM	55.70	UG/L	B	200
B410789	DN	9/25/95	DMETADD	MOLYBDENUM	6.20	UG/L	J	200
5086	DN	1/23/95	DSMETCLP	SELENIUM	6.20	UG/L		3
5086	DN	4/20/95	DSMETCLP	SELENIUM	3.10	UG/L	B	3
B110989	DN	1/20/95	DSMETCLP	SELENIUM	3.90	UG/L	B	3
B110989	DN	1/20/95	DSMETCLP	SELENIUM	4.50	UG/L	B	3
B111189	DN	1/20/95	DSMETCLP	SELENIUM	3.09	UG/L	B	3
B111189	DN	4/19/95	DSMETCLP	SELENIUM	3.20	UG/L	B	3

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
B410589	DN	1/25/95	DSMETCLP	SELENIUM	6.00	UG/L		3
B410789	DN	1/25/95	DSMETCLP	SELENIUM	7.90	UG/L		3
B410789	DN	4/28/95	DSMETCLP	SELENIUM	3.70	UG/L	B	5
B110989	DN	1/20/95	DSMETCLP	SILVER	4.20	UG/L	B	4
B110889	DN	5/5/95	DSMETCLP	THALLIUM	21.10	UG/L		10
B110889	DN	7/20/95	DSMETCLP	THALLIUM	7.10	UG/L	J	10
B110989	DN	9/25/95	DSMETCLP	THALLIUM	8.10	UG/L	J	10
B110989	DN	9/25/95	DSMETCLP	THALLIUM	6.50	UG/L	J	10
B111189	DN	8/24/95	DSMETCLP	THALLIUM	9.20	UG/L	J	10
5086	DN	8/14/95	DSMETCLP	VANADIUM	2.00	UG/L	B	0.9
B110989	DN	9/25/95	DSMETCLP	VANADIUM	3.30	UG/L	J	50
B410589	DN	4/12/95	DSMETCLP	VANADIUM	2.20	UG/L	B	1.4
B410789	DN	4/28/95	DSMETCLP	VANADIUM	12.00	UG/L	B	50
51194	DN	5/8/95	DMETADD	TIN	31.10	UG/L	B	200
B110889	DN	1/18/95	DMETADD	TIN	28.40	UG/L	B	24
B111189	DN	4/19/95	DMETADD	TIN	40.10	UG/L	B	24
5086	DN	8/14/95	DSMETCLP	ZINC	12.70	UG/L	B	6.7
51194	DN	5/8/95	DSMETCLP	ZINC	28.40	UG/L		20
B110889	DN	7/20/95	DSMETCLP	ZINC	181.00	UG/L		20
B110989	DN	9/25/95	DSMETCLP	ZINC	2.80	UG/L	J	20
B110989	DN	9/25/95	DSMETCLP	ZINC	2.30	UG/L	J	20
B111189	DN	1/20/95	DSMETCLP	ZINC	2.32	UG/L	B	2
B111189	DN	4/19/95	DSMETCLP	ZINC	4.00	UG/L	B	3
B410689	DN	4/13/95	DSMETCLP	ZINC	4.90	UG/L	B	3
B410789	DN	4/28/95	DSMETCLP	ZINC	21.90	UG/L		20

TABLE 4-4 Infrequently Detected Dissolved Radionuclides in Downgradient Alluvial Groundwater, West Spray Field

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
51194	DN	5/8/95	DRADS	AMERICIUM-241	0.00	PCI/L		0
51194	DN	5/8/95	DRADS	PLUTONIUM-238	0.00	PCI/L	J	0
51194	DN	5/8/95	DRADS	PLUTONIUM-239/240	0.00	PCI/L	J	0

TABLE 4-5 Infrequently Detected Anions/Water-Quality Parameters in Downgradient Alluvial Groundwater, West Spray Field

LOCATION	GRAD	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	DETECT
B410789	DN	4/28/95	WQPL	ALKALINITY AS CACO3	108000.00	UG/L		10000
5086	DN	1/23/95	WQPL	AMMONIA	291.00	UG/L	N*	50
B110889	DN	1/18/95	WQPL	AMMONIA	20.00	UG/L	B	50
B110889	DN	5/5/95	WQPL	AMMONIA	51.00	UG/L	J	100
B110989	DN	1/20/95	WQPL	AMMONIA	45.00	UG/L	B	50
B410789	DN	1/25/95	WQPL	AMMONIA	53.00	UG/L	*	50
B410789	DN	4/28/95	WQPL	AMMONIA	81.00	UG/L	J	100
5086	DN	8/14/95	WQPL	CHEMICAL OXYGEN DEMAND	13000.00	UG/L		10000
B110889	DN	7/20/95	WQPL	CYANIDE	1.60	UG/L	J	50
B111189	DN	8/24/95	WQPL	CYANIDE	1.30	UG/L	J	50
B110989	DN	9/25/95	WQPL	TOTAL ORGANIC CARBON	810.00	UG/L	J	1000
B410789	DN	9/25/95	WQPL	TOTAL ORGANIC CARBON	930.00	UG/L	J	1000

Table 4-6
Results of ANOVA Testing for Alluvial Groundwater, West Spray Field Evaporation Ponds

UHSU Alluvium	Normal	Lognormal	Nonparametric	Significant ?	
Dissolved Metals					
Barium			0.0366	YES	
Calcium			0.0002	YES	
Magnesium			0.0003	YES	
Potassium	0.1151			No	X
Silicon			0.0465	YES	
Sodium	0.0001			YES	
Strontium			0.0003	YES	
Water-Quality/Anions					
Bicarbonate as CaCO3			0.0001	YES	
Chloride			0.0004	YES	
Fluoride			0.0020	YES	
Nitrate/Nitrite			0.0360	YES	X
Specific Conductivity			0.0007	YES	
Sulfate			0.0103	YES	X
TDS			0.0103	YES	
TSS			0.2148	No	X
Dissolved Radionuclides					
Cesium-134	0.1008			No	
Cesium-137	0.7645			No	
Gross alpha	0.0004			YES	
Gross beta	0.5419			No	
Strontium-89+90	0.3266			No	
Total Radiocesium	0.6936			No	
Uranium-233+234			0.0187	YES	
Uranium-235		0.8453		No	
Uranium-238			0.0122	YES	
Total Radionuclides					
Americium-241			0.3259	No	
Plutonium-238			0.6514	No	
Plutonium-239+240			0.7224	No	
Tritium	0.4195			No	

Significance is at the 5-percent level; therefore, any p-value result less than 0.05 indicates a significant difference between upgradient and downgradient groundwater. An "X" indicates a change from the statistical results presented in the 1995 Annual RCRA Report. Note that analytes must have a detection rate equal to or greater than 50 percent, and 2 or more detects to be included in the statistical analysis. Results of statistical tests are provided on diskette in Appendix B.

APPENDIX A

ANALYTICAL DATABASE FOR 1995
(On Diskette)

APPENDIX B

TABLES OF FOURTH-QUARTER DATA, 1995

TABLE B-1 Organic Compounds Detected in Alluvial Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
1386		ALL	GW02996GA	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.70	UG/L	BJ	Y
1386		ALL	GW02996GA	11/13/95	VOA524.2	NAPHTHALENE	0.50	UG/L	J	Y
1786		ALL	GW02998GA	11/8/95	VOA524.2	CARBON TETRACHLORIDE	0.30	UG/L	J	Y
1786		ALL	GW02998GA	11/8/95	VOA524.2	METHYLENE CHLORIDE	0.20	UG/L	BJ	Y
1786		ALL	GW02998GA	11/8/95	VOA524.2	TRICHLOROETHENE	0.60	UG/L		Y
2686	DN	ALL	GW02955GA	11/20/95	VOA524.2	TRICHLOROETHENE	4.00	UG/L		V1
B208789		ALL	GW03065GA	11/27/95	VOA524.2	NAPHTHALENE	0.30	UG/L	BJ	Y
B210489		ALL	GW03066GA	11/16/95	VOA524.2	METHYLENE CHLORIDE	0.40	UG/L	BJ	Y
P207689	DN	ALL	GW02947GA	10/25/95	VOA524.2	CHLOROFORM	0.20	UG/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	VOA524.2	TETRACHLOROETHENE	0.30	UG/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	VOA524.2	TETRACHLOROETHENE	4.00	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	VOA524.2	TRICHLOROETHENE	4.00	UG/L		Y
P219189		ALL	GW02989GA	11/20/95	VOA524.2	1,1,1-TRICHLOROETHANE	6.00	UG/L		V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	1,1,2-TRICHLOROETHANE	1.00	UG/L	J	V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	1,1-DICHLOROETHANE	37.00	UG/L		V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	1,1-DICHLOROETHENE	26.00	UG/L		V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	1,2-DICHLOROPROPANE	0.40	UG/L	J	V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	CHLOROFORM	1.00	UG/L	J	V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	METHYLENE CHLORIDE	0.80	UG/L	J	V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	TRICHLOROETHENE	0.20	UG/L	J	V1
P219189		ALL	GW02989GA	11/20/95	VOA524.2	cis-1,2-DICHLOROETHENE	0.80	UG/L	J	V1
P219489		ALL	GW02990GA	11/20/95	VOA524.2	TETRACHLOROETHENE	0.20	UG/L	J	V1

TABLE B-2 Metals Detected in Alluvial Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
1386		ALL	GW02996GA	11/13/95	DMETSOW	BARIUM	127	UG/L	B	Y
1386		ALL	GW02996GA	11/13/95	DMETSOW	CALCIUM	129000	UG/L		Y
1386		ALL	GW02996GA	11/13/95	DMETSOW	LITHIUM	56.5	UG/L	B	Y
1386		ALL	GW02996GA	11/13/95	DMETSOW	MAGNESIUM	41000	UG/L		Y
1386		ALL	GW02996GA	11/13/95	DMETSOW	NICKEL	104	UG/L		Y
1386		ALL	GW02996GA	11/13/95	DMETSOW	SODIUM	93700	UG/L		Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	BARIUM	299	UG/L		Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	CALCIUM	210000	UG/L		Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	LITHIUM	50.6	UG/L	J	Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	MAGNESIUM	50800	UG/L		Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	POTASSIUM	2180	UG/L	J	Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	SELENIUM	69.7	UG/L		Y
1586		ALL	GW02893GA	10/23/95	DMETSOW	SODIUM	145000	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	BARIUM	252	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	CALCIUM	586000	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	LITHIUM	335	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	MAGNESIUM	196000	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	NICKEL	12.5	UG/L	B	Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	POTASSIUM	5510	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	SELENIUM	180	UG/L		Y
1786		ALL	GW02998GA	11/8/95	DMETSOW	SODIUM	260000	UG/L		Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	BARIUM	146	UG/L	B	Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	CALCIUM	197000	UG/L		Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	LITHIUM	23.5	UG/L	B	Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	MAGNESIUM	53000	UG/L		Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	POTASSIUM	2810	UG/L	B	Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	SELENIUM	2.7	UG/L	B	Y
75992		ALL	GW03054GA	11/28/95	DMETSOW	SODIUM	129000	UG/L		Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	BARIUM	49.2	UG/L	J	Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	CALCIUM	419000	UG/L		Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	LITHIUM	193	UG/L		Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	MAGNESIUM	140000	UG/L		Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	NICKEL	8.2	UG/L	J	Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	POTASSIUM	2060	UG/L	J	Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	SELENIUM	210	UG/L		Y
B208589		ALL	GW03064GA	11/20/95	DMETSOW	SODIUM	283000	UG/L		Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	BARIUM	65	UG/L	B	Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	CALCIUM	186000	UG/L		Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	LITHIUM	18.2	UG/L	B	Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	MAGNESIUM	52500	UG/L		Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	NICKEL	22.6	UG/L	B	Y
B208789		ALL	GW03065GA	11/27/95	DMETSOW	SODIUM	179000	UG/L		Y
B210489		ALL	GW03066GA	11/16/95	DMETSOW	BARIUM	129	UG/L	B	Y
B210489		ALL	GW03066GA	11/16/95	DMETSOW	CALCIUM	456000	UG/L		Y
B210489		ALL	GW03066GA	11/16/95	DMETSOW	LITHIUM	187	UG/L		Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B210489		ALL	GW03066GA	11/16/95	DMETSOW	MAGNESIUM	149000	UG/L		Y
B210489		ALL	GW03066GA	11/16/95	DMETSOW	SELENIUM	232	UG/L		Y
B210489		ALL	GW03066GA	11/16/95	DMETSOW	SODIUM	265000	UG/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	BARIUM	67.5	UG/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	CALCIUM	74700	UG/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	LITHIUM	34.4	UG/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	MAGNESIUM	67600	UG/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	POTASSIUM	728	UG/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	SELENIUM	56.2	UG/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DMETSOW	SODIUM	94800	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	BARIUM	272	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	CALCIUM	144000	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	LITHIUM	88.6	UG/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	MAGNESIUM	60300	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	POTASSIUM	4510	UG/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	SELENIUM	45	UG/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DMETSOW	SODIUM	142000	UG/L		Y

TABLE B-3 Activities of Radionuclides in Alluvial Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
1386		ALL	GW02996GA	11/13/95	DRADS	GROSS ALPHA	11.32	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	GROSS BETA	9.26	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	RADIUM-226	0.26	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	RADIUM-228	0.89	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	URANIUM-233,-234	7.44	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	URANIUM-235	0.62	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	DRADS	URANIUM-238	6.76	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	GROSS ALPHA	25.04	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	GROSS BETA	9.64	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	RADIUM-226	0.26	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	RADIUM-228	0.81	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	URANIUM-233,-234	19.34	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	URANIUM-235	0.59	PCI/L		Y
1586		ALL	GW02893GA	10/23/95	DRADS	URANIUM-238	16.37	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	GROSS ALPHA	45.95	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	GROSS BETA	34.47	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	RADIUM-226	0.47	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	RADIUM-228	1.49	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	URANIUM-233,-234	32.16	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	URANIUM-235	0.85	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	DRADS	URANIUM-238	23.4	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	GROSS ALPHA	21.68	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	GROSS BETA	12.21	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	RADIUM-226	0.66	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	URANIUM-233,-234	15.54	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	URANIUM-235	0.5	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	DRADS	URANIUM-238	12.3	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	GROSS ALPHA	34.42	PCI/L.		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	GROSS BETA	18.9	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	RADIUM-226	0.27	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	RADIUM-228	1.41	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	URANIUM-233,-234	26.91	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	URANIUM-235	1.2	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	DRADS	URANIUM-238	21.35	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	GROSS ALPHA	6.78	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	GROSS BETA	8.89	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	RADIUM-226	0.67	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	URANIUM-233,-234	8.42	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	URANIUM-235	0.33	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	DRADS	URANIUM-238	7.36	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	GROSS ALPHA	28.75	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	GROSS BETA	16.54	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	RADIUM-226	1.18	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	RADIUM-228	3.96	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	URANIUM-233,-234	25.5	PCI/L		Y
B210489		ALL	GW03066GA	11/16/95	DRADS	URANIUM-235	0.87	PCI/L		Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B210489		ALL	GW03066GA	11/16/95	DRADS	URANIUM-238	20.01	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	GROSS ALPHA	10.89	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	GROSS BETA	9.82	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	RADIUM-226	0.18	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	RADIUM-228	0.69	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	URANIUM-233,-234	7.08	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	URANIUM-235	0.44	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	DRADS	URANIUM-238	5.73	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	GROSS ALPHA	27.18	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	GROSS BETA	15.92	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	RADIUM-226	0.46	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	RADIUM-228	2.04	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	URANIUM-233,-234	18.85	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	URANIUM-235	0.55	PCI/L		Y
P209789	DN	ALL	GW02966GA	10/24/95	DRADS	URANIUM-238	7.11	PCI/L		Y
1386		ALL	GW02996GA	11/13/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
1386		ALL	GW02996GA	11/13/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
1386		ALL	GW02996GA	11/13/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
1386		ALL	GW02996GA	11/13/95	TRADS	TRITIUM	214.1	PCI/L	J	Y
1586		ALL	GW02893GA	10/23/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
1586		ALL	GW02893GA	10/23/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
1586		ALL	GW02893GA	10/23/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
1586		ALL	GW02893GA	10/23/95	TRADS	TRITIUM	163.5	PCI/L	J	Y
1786		ALL	GW02998GA	11/8/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
1786		ALL	GW02998GA	11/8/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
1786		ALL	GW02998GA	11/8/95	TRADS	PLUTONIUM-239/240	0	PCI/L		Y
1786		ALL	GW02998GA	11/8/95	TRADS	TRITIUM	555.8	PCI/L		Y
2686	DN	ALL	GW02955GA	11/20/95	TRADS	TRITIUM	325.5	PCI/L		Y
75992		ALL	GW03054GA	11/28/95	TRADS	TRITIUM	73.32	PCI/L	J	Y
B208589		ALL	GW03064GA	11/20/95	TRADS	AMERICIUM-241	0.01	PCI/L		Y
B208589		ALL	GW03064GA	11/20/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
B208589		ALL	GW03064GA	11/20/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
B208589		ALL	GW03064GA	11/20/95	TRADS	TRITIUM	552.9	PCI/L		Y
B208789		ALL	GW03065GA	11/27/95	TRADS	TRITIUM	51.79	PCI/L	J	Y
B210489		ALL	GW03066GA	11/16/95	TRADS	AMERICIUM-241	0.01	PCI/L	J	Y
B210489		ALL	GW03066GA	11/16/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
B210489		ALL	GW03066GA	11/16/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
B210489		ALL	GW03066GA	11/16/95	TRADS	TRITIUM	461.9	PCI/L		Y
P207689	DN	ALL	GW02947GA	10/25/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
P207689	DN	ALL	GW02947GA	10/25/95	TRADS	TRITIUM	-37.4	PCI/L	J	Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
P209789	DN	ALL	GW02966GA	10/24/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
P209789	DN	ALL	GW02966GA	10/24/95	TRADS	TRITIUM	1280	PCI/L		Y
P218389		ALL	GW02988GA	11/13/95	TRADS	TRITIUM	155.1	PCI/L	J	Y
P219489		ALL	GW02990GA	11/20/95	TRADS	TRITIUM	562.1	PCI/L		Y

TABLE B-4 Anions/Water-Quality Parameters Detected in Alluvial Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
76292		WBR	GW02943GA	10/25/95	WQPL	BICARBONATE AS CACO3	186000	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	CHLORIDE	12300	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	NITRATE/NITRITE	25800	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	SULFATE	46900	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	TOTAL DISSOLVED SOLIDS	432000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	BICARBONATE AS CACO3	476000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	CHLORIDE	134000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	NITRATE/NITRITE	246	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	SULFATE	1870000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	4298000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	BICARBONATE AS CACO3	435000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	CHLORIDE	115000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	NITRATE/NITRITE	650	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	SULFATE	1650000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	3725000	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	BICARBONATE AS CACO3	305000	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	CHLORIDE	48700	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	NITRATE/NITRITE	2700	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	SULFATE	55800	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	TOTAL DISSOLVED SOLIDS	480000	UG/L		Y
P207789	DN	WBR	GW02948GA	10/24/95	WQPL	NITRATE/NITRITE	1200	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	BICARBONATE AS CACO3	306000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	CHLORIDE	224000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	NITRATE/NITRITE	4400	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	SULFATE	315000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	TOTAL DISSOLVED SOLIDS	1210000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	BICARBONATE AS CACO3	153000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	CHLORIDE	84300	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	NITRATE/NITRITE	5620	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	SULFATE	165000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	606000	UG/L		Y
P209589	DN	WBR	GW02953GA	11/13/95	WQPL	NITRATE/NITRITE	5210000	UG/L		Y
P209689	DN	WBR	GW02954GA	10/24/95	WQPL	NITRATE/NITRITE	56400	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	BICARBONATE AS CACO3	143000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	CHLORIDE	527000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	NITRATE/NITRITE	184000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	SULFATE	688000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	3281000	UG/L		Y

TABLE B-5 Organic Compounds Detected in UHSU Bedrock Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B210389		WBR	GW02945GA	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.7	UG/L	BJ	Y
P207389	UP	WBR	GW02946GA	12/7/95	VOA524.2	CHLOROFORM	0.2	UG/L	J	V1
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.8	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	1,1-DICHLOROETHANE	0.9	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	1,1-DICHLOROETHENE	28	UG/L	E	Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	CARBON TETRACHLORIDE	3	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	CHLOROFORM	4	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.2	UG/L	BJ	Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	TETRACHLOROETHENE	1	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	TRICHLOROETHENE	0.7	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	VOA524.2	cis-1,2-DICHLOROETHENE	0.5	UG/L		Y
P209589	DN	WBR	GW02953GA	11/13/95	VOA524.2	CHLOROFORM	0.5	UG/L		Y
P209589	DN	WBR	GW02953GA	11/13/95	VOA524.2	METHYLENE CHLORIDE	0.7	UG/L	BJ	Y
P209589	DN	WBR	GW02953GA	11/13/95	VOA524.2	TOLUENE	0.3	UG/L	J	Y

TABLE B-6 Metals Detected in UHSU Bedrock Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
76292		WBR	GW02943GA	10/25/95	DMETSOW	BARIUM	140	UG/L	J	Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	CALCIUM	90500	UG/L		Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	LITHIUM	17.7	UG/L	J	Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	MAGNESIUM	18600	UG/L		Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	POTASSIUM	1170	UG/L	J	Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	SELENIUM	29.2	UG/L		Y
76292		WBR	GW02943GA	10/25/95	DMETSOW	SODIUM	27700	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	BARIUM	24.4	UG/L	B	Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	CALCIUM	498000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	CHROMIUM	3.9	UG/L	B	Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	LITHIUM	785	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	MAGNESIUM	192000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	POTASSIUM	12400	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	SELENIUM	5.6	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	DMETSOW	SODIUM	361000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	BARIUM	26	UG/L	B	Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	CALCIUM	500000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	LITHIUM	666	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	MAGNESIUM	176000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	POTASSIUM	10100	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	SELENIUM	14.3	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	DMETSOW	SODIUM	261000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DMETSOW	BARIUM	93.9	UG/L	B	Y
P209389	UP	WBR	GW02951GA	11/13/95	DMETSOW	CALCIUM	118000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DMETSOW	LITHIUM	42.6	UG/L	B	Y
P209389	UP	WBR	GW02951GA	11/13/95	DMETSOW	MAGNESIUM	18000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DMETSOW	SODIUM	50500	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	BARIUM	42.5	UG/L	B	Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	CALCIUM	431000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	LITHIUM	366	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	MAGNESIUM	117000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	POTASSIUM	6340	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	SELENIUM	1060	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	DMETSOW	SODIUM	314000	UG/L		Y

TABLE B-7 Activities of Radionuclides in UHSU Bedrock Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
76292		WBR	GW02943GA	10/25/95	DRADS	GROSS ALPHA	2.62	PCI/L		Y
76292		WBR	GW02943GA	10/25/95	DRADS	GROSS BETA	3.04	PCI/L		Y
76292		WBR	GW02943GA	10/25/95	DRADS	RADIUM-226	0.47	PCI/L		Y
76292		WBR	GW02943GA	10/25/95	DRADS	RADIUM-228	1.02	PCI/L		Y
76292		WBR	GW02943GA	10/25/95	DRADS	URANIUM-233,-234	1.23	PCI/L		Y
76292		WBR	GW02943GA	10/25/95	DRADS	URANIUM-235	0.04	PCI/L	J	Y
76292		WBR	GW02943GA	10/25/95	DRADS	URANIUM-238	1.11	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	GROSS ALPHA	111.4	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	GROSS BETA	49.49	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	RADIUM-226	0.6	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	URANIUM-233,-234	72.4	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	URANIUM-235	2.38	PCI/L		Y
B208689		WBR	GW02944GA	11/13/95	DRADS	URANIUM-238	46.83	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	GROSS ALPHA	105.8	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	GROSS BETA	48.65	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	RADIUM-226	0.46	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	URANIUM-233,-234	80.85	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	URANIUM-235	2.19	PCI/L		Y
B210389		WBR	GW02945GA	11/13/95	DRADS	URANIUM-238	49.93	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	GROSS ALPHA	5.32	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	GROSS BETA	5.08	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	RADIUM-226	0.34	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	RADIUM-228	0.78	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	URANIUM-233,-234	2.86	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	URANIUM-235	0.14	PCI/L	J	Y
P207389	UP	WBR	GW02946GA	12/7/95	DRADS	URANIUM-238	2.33	PCI/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	DRADS	GROSS ALPHA	47.99	PCI/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	DRADS	GROSS BETA	28.53	PCI/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	DRADS	URANIUM-233,-234	30.65	PCI/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	DRADS	URANIUM-235	1.23	PCI/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	DRADS	URANIUM-238	22.44	PCI/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	GROSS ALPHA	2.49	PCI/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	GROSS BETA	1.25	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	RADIUM-226	0.41	PCI/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	RADIUM-228	0.49	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	URANIUM-233,-234	0.46	PCI/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	URANIUM-235	0	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	DRADS	URANIUM-238	0.4	PCI/L		Y
P210089		WBR	GW03036GA	11/13/95	DRADS	GROSS ALPHA	5.1	PCI/L	J	Y
P210089		WBR	GW03036GA	11/13/95	DRADS	GROSS BETA	10.66	PCI/L	J	Y
P210089		WBR	GW03036GA	11/13/95	DRADS	RADIUM-226	0.69	PCI/L		Y
P210089		WBR	GW03036GA	11/13/95	DRADS	RADIUM-228	1.59	PCI/L		Y
P210089		WBR	GW03036GA	11/13/95	DRADS	URANIUM-233,-234	3.64	PCI/L		Y
P210089		WBR	GW03036GA	11/13/95	DRADS	URANIUM-235	0.15	PCI/L	J	Y
P210089		WBR	GW03036GA	11/13/95	DRADS	URANIUM-238	2.72	PCI/L		Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
76292		WBR	GW02943GA	10/25/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
76292		WBR	GW02943GA	10/25/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
76292		WBR	GW02943GA	10/25/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
76292		WBR	GW02943GA	10/25/95	TRADS	TRITIUM	151.3	PCI/L	J	Y
B208689		WBR	GW02944GA	11/13/95	TRADS	TRITIUM	102.7	PCI/L	J	Y
B210389		WBR	GW02945GA	11/13/95	TRADS	TRITIUM	-30.8	PCI/L	J	Y
P207389	UP	WBR	GW02946GA	12/7/95	TRADS	AMERICIUM-241	0.01	PCI/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
P207389	UP	WBR	GW02946GA	12/7/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
P207389	UP	WBR	GW02946GA	12/7/95	TRADS	TRITIUM	296.7	PCI/L	J	Y
P207789	DN	WBR	GW02948GA	10/24/95	TRADS	TRITIUM	-63.1	PCI/L	J	Y
P207989	DN	WBR	GW02950GA	10/24/95	TRADS	TRITIUM	-117	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
P209389	UP	WBR	GW02951GA	11/13/95	TRADS	TRITIUM	412.8	PCI/L		Y
P209589	DN	WBR	GW02953GA	11/13/95	TRADS	TRITIUM	11740	PCI/L		Y
P209689	DN	WBR	GW02954GA	10/24/95	TRADS	TRITIUM	-144	PCI/L	J	Y
P210089		WBR	GW03036GA	11/13/95	TRADS	TRITIUM	33.89	PCI/L	J	Y

TABLE B-8 Anions/Water-Quality Parameters Detected in UHSU Bedrock Groundwater at the Solar Evaporation Ponds, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	V
76292		WBR	GW02943GA	10/25/95	WQPL	BICARBONATE AS CACO3	186000	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	CHLORIDE	12300	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	NITRATE/NITRITE	25800	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	SULFATE	46900	UG/L		Y
76292		WBR	GW02943GA	10/25/95	WQPL	TOTAL DISSOLVED SOLIDS	432000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	BICARBONATE AS CACO3	476000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	CHLORIDE	134000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	NITRATE/NITRITE	246	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	SULFATE	1870000	UG/L		Y
B208689		WBR	GW02944GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	4298000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	BICARBONATE AS CACO3	435000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	CHLORIDE	115000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	NITRATE/NITRITE	650	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	SULFATE	1650000	UG/L		Y
B210389		WBR	GW02945GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	3725000	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	BICARBONATE AS CACO3	305000	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	CHLORIDE	48700	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	NITRATE/NITRITE	2700	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	SULFATE	55800	UG/L		Y
P207389	UP	WBR	GW02946GA	12/7/95	WQPL	TOTAL DISSOLVED SOLIDS	480000	UG/L		
P207789	DN	WBR	GW02948GA	10/24/95	WQPL	NITRATE/NITRITE	1200	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	BICARBONATE AS CACO3	306000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	CHLORIDE	224000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	NITRATE/NITRITE	4400	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	SULFATE	315000	UG/L		Y
P207989	DN	WBR	GW02950GA	10/24/95	WQPL	TOTAL DISSOLVED SOLIDS	1210000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	BICARBONATE AS CACO3	153000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	CHLORIDE	84300	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	NITRATE/NITRITE	5620	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	SULFATE	165000	UG/L		Y
P209389	UP	WBR	GW02951GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	606000	UG/L		Y
P209589	DN	WBR	GW02953GA	11/13/95	WQPL	NITRATE/NITRITE	5210000	UG/L		Y
P209689	DN	WBR	GW02954GA	10/24/95	WQPL	NITRATE/NITRITE	56400	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	BICARBONATE AS CACO3	143000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	CHLORIDE	527000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	NITRATE/NITRITE	184000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	SULFATE	688000	UG/L		Y
P210089		WBR	GW03036GA	11/13/95	WQPL	TOTAL DISSOLVED SOLIDS	3281000	UG/L		Y

TABLE B-9 Organic Compounds Detected in Total UHSU Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
53194		ALL	GW03013GA	11/15/95	VOA524.2	METHYLENE CHLORIDE	0.40	UG/L	BJ	Y
5887	UP	ALL	GW02900GA	10/23/95	VOA524.2	TRICHLOROETHENE	0.80	UG/L	J	Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	1,1,1-TRICHLOROETHANE	27.00	UG/L	E	Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	1,1-DICHLOROETHENE	10.00	UG/L		Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	CARBON TETRACHLORIDE	1.00	UG/L		Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	CHLOROFORM	0.40	UG/L	J	Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	METHYLENE CHLORIDE	0.40	UG/L	BJ	Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	TETRACHLOROETHENE	1.00	UG/L		Y
6687		ALL	GW03049GA	11/15/95	VOA524.2	TRICHLOROETHENE	7.00	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.70	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	VOA524.2	TOTAL XYLENES	0.30	UG/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.10	UG/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	VOA524.2	CHLOROFORM	0.70	UG/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	1,1,1-TRICHLOROETHANE	43.00	UG/L		V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	1,1-DICHLOROETHANE	1.00	UG/L		V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	1,1-DICHLOROETHENE	13.00	UG/L		V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	CHLOROFORM	0.30	UG/L	J	V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	TETRACHLOROETHENE	6.00	UG/L		V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	TRICHLOROETHENE	23.00	UG/L		V1
70393	UP	ALL	GW02941GA	11/21/95	VOA524.2	cis-1,2-DICHLOROETHENE	0.40	UG/L	J	V1
70493	UP	WBR	GW03052GA	11/22/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.60	UG/L	J	V1
70493	UP	WBR	GW03052GA	11/22/95	VOA524.2	TRICHLOROETHENE	0.80	UG/L	J	V1
B206989	DN	WBR	GW02902GA	11/6/95	VOA524.2	METHYLENE CHLORIDE	2.00	UG/L	B	Y

TABLE B-10 Metals Detected in Total UHSU Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VA
53194		ALL	GW03013GA	11/15/95	DMETSOW	BARIUM	32.0	UG/L	B	Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	CALCIUM	43600.0	UG/L		Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	LITHIUM	158.0	UG/L		Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	MAGNESIUM	21700.0	UG/L		Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	POTASSIUM	1810.0	UG/L	B	Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	SELENIUM	8.8	UG/L		Y
53194		ALL	GW03013GA	11/15/95	DMETSOW	SODIUM	149000.0	UG/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	BARIUM	74.3	UG/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	CALCIUM	21900.0	UG/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	LITHIUM	8.2	UG/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	MAGNESIUM	4730.0	UG/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	POTASSIUM	1180.0	UG/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	SELENIUM	7.3	UG/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DMETSOW	SODIUM	10100.0	UG/L		Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	BARIUM	18.0	UG/L	B	Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	CALCIUM	86400.0	UG/L		Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	LITHIUM	29.9	UG/L	B	Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	MAGNESIUM	20800.0	UG/L		Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	POTASSIUM	2440.0	UG/L	B	Y
6687		ALL	GW03049GA	11/15/95	DMETSOW	SODIUM	19800.0	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	BARIUM	63.8	UG/L	B	[illegible]
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	CALCIUM	21100.0	UG/L		[illegible]
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	LITHIUM	16.8	UG/L	B	Y
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	MAGNESIUM	4060.0	UG/L	B	Y
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	NICKEL	13.3	UG/L	B	Y
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	SELENIUM	6.2	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	DMETSOW	SODIUM	9540.0	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	BARIUM	57.8	UG/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	CALCIUM	18000.0	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	LITHIUM	17.1	UG/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	MAGNESIUM	3520.0	UG/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	POTASSIUM	690.0	UG/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	SELENIUM	6.9	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	DMETSOW	SODIUM	12700.0	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	BARIUM	98.9	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	CALCIUM	32200.0	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	LITHIUM	22.4	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	MAGNESIUM	7270.0	UG/L		Y
~~70493~~	~~UP~~	~~WBR~~	~~GW03052GA~~	~~11/22/95~~	~~DMETSOW~~	~~POTASSIUM~~	~~1430.0~~	~~UG/L~~	~~J~~	~~Y~~
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	SELENIUM	16.5	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	SODIUM	17300.0	UG/L		Y

TABLE B-11 Activities of Radionuclides in Total UHSU Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
53194		ALL	GW03013GA	11/15/95	DRADS	GROSS ALPHA	15.98	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	GROSS BETA	7.688	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	RADIUM-226	0.215	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	RADIUM-228	0.743	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	URANIUM-233,-234	10.38	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	URANIUM-235	0.339	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	DRADS	URANIUM-238	6.957	PCI/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	GROSS ALPHA	0.633	PCI/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	GROSS BETA	2.182	PCI/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	RADIUM-226	0.251	PCI/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	RADIUM-228	0.398	PCI/L		Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	URANIUM-233,-234	0.024	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	URANIUM-235	0.028	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	DRADS	URANIUM-238	0.024	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	DRADS	GROSS ALPHA	0.586	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	DRADS	GROSS BETA	3.038	PCI/L		Y
6687		ALL	GW03049GA	11/15/95	DRADS	RADIUM-226	0.191	PCI/L		Y
6687		ALL	GW03049GA	11/15/95	DRADS	RADIUM-228	0.387	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	DRADS	URANIUM-233,-234	0.025	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	DRADS	URANIUM-235	0.048	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	DRADS	URANIUM-238	0.016	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	GROSS ALPHA	0.304	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	GROSS BETA	2.945	PCI/L		Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	RADIUM-226	0.159	PCI/L		Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	RADIUM-228	0.446	PCI/L		Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	URANIUM-233,-234	0.076	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	URANIUM-235	0.083	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	DRADS	URANIUM-238	-0.02	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	GROSS ALPHA	-0.012	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	GROSS BETA	2.514	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	RADIUM-226	0.271	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	RADIUM-228	0.672	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-233,-234	0.046	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-235	-0.004	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-238	-0.026	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	GROSS ALPHA	0.264	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	GROSS BETA	1.544	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	RADIUM-226	0.119	PCI/L		Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	RADIUM-228	0.249	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	URANIUM-233,-234	0.049	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	URANIUM-235	0.041	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	DRADS	URANIUM-238	0.045	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	GROSS ALPHA	1.821	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	GROSS BETA	2.433	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	RADIUM-226	0.227	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	RADIUM-228	0.562	PCI/L		Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-233,-234	0.815	PCI/L		Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-235	-0.004	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-238	0.563	PCI/L		Y
53194		ALL	GW03013GA	11/15/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
53194		ALL	GW03013GA	11/15/95	TRADS	PLUTONIUM-238	0.002	PCI/L	J	Y
53194		ALL	GW03013GA	11/15/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
53194		ALL	GW03013GA	11/15/95	TRADS	TRITIUM	136.5	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	TRADS	AMERICIUM-241	0.003	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	TRADS	PLUTONIUM-238	0.001	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	TRADS	PLUTONIUM-239/240	-0.001	PCI/L	J	Y
5887	UP	ALL	GW02900GA	10/23/95	TRADS	TRITIUM	-31.8	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	TRADS	AMERICIUM-241	0.001	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	TRADS	PLUTONIUM-239/240	0.002	PCI/L	J	Y
6687		ALL	GW03049GA	11/15/95	TRADS	TRITIUM	56.97	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	TRADS	AMERICIUM-241	0.002	PCI/L	J	Y
70093	UP	ALL	GW02903GA	11/9/95	TRADS	PLUTONIUM-238	1.022	PCI/L		Y
70093	UP	ALL	GW02903GA	11/9/95	TRADS	PLUTONIUM-239/240	0.215	PCI/L		Y
70093	UP	ALL	GW02903GA	11/9/95	TRADS	TRITIUM	63.62	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	AMERICIUM-241	0.003	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	PLUTONIUM-238	0.004	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	PLUTONIUM-239/240	0.002	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	TRITIUM	-53.4	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
70393	UP	ALL	GW02941GA	11/21/95	TRADS	TRITIUM	345.9	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	AMERICIUM-241	0.002	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	PLUTONIUM-238	0	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	PLUTONIUM-239/240	0.003	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	TRITIUM	67.75	PCI/L	J	Y
76992		ALL	GW03055GA	11/27/95	TRADS	TRITIUM	140	PCI/L	J	Y
B206989	DN	WBR	GW02902GA	11/6/95	TRADS	TRITIUM	-68.8	PCI/L	J	Y

TABLE B-12 Anions/Water-Quality Parameters Detected in Total UHSU Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
53194		ALL	GW03013GA	11/15/95	WQPL	BICARBONATE AS CACO3	414000	UG/L		Y
53194		ALL	GW03013GA	11/15/95	WQPL	CHLORIDE	22900	UG/L		Y
53194		ALL	GW03013GA	11/15/95	WQPL	NITRATE/NITRITE	118	UG/L		Y
53194		ALL	GW03013GA	11/15/95	WQPL	SULFATE	95500	UG/L		Y
53194		ALL	GW03013GA	11/15/95	WQPL	TOTAL DISSOLVED SOLIDS	653000	UG/L		Y
6687		ALL	GW03049GA	11/15/95	WQPL	BICARBONATE AS CACO3	49000	UG/L		Y
6687		ALL	GW03049GA	11/15/95	WQPL	CHLORIDE	6060	UG/L		Y
6687		ALL	GW03049GA	11/15/95	WQPL	NITRATE/NITRITE	7120	UG/L		Y
6687		ALL	GW03049GA	11/15/95	WQPL	SULFATE	231000	UG/L		Y
6687		ALL	GW03049GA	11/15/95	WQPL	TOTAL DISSOLVED SOLIDS	510000	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	WQPL	BICARBONATE AS CACO3	34900	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	WQPL	CHLORIDE	4310	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	WQPL	NITRATE/NITRITE	1920	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	WQPL	SULFATE	33300	UG/L		Y
70093	UP	ALL	GW02903GA	11/9/95	WQPL	TOTAL DISSOLVED SOLIDS	165000	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	WQPL	BICARBONATE AS CACO3	40800	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	WQPL	CHLORIDE	5400	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	WQPL	NITRATE/NITRITE	2800	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	WQPL	SULFATE	24200	UG/L		Y
70393	UP	ALL	GW02941GA	11/21/95	WQPL	TOTAL DISSOLVED SOLIDS	166000	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	BICARBONATE AS CACO3	122000	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	CHLORIDE	2700	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	NITRATE/NITRITE	2000	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	SULFATE	11400	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	TOTAL DISSOLVED SOLIDS	210000	UG/L		Y
B206989	DN	WBR	GW02902GA	11/6/95	WQPL	NITRATE/NITRITE	29300	UG/L		Y

TABLE B-13 Organic Compounds Detected in UHSU Bedrock Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VA
70193	UP	WBR	GW02940GA	12/18/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.1	UG/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	VOA524.2	CHLOROFORM	0.7	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	VOA524.2	1,1,1-TRICHLOROETHANE	0.6	UG/L	J	V1
70493	UP	WBR	GW03052GA	11/22/95	VOA524.2	TRICHLOROETHENE	0.8	UG/L	J	V1
B206989	DN	WBR	GW02902GA	11/6/95	VOA524.2	METHYLENE CHLORIDE	2.0	UG/L	B	Y

TABLE B-14 Metals Detected in UHSU Bedrock Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	BARIUM	98.9	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	CALCIUM	32200	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	LITHIUM	22.4	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	MAGNESIUM	7270	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	POTASSIUM	1430	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	SELENIUM	16.5	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DMETSOW	SODIUM	17300	UG/L		Y

TABLE B-15 Activities of Radionuclides in UHSU Bedrock Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
70193	UP	WBR	GW02940GA	12/18/95	DRADS	GROSS ALPHA	-0.012	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	GROSS BETA	2.514	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	RADIUM-226	0.2705	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	RADIUM-228	0.6716	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-233,-234	0.0463	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-235	-0.0044	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	DRADS	URANIUM-238	-0.0264	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	GROSS ALPHA	1.821	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	GROSS BETA	2.433	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	RADIUM-226	0.2272	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	RADIUM-228	0.5624	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-233,-234	0.8152	PCI/L		Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-235	-0.0041	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	DRADS	URANIUM-238	0.5632	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	AMERICIUM-241	0.0027	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	PLUTONIUM-238	0.0037	PCI/L		Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	PLUTONIUM-239/240	0.0019	PCI/L	J	Y
70193	UP	WBR	GW02940GA	12/18/95	TRADS	TRITIUM	-53.4	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	AMERICIUM-241	0.0018	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	PLUTONIUM-238	-0.0005	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	PLUTONIUM-239/240	0.003	PCI/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	TRADS	TRITIUM	67.75	PCI/L	J	Y
B206989	DN	WBR	GW02902GA	11/6/95	TRADS	TRITIUM	-68.8	PCI/L	J	Y

TABLE B-16 Anions/Water-Quality Parameters Detected in UHSU Bedrock Groundwater at the Present Landfill, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VA
70493	UP	WBR	GW03052GA	11/22/95	WQPL	BICARBONATE AS CACO3	122000	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	CHLORIDE	2700	UG/L	J	Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	NITRATE/NITRITE	2000	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	SULFATE	11400	UG/L		Y
70493	UP	WBR	GW03052GA	11/22/95	WQPL	TOTAL DISSOLVED SOLIDS	210000	UG/L		Y
B206989	DN	WBR	GW02902GA	11/6/95	WQPL	NITRATE/NITRITE	29300	UG/L		Y

TABLE B-17 Organic Compounds Detected in UHSU Groundwater at the West Spray Field, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B110989	DN	ALL	GW02765GA	9/25/95	VOA524.2	METHYLENE CHLORIDE	0.2	UG/L	JB	Y
B410789	DN	ALL	GW02709GA	9/25/95	VOA524.2	METHYLENE CHLORIDE	0.2	UG/L	JB	Y
P114589		ALL	GW02909GA	11/13/95	VOA524.2	METHYLENE CHLORIDE	6	UG/L	B	Y
P114589		ALL	GW02909GA	11/13/95	VOA524.2	TRICHLOROFLUOROMETHANE	2	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	VOA524.2	CHLOROFORM	34	UG/L	E	Y
P416289		ALL	GW02926GA	11/6/95	VOA524.2	METHYLENE CHLORIDE	3	UG/L	B	Y
P416589		ALL	GW02928GA	10/18/95	VOA524.2	CHLOROFORM	0.09	UG/L	J	V1
P416589		ALL	GW02928GA	10/18/95	VOA524.2	TETRACHLOROETHENE	0.3	UG/L	J	V1

76

TABLE B-18 Metals Detected in UHSU Groundwater at the West Spray Field, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	ANTIMONY	21.4	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	BARIUM	53.5	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	BARIUM	52	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	BERYLLIUM	0.74	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	CALCIUM	20200	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	CALCIUM	20100	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	COPPER	3.8	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DMETADD	LITHIUM	3.8	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DMETADD	LITHIUM	3.8	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	MAGNESIUM	4290	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	MAGNESIUM	4240	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	POTASSIUM	572	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	POTASSIUM	537	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DMETADD	SILICON	12300	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DMETADD	SILICON	12200	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	SODIUM	16600	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	SODIUM	16700	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	DMETADD	STRONTIUM	121	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DMETADD	STRONTIUM	115	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	THALLIUM	8.1	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	THALLIUM	6.5	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	VANADIUM	3.3	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DSMETCLP	ZINC	2.8	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DSMETCLP	ZINC	2.3	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	ANTIMONY	18.9	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	BARIUM	79.1	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	BERYLLIUM	0.74	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	CALCIUM	46900	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DMETADD	LITHIUM	4.1	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	MAGNESIUM	8940	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DMETADD	MOLYBDENUM	6.2	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	POTASSIUM	599	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DMETADD	SILICON	10900	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DSMETCLP	SODIUM	12400	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DMETADD	STRONTIUM	239	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	BARIUM	56.5	UG/L	B	Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	CALCIUM	29400	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	CHROMIUM	4.2	UG/L	B	Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	LITHIUM	19	UG/L	B	Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	MAGNESIUM	4320	UG/L	B	Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	POTASSIUM	2680	UG/L	B	Y
P416289		ALL	GW02926GA	11/6/95	DMETSOW	SODIUM	91400	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	ALUMINUM	21.3	UG/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	BARIUM	113	UG/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	CALCIUM	74000	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DMETADD	LITHIUM	6.7	UG/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	MAGNESIUM	11000	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	MERCURY	0.08	UG/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	POTASSIUM	947	UG/L	J	Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
P416589		ALL	GW02928GA	10/18/95	DMETADD	SILICON	9770	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	SODIUM	10200	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DMETADD	STRONTIUM	330	UG/L		Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	THALLIUM	7.2	UG/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DSMETCLP	ZINC	8.2	UG/L	J	Y

TABLE B-19 Activities of Radionuclides in UHSU Groundwater at the West Spray Field, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	CESIUM-134	-0.45	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	CESIUM-134	-0.315	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	CESIUM-137	0.194	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	CESIUM-137	0.288	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	GROSS ALPHA	2.065	PCI/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	GROSS ALPHA	1.107	PCI/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	GROSS BETA	3.221	PCI/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	GROSS BETA	3.121	PCI/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	STRONTIUM-89,90	0.256	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	STRONTIUM-89,90	0.411	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	URANIUM-233,-234	0.176	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	URANIUM-233,-234	0.123	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	URANIUM-235	0.038	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	URANIUM-235	-0.011	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	DRADS	URANIUM-238	0.194	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	DRADS	URANIUM-238	0.17	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	CESIUM-134	0.034	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	CESIUM-137	0.191	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	GROSS ALPHA	1.49	PCI/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	GROSS BETA	2.892	PCI/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	STRONTIUM-89,90	0.718	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	URANIUM-233,-234	0.611	PCI/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	URANIUM-235	-0.014	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	DRADS	URANIUM-238	0.484	PCI/L		Y
P416289		ALL	GW02926GA	11/6/95	DRADS	GROSS ALPHA	7.799	PCI/L		Y
P416289		ALL	GW02926GA	11/6/95	DRADS	GROSS BETA	4.714	PCI/L		Y
P416289		ALL	GW02926GA	11/6/95	DRADS	RADIUM-226	0.302	PCI/L		Y
P416289		ALL	GW02926GA	11/6/95	DRADS	URANIUM-233,-234	9.51	PCI/L		Y
P416289		ALL	GW02926GA	11/6/95	DRADS	URANIUM-235	0.051	PCI/L	J	Y
P416289		ALL	GW02926GA	11/6/95	DRADS	URANIUM-238	1.931	PCI/L		Y
P416589		ALL	GW02928GA	10/18/95	DRADS	GROSS ALPHA	0.96	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DRADS	GROSS BETA	0.523	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DRADS	RADIUM-226	0.129	PCI/L		Y
P416589		ALL	GW02928GA	10/18/95	DRADS	RADIUM-228	0.361	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DRADS	URANIUM-233,-234	1.058	PCI/L		Y
P416589		ALL	GW02928GA	10/18/95	DRADS	URANIUM-235	-0.037	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	DRADS	URANIUM-238	0.125	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	TRADS	AMERICIUM-241	0.001	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	TRADS	AMERICIUM-241	0.003	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	TRADS	PLUTONIUM-238	0.001	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	TRADS	PLUTONIUM-238	-0.001	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	TRADS	PLUTONIUM-239/240	-0.001	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	TRADS	PLUTONIUM-239/240	0	PCI/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	TRADS	TRITIUM	129.7	PCI/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	TRADS	TRITIUM	9.743	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	TRADS	AMERICIUM-241	-0.001	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	TRADS	PLUTONIUM-238	-0.001	PCI/L	J	Y

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B410789	DN	ALL	GW02709GA	9/25/95	TRADS	PLUTONIUM-239/240	-0.001	PCI/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	TRADS	TRITIUM	-59	PCI/L	J	Y
P114589		ALL	GW02909GA	11/13/95	TRADS	TRITIUM	101.6	PCI/L	J	Y
P416289		ALL	GW02926GA	11/6/95	TRADS	AMERICIUM-241	0.005	PCI/L	J	Y
P416289		ALL	GW02926GA	11/6/95	TRADS	PLUTONIUM-238	0.003	PCI/L	J	Y
P416289		ALL	GW02926GA	11/6/95	TRADS	PLUTONIUM-239/240	0.001	PCI/L	J	Y
P416289		ALL	GW02926GA	11/6/95	TRADS	TRITIUM	2.566	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	TRADS	AMERICIUM-241	0	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	TRADS	PLUTONIUM-238	0.001	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	TRADS	PLUTONIUM-239/240	-0.001	PCI/L	J	Y
P416589		ALL	GW02928GA	10/18/95	TRADS	TRITIUM	168.8	PCI/L	J	Y

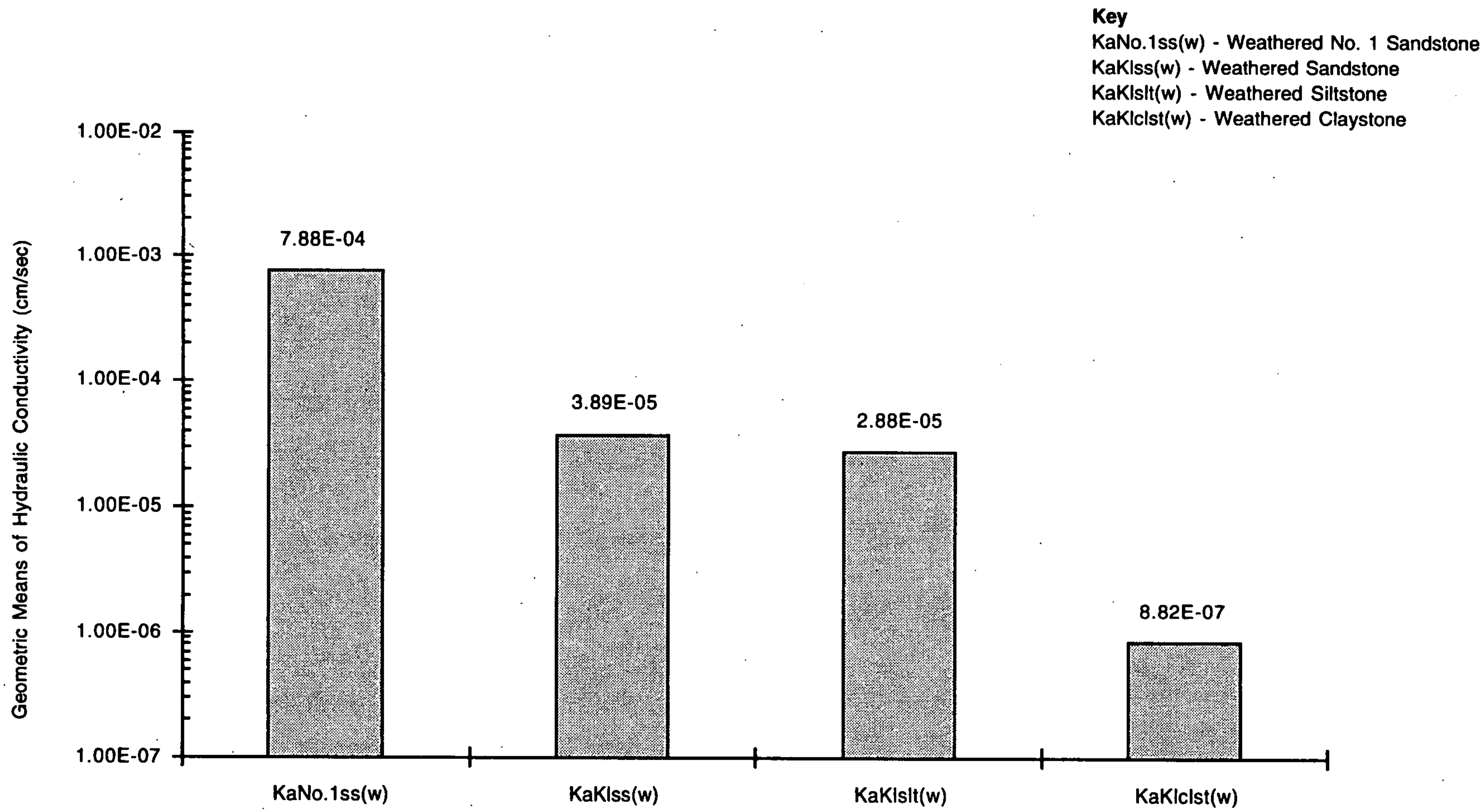
TABLE B-20 Anions/Water-Quality Parameters Detected in UHSU Groundwater at the West Spray Field, 4th Quarter, 1995

LOCATION	GRAD	STRAT	SAMPLE	SDATE	GROUP	ANALYTE	RESULT	UNITS	QUAL	VAL
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	BICARBONATE AS CACO3	76400	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	BICARBONATE AS CACO3	77100	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	CHLORIDE	7100	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	CHLORIDE	6900	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	FLUORIDE	260	UG/L	J	Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	FLUORIDE	250	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	NITRATE/NITRITE	1100	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	NITRATE/NITRITE	1100	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	SPECIFIC CONDUCTIVITY	201	UMHOS/CM		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	SPECIFIC CONDUCTIVITY	202	UMHOS/CM		Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	SULFATE	7400	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	SULFATE	7400	UG/L		Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	TOTAL DISSOLVED SOLIDS	147000	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	TOTAL DISSOLVED SOLIDS	154000	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	TOTAL ORGANIC CARBON	810	UG/L	J	Y
B110989	DN	ALL	GW02762GA	9/25/95	WQPL	TOTAL SUSPENDED SOLIDS	62800	UG/L		Y
B110989	DN	ALL	GW02765GA	9/25/95	WQPL	TOTAL SUSPENDED SOLIDS	57600	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	BICARBONATE AS CACO3	110000	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	CHLORIDE	20600	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	FLUORIDE	370	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	NITRATE/NITRITE	3800	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	SPECIFIC CONDUCTIVITY	354	UMHOS/CM		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	SULFATE	16200	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	TOTAL DISSOLVED SOLIDS	222000	UG/L		Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	TOTAL ORGANIC CARBON	930	UG/L	J	Y
B410789	DN	ALL	GW02709GA	9/25/95	WQPL	TOTAL SUSPENDED SOLIDS	16400	UG/L		Y
P114589		ALL	GW02909GA	11/13/95	WQPL	NITRATE/NITRITE	686	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	WQPL	BICARBONATE AS CACO3	174000	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	WQPL	CHLORIDE	29700	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	WQPL	NITRATE/NITRITE	4930	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	WQPL	SULFATE	41300	UG/L		Y
P416289		ALL	GW02926GA	11/6/95	WQPL	TOTAL DISSOLVED SOLIDS	334000	UG/L		Y

APPENDIX C

RESULTS OF STATISTICAL COMPARISONS
(On Diskette)

82



EG&G ROCKY FLATS

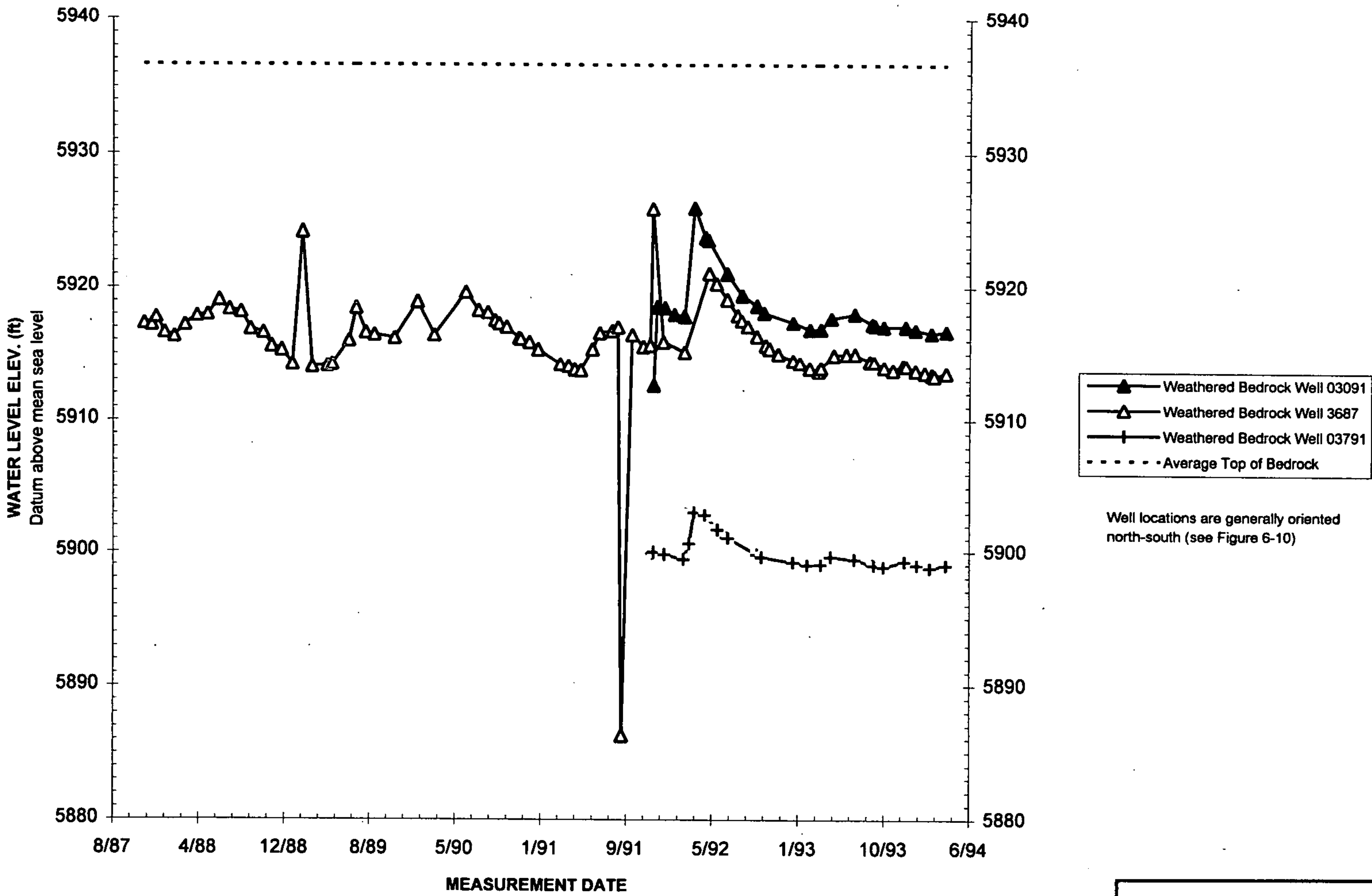
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Weathered Bedrock Units at the Rocky Flats Site

Hydrogeologic Characterization Report

April 1995	Figure 6-9

26



EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

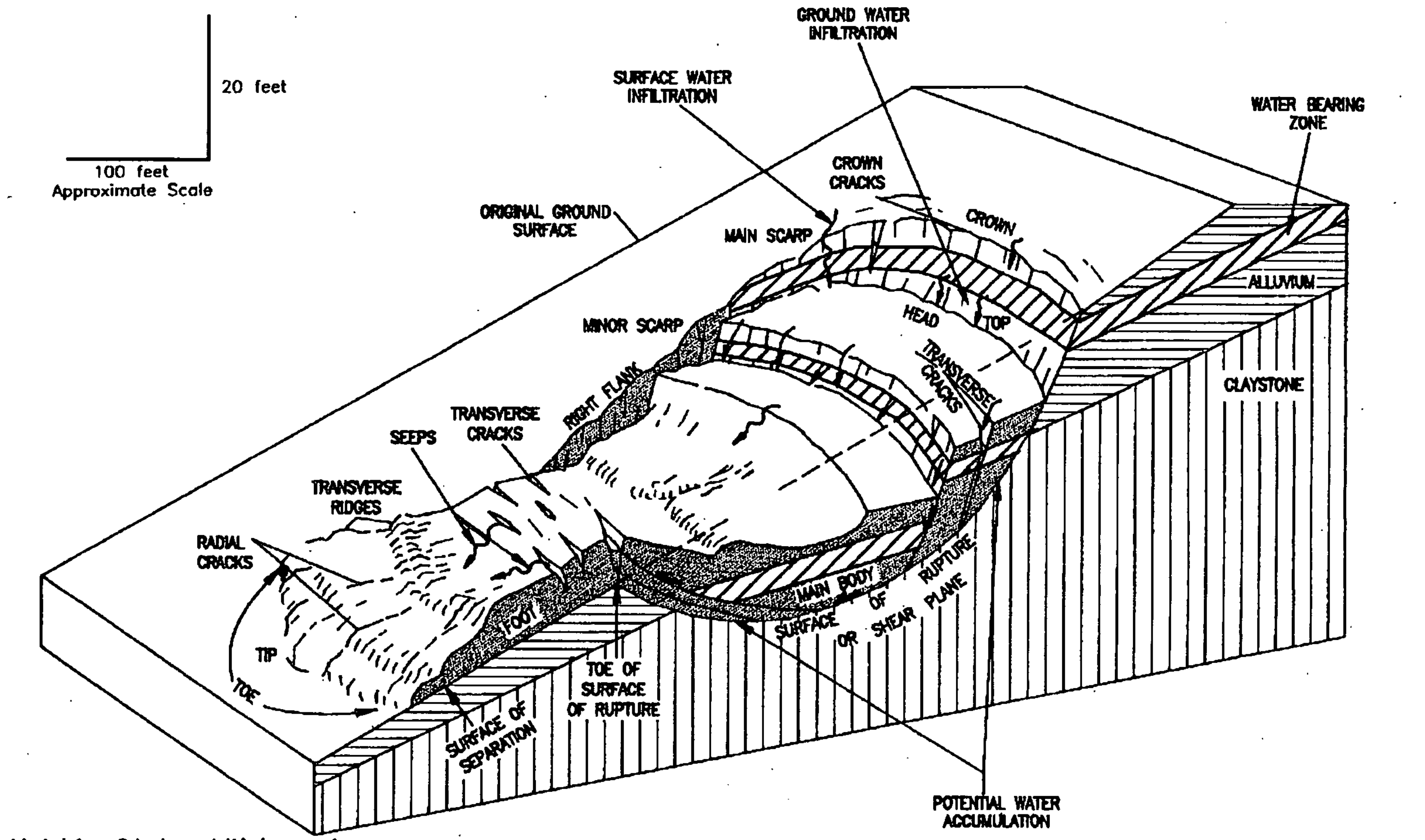
Hydrograph of Arapahoe Sandstone Wells

Hydrogeologic Characterization Report

April 1995	Figure 6-12

g95\es\hydrodoc\hydrodoc graphs.cdw

94



Adapted from Schuster and Krizek, see references.

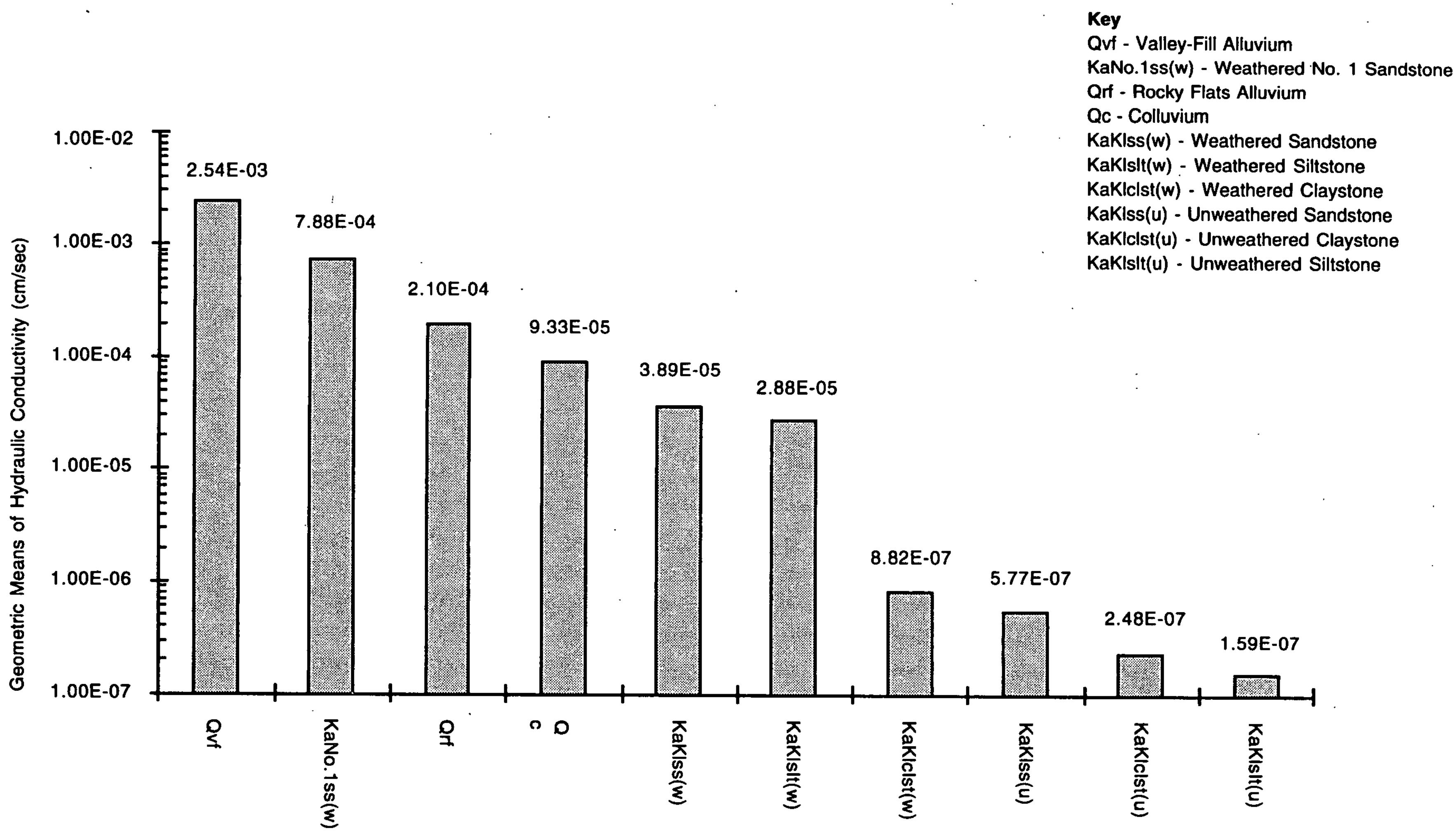
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Potential Hydrogeologic Conditions of a Typical Slump

Hydrogeologic Characterization Report

April 1995	Figure 6-14

g95\es\hydrodocctypical slump.cdw



EG&G ROCKY FLATS

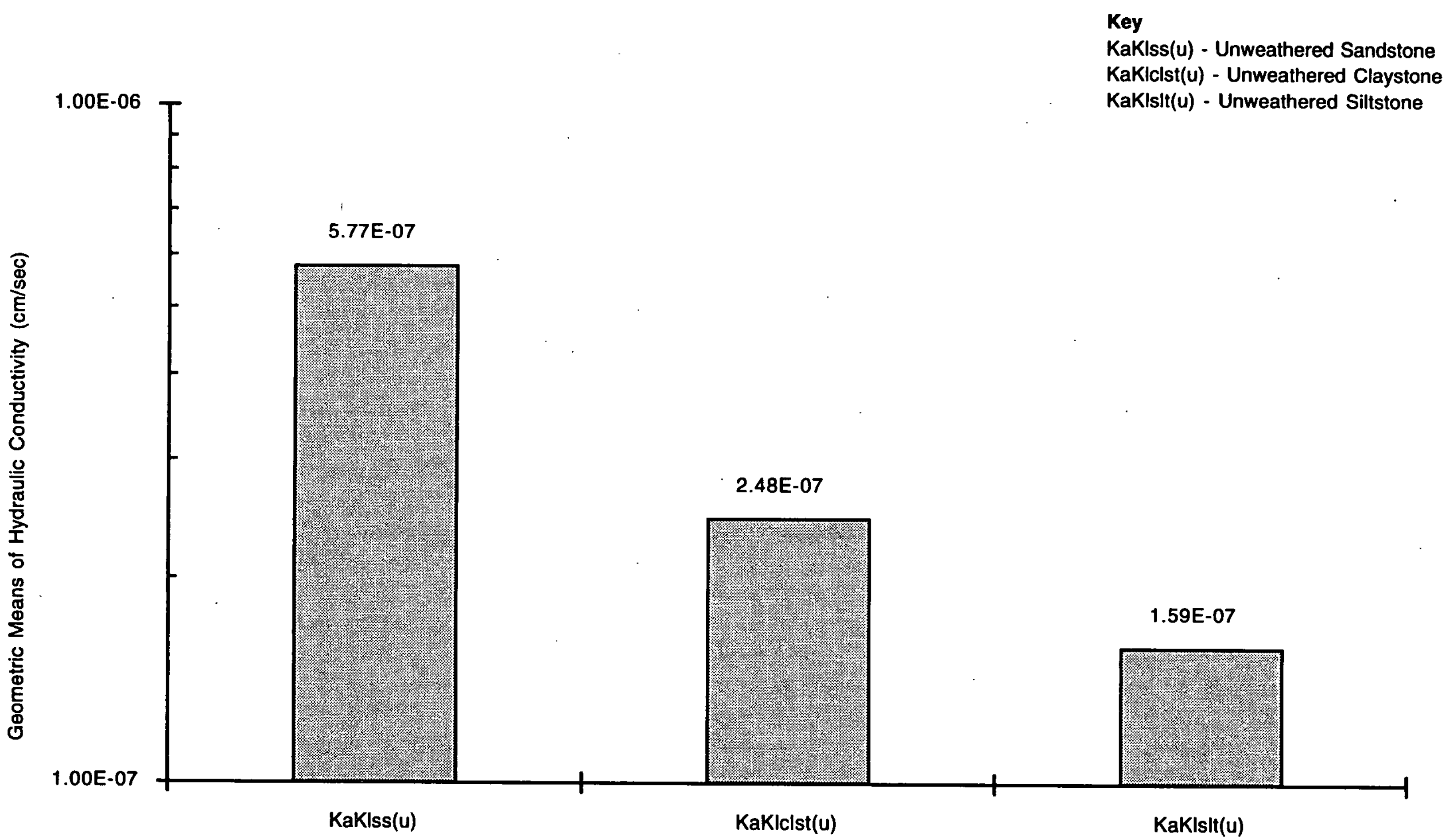
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Different Lithologic Units at the Rocky Flats Site

Hydrogeologic Characterization Report

April 1995	Figure 6-18

102



EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Unweathered Bedrock Units at the Rocky Flats Site

Hydrogeologic Characterization Report

April 1995	Figure 6-20

m\es\hydrodoc\hydrodoc graphs.mdw\10-11-94

7. Recommendations for Additional Groundwater Studies

The following recommendations were compiled to guide future hydrogeologic characterization studies at Rocky Flats. These recommendations address sites that are important for hydrogeologic characterization, potential groundwater pathways for offsite contaminant migration, and characterization of the groundwater flow system at Rocky Flats. This information will be useful for designing groundwater remediation systems at Rocky Flats.

- The influence of the Laramie/Fox Hills subcrop on groundwater flow is unknown. This feature may inhibit groundwater flow in the western portion of the Rocky Flats site and result in lower groundwater levels in the OU11 area. Shallow seismic refraction techniques would be useful for delineating the subcrop and would provide preliminary data useful for designing a drilling program for characterizing the impact of the subcrop on groundwater flow. This characterization will also assist with sitewide groundwater modeling and water-balance efforts.

- The lower drainages, below the terminal ponds in Walnut Creek and Woman Creek, are the primary pathways for offsite migration of contaminated groundwater. However, groundwater flow in these areas is not well characterized. Groundwater wells should be installed to characterize the nature of groundwater flow in the lower drainages below the terminal ponds and to provide sufficient information to determine the groundwater flux across the Indiana Street boundary.

- Nested piezometers should be installed to investigate vertical groundwater flow using screen intervals specifically designed for determining the vertical distribution of head in surficial deposits, weathered bedrock, and unweathered bedrock. These data would be useful for constructing two-dimensional flow net models characterizing the nature of groundwater flow within and between pediments, hillsides, and stream drainages. These data could also be used to characterize vertical groundwater flow within the LHSU.

- The hydrogeologic significance of fault and fracture flow should be investigated. These data would be useful for determining if faults and fractures represent significant pathways for offsite contaminant transport.

- Well logs, geologic logs, and well-construction information should be published as controlled documents so that accurate information is readily available.

8. References

Abriola, L.M., and Pinder, G.F., 1982, Calculation of velocity in three space dimensions from hydraulic head measurements: *Ground Water*, Vol. 20, No. 2.

ASI (Advanced Sciences, Inc.), 1990, Wetlands Assessment Rocky Flats Site: ASI Project No. 667, Task 12.

ASI (Advanced Sciences, Inc.), 1991, Sanitary Sewer Infiltration/Inflow and Exfiltration Study, Task 1 of the Zero-Offsite Water-Discharge Study: Prepared for EG&G Rocky Flats, Inc., Golden, Colorado.

Barbour, M.G., J.H. Burk, and W.D. Pitts, 1987, *Terrestrial Plant Ecology*: The Benjamin/Cummings Publishing Company, Menlo Park, Ca., 634 p.

Boss, M. R., 1973, Well Sampling at Rocky Flats: Including a Summary of Data Collected During 1972, Rocky Flats, Golden, Colorado. July 11.

Bouwer, H., and R.C. Rice, 1976, A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells: *Water Resources Research*, Vol. 12, No. 3.

Clark, S.V., P.J. Weber, V. Komarkova, and W.A. Weber, 1980, Map of mixed prairie grassland vegetation, Rocky Flats, Colorado: Institute of Arctic and Alpine Research, University of Colorado, Boulder, Occasional Paper No. 35.

Colton, R.B. and R.L. Lowrie, 1973, Map showing mined areas of the Boulder-Weld coal field, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-513.

Colton, R.B., 1978, Geologic map of the Boulder-Fort Collins-Greeley area, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Greater Denver Area, Colorado Map I-855-G.

Davis, S.N., and R.J.M. DeWiest, 1966, *Hydrogeology*: John Wiley and Sons, New York, 463 p.

DOE (U.S. Department of Energy), 1987, Phase I Remedial Investigation, 903 Pad, Mound, and East Trenches, Operable Unit No. 2, Medium Priority Sites.

DOE (U.S. Department of Energy), 1989a, Agreement in Principle (AIP) Between the United States Department of Energy and the State of Colorado: Rocky Flats Plant, Golden, Colorado, August.

DOE (U.S. Department of Energy), 1989b, Ground-Water Assessment Plan, Rocky Flats Plant: U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, September.

DOE (U.S. Department of Energy), 1991, Final Phase II RFI/RI Work Plan (Alluvial) Revision 1, 903 Pad, Mound, and East Trenches Areas (Operable Unit No. 2): February.

DOE (U.S. Department of Energy), 1992a, Baseline Biological Characterization of the Terrestrial and Aquatic Habitats at Rocky Flats Plant, Final Report.

DOE (U.S. Department of Energy), 1992b, Final Phase I RFI/RI Work Plan - Woman Creek Priority Drainage (Operable Unit No. 5): U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, February.

DOE (U.S. Department of Energy), 1992c, Phase I RFI/RI Work Plan for Operable Unit No. 6 - Walnut Creek Priority Drainage: Manual No. 21100-WP-OU 6.01, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1992d, Draft Final Phase III RFI/RI - Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1): Golden, Colorado, October.

DOE (U.S. Department of Energy), 1992e, Historical Release Report for the Rocky Flats Plant: U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1993a, Final Groundwater Assessment Plan: U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1993b, Phase II RFI/RI Report, 903 Pad, Mound and East Trenches Area, Operable Unit No. 2, Preliminary Draft: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1994a, Technical Memorandum Revised Work Plan Operable Unit No. 7 - Present Landfill and Inactive Hazardous Waste Storage Area. May.

DOE (U.S. Department of Energy), 1994b, Draft Final Phase I RFI/RI Report Operable Unit No. 4: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

106

DOE (U.S. Department of Energy), 1994c, Operable Unit No. 4 Draft Phase II RFI/RI Work Plan: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1994d, Technical Memorandum, Revised Field Sampling Plan and Data Quality Objectives, the West Spray Field (IHSS 168), Operable Unit No. 11: June.

DOE (U.S. Department of Energy), 1994e, Technical Memorandum, Final Work Plan, Operable Unit No. 7 - Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203): September.

DOE (U.S. Department of Energy), 1994f, Operable Unit No. 4 Solar Evaporation Ponds IM/IRA Environmental Assessment Decision Document, Revision, Proposed Draft, Part II: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1994g, Final Phase III RFI/RI Rocky Flats Plant 881 Hillside (Operable Unit No. 1): June.

DOE (U.S. Department of Energy), 1994h, Proposed IM/IRA Decision Document for the Rocky Flats Industrial Area, Draft Final: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

DOE (U.S. Department of Energy), 1994i, Draft Technical Memorandum – Operable Unit No. 8: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Duffield, G.M., and J.O. Rumbaugh, 1991, Geraghty & Miller's AQTESOLV Aquifer Test Solver, Version 1.00 Documentation: Geraghty & Miller, Inc.

EG&G (EG&G Rocky Flats, Inc.), 1990a, French Drain Geotechnical Investigation.

EG&G (EG&G Rocky Flats, Inc.), 1990b, General Radiochemistry and Routine Analytical Service Protocol: revised October 1993.

EG&G (EG&G Rocky Flats, Inc.), 1991a, Draft Rocky Flats Surface Water Management Plan, Volume 1: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1991b, Geologic Characterization Report: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1991c, Final Groundwater Protection and Monitoring Program Plan: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1991d, EG&G Environmental Management Department, Volume II, Groundwater: Manual No. 5-21000-OPS-GW.

EG&G (EG&G Rocky Flats, Inc.), 1991e, EG&G Environmental Management Department, Volume III, Groundwater: Manual No. 5-21000-OPS-GT.

EG&G (EG&G Rocky Flats, Inc.), 1992a, 1990 Surface Water and Sediment Geochemical Characterization Report: March 17.

EG&G (EG&G, Rocky Flats, Inc.), 1992b, Phase II Geologic Characterization Data Acquisition Report: Task 6 - Surface Geologic Mapping of the Rocky Flats Plant and Vicinity, Jefferson and Boulder Counties, Colorado: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1992c, 1991 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1992d, 1989 Surface-Water and Sediment Geochemical Characterization Report, Final: April 1.

EG&G (EG&G Rocky Flats, Inc.), 1993a, Rocky Flats Plant Site Environmental Report, January through December 1992: Prepared for U.S. Department of Energy.

EG&G (EG&G Rocky Flats, Inc.), 1993b, Event-Related Surface-Water Monitoring Report, Rocky Flats Plant, Water Years 1991 and 1992: November.

EG&G (EG&G Rocky Flats, Inc.), 1993c, Groundwater Protection and Monitoring Program Plan for Rocky Flats Plant: Golden, Colorado, October 31.

EG&G (EG&G Rocky Flats, Inc.), 1993d, Groundwater Monitoring Plan for the New Sanitary Landfill: Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1993e, Interim Report, Groundwater Recharge Study, Rocky Flats Plant: Golden, Colorado, October 31.

EG&G (EG&G Rocky Flats, Inc.), 1993f, 1992 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1993g, Geotechnical Engineering Report for Geotechnical Analysis of Earthen Dams A-3, B-1, B-3, and Landfill Dam: EG&G, Golden, Colorado, January.

EG&G (EG&G Rocky Flats, Inc.), 1993h, Map, Woman Creek Infiltration/Exfiltration Summary Plate, SWD: June.

EG&G (EG&G Rocky Flats, Inc.), 1993i, SWD Field Report Series - 1993, Internal Report: Golden, Colorado, April.

EG&G (EG&G Rocky Flats, Inc.), 1994a, Final 1993 Well Evaluation Report: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats Inc.), 1994b, 1993 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant: Prepared for U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1994c, Groundwater Monitoring Plan for the Rocky Flats Plant: Rocky Flats Plant, Golden, Colorado.

EG&G (EG&G Rocky Flats, Inc.), 1994d, Analyses of Aquifer Tests, EOM-94-0007-UN, September.

EG&G (EG&G Rocky Flats, Inc.), 1994e, Event-Related Surface-Water Monitoring Report: Draft, Environmental Protection Management, August.

EG&G (EG&G Rocky Flats, Inc.), 1995a, Geologic Characterization Report for the Rocky Flats Environmental Technology Site, Draft, Volume I of the Sitewide Geoscience Characterization Study: EG&G Rocky Flats, Inc., Rocky Flats Environmental Technology Site, Golden, Colorado, December 1994.

EG&G (EG&G Rocky Flats, Inc.), 1995b, Groundwater Geochemistry Report for the Rocky Flats Environmental Technology Site, Final Report, Volume III of the Sitewide Geoscience Characterization Study: EG&G Rocky Flats, Inc., Rocky Flats Environmental Technology Site, Golden, Colorado, January.

EPA (U.S. Environmental Protection Agency), 1986, RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD): September.

ERDA (Energy Research and Development Administration), 1980, Final Environmental Impact Statement (DOE/EIS-0064 [ERDA 1545-D]): Rocky Flats Plant, Golden, Colorado.

Fedors, R., and J.W. Warner, 1993, Characterization of Physical and Hydraulic Properties of Surficial Materials and Groundwater/Surface Water Interaction Study at Rocky Flats Plant, Golden, Colorado: Colorado State University, Fort Collins, Colorado.

Fetter, C.W., Jr., 1988, *Applied Hydrogeology*, (2nd ed.): Merrill Publishing Company Columbus, Ohio.

Fox Consultants, 1984, Task 3 Site Characterization and Contaminant Migration Report for the Active Boulder and Inactive Marshall Landfills, Boulder, County, Colorado, Addendum, Response to Comments and Evaluation of 1984 Field and Laboratory Results: Prepared for Landfill, Inc., Denver, Colorado.

Freeze, R.A., and J.A. Cherry, 1979, *Groundwater*: Prentice-Hall, Inc., Englewood Cliffs, NJ.

Grigsby, S.F., 1994, EG&G Rocky Flats, Inc., Personal Communication.

Hillier, D.E., and P.A. Schneider, Jr., 1979a, Depth to water table in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-855-L.

Hillier, D.E. and P.A. Schneider, Jr., 1979b, Well yields and chemical quality of water from water-table aquifers in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-855-J.

Hillier, D.E., P.A. Schneider, Jr., and E.C. Hutchinson, 1983a, Depth to water table in the greater Denver area, Front Range Urban Corridor, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-856-J.

Hillier, D.E., P.A. Schneider, Jr., and E.C. Hutchinson, 1983b, Well yields and chemical quality of water from water-table aquifers in the greater Denver area, Front Range Urban Corridor, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-856-J.

Hvorslev, H.J., Time Lag and Soil Permeability in Ground Water Observations.

Hunt, C.B., 1954, Pleistocene and Recent deposits in the Denver area, Colorado: U.S. Geological Survey Bulletin 996-C, p. 91-140.

Hurr, R. T., 1976, Hydrology of a nuclear-processing plant site, Rocky Flats, Jefferson County, Colorado: U.S. Geological Survey Open-File Report 76-268.

Hurr, R.T. and P.A. Schneider, 1972, Hydrologic characteristics of the valley-fill aquifer in the Brighton reach of the South Platte River valley, Colorado: U.S. Geological Survey Open- File Report 72-332.

Hydro-Search, Inc., 1986, Geological and Hydrogeological Data Summary, Rocky Flats Plant, Golden, Colorado: Prepared for the U.S. Department of Energy.

Illsley, C. T., 1976, Letter to Jerry Lackey of EG&G, Analyses of Waters From Deep Wells: January 9.

Jamieson, W.R., and D.W. Stearns, 1982, Tectonic deformations of the Wingate Sandstone, Colorado National Monument: *American Association of Petroleum Geologists Bulletin*, v. 66, p. 2584-2608.

Koffer, J.P., 1989, Investigation of the surface and groundwater flow mechanics on an evaporation spray field at the Rocky Flats Nuclear Weapons Plant, Jefferson County, Colorado: Thesis - Colorado School of Mines.

Lovseth, T.P., 1994, Personal Communication.

Malde, H.E., 1955, Surficial geology of the Louisville quadrangle, Colorado: U.S. Geological Survey Bulletin 996-E, p. 217-259.

McConaghy, J.A., G.H. Chase, A.J. Boettcher, and T.J. Major, 1964, Hydrogeologic data for the Denver Basin, Colorado: Colorado Water Conservation Board Basic-Data Report 15.

McWhorter, D., and D.K. Sunada, 1977, *Ground-Water Hydrology and Hydraulics*: Water Resources Publications, Fort Collins, CO.

Merrick & Company, 1991, Preliminary Conceptual Design Document for Sanitary Land Fill: April.

Mitsch, W.J. and J.G. Gosselink, 1986, *Wetlands*: Van Nostrand Reinhold, New York.

Norris, J.M., S.G. Robson, and R.S. Parker, 1985, Summary of hydrologic information for the Denver coal region, Colorado: U.S. Geological Survey Water-Resources Investigations Report 84-4337.

Ramey, Jr., H. J., R.G. Agarwal, and I. Martin, 1975, Analysis of Slug Test or DST Flow Period Data: *Jour. Can. Pet. Tech.*, p. 37-42.

111

Robson, S.G., 1983, Hydraulic characteristics of the principal bedrock aquifers in the Denver Basin, Colorado: U.S. Geological Survey Hydrogeologic Investigations Atlas HA-659.

Robson, S.G., 1987, Bedrock aquifers in the Denver Basin, Colorado - A quantitative water-resources appraisal: U.S. Geological Survey Professional Paper 1257.

Robson, S.G., 1989, Alluvial and bedrock aquifers of the Denver Basin - Eastern Colorado's dual groundwater resource: U.S. Geological Survey Water-Supply Paper 2302.

Robson, S.G., 1994: U.S. Geological Survey, Personal Communication.

Robson, S.G., and E.R. Banta, 1987, Geology and hydrology of deep bedrock aquifers in eastern Colorado: U.S. Geological Survey Water-Resources Investigation Report 85-4240.

Robson, S.G., J.C. Romero, and A. Wacinski, 1981a, Geologic structure, hydrology, and water quality of the Arapahoe aquifer in the Denver Basin, Colorado: U.S. Geological Survey Hydrogeologic Investigations Atlas HA-647.

Robson, S.G., A. Wacinski, S. Zawistowski, and J.C. Romero, 1981b, Geologic structure, hydrology, and water quality of Laramie-Fox Hills aquifer in the Denver Basin, Colorado: U.S. Geological Survey Hydrogeologic Investigations Atlas Map HA-650.

Rockwell International, 1986a, Geological and Hydrogeological Data Summary, Rocky Flats Plant.

Rockwell International, 1986b, Resource Conservation and Recovery Act Part B - Operating Permit Application for U.S. Department of Energy, Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes (CO7890010526): November.

Rockwell International, 1987, Remedial Investigation Report for 903 Pad, Mound, and East Trenches Area.

Rockwell International, 1988, Groundwater Monitoring at Regulated Units: Rocky Flats Plant, Golden, Colorado, March.

Romero, J.C., 1976, Ground-water resources of the bedrock aquifers of the Denver Basin, Colorado: Colorado Division of Water Resources.

Romero, J.C., and H.C. Bainbridge, 1993, Water levels in the Denver Basin aquifers - spring 1993: Office of the State Engineer, Division of Water Resources.

Schneider, P.A., 1980, Water-supply assessment of the Laramie-Fox Hills aquifer in parts of Adams, Boulder, Jefferson, and Weld counties, Colorado: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-327.

Schuster, R.L., and R.J. Krizek, eds., 1978, Landslides analysis and control: in: Special Report 176, Transportation Research Board, Commission on Sociotechnical System, National Research Council, National Academy of Sciences, Washington, D.C.

Smith, R., 1994, EG&G Rocky Flats, Inc., Personal Communication.

Tipton & Kalmbach, Inc., 1989, Engineering Report, Change of Water Rights for the City of Westminster: Case Nos. 86CW397, 88CW267, and 89CW397.

Trimble, D.E., and M.N. Machette, 1979, Geologic map of the greater Denver area, Front Range Urban Corridor, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Greater Denver Area, Colorado Map I-856-H.

U.S. Army Corps of Engineers. 1994. Rocky Flats Plant Wetlands Mapping and Resource Study: Prepared for U.S. Department of Energy, Golden, Colorado. December.

Varnes, D.J., 1978, Slope movement types and process: in R.L. Schuster and R.J. Krizek, eds., Landslides, Analysis, and Control, National Academy of Sciences, Transportation Research Board Special Report 176, p. 11-33.

40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal Facilities, Subpart B (1994), General Facility Standards.

40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal Facilities, Subpart F (1994), Releases from Solid Waste Management Units.

40 CFR 191.12 (I), Protection of Environment, Subpart B, Environmental Standards for Disposal.

42 USC 6928 (1992), Resource Conservation Recovery Act, Federal Enforcement.

9. Glossary of Terms

alluvial
: Pertaining to or composed of alluvium or deposited by a stream or running water.

alluvium
: A general term for clay, silt, sand, and gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, as a cone or fan at the base of a mountain slope.

anion
: A negatively charged ion that migrates to an anode, as in electrolysis.

anisotropy
: The condition of having different properties in different directions, as in geologic strata that exhibit different hydraulic conductivities in the vertical and horizontal directions.

aquifer
: A water-bearing layer of rock that will yield a significant quantity of water to a well or spring.

bailer-recovery test
: Water is removed from a well by bailer, and recovery of water level is measured. Ideally, the time and volume is recorded for each bailer of water removed. However, in typical applications, only the number of bailers removed, total time of bailing, and volume of the bailer are recorded. A bailer-recovery test is differentiated from a slug test by the time of bailing. Although a bailer can be used to remove water during a slug test, all water would need to be removed instantaneously. If the period of bailing is short and the period of water-level recovery is long, for example bailing of five minutes with recovery of two hours, a bailer-recovery test can be interpreted successfully with slug-test methods. However, bailer-recovery tests generally must be interpreted with the This recovery method for constant-rate tests or an appropriate modification to that method.

baseflow
: Discharge from groundwater seeping into a surface-water body such as a stream or pond.

bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
caliche	Gravel, sand, or desert debris cemented by porous calcium carbonate.
capillary fringe	The lower subdivision of the zone of aeration, immediately above the water table, in which the interstices are filled with water under pressure less than that of the atmosphere, being continuous with the water below the water table but held above it by surface tension. Its upper body boundary with the intermediate belt is indistinct but is sometimes defined arbitrarily as the level at which 50 percent of the interstices are filled with water.
cataclastic	Pertaining to the structure produced in a rock by the action of severe mechanic stress during dynamic metamorphism or a coarse fragmentation of a rock in transit.
cation	An ion having a positive charge and, in electrolysis, characteristically moving toward a negative electrode.
colluvium	A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.
confined aquifer	A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.
confining layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer.
constant-rate test	Water is removed or introduced to a well at a constant or nearly constant rate for a period generally measured in hours or days. Changes in water level or hydraulic head are measured in the pumping or injection well and nearby observation wells. Water-level changes generally are measured during the pumping or injection period as well as during the subsequent water-level recovery period. The test commonly is called a pumping test if

	water is removed from the well. A wide variety of methods are available to interpret constant-rate tests depending on the hydrogeologic and well characteristics of the test location. A constant head test is an important variation of the constant-rate test and involves placing a hydraulic stress on an aquifer by elevating or depressing the hydraulic head in the well for an extended period.
Darcy's law	A derived equation for the flow of fluids on the assumption that the flow is laminar and that inertia can be neglected. An equation that can be used to compute the quantity of water flowing through an aquifer.
diagenetic	Pertaining to or caused by all the chemical, physical, and biologic changes undergone by a sediment after its initial deposition and during and after its lithification, exclusive of surficial alteration (weathering) and metamorphism.
discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
discharge area	An area in which groundwater is flowing toward the surface and may escape as a spring, seep, or baseflow or by evaporation and transpiration.
downgradient	Direction of decreasing static head.
drainage basin	The land area from which surface runoff drains into a stream channel or system of channels or to a lake, reservoir, or other body of water.
drawdown	*See* slug test.
drawdown recovery test	A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping or bailing of groundwater from wells. See bailer-recovery test.
effective porosity	The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.

116

effluent	A waste liquid discharge from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment.
effluent stream	A stream or reach of a stream, the flow of which is being increased by inflow of groundwater.
ephemeral seep	A seep that is intermittent in nature.
equipotential line	A contour line on the water table or potentiometric surface; a line along which the pressure head of groundwater in an aquifer is the same. Fluid flow is normal to these lines in the direction of decreasing fluid potential.
evapotranspiration	Loss of water from a land area through transpiration of plants and evaporation from the soil.
fault	A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture.
flow lines	Lines indicating the direction of groundwater flow toward points of discharge. Flow lines are perpendicular to equipotential lines.
frequency distribution	The numerical or quantitative distribution of objects or material in a series of closely related classes. It is generally selected on the basis of some progressively variable physical characteristic.
gaining stream	A stream or reach of a stream, the flow of which is being increased by inflow of ground water. Also known as an effluent stream.
heterogeneous	Nonuniform in structure or composition throughout.
hydraulic conductivity	A coefficient of proportionality describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.
hydraulic connection	Two units are in complete hydraulic connection when a change in head in one unit is immediately reflected in the other.

117

hydraulic gradient	The rate of change in total head per unit of distance of flow in a given direction.
hydraulic head	The sum total of elevation and pressure head.
hydrograph	A graph that shows some property of ground water or surface water as a function of time.
hydrostratigraphic unit	A formation, part of a formation, or group of formations in which there are similar hydrologic characteristics allowing for grouping into aquifers or confining layers.
infiltration	The flow of water downward from the land surface into and through the upper soil layers.
influent stream	A stream or reach of a stream that is losing water by seepage into the ground.
interflow	The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake.
intermittent seep	A seep that discharges only periodically.
isopach	A line drawn on a map through points of equal true thickness of a designated stratigraphic unit, group of stratigraphic units, or hydrostratigraphic unit.
isotropic	The condition in which hydraulic properties of the aquifer are equal in all directions.
kurtosis	The peakedness or flatness of the graphic representation of a statistical distribution; specifically, a measure of the peakedness of a frequency distribution.
leptokurtic	Said of a frequency distribution that has a concentration of values about its mean greater than for the corresponding normal distribution; a very peaked distribution.
lithostratigraphic unit	A rock unit that is distinctive in its physical characteristics, including hand specimen and outcrop descriptions, based on such characteristics as color, mineralogic composition, and grain size.

losing stream	A stream or reach of a stream that is losing water by seepage into the ground. Also known as an influent stream.
lower hydro-stratigraphic unit	At the Rocky Flats site, the lower hydrostratigraphic unit consists of unweathered bedrock. Also known as LHSU.
macropore flow	A type of preferential flow that occurs in large pores or cracks at or near saturation that can result in the rapid bypass of water and dissolved chemicals through the soil.
mesokurtic	Closely resembling a normal frequency distribution; e.g., said of a distribution curve that is neither leptokurtic (very peaked) nor platykurtic (flat across the top).
meteoric water	Pertaining to water of recent atmospheric origin.
packer test	A packer test generally is conducted in an open hole and may be conducted in either saturated or unsaturated conditions. Packers are used to isolate a portion of the hole, and a series of constant pressure tests are conducted. The rate of water injection is measured. Ideally, the injection rate is monitored until it stabilizes, indicating steady-state conditions have occurred. However, the typical test procedure involves injecting for a specified time, generally measured in minutes, and recording either the final injection rate or the average injection rate. Test results generally are interpreted by a modification of the Theim equation.
paleochannel	A remnant of a stream channel cut in older rock and filled by the sediments of younger overlying rock.
pediment	A broad, gently sloping rock-floored erosion surface or plain of low relief, typically developed by subaerial agents in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment and underlain by bedrock.
perched water table	Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.
perennial seep	A seep that flows continuously, as opposed to an intermittent seep or a periodic seep.

permeability	The property or capacity of a porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.
permeameter test	A laboratory test using a permeameter to measure the intrinsic permeability and hydraulic conductivity of a soil or rock sample.
phreatophyte	A type of plant that typically has a high rate of transpiration by virtue of a taproot extending to the water table.
piezometer	A nonpumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.
platykurtic	Said of a frequency distribution that has a concentration of values about its mean less than for the corresponding normal distribution; a distribution that is flat across the top.
porosity	The percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.
potentiometric surface	An imaginary surface representing the total head of groundwater in a confined or unconfined aquifer that is defined by the level to which water will rise in a well.
preferential flow	Refers to any mechanism that results in flow in isolated regions or channels that bypass the soil matrix.
recharge	The addition of water to the zone of saturation; also, the amount of water added.
runoff	That part of precipitation flowing to surface streams.
saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer.
secondary permeability	The permeability that has been caused by fractures or weathering in a rock or sediment after it has been formed.

semi-confined	A confined aquifer that can lose or gain water through either or both of the formations bounding it. Although flow may be limited through the bounding formations, over large areas significant quantities of water may flow into or out of the aquifer.
skewness	The condition of being disordered or lacking symmetry; specifically, the state of asymmetry shown by a frequency distribution that is bunched on one side of the average and tails off on the other side.
slug test	A known volume or "slug" of water is suddenly injected into or removed from a well and the decline or recovery of water level is measured. If conducted by instantaneously adding water, the test may be referred to as a "slug in" test. If conducted by instantaneously removing water, the test may be referred to as a "slug out" test. As an alternative to instantaneous injection or removal of water, a weight of known volume may be suddenly introduced or removed from the well. Slug tests originally were developed to evaluate low-permeability hydrogeologic units. However, with improvements in pressure transducer and data-logger technology, slug tests have found wide application in contaminated aquifers where the large hydraulic stresses of long-term tests are not advisable. The duration of a test generally is measured in minutes. However, test duration exceeding an hour is common in low-permeability rock. Methods of test analysis have been developed for fully penetrating and partially penetrating wells under confined or water-table conditions. Methods for analysis of both porous media and fractured media are available.
specific yield	The ration of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is stated as a percentage.
static water level	The level of water in a well that is not being affected by withdrawal of groundwater.
storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to the specific yield. Also called storage coefficient.

stratigraphic unit	A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess, for any purpose such as description, mapping, and correlation.
subcrop	An occurrence of strata in contact with the undersurface of an inclusive stratigraphic unit that succeeds an important unconformity of which overstep is conspicuous; a "subsurface outcrop" that describes the areal limits of a truncated rock unit at a buried surface of unconformity.
topography	The natural or physical surface features of a region, considered collectively as to form the features revealed by the contour lines of a map.
transmissivity	The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.
transpiration	The process by which plants give off water vapor through their leaves.
unconfined aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.
unsaturated zone	The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.
upgradient	Direction of increasing static head.
upper hydro-stratigraphic unit	At the Rocky Flats site, the upper hydrostratigraphic unit consists of all unconsolidated surficial materials and weathered bedrock. Also known as UHSU.
vadose zone	*See* unsaturated zone.
valley fill	The unconsolidated sediment deposited by an agent so as to fill or partly fill a valley.

water table — The surface between the vadose zone and the groundwater; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere.

watershed — *See* drainage basin.

δD — The deuterium isotopic composition of water expressed as parts-per-thousand difference from standard mean ocean water.

$\delta^{18}O$ — The ^{18}O isotopic composition of water expressed as parts-per-thousand difference from standard mean ocean water.

Table 5-1
Wells and Piezometers Installed by Year

Year	Total Wells and Piezometers	Active Wells	Active Piezometers
Pre-1986	100	0	14
1986	71	49	11
1987	67	45	15
1988	10	0	0
1989	163	79	65
1990	17	4	4
1991	143	99	32
1992	49	38	0
1993	152	40	25
1994[1]	41	28	13
Total	**780**	**382**	**179**

[1] As of 3rd quarter 1994. No wells were installed during the first two quarters of 1994.

124

Table 5-2
Chemical Constituents Monitored in Groundwater During 1994

Field Parameters
pH
Specific Conductance
Temperature
Dissolved Oxygen
Alkalinity
Indicators
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
pH[1]
Metals
Target Analyte List:
Aluminum (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Cadmium (Cd)
Calcium (Ca)
Chromium (Cr)[2]
Cobalt (Co)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Magnesium (Mg)
Manganese (Mn)
Mercury (Hg)
Nickel (Ni)
Potassium (K)
Selenium (Se)

125

Table 5-2
Chemical Constituents Monitored in Groundwater During 1994

Silver (Ag)
Sodium (Na)
Thallium (Tl)
Vanadium (V)
Zinc (Zn)
Others
Cesium (Cs)
Lithium (Li)[3]
Molybdenum (Mo)
Strontium (Sr)
Tin (Sn)[1]
Anions
Carbonate (CO_3)
Bicarbonate (HCO_3)
Chloride (Cl)
Fluoride (F)
Sulfate (SO_4)
Nitrate/Nitrite (NO_2/NO_3)
Cyanide (as N)[4]
Volatile Organic Compounds[5]
Target Compound List - Volatiles:
Chloromethane (CH_3CL)
Bromomethane (CH_3Br)
Vinyl Chloride (C_2H_3CL)
Chloroethane (C_2H_5Cl)
Methylene Chloride (CH_2CL_2)
Acetone
Carbon Disulfide
1,1-Dichloroethane (1,1-DCA)
1,1,-Dichloroethene (1,1-DCE)
trans-1,2-Dichloroethene
1,2-Dichloroethene (total) (total 1,2-DCE)

Table 5-2
Chemical Constituents Monitored in Groundwater During 1994

Chloroform ($CHCl_3$)
1,2-Dichloroethane (1,2-DCA)
2-Butanone (MEK)
1,1,1-Trichloroethane (1,1,1-TCA)
Carbon Tetrachloride (CCL_4)
Vinyl Acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane (1,2-DCP)
trans-1,3-Dichloropropene
Trichloroethylene (TCE)
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
Bromoform(CBr_4)
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene (PCE)
Toluene (C_7H_8)
Chlorobenzene (C_6H_5CL)
Ethyl Benzene
Styrene
Xylenes (Total)
Radionuclides[6]
Gross Alpha - dissolved
Gross Beta - dissolved
Uranium 233/234; 235 - total; and Uranium 233, 234, 235 and 238 - dissolved
Americium 241 (Am-241) - total
Plutonium 239+240 (Pu-239,240) - total
Strontium 89+90[7] (Sr-89,90)[8] - dissolved
Cesium 137 (Cs-137) - dissolved

Table 5-2
Chemical Constituents Monitored in Groundwater During 1994

Tritium
Radium 226; 228 (Ra-226,228) - dissolved

1. Not analyzed prior to 1989.
2. Analyses in 1990 are for total chromium. Chromium (IV) was analyzed during fourth quarter 1987 only.
3. Prior to 1989, lithium was only analyzed during fourth quarter 1987 and first quarter 1988.
4. Cyanide was not analyzed during fourth quarter 1987.
5. Not analyzed in background samples in 1989.
6. Dissolved radionuclides replaced total radionuclides (except tritium) beginning with the third quarter 1987. During 1991 and 1992, total concentrations of Am-241, Pu-239,240, and tritium were analyzed.
7. Strontium 89+90 was not analyzed during first quarter 1988.
8. Not analyzed prior to 1989 and only analyzed if gross alpha exceeds 5 pCi/L.

Table 5-3
Aquifer Slug Tests Conducted in 1994 by Well Number

3086	B203489	P414189	P416589	03391
3886	B203589	P114389	P416689	11791
4086	B203789	P114489	P416789	11891
4486	B203889	P114689	P416889	13491
4686	B203989	P114789	P416989	20291
4886	B204089	P114889	B217489	20491
6186	B204189	P114989	B217589	20591
6686	B304889	P115089	B217689	20691
1687	B304989	B315289	B217789	20791
1887	B405289	P115489	P317989	20891
2087	B305289	P115589	P218089	20991
2287	B405689	P115689	P119389	46392
2387	B405789	P215789	P419689	46492
2587	B206589	P415889	P320089	46692
2887	B206789	P415989	0590	46792
3187	P207989	P416089	0690	46892
3487	P313489	P416189	0790	00293
3687	P313589	P416289	0990	23193
B203189	P213689	P416389	00491	70593
B203289	P314089	P416489	01991	

129

6. Hydrogeology of the Rocky Flats Site

This section discusses the hydrogeology of the Rocky Flats site and includes a discussion of the hydrostratigraphic unit concept as currently applied at the site, surface-water/groundwater interactions, and the occurrence and flow of groundwater in each sub-unit composing the upper hydrostratigraphic unit (UHSU) and lower hydrostratigraphic unit (LHSU). Specific examples of important hydrogeologic features, such as hillside colluvial hydrology and bedrock controls of UHSU groundwater flow, are also provided.

6.1 Definition of Hydrostratigraphic Units

The interpretation of and the terminology used to describe the hydrogeologic setting at the Rocky Flats site has evolved with the accumulation of data. The terminology used is intended to conform with RCRA and CERCLA regulations. Early hydrogeologic characterization of the Rocky Flats site in the Final Environmental Impact Statement recognized and described separate groundwater flow systems within the Rocky Flats Alluvium, the Arapahoe Formation, and the Laramie/Fox Hills Formation (ERDA, 1980). Later hydrogeologic summaries described shallow and deep groundwater flow systems at Rocky Flats. The shallow system included groundwater within the Rocky Flats Alluvium, colluvium, and valley-fill alluvium, and the deep system included groundwater within the claystones and sandstones of the Arapahoe Formation (Hydro-Search Inc., 1986; Rockwell International, 1986b). The most current interpretation used to describe the hydrologic setting is the UHSU/LHSU distinction. This definition is supported by hydraulic data and geochemical and isotopic studies reported in the Groundwater Geochemistry Report (EG&G, 1995b).

6.1.1 Hydrostratigraphy as Defined by Regulatory Guidance

RCRA legislation required the implementation of a groundwater monitoring program that was "capable of determining the facilities impact on the quality of groundwater in the uppermost aquifer underlying the facility." This necessitated the interpretation of the "uppermost aquifer" for groundwater monitoring and compliance at RCRA-regulated units. The uppermost aquifer "means the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facilities boundary" (40 CFR 264, Subpart F).

The term "aquifer" is defined in 40 CFR 191.12(I), Subpart B, as any geologic formation, group of formations, or portion of a formation capable of yielding significant and useable quantities of groundwater to wells or springs. This may include fill material that is saturated. CERCLA guidance defines aquifer in a similar manner but includes any geologic material that is currently used or could be used as a source of water. Identification of formations capable of "significant yield" must be made on a case-by-case basis (EPA, 1986). Monitoring of the uppermost aquifer is required under 40 CFR 264, Subpart F, in order to immediately detect contaminant releases. The identification of the confining layer or lower boundary is an essential facet of the definition of the uppermost aquifer (EPA, 1986). The confining unit or lower boundary must be proven to be of low enough permeability to minimize the passage of contaminants to lower saturated units. Determination of the hydraulic connection between stratigraphic units should be based on multiple well pump tests. If drawdown in a well in one unit is reflected in wells from the other unit, the lower boundary should not be considered of low enough permeability to significantly retard contaminant migration between the units. Wells within a hydrostratigraphic unit should display similar patterns of drawdown and response to seasonal recharge and discharge events.

If zones of saturation capable of yielding significant amounts of water are interconnected (based on information from pump tests), they all compose the uppermost aquifer. Quality and use of groundwater are not factors in the definition of the uppermost aquifer. Even though a saturated formation may not be in use currently or contain water not suitable for human consumption, it may deserve protection because contamination may threaten human health or the environment (EPA, 1986).

Saturated zones that are not capable of yielding significant amounts of water, such as low-permeability clays, may act as pathways for contaminant transport (EPA, 1986). Migration of contaminants along these pathways may result in contamination of zones capable of yielding significant amounts of water. Monitoring of these zones of low permeability may be required under RCRA, 42 USC 6928, interim status corrective action section 3008(h) and corrective action for permitting section 3004(u). However, if contaminants have been detected in a unit, the plume should be characterized regardless of the groundwater yield of the unit (EPA, 1986).

Based on the regulatory, as well as technical, definitions of an aquifer, annual RCRA reports for regulated units at Rocky Flats have determined that the upper groundwater flow system at the Rocky Flats site is not an aquifer because the yield of water to wells is typically low and broad areas of the system are unsaturated during the fall and early winter. Given these conditions it is unlikely that the upper flow system could yield significant amounts of water; however, it has been described as water bearing (DOE, 1989). Although the upper flow system at Rocky Flats is not considered to be an aquifer, the RCRA definitions have been applied for the development of a practical groundwater monitoring system that complies with the intent of the 40 CFR 264, Subpart F, groundwater protection regulations and ensures the protection of public health and the environment.

Annual RCRA reports for regulated units at Rocky Flats for 1986, 1988, 1991, and 1992 described the Rocky Flats Alluvium, colluvium, and valley-fill alluvium to best fit the RCRA definition of the uppermost aquifer based on their proximity to the ground surface and their relatively high hydraulic conductivities. The units also are connected hydraulically as indicated by the well hydrographs discussed in Section 6.2.3. There is considerable interflow between these units, and discharge from one unit may recharge other units. Discharge from the Rocky Flats Alluvium recharges hillside colluvium, and discharge from hillside colluvium recharges valley-fill colluvium (see Section 6.2.3 for a more complete discussion).

It also was recognized that in certain areas the hydraulic conductivities of some weathered sandstones and claystones within the Arapahoe and Laramie formations were similar to those in the unconsolidated surficial materials. These units also appear to be connected hydraulically with the surficial deposits based on analysis of hydrographs (see Section 6.2.3). Discharge from surficial deposits generally recharges weathered bedrock; however, this relationship is reversed in some cases. The hydraulic connection between some sandstones and weathered bedrock and surficial deposits indicates that they should be considered as part of the same hydrostratigraphic unit because of the absence of a low-permeability layer capable of minimizing flow between these units. Therefore, the sandstones and weathered claystone were considered part of the "uppermost aquifer" where they subcropped beneath saturated surficial material that had been contaminated by a RCRA regulated unit (Rockwell International, 1986b and 1988; EG&G, 1992c, 1993f, and 1994b). For a complete discussion of interaction between surficial deposits and weathered bedrock, see Section 6.2.3.

Unweathered bedrock of the Arapahoe and Laramie formations represents a significant contrast in permeability to the weathered bedrock and surficial deposits. In general, wells completed in unweathered bedrock do not display direct hydraulic connection to overlying surficial deposits and weathered bedrock, as indicated by well-cluster hydrographs. However, local groundwater interaction between weathered and unweathered bedrock is evident at some locations (see Section 6.4). In general, the low hydraulic conductivity of the unweathered bedrock acts as an effective barrier to downward groundwater flow. Unweathered bedrock of the Arapahoe and Laramie formations is not considered part of the UHSU due to its contrast in permeability and lack of hydraulic connection with the overlying weathered bedrock and unconsolidated surficial deposits. The unweathered bedrock units are identified as a confining layer capable of minimizing vertical migration based on these characteristics.

6.1.2 Hydrostratigraphy at Other Front Range Superfund Sites

The concept of hydrostratigraphic units has been used to describe the hydrogeologic setting at the Rocky Mountain Arsenal. The two main water-bearing units at the Rocky

Mountain Arsenal are the unconsolidated alluvial deposits and the underlying Denver Formation. The hydraulic properties of these two units, including hydraulic conductivity, are distinctly different, and the two units behave as two distinct hydrostratigraphic units. The alluvial deposits and the weathered portions of the Denver and Arapahoe formations are included in the upper hydrostratigraphic unit, and the lower hydrostratigraphic unit exists within the underlying Denver and Arapahoe formations. The alluvial material at Chemical Sales, Sand Creek Industrial, Woodbury Chemical, and Broderick Wood Products Superfund sites are hydrogeologically described as water-bearing units or as aquifers and are not characterized as and incorporated into hydrostratigraphic units (EG&G, 1995b).

6.1.3 Hydrostratigraphy at the Rocky Flats Site

The 1991 Geologic Characterization Report (EG&G, 1991b) used the concept of hydrostratigraphic units rather than aquifers to describe the hydrogeologic setting at the Rocky Flats site. Fetter (1988) defines hydrostratigraphic unit as a formation, part of a formation, or group of formations in which there are similar hydrologic characteristics allowing for grouping into aquifers or confining layers. Hydrostratigraphic units comprise geologic units grouped together on the basis of similar hydraulic properties. Several geologic formations may be grouped into a single aquifer, or a single geologic formation may be divided into both aquifers and confining units. The geologic characterization performed in 1991 considered the uppermost hydrostratigraphic unit at Rocky Flats to consist of alluvial material and subcropping sandstones.

The 1993 Annual RCRA Report was the first RCRA report to employ the concept of upper and lower hydrostratigraphic units at the Rocky Flats site to describe and identify the "uppermost aquifer." The report describes the UHSU as comprising several distinct lithostratigraphic units: Quaternary alluvium, colluvium, valley-fill alluvium, weathered bedrock of the Arapahoe and Laramie formations, and all sandstones within the Arapahoe and Laramie formations that are in hydraulic connection with overlying unconsolidated surficial deposits or the ground surface. They describe the LHSU as comprising unweathered bedrock of the Arapahoe and Laramie formations. The base of weathering in bedrock was used as the marker separating the upper and lower hydrostratigraphic units. This hydrostratigraphic unit designation was based on hydrologic and geochemical data that demonstrated hydraulic connection between the distinct lithostratigraphic units above the base of weathering in bedrock and a general hydraulic separation between unweathered bedrock and overlying units (EG&G, 1994b). Hydrologic, geologic, and geochemical data collected for the sitewide geoscience characterization reports were used to further evaluate the upper and lower hydrostratigraphic unit concept and the legitimacy of using the base of weathering in bedrock as the distinction between the UHSU and LHSU.

Hydraulic conductivity data can be used in a relative sense to evaluate the potential for hydraulic connection between various lithologic units. Hydraulic connection between unconsolidated surficial deposits and the underlying weathered bedrock at Rocky Flats is indicated by their similar hydraulic conductivities. Weathered bedrock sandstones and siltstones have geometric mean hydraulic conductivities of 3.89E-05 cm/sec and 2.88E-05 cm/sec, respectively. The geometric mean hydraulic conductivity of the weathered Arapahoe Formation sandstone is 7.88E-04 cm/sec. The Rocky Flats Alluvium, valley-fill alluvium, and colluvium have geometric mean hydraulic conductivities of 2.06E-04, 2.16E-03, and 1.15E-04, respectively. Mean hydraulic conductivities of weathered bedrock sandstones and siltstones are equal to or within one order of magnitude of unconsolidated surficial deposit hydraulic conductivities. This suggests the potential for hydraulic connection between weathered bedrock sandstones and siltstones and the overlying unconsolidated surficial deposits. The mean hydraulic conductivity of weathered bedrock claystone is 8.82E-07 cm/sec which is more comparable to the hydraulic conductivities of unweathered bedrock lithologies than to unconsolidated surficial deposits. Unweathered bedrock sandstone, siltstone, and claystone mean hydraulic conductivities are 5.77E-07, 1.59E-07, and 2.48E-07, respectively. The relatively low hydraulic conductivity of the unweathered bedrock suggests that it acts as a barrier to downward groundwater flow and that it effectively minimizes groundwater interaction between units above and below the base of weathering. This is supported by hydrograph data that indicate unweathered bedrock and UHSU deposits are not hydraulically connected.

Characteristics of groundwater flow within and among the various lithostratigraphic units that comprise the UHSU must be similar in order for the present upper and lower hydrostratigraphic unit concept at the Rocky Flats site to be used effectively in evaluating potential contaminant migration. Reports have shown that the potentiometric surface within the weathered bedrock is similar to that within the unconsolidated deposits. Thus, groundwater flow patterns within the weathered bedrock are expected generally to parallel those observed in the unconsolidated deposits. Figure 6-1 illustrates the hydrostratigraphy at Rocky Flats using an example from OU2 (DOE, 1991). The schematic cross section depicts several important groundwater flow characteristics related to the UHSU and LHSU classification at the Rocky Flats site. These include direct hydraulic connection between the lithostratigraphic units that compose the UHSU, which results in groundwater flowpaths that pass between different lithostratigraphic units within the UHSU. The contrast in hydraulic properties between the UHSU and LHSU results in predominately lateral groundwater flow at the UHSU/LHSU boundary.

Similar seasonal groundwater-level fluctuations occur in unconsolidated surficial deposit and weathered-bedrock wells. Although seasonal groundwater-level fluctuations do not occur at all unconsolidated deposit or weathered-bedrock wells, the temporal nature of the fluctuations are comparable. High groundwater levels in both the unconsolidated deposits and the weathered bedrock occur in the spring, and low groundwater levels occur in late summer and fall. These groundwater fluctuations indicate that the unconsolidated surficial deposits and the weathered bedrock respond similarly to seasonal recharge events. Although this response is not universal, it does indicate local hydraulic connection between the unconsolidated surficial deposits and weathered bedrock. This is discussed in more detail in Section 6.3.2.

Well clusters that are screened in unconsolidated deposits and weathered bedrock reveal that the dominant vertical hydraulic gradient is downward. Some clusters indicate a complete hydraulic connection between the unconsolidated deposits and the weathered bedrock because their potentiometric surfaces are essentially equal. Other clusters identify areas in which groundwater within the unconsolidated surficial deposits is perched on top of less permeable weathered bedrock and the upper portion of the weathered bedrock is unsaturated. Downward vertical hydraulic gradients within these areas suggest vertical groundwater flow from unconsolidated deposits into the weathered bedrock. Subcropping weathered sandstones and siltstones have similar hydraulic conductivities as the overlying unconsolidated deposits, enhancing the amount of interaction between the units. Bedrock structural features such as faults and slumps may also enhance groundwater interaction between weathered bedrock and the unconsolidated surficial deposits. For a complete discussion on unconsolidated surficial deposit/weathered-bedrock groundwater interactions, refer to Section 6.2.3.

Well clusters screened in units above and below the base of weathering in bedrock generally indicate minimal hydraulic connection between weathered and unweathered bedrock. However, some well clusters in weathered/unweathered bedrock show similar groundwater-level responses above and below the base of weathering in bedrock. The specific interactions are discussed in Section 6.4.1.1. Similar groundwater fluctuations in well clusters screened at relatively shallow depths within the unweathered bedrock and UHSU wells may indicate localized areas of hydraulic connection between weathered and unweathered bedrock. However, the relatively low hydraulic conductivity of the unweathered bedrock and the general lack of correlation in water-level responses between LHSU and UHSU wells suggests that the unweathered bedrock generally acts as an effective barrier to downward groundwater flow. For a complete discussion on UHSU and LHSU interactions, refer to Section 6.4.

Groundwaters collected from unconsolidated surficial deposits and from weathered bedrock are not typically distinguishable from one another on the basis of their major-ion compositions. The Rocky Flats Alluvium, colluvium, valley-fill alluvium, and weathered bedrock all contain predominantly calcium-bicarbonate-type groundwater (EG&G, 1993b and 1994e). The similarity in the composition of groundwater from these units suggests that the units receive recharge from the same source and that they are hydraulically connected to one another.

In contrast, groundwater from unweathered bedrock is much more variable in its chemical composition, and it typically has a different major-ion composition than groundwater from the other lithostratigraphic units at Rocky Flats. In general, groundwater from unweathered bedrock is more sodium-rich than groundwater from the other units and it has a sodium-bicarbonate to sodium-sulfate composition (EG&G, 1995b).

Groundwaters from the various lithostratigraphic units are not generally distinguishable from one another on the basis of $\delta^{18}O$ and δD values. There is a shift to slightly higher $\delta^{18}O$ and δD values with increasing depth in unweathered bedrock. However, no clear break in groundwater types is indicated by $\delta^{18}O$ and δD data (EG&G, 1995b).

A general contrast in groundwater tritium contents exists between lithostratigraphic units above and below the base of weathering in bedrock. Tritium contents in groundwater within the weathered bedrock and unconsolidated surficial deposits typically range from 10 to 50 tritium units (TU). There is generally no measurable tritium in groundwater within the unweathered bedrock. The contrast in tritium contents from above and below the base of weathering in bedrock appears related to distinct sources of recharge but may also reflect large differences in the age of groundwater above and below the base of weathering in bedrock. Non-detectable amounts of tritium indicate that the main component of groundwater in the unweathered bedrock is more than 40 years old. Tritium concentrations in groundwater from weathered bedrock and the overlying unconsolidated deposits are consistent with groundwater ages of less than 40 years, indicating that recharge to these units is more recent. The relatively sharp break in the vertical profile of groundwater tritium contents at the base of weathering in bedrock may be the result of the low permeability of the unweathered bedrock. However, despite the break in tritium contents, there is evidence for some mixing between units above and below the base of weathering in bedrock. Detectable concentrations of volatile organic compounds (VOCs) in unweathered bedrock groundwater indicate relatively recent recharge from the upper units (EG&G, 1995b).

Hydraulic data from well clusters and groundwater geochemical data provide a basis for defining separate hydrostratigraphic units above and below the base of weathering in bedrock. The inclusion of weathered bedrock into the UHSU is also generally supported by hydraulic and geochemical data. On a sitewide scale, the relatively low hydraulic conductivity of unweathered bedrock distinguishes it hydraulically from the overlying units, although some data indicate localized areas of hydraulic connection between lithostratigraphic units above and below the base of weathering in bedrock.

6.2 Upper Hydrostratigraphic Unit

The UHSU at Rocky Flats consists of unconsolidated surficial deposits, weathered bedrock, and sandstones in hydraulic connection with overlying units.

6.2.1 Surficial Deposits

This description of the hydrogeology of unconsolidated surficial deposits focuses on the Rocky Flats Alluvium, colluvium, landslide deposits, and valley-fill alluvium. These units represent the bulk of the surficial deposits that are present at the Rocky Flats site. Other alluvial deposits such as the Verdos Alluvium, Slocum Alluvium, and undifferentiated terrace alluvium are present in relatively minor quantities and do not represent a significant component of the hydrogeologic system at the Rocky Flats site.

Included in this section are the following discussions: a summary of surficial deposits geology; the occurrence and distribution of groundwater; descriptions of recharge and discharge; a summary of the hydraulic properties of the surficial deposits; and presentation of the flow conditions present in the surficial deposits, including specific examples from various locations at the Rocky Flats site.

6.2.1.1 Geology of the Surficial Deposits

This section summarizes the surficial deposits geology as presented in the Geologic Characterization Report (EG&G, 1995a). For a more detailed discussion of the surficial geology, please refer to Section 4 of the Geologic Characterization Report.

Surficial deposits at the Rocky Flats site consist of Quaternary-age units that unconformably overlie the Arapahoe and Laramie formations. The Industrial Area is located on a pediment capped by Rocky Flats Alluvium, which is the oldest and topographically highest of the surficial deposits in the area. This pediment has been eroded by streams that have cut steep valleys into the Rocky Flats Alluvium and underlying bedrock. As a result, reworked Rocky Flats Alluvium and bedrock have been deposited as colluvium on the valley slopes. The continued undercutting of the valley slopes by streams has also caused landslides to occur along the margins of the Rocky Flats Alluvium. In the bottom of the incised valleys, deposits of valley-fill alluvium represent the most recent episode of deposition in the Rocky Flats area. Plate 2-1 (EG&G, 1995a) provides a map of the surficial deposits showing the topographic and lateral relationships of the units.

Rocky Flats Alluvium is composed of a series of coalescing alluvial fans deposited during the Pleistocene. The Rocky Flats Alluvium is thickest near the mouth of Coal Creek Canyon and thins to the east at the depositional limits of the fan. At the Rocky Flats site, the Rocky Flats Alluvium ranges in thickness from less than 5 to more than

137

100 feet (EG&G, 1995a). The Rocky Flats Alluvium generally consists of unconsolidated, well-graded coarse gravels, coarse sands, and gravelly clays. Discontinuous lenses of clay, silt, and sand are also common within the unit indicating the heterogeneous nature of Rocky Flats Alluvium (EG&G, 1994a).

Holocene-age colluvium is typically present on valley slopes and is composed of reworked Rocky Flats Alluvium and bedrock materials. Sheet erosion and gravity creep processes formed the colluvial sequences, which vary in thickness from 3 to 15 feet (EG&G, 1995a). The thickest deposits occur at the base of valley slopes. Colluvial deposits are composed of clay, clayey gravel, and gravelly clay with smaller amounts of sand and silt. The clay and silt content of the colluvial deposits derived from the Arapahoe and Laramie formations is relatively higher than that of the colluvium derived from Rocky Flats Alluvium (EG&G, 1994a).

Landslide and slump deposits at the Rocky Flats site were formed by a variety of mass movement processes involving the downslope transport of unconsolidated material and rock *en masse*. Landslide and slump deposits are most common on valley slopes and vary in thickness from 10 to 50 feet. Unsorted and unstratified unconsolidated material and rock fragments of varying sizes are characteristic of the landslide deposits. Earth flows, earth slump, debris flows, debris slumps, rock-block slides, and complex landslides are landslide types that have been identified in the Rocky Flats area (Varnes, 1978). In some cases, landslides may consist of large debris flows containing primarily surficial deposits, and other landslide deposits are a combination of both surficial deposits and large rotated blocks of bedrock.

For purposes of this discussion of sitewide hydrogeology, the landslide deposits are grouped together with colluvial deposits. This assumption is valid for a discussion of the hydrogeology of the surficial deposits for the following reasons:

- The physical and hydraulic properties of the two units are expected to be largely the same because they are composed of the same material.
- The same processes are generally responsible for deposition of both landslide material and colluvium.
- A primary difference in landslide and colluvial deposits is the scale of slumping and mass wasting.
- Landslide and colluvial deposits occur in similar areas.

Valley-fill alluvium consists of fluvial-alluvial deposits, which occur in and adjacent to the ephemeral streams present at the Rocky Flats site. The valley-fill alluvium, also referred to as the Piney Creek Alluvium, includes the Piney Creek Alluvium of Hunt

(1954) and the post-Piney Creek Alluvium of Malde (1955). These sediments are composed of clay, silt, sand, and pebbly sand with silty and cobbly gravel lenses. Valley-fill deposits range in thickness from 0 to greater than 40 feet, with an average thickness of 10 feet.

6.2.1.2 *Groundwater Occurrence and Distribution*

Groundwater within surficial deposits generally occurs under unconfined conditions. The occurrence and distribution of groundwater in this system are influenced by the following factors: surface topography, bedrock topography, seasonal variations in precipitation, thickness of the surficial deposits, the presence of engineered structures, and the presence of impermeable zones.

Potentiometric Surface

Potentiometric-surface maps of groundwater within the surficial deposits were constructed for spring and fall (second and fourth quarters) of 1993 (Plates 2 and 3). These maps indicate that groundwater flow is largely controlled by the topography of the bedrock surface. Generally, the configuration of the potentiometric surface resembles bedrock topography. Groundwater in the ridge tops generally flows toward the east-northeast. In areas where the ridge tops are dissected by the east-northeast-trending stream drainages, groundwater flows to the north or south toward the bottom of the valleys. In the valley bottoms, groundwater flows to the east, generally following the course of the stream.

Seasonal variations in precipitation are reflected in the potentiometric surface. The potentiometric surface is typically higher in the spring (second quarter) and lower in the winter (fourth quarter). Seasonal variations generally do not affect the sitewide flow directions. Areas of unsaturated surficial deposits, however, are larger in the fourth quarter when water levels are typically lowest. The variation in the extent of unsaturated areas is greatest in the eastern part of the site in OUs 1, 2, and 4. In the western part of the site, unsaturated areas are small or not present (Plates 2 and 3).

Saturated Thickness

The saturated thickness of the surficial deposits is generally greatest in the western part of the site and decreases across the Industrial Area and eastern portions of the site (Plates 4 and 5). Saturated thickness ranges from over 40 feet in the western Buffer Zone to less than 5 feet in the eastern half of the Industrial Area. Along the hillsides and stream valleys, the saturated thickness is typically less than 5 feet. In addition, there are unsaturated zones in many locations across the site particularly in the eastern half of the Industrial Area. The volume of water stored in the units beneath Rocky Flats was estimated in the Groundwater Protection and Monitoring Program Plan

(EG&G, 1991c). This report estimates that the volume of water stored in the alluvium and valley-fill as 19,400 acre-feet (Table 6-1).

The size of unsaturated areas at the Rocky Flats site varies seasonally. For example, the unsaturated areas in OU2 are less extensive during the second quarter (Plate 4). During the spring when water levels are highest, additional areas of surficial deposits become saturated. The occurrence of these saturated and unsaturated areas in OU2 is controlled largely by bedrock topography. Surficial deposits overlying bedrock ridges are typically unsaturated, and deposits overlying bedrock valleys are more likely to be saturated (DOE, 1993b). In OU4, the bedrock surface affects the occurrence of unsaturated areas in a similar fashion. However, the large unsaturated area located north of the Solar Ponds and outside of the central portion of the Industrial Area is caused primarily by the Interceptor Trench System. This system removes groundwater from the surficial deposits by means of a series of French drains (DOE, 1994b).

Variations in surface and bedrock topography result in changes of the saturated thickness of surficial deposits. The surficial deposits isopach map (EG&G, 1995a, Plate 4-2) shows the net variation in the bedrock and topographic surfaces. In the western half of the site, thickness of surficial deposits ranges from 40 to 100 feet and saturated thickness ranges from 20 to 40 feet. Potential water storage in the surficial deposits is greater in this area because of the greater thicknesses of surficial deposits and because there are no stream valleys draining this area. In the central part of the site, the surficial deposits are thinner (5 to 30 feet), and saturated thicknesses also decrease (0 to 20 feet). Here, much of the groundwater flows from the ridge tops downward to the stream valleys or is discharged to the surface at contact seeps along the margins of the ridges. As a result, saturated thickness decreases due to discharges to the surface and stream valleys. Examples of contact seeps that represent discharge from colluvial/alluvial groundwater are the seeps south of Pond B-5 (DOE, 1993b) and some of the seeps north of the Solar Ponds (DOE, 1994c).

The decrease in saturated thickness may also be caused by impermeable areas in the Industrial Area. The impermeable areas greatly limit the infiltration and remove a source of recharge to surficial deposits in the Industrial Area. Approximately 190 of 438 acres within the Industrial Area are covered by impermeable areas.

Bedrock channels also locally affect the saturated thickness of surficial deposits. For example, a well-defined bedrock channel exists in OU2 near the southeastern perimeter (EG&G, 1995a, Plate 4-3) of the Industrial Area (EG&G, 1995a, Plate 4-3). The channel is approximately 25 feet deep; 300 feet wide; and 2,000 feet long. Surficial deposits in the bottom of this channel are perennially saturated; whereas the surficial deposits overlying the bedrock ridges adjacent to the channel are unsaturated (DOE, 1993b). Another bedrock channel trending north-south in the West Spray Field is also associated with an area of locally increased saturated thickness (Plates 4, 5, and 6). This channel is poorly delineated by existing well control. Bedrock channels in the OU4 area also affect the occurrence of unsaturated zones. However, the channels in OU4 are much shallower and narrower than those found in OU2. For example, one channel that affects the saturated thickness of the overlying surficial deposits measures approximately 30 feet wide by 5 feet deep (DOE, 1994c). However, due to the limited saturated thickness of surficial deposits in OU4, bedrock channels play an important role in the occurrence of saturated areas.

Engineered structures also cause variations in saturated thickness of the surficial deposits. In the southwestern part of the Rocky Flats site, geochemical data indicate that Rocky Flats Lake recharges surficial deposits and results in an increase in saturated thickness (EG&G, 1995b) (Plates 3 and 4).

Other examples of engineered structures that affect the saturated thickness of the surficial deposits include the Interceptor Trench System (ITS), located north of the Solar Evaporation Ponds, and the OU1 French drain. These systems locally remove groundwater from surficial deposits (DOE, 1992d and 1994f). The OU4 ITS collects approximately 3.1 million gallons of water per year along a 1,500-foot reach and removes groundwater from approximately 80 percent of the area it covers. As much as 36 percent of the water collected by the ITS may be stormwater runoff from the Building 779 area (DOE, 1994c). Engineered structures around the Present Landfill lower the water table as much as 15 feet in surficial deposits. However, a breach in the northern part of the Groundwater Intercept System has allowed groundwater inflow into the center of the landfill resulting in a locally greater thickness of saturated material (DOE, 1994a).

Depth to Water

Average depth to water across the Rocky Flats site varies from 0 to 70 feet (Plate 7). Depth to water is commonly used as an indicator of recharge and discharge areas. Recharge zones are often associated with areas of greater depth to water, whereas discharge areas are found where depth to water approaches zero. At the Rocky Flats site, depth to water is greatest in the western portions of the site indicating that this area is a recharge zone. Depth to water decreases across the Industrial Area to the east, in stream drainages, and at seeps, which are generally located along the extent of the Rocky Flats Alluvium.

In general, the depth to water appears to be controlled by the thickness of the surficial deposits, which is a function of the surface and bedrock topography. In areas of thickest alluvium such as the greater West Spray Field area, the northeast-trending ridge south of Rock Creek, the ridge south of the B-series ponds, and the area northeast of Rocky Flats Lake, depth to water is generally greater indicating that these areas of the pediment alluvium are recharge zones. Depth to water decreases in areas of thinner surficial deposits such as the Industrial Area, margins of the Rocky Flats Alluvium, and creek drainages. This decrease in depth to water suggests that these areas are more likely to be associated with groundwater discharge. Depth to water reaches a minimum in the locations of seeps where the depth to water is effectively zero (Plate 7).

Temporal Variations in Saturated Thickness

Annual variations in the saturated thickness of surficial deposits are greatest in the developed areas of the Rocky Flats site (Plate 6). Annual variations in saturated thickness in and immediately adjacent to the Industrial Area are generally greater than 3 feet. At several locations in and adjacent to the Industrial Area, variations in saturated thickness of more than 9 feet have been measured. Large variations in saturated thickness also occur adjacent to the Groundwater Intercept System at the Present Landfill (Plate 6).

Many of the areas exhibiting large fluctuations in saturated thickness appear to be associated with engineered structures. In the Industrial Area, much of the ground surface is impermeable due to the presence of buildings and parking lots (Plate 8). As a result, a greater amount of stormwater runoff is available to permeable areas. Increased infiltration of stormwater runoff may account for the large variations in saturated thickness in some parts of the Industrial Area.

Variations in saturated thickness also occur northeast of Rocky Flats Lake and along drainages at the Rocky Flats site. Along Smart Ditches 1 and 2, South Walnut Creek, and North Walnut Creek, fluctuations in the saturated thickness may result from the periodic movement of water stored in Rocky Flats Lake and the B-series ponds through South Walnut Creek and Smart Ditches 1 and 2.

6.2.1.3 Recharge

An important source of recharge to the UHSU surficial deposits is infiltration of precipitation. The stable isotope composition of groundwater and water-level fluctuations indicate that infiltration of precipitation is the primary source of recharge to UHSU materials (EG&G, 1995b). Nearly 15.5 inches of precipitation falls annually at the Rocky Flats site (Table 3-3), with the majority of the precipitation falling during April, May, and June (EG&G, 1993a). Most precipitation, however, is lost to runoff and evapotranspiration. Portions of the surficial deposits are recharged by infiltration from streams during the dry months of the year in areas where the water-table elevation is lower than the stream-stage elevation (Section 6.5).

The amount of precipitation that infiltrates surficial deposits is affected locally by the physical and hydrologic characteristics of the soils and subsoils. Infiltration through the vadose zone may occur as uniform areal infiltration through interstitial pore spaces or through isolated channels or regions in the soil. In general, the amount and rate of infiltration is controlled by the slope of the ground surface, the amount and type of vegetation present, the permeability of the surficial materials, and the initial water content of the surface materials.

Upward gradients indicate that the weathered bedrock supplies water to the surficial deposits in a few localized areas of the site. However, insufficient data are available to quantify the vertical movement of water in these areas, and the volumes are expected to be relatively low due to the low permeability of the weathered bedrock. Weathered bedrock recharge of the unconsolidated materials is discussed in Section 6.2.3.

Engineered structures also locally provide a source of water to surficial deposits. The ponds and reservoirs constructed in the Rocky Flats area locally recharge surficial deposits (DOE, 1992c). Leakage from the Solar Evaporation Ponds historically may have been a source of recharge to the surficial deposits in OU4, although only two of the ponds contained liquids as of June 1994. Insufficient historical data are available for determining if groundwater levels have decreased in the Solar Evaporation Ponds area since the ponds were drained (DOE, 1994b and 1994e). Recharge to surficial deposits also historically occurred at the East and West Spray Fields, adjacent to the Landfill Pond, and adjacent to some of the impoundment ponds in North Walnut Creek as a result of spray evaporation of wastewater (DOE, 1994d). Currently, wastewater is not treated by means of spray evaporation at the Rocky Flats site.

UHSU groundwater collected from wells near Rocky Flats Lake and the clay pit on the west side of the site is isotopically heavier than groundwater from most other areas at the Rocky Flats site. This suggests that the groundwater contains a component derived from isotopically heavier sources (i.e., sources that have undergone O^{16} depletion due to evaporation) such as Rocky Flats Lake or the clay pit (EG&G, 1995b).

Stable-isotope studies indicate that surface-water bodies located west of the Rocky Flats site provide recharge to the UHSU. These surface-water bodies (one upgradient of the Rocky Flats site) include Rocky Flats Lake and a flooded clay pit.

Additional engineered structures recharging surficial deposits may include footing drains that discharge to the ground surface or directly to the subsurface via leaking pipes. For example, the Building 881 footing drain in OU1 formerly discharged to the ground surface. During the construction of the French drain, the footing drain was connected to the French drain, and water levels in the vicinity of the former discharge point have subsequently dropped (DOE, 1992d). Infiltration from drainage ditches may also locally act as a source of recharge. These structures have the potential to locally affect the groundwater system in surficial deposits. For example, in OU1 the former skimming pond locally elevated the water table and caused seeps on the 881 Hillside (EG&G, 1992a).

Macropores have been identified as another mechanism that may result in rapid and increased recharge to surficial deposits. Macropores within the soil column may occur as desiccation cracks, large pores greater than 1 millimeter, root channels, rodent holes, and man-made features. In areas where these features are present in significant amounts, a dual porosity system of macropores and interstitial pores exists. In areas where the water table is shallow, such as OU4, macropores allow water to infiltrate rapidly (relative to the saturated hydraulic conductivities of the surficial deposits) causing changes in water-table elevation as quickly as eight hours after precipitation events (DOE, 1994b).

6.2.1.4 Discharge

Discharge of surficial deposits groundwater occurs by a number of different mechanisms. These include transpiration by vegetation, evaporation in the capillary zone, discharge to seeps and ephemeral streams; and infiltration into the underlying weathered bedrock.

Shallow groundwater is transpired by phreatophytes typically growing near seeps and along streams. In these areas, the water table is closer to the surface, allowing the roots of phreatophytes to reach saturated or nearly saturated areas in the subsurface. Shallow groundwater is also discharged to the atmosphere via evaporation in the capillary zone. Evidence of this evaporation is left in the form of caliche zones in the subsurface. These zones form as a result of the evaporation of groundwater and subsequent precipitation of calcium carbonate in the capillary fringe. Caliche zones also form at or near the surface where seeps are located (DOE, 1994b).

Seeps are important discharge points of groundwater at the Rocky Flats site. Seeps are commonly located at the contact between bedrock and surficial deposits along the slopes of the incised valleys. Examples of contact seeps are present south of Pond B-5 on the hillside and north of the Solar Evaporation Ponds (Plate 9). Seeps may also occur adjacent to outcrops of more permeable zones within the bedrock such as the seeps located south of Pond B-1 in OU2 (Plate 9). The location of seeps is commonly expressed by changes in vegetation (DOE, 1993b).

Groundwater is also discharged to streams in the Rocky Flats area. Discharge to streams varies seasonally and typically decreases during the drier months (Fedors and Warner, 1993). A particular reach of stream may be gaining during the spring and losing during the late summer, fall, and winter. Discharge from streams also varies spatially. The western reaches of the streams are generally gaining for some of the year, while the central or eastern reaches of the streams are more often losing reaches. A detailed discussion of surface-water and groundwater interactions is provided in Section 6.5.

Groundwater from surficial deposits also infiltrates into the underlying weathered bedrock. Locally, both downward and upward hydraulic gradients have been observed between the weathered bedrock and surficial deposits (EG&G, 1994a), indicating that discharge to weathered bedrock varies spatially and temporally. The rate of infiltration is controlled by the vertical hydraulic gradient and the hydraulic conductivity of the units. Section 6.2.3 further discusses interaction between the surficial deposits and the weathered bedrock.

Engineered structures also act as points of discharge for surficial deposits. The French drain along the 881 Hillside and the ITS north of the Solar Evaporation Ponds remove groundwater from the surficial deposits causing them to be locally unsaturated (DOE, 1992d and 1994f). Locally, drainage ditches may also remove water from the surficial deposits (DOE, 1993b). The Groundwater Intercept System also removes groundwater from the surficial deposits upgradient of the Present Landfill (DOE, 1994a).

6.2.1.5 Hydraulic Properties

A thorough review and reanalysis of aquifer tests was performed as part of this study to accurately define the hydraulic properties associated with the UHSU at the Rocky Flats site. Results from packer, slug, and pumping tests were evaluated for usability and reanalyzed in many cases (EG&G, 1994d; Appendix H). As a result of this effort, estimates of saturated hydraulic conductivity for UHSU and LHSU lithologic units were calculated. Estimates of other hydraulic properties such as storativity and effective porosity are not widely available for the Rocky Flats site, and the few values that are available are not considered reliable (Smith, 1994).

The results of the tests were compiled, and geometric means of saturated hydraulic conductivity for different lithologic units of the UHSU and LHSU were calculated. Estimates of saturated hydraulic conductivity were compiled for the following lithologic units: Rocky Flats Alluvium, colluvium, valley-fill alluvium, weathered bedrock claystones, weathered bedrock siltstones, weathered bedrock Arapahoe Formation sandstone, other weathered bedrock sandstones, unweathered claystones, unweathered siltstones, and unweathered sandstones. These values compare favorably to those provided in other documents such as the 1993 Annual RCRA Groundwater Monitoring Report (EG&G, 1994b).

The geometric mean of hydraulic conductivity values for the Rocky Flats Alluvium, colluvium, and valley-fill alluvium are 2.06E-04, 1.15E-04 and 2.16E-03 cm/sec,

145

respectively (Figure 6-2). The estimates of saturated hydraulic conductivity reflect the lithology of the individual units. Valley-fill alluvium contains relatively more sand and gravel and, consequently, has a hydraulic conductivity higher than other surficial deposits. The mean saturated hydraulic conductivity values for the colluvium and Rocky Flats Alluvium are essentially the same indicating that they have the same ability to transmit water under a given hydraulic gradient.

Table G-2 summarizes the hydraulic data statistics. The statistics indicate that the Rocky Flats Alluvium is the most heterogeneous unit of the surficial deposits. However, this may be due partially to the fact that the largest number of observations have been collected in the Rocky Flats Alluvium. The median and mean of the hydraulic conductivity data for Rocky Flats Alluvium differ by one order of magnitude, and the minimum and maximum value differ by six orders of magnitude. For normal distributions, the median and mean are roughly equal.

The coefficients of skewness and kurtosis are also used to describe the shape of a distribution. A distribution that is asymmetric can be skewed to the left (negatively skewed) or skewed to the right (positively skewed). If the coefficient of skewness is less than 0.5 and greater than -1.0, the data are not significantly skewed. If the coefficient of skewness is greater than 0.5 the data are positively skewed, and if the coefficient of skewness is less than -1.0, the data are negatively skewed (Stednick, 1991). Kurtosis describes the degree of peakedness of a distribution relative to the length and size of its tails. A kurtosis value between two and four indicates normally peaked (mesokurtic) data; less than two indicates flat (platykurtic) data; and greater than four indicates highly peaked (leptokurtic) data (Stednick, 1991). The skewness and kurtosis of the hydraulic conductivity data for Rocky Flats Alluvium are 3.46 and 12.7, respectively, indicating that the data are positively skewed and leptokurtic. The coefficient of variation (standard deviation/mean) for Rocky Flats Alluvium is 2.44. A coefficient of variation greater than 1 is indicative of significant variation within the data (Jury, 1985).

A large set of hydraulic conductivity values (116) were available for analysis. Thus, the characteristics of the Rocky Flats Alluvium hydraulic conductivity are most likely well represented by this data set. Hurr (1976) estimated the hydraulic conductivity of the Rocky Flats Alluvium to be about 35 ft/d (1.23E-02 cm/sec) compared to a geometric mean of 2.06E-04 for the current data.

Because a significant amount of hydraulic conductivity data is available for Rocky Flats Alluvium, a map is presented showing the spatial distribution of hydraulic conductivity at the site (Figure 6-3). Several estimates of hydraulic conductivity are available for most wells. For these wells, the average of the values is posted. Values are not contoured because of a lack of coverage in many areas. There are wide variations in hydraulic conductivities over relatively short distances; however in general, higher hydraulic conductivities (>1.00E-03 cm/sec) occur in most areas of the site, and the lower conductivities (<1.00E-06 cm/sec) are limited to the central and western portions of the site (Figure 6-3).

Hydraulic conductivity values for valley-fill alluvium are less heterogeneous than values in Rocky Flats Alluvium. The median and mean differ by one order of magnitude, and the minimum and maximum value differ by four orders of magnitude (Table G-1). The coefficient of variation (standard deviation/mean) for hydraulic conductivity values in valley-fill alluvium is 1.12 indicating significant variation within the data. The skewness and kurtosis of the data are 0.68 and -0.89, respectively, indicating that the data are not significantly skewed and platykurtic. A moderate number of values (42) for valley-fill hydraulic conductivity were analyzed, and the characteristics of the valley-fill alluvium are thought to be reasonably well represented by these data. The distribution of saturated hydraulic conductivities in valley-fill alluvium is shown in Figure 6-4.

Statistics indicate that colluvium is the most homogenous of the surficial deposits (Table G-1). The median and mean are approximately equal, and the range of values is approximately two orders of magnitude. The coefficient of variation (standard deviation/mean) for valley-fill alluvium is 1.08. The skewness and kurtosis of the data are 2.14 and 5.63, respectively, indicating that the data are positively skewed and leptokurtic. Though the colluvium appears to be relatively homogenous in terms of hydraulic conductivity, the hydraulic conductivity of the colluvium is characterized by only 15 values and this population may not be large enough to accurately characterize the heterogeneity of the colluvium. The distribution of saturated hydraulic conductivity values in colluvium is shown in Figure 6-5.

Box-and-whisker plots for saturated hydraulic conductivity values from different geologic units are presented in Appendix G. Box-and-whisker plots provide a visual impression of the data and are useful for evaluating outliers. As demonstrated in these plots, the Rocky Flats Alluvium has several values plotted beyond the upper quartile range. The colluvium has only a single outlier value extending beyond the upper quartile range. Conversely, the valley-fill alluvium has no outlier values. Because these hydraulic data were deemed usable through extensive review and reanalysis (refer to Table G-1 and Appendix H), these outliers likely represent heterogeneities in the flow system. The construction of these plots is discussed in detail in Appendix G.

Hydraulic conductivities have also been estimated using permeameter tests. In analyzing these data, the hydraulic conductivity values were separated into three categories: unconsolidated surficial deposits, weathered bedrock, and unweathered bedrock. Hydraulic conductivity values for unconsolidated surficial deposits range from 1.20E-08 to 3.60E-03 cm/sec with a geometric mean of 2.24E-04 cm/sec (Table G-3). These hydraulic conductivity values are very similar to those estimated by aquifer tests (EG&G, 1994d).

Estimated well yields for the unconsolidated surficial deposits are presented in Table G-7. Well yields for the different geologic units vary by orders of magnitude. For example, estimated well yields for the Rocky Flats alluvium range from 0.056 gpm to 12.06 gpm. The reported well yields for colluvium are less than 1.0 gpm, ranging from 0.055 gpm to 0.73 gpm. The single reported value for valley-fill alluvium is 1.56 gpm.

Contaminant transport in the surficial deposits is controlled by both advective and diffusive processes depending on the median grain size and average linear groundwater velocity of the unit. Calculations assessing the relative importance of diffusion and advection in the transport of contaminants are provided in Appendix G.

Contaminant transport in the Rocky Flats Alluvium is controlled by either diffusion, advection, or both mechanisms depending on grain size (Figure G-11). Contaminant migration in valley-fill alluvium is controlled by advection in more coarse-grained material and both advection and diffusion in the more fine-grained material (Figure G-5). Colluvium is generally more fine grained than Rocky Flats Alluvium or valley-fill alluvium. Consequently, contaminant transport is controlled by either diffusion or a combination of diffusion and advection in the colluvial deposits (Figure G-11).

6.2.2 Weathered Bedrock

This section discusses the hydrogeology of the weathered bedrock at the Rocky Flats site and includes a description of weathered bedrock geology, the distribution and occurrence of weathered bedrock groundwater, the recharge and discharge relationships within weathered bedrock, and an evaluation of hydraulic properties and flow conditions in weathered bedrock.

6.2.2.1 Geology of Weathered Bedrock

The geology of the weathered bedrock has been summarized in previous studies (EG&G, 1992b) and is discussed in detail in the Geologic Characterization Report (EG&G, 1995a). Bedrock is defined as the first occurrence of consolidated rocks under the surficial deposits (EG&G, 1995a). At the Rocky Flats site, bedrock is composed of the Cretaceous Arapahoe and Laramie formations.

Weathered bedrock is composed of sandstones, siltstones, and claystones and is characterized by an abundance of iron-oxide staining, healed and unhealed fractures, and increased friability in the coarser units. Weathered bedrock is identified by color changes, mottling, and the degree of iron-oxide staining. Fractures appear more extensively in the weathered zones than in unweathered bedrock (EG&G, 1995a). Fractures commonly occur within 15 feet below the top of weathered bedrock, and a few have been found as deep as 100 feet below the top of weathered bedrock (EG&G, 1994a; EG&G, 1993g).

Weathered bedrock underlies the entire Rocky Flats site and ranges from less than 10 feet to more than 60 feet thick. Weathered bedrock is thickest in the western portion of the site and thins to the east. The thickness of weathered bedrock varies less in the western and eastern parts of Rocky Flats than in the central portion of the site. Due to the extensive erosion of the Rocky Flats Alluvium in the eastern portion of the site, much of the weathered bedrock has been removed. In the middle section of the site, erosion is actively incising modern streams into weathered bedrock. In the western portion of the site, the thick mantle of surficial deposits has prevented erosion of the weathered bedrock surface.

In general, locally thicker areas of weathered bedrock may indicate the presence of UHSU sandstones. In OU2 and OU4, weathered bedrock is found beneath weathered sandstones. Locally, weathered bedrock has been found to be thickest in valley bottoms (DOE, 1993b; EG&G, 1992b and 1994a). However, examination of the isopach map of weathered bedrock in the Geologic Characterization Report (EG&G, 1995a) reveals no obvious relationship between areas where weathered bedrock is thicker and modern channels or paleochannels. This apparent discrepancy may be due to the scale of the weathered bedrock map, as compared to the scale of local (OU-wide) investigations.

Sandstones and siltstones within weathered bedrock are commonly lenticular and discontinuous and are usually isolated both vertically and horizontally by thick sequences of claystones and siltstones, although a few isolated, stacked sandstones have been documented (EG&G, 1995a). Sandstones, siltstones, and claystones from both the Arapahoe and the Laramie formations can subcrop together. However, because of stratigraphic and lithologic similarities, it is often difficult to differentiate between the Arapahoe and Laramie Formation siltstones and claystones. These units have similar hydraulic properties; therefore, the stratigraphic labeling of subcropping claystones and siltstones is not necessary for hydrogeologic characterization. These units are grouped together as weathered bedrock claystones and siltstones (EG&G, 1995a). Laramie Formation sandstones also have hydraulic conductivity values similar to weathered siltstones and claystones. However, Arapahoe Formation sandstones have higher hydraulic conductivities than the other weathered bedrock lithologies and will be discussed separately. The hydraulic properties of the weathered bedrock are discussed further in Section 6.2.2.5.

All sandstones that are in hydraulic connection with surficial deposits are considered part of the UHSU (DOE, 1994c and 1993a). Laramie and Arapahoe Formation sandstones occur in weathered bedrock and have distinguishing geologic and hydraulic characteristics. All weathered sandstones not identified as Arapahoe Formation sandstones are referred to as weathered sandstones. Weathered Arapahoe Formation sandstones identified as Arapahoe No. 1 sandstones in previous studies are referred to as Arapahoe Formation sandstones in this report (EG&G, 1995a).

The Arapahoe Formation sandstone has the greatest lateral extent and highest hydraulic permeability of any UHSU sandstone (EG&G, 1995a). The Arapahoe Formation sandstone lies stratigraphically in the upper parts of weathered bedrock and subcrops in areas such as OU4 and OU2. As a general rule, sandstones subcropping on the pediment are usually Arapahoe Formation sandstones, whereas sandstones that subcrop on valley slopes and floors are Laramie Formation sandstones. The Arapahoe Formation sandstone isolith map shows the distribution and thickness of the Arapahoe Formation sandstones (EG&G, 1995a, Plate 5-10).

The top of weathered bedrock is a gently sloping erosion surface or pediment, dipping toward the east. Numerous paleochannels are incised into the top of bedrock and generally follow the same trends as modern drainages. Similar to modern drainages at Rocky Flats, the larger incised paleochannels drained eastward and smaller paleochannels ran north and south toward modern-day stream valleys. Studies in OU2 and OU4 have documented that coarse unconsolidated sediments may fill the paleochannels (EG&G, 1995a). Gravel-lined channels can have hydraulic significance by creating preferential flowpaths within surficial deposits. This is discussed further in Section 6.2.3

The bedrock-surface elevation map shows that paleodrainages project upstream from the headwaters of modern streams (EG&G, 1995a, Plate 4-3). At Antelope Springs, east of Rocky Flats Lake, the top-of-bedrock contour map reveals a paleochannel continuing under the Rocky Flats Alluvium. It appears that the paleochannel may act as a conduit to channel water to Antelope Springs. Other evidence that paleochannels are serving as "pipelines" to guide water to modern streams has been seen in OU2, where head values in the paleochannel indicate discharge toward the seep area. The paleochannel is probably in direct hydraulic connection with the small tributary and associated perennial springs found along the hillside (EG&G, 1993g). Paleochannels in weathered bedrock may also locally contribute water to modern tributaries at other locations at Rocky Flats.

6.2.2.2 *Occurrence and Distribution of Groundwater*

Delineating the occurrence and distribution of groundwater within weathered bedrock is difficult because of the manner in which weathered-bedrock wells are constructed at the Rocky Flats site. Screens for weathered-bedrock wells are commonly preferentially placed near the top of bedrock. This preferential placement of well screens limits the usefulness of the water-level data. Because the weathered-bedrock wells are not screened at the base of the unit, a dry well does not necessarily indicate that the weathered bedrock is completely unsaturated. Therefore, it is difficult to construct accurate sitewide maps of the potentiometric surface and saturated thickness of the weathered bedrock.

Groundwater within weathered bedrock at the Rocky Flats site exists under both confined and unconfined conditions. Groundwater in weathered bedrock sandstones is locally confined in areas where they are overlain by siltstones and claystones (DOE, 1993b). These conditions occur in OU2 and in the Industrial Area (well P207389). Groundwater in the weathered bedrock occurs under unconfined conditions in areas where the water levels in the weathered bedrock and surficial deposits are the same; surficial deposits are unsaturated; the potentiometric surface of weathered bedrock is below the top of bedrock; or surficial deposits groundwater is perched above the weathered bedrock contact.

The volume of water stored in the Arapahoe Formation beneath Rocky Flats was estimated in the Groundwater Protection and Monitoring Program Plan (EG&G, 1991c). This report estimates that the volume of water stored in Arapahoe Formation sandstones and siltstones is 52,200 acre-feet (Table 6-1).

Potentiometric Surface

Potentiometric maps of weathered bedrock have been constructed for OU4 (EG&G, 1994b) and OU7 (DOE, 1994e). These reports show that the potentiometric surface of weathered bedrock generally resembles the potentiometric surface of surficial materials but is slightly lower in most areas. One exception to this occurs in OU2, where a large sandstone unit subcrops. The potentiometric surface of the weathered bedrock sandstone and surficial deposits is essentially the same in this area (DOE, 1993b). Similar conditions are expected in areas where sandstones subcrop beneath the alluvium. Based on the similarities in the potentiometric surface for surficial deposits and weathered bedrock, sitewide flow patterns within the two lithologic units are expected to be similar, and general statements about flow within the weathered bedrock can be made.

Weathered-bedrock groundwater in topographically high ridges is expected to flow generally toward the east-northeast following the surficial deposits flow pattern.

Evidence of this pattern is shown in potentiometric maps constructed for weathered bedrock in the Solar Evaporation Ponds area in the 1993 Annual RCRA Groundwater Monitoring Report (Figure 6-6) (EG&G, 1994b). In areas where ridges are dissected by the east-northeast-trending stream drainages, groundwater flows to the north or south toward valley bottoms. In the valley bottoms, groundwater flows to the east, generally following the course of the streams. The effect of stream drainages on groundwater flow within weathered bedrock is clearly shown in the potentiometric maps for weathered bedrock at the Present Landfill (Figure 6-7) (DOE, 1994e).

Hydrographs indicate that seasonal variations in precipitation are reflected in some, but not all, weathered-bedrock wells. Wells that show the strongest correlation between water level and seasonal precipitation are typically screened in sandstone (Appendix D, well-cluster hydrographs 2, 19, and 38), but some wells screened in siltstone or claystone also exhibit seasonal variations (well-cluster hydrographs 1, 8, and 41). In some cases, wells screened in weathered claystone and siltstone appear to be influenced by sampling events. The removal of three well volumes of water from the wells prior to sampling (as required by Rocky Flats standard operating procedures) causes significant drawdown in the wells, and the relatively low hydraulic conductivity of the weathered bedrock claystones and siltstones results in long water-level recovery times. Hydrographs indicate that water levels in many weathered bedrock wells do not fully recover prior to the next sampling event (well-cluster hydrographs 10, 15, 20, 46, and 47). Thus, any seasonal fluctuation in water levels in these wells may be masked by sampling-and-recovery patterns.

6.2.2.3 Recharge

The primary sources of recharge to the weathered bedrock are infiltration through the surficial deposits and direct recharge at outcrops in the western portions of the Rocky Flats site (EG&G, 1994a). Geochemical data indicate that surface water also recharges weathered bedrock. Recharge from surface-water bodies may occur indirectly via infiltration of surficial deposits groundwater or directly in areas where weathered bedrock is in direct contact with surface water (EG&G, 1995b).

The Landfill Pond sits directly on weathered bedrock, and potentiometric data indicate that a downward gradient exists in the pond area and that weathered bedrock is recharged by the Landfill Pond (DOE, 1994e). Weathered bedrock is also believed to be in direct contact with surface water beneath some of the ponds constructed in North and South Walnut Creeks. During construction of some of these ponds, all surficial deposits were removed to increase the capacity of the ponds (EG&G, 1993g).

Recharge to the weathered bedrock occurs across the Rocky Flats site but is expected to be greatest where the overlying surficial deposits are perennially saturated. In the western portion of the site, bedrock outcrops are saturated in most areas and precipitation can directly recharge weathered bedrock. In the central and eastern portions of the site, surficial deposits on ridge tops are unsaturated in places limiting recharge to weathered bedrock. Potentiometric data from OU1, OU2, and OU4 indicate that surficial deposits on the hillsides are largely unsaturated (DOE, 1993b, 1994f, and 1994g), and only minor amounts of recharge to weathered bedrock are expected in these areas. In the stream drainages, surficial deposits are typically saturated and downward infiltration of groundwater into the weathered bedrock is expected. Weathered bedrock is also recharged by surface water beneath the Landfill Pond and possibly beneath some of the A- or B-series ponds. At these locations, surface water is in direct contact with the weathered bedrock.

Factors that influence infiltration from the surficial deposits include the vertical hydraulic gradient between surficial deposits and weathered bedrock, the saturated hydraulic conductivity of weathered bedrock, and the presence of an unsaturated zone at the top of bedrock. Vertical hydraulic gradients between surficial deposits and weathered bedrock at the Rocky Flats site are usually downward (Figure 6-8), indicating that groundwater is flowing from surficial deposits into weathered bedrock. However, these calculated gradients are only estimates of the hydraulic conditions present at the site and should be used primarily qualitatively.

The lithology and saturated hydraulic conductivity of weathered bedrock influence the infiltration of groundwater from surficial deposits into weathered bedrock. High hydraulic conductivity units (sandstones) in the weathered bedrock will allow groundwater within surficial deposits to more readily flow into weathered bedrock. For example, the subcropping sandstones in OU4 and OU2 are preferential flowpaths for groundwater (DOE, 1994c and 1993). The occurrence of a subcropping sandstone in OU4 results in the complete desaturation of the overlying surficial deposits (DOE, 1994f). The subcropping lithofacies at the Rocky Flats site were mapped as part of the Geologic Characterization Report (EG&G, 1995a, Plate 5-1).

Hydrographs indicate that unsaturated zones exist at the top of weathered bedrock below saturated surficial deposits in some areas. The occurrence of these unsaturated zones is not limited to any particular setting at Rocky Flats. Where present, these unsaturated zones are generally expected to inhibit the downward movement of groundwater.

6.2.2.4 Discharge

Weathered-bedrock groundwater at Rocky Flats is discharged to surficial deposits, to the unweathered bedrock, and to engineered structures. Along the hillsides, the topography of the bedrock surface changes rapidly, causing the weathered-bedrock potentiometric surface to intersect the top of bedrock in many places. At these locations, weathered-bedrock groundwater discharges to the surficial deposits, and surface seeps form in some of these areas. For example, a weathered bedrock sandstone subcrops south of Pond B-2 and discharges groundwater to the surficial deposits. As a result, an ephemeral seep is present on the hillside (DOE, 1993b).

Weathered bedrock also discharges to the surficial deposits in a few other localized areas. Well-cluster hydrograph 38 (Appendix D) indicates that there is an upward gradient from the weathered bedrock to the surficial deposits southwest of the Solar Evaporation Ponds (Figure 6-8). At this location, weathered bedrock sandstones are confined by claystones and groundwater is potentially discharging through the confining claystone to the overlying surficial deposits. At another location along Smart Ditch #1, weathered bedrock may periodically discharge to the surficial deposits. Well-cluster hydrograph 8 (Appendix D) shows that the potentiometric surface in the weathered bedrock is occasionally higher than that of the surficial deposits. However, other well-cluster hydrographs located adjacent to streams do not show similar patterns.

Engineered structures may act as discharge points for weathered-bedrock groundwater in some cases. Building footing drains constructed below the top of bedrock are expected to act as discharge points for weathered-bedrock groundwater. Other Groundwater Intercept Systems such as the OU4 ITS and OU1 French drain are not expected to intercept significant amounts of weathered bedrock groundwater because these structures penetrate only the uppermost 1 to 2 feet of the bedrock (DOE, 1994c and 1994g).

Discharge of weathered-bedrock groundwater to surface-water bodies is possible in areas where the weathered-bedrock potentiometric surface is higher than the surface-water elevation. However, there is no indication that these conditions presently occur at the site (Section 6.5).

6.2.2.5 Hydraulic Properties

Estimates of saturated hydraulic conductivity for weathered bedrock were compiled for the following lithologic units: weathered bedrock claystones, weathered bedrock siltstones, weathered bedrock Arapahoe Formation sandstone, and other weathered bedrock sandstones. These values compare favorably to those given in other documents such as the 1993 Annual RCRA Groundwater Monitoring Report (EG&G, 1994b).

The geometric means of hydraulic conductivity values for the weathered bedrock claystones, siltstone, Arapahoe Formation sandstone, and other sandstones are 8.82E-07, 2.88E-05, 7.88E-04, and 3.89E-05 cm/sec, respectively (Figure 6-9). Weathered claystones exhibit the lowest hydraulic conductivity. Weathered siltstones and "other"

154

sandstones have similar hydraulic conductivities and are more permeable than weathered claystones. The Arapahoe Formation sandstones are the most permeable weathered bedrock unit.

The statistics for hydraulic data indicate that weathered bedrock claystones are the most heterogeneous of the weathered bedrock lithologies (Table G-2). The median and mean differ by two orders of magnitude, and the minimum and maximum value differ by four orders of magnitude. The coefficient of variation (standard deviation/mean) for weathered bedrock is 5.66. The skewness and kurtosis of the data are 6.9 and 48.2, respectively, indicating that the data are positively skewed and leptokurtic. The relatively large number of hydraulic conductivity values (49) available for analysis provide an adequate characterization of weathered claystone hydraulic conductivity.

The hydraulic properties of weathered bedrock siltstones are not well characterized by the available data because only three values are available for analysis. However, the three values fall within a narrow range (2.34E-05 to 3.40E-05 cm/sec), and the coefficient of variation is accordingly small (0.184). The skewness of the data is -0.71, indicating that the data are not significantly skewed. There are not enough estimates of weathered bedrock siltstone hydraulic conductivity to calculate the kurtosis of the data.

Weathered sandstones are relatively homogeneous. The median and mean differ by less than one order of magnitude, and the minimum and maximum value differ by two orders of magnitude (Table G-2). However, there are only eight values for non-Arapahoe Formation sandstone hydraulic conductivity. Therefore, the properties of the sandstone may not be well represented. The coefficient of variation (standard deviation/mean) for weathered sandstone's is 1.08. The skewness and kurtosis of the data are 1.06 and -0.54 respectively, indicating that the data are positively skewed and platykurtic.

The Arapahoe Formation sandstone is moderately heterogeneous in terms of saturated hydraulic conductivity. The median and mean differ by one order of magnitude, and the range of values is approximately two orders of magnitude. The coefficient of variation for valley-fill alluvium is 1.26. The skewness and kurtosis of the data are 1.68 and 2.26, respectively, indicating that the data are positively skewed and mesokurtic. The Arapahoe Formation sandstone is characterized by 34 values and, therefore, is thought to be reasonably well characterized.

Box-and-whisker plots for saturated hydraulic conductivity values from weathered bedrock units are presented in Appendix G. Box-and-whisker plots provide a visual impression of the data and are useful for evaluating outliers. As demonstrated in these plots, only the Arapahoe Sandstone and weathered claystones show outliers beyond the upper quartile ranges. Because these hydraulic data were deemed usable through extensive review and reanalysis (refer to Table G-1 and Appendix H), these outliers likely represent heterogeneities in the flow system. The construction of these plots is discussed in Appendix G.

Estimated well yields for weathered bedrock are presented in Table G-4. Well yields for different bedrock units vary by orders of magnitude. For example, the single value of 0.026 gpm for weathered sandstone is significantly less than the range of values (1.62 gpm to 6.14 gpm) for the Arapahoe Formation sandstone.

Contaminant transport in the weathered bedrock is controlled by both advective and diffusive processes depending on the median grain size and average linear groundwater velocity of the unit (Figure G-12). Calculations assessing the relative importance of diffusion and advection during contaminant transport are provided in Appendix G. These calculations indicate that contaminant transport is controlled by diffusion in claystones, by a combination of diffusion and advection in siltstones and non-Arapahoe Formation sandstones, and predominately by advection in the Arapahoe No. 1 sandstones.

6.2.3 Summary of UHSU Groundwater Flow

Groundwater flow within the UHSU at the Rocky Flats site is controlled by both regional and local features. This presentation includes discussion of both general sitewide flow patterns and factors that locally control flow. Several examples from different areas of the site are also presented to provide the reader with an understanding of the different controlling factors that affect groundwater flow within the UHSU and groundwater interactions between the different sub-units of the UHSU.

6.2.3.1 Sitewide Flow Patterns

Groundwater in the UHSU generally flows from west to east across the Rocky Flats site following the regional topography of the bedrock surface and ground surface. The incised valleys in the central area of the site have formed east-west-trending ridges and east-draining valleys that also affect the movement of groundwater in the UHSU. UHSU groundwater is present in the Rocky Flats Alluvium on the ridge tops, in colluvium on the valley sides, in valley-fill alluvium in the valley bottoms, and in the weathered bedrock that underlies all of the surficial deposits. Typical groundwater interactions between these UHSU sub-units are discussed below.

Groundwater flow in the surficial deposits typically follows the topography of the ground surface and relief of the bedrock surface. Along the ridge tops within the Rocky Flats Alluvium, groundwater generally flows to the east with components of flow toward the incised valleys. Groundwater within Rocky Flats Alluvium is discharged as interflow to the colluvium or to the surface at contact seeps along the margins of the Rocky Flats Alluvium. Seeps are commonly located in areas where surficial deposits thin at bedrock unconformities near the margins of ridges. In the incised valleys, groundwater flows toward valley bottoms from the colluvium into the valley-fill alluvium. In stream valleys, groundwater in valley-fill alluvium flows to the east down the base of the valley. Groundwater flow along stream drainages represents the most significant potential pathway for the offsite migration of contaminants within groundwater. Table G-9, presented in Appendix G, displays calculated seepage velocities for contaminants occurring in groundwater at the Rocky Flats site. These data indicate that seepage velocities are much greater along stream drainages than in other physiographic settings at Rocky Flats. Influent and effluent conditions occur within the valley-fill alluvium along stream channels. Surface-water and groundwater interactions are dependent on the local hydrology and seasonal variations in precipitation. Surface-water and groundwater interactions are discussed in detail in Section 6.5.

Although no sitewide maps of groundwater flow within the UHSU weathered bedrock are presented in this report, other reports have shown that the shape of the weathered bedrock potentiometric surface closely resembles that of the surficial deposits (DOE, 1994c). Thus, groundwater flow patterns within the weathered bedrock are expected to generally parallel those observed in surficial deposits. Groundwater flow within the weathered bedrock, however, is locally affected by the bedrock lithology and structural features. Groundwater preferentially flows in UHSU bedrock sandstones, and the presence of subcropping sands enhances the amount of interaction between weathered bedrock and surficial deposits. During OU1 field investigations, groundwater was observed in the margins and glide planes of slumps existing in weathered bedrock. In some cases, these features may act as preferential pathways for groundwater flow.

Hydrographs show evidence of the groundwater interaction between the surficial deposits and weathered bedrock. Seasonal variations in water levels occur in both surficial deposits and weathered bedrock at some locations indicating that the two units are hydraulically well connected. For example, well-cluster hydrograph 19 (Appendix D) shows that the water-level variations within the Rocky Flats Alluvium (well 2286) and the weathered bedrock sandstone (well P210189) are very similar. In other areas, however, weathered bedrock sandstones do not appear to be in direct hydraulic connection with surficial deposits (well-cluster hydrograph 45). Although the hydraulic connection between surficial deposits and weathered bedrock sandstones is usually good, the amount of hydraulic connection between surficial deposits and weathered bedrock claystones and siltstones is generally limited. The groundwater within the surficial deposits is perched on weathered bedrock claystone in many areas at the Rocky Flats site (well-cluster hydrograph 26).

Vertical hydraulic gradients calculated using adjacent wells screened in surficial deposits and weathered bedrock indicate that groundwater generally flows downward into weathered bedrock. (Refer to Appendix D for a discussion of the method used to calculate vertical hydraulic gradients.) Exceptions to this condition occur along the hillsides where weathered bedrock recharges surficial deposits (e.g., OU4 and OU2) or where weathered bedrock sandstones are locally confined (DOE, 1993b). The volume of water flowing into the weathered bedrock from the surficial deposits is dependent on vertical hydraulic gradients and the hydraulic conductivity of weathered bedrock. Because the hydraulic conductivity of weathered bedrock is generally one to three orders of magnitude lower than surficial deposits, the flux from surficial deposits to weathered bedrock is controlled by the weathered bedrock conductivity except in areas where weathered bedrock consists of the Arapahoe Formation sandstone.

A conceptual description of unconfined groundwater flow was developed for the Rocky Flats site as part of the Well Evaluation Report (EG&G, 1994a). That report described three general zones where the characteristics of groundwater flow are distinctive. These zones trend north to south and occupy the western, central, and eastern portions of the site.

The western zone is characterized by a relatively unbroken topographic slope formed on the Rocky Flats Alluvium. In this zone, the thickness of surficial deposits is greatest, water-level fluctuations are minor, and the surficial deposits are rarely, if ever, completely unsaturated. Groundwater in the UHSU flows generally east with slight variations in flow direction along the top of the bedrock surface. The predominantly claystone bedrock impedes downward vertical migration of groundwater and directs flow laterally to the east (EG&G, 1994a).

The central zone has a gently eastward-sloping topographic surface that is incised by east-west-trending drainages. Topographic highs are capped by thick deposits of Rocky Flats Alluvium and flanked by colluvium. Groundwater in the Rocky Flats Alluvium flows along the bedrock surface and either emerges at seeps, flows into hillside colluvium, or migrates vertically into lower lithostratigraphic units (weathered bedrock). The potentiometric surface of groundwater in the UHSU generally resembles the ground and bedrock surfaces. The potentiometric surface slopes gently to the east and more steeply north-northeast and south-southeast along hillslopes of the incised drainage valleys. Groundwater flows from broad areas of recharge located upgradient and on nearby topographic highs toward the erosional limit of Rocky Flats Alluvium. From the limit of Rocky Flats Alluvium deposits, groundwater flows toward creeks in the incised drainages (EG&G, 1994a).

In the central zone, ground and bedrock surfaces affect the movement and occurrence of groundwater more significantly than in the western zone. The incised drainages provide a mechanism for draining the UHSU on the ridges of the central zone. Both the ground and bedrock surfaces slope steeply into the drainages causing seeps on valley sides and groundwater flow toward the streams. The draining of the surficial deposits into stream valleys is responsible for reducing the saturated thickness of surficial deposits in the central portions of Rocky Flats. Because of the relatively thinner saturated thicknesses of surficial deposits in this area, the bedrock topography strongly influences the occurrence, distribution, and movement of groundwater in surficial deposits. Surficial deposits are commonly unsaturated over bedrock ridges and saturated in the bedrock channels or depressions. Bedrock channels also act as preferential flowpaths in the central portion of Rocky Flats. For example, groundwater preferentially flows in bedrock channels in OU2 and OU4. The bedrock ridges in these areas are often unsaturated (DOE, 1993b and 1994b).

The eastern zone is characterized by relatively flat surface topography, the absence of thick alluvial deposits (Rocky Flats Alluvium), and more widespread valley-fill deposits. The ground surface is generally covered by thin deposits of colluvium. Horizontal hydraulic gradients are relatively low, and groundwater in surficial deposits may not flow directly toward the axes of stream valleys. Baseflow to creeks is probably also diminished relative to the central zone as a result of lower horizontal hydraulic gradients.

6.2.3.2 Factors Controlling Groundwater Flow

The principal factors that control the flow of groundwater within the UHSU include bedrock topography, surface topography, bedrock lithology and conductivity, lithology and conductivity of surficial deposits, structural features, engineered structures, seasonal variations in precipitation, and hydraulic gradients. A brief description of the influence of each factor is given below, and specific examples of groundwater flow conditions at Rocky Flats are provided in Section 6.2.3.3.

Bedrock Topography

The configuration of the bedrock surface controls the movement of groundwater at both the regional and local scale. Regional groundwater flow is to the east, reflecting the regional easterly dip on the bedrock surface. In the central area of the site where saturated thickness decreases, the topography of the bedrock surface is of greater importance in affecting local flow patterns. Locally, the topography of the bedrock surface directs flow of groundwater and controls occurrence of unsaturated zones. Surficial deposits above bedrock ridges may be unsaturated, whereas the surficial deposits are usually saturated in bedrock channels. These channels also cause springs in areas where channels intersect steep valley slopes (DOE, 1994f and 1994g).

Surface Topography

Steep hillsides and variation in the thickness of surficial deposits affect the flow of groundwater at Rocky Flats. Variations in surface and bedrock elevation cause changes in the thickness of surficial deposits. Decreases in the thickness of surficial deposits reduces the total volume of pore space available for water storage. Rapid changes in surface elevation along the hillsides allow groundwater in the weathered bedrock to laterally flow into surficial deposits in some areas. The thickness of the surficial deposits typically decreases along the hillsides causing the potentiometric surface to intersect the ground surface and forming seeps in many areas (DOE, 1993b).

Lithology of Subcropping Weathered Bedrock

Lithology of the uppermost bedrock unit influences the movement of groundwater locally. In most locations at Rocky Flats, the subcropping bedrock lithology is claystone or siltstone. Sandstone subcrops beneath the surficial deposits in some areas greatly enhancing hydraulic connection between weathered bedrock and surficial deposits. Subcropping bedrock sandstones may act as either a source or a sink of surficial deposits groundwater depending on vertical gradients. Typically, subcropping bedrock sandstones that occur on ridge tops drain the surficial deposits, whereas bedrock sandstones that subcrop along hillsides recharge the overlying surficial deposits (DOE, 1993b and 1994b). Plate 5-1 (EG&G, 1995a) shows the lithofacies of subcropping bedrock across the site.

Lithology of Surficial Deposits

The lithology of the surficial deposits, particularly the material directly overlying bedrock, affects the flow of groundwater. In general, gravels and sands have higher hydraulic conductivities than silts and clays. The lithology of the surficial deposits directly overlying bedrock is shown in Plate 4-5 (EG&G, 1995a), gravels and sands lie directly over bedrock in the present stream drainages and other, smaller bedrock channels. Analysis of hydraulic conductivity data shows that these valley-fill deposits are generally more permeable than other surficial deposits. Because the stream valleys are lower and are filled with material of higher permeability, they represent preferential pathways for groundwater flow.

Structural Features

Structural features such as slump blocks or faults may influence the movement of groundwater by providing preferential pathways for groundwater flow. Along the margins of slump blocks, evidence suggests that groundwater preferentially flows along the glide planes of slump blocks (DOE, 1992d).

The presence of faults within bedrock at Rocky Flats has been postulated in the Geologic Characterization Report (EG&G, 1995a). Brecciated zones have been noted during drilling of boreholes near the postulated faults. If faults do exist at Rocky Flats, they could act as either conduits or barriers to lateral and vertical groundwater flow (F. Grigsby, personal communication, 1994). Faults within the predominately claystone and siltstone bedrock at Rocky Flats could act as conduits to groundwater flow if permeable brecciated zones are associated with fault zones. If the plasticity of the claystones and siltstones is high, fractures in fault zones may heal causing the faults to act as barriers to groundwater flow. Additional studies are needed to confirm the presence of faults and determine their effect on groundwater flow at the site.

Engineered Structures

Engineered structures, including groundwater diversion systems, buildings, and impervious zones, and surface-water control structures affect UHSU groundwater conditions at the Rocky Flats site. Groundwater diversion systems currently present at the site include the OU4 ITS, the OU1 French drain, and the OU7 Groundwater Intercept System. These systems intercept groundwater and locally desaturate surficial deposits. Buildings and impervious zones locally prevent the infiltration of precipitation (Plate 8). Footing drains adjacent to buildings may also locally desaturate subsurface materials. Surface-water control structures including the A-, B-, and C-series ponds and all stormwater ditches locally provide additional recharge to the UHSU and, thus, influence groundwater flow. Surface-water and groundwater interactions are discussed in detail in Section 6.5.

Vertical Hydraulic Gradients

Vertical hydraulic gradients were calculated using adjacent wells screened across different water-bearing units. In order to understand the flow conditions in the UHSU, gradients were calculated between surficial deposits and the weathered bedrock. A summary table of all gradients calculated and an explanation of the method used to calculate gradients are presented in Appendix G.

Generally, most vertical hydraulic gradients between the surficial deposits and the weathered bedrock are downward (Figure 6-8), ranging from 0.03 to 1.12. At well-cluster 38 in the Industrial Area, an upward vertical hydraulic gradient of 0.05 exists. At this location, weathered bedrock sandstones are overlain by weathered claystones. Potentiometric data suggest that the claystone locally acts as a confining layer. Groundwater movement from weathered bedrock to surficial deposits has also been documented along the hillsides where weathered bedrock recharges surficial deposits (DOE, 1993b). The flow vectors presented in hydrogeologic cross sections D-D' (Plate

13) and G-G' (Plate 16) qualitatively show the flow relationships between these two units.

Downward vertical hydraulic gradients greater than 1.0 are indicative of unsaturated flow. However, comparison of hydrographs and the calculated gradients reveals that all calculated gradients greater than 0.6 occur in areas where an unsaturated zone exists at the top of weathered bedrock. At these locations, the surficial deposits groundwater is perched on bedrock of lower hydraulic conductivity. These areas of perched surficial deposits groundwater are not limited to any particular physiographic setting at Rocky Flats and occur in both stream drainages and ridge tops. However, groundwater levels in some weathered bedrock wells may be artificially low due to the long recovery times after sampling (EG&G, 1994a).

Seasonal Variations in Precipitation

Seasonal variations in precipitation cause water levels within the UHSU, particularly in surficial deposits, to vary. During the drier seasons, water levels are lowest. In the eastern and central zones of the Rocky Flats site, large areas of the surficial deposits become unsaturated during dry periods, and groundwater may occur only in topographically lower areas of the bedrock surface. Seasonal variations in the potentiometric surface also affect the occurrence of seeps. Many of the seeps at Rocky Flats are present only during the wetter, spring months (DOE, 1994c).

6.2.3.3 *Examples of Groundwater Flow Conditions in the UHSU*

In this section, summaries of the UHSU groundwater systems at several OUs are presented to demonstrate the groundwater flow conditions at Rocky Flats. Emphasis is placed on the factors that affect groundwater flow and the interaction between UHSU sub-units. The reader should refer to the referenced reports for a complete description of the groundwater systems discussed below.

Operable Unit Number 1

OU1 is located along the hillside south and southeast of Building 881. At this location, Rocky Flats Alluvium is present at the top of the hillside, colluvium and artificial fill cover the hillside, and valley-fill alluvium is present in the stream drainage at the base of the hillside. The surficial deposits are underlain by claystone, siltstone, and sandstone of the Laramie Formation (DOE, 1994g).

The primary factors affecting groundwater flow at OU1 are slump features, bedrock topography, lithology of the surficial deposits, and the presence of engineered structures. Bedrock topography is displayed in Figure 6-13. Fine-grained bedrock sandstones subcrop beneath the surficial deposits but are not laterally extensive and do not significantly affect groundwater flow in OU1 (DOE, 1994g).

Slump features present along the 881 Hillside influence groundwater movement and surface-water and groundwater interaction. During the installation of the French drain, caliche-rich zones were found in both surficial deposits and weathered bedrock. In surficial deposits, caliche zones bounded apparent slump blocks indicating that flow previously occurred in the glide planes and disrupted zones. Caliche zones in the bedrock were found in the slump glide planes as well. Some small amounts of seepage were observed from the glide planes indicating that groundwater may preferentially reside in the disturbed materials with potentially higher permeability associated with slumps. However, little groundwater movement is expected through these bedrock features because the high plasticity of the claystone is expected to permit healing of the fractures and voids caused by slumping (DOE, 1994g). Figure 6-14 delineates the potential groundwater conditions associated with a typical slump.

The location of slumps may be related to the location of seeps in OU1. Near the head region of slumps, seeps and water-tolerant vegetation such as cattails have been noted. Groundwater may be flowing from depressions in the bedrock surface near the head region of the slumps causing seeps. Other surface seeps appear to be related to slump margins (DOE, 1994g).

Bedrock depressions or paleoscours along the hillside influence the movement of groundwater. Areas where the saturated thickness of the surficial deposits is greater are commonly associated with local bedrock surface depressions (Figures 6-13 and 6-15). These bedrock lows may represent paleochannels or may be associated with the lateral margins or head regions of slumps. Groundwater preferentially flows in these lower areas toward Woman Creek. The OU1 French drain was installed to intercept the flow of groundwater along these pathways (DOE, 1994g).

Excavation for construction of the French drain exposed a large cross section of the UHSU which was studied in detail. During excavation activities, groundwater was discharged into the trench from both sandy, gravelly layers underlain by bedrock and by sandy, silty clay lenses that were bounded by denser clays or claystones. Dry zones within bedrock directly below saturated lenses of surficial deposits were also noted. These observations indicate that UHSU groundwater flows preferentially in these relatively coarse-grained horizons (DOE, 1994g).

Engineered structures including the French drain and the footing drain for Building 881 affect groundwater conditions at OU1. Prior to construction of the French drain, the footing drain for Building 881 discharged to surficial deposits on the hillside. The footing drain is now hydraulically connected to the French drain, effectively removing a source of recharge to the UHSU. The French drain was designed to intercept groundwater in the surficial deposits flowing toward Woman Creek. By installing the French drain, both a source of groundwater and existing groundwater are removed from the surficial deposits in OU1. As a result, the volume of groundwater in the surficial deposits has decreased (DOE, 1994g).

Operable Unit Number 2

OU2 is located near the southeast perimeter of the Industrial Area of the Rocky Flats site (Figure 6-10) and includes the 903 Pad, East Trenches, and East Spray Fields. Most of OU2 is situated on an east-west-trending ridge bounded to the south by the Woman Creek drainage and to the north by South Walnut Creek (DOE, 1993b).

At OU2, surficial deposits of the Rocky Flats Alluvium cap a bedrock ridge, whereas flanks of the ridge, or valley sides, are covered with thinner deposits of colluvium (Figure 6-10). A paleochannel, known as the medial paleoscour, trends northeast and cuts down into claystone and Arapahoe Formation sandstone (Figure 6-10). The bedrock surface is also cut by smaller paleochannels on top of the ridge and by "paleogullies" along the south side of the ridge (DOE, 1993b). Figure 6-10 shows a schematic north-south cross section through the OU2 pediment.

Groundwater flow conditions in OU2 typify the hydrogeologic setting of the central zone of the Rocky Flats site. The primary factors affecting groundwater flow in OU2 are bedrock topography, bedrock lithology, and surface topography. Bedrock topography locally directs the flow of groundwater within the surficial deposits and controls the occurrence of saturated and unsaturated areas. Groundwater in the surficial deposits flows primarily toward and within the medial paleoscour because of the relatively higher permeability of the surficial deposits relative to weathered bedrock. The bedrock ridges bounding the paleoscour restrict groundwater outflow to the north and south, particularly during the drier seasons when the water table is lowest (Figures 6-1, 6-10, and 6-11). Groundwater, however, sometimes flows over the southern bedrock ridge toward Woman Creek during high-water conditions in the spring. The saturated thickness of the surficial deposits is greatest along the axis of the paleochannel, whereas some parts of the bounding bedrock ridges are always unsaturated (DOE, 1993b).

The lithology of subcropping bedrock affects the amount of interaction between the surficial deposits and bedrock portions of the UHSU at OU2. The Arapahoe Formation sandstone subcrops directly beneath the Rocky Flats Alluvium along portions of the medial paleoscour and beneath the colluvium on the hillside facing South Walnut Creek and Woman Creek. Potentiometric data indicate that groundwater flows from the Rocky Flats Alluvium to the underlying Arapahoe Formation sandstone in the medial paleoscour. Figure 6-12 shows the hydrographs for three wells screened in the Arapahoe Formation sandstone. The water level decreases away from the limit of the sandstone subcrop indicating that groundwater flows away from the medial paleoscour in the sandstone. In addition, water-quality data indicate that VOCs in surficial deposits groundwater have migrated into the Arapahoe Formation sandstone in locations where the sandstone subcrops (DOE, 1993b).

Groundwater flow within the sandstone is controlled by the geometry of the sandstone and the location of subcrops. Potentiometric-surface maps (Plates 2 and 3) indicate that flow in the Arapahoe Formation sandstone diverges from where it subcrops the Rocky Flats Alluvium to the north, northeast, and southeast. Groundwater in the sandstone flows toward the Woman Creek and South Walnut Creek drainages. At these locations, groundwater discharges as interflow to the colluvium and causes surface seeps (Figures 6-1 and 6-11) (DOE, 1993b).

Seeps in OU2 are also caused by bedrock and surface topography. A large seep along South Walnut Creek is caused by discharge of groundwater from the northeast end of the paleoscour. At this location, the bedrock channel acts as a source of groundwater to the hillside. The location of other surface seeps at OU2 is controlled by surface topography. In some locations along the hillsides, the elevation of the ground surface changes more rapidly than that of the water table, and the ground surface intersects the water table forming seeps at these locations (DOE, 1993b).

Operable Unit Number 7

OU7 is located north of the Industrial Area at the upper reaches of the No Name Gulch drainage. OU7 is situated on a gravel-capped pediment which is dissected by Rock Creek to the north and North Walnut Creek to the south. Included within OU7 are the Present Landfill, the Inactive Hazardous Waste Storage Area, the Landfill Pond, and adjacent spray evaporation areas (DOE, 1994e).

Surficial deposits and weathered bedrock are the two water-bearing lithostratigraphic units that compose the UHSU at OU7. Surficial deposits include the Rocky Flats Alluvium, colluvium, valley-fill alluvium, and artificial fill. Rocky Flats Alluvium caps the ridge north and south of No Name Gulch. Colluvium is present on the hillslopes surrounding the Landfill Pond and No Name Gulch. Deposits of valley-fill alluvium are located in the No Name Gulch stream channel. Artificial fill comprises excavated gravels from nearby stockpiles, construction materials, and landfill debris. Artificial fill covers the westernmost extent of the No Name Gulch drainage within the boundaries of the Present Landfill (DOE, 1994e).

165

Groundwater flow also occurs within weathered bedrock of the undifferentiated Arapahoe and Laramie formations. Weathered bedrock generally comprises claystone and interbedded siltstones. However, a fine-grained, silty sandstone subcrops beneath the valley-fill alluvium downgradient of the Landfill Pond embankment. Borehole data suggest that this sandstone is discontinuous and pinches out a few hundred feet downstream (DOE, 1994e).

The Groundwater Intercept System around the perimeter of the landfill was designed to divert groundwater within the surficial deposits away from the landfill to minimize the generation of waste leachate. The Groundwater Intercept System is a combination of engineered structures that includes a subsurface drainage system, leachate collection system, and two slurry walls (Figure 6-16). Groundwater elevation and geochemistry data indicate that the Groundwater Intercept System is marginally effective in diverting groundwater away from the landfill (DOE, 1994e). Apparently, groundwater inflow occurs on the north side of the landfill where a 444-foot-long breach in the system was identified. Geological and geophysical data suggest that the Groundwater Intercept System on the north side of the landfill is not keyed into bedrock, inferring that groundwater inflow occurs underneath the Groundwater Intercept System. Potentiometric data indicate that groundwater/leachate flow within the landfill is controlled by the topography of the weathered bedrock surface and that the potentiometric surface resembles the configuration of the buried drainage (Figure 6-17). Groundwater/leachate within the surficial deposits is directed toward the center of the buried drainage where it eventually discharges at a seep located at the toe of the landfill or as baseflow to the Landfill Pond (DOE, 1994e).

Groundwater within the weathered bedrock does not appear to be affected by the Groundwater Intercept System. However, similar to groundwater flow within surficial deposits, the configuration of the potentiometric-surface map (Figure 6-7) indicates that groundwater within weathered bedrock is controlled by the bedrock topography and flows toward the center of the Landfill Pond drainage. Groundwater elevation data show that there is a downward component of flow from the surficial deposits groundwater system. The presence of contamination within the weathered bedrock confirms that there is hydraulic connection with the overlying surficial deposits. Groundwater elevation data also indicate that the weathered bedrock locally receives recharge from the Landfill Pond (DOE, 1994e).

6.3 Lower Hydrostratigraphic Unit

The LHSU at the Rocky Flats site consists of low-permeability, unweathered bedrock of the Arapahoe and Laramie formations. A discussion of the occurrence and distribution of LHSU groundwater, LHSU recharge and discharge, and hydraulic properties within the LHSU is presented to provide a conceptual understanding of groundwater flow patterns within the LHSU.

6.3.1 Geology of the LHSU

The Arapahoe and Laramie formations consist primarily of claystone with lesser amounts of siltstone and sandstone. These formations were deposited in a low-energy, fluvial and delta-plain setting, which typically produces a high percentage of fine-grained materials such as clays and silts. A relatively small percentage of sandstone exists within the unweathered bedrock.

The sandstones are likely to have been deposited as channel, bar, and flood-plain deposits (EG&G, 1995a). Individual sandstones can be stacked by vertical aggradation, but most are separated from each other by a substantial thickness of claystone. Where these sandstones are isolated, groundwater flow will be largely controlled by the surrounding deposits of low permeability. The channel sandstones are characterized by lenticular, shoestring geometries. These characteristics tend to decrease hydraulic conductivity in the vertical dimension and laterally across the dip direction (perpendicular to channel axis).

Unweathered bedrock exhibits lower permeability than the overlying weathered bedrock and surficial deposits (Figure 6-18). The contrast in permeability between UHSU deposits and LHSU bedrock differentiates the LHSU from the UHSU. The LHSU begins at the uppermost low-permeability boundary within the bedrock, which is the base of weathering. Higher permeability bedrock deposits that are in hydraulic connection with the overlying alluvial deposits such as weathered bedrock and subcropping sandstones are part of the UHSU.

Other geologic information relevant to conceptualization of LHSU groundwater occurrence and flow includes the potential for faulting. Faults have been mapped in several areas surrounding the Rocky Flats site; typically they trend toward the northeast. For example, northeast-trending faults have been mapped at the Boulder-Marshall Landfill, located northeast of the Rocky Flats site. Offset along these faults has placed claystones of the Laramie Formation against sandstones of the Laramie/Fox Hills aquifer. This structural configuration has significantly restricted lateral flow, as evidenced by anomalous water-table elevations in this area (Fox Consultants, 1984).

Recent geologic investigations at the Rocky Flats site have identified several north- to northeast-trending faults in the shallow bedrock. These faults are described in the companion Geologic Characterization Report (EG&G, 1995a). Fault displacement appears to range from 10 to 120 feet, based on structural cross sections and bedrock structure contours.

167

In addition to displacement, faulting can produce a zone of fracturing. Fractures may be open or completely filled with mineral precipitates derived from groundwater or percolation of meteoric water. The nature and degree of fracture fill and interconnectedness of the fracture system determines the degree to which fracturing enhances or reduces permeability.

In Arapahoe Formation sandstones, fault-related, small-scale displacements have been shown to exhibit cataclastic textures resulting from brecciation of sand grains during faulting (Jamieson and Stearns, 1982). These cataclasites have the appearance of gouge-filled fractures. The gouge surfaces may become interconnected and form a zone of increased or reduced permeability. As sandstones become more cemented and compacted, the contribution of fractures to the materials permeability increases. Many sandstones have higher horizontal than vertical permeabilities. However, this may be reversed in highly fractured sandstones by a preference for higher fracture permeability in the vertical direction (Freeze and Cherry, 1979). In general, matrix porosities are greater than fracture porosities and fracture porosities probably decrease with depth.

Recent drilling along a northeast-oriented inferred fault just north of the Landfill Pond (OU7) suggests enhanced permeability along the inferred fault. Two boreholes that did not intercept the fault remained relatively dry following drilling, while a third borehole drilled closer to the inferred fault encountered a highly fractured zone that immediately filled with water (F. Grigsby, personal communication, 1994).

6.3.2 Groundwater Occurrence and Distribution

Groundwater in the LHSU exists within interstitial pore spaces, fractures, and possibly faults. Groundwater in the LHSU can be either confined or unconfined, depending on location. In many cases, however, it is difficult to make this determination because a discrete confining unit is not present. The UHSU exists because of a permeability difference between the UHSU and LHSU rather than the existence of a discrete confining layer. In general, water levels of wells screened in the LHSU are above screened intervals and are occasionally above the top of bedrock. However, the interpretation of hydrographs is difficult because of the effect of sampling on water levels. Groundwater may appear to be unconfined following sampling events when water levels drop below the top of the unweathered bedrock (well-cluster hydrograph 14, Appendix G).

Potentiometric elevations within the LHSU were not contoured because potentiometric data are limited and because isolated sandstone units are preferentially screened in LHSU wells. LHSU wells screened in isolated sandstones represent only local hydraulic conditions and not conditions throughout the LHSU. In general, groundwater flow within the LHSU has a strong downward component as indicated by well-cluster hydrographs 53 and 55 (Appendix D). Locally, upward vertical gradients between unweathered bedrock and UHSU materials can exist in valley bottoms (see well-cluster hydrographs 8, 9, and 10, Appendix D). On the regional scale, flow in the LHSU is from west to east as indicated by the potentiometric-surface map for the Arapahoe aquifer shown in Figure 4-3.

6.3.3 Recharge

Recharge to the LHSU can occur directly from precipitation in the western portions of the Rocky Flats site where bedrock outcrops or as infiltration from the UHSU. In most areas the vertical gradient between the UHSU and the LHSU is downward, indicating the potential for downward recharge (Figure 6-19). This downward component of flow is schematically shown in hydrogeologic cross sections D-D' (Plate 13) and G-G' (Plate 16). Due to the limited amount of potentiometric data in the LHSU, the magnitude of downward flow cannot be inferred from these cross sections. However, the low permeability of LHSU deposits limits the volume of water recharging the LHSU from the UHSU. This interpretation is supported by geochemical information which shows that the UHSU and LHSU groundwater have larger distinct chemistries (EG&G, 1995b). Groundwater from the LHSU is characterized as sodium-sulfate to sodium carbonate, whereas UHSU groundwater is characterized as calcium-bicarbonate. Also, major-ion concentrations in LHSU groundwater exhibit larger variations than in UHSU groundwater. This variation may reflect greater isolation between water-bearing zones in the LHSU (due to isolated regions of flow within low-permeability material). Anthropogenic analytes present in the UHSU are rarely detected in the LHSU (EG&G, 1995b). These distinctions in groundwater chemistry support the concept of limited LHSU recharge from UHSU groundwater.

6.3.4 Discharge

Water-level elevations in LHSU wells indicate that, in general, the horizontal hydraulic gradient within the LHSU follows the regional eastward gradient. This can be seen by examining average water-level elevations in LHSU wells displayed in well-cluster hydrographs 1, 8, and 10 (Appendix D), which indicate lower water-level elevations from west to east across the site. Because gradients reflect the direction of recharge to discharge, an eastward discharge of water through the LHSU is indicated.

Locally, upward gradients from the LHSU to the UHSU exist in stream drainages (well clusters 8, 9, and 10, Appendix D). Upward vertical gradients in stream drainages result from the lower head potential of the UHSU in these areas. Water-level elevations in the LHSU are less affected by changes in surface topography, and LHSU groundwater may locally discharge to the UHSU in stream drainages. However, the volume of groundwater discharging to the UHSU would be limited by the low permeability of LHSU materials.

The LHSU may also discharge to the underlying Laramie/Fox Hills aquifer. However, the upper portion of the Laramie Formation is composed predominantly of claystone and forms a confining unit (see Section 4.5). At Rocky Flats, the upper Laramie Formation unit has been estimated to be 300 to 500 feet thick. This unit probably limits LHSU discharge into the Laramie/Fox Hills aquifer due to its low permeability and thickness.

6.3.5 Hydraulic Properties

The results of aquifer tests were compiled, and geometric means of saturated hydraulic conductivity for different lithologic units of the LHSU were calculated (Table G-1). Estimates of saturated hydraulic conductivity were compiled for unweathered bedrock claystones, siltstones, and sandstones. Figure 6-20 shows that the geometric mean of hydraulic conductivity values for LHSU claystones, siltstones, and sandstones are 2.48E-07, 1.59E-07, and 5.77E-07 cm/sec, respectively (EG&G, 1994d). These estimates of saturated hydraulic conductivity indicate that LHSU sandstones are only slightly more permeable than LHSU claystones and siltstones. This indicates that flow rates in the LHSU are only marginally impacted by changes in lithology.

The statistics computed for hydraulic data (Table G-2) show that unweathered claystone is the most heterogeneous unit of the LHSU. The median and mean differ by two orders of magnitude, and the minimum and maximum value differ by five orders of magnitude. The coefficient of variation (standard deviation/mean) for unweathered claystone is 12.2. The skewness and kurtosis of the data are 12.6 and 160 respectively, indicating that the data are positively skewed and leptokurtic. The large variations in hydraulic conductivity may be caused by variations in secondary porosity (such as fractures) within the claystone. A large set of hydraulic conductivity values (160) were available for analysis indicating that unweathered claystone hydraulic conductivity is well characterized.

The hydraulic conductivities of both siltstones and sandstones in the LHSU are heterogeneous. The median and mean of each unit differ by one order of magnitude, and the minimum and maximum value of each unit differ by three orders of magnitude (Table G-2). The coefficients of variation for unweathered siltstone and unweathered sandstone are 2.47 and 2.85, respectively. The skewness of the siltstone and sandstone data is 3.2 and 4.4, respectively. The kurtosis of unweathered bedrock hydraulic conductivities for siltstone and sandstone is 10.4 and 21.1, respectively. Thus, both the unweathered siltstone and sandstone data are positively skewed and leptokurtic. A moderate number of values for LHSU siltstones (39) and sandstones (41) were analyzed; therefore, the characteristics of these units are reasonably well characterized.

Box-and-whisker plots for saturated hydraulic conductivity values from different unweathered bedrock units are presented in Appendix G. The unweathered claystones, siltstones, and sandstones all exhibit saturated hydraulic conductivity values that exceed the upper quartile ranges. Because these hydraulic data were deemed usable through extensive review and reanalysis (refer to Table G-1 and Appendix H), these outliers likely represent heterogeneities in the flow system.

Estimated well yields for different lithologic units are presented in Table G-4. The single well yield value of 0.021 gpm for unweathered sandstone is significantly less than reported values for the UHSU.

Contaminant transport in the unweathered bedrock is controlled primarily by diffusion because of the relatively low average linear groundwater velocities within the unit (Figure G-13). Calculations supporting this conclusion are presented in Appendix G.

6.3.6 Summary

The LHSU at the Rocky Flats site is composed of low-permeability, unweathered bedrock of the Arapahoe and Laramie formations. The Arapahoe and Laramie formations consist primarily of claystone with lesser amounts of siltstone and sandstone. These units exhibit lower permeability than the overlying weathered bedrock and surficial deposits that comprise the UHSU. Higher permeability bedrock deposits that are in hydraulic connection with the overlying alluvial deposits (e.g., subcropping sandstones) are part of the UHSU.

Groundwater in the LHSU can be either confined or unconfined and exists within interstitial pore spaces, fractures, and possibly faults. On the regional scale, flow in the LHSU is from west to east. Locally, groundwater flow within the LHSU may be affected by faults and fracture zones within the bedrock. The degree to which the fracture fill and interconnectedness of the fracture system enhances or reduces permeability is unknown.

Recharge to the LHSU can occur directly from precipitation in the western portions of the Rocky Flats site where bedrock outcrops or as infiltration from the UHSU. In most areas, there is potential for downward recharge where the vertical gradient between the UHSU and LHSU is downward. However, distinctions in groundwater chemistry data between the UHSU and LHSU indicate there is limited LHSU recharge from UHSU groundwater.

171

Discharge to the UHSU from the LHSU may locally occur in stream drainages where upward gradients have been observed. Discharge does not likely occur downward into the underlying Laramie/Fox Hills aquifer because the upper portion of the Laramie Formation is composed primarily of low-permeability claystone which has been estimated to be 300 to 500 feet thick.

The geometric mean of hydraulic conductivity values for LHSU claystones is 2.48E-07 cm/sec, the hydraulic conductivity of LHSU siltstones is 1.59E-07 cm/sec, and the hydraulic conductivity of LHSU sandstones is 5.77E-07 cm/sec. These close values indicate that flow rates in the LHSU are only marginally impacted by changes in lithology. Contaminant transport in the unweathered bedrock is controlled primarily by diffusion because of the relatively low average linear groundwater velocities within the unit.

6.4 UHSU\LHSU Interactions

The degree of hydraulic interaction between the UHSU and LHSU at the Rocky Flats site is a function of the hydrostratigraphy of the two units. The hydraulic interaction between the hydrostratigraphic units is important in assessing the vertical movement of groundwater and contamination between the hydrostratigraphic units and the potential offsite migration of contaminated groundwater. The interactions between the UHSU and LHSU are examined by discussing the hydraulic properties of the two units, the potential for vertical flow between the two units, the major-ion chemistry and stable isotope composition of the two units, the presence of contamination in the LHSU, and the potential for vertical groundwater movement through secondary permeability such as faults or fractures.

6.4.1 Hydrostratigraphy of the Upper and Lower Hydrostratigraphic Units

The upper and lower hydrostratigraphic units represent the two shallowest groundwater flow regimes at the Rocky Flats site. The UHSU comprises unconsolidated surficial deposits which consist of the Rocky Flats Alluvium, colluvium, valley-fill alluvium, artificial fill, weathered bedrock of the Arapahoe and Laramie formations, and Arapahoe Formation sandstones in hydraulic contact with surficial deposits. The LHSU comprises unweathered bedrock of the Arapahoe and Laramie formations.

The hydrogeologic cross sections and profiles (Plates 10 through 20) illustrate the hydrostratigraphy of the UHSU and LHSU. The contact separating the two hydrostratigraphic units is identified as the base of the weathered zone in the Arapahoe and Laramie formations. Generally, the base of the UHSU gently slopes toward the east, reflecting the relief of the surface topography. The UHSU is thickest on the ridge tops and becomes relatively thin along the stream valleys. The relatively low saturated hydraulic conductivity (10^{-7} cm/sec) of the unweathered claystones and siltstones indicates that the LHSU acts as an effective hydraulic barrier to downward migration of groundwater from the UHSU. However, there are saturated sandstone units within the LHSU that may enhance hydraulic interaction with the overlying UHSU. For example, in OU2 LHSU sandstones either subcrop on hillslopes or are within close vertical proximity of the UHSU (DOE, 1993b). The lithology and hydraulic properties of the UHSU and LHSU are discussed in greater detail in Sections 6.2 and 6.3.

6.4.1.1 Well-Cluster Hydrographs

Thirty well-cluster hydrographs demonstrate the hydraulic interactions between the UHSU and LHSU by displaying water-level fluctuations in each unit (Appendix D). The well-cluster data were used for a qualitative assessment of hydraulic interaction between the UHSU and LHSU based on well-completion intervals and potentiometric data. Figure 6-21 shows the locations of the 30 well clusters in relation to the hydrography at the Rocky Flats site.

The majority (25 out of 30) of the LHSU hydrographs do not show seasonal water-level fluctuations similar to those displayed in the UHSU. The completion depths of these LHSU wells range from approximately 25 to 146 feet below the bedrock contact. These wells are spaced randomly throughout the site, located on ridge tops and within drainages. One well cluster (52), completed approximately 44 feet below the bedrock contact, exhibits constant unsaturated conditions. These data suggest that in general the two units are not in direct hydraulic connection. The difference in hydrograph responses are probably a reflection of the contrast in lithology and hydraulic properties between the two units. In some cases, analysis of LHSU water-level data is complicated by abrupt downward shifts in (hydraulic) head followed by slow gradual recovery to static conditions. This is most likely caused by sampling events. The slow recovery time observed on the hydrographs demonstrates the relatively low hydraulic conductivity and slow recharge rates of the LHSU.

Two well clusters (53 and 55) demonstrate hydraulic interactions within the LHSU. The hydrographs of well clusters 53 and 55 display water levels of LHSU wells completed at various depths. Well cluster 53 has three wells completed in the LHSU at depths of approximately 48, 74, and 122 feet below the bedrock contact. These wells show a consistent downward gradient with the two deepest wells showing similar changes in head. The LHSU wells at well cluster 55 are completed at depths of approximately 86 and 108 feet below the bedrock contact. The water levels displayed in these wells show nearly identical changes in head. These well-cluster hydrographs show that changes in head in the LHSU wells are of approximately the same magnitude and frequency suggesting that the LHSU functions as one unit at these locations.

Of the 30 well-cluster hydrographs evaluated, only three displayed similar changes in water-level fluctuations between UHSU and LHSU wells. Well clusters 6, 14, and 35 exhibit seasonal water-level fluctuations in the LHSU that correlate with water-level changes observed in the UHSU. The magnitude of these water-level fluctuations reflect storage changes in the two units. The similarity in frequency and magnitude of storage changes within the two hydrostratigraphic units suggest a hydraulic connection between these two units. The following observations were noted at each of these well clusters:

- Well cluster 6 is located in South Walnut Creek near OU4. The LHSU well is completed in unweathered sandstone and claystone approximately 28 feet below the contact between the bedrock and overlying surficial deposits. The magnitude of the storage changes within the LHSU is slightly less than that of the overlying UHSU, indicating a possible hydraulic connection between the two hydrostratigraphic units at this location.

- Well cluster 14 is located in OU2. The LHSU well is completed in unweathered claystone approximately 42 feet below the contact between the bedrock and the overlying alluvium. The LHSU and UHSU (surficial deposits) wells showed an abrupt decrease in storage in 1990, approximately the same time spray evaporation activities in OU2 ceased. The decline in water levels in the LHSU well is less dramatic than in the UHSU, implying that some recharge may have been reaching the LHSU during spray-evaporation activities.

- Well cluster 53 is also located in OU2. There are three LHSU wells completed at depths of approximately 48, 74, and 122 feet below the bedrock contact at this well cluster. The uppermost LHSU well exhibits slight seasonal cyclic fluctuations similar to those observed in the UHSU, while the two deeper wells do not appear to be hydraulically connected to the UHSU. The shallow LHSU well is completed in unweathered silty sandstone and siltstone. The seasonal water-level fluctuations in the shallow LHSU well subtly reflect the storage changes in the overlying UHSU, indicating that limited hydraulic connection between the two hydrostratigraphic units may only exist at the shallowest depth.

Based on these observations, the LHSU appears to have only limited hydraulic connection with the UHSU and only at shallow depths (within 50 feet of the weathered bedrock/unweathered bedrock contact) in some areas. As demonstrated by the two well clusters in OU2 and the well cluster on the 881 Hillside, hydraulic connection between the hydrostratigraphic units is enhanced in areas where LHSU sandstones subcrop or are within close vertical proximity of the base of the UHSU. It is quite possible that the permeability of the claystone may be enhanced by interconnected fracturing within the unit (discussed in greater detail in Section 6.4.5) Some limited hydraulic connection between the two units is further confirmed by the presence of low concentrations of

VOCs such as benzene, ethyl benzene, and trichloroethane in the LHSU at well clusters 6 and 53.

6.4.1.2 Hydraulic Properties

The rate and magnitude of downward seepage from the UHSU to the LHSU is a function of the permeability of the LHSU and the downward hydraulic gradient between the hydrostratigraphic units. Saturated hydraulic conductivity values for the LHSU (10^{-7} cm/sec) are generally two orders of magnitude less than the overlying weathered bedrock strata (10^{-5} cm/sec). The saturated geometric mean hydraulic conductivity values within the LHSU (Table G-2) show slight variation between lithologic units (e.g., unweathered siltstone 1.59E-07 cm/sec, unweathered claystone 2.48E-07 cm/sec, and unweathered sandstone 5.77E-07 cm/sec). The saturated hydraulic conductivity values of these three lithologic units are within the same order of magnitude, suggesting that the rate of groundwater movement within the LHSU remains relatively constant despite changes in lithology. However, vertical saturated hydraulic conductivities may be less than 10^{-7} cm/sec. Anisotropy of the LHSU is demonstrated by results of falling-head permeameter tests presented in Table G-3. The geometric mean of the vertical saturated hydraulic conductivity values is 5.83E-08 cm/sec, an order of magnitude less than the horizontal saturated hydraulic conductivity values presented in Figure 6-20. The range of vertical saturated hydraulic conductivity values (10^{-6} cm/sec to 10^{-10} cm/sec) indicates that the LHSU acts as an effective hydraulic barrier to downward groundwater flow.

Vertical hydraulic gradients determine the direction of flow between the UHSU and LHSU. Of the 11 well clusters used to calculate vertical hydraulic gradients, seven indicated downward flow (Figure 6-19), downward gradients range from 0.03 to 1.00 (Table D-1). Generally, the well clusters showing downward gradients are located on the ridge tops between the incised drainages.

Three of the well-cluster hydrographs (8, 9, 10) exhibited consistent upward gradients; gradients range from 0.02 to 0.24 (Table D-1). These well clusters are located in or near stream channels (Figure 6-19). The upward gradients indicate that LHSU groundwater may recharge the UHSU locally.

It is possible to estimate the magnitude of downward vertical flow into the LHSU from the UHSU using Darcy's law. Assuming homogeneous, isotropic, steady-state, one-dimensional flow and full saturation, downward seepage through the LHSU can be estimated. Using a vertical saturated hydraulic conductivity value of 5.83E-08 cm/sec (geometric mean for the LHSU from Table G-3), a hydraulic gradient of one, and Darcy's law, the downward flux is estimated as:

$$q = K\frac{dh}{dz} = 5.83\text{E-08 cm/sec}$$

The Darcy flux is estimated as 5.83E-08 cm/sec or 8.58E-07 gpm/ft^2. Using the previously stated assumptions and a Darcy flux of 5.83E-08 cm/sec and assuming an effective porosity of 0.10 (η), the seepage velocity (v) can be obtained from the Darcy flux using the following relationship:

$$v = \frac{q}{\eta} = 5.83E-07\,cm/sec$$

The seepage velocity represents the advective transport rate of nonreactive contaminants. The estimated seepage velocity of 5.83E-07 cm/sec demonstrates the relatively slow vertical movement of groundwater in the LHSU. At the rate of 5.83E-07 cm/sec, a conservative contaminant will only have traveled 9 meters through the LHSU in approximately 50 years.

6.4.2 Groundwater Geochemistry

The major-ion chemistry and environmental isotope compositions of the upper and lower hydrostratigraphic units were evaluated in the Groundwater Geochemistry Report (EG&G, 1995b). The results of these analyses were used as supplemental information for evaluating the interaction between the UHSU and LHSU. Findings from the Groundwater Geochemistry Report are summarized in this section.

The major-ion chemistry of the hydrostratigraphic units was evaluated using Stiff and Piper trilinear diagrams. Stiff diagrams show that the major-ion chemistry of the UHSU groundwater is distinctly different than that of the LHSU groundwater. Other than some wells within IHSSs, the Stiff diagrams of various geologic units within the UHSU consistently show similar ion contents and can generally be described as a calcium-bicarbonate type. Conversely, Stiff diagrams of LHSU groundwater indicate a sodium-bicarbonate to sodium-sulfate water type. LHSU groundwater also displayed wider variations in ionic content than UHSU groundwater. These factors indicate that the ion chemistry of the UHSU and LHSU are significantly different (EG&G, 1995b).

Piper trilinear diagrams also displayed significant differences in major ion chemistry between the UHSU and LHSU. In the Rock Creek area, Piper diagrams indicate a distinct difference in the cation content of groundwater of the two hydrostratigraphic units. The LHSU groundwater generally has a higher sodium content and a wider variation in cation content than the UHSU. In the OU4 area, the major-ion chemistry is slightly reversed. The UHSU groundwater geochemistry is more variable; however, this may be related to contamination sources in the Industrial Area (EG&G, 1995b).

Environmental isotope compositions of oxygen (^{18}O) and hydrogen (deuterium [D] and tritium [^3H]) are useful indicators for determining the degree of hydraulic interaction between the upper and lower hydrostratigraphic units. The isotope compositions of $\delta^{18}O$ and δD are expressed as parts per thousand ($^o/_{oo}$, per mil) difference from the Standard Mean Ocean Water (SMOW) given by the following expression:

$$\delta D \text{‰} = \{(D/^3H_{(sample)} - D/^3H_{(SMOW)})/D/^3H_{(SMOW)}\} * 10^3$$

$$\delta^{18}O \text{‰} = \{(^{18}O/^{16}O_{(sample)} - ^{18}O/^{16}O_{(SMOW)})/^{18}O/^{16}O_{(SMOW)}\} * 10^3$$

Histograms displaying $\delta^{18}O$ values show distinct variations in the range of values and central tendency of $\delta^{18}O$ distributions between the UHSU and LHSU. The $\delta^{18}O$ values in the UHSU range from -16.5 to -10.3 in surficial deposits groundwater and -19.2 to -10.1 in weathered bedrock groundwater. The range of $\delta^{18}O$ (-15.5 to -10.5) for the LHSU groundwater is similar to the range of $\delta^{18}O$ values in surficial deposits groundwater but has much less variation than weathered bedrock groundwater. However, there is a shift in increased ^{18}O and D contents with depth within the LHSU, thereby indicating a recharge source other than the UHSU groundwater.

Tritium is a useful indicator for determining the relative ages of groundwater flow systems. The majority of tritium in the natural environment is attributed to atmospheric fallout from nuclear weapons testing. Because the half-life of tritium is 12.43 years, tritium concentrations in groundwater are indicators of the age of natural waters. The expected tritium content of water infiltrating into the groundwater system prior to nuclear testing is typically less than three TUs.

The tritium content of UHSU groundwater ranges from 10 to 50 TUs. Tritium content in the UHSU is highly variable at shallow depths due to mixing with surface water recharge. This variation in tritium content decreases with depth in the UHSU. In contrast, the majority of the tritium samples in the LHSU were below the detection limit. These results suggest that LHSU groundwater is older than UHSU groundwater and may originate from different sources of recharge (EG&G, 1995b).

Generally, the isotope data suggests that the LHSU and UHSU are distinct groundwater flow systems that are not in direct hydraulic connection. At deeper depths there is a slight positive shift in $\delta^{18}O$ and δD contents suggesting another source of recharge that is indicated by the tritium contents to be much older than the UHSU groundwater. The low tritium concentrations in the LHSU also indicate that the age of this groundwater system is greater than 40 years (EG&G, 1995b). The isotope data coincide with the hydrograph analysis (refer to Section 6.4.11) which suggests that the LHSU and UHSU

177

are generally two separate groundwater flow systems with little or insignificant amount of hydraulic connection between the two units.

However, hydraulic connection between the UHSU and LHSU may occur in isolated areas. Despite the positive shift in $\delta^{18}O$ and δD content and lower tritium concentrations in the LHSU groundwater, VOCs detected in the LHSU indicate potential mixing of upper and lower HSU groundwaters in some areas at Rocky Flats (EG&G, 1994a). The presence of trichloroethylene (TCE) in LHSU groundwater at OU2 (well 23193) (DOE, 1993b) and other VOCs at well clusters 6 and 53 may indicate limited hydraulic connection between the upper and lower hydrostratigraphic units in some areas. It has been postulated, however, that some of these occurrences of VOCs may have resulted from cross-contamination during well installation (DOE, 1994c).

6.4.3 Preferential Groundwater Flow Through Secondary Permeability

Secondary permeability through interconnected high-angle fractures and fault zones in the unweathered bedrock may enhance localized hydraulic interactions between the upper and lower HSU. In OU2, open continuous fractures were observed to a depth of approximately 60 feet. Iron-oxide staining along the fracture planes confirms the downward movement of groundwater. Acoustic televiewer logs (of well 21593) showed that the degree of fracturing began to decrease approximately 100 feet below ground surface (DOE, 1993b).

Postulated fault zones within the bedrock were identified in the Geologic Characterization Report (EG&G, 1995a). Inferred bedrock faults in or near the Industrial Area may have an impact on preferential groundwater flow. A north-south-trending fault is inferred below the Solar Evaporation Ponds in OU4. This fault is truncated on the north and south by two prominent northeast-trending faults. The northeast-trending fault to the north of OU4 is inferred beneath the Industrial Area and OU7. This fault also truncates a minor north-northeast-trending fault near OU10. A second northeast-trending fault to the south of the Industrial Area is inferred under OUs 1 and 2. Brecciated zones within the bedrock along the traces of these postulated faults were noted during drilling investigations (F. Grigsby, personal communication, 1994). Well cluster 6 exhibits a hydraulic connection between the upper and lower hydrostratigraphic units and is near one of these faults. This may suggest that these fault zones are enhancing the permeability of the bedrock, effectively creating a preferential flowpath between the upper and lower hydrostratigraphic units (EG&G, 1995a).

6.4.4 Conclusions

Well-cluster hydrographs and geochemical data demonstrate a minimal or insignificant amount of hydraulic interaction between the UHSU and LHSU. However, in some areas the LHSU only appears to be in direct hydraulic connection with the overlying UHSU at depths of less than 50 feet below the bedrock unconformity. There is evidence of hydraulic connection between the hydrostratigraphic units in OU2 where LHSU sandstones subcrop or are within close vertical proximity of the UHSU. However, the geometry of these LHSU sandstone units has been characterized as being laterally discontinuous in nature and, therefore, these sandstone units are unlikely to represent pathways for offsite contaminant migration (EG&G, 1995a). Generally, flow in the LHSU is downward on the ridge tops. However, some upward components of flow are present in stream valleys. The relatively low saturated hydraulic conductivity of the LHSU (e.g., 10^{-7} cm/sec horizontal saturated hydraulic conductivity and 10^{-8} cm/sec vertical saturated hydraulic conductivity) suggests that the LHSU generally acts as an effective barrier to downward flow.

The groundwater geochemistry of the two hydrostratigraphic units is distinctly different. The UHSU groundwater is generally classified as a calcium-bicarbonate-type water compared to the sodium-bicarbonate to sodium-sulfate classification for LHSU groundwater. The relative increase in $\delta^{18}O$ and δD with depth and low tritium concentrations in the LHSU suggest that the hydraulic interaction between the UHSU and LHSU is generally insignificant and at the most very limited (EG&G, 1995b).

The geochemistry and hydraulic properties of the upper and lower hydrostratigraphic units indicate that the interactions between the two units are minimal. However, in some areas the limited presence of low concentrations of VOCs in the LHSU demonstrates that some movement of groundwater may occur between the two units. Interconnected fracturing and fault zones in bedrock may increase permeability, thereby enhancing the hydraulic interactions between the two units. These interconnected fractured zones have been observed in OU2. Potential bedrock faults have also been inferred under the Industrial Area and in OUs 1, 2, 4, and 7 (EG&G, 1995a).

6.5 Surface-Water/Groundwater Interactions

This section describes surface-water/groundwater interactions at the Rocky Flats site. Potentiometric-surface maps, a seep location map, stream/well-cluster hydrographs, longitudinal profiles, pond dam design, dam piezometer data, stream-gaging data, Woman and Walnut Creek water-balance studies, and East Spray Field data were used to characterize surface-water/groundwater interactions at Rocky Flats.

Surface water at Rocky Flats occurs as streams, seeps, ponds, ditches, and lakes. A description of surface-water features at Rocky Flats is presented in Section 3.3.1.

Shallow groundwater at Rocky Flats exists within the UHSU, which is described in Section 6.2. There is considerable interaction between surface water and groundwater at Rocky Flats (EG&G, 1991c). Surface-water seepage into shallow groundwater occurs at streams, seeps, ponds, ditches, and lakes. Shallow groundwater discharges to the surface at seeps and within drainages. All of these interactions vary spatially and temporally.

Due to the limited nature of data describing surface-water/groundwater interactions at the Rocky Flats site, two sources of information were used to develop a conceptual understanding of these interactions. The Woman Creek Infiltration/Exfiltration Study (EG&G, 1993h) and the Walnut Creek Water Balance (EG&G, 1994d) were used to develop a conceptual understanding of the spatial and temporal patterns of surface-water/groundwater interaction at Rocky Flats. Other data from hydrographs, seeps, and dam piezometers were then used to confirm the conceptual model of surface-water/groundwater interactions developed from the two studies.

6.5.1 Woman Creek Infiltration/Exfiltration Study

Woman Creek has been the focus of most of the investigative research on the interaction of surface water (stream flow) and groundwater at the Rocky Flats site. Stream flow measurements were collected with Cutthroat flumes at 29 stations along Woman Creek on a monthly basis from August 1992 to September 1993 (Fedors and Warner, 1993). The results were used to identify gaining and losing segments of the stream. A stream or reach of a stream that is increasing in flow volume as the result of inflow from groundwater is considered gaining or effluent. Conversely, a stream or reach of a stream that is losing water by seepage into the ground is considered losing or influent. Segments of Woman Creek were placed into one of the following four general classifications: creek gains year-round, creek gains during spring (December through March or April) and loses during the rest of the year, creek losses year-round, or creek experiences a gain for two months or less and losses during the rest of the year (EG&G, 1993c). The stream segments and their corresponding classifications are presented on Figure 6-22.

In the upper Woman Creek drainage near the western boundary of the Rocky Flats site, several segments of the stream gain water year-round. These segments are between stations 5-6, 6-7, and 9-10 and upstream of station 14 (Figure 6-22). Perennial seeps and associated high groundwater levels in the area are probably the groundwater source for these gaining stream segments. The largest of these perennial seeps is Antelope Springs. Stable flow from Antelope Springs implies that it is either a discharge point for a regional flow system or that there is a consistent recharge source to the aquifer. Potential upgradient sources of recharge to the UHSU include Rocky Flats Lake and the South Boulder Diversion Canal, both of which may lose water to the groundwater through seepage (DOE, 1992b). Isotope chemistry indicates that Rocky Flats Lake is a recharge source to the UHSU and Antelope Springs. Heavy-isotope-enriched water at Antelope Springs suggests that the water ultimately originates, at least in part, from Rocky Flats Lake (EG&G, 1994d), which is enriched in heavy isotopes due to evaporative fractionation.

Stream segments between stations 1-2, 2-3, 3-4, 4-8, 8-9, and 11-12, on Woman Creek in the western portion of the Rocky Flats site gain in the spring and lose during the rest of the year. Groundwater elevations within the unconsolidated materials rise in the spring in response to high recharge rates. These stream segments probably gain water from the seasonally high water table and from ephemeral seeps. With reduced recharge in the late summer and fall and lowered water-table elevations, discharge from ephemeral seeps ceases, and gaining segments of Woman Creek lose water to the valley-fill alluvium as the water table drops below the bottom of the channel.

The eastern portion of Woman Creek at Rocky Flats generally loses water to groundwater year-round or for all but two months out of the year. These influent conditions occur along the stream segments between stations 10-11, 12-16, 16-17, C1-18, 20-21, 21-22, 22-23, and 23-24 (Figure 6-22). Near Ponds C-1 and C-2, groundwater within the valley-fill alluvium is typically 5 to 7 feet below ground surface (DOE, 1992b). Within the Woman Creek drainage, unsaturated conditions are typical within the unconsolidated material downstream from Pond C-2 following the high-water stage in the spring (Plate 3). Longitudinal profile D'-D" (Plate 13) illustrates the unsaturated nature of the unconsolidated material below Pond C-2 during the fourth quarter of 1993. The depth to groundwater and unsaturated conditions within unconsolidated materials result in the general influent nature of the eastern portions of Woman Creek.

There are, however, several short segments of Woman Creek, east of the confluence with the Antelope Springs drainage, that gain either year-round or during the spring. These stream segments are between stations 17-C1, 18-19, and 19-20 (Figure 6-22). A thicker section of the valley-fill alluvium is saturated in the spring when recharge to the alluvium is high within these sections (Plate 4). The short, seasonally gaining segments of Woman Creek could result from the seasonal increase in saturated thickness at these locations. One short segment of Woman Creek east of the confluence with the Antelope Springs drainage gains year-round (Segment 18-19). This may be due to small paleochannels incised on the bedrock surface along the hillslopes within the Woman Creek drainage (EG&G, 1995a, Plate 4-3). These bedrock paleochannels may preferentially collect and move groundwater downslope to a discharge point corresponding to this gaining segment of Woman Creek. The effect of bedrock paleochannels on groundwater flow is discussed in Sections 6.2.3.2 and 6.2.3.3.

Another surface-water feature within the Woman Creek drainage that may interact with shallow groundwater is the SID. The SID was constructed in 1980 to intercept surface runoff from the Industrial Area. Flow in the SID is intermittent and generally occurs only following precipitation events or snowmelt (DOE, 1992b). Because the SID is engineered with a series of riprap-lined plunge pools instead of a continuous grade, it is difficult to determine whether various segments of the ditch are gaining or losing. The western portion of the SID may gain or lose water depending on local groundwater elevations; however, the eastern portion of the SID appears to lose water as the plunge pools along this reach are almost always dry (EG&G, 1992e).

The results of the Woman Creek study generally indicate that Woman Creek gains water from the groundwater, particularly during the wet spring months, from the western Rocky Flats site boundary to its confluence with the Antelope Springs drainage. Downgradient from the Antelope Springs drainage to the eastern Rocky Flats site boundary, Woman Creek generally loses water through seepage into the valley-fill alluvium. The spatial distribution of gaining and losing sections of Woman Creek is controlled by the location of groundwater sources from seeps, springs, or bedrock paleochannels and the relative elevation of groundwater to the channel bottom. This is confirmed by the generally influent nature of Woman Creek in the eastern portion of Rocky Flats where these sources are not present and the thickness of unsaturated surficial deposits increases. The ephemeral nature of stream flow at Rocky Flats is due to the fact that most streams lose flow to groundwater during most of the year except in localized areas near springs, seeps, and other groundwater discharges such as hillside bedrock paleochannels.

6.5.2 Walnut Creek Water Balance

Of the three major drainages at Rocky Flats, Walnut Creek receives most of the surface runoff from the Industrial Area (EG&G, 1992d). As a result, surface water in the Walnut Creek drainage is heavily managed and flow is controlled and influenced by a series of detention ponds and various interceptor and diversion ditches. In addition, effluent from the Waste Water Treatment Plant (WWTP) is discharged into the drainage at Pond B-3. Surface-water features within Walnut Creek are discussed in Section 3.3.1. Discharge volumes from seven surface-water gaging stations in the Walnut Creek drainage were measured for eight periods of continuous record during water year 1993. The seven stream gaging stations were GS03, GS08, GS09, GS10, GS11, GS12, and GS13. These stations are posted on Figure 6-23. These data were used to calculate the contribution of flow to Walnut Creek from North Walnut Creek, South Walnut Creek, and the WWTP and to determine the percent gain/loss of surface-water flow for the basin and for individual segments within the basin.

Definite gain/loss patterns were calculated for only one of the measured segments of Walnut Creek. Data indicated that the segment of Walnut Creek from Pond A-4 (GS11) to the eastern site boundary (GS03) loses water to the valley-fill alluvium throughout the year. The calculated loss through this segment ranges from approximately 8 to 41 percent of the surface-water flow within the stream. The gain/loss pattern of other measured segments within Walnut Creek could not be positively explained, possibly due to inaccurate pond-level measurement and discharge data. However, fairly consistent baseflow in the western portion of North Walnut Creek at station GS13 is due to groundwater seepage (EG&G, 1994d). Although stream gaging data on Walnut Creek are not sufficiently accurate to allow for definite determination of gain/loss patterns, general spatial and temporal trends are discernible. Effluent stream conditions are dominant along western portions of the drainage in the spring, and the eastern segment of the drainage is consistently influent.

6.5.3 Comparison of Stream-Gaging Data and Alluvial-Well Hydrographs

Thirteen primary stream-gaging stations (GS01–GS13) are used to monitor stream flow at Rocky Flats (Figure 6-23). Mean values for daily discharge values are generated from stage data collected at each of the stations. Surficial-deposit wells located near 11 of the stream-gaging stations were evaluated with stream-stage data to characterize gaining and losing stream segments. Elevations of the stream-gaging stations have not been determined, and the associated surficial wells are commonly some distance away from the stream-gaging station. The lack of accurate stage data and the inaccuracies of stage measurement allow only the identification of general trends in surface-water/groundwater interactions using these data. Locations of surficial-deposit wells are included on Plate 2, and the combined stream stage/surficial-deposit well hydrographs are presented in Appendix F.

All of the stream-gaging stations reflect the ephemeral nature of stream flow in the drainages at Rocky Flats. When the effect of pond and Industrial Area discharges are removed, all of the stations exhibit similar seasonal discharge patterns. Flow is generally minimal or zero during much of the year. The majority of the flow occurs during snowmelt and precipitation events in the spring. Stream discharge in the spring is in response to increased precipitation and recharge, rising groundwater levels, ephemeral seep discharge, and saturated soils (EG&G, 1993b).

Surficial deposit wells B402689 and 5386 are located near stream gaging stations GS05 and GS06, respectively, on the western boundary of the Rocky Flats site in tributaries of Woman Creek (Figure 6-23). Groundwater levels within these wells correspond to seasonal fluctuations in stream discharge. Water levels within the surficial deposits at these wells are highest during the spring months and become unsaturated in the summer and fall (Appendix C). High groundwater levels in the spring rise to within

183

1.4 and 3 feet of the ground surface at wells B402689 and 5386, respectively. The majority of stream flow at stream-gaging stations GS05 and GS06 occurs during this high-water period in the spring. Discharge volumes at these stations is low or zero during much of the rest of the year. Potentiometric and stream-stage data suggest that these stream segments may gain water during the spring but lose water, if and when flow occurs, during most of the year. This general interaction is supported by the Woman Creek Infiltration/Exfiltration Study (Section 6.5.1) (EG&G, 1993h).

Stream-gaging stations GS08, GS09, GS11, and GS12 are located on the principal outlets below Ponds B-5, B-4, A-4 and A-3, respectively (Figure 6-23), in the Walnut Creek Drainage. Station GS08 is always dry because no water is presently discharged downstream from Pond B-5. Stream flow at station GS09 is heavily influenced by discharge from the sewage treatment plant and Industrial Area footing drains. Baseflow at station GS09 is maintained year-round by the sewage treatment plant operations. Stations GS11 and GS12 only record flow when water is discharged from Ponds A-4 and A-3, respectively. The absence of stream flow below these pond embankments except during discharge periods supports the hypothesis that the dams are generally effective in impeding flow and that these sections are not gaining flow from groundwater.

Four stream gaging stations are located along the eastern and northern boundaries of Rocky Flats where major stream drainages leave the site. These stations are GS01, GS02, GS03, and GS04 and are respectively located on Woman Creek, Mower Ditch, Walnut Creek, and Rock Creek (Figure 6-23). The majority of flow at all of these stations results from snowmelt and precipitation in the spring. These stations are generally dry during the rest of the year. Surficial deposit wells 0186 and 41491 are located near station GS01 in Woman Creek. Groundwater levels within the alluvium at these wells fluctuates seasonally with high water levels occurring in the spring and unsaturated conditions occurring in the summer and fall (Appendix C). During the high-water stage in the spring, groundwater within the alluvium at these wells is greater than 4 feet below the ground surface, and it is likely that this stream segment loses water through seepage into the alluvium. The influent conditions along the eastern portions of the drainages at Rocky Flats is supported by the Woman Creek Infiltration/Exfiltration Study (EG&G, 1993h) and the Walnut Creek water balance (EG&G, 1994d).

Well 40791 is located 500 feet upstream of stream gaging station GS02 on Mower Ditch. The surficial deposits at this well are always unsaturated. The absence of shallow groundwater within the alluvium indicates that this stream segment loses water through seepage into the alluvium.

Wells 0486 and 41691 are located on Walnut Creek near stream gaging station GS03. The alluvium at these two wells is typically partially saturated with seasonal fluctuation in groundwater elevation. Maximum groundwater elevations occur in the spring (see single-well hydrographs, Appendix C). High water levels within these two wells are approximately 4 feet below the ground surface, indicating a downward flow into surficial deposits and a losing stream segment.

Alluvial well B202589 is located near stream gaging station GS04 on Rock Creek (Figure 6-23). Only large storm or snowmelt events occurring on previously saturated soils produce measurable runoff at this station (EG&G, 1993b). Some saturated alluvium exists at well B202589 year-round and water levels display limited seasonal fluctuations (Appendix C). High water elevations in this well are within 1.5 feet of the ground surface. The general lack of stream flow and the depth to groundwater suggest that the segment loses flow to groundwater when surface water is present.

The stream stage/alluvial-well hydrographs on the western boundary of the Rocky Flats site (GS05/B402689 and GS06/5386), near the drainage headwaters, suggest a seasonal change in the gain/loss status of these stream segments. These stream segments may gain water from groundwater in the spring and probably lose water to groundwater during the rest of the year. Whereas, stream stage/alluvial-well hydrographs on the eastern boundary of the Rocky Flats site (GS01/0186 and 41491, GS02/40791, GS03/0486 and 41691, and GS04/B202589) appear to lose water to the groundwater throughout most of the year. These observations are supported by the Woman Creek Infiltration/Exfiltration Study (EG&G, 1993h) as well as the Walnut Creek water balance (EG&G, 1994d).

6.5.4 Stream Profile/Hydrogeologic Cross Sections

Stream profile/hydrogeologic cross sections were constructed along No Name Gulch, North Walnut Creek, South Walnut Creek, and Woman Creek. The potentiometric surface within the unconsolidated surficial deposits during the second and fourth quarters of 1993 were plotted on each of the cross sections (Plates 17, 18, 19, and 20). The stream profile cross sections illustrate the drop in groundwater elevations from the second to the fourth quarter of the year. Higher groundwater elevations during the spring correspond to seasonal effluent conditions along localized stream segments. The cross sections also illustrate the general unsaturated nature of the unconsolidated surficial deposits during the fourth quarter of the year, particularly along the eastern portions of the streams. Lower groundwater elevations and unsaturated conditions within the unconsolidated surficial deposits during the fourth quarter correspond to the general influent or losing nature of the streams.

6.5.5 Dam Piezometer Data

Surface-water management at the Rocky Flats site includes a series of detention ponds in the Walnut and Woman Creek drainages. All of the dams are earthen structures that are typically keyed into bedrock. Piezometers installed in the crest and toe of these structures are used to monitor water levels within the structures and to determine the stability of the dams. Pond dam design and piezometer data were qualitatively evaluated to assess seepage through the dams and to characterize surface-water/groundwater interactions associated with these structures.

Dam piezometer data are presented and evaluated in the SWD Field Report Series (EG&G, 1993i). Dam piezometer hydrographs are presented in Appendix E. All but one of the dam crest piezometers indicate a direct relationship to pond-level changes. Similarly, most of the piezometers located at the toe of the dams show direct relationships to changes in pond levels; however, they are also influenced to some degree by local groundwater (EG&G, 1993i). Toe piezometers on dams A-4 and C-2 respond to physical factors unrelated to pond levels. Water-level data for these piezometers suggest that bedrock groundwater and pond water are not hydraulically connected at these locations. However, the general positive relationship between pond levels and dam piezometers indicates a hydraulic connection between the ponds and the embankment materials.

Hydraulic conductivity values measured in the crest piezometers are relatively low (10^{-6} cm/sec to 10^{-9} cm/sec); however, the presence of water in piezometers installed at the toe of the dams indicates that some flow through or around the embankments takes place (EG&G, 1993i). Seeps identified on the downstream slopes of dams B-3 and B-5 verify that groundwater flow takes place through these embankments (EG&G, 1994a and EG&G, 1993g).

Although piezometers and seeps indicate groundwater movement through the embankments, actual flow volumes are probably small. This is due to the low hydraulic conductivities of the embankment cores and the low permeability of the bedrock. Surficial deposit wells positioned below several of the dams are unsaturated for at least a portion of the year. A water balance performed on the Landfill Pond supports the idea that minimal groundwater flow occurs through the embankment. The water balance estimated that the groundwater volume flux beneath the dam was 9.23E-07 ft^3/sec, which equates to 218 gallons per year (DOE, 1994a).

As-built construction diagrams of dams A-3, A-4, B-1, B-3, B-5, and C-2 and the Landfill Pond dam indicate that the embankment cores of these dams are keyed into bedrock; (EG&G, 1993g, and DOE 1992b and 1992c). Bedrock beneath dams A-3, A-4, and B-1 consists of consolidated claystone. Due to the low permeability of the claystone, it is unlikely that a large volume of groundwater seeps below these dam foundations (EG&G, 1994a). Bedrock beneath dam B-3 and the Landfill Pond dam consists of consolidated silty sandstone, siltstone, and claystone (EG&G, 1993g). The degree to which impounded surface water within these ponds migrates into bedrock groundwater has not been assessed, nor has the degree to which bedrock groundwater may migrate beneath the dams (EG&G, 1994a). Bedrock lithologies beneath dams B-5 and C-2 were not described in the as-built diagrams, but all unconsolidated material was probably removed during construction.

Groundwater-elevation data from the surficial materials near the Landfill Pond indicate that groundwater levels are consistently higher than the pond level, suggesting that surficial groundwater deposits are continuously recharging the pond. Groundwater elevations in the unconsolidated material near the Landfill Pond and surface-water elevations of the Landfill Pond have similar seasonal trends, suggesting that the two are hydraulically connected. Although the Landfill Pond appears to be continuously recharged from groundwater within the surficial deposits, water levels in a weathered bedrock well near the shoreline are consistently lower than the pond water. This indicates that the Landfill Pond may be recharging weathered bedrock near the shoreline. These data support the existence of surface-water/groundwater interaction in association with the pond and provide evidence as to the complexity of these interactions (DOE, 1994a).

6.5.6 Seeps

A seep location map was generated for the Rocky Flats site utilizing previously compiled seep maps, aerial photography, and field reconnaissance (Plate 9). Seep distribution and occurrence is strongly controlled by geology. Seeps at Rocky Flats are common along the eastern extent of the Rocky Flats Alluvium. The contrasting hydraulic conductivities of the permeable unconsolidated surficial deposits and the relatively impermeable underlying bedrock produces lateral groundwater movement along this contact. Much of the groundwater within the unconsolidated surficial deposits discharges at seeps along the upper margin of the drainages where the contact between the Rocky Flats Alluvium and the underlying claystone subcrops (EG&G, 1994a). Lateral groundwater movement at the surficial-deposit/bedrock contact may also flow preferentially along paleochannels within the surface of the bedrock. Some seeps are located where paleochannels intersect the drainage slopes (DOE, 1994f and DOE, 1994g). Most of the seeps along the eastern extent of the Rocky Flats Alluvium occur on the north side of the pediment ridges. This general pattern of seep occurrence results primarily from bedrock control of groundwater flow within the Rocky Flats Alluvium. The bedrock surface at Rocky Flats dips slightly to the northeast resulting in a northeastern component of groundwater flow within the Rocky Flats Alluvium. Bedrock paleochannels also generally trend to the northeast. Groundwater flow within the Rocky Flats Alluvium follows the northeast trend of the bedrock surface toward seeps on the north side of the pediment ridges.

Most of the seeps at Rocky Flats are ephemeral in nature and only discharge in the spring. Ephemeral seeps at Rocky Flats follow a seasonal trend similar to water levels in the unconsolidated surficial deposits. Seep flow at Rocky Flats is greatest during the high-water period in the spring. Reduced recharge to the unconsolidated material in the summer and fall causes water levels to drop, and seep activity is correspondingly reduced. Many of the seep areas stop discharging in the summer and fall.

Seep discharge does not always result in surface-water flow but may occur through transpiration (Section 3.2.1). Distinctive plant communities are associated with wetlands at Rocky Flats and are useful in delineating wetland and seep areas (U.S. Army Corps of Engineers, 1994). Seasonal fluctuations in transpiration rates affect surficial seep discharge at RFETS. High transpiration rates in the summer reduce or eliminate surface flow at some seeps, and surficial flow resumes or increases at these seeps in the fall when plants become dormant and water is no longer transpired by the vegetation.

In the OU2 area, seeps along the edge of the drainages are associated with a thick sandstone unit (Arapahoe Formation sandstone) that subcrops beneath the Rocky Flats Alluvium. The Arapahoe Formation sandstone is recharged from the overlying surficial-deposits. Groundwater within the Arapahoe Formation sandstone flows toward the South Walnut Creek and Woman Creek drainages and discharges at seeps on hillsides where the sandstone subcrops beneath the colluvium (EG&G, 1994a). Another seep within OU2 along South Walnut Creek is caused by the discharge of groundwater from the northeast end of a bedrock paleochannel. At this location, the bedrock channel acts as a conduit of groundwater to the hillside (EG&G, 1994a). Seep activity within OU2 is ephemeral and discharge occurs in the spring.

Within OU1, seeps have been noted near the head region of slumps that exist on the northern hillside within the Woman Creek drainage. This suggests that groundwater may be flowing from depressions in the bedrock surface near the head region of slumps. Other seeps appear to be related to slump margins (DOE, 1994g). Seep activity is ephemeral and discharge is associated with high groundwater levels in the spring.

Within No Name Gulch in OU7, groundwater and leachate within surficial deposits and landfill materials flow toward the center of the buried drainage and eventually discharge at a seep located at the toe of the landfill. The seep is perennial and discharges into the Landfill Pond (DOE, 1994a).

Seeps are an important surface-water feature within OU4. Several seeps have been observed near the surficial deposit/bedrock contact on the hillside north of the Solar Evaporation Ponds since the original bentonite-lined pond was installed. Additional seeps were noted along the northern hillside after the construction of the present lined Solar Evaporation Ponds. These seeps are associated with discharge sumps at the end of drainage tiles installed beneath the Solar Evaporation Ponds. Flow rates and volumes from these seeps are not available but the seeps are ephemeral in nature. Some component of flow from these seeps probably originates from the Solar Evaporation Ponds as indicated by elevated nitrate/nitrite concentrations (DOE, 1994c).

Antelope Springs is a large perennial seep area located along the Rocky Flats Alluvium/bedrock contact at the western headwaters of a tributary to Woman Creek (Plate 9). Discharge at Antelope Springs is fairly consistent. Tritium data indicate that Rocky Flats Lake is a source of recharge to the Rocky Flats Alluvium that eventually discharges at Antelope Springs.

Other seep areas on drainage hillsides throughout the site may be due to thinning of the colluvial materials. These seeps form where groundwater is flowing within the colluvium on top of the underlying impermeable bedrock and the colluvium thins to the point where the potentiometric surface intersects the ground surface. Ephemeral seeps of this nature are located on hillsides within OU1 and OU2 (DOE, 1992d and 1993b).

6.5.7 South Spray Area

The South Area of the East Spray Field (OU2) received sewage treatment plant effluent from Pond C-3 from the early 1980s to 1990. The South Spray Area was located on the ridge between South Walnut Creek and Woman Creek, south of the East Access Road. Water was applied to the fields through spray irrigation. It is estimated that as much as 20 million gallons of water per year were disposed of at the East Spray Fields. Spray irrigation was initiated as an action to achieve zero offsite discharge of sanitary effluent from the Rocky Flats site. The spray operation was intended to return the effluent to the hydrologic system through evaporation (DOE, 1992c).

A water balance performed on the South Spray Area determined that a large portion of the applied water did not evaporate but was lost to runoff and infiltration (Koffer, 1989). The study indicated that during warm months when the ground was thawed about 35 percent of the sprayed water infiltrated into and recharged the shallow water table. The large volume of recharge to the alluvium affected local water-table elevations. Three alluvial wells (2787, 3287, and 4186) located near the western end of the South Spray Area clearly show the effects of spray irrigation on the water table. Hydrographs from these three wells (Appendix C) show that prior to 1990, during spray irrigation operations, a saturated thickness of 10 feet was common within the alluvium.

Following the end of spray irrigation in 1990, water-table elevations rapidly dropped, and the alluvium is now generally unsaturated.

In the 1980s when the South Spray Area was in operation and a portion of the surficial deposits were saturated, an ephemeral seep along the upper edge of the Woman Creek drainage appears to have been a major discharge area for this alluvial groundwater (EG&G, 1994a). Since spray irrigation was discontinued, the surficial deposits have become unsaturated, and discharge from the seep has ceased.

6.5.8 Conclusions

Seasonal fluctuations in precipitation, recharge, groundwater levels, and stream and ditch flow are reflected in surface-water/groundwater interactions at Rocky Flats. Effluent conditions are dominant in the spring along localized stream segments and influent conditions are common in the late summer and fall along most stream reaches. Effluent conditions within the drainages are more common along western stream segments of the site and influent conditions are dominant along eastern stream segments of the site.

Stream-stage and water-balance data from Woman and Walnut Creeks were used to describe surface-water/groundwater interactions at the Rocky Flats site. The effluent or influent nature of various stream segments was described using these data. The western and central portions of drainages at the site generally exhibit gaining or effluent conditions during the spring, especially in locations where groundwater sources were available in the form of springs, seeps, or bedrock paleochannels. The eastern portions of these drainages on the Rocky Flats site are dominantly influent or losing.

Groundwater movement within the drainages at Rocky Flats is modified by the pond dams. Most of the surface-water/groundwater interactions associated with these impoundments occur upstream of the dam structures as they appear to significantly impede groundwater movement downstream.

The geology at Rocky Flats exerts strong controls on seep activity and location. The majority of seep activity at Rocky Flats occurs on hillslopes at the contact between alluvium and bedrock along the eastern erosional edge of the Rocky Flats Alluvium and is ephemeral in nature.

Past spray-evaporation activities in the South Spray Area of the East Spray Field interacted with shallow groundwater in the unconsolidated material beneath the spray field. Groundwater levels were elevated and an associated seep was active during the operation of the field. Since the spray operation was discontinued, the unconsolidated materials beneath the field have become unsaturated, and the seep activity has ceased.

Table 6-1
Estimated Quantity of Groundwater Beneath the Rocky Flats Site

Hydrostratigraphic Unit	Area (acre)	Average Thickness (ft)	Average Saturated Thickness (ft)	Porosity[a] (%)	Water in Storage (acre-ft)	Water in Storage (gals x 10^9)
Alluvium and Valley-Fill	6,470	(b)	10[c]	30	19,400	6.3
Arapahoe Formation	4,970	35[d]	35	30	52,200	17.0
Laramie/Fox Hills	6,350	200	120	30	228,600	74.5
Total					**300,200**	**97.8**

(a) Assumed value based on data presented by Robson (1987)

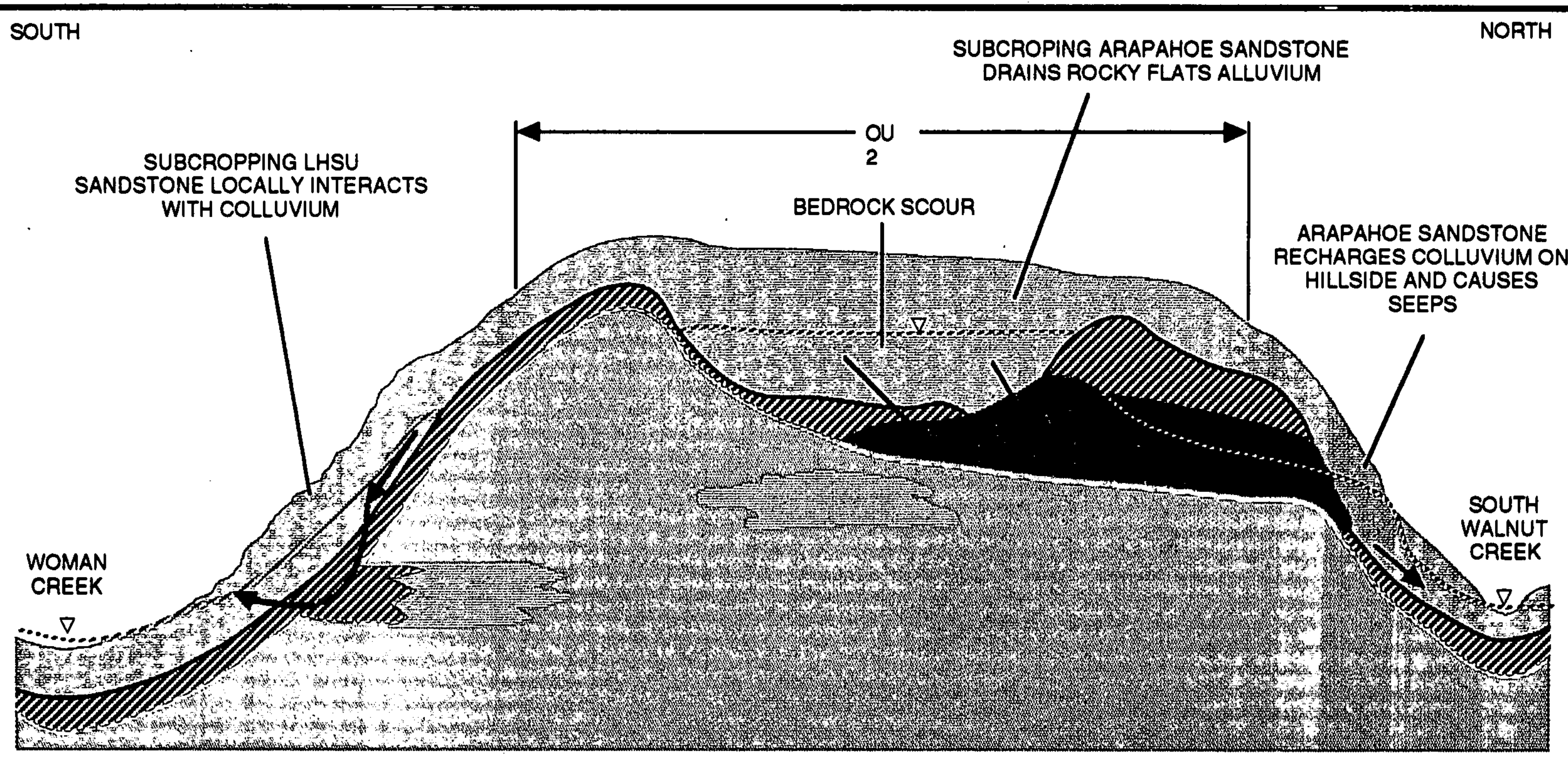
(b) Not estimated

(c) Estimated from the difference between alluvial and valley-fill groundwater elevation and bedrock elevation throughout the Rocky Flats site.

(d) Thickness of all Arapahoe Formation siltstones and sandstones. This does not include claystone which is assumed to have no significant recoverable water. This reflects a composite thickness of sandstones which may contain recoverable water.

Source: EG&G, 1991c

191



EXPLANATION

- (Qrf) ROCKY FLATS ALLUVIUM
- (Qc) COLLUVIUM
- UNWEATHERED CLAYSTONE/ SILTSTONE BEDROCK
- WEATHERED BEDROCK
- WEATHERED ARAPAHOE #1 SANDSTONE BEDROCK
- LHSU UNWEATHERED SANDSTONE BEDROCK
- GROUND WATER FLOW DIRECTION
- CONCEPTUAL UHSU/LHSU BOUNDARY
- WATER TABLE

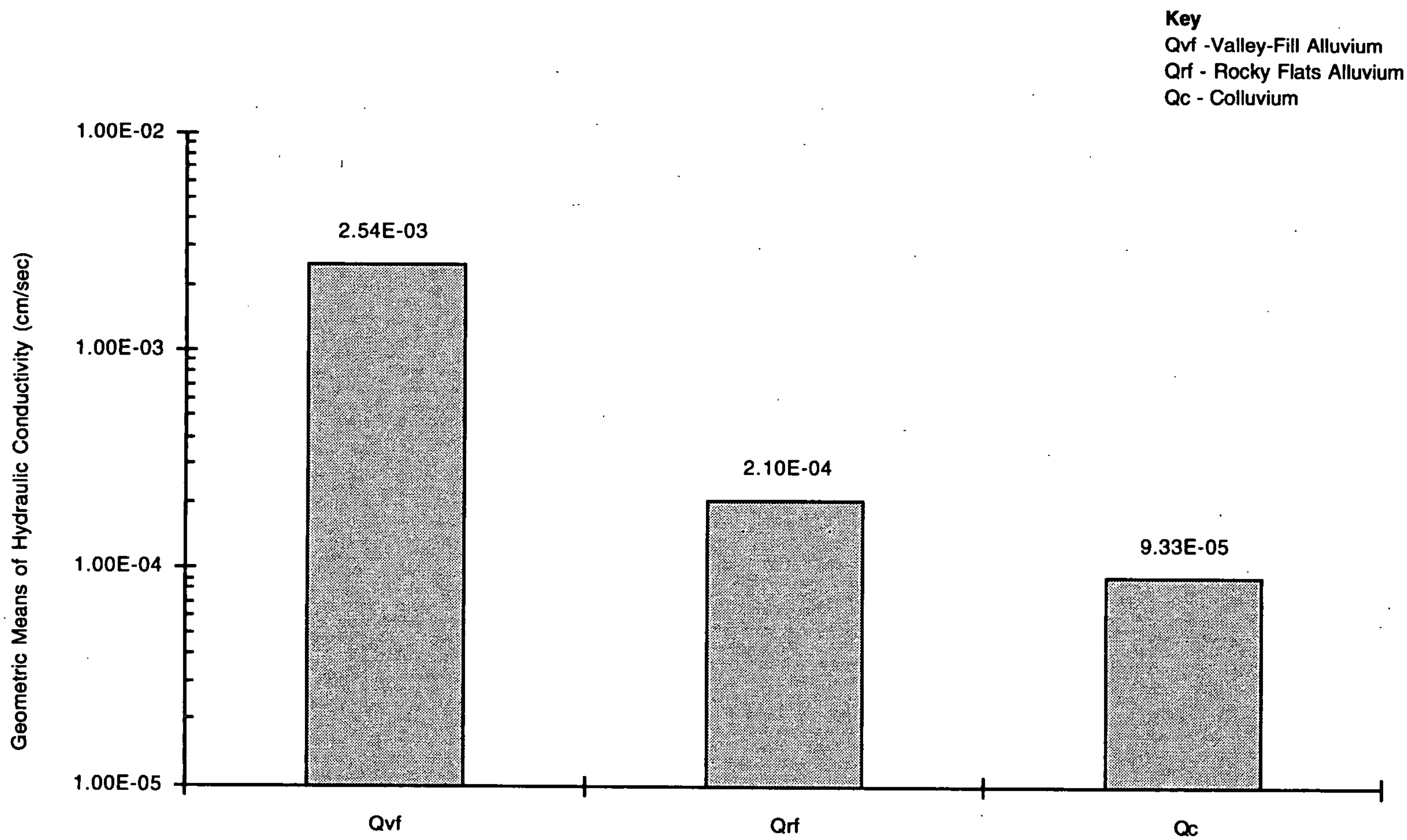
DRAFT OU2 PHASE II RFI/RI

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Schematic Cross Section of Hydrostratigraphy at OU2

April 1995	Figure 6-1

g95\ES\hydrodoc\hydrostat cross-sectn..odw



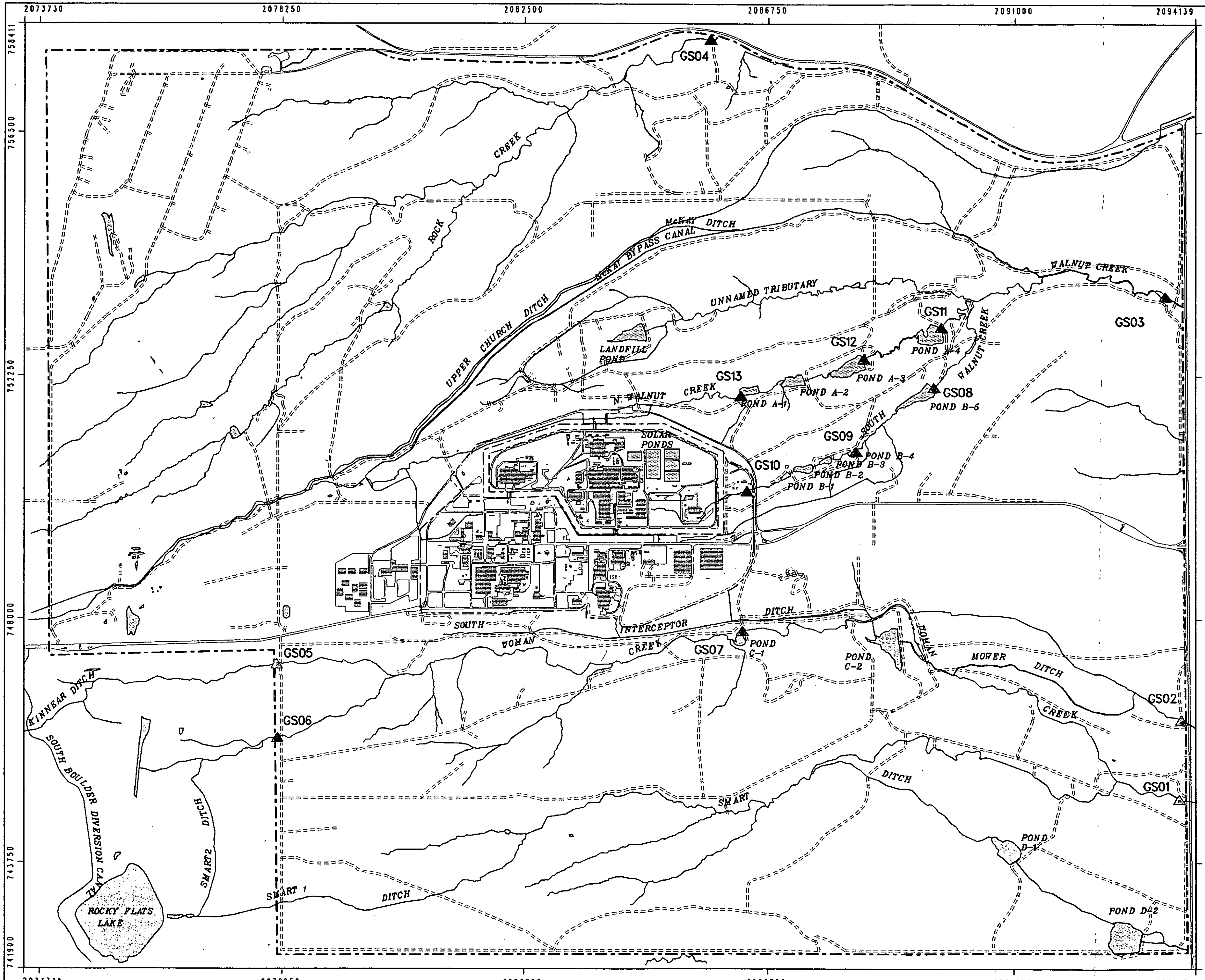
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Unconsolidated Surficial Deposits at the Rocky Flats Site

Hydrogeologic Characterization Report

April 1995	Figure 6-2

m\es\hydrodoc\hydrodoc graphs.mdw\10-11-94



EXPLANATION

Symbol	Description
△	Stream Gaging and Sampling Stations
———	Streams and Drainages
═══	Paved Roads
======	Dirt Roads
— — —	Rocky Flats Plant Site and Security Zone Boundaries
—·—	Rocky Flats Site Boundary
(light shading)	Surface Water Impoundments
(dark shading)	Buildings

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

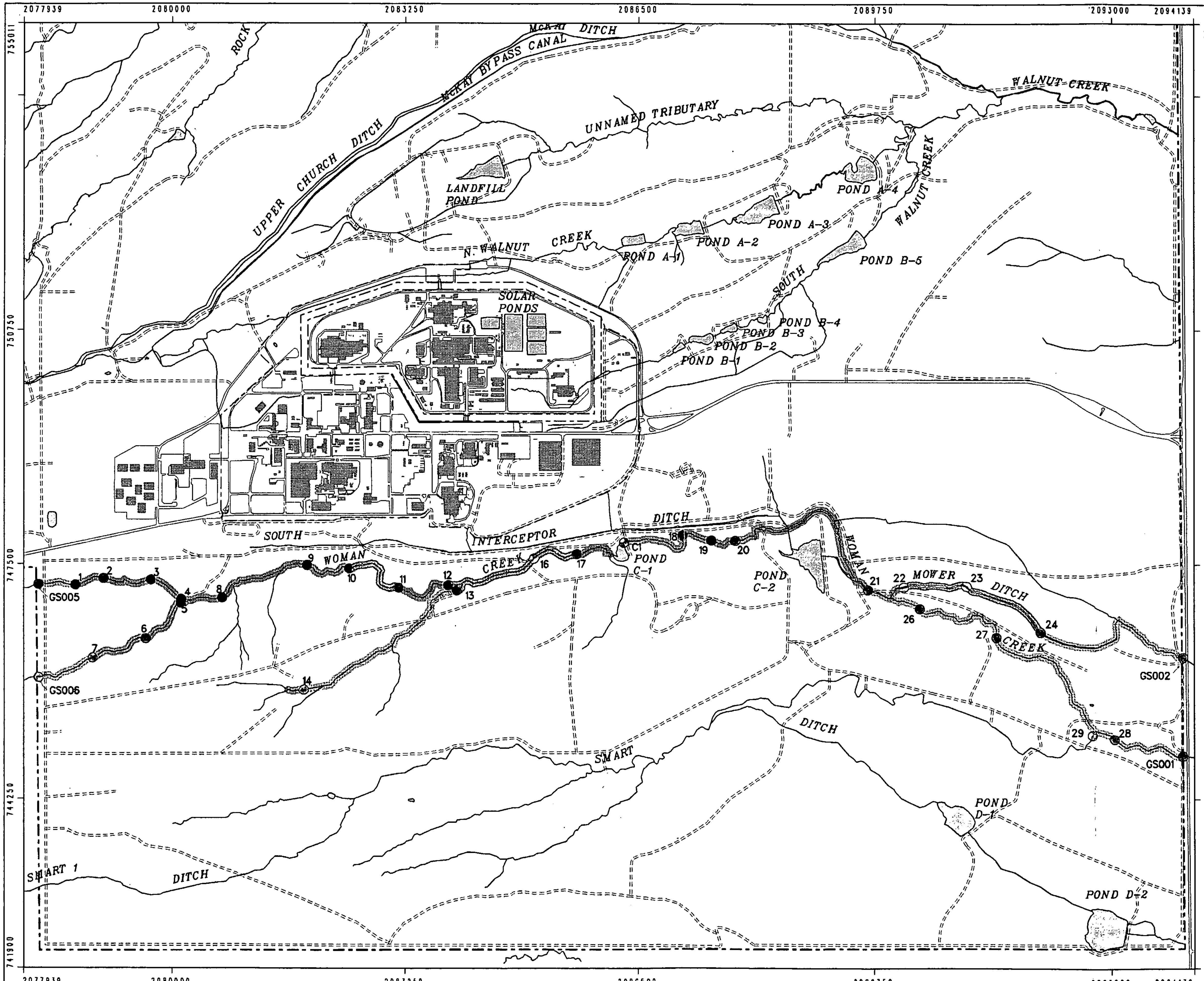
Rocky Flats Site, Golden, Colorado

Sitewide
Gaging Station
Network

Hydrogeologic Characterization Report

April 1995 | Figure 6-23

103



EXPLANATION

General Segment Classification

- Stream Gains Year-Round
- Stream Gains During Spring (December - March or April) Loses Rest of Year
- Stream Loses Year-Round
- Stream Experiences a Gain For 2 Months or Less During Year, Loses Rest of Year
- Creek Not Classified Due to Inadequate or Uncalibrated Data
- Measurement Location
- Surface Water Impoundments
- Buildings
- Streams and Drainages
- Paved Roads
- Dirt Roads
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Site Boundary

N

Scale = 1 : 18200
1 inch = 1350 feet

675 0 1350ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

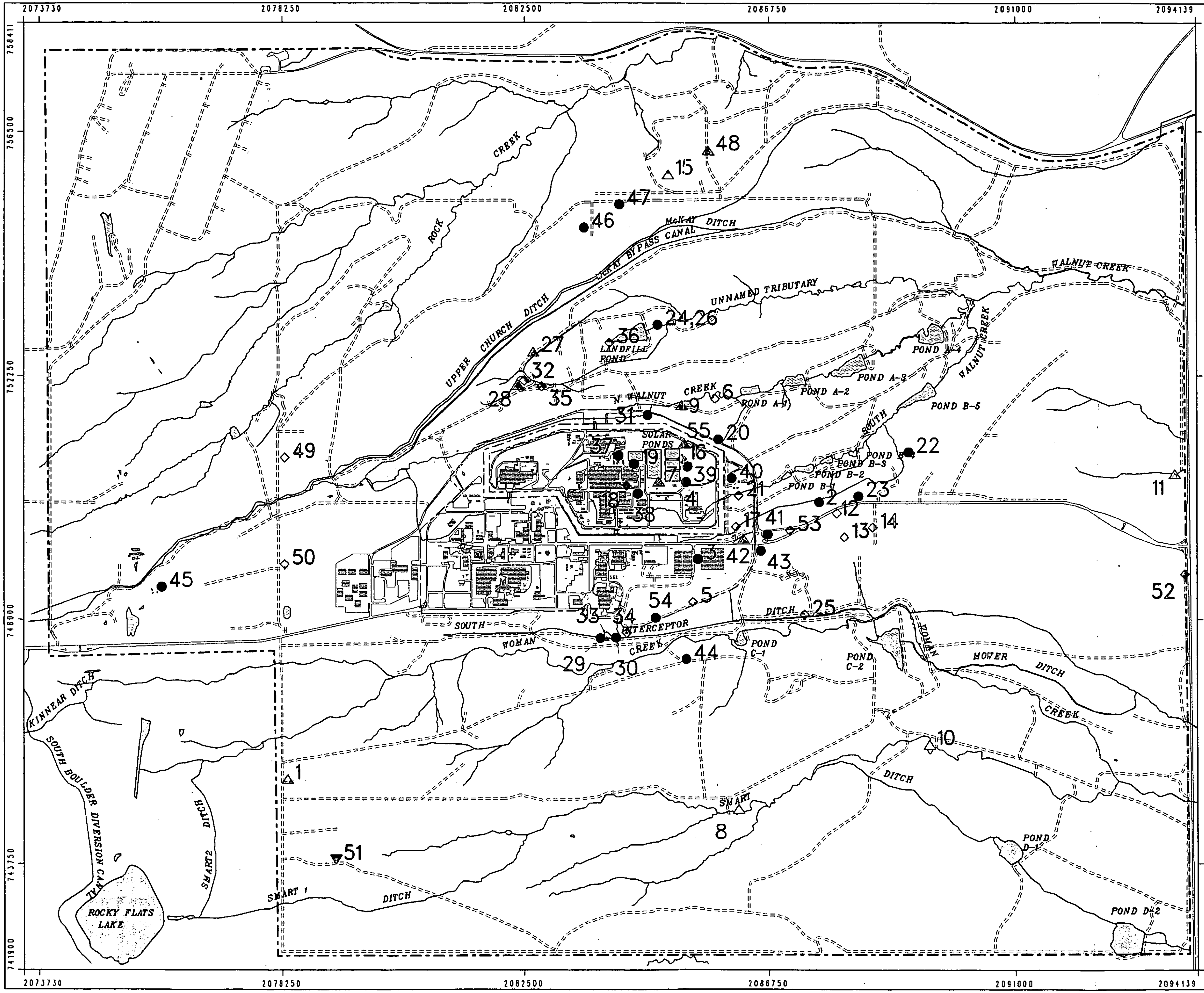
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Woman Creek
Infiltration/Exfiltration
Stream Segment Classification

Hydrogeologic Characterization Report

April 1995 | Figure 6-22



EXPLANATION

Completion Zone

- ● Alluvium, Weathered Bedrock
- ◇ Alluvium, Unweathered Bedrock
- △ Alluvium, Weathered Bedrock, Unweathered Bedrock
- ▼ Alluvium Only

- Streams and Drainages
- Paved Roads
- Dirt Roads
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Site Boundary
- Surface Water Impoundments
- Buildings

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

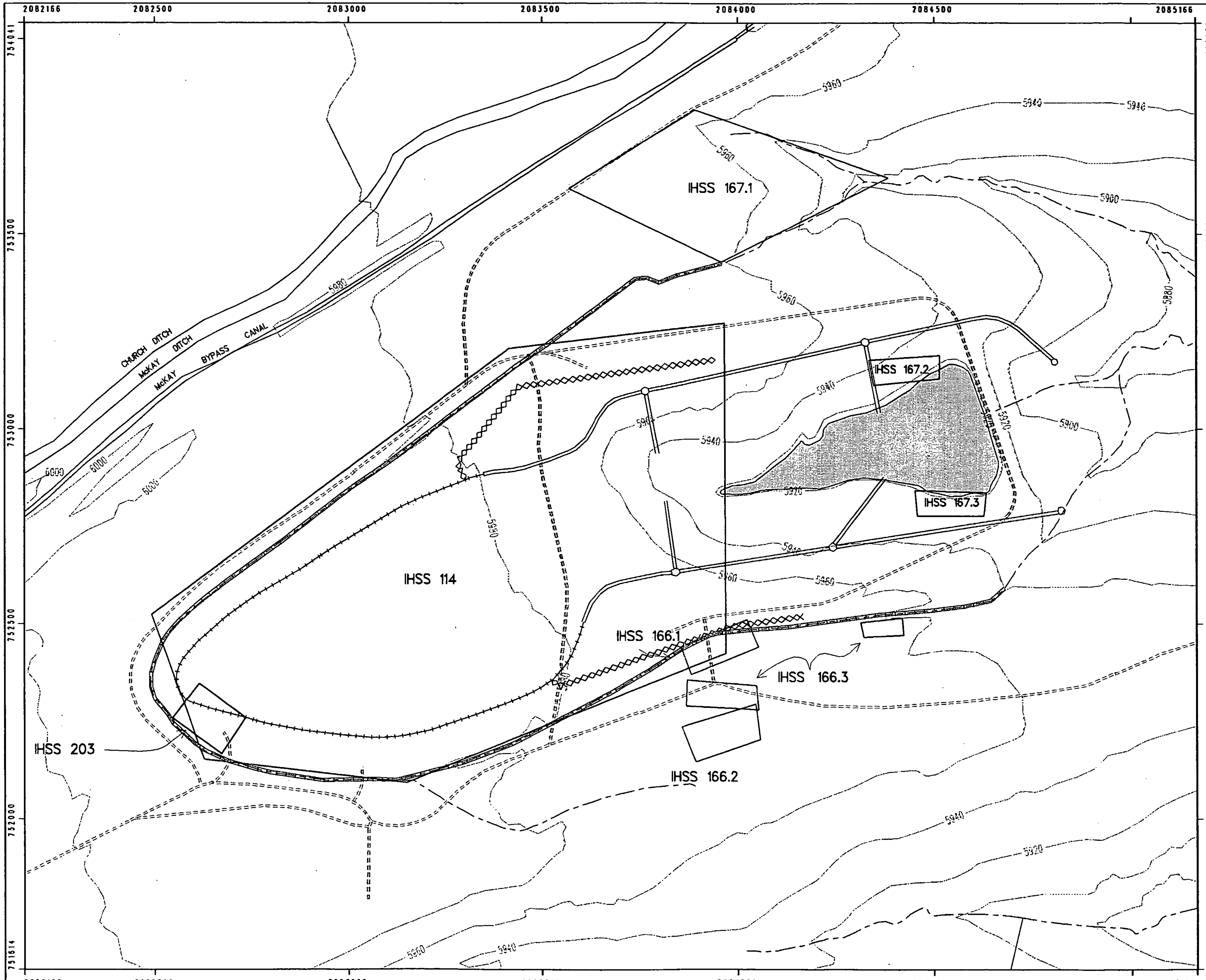
Rocky Flats Site, Golden, Colorado

Locations of Well Clusters

Hydrogeologic Characterization Report

April 1995 | Figure 6-21

101



EXPLANATION

- Dirt Roads
- Topographic Contours
- Streams and Ditches
- Intermittent Streams
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
- (perforated)
- (non-perforated)

Scale = 1 : 3000
1 inch = 250 feet
125 0 250ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

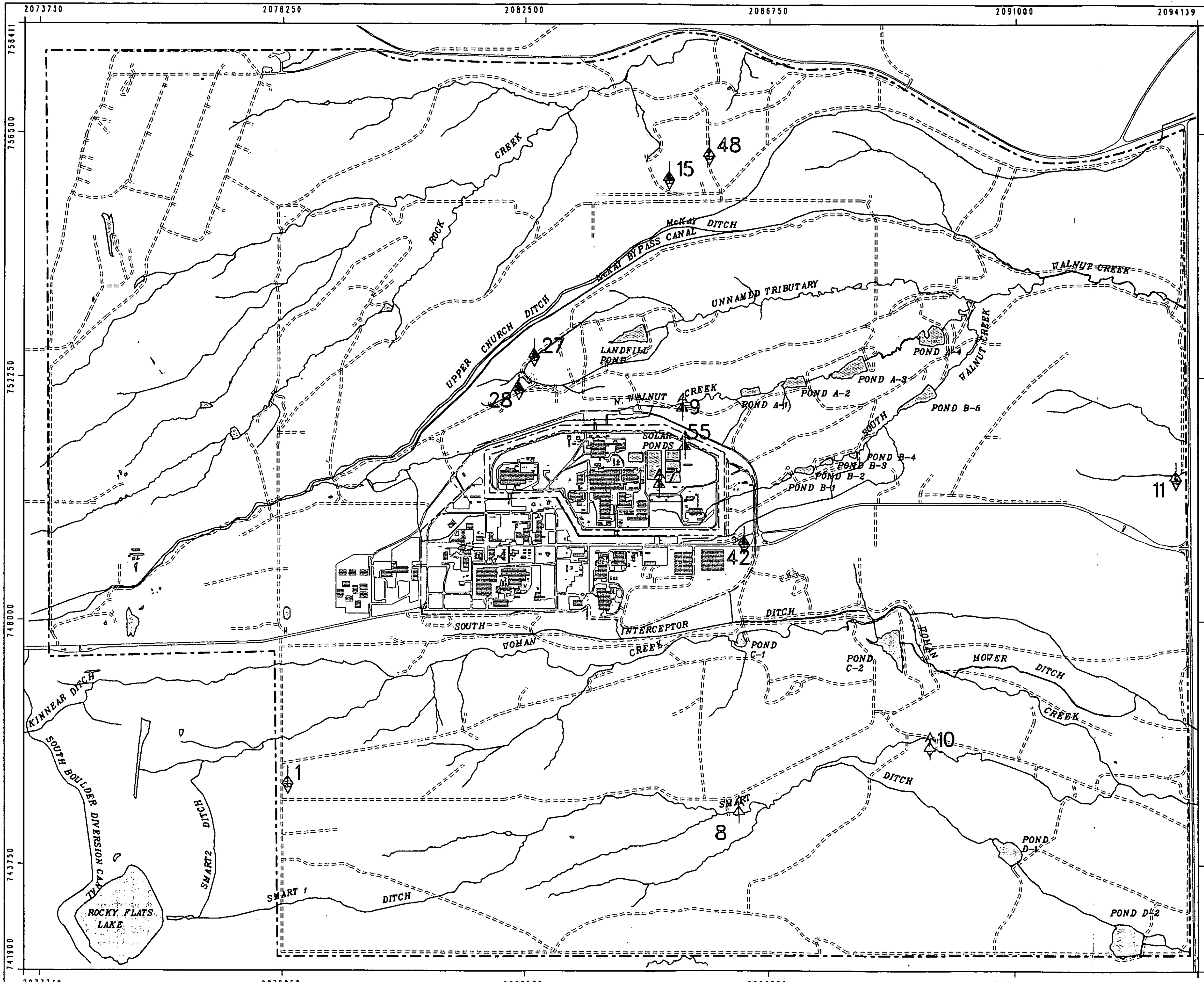
Rocky Flats Site, Golden, Colorado

Locations of Landfill Structures, Operable Unit No. 7 (from: DOE, 1994a)

Hydrogeologic Characterization Report

April 1995 | Figure 6-16

96



EXPLANATION

Completion Zone

Weathered Bedrock
Unweathered Bedrock

Upward Vertical Hydraulic Gradient

Downward Vertical Hydraulic Gradient

Streams and Drainages

Paved Roads

Dirt Roads

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Site Boundary

Surface Water Impoundments

Buildings

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

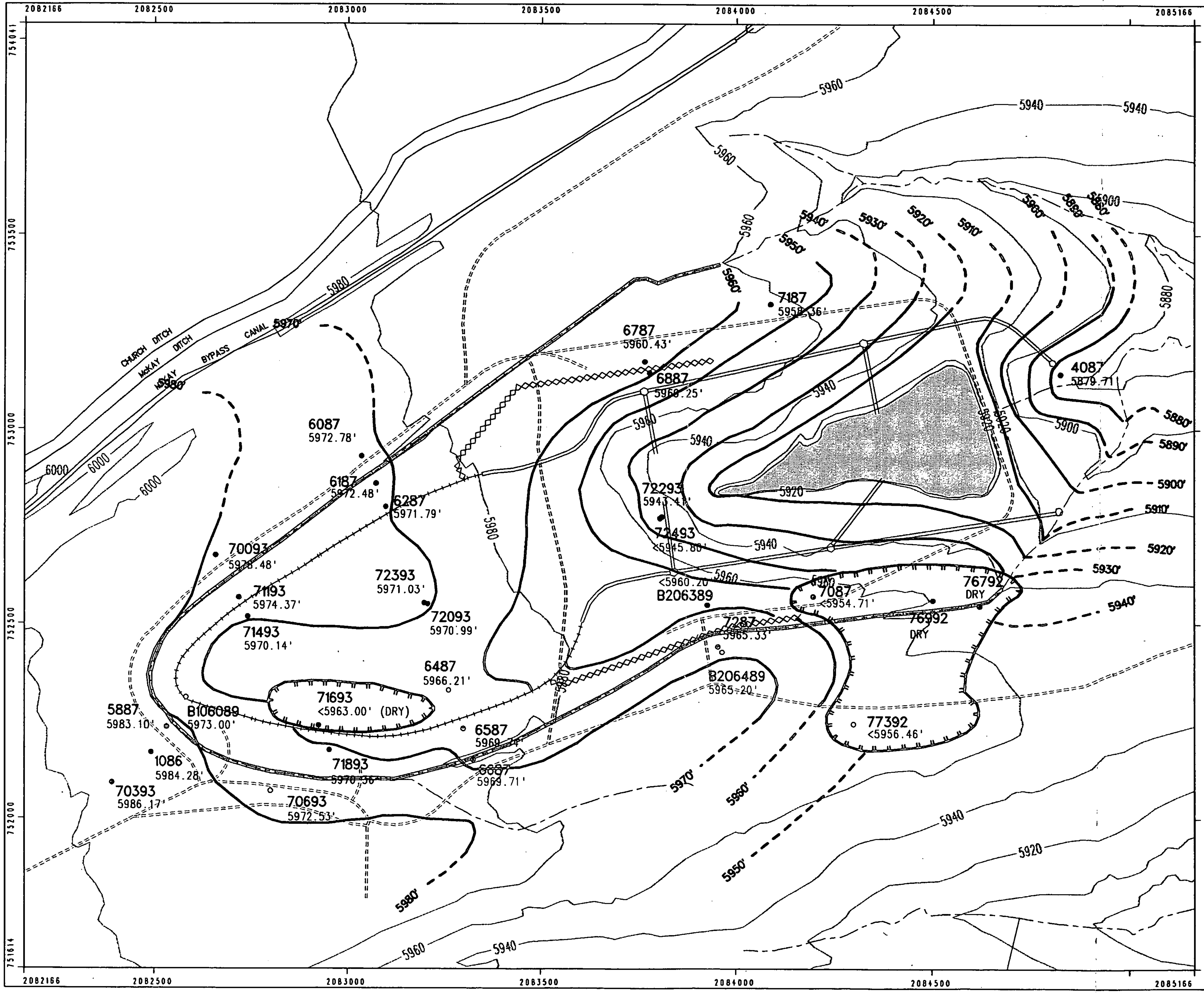
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Vertical Hydraulic Gradients Between Weathered and Unweathered Bedrock

Hydrogeologic Characterization Report

April 1995 | Figure 6-19



EXPLANATION

- Alluvial Well
- Line of Equal Potentiometric Surface
- (dashed where inferred)
- Areas of Unsaturated Surficial Material
- (dashed where inferred)
- Dirt Roads
- Topographic Contours
- Streams and Ditches
- Intermittent Streams
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
- (perforated)
- (non-perforated)
- Water Level Measured Below Screened Interval
- Screened in Surficial Materials and Weathered Bedrock

Scale = 1 : 3000
1 inch = 250 feet

125 0 250ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

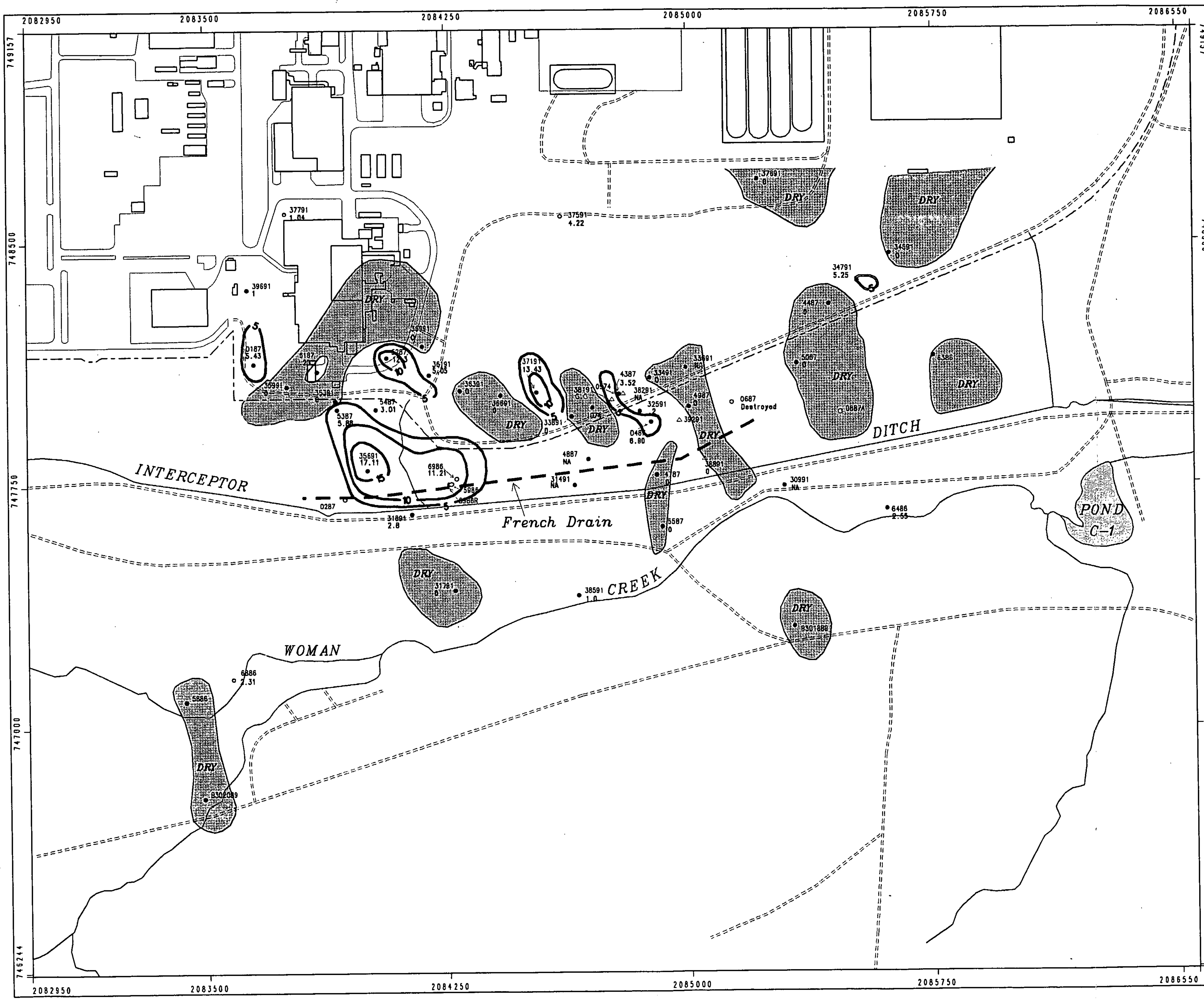
Rocky Flats Site, Golden, Colorado

Potentiometric Surface Map
of Surficial Material
at Present Landfill Area
March 1993
(from: DOE, 1994a)

Hydrogeologic Characterization Report

April 1995 | Figure 6-17

91



EXPLANATION

- Wells
- Abandoned Wells
- Piezometer
- Line of Equal Saturated Thickness
- French Drain
- Streams and Drainages
- Paved Roads
- Dirt Roads
- Rocky Flats Plant Site and Security Zone Boundaries
- Approximate Extent of Unsaturated Areas
- Surface Water Impoundments
- Buildings

Scale = 1 : 3600
1 inch = 300 feet

150 0 300ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

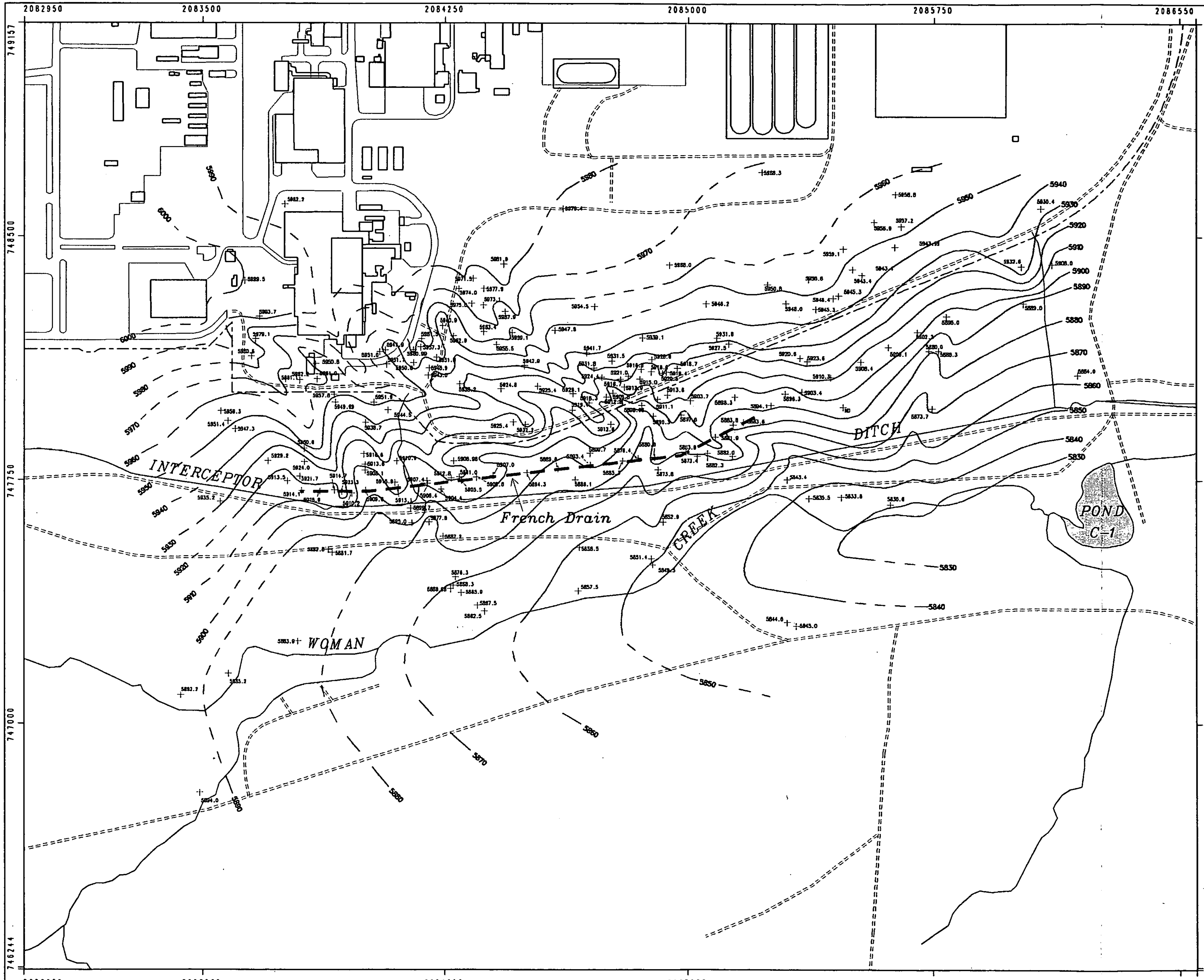
Rocky Flats Site, Golden, Colorado

Saturated Thickness of Surficial Deposits in the 881 Hillside Area Operable Unit No. 1 (from: DOE, 1994g)

Hydrogeologic Characterization Report

April 1995 | Figure 6-15

95



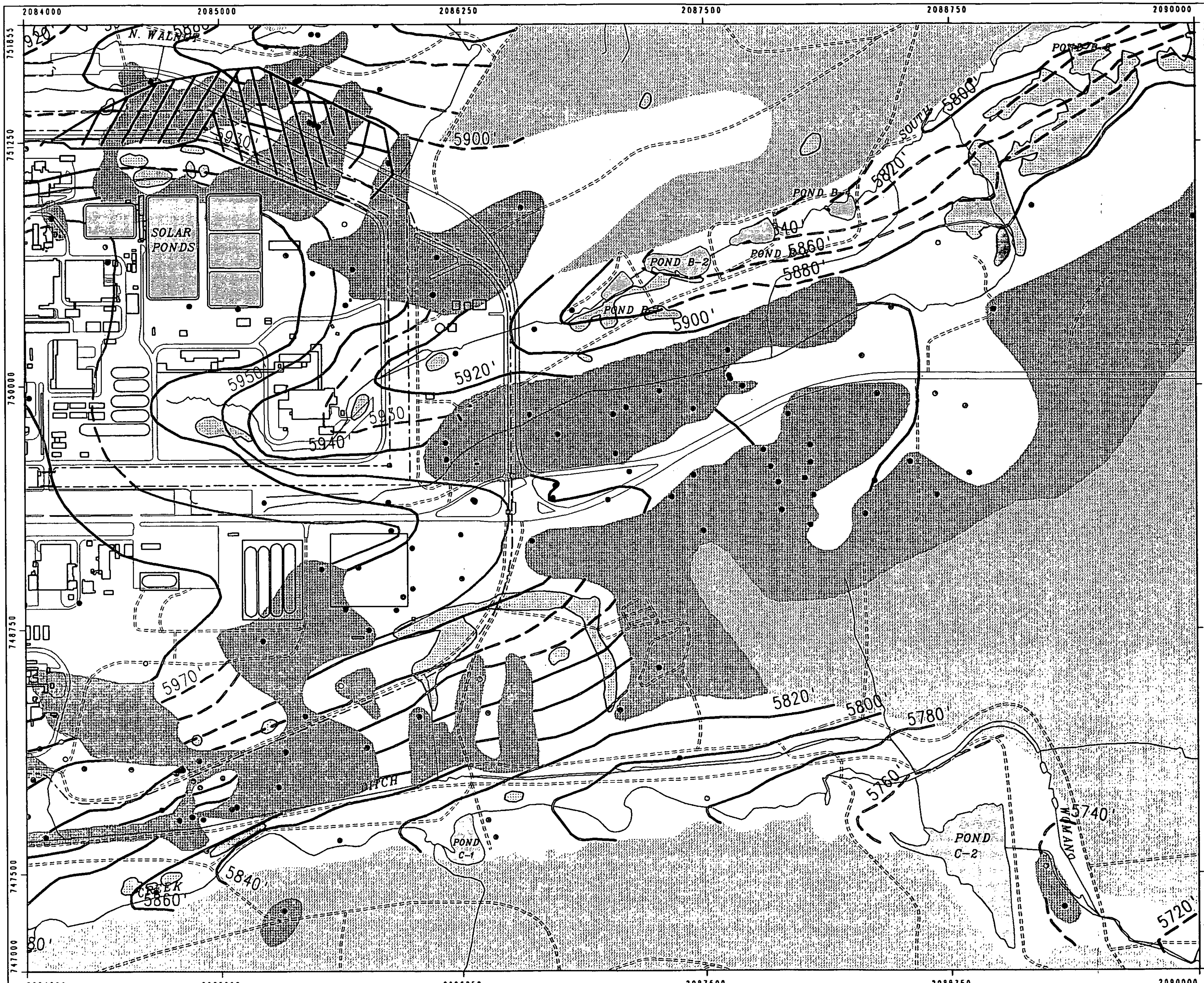
Rocky Flats Site, Golden, Colorado

Bedrock Topography of 881 Hillside Area Operable Unit No. 1 (from: EG&G, 1994c)

Hydrogeologic Characterization Report

April 1995	Figure 6-13

93



EXPLANATION

- Wells with 2nd Quarter Potentiometric Data
- Water Level Contour
- Intermediate Water Level Contour
- Paved Roads
- Dirt Roads
- Rocky Flats Plant Site and Security Zone Boundaries
- French Drain
- Approximate Extent of Unsaturated Areas
- Perennial Seep
- Ephemeral Seep
- Areas Without Groundwater Elevation Data
- Surface Water Impoundments
- Buildings

N

Scale = 1 : 6000
1 inch = 500 feet

250 0 500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

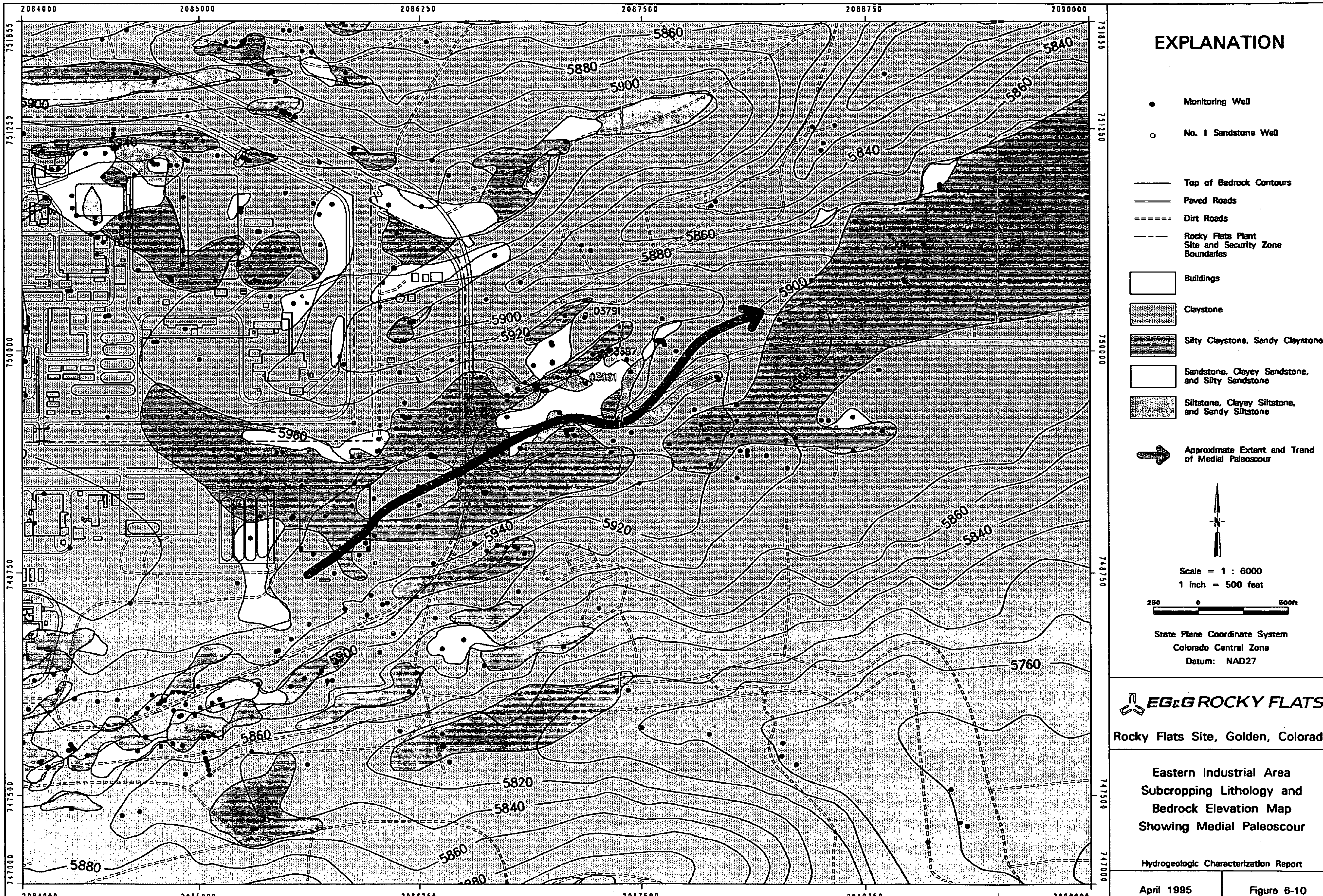
Rocky Flats Site, Golden, Colorado

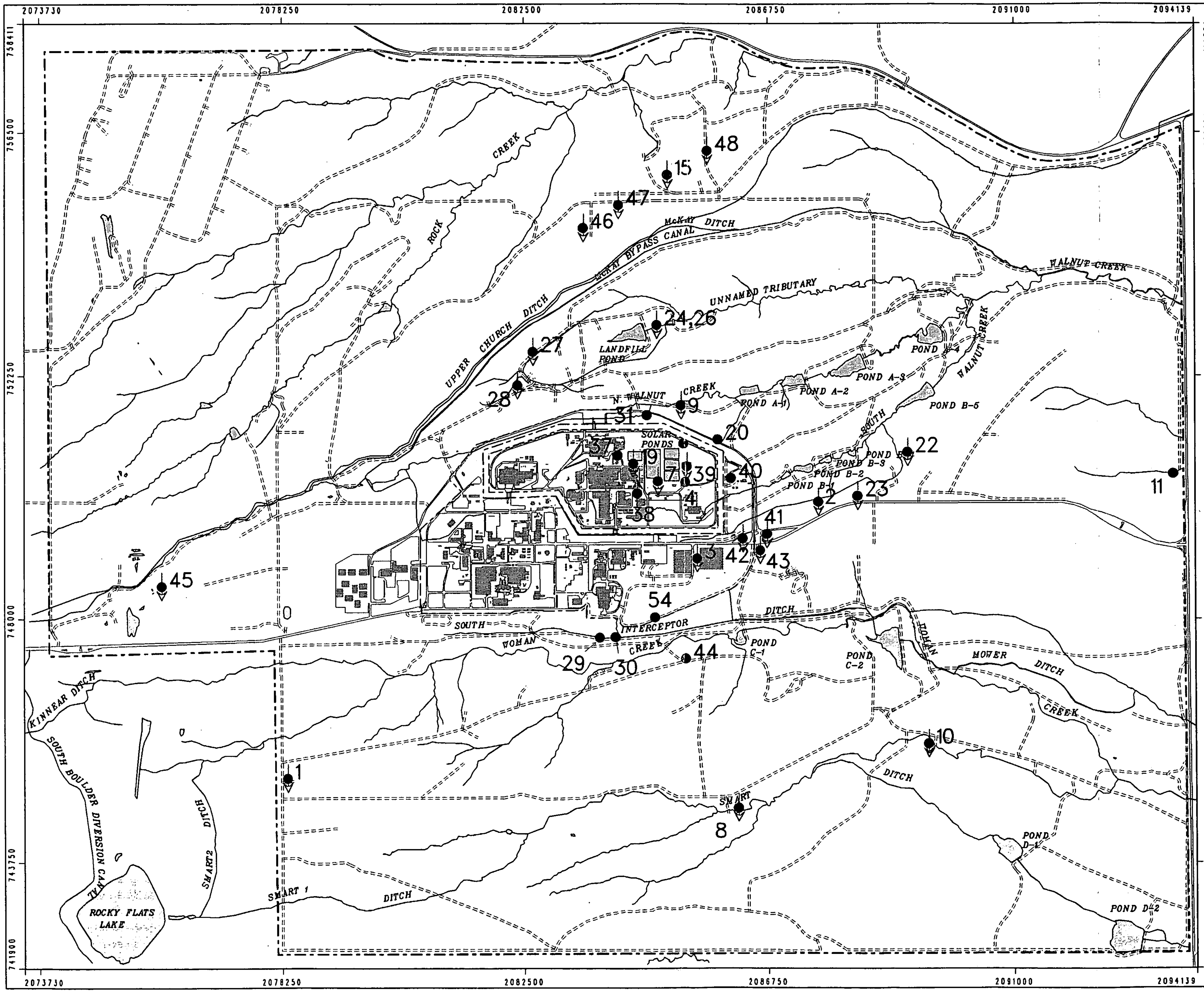
Potentiometric Surface in Unconsolidated Surficial Deposits of the Eastern Industrial Area Second Quarter 1993

Hydrogeologic Characterization Report

April 1995	Figure 6-11

91


EXPLANATION
Monitoring Well
No. 1 Sandstone Well
Top of Bedrock Contours
Paved Roads
Dirt Roads
Rocky Flats Plant Site and Security Zone Boundaries
Buildings
Claystone
Silty Claystone, Sandy Claystone
Sandstone, Clayey Sandstone, and Silty Sandstone
Siltstone, Clayey Siltstone, and Sandy Siltstone
Approximate Extent and Trend of Medial Paleoscour
N
Scale = 1 : 6000
1 inch = 500 feet
250
0
500ft
State Plane Coordinate System
Colorado Central Zone
Datum: NAD27
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado
Eastern Industrial Area
Subcropping Lithology and
Bedrock Elevation Map
Showing Medial Paleoscour
Hydrogeologic Characterization Report
April 1995
Figure 6-10
2084000
2085000
2086250
2087500
2088750
2090000
751855
751250
750000
748750
747500
747000
5860
5880
5900
5840
5940
5960
5920
5760
5820
03791
03091



EXPLANATION

Completion Zone

Alluvium, Weathered Bedrock

Upward Vertical Hydraulic Gradient

Downward Vertical Hydraulic Gradient

Streams and Drainages

Paved Roads

Dirt Roads

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Site Boundary

Surface Water Impoundments

Buildings

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

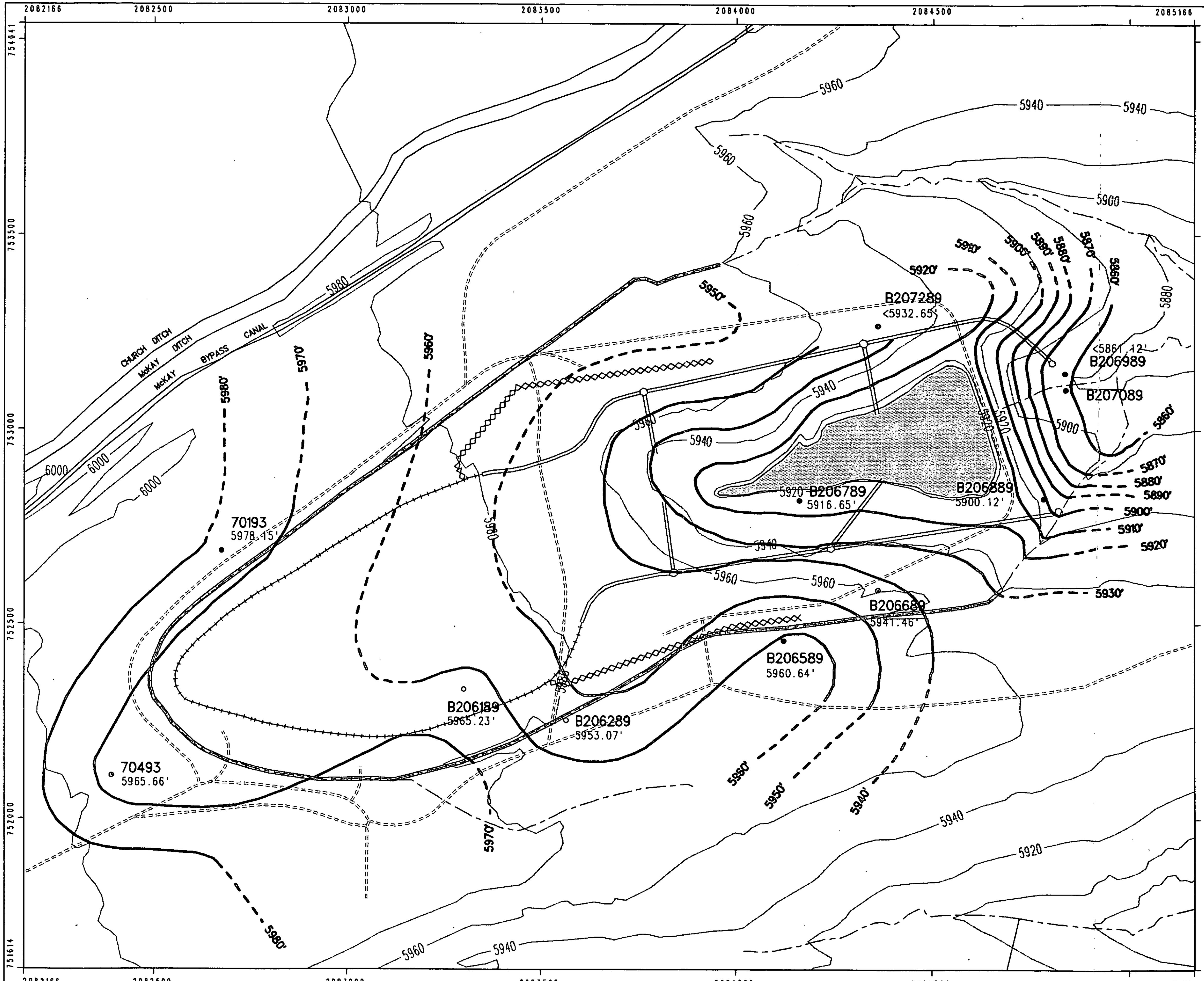
Vertical Hydraulic Gradients Between Unconsolidated Materials and Weathered Bedrock

Hydrogeologic Characterization Report

April 1995

Figure 6-8

88



EXPLANATION

- o Bedrock Well
- Line of Equal Potentiometric Surface
- (dashed where inferred)
- Dirt Roads
- Topographic Contours
- Streams and Ditches
- Intermittent Streams
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
- (perforated)
- (non-perforated)

Scale = 1 : 3000
1 inch = 250 feet

125 0 250ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

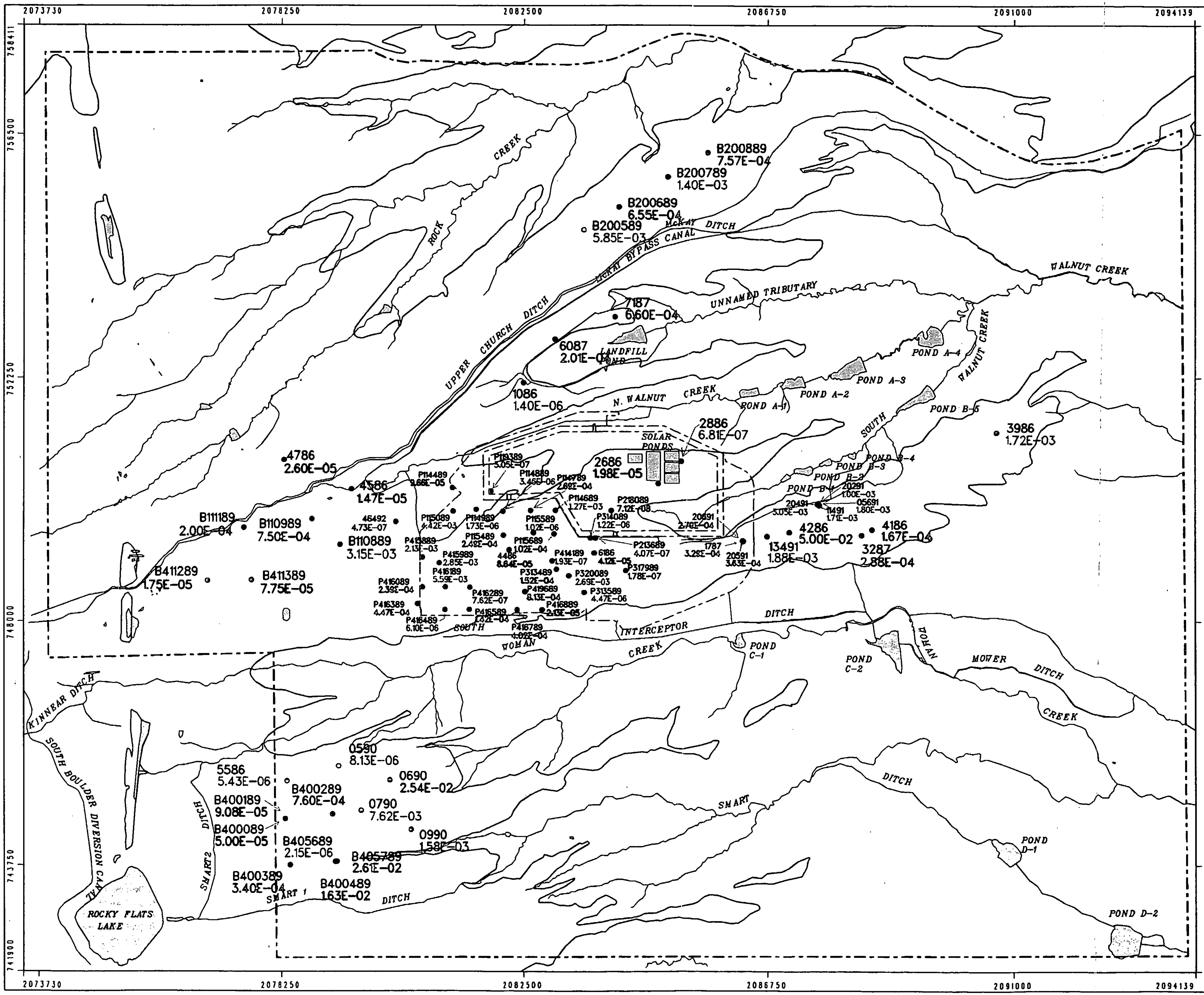
Rocky Flats Site, Golden, Colorado

Potentiometric Surface Map of Weathered Bedrock at Present Landfill Area March 1993 (from: DOE, 1994a)

Hydrogeologic Characterization Report

April 1995	Figure 6-7

87



EXPLANATION

- Wells with Hydraulic Conductivity Data

Values Reported in Centimeters/Second

Color Chart for Hydraulic Conductivity Ranges

- E -02
- E -03
- E -04
- E -05
- E -06
- E -07
- Streams and Drainages
- Approximate Extent of Rocky Flats Alluvium
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Site Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

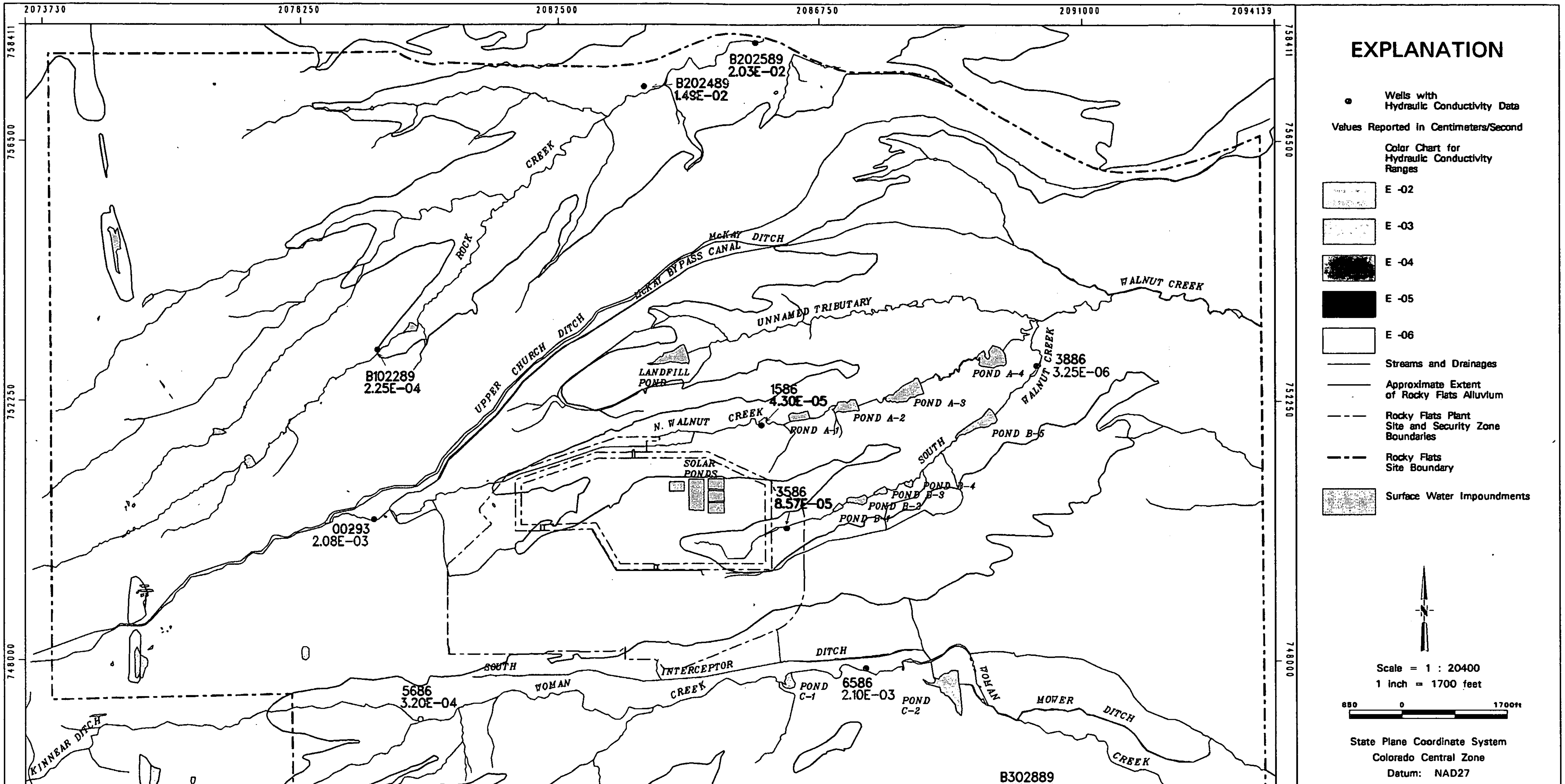
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Rocky Flats Alluvium (Qrf)

Hydrogeologic Characterization Report

April 1995	Figure 6-3

83



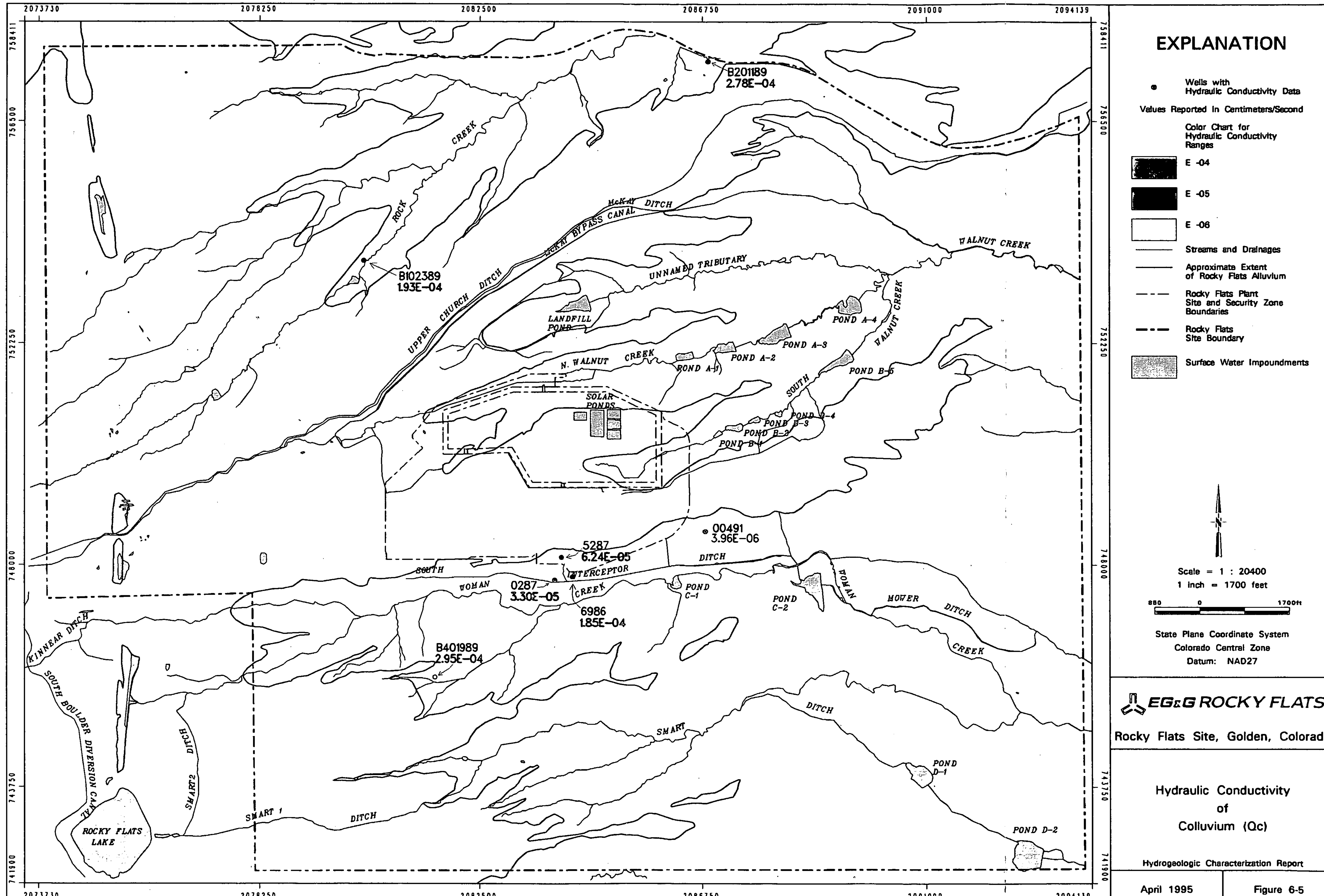
EG&G ROCKY FLATS

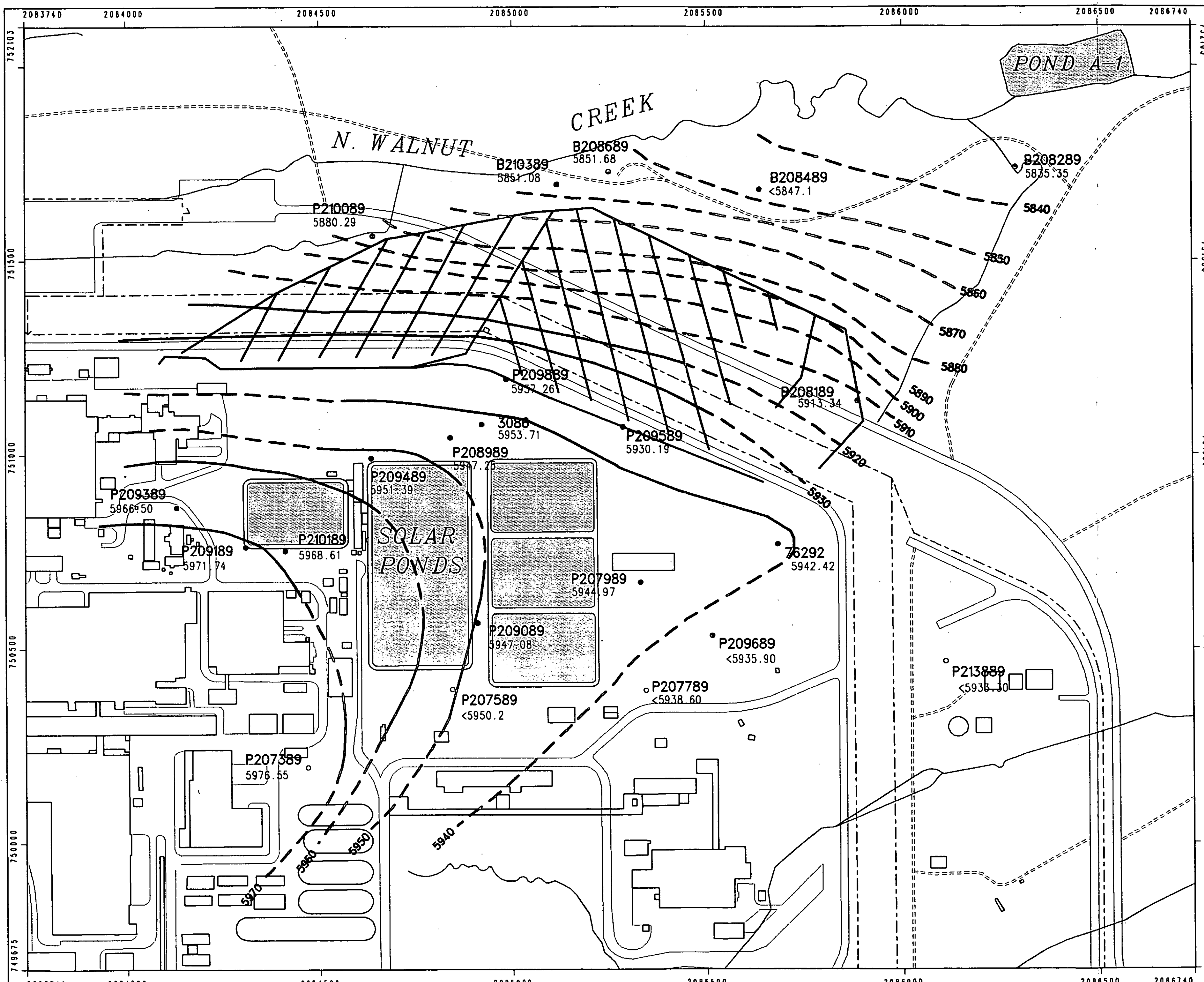
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity of Valley Fill Alluvium (Qvf)

Hydrogeologic Characterization Report

April 1995 | Figure 6-4


EXPLANATION
Wells with Hydraulic Conductivity Data
Values Reported In Centimeters/Second
Color Chart for Hydraulic Conductivity Ranges
E -04
E -05
E -06
Streams and Drainages
Approximate Extent of Rocky Flats Alluvium
Rocky Flats Plant Site and Security Zone Boundaries
Rocky Flats Site Boundary
Surface Water Impoundments
Scale = 1 : 20400
1 inch = 1700 feet
State Plane Coordinate System
Colorado Central Zone
Datum: NAD27
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado
Hydraulic Conductivity of Colluvium (Qc)
Hydrogeologic Characterization Report
April 1995
Figure 6-5
B201189
2.78E-04
B102389
1.93E-04
00491
3.96E-06
5287
6.24E-05
0287
3.30E-05
6986
1.85E-04
B401989
2.95E-04
ROCK CREEK
McKAY DITCH
McKAY BYPASS CANAL
UPPER CHURCH DITCH
UNNAMED TRIBUTARY
WALNUT CREEK
LANDFILL POND
N. WALNUT CREEK
POND A-1
POND A-2
POND A-3
POND A-4
POND B-1
POND B-2
POND B-3
POND B-4
POND B-5
SOUTH WALNUT CREEK
SOLAR PONDS
SOUTH INTERCEPTOR DITCH
WOMAN CREEK
POND C-1
POND C-2
MOWER DITCH
KINNEAR DITCH
SOUTH BOULDER DIVERSION CANAL
SMART 2 DITCH
SMART 1 DITCH
SMART DITCH
ROCKY FLATS LAKE
POND D-1
POND D-2
2073730
2078250
2082500
2086750
2091000
2094139
758411
756500
752250
748000
743750
741900



EXPLANATION

- Weathered Bedrock Well
- Line of Equal Potentiometric Surface (dashed where inferred)
- Streams and Drainages
- Paved Roads
- Dirt Roads
- Rocky Flats Plant Site and Security Zone Boundaries
- French Drain
- Surface Water Impoundments
- Buildings

N

Scale = 1 : 3000
1 inch = 250 feet
125 0 250ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Potentiometric Surface Map
of Weathered Bedrock
at Solar Ponds Area
April 1993
(from: EG&G, 1994b)

Hydrogeologic Characterization Report

April 1995	Figure 6-6

86