Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee

Volume 2.

Appendix A—Waste Sites, Source Terms,
and Waste Inventory Report

Appendix B—Description of the Field Activities
and Report Database

Appendix C—Characterization of Hydrogeologic
Setting Report

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Energy Systems Environmental Restoration Program

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at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee**

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Setting Report**

Date Issued—September 1996

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PREFACE

This Remedial Investigation Report on the Bear Creek Valley Characterization Area at the Oak Ridge Y-12 Plant (DOE/OR/01-1455/V1&D1, -1455/V2&D1, -1455/V3&D1, -1455/V4&D1, -1455/V5&D1, and -1455/V6&D1) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for reporting the results of a site characterization for public review. This work was performed under Work Breakdown Structure 1.4.12.1.1.02.41 (Activity Data Sheet 2302 "Bear Creek Valley"). Publication of this document on September 15, 1996, will meet a Federal Facilities Agreement milestone. This document provides the Environmental Restoration Program with information on the Bear Creek Valley remedial investigations that include results of the Bear Creek Valley OU 1 (1995) and OU 4 (1994) and Bear Creek Valley Floodplain Soils (1995) investigations, plus results of numerous other investigations and monitoring conducted in Bear Creek Valley. It includes information on risk assessments that have evaluated long-term impacts to human health and the environment. Information provided in this document forms the basis for the development of the Feasibility Study/Environmental Assessment Report.

CONTENTS

PREFACE	iii
FIGURES	ix
TABLES	xvii
ACRONYMS AND ABBREVIATIONS	xxi
EXECUTIVE SUMMARY	ES-1
A.1 SITE DESCRIPTION	A1-3
A.1.1 GEOGRAPHICAL INFORMATION	A1-3
A.1.2 BACKGROUND INFORMATION	A1-4
A.1.3 OPERATIONAL INFORMATION AND DESCRIPTION OF WASTE AREAS	A1-4
A.2 RELEASES	A2-1
A.3 REFERENCES	A3-1
A.4 FIGURES	A4-1
A.5 PLATES	A5-1
A.6 TABLES	A6-1
A.7 SUPPORTING INFORMATION FOR APPENDIX A: BEAR CREEK BURIAL GROUNDS WASTE INVENTORY	A7-1
A.7.1 INTRODUCTION	A7-3
A.7.2 WASTE DISPOSAL RECORDS	A7-3
A.7.3 INVENTORY REVIEW	A7-5
A.7.4 PRIMARY ASSUMPTIONS	A7-5
A.7.5 TOTAL URANIUM ESTIMATE COMPARISONS	A7-10
A.8 SUPPORTING INFORMATION FOR APPENDIX A—TABLES	A8-1
B.1 INTRODUCTION	B1-3
B.2 SUMMARY OF HISTORICAL DATA FOR BCV	B2-1
B.2.1 GROUNDWATER	B2-2
B.2.2 SOIL	B2-2
B.2.3 FLOODPLAIN SOIL/SEDIMENT	B2-2
B.2.4 SURFACE WATER	B2-3
B.2.5 OTHER STUDIES	B2-3
B.3 BCV OU 1 RI FIELD ACTIVITIES	B3-1
B.3.1 SUMMARY OF FIELD INVESTIGATIONS	B3-1

B.3.2	DEVIATION FROM THE SAMPLING AND ANALYSIS PLAN	B3-1
B.3.3	SITE SAMPLING ACTIVITIES	B3-1
B.4	BCV OU 4 FIELD ACTIVITIES	B4-1
B.4.1	SUMMARY OF FIELD INVESTIGATIONS	B4-1
B.4.2	DEVIATIONS FROM THE SAMPLING AND ANALYSIS PLAN	B4-1
B.4.3	SITE SAMPLING ACTIVITIES	B4-3
B.5	FIELD DATA COLLECTION—FLOODPLAIN SOILS AND SEDIMENTS	B5-1
B.5.1	SUMMARY OF FIELD INVESTIGATIONS	B5-1
B.5.2	BACKGROUND DETERMINATIONS (REFERENCE SAMPLES AND VALUES)	B5-1
B.5.3	SOIL SAMPLING	B5-2
B.5.4	BEAR CREEK STREAM SEDIMENT CHARACTERIZATION	B5-7
B.5.5	SOURCE TERM ECOLOGICAL CHARACTERIZATION	B5-8
B.6	FIELD DATA COLLECTION—BIOTA SAMPLING	B6-1
B.6.1	PROCEDURES	B6-1
B.6.2	SOURCE TERM ECOLOGICAL CHARACTERIZATION	B6-2
B.6.3	BIOTA SAMPLING AT FLOODPLAIN AFIs	B6-3
B.6.4	ECOLOGICAL REFERENCE SAMPLES	B6-4
B.7	GWQR DATA QUALITY ASSESSMENT	B7-1
B.7.1	PURPOSE	B7-1
B.7.2	SCOPE	B7-1
B.7.3	RI DATA QUALITY OBJECTIVES	B7-1
B.7.4	DATA UNCERTAINTY	B7-3
B.7.5	CONCLUSIONS	B7-11
B.8	BCV INTEGRATING DATA QUALITY ASSESSMENT	B8-1
B.8.1	PURPOSE	B8-1
B.8.2	SCOPE	B8-1
B.8.3	DATA ACCEPTABILITY	B8-1
B.8.4	QUALITY ASSURANCE PROGRAM	B8-3
B.8.5	DATA EVALUATION	B8-5
B.8.6	CONCLUSIONS	B8-14
B.9	REFERENCES	B9-1
B.10	FIGURES	B10-1
B.11	PLATES	B11-1
B.12	TABLES	B12-1
B.13	SUPPORTING INFORMATION FOR APPENDIX B— LITHOLOGIC LOGS	B13-1

C.1 CLIMATE	C1-3
C.1.1 TEMPERATURE	C1-4
C.1.2 WINDS	C1-4
C.1.3 PRECIPITATION	C1-4
C.2 TOPOGRAPHY	C2-1
C.3 BCV HYDROGEOLOGIC CONCEPTUAL MODEL — GEOLOGY	C3-1
C.3.1 BCV STRATIGRAPHY	C3-1
C.3.2 STRUCTURAL GEOLOGY OF THE ORR	C3-4
C.3.3 BCV BEDROCK STRUCTURES	C3-5
C.3.4 FORMATION HYDRAULIC CHARACTERISTICS	C3-7
C.4 BCV HYDROGEOLOGIC CONCEPTUAL MODEL — HYDROLOGY	C4-1
C.4.1 WATER BALANCE MODEL FOR BCV	C4-4
C.4.2 GROUNDWATER FLOW CHARACTERISTICS	C4-5
C.4.3 TRANSIENT RESPONSES TO ANNUAL CHANGE	C4-8
C.4.4 TRANSIENT RESPONSES TO STORMS	C4-9
C.4.5 BEAR CREEK/MAYNARDVILLE LIMESTONE RECHARGE/DISCHARGE RELATIONSHIPS	C4-14
C.5 REFERENCES	C5-1
C.6 FIGURES	C6-1
C.7 TABLES	C7-1
C.8 SUPPORTING INFORMATION FOR APPENDIX C—DETAILED ANALYSIS OF HYDROGEOLOGIC MONITORING DATA FOR BCV OU 4 RIFA	C8-1
C.8.1 VERTICAL HYDRAULIC GRADIENTS	C8-3
C.8.2 PRESSURE PULSES IN RESPONSE TO RAINFALL	C8-5
C.8.3 SURFACE WATER FLOW MONITORING DATA	C8-12
C.8.4 STORMFLOW TUBE MONITORING	C8-13
C.8.5 WATER BALANCE CALCULATION METHODOLOGY	C8-14
C.9 SUPPORTING INFORMATION FOR APPENDIX C—FIGURES	C9-1
C.10 SUPPORTING INFORMATION FOR APPENDIX C—TABLES	C10-1

FIGURES

A.1	Location map for BCV	A4-3
A.2	Locations of waste storage areas and treatment and storage facilities in BCV	A4-5
A.3	Map of the S-3 Site	A4-6
A.4	Locations of plots in the former Oil Landfarm	A4-7
A.5	Site map for the Oil Landfarm Area, including the Oil Landfarm, the Boneyard/Burnyard, and the SL 1	A4-8
A.6	Locations of trenches, oil disposal pits, standpipes, and the isolation area in BG-A North and BG-A South	A4-9
A.7	Locations of trenches, oil disposal pits, standpipes, and the isolation area in BG-B, -C, -D, -E, and -J, and the Walk-In Pits	A4-10
A.8	Site map for the Burial Grounds	A4-11
A.9	Estimated uranium concentrations in Burial Grounds	A4-12
B.1	Historical sampling sites in Bear Creek Valley	B10-3
B.2	Locations of OU 1 sampling activities at the S-3 Site	B10-5
B.3	Locations of OU 1 sampling activities at BYBY, Oil Landfarm, and SL 1	B10-6
B.4	Locations of OU 1 sampling activities at BCBG	B10-7
B.5	Locations of OU 4 sampling activities in BCV	B10-9
B.6	Surface water and groundwater sampling locations for August 1995 radiological sampling task in BCV	B10-10
B.7	Surface water hydrographs showing flow during sampling periods for samples 2 through 7 at BCK 12.38 N Tunnel	B10-11
B.8	Surface water hydrographs showing flow during sampling periods for samples 8 through 11, 13, and 17 at BCK 12.38 N Tunnel	B10-12
B.9	Surface water hydrographs showing flow during sampling periods for samples 18 through 21 at BCK 12.38 N Tunnel	B10-13
B.10	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at BCK 12.38 S Tunnel	B10-14
B.11	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at BCK 12.38 S Tunnel	B10-15
B.12	Surface water hydrographs showing flow during sampling periods for samples 13, 14, 16 through 19 at BCK 12.38 S Tunnel	B10-16
B.13	Surface water hydrographs showing flow during sampling periods for samples 20 and 21 at BCK 12.38 S Tunnel	B10-17
B.14	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-2	B10-18
B.15	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at NT-2	B10-19
B.16	Surface water hydrographs showing flow during sampling periods for samples 13 through 18 at NT-2	B10-20
B.17	Surface water hydrographs showing flow during sampling periods for samples 19 through 21 at NT-2	B10-21
B.18	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-3	B10-22

B.18	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-3	B10-22
B.19	Surface water hydrographs showing flow during sampling periods for samples 7 through 9 and 14 through 16 at NT-3	B10-23
B.20	Surface water hydrographs showing flow during sampling periods for samples 17, 18, 20, and 21 at NT-3	B10-24
B.21	Surface water hydrographs showing flow during sampling periods for samples 2 through 7 at NT-4	B10-25
B.22	Surface water hydrographs showing flow during sampling periods for samples 8 through 12 at NT-4	B10-26
B.23	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-5	B10-27
B.24	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at NT-5	B10-28
B.25	Surface water hydrographs showing flow during sampling periods for sample 13 at NT-5	B10-29
B.26	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-6	B10-30
B.27	Surface water hydrographs showing flow during sampling periods for samples 7, 8, and 12 through 15 at NT-6	B10-31
B.28	Surface water hydrographs showing flow during sampling periods for samples 18 through 21 at NT-6	B10-32
B.29	Surface water hydrographs showing flow during sampling periods for samples 2 and 4 through 8 at NT-7	B10-33
B.30	Surface water hydrographs showing flow during sampling periods for samples 9 through 14 at NT-7	B10-34
B.31	Surface water hydrographs showing flow during sampling periods for samples 15 through 17, and 20 and 21 at NT-7	B10-35
B.32	Surface water hydrographs showing flow during sampling periods for samples 2 through 5, and 9 and 10 at NT-8	B10-36
B.33	Surface water hydrographs showing flow during sampling periods for samples 11 and 12 at NT-8	B10-37
B.34	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at BCK 9.47	B10-38
B.35	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at BCK 9.47	B10-39
B.36	Surface water hydrographs showing flow during sampling periods for samples 14 through 18, and 22 at BCK 9.47	B10-40
B.37	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at SS-1	B10-41
B.38	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at SS-1	B10-42
B.39	Surface water hydrographs showing flow during sampling periods for sample 13 at SS-1	B10-43
B.40	Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at SS-4	B10-44
B.41	Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at SS-4	B10-45

B.42	Surface water hydrographs showing flow during sampling periods for sample 13 at SS-4	B10-46
B.43	Surface water hydrographs showing flow during sampling periods for samples 1 through 3 and 5 through 7 at SS-5	B10-47
B.44	Surface water hydrographs showing flow during sampling periods for samples 8 through 13 at SS-5	B10-48
B.45	Surface water hydrographs showing flow during sampling periods for samples 1, 3, and 6 through 9 at SS-6	B10-49
B.46	Surface water hydrographs showing flow during sampling periods for samples 10, 12, and 13 at SS-6	B10-50
B.47	Diagrammatic representation of the method for calculating flow from stage at BCK 12.38	B10-51
B.48	Rating curve for BCK 9.47	B10-52
B.49	Flowchart outlining sampling activities for BCV Floodplain soils investigation	B10-53
B.50	Locations of Floodplain soils sampling activities in BCV	B10-55
B.51	Summary of samples collected for the BCV OU 4 RI field activities by matrix, site, and analyte group	B10-57
B.52	Summary of samples taken for the BCV OU 1 RIFA by matrix, site, and analyte group	B10-58
B.53	Summary of samples taken for the FPSS field activities by matrix, site, and analyte group	B10-59
C.1	Meteorological data of ORR	C6-3
C.2	Map of BCV showing topography, named tributaries, and springs	C6-5
C.3	Geological map of BCV and surrounding areas	C6-7
C.4	Geology of BCV	C6-9
C.5	Along-strike section of Maynardville Limestone in BCV	C6-10
C.6	Structural cross section of the Oak Ridge area	C6-11
C.7	Hydraulic head, fractures, and fracture characteristics in Nolichucky Shale from GW-726 and GW-727	C6-12
C.8	Conceptual model for groundwater flow in BCV	C6-13
C.9	A schematic showing conceptual shallow groundwater flow for BCV	C6-14
C.10	Water balance model for BCV above BCK 9.47	C6-15
C.11	BCV groundwater elevations for January 10–13, 1994—groundwater piezometric head in BCV for water table and bedrock intervals during high-flow season	C6-17
C.12	BCV groundwater elevations for August 23–31, 1994—groundwater piezometric head in BCV for water table and bedrock intervals during low-flow season	C6-19
C.13	Hydrologic cross section in strike-perpendicular section showing detailed hydraulic head measurements from four coreholes (GW-132, -133, -134, and -135)	C6-20
C.14	Hydraulic gradients in the Nolichucky Shale and Maynardville Limestone in BCV	C6-21
C.15	Water-type regimes in a strike-perpendicular cross section of BCV	C6-22
C.16	Piper diagram illustrating groundwater geochemistry in BCV	C6-23
C.17	Reaction path model for groundwater in BCV	C6-24
C.18	Stream hydrograph from BCK 9.47 from March 1994 to January 1995	C6-25
C.19	Variation of head from instantaneous measurement in GW-227 and GW-228	C6-26
C.20	Hydraulic head monitoring in wells GW-624, -626, and -629 in the Nolichucky Shale	C6-27

C.21	Well hydrographs for GW-725 and GW-726 at BYBY, and for GW-227 and GW-228 at SL 1	C6-28
C.22	Monitoring of changes in soil saturation, stream flow, and groundwater at the BCBG for a storm on April 15, 1994	C6-29
C.23	Monitoring of changes in soil saturation, stream flow, and groundwater at the S-3 Site during storms on July 26-28, 1994	C6-30
C.24	Example well hydrographs for the water table interval of the Nolichucky Shale	C6-31
C.25	Hydraulic head monitoring in wells at the Western Picket in the Maynardville Limestone	C6-32
C.26	Relative magnitudes of λ for stream flow, stormflow tubes, and groundwater in BCV	C6-33
C.27	Identification of gaining and losing reaches in Bear Creek during a high-baseflow period in April 1994	C6-34
C.28	Identification of gaining and losing reaches in Bear Creek during a low-baseflow period in April 1994	C6-35
C.29	West-East profiles of Bear Creek showing flow and conductivity during the high and low baseflow spring and seep surveys (low-flow profile — September 1994 and high-flow profile — March 1995)	C6-36
C.30	Well hydrograph and specific conductivity for GW-045 at depth of 15.2 ft at BCBG for March 15 to April 18	C9-3
C.31	Well hydrograph and specific conductivity for GW-053 at depth of 39.7 ft	C9-4
C.32	Well hydrograph and specific conductivity for GW-076 at depth of 81 ft at OLF for April 28 to June 2	C9-5
C.33	Well hydrograph for GW-085 at depth of 62 ft at OLF for May 3 to June 1	C9-6
C.34	Well hydrograph and specific conductivity for GW-086 at depth of 33.5 ft at OLF for May 3 to June 1	C9-7
C.35	Well hydrograph and specific conductivity for GW-094 at depth of 131 ft at BCBG for March 14 to April 18	C9-8
C.36	Well hydrograph and specific conductivity for GW-095 at depth of 156 ft at BCBG for March 15 to April 18	C9-9
C.37	Well hydrograph and specific conductivity for GW-101 at depth of 17.5 ft at S-3 Site for July 18 to August 4	C9-10
C.38	Well hydrograph for GW-101 at depth of 17.5 ft at S-3 Site for January 18 to March 2	C9-11
C.39	Well hydrograph for GW-122 at depth of 92 ft at S-3 Site for July 18 to August 4	C9-12
C.40	Well hydrograph for GW-124 at depth of 100 ft at S-3 Site for July 8 to August 4	C9-13
C.41	Well hydrograph for GW-126 at depth of 105 ft at BCBG for March 14 to April 18	C9-14
C.42	Well hydrograph for GW-127 at depth of 24.0 ft at S-3 Site for January 18 to March 2	C9-15
C.43	Well hydrograph and specific conductivity for GW-227 at depth of 30 ft at OLF for April 28 to May 30	C9-16
C.44	Well hydrograph and specific conductivity for GW-228 at depth of 80 ft at OLF for April 27 to May 29	C9-17

C.45	Well hydrograph for GW-276 at depth of 18.5 ft at S-3 Site for February 3 to March 2	C9-18
C.46	Well hydrograph and specific conductivity for GW-345 at depth of 26 ft at S-3 Site for July 8 to August 4	C9-19
C.47	Well hydrograph and specific conductivity for GW-346 at depth of 65 ft at S-3 Site for April 29 to June 3	C9-20
C.48	Well hydrograph and specific conductivity for GW-526 at depth of 101 ft at S-3 Site for April 28 to June 2	C9-21
C.49	Well hydrograph and specific conductivity for GW-537 at depth of 24.5 ft at OLF for May 3 to May 30	C9-22
C.50	Well hydrograph and specific conductivity for GW-616 at depth of 219 ft at S-3 Site for July 8 to August 4	C9-23
C.51	Well hydrograph, specific conductivity, and temperature for GW-624 for March 15 to April 18	C9-24
C.52	Well hydrograph and specific conductivity for GW-626 at depth of 78 ft at BCBG for March 19 to April 18	C9-25
C.53	Well hydrograph and specific conductivity for GW-629 at depth of 262 ft at BCBG for March 14 to April 18	C9-26
C.54	Well hydrograph and specific conductivity for GW-651 at depth of 52 ft at BCBG for March 14 to April 18	C9-27
C.55	Well hydrograph for GW-710 at depth of 539 ft at Western Picket for November 1 to January 4	C9-28
C.56	Well hydrograph for GW-711 at depth of 616 ft at Western Picket for November 1 to January 4	C9-29
C.57	Well hydrograph for GW-712 at depth of 451 ft at Western Picket for November 1 to January 4	C9-30
C.58	Well hydrograph for GW-713 at depth of 305 ft at Western Picket for November 1 to January 4	C9-31
C.59	Well hydrograph for GW-714 at depth of 113 ft at Western Picket for November 3 to January 4	C9-32
C.60	Well hydrograph for GW-715 at depth of 75 ft at Western Picket for November 3 to January 4	C9-33
C.61	Well hydrograph and specific conductivity for GW-725 at depth of 132.5 ft at OLF for May 2 to June 3	C9-34
C.62	Well hydrograph and specific conductivity for GW-736 at depth 102 ft at OLF for May 2 to June 2	C9-35
C.63	Well hydrograph for S3-1 at depth of 11.5 ft at S-3 Site for January 17 to March 2	C9-36
C.64	Well hydrograph for S3-3 at depth of 6.0 ft at S-3 Site for January 18 to March 2	C9-37
C.65	Well hydrograph for S3-5 at depth of 12.0 ft at S-3 Site for January 18 to March 2	C9-38
C.66	Well hydrograph for S3-6 at depth of 18.8 ft at S-3 Site for January 17 to March 2	C9-39
C.67	Well hydrograph for S3-7 at depth of 27.9 ft at S-3 Site for January 18 to March 2	C9-40
C.68	Well hydrograph for S3-8 at depth of 95 ft at S-3 Site for January 18 to March 2	C9-41

C.69	Well hydrographs for GW-526 and GW-346 at S-3 Site and for GW-085 and GW-086 at BYBY	C9-42
C.70	Well hydrographs for GW-045 and GW-095 at BCBG	C9-43
C.71	Well hydrographs for GW-094, GW-122, and GW-124 plotted in semi-log space	C9-44
C.72	Hydrographs from stormflow tubes SFT 1, SFT 2, and SFT 3 from April to October 1994	C9-45
C.73	Hydrographs from stormflow tubes SFT 4, SFT 5, and SFT 6 from April to October 1994	C9-46

PLATES

A.1	Upper Bear Creek and the Y-12 Plant, circa 1947	A5-3
A.2	Upper Bear Creek, circa late 1980s	A5-3
A.3	Ponds during neutralization and bionitrification, circa 1983	A5-5
A.4	Ponds during closure, filling, and structural stabilization, circa late 1980s	A5-5
A.5	Foreground: OLF area HCDA in operation, with small percolation pond in SW corner. Background: OLF, SL 1, and NT-3, circa 1980s	A5-7
A.6	Trench, possibly located at BYBY	A5-7
A.7	Burial Grounds, circa 1980s. (Note possible uranium fire in the BG-D area)	A5-9
A.8	Unidentified trench in BG-A South, circa 1980s. (Note the heat haze from uranium tailings fire)	A5-9
A.9	Unidentified trench in BG-A South, circa 1980s. (Note burn pit in foreground with firebricks)	A5-11
A.10	Unidentified trench, probably located in area D, E, or J	A5-11
A.11	ORP-1 (Burial Grounds), circa 1980s. Picture taken after draining the pond during closure operation. Equipment in background is oil/water separator	A5-13
B.1	Photograph showing the floodplain soil sample at transect 2	B11-3
B.2	Photograph showing the floodplain soil sample at transect 3	B11-3

TABLES

A.1	Sites considered in this RI report that are listed in the FFA or have been identified as solid waste management units	A6-3
A.2	Chronological list of events at the S-3 Ponds	A6-6
A.3	Source term characterization for S-3 Site	A6-9
A.4	Chronological list of events at the Oil Landfarm	A6-11
A.5	Summary of waste coolant disposals at Y-12 Plant Oil Landfarm	A6-13
A.6	Summary of waste oil disposals at the Y-12 Plant Oil Landfarm	A6-14
A.7	OLF storage pad soil data summary	A6-15
A.8	OLF soils-in-place analytical results summary	A6-17
A.9	Chronological list of events at the Boneyard/Burnyard	A6-18
A.10	Chronological list of events at SL 1	A6-19
A.11	Chronological list of events at the Burial Grounds	A6-20
A.12	DARA soil data summary	A6-23
A.13	Estimated disposals at Burial Ground A-South	A8-3
A.14	Estimated disposals at Burial Ground A-North	A8-5
A.15	Estimated disposals at Burial Ground A-16	A8-6
A.16	Estimated disposals at Burial Ground A-17	A8-6
A.17	Estimated disposals at Burial Ground A-18	A8-6
A.18	Estimated disposals at Burial Ground B	A8-7
A.19	Estimated disposals at Burial Ground C-East	A8-8
A.20	Estimated disposals at Burial Ground C-West	A8-9
A.21	Estimated disposals at Burial Ground D-East	A8-10
A.22	Estimated disposals at Burial Ground D-South	A8-10
A.23	Estimated disposals at Burial Grounds D-West, E, and J	A8-10
A.24	Estimated disposals at Burial Ground Walk-In Pit 1 (North)	A8-11
A.25	Estimated disposals at Burial Ground Walk-In Pits 2 and 3 (South)	A8-14
A.26	BG-A - Summary of recorded disposals and removals	A8-15
A.27	Summary of estimated uranium quantities by Burial Grounds area	A8-16
B.1	Historical data from special studies, subcontractor sampling events, and monitoring activities within BCV	B12-3
B.2	Summary of number of samples per analyte per project and medium	B12-24
B.3	Procedure numbers and titles for BCV OU 1 RIFA	B12-36
B.4	List of changes to SAP for OU 1	B12-37
B.5	List of analytes and reported quantitation limits for surface and subsurface soils in BCV OU 1	B12-40
B.6	Geotechnical and physical parameters for soil samples taken in BCV OU 1 RIFA	B12-47
B.7	List of analytes and reported quantitation limits for groundwater and surface water in BCV OU 1	B12-48
B.8	Groundwater sample intervals for groundwater collected during BCV OU 1 RIFA	B12-56
B.9	Technical sampling procedures used during BCV OU 4 RIFA	B12-57
B.10	List of minor changes to the BCV OU 4 RIFA	B12-58
B.11	List of activities completed for BCV OU 4 RIFA	B12-63

B.12	List of analytes and reported quantitation limits for surface water in BCV OU 4	B12-65
B.13	Time periods and the stage to flow conversions for each surface water site in BCV OU 4	B12-69
B.14	Flow monitoring periods, total flow, and average flow for the monitoring station at BCK 12.38	B12-70
B.15	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-2	B12-71
B.16	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-3	B12-72
B.17	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-4	B12-73
B.18	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-5	B12-74
B.19	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-6	B12-75
B.20	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-7	B12-76
B.21	Flow monitoring periods, total flow, and average flow for the monitoring station at NT-8	B12-77
B.22	Flow monitoring periods, total flow, and average flow for the monitoring station at BCK 9.47	B12-78
B.23	Flow monitoring periods, total flow, and average flow for the monitoring station at SS-1	B12-79
B.24	Flow monitoring periods, total flow, and average flow for the monitoring station at SS-4	B12-80
B.25	Flow monitoring periods, total flow, and average flow for the monitoring station at SS-5	B12-81
B.26	Flow monitoring periods, total flow, and average flow for the monitoring station at SS-6	B12-82
B.27	Rating curve for Bear Creek at BCK 9.47	B12-83
B.28	List of monitoring wells and monitoring periods for BCV OU 4 RIFA head monitoring activities	B12-84
B.29	List of minor changes to the BCV FPSS field activities	B12-86
B.30	Large-scale characterization sample location and analysis matrix	B12-88
B.31	List of analytes and reported quantitation limits for soils and sediment in BCV FPSS	B12-89
B.32	Fine-scale characterization, stream sediment and soil reference, sample location, and analysis matrices	B12-95
B.33	Technical sampling procedures used in the course of BCV Floodplain investigation	B12-96
B.34	Technical procedures for collection of BCV biota samples	B12-97
B.35	Biota samples collected for the BCV RI	B12-98
B.36	Summary of analytical methods used for the GWQR dataset	B12-99
B.37	Minimum and maximum non-detects for groundwater in the S-3 aggregate	B12-101
B.38	Minimum and maximum non-detects for groundwater in the OLF aggregate	B12-108
B.39	Minimum and maximum non-detects for groundwater in the BCBG aggregate	B12-115

B.40	Minimum and maximum non-detects for groundwater in the Maynardville aggregate	B12-120
B.41	Analyses eliminated for use due to high total suspended solids, sodium, or chloride	B12-124
B.42	Analytical holding times and preservatives	B12-125
B.43	Index of available numbers of samples from each source and media providing qualitative or quantitative information	B12-126
B.44	Audits and surveillances of Bear Creek field activities	B12-127
B.45	SPARCC parameter criteria for BCV OU 4, OU 1, and FPSS projects	B12-132
B.46	Accuracy in the BCV OU 4, OU 1, and FPSS datasets	B12-133
B.47	Overall precision in the BCV RI dataset	B12-134
B.48	BCV OU 4 samples that may have been mis-identified during analysis	B12-135
B.49	Data usability in the BCV OU 4, OU 1, and FPSS datasets	B12-136
C.1	Thickness of zones identified in the Maynardville Limestone	C7-3
C.2	Valley-wide summary of results from the BCV and Grassy Creek spring and seep survey	C7-5
C.3	Vertical hydraulic gradients in the Nolichucky Shale in BCV	C10-3
C.4	Analysis of selected well hydrographs in BCV	C10-5
C.5	Analysis of selected stream hydrographs in BCV	C10-6
C.6	Analysis of selected stormflow tube hydrographs in BCV	C10-7

ACRONYMS AND ABBREVIATIONS

APPENDIX A

BCBG	Bear Creek Burial Grounds
BCV	Bear Creek Valley
BYBY	Boneyard/Burnyard
CA	Characterization Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DARA	Disposal Area Remedial Action
DOE	Department of Energy
Energy Systems	Lockheed Martin Energy Systems, Inc.
EPA	Environmental Protection Agency
HCDA	Hazardous Chemical Disposal Area
HWDU	Hazardous Waste Disposal Unit
MOU	Memorandum of Understanding
OLF	Oil Landfarm
ORP	Oil Retention Pond
ORR	Oak Ridge Reservation
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SL 1	Sanitary Landfill 1
TDEC	Tennessee Department of Environment and Conservation
WIP	Walk-In Pits

APPENDIX B

ADNCR	Analytical Data Non-Conformance Report
AFI	area for further investigation
ASTM	American Society for Testing and Materials
ATV	all-terrain vehicle
BCBG	Bear Creek Burial Grounds
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
BEIDMS	Bechtel Environmental Information Data Management System
bgs	below ground surface
BNI	Bechtel National, Inc.
BSCP	Background Soil Characterization Project
BYBY	Boneyard/Burnyard
CA	Characterization Area
CLP	Contract Laboratory Program
DQO	data quality objective
Energy Systems	Lockheed Martin Energy Systems, Inc.
EPA	Environmental Protection Agency

FPSS	floodplain soil/sediment
GFAA	graphite furnace atomic absorption
GWPP	Groundwater Protection Program
GWQR	Groundwater Quality Report
HCDA	Hazardous Chemical Disposal Area
ICP	inductively coupled plasma
NCR	non-conformance report
NT	North Tributary
OLF	Oil Landfarm
ORNL	Oak Ridge National Laboratory
ORP	Oil Retention Pond
OU	Operable Unit
PCB	polychlorinated biphenyl
RI	Remedial Investigation
RPD	relative percent difference
SAP	Sampling and Analysis Plan
SAIC	Science Applications International Corporation
SL 1	Sanitary Landfill 1
SPARCC	sensitivity, precision, accuracy, representativeness, completeness and comparability
SVOC	semivolatile organic compound
USGS	U.S. Geological Survey
USRADS	Ultrasonic Ranging and Data System
VOC	volatile organic compound

APPENDIX C

amsl	above mean sea level
BCBG	Bear Creek Burial Grounds
BCHR	Bear Creek Hydrogeologic Regime
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
bgs	below ground surface
BYBY	Boneyard/Burnyard
cfs	cubic foot/second
GWPP	Groundwater Protection Program
GWQR	Groundwater Quality Report
NT	North Tributary
ORR	Oak Ridge Reservation
ORRHAGS	ORR Hydrology and Geology Studies
OU	Operable Unit
ppb	parts per billion
RI	Remedial Investigation
RIFA	RI Field Activities
SL 1	Sanitary Landfill 1
TDS	total dissolved solids

EXECUTIVE SUMMARY

This Remedial Investigation (RI) Report characterizes the nature and extent of contamination, evaluates the fate and transport of contaminants, and assesses risk to human health and the environment resulting from waste disposal and other U.S. Department of Energy (DOE) operations in Bear Creek Valley (BCV). BCV, which is located within the DOE Oak Ridge Reservation (ORR) (Fig. ES.1), encompasses multiple waste units containing hazardous and radioactive wastes arising from operations at the adjacent Oak Ridge Y-12 Plant (Fig. ES.2). The primary waste units discussed in this RI Report are the S-3 Site, Oil Landfarm (OLF), Boneyard/Burnyard (BYBY), Sanitary Landfill 1 (SL 1), and Bear Creek Burial Grounds (BCBG). These waste units, plus the contaminated media resulting from environmental transport of the wastes from these units, are the subject of this RI.

Consistent with the Watershed Approach to remedial investigation/feasibility study (RI/FS) planning adopted by the Oak Ridge Federal Facility Agreement (FFA) parties, the environmental media and waste sites in BCV have been combined into a single Characterization Area (CA) encompassing the entire Bear Creek watershed. The benefits of this approach have included:

- a significantly reduced site investigation phase, with more reliance on historical data as the basis for remedial action decisions;
- development of more consistent Remedial Goal Options (RGOs) across the multiple source units;
- an increased focus on development of an integrated prioritization for remedial actions, particularly for sites appropriate for near-term actions; and
- an overall reduction in cost and schedule for the RI/FS process.

Accordingly, the BCV RI Report documents and interprets the results of numerous historical field characterization efforts conducted in BCV prior to 1994 as well as three limited RI field projects covering specific portions of the watershed in 1994 and 1995. This interpretation provides a comprehensive evaluation of the conditions at and risks associated with the waste sites, associated floodplain, and groundwater in the valley.

Inherent in the accelerated watershed approach is the heavy reliance on historical data to form the basis of the RI. For BCV, a significant historical data set existed, thus minimal effort was spent by the watershed RI team in gathering additional extent of contamination information. While this approach greatly reduces the schedule and cost of the RI, it does result in higher levels of uncertainty in the evaluation results. The likelihood of important data gaps in the BCV RI was minimized by adherence to the Data Quality Objective (DQO) process during the planning phase, and by proactive uncertainty management during the data collection and evaluation phases. The resulting FS will accommodate the identified uncertainties through selection of contingent actions that will allow for flexibility within the remedy selection.

This BCV RI Report represents the first major step in the decision-making process for the BCV watershed. The RI results, in concert with the follow-on FS (to be available for public review in April 1997), will form the basis for the Proposed Plan and Record of Decision for all BCV sites. This comprehensive decision document process will meet the objectives of the watershed approach for

ES-2

- SAIC CAD DWG: 94020\DWGS\507REACH

Figure ES.1. Location map for the Bear Creek Valley Characterization Area showing major geographical and hydrological features.

BEAR CREEK VALLEY

LEGEND:

- ===== ROADS
- BEAR CREEK & TRIBUTARIES
- SS4 OU4 SURFACE WATER SAMPLE AT SPRINGS
- ⊕ GW-684 GROUNDWATER WELL
- WASTE AREA UNITS

Figure ES.2. Location map for waste areas in the Bear Creek Valley Characterization Area.

BCV, which include: (1) prioritization of remedial action decisions, (2) expeditious implementation of highest priority remedial actions, and (3) increased cost effectiveness of remedial action by setting watershed Remedial Action Objectives (RAOs) based on an integrated, valley-wide, future land use plan. By conducting the evaluation within the watershed framework, DOE can ensure consistent actions that achieve the RAOs across all the units and cost effectively optimize the extent and type of remedies, regardless of location.

ES.1 MAJOR CONCLUSIONS FOR THE RI REPORT

The BCV RI Report contains a detailed analysis of environmental data for BCV. The major conclusions from the analysis are conveyed via conceptual models for the nature and extent of contamination and fate and transport of contaminants. Common to each of the major waste units located on the north side of Bear Creek are the following major conclusions:

- There are a number of physical and chemical aspects of the source sites that will complicate cleanup of the sources areas and will limit the ability to allow unrestricted, e.g., residential or industrial, use at these sites (S-3 Site, BYBY, and the BCBG). These are:
 - large volumes of buried waste exist at each source area in unlined trenches;
 - portions of the waste at each source area are inundated by shallow groundwater;
 - groundwater at the sources is contaminated to over 120 m (400 ft) depth and dense non-aqueous phase liquid (DNAPL) is present; at the S-3 Site and BCBG, contamination in groundwater is a secondary source that is of equal or greater magnitude than the primary waste source; and
 - the sources are situated on low permeability, fractured shale rock. Diffusion of contaminated groundwater into the rock pores has resulted in a reservoir of contaminated groundwater that can only be released from the rock at a slow rate.
- Contaminants migrating from the waste sites in BCV converge at Bear Creek Kilometer (BCK) 9.47/South Spring (SS)-5 (Fig. ES.1): more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater. Thus a north-south line drawn at BCK 9.47/SS-5 is a convenient location to conduct an integrator point/plane (IP) assessment of contaminant fluxes from the waste areas (Note: in some of the FS alternatives, unrestricted land use starts to the west of this line). At the IP, potential risks from exposure to groundwater or surface water exceed 10^{-6} or a Hazard Index (HI) >1 (Fig ES.3). The chemicals of concern (COCs) at the IP are uranium, nitrate, boron, and fluoride. In addition, applicable or relevant and appropriate requirements (ARARs) for nitrate are exceeded in groundwater at the IP and also most likely for uranium (Note: uranium contamination in GW-684 at the IP does not exceed the ARAR; however, groundwater discharge at SS-5 periodically exceeds the uranium ARAR). Although it is not clear how far the elevated hazard and ARAR exceedances extend to the west, they do not extend as far as Highway 95.
- Contaminated groundwater at waste areas migrates along geological strike to nearby tributaries of Bear Creek [i.e., North Tributary (NT) -1, -2, -3, -6, -7, and -8] causing the tributaries and Bear Creek to become contaminated. This is the principal exit pathway for contaminants leaving the waste areas and moving to the IP. Figure ES.3 shows what sources and tributaries contribute the most to contamination at the IP. The S-3 Site (NT-1, NT-2, and Bear Creek above

Potential Risks and Toxic Effects at the Integrator Plane

BCK 9.4/SS-5 Aggregate

GW 684 Groundwater

*COPCs not listed individually have individual potential risk $< 10^{-5}$ or HI < 0.1

Relative Contribution of Uranium and Nitrate at the IP from Source Areas

Uranium Flux

*Assumed distribution of ungauged flux is 70% BYBY, 30% S-3 Site.

Nitrate Flux

Figure ES.3. Potential risks and hazards at the Integrator point/plane and the relative magnitude of the sources for nitrate and uranium.

BCK 12.36) and BYBY (NT-3) sites are currently contributing more than 80% of the potential hazard at the IP through releases of uranium and, to a lesser extent, nitrate. The total flux from NT-1 and NT-2 is expected to increase in the foreseeable future and may result in a greater hazard at the IP. A 50 to 75% reduction in the current contaminant flux through tributaries or shallow groundwater at the S-3 Site and BYBY could reduce the total HI at the IP below 0.8.

- Discharges to surface water from a plume of contaminated groundwater at the S-3 Site are the primary causes of current impacts on the aquatic ecology in Bear Creek, east of BCK 9.47.
- Impacts of contamination at waste areas have been lessened by capping waste areas. In addition, seep collection at BCBG has lessened the downgradient impact of contamination migrating away from this source.

ES.2 BCV HYDROGEOLOGICAL CONCEPTUAL MODEL

The hydrogeological system in BCV is governed by the valley's geology. Rocks underlying BCV fall into two broad categories: those that are dominated by clastic lithologies (e.g., Nolichucky Shale) and those that are predominantly carbonates (e.g., Maynardville Limestone). The primary permeability of the rocks underlying BCV is very low. The formations are extensively fractured and, in the case of carbonate formations, karstified, creating a secondary porosity that results in substantially increased permeability.

Groundwater flows through fractures or solution conduits, which are well-connected and mostly parallel to geological strike (Fig. ES.4). Fracture aperture width generally decreases with depth, restricting the depth of active groundwater circulation. The shallow interval [top 30 m (100 ft)] of the Maynardville Limestone contains a well-connected maze of conduits that is able to transport water rapidly along strike, west in the axis of BCV. Groundwater in this interval is closely connected to flow in Bear Creek. Below 30 m (100 ft) in this formation, along strike flow occurs through discrete solution conduits and fractures that are not as well-interconnected than those in the shallow interval.

The Nolichucky Shale is the principal clastic formation that forms the northern flank of BCV. Most groundwater flow in the clastic formations occurs during and immediately following precipitation at the water table and shallow bedrock intervals [probably <15 m (50 ft) depth]. Flow is predominantly along strike, and discharge is to tributaries of Bear Creek after short flowpaths. During storms, flow in these shallow intervals may be rapid (up to 40 m/d).

As a result of predominantly short and shallow flow paths for groundwater in the clastic formations in BCV, although the largest mass of water (and consequently the largest mass of contaminants) exits BCV via surface water, groundwater is the principal pathway for contaminants leaving the waste units. The main flow and contaminant transport pathways in groundwater at the waste units are along strike with the discharge points at tributaries to Bear Creek. Fluxes in flow paths at the waste units (overland flow, soil interflow, and groundwater flow) have not been quantified but recharge followed by groundwater flow to tributaries constitutes the main water flux pathway. During a 10-month surface water monitoring program, an estimated 97% of water available for flow (precipitation and evapotranspiration) exited the section of the valley above BCK 9.47 as surface water flow.

BC-125a

Figure ES.4. Hydrogeological conceptual model for Bear Creek Valley.

ES.3 NATURE AND EXTENT OF CONTAMINATION

ES.3.1 Environmental Database

The environmental database used for the BCV RI includes 75,000 soil, sediment, groundwater, surface water, and biota analyses obtained during the RI field projects conducted during 1994 and 1995, and 20,000 soil, sediment, groundwater, and surface water analyses obtained from historical field studies conducted in the 1980s and early 1990s. A detailed data quality assessment review demonstrated that the quality of both the recent and historical chemical data is adequate: <1% of the recent data were considered unacceptable, and only 1.3% of the historical chemical data were rejected. Historical radiological data for groundwater were deemed unacceptable for use in the RI and the Human Health Risk Assessment, therefore, additional groundwater samples were taken during the RI to complete the radiological database.

ES.3.2 Waste Sites

The primary waste sites characterized in this BCV RI report are the S-3 Site, OLF, BYBY, SL 1, and BCBG (Fig. ES.2). Three other primary waste sites within BCV — Spoil Area 1, Rust Spoil Area, and SY-200 Yard — are discussed in the BCV OU 2 RI (Energy Systems 1995). Although these sources were described in the BCV OU 2 RI Report, the watershed approach dictates that their impacts on the environment in BCV are considered in this report. In addition, numerous smaller waste disposal or storage areas throughout BCV, such as the OLF Storage Containment Pad, Bear Creek Road Debris Burial area, and Creekside Debris Burial area, are also considered as potential contaminant sources.

During the DQO process for BCV, the RI team decided that direct sampling to characterize the waste materials was not feasible (DQO meeting minutes). Instead, the physical and chemical characteristics of the contaminant sources were derived from interpretation of historical data and information in waste management records: pre-closure sampling data were used to quantify waste contamination at the S-3 Ponds and OLF sites; a detailed waste inventory was used for BCBG; and data from recent (1994) soil sampling were used for BYBY and SL 1. Where possible, current conditions within each source area were estimated to allow modeling of the potential future releases and assessment of current and future risks.

The waste areas in BCV are located in the upper 3.5 km (2.2 miles) of the valley (east of the IP) (Fig ES.2). Both solid and liquid wastes were disposed of at these sites. Most liquid waste has either infiltrated to groundwater below the waste sites or has migrated in groundwater and surface water away from the source areas. The following volumes of waste, contaminated soil, and contaminated groundwater are estimated to be present in BCV (Note: volume estimates for soils and wastes do not include materials in waste area caps):

S-3 Site	1,600 m ³ waste and contaminated soils 7.1 × 10 ⁶ m ³ (5740 acre-ft) contaminated groundwater
Oil Landfarm	25,000 m ³ waste and contaminated soils
BYBY	90,000 m ³ waste and contaminated soils 0.4 × 10 ⁶ m ³ (320 acre-ft) contaminated groundwater

SL 1	110,000 m ³ waste and contaminated soils
BCBG	190,000 m ³ waste and contaminated soils 4.0 × 10 ⁶ m ³ (3200 acre-ft) contaminated groundwater

In addition, there is an estimated 5.7×10^6 m³ (4600 acre-ft) of contaminated groundwater in the Maynardville Limestone, and < 1,000 m³ of contaminated soils and waste materials on the BCV floodplain.

ES.3.3 Nature and Extent of Contamination in Environmental Media and Wastes

The data available for the BCV CA were divided into four functional areas (FAs), each of which contains data that are logically interpreted together because of location and/or contaminant source. Three of the FAs — the S-3 FA, the OLF FA, and the BCBG FA — include data that relate to the three primary waste areas (Fig. ES.2). The fourth FA is the Maynardville Limestone and Bear Creek FA, which is located downgradient of the source FAs and acts as an integrated exit pathway for contaminants migrating away from the source units, via groundwater in the Maynardville Limestone or surface water flow in Bear Creek.

S-3 Functional Area

The S-3 FA includes the soils, groundwater, and surface water at and immediately downgradient of the S-3 Site.

Sources and contaminants. At the S-3 Site FA, primary contaminant sources are (1) a plume of contaminated groundwater derived from infiltration of nitric acid waste water and density-driven flow downward into bedrock, and (2) sludges remaining in place in the former ponds. Thirty years of disposal of concentrated (~1 molar) nitric acid solutions at the S-3 Site has resulted in a reservoir of contaminated groundwater with high (> 10,000 mg/L) total dissolved solids (TDS) in the Nolichucky Shale at this site. Discharge of groundwater from this contaminated plume results in contaminated surface water with elevated TDS (maximum > 1000 mg/L).

Contamination derived from the S-3 Site can be identified in the Maynardville Limestone as far west as Picket W and in surface water at BCK 4.55. Primary contaminants that have migrated away from the S-3 Site include (1) nitrate, uranium, ⁹⁹Tc, barium, boron, cadmium, strontium, acetone, and tetrachloroethene (PCE) in groundwater, and (2) nitrate, cadmium, uranium, and ⁹⁹Tc in surface water. Contaminant concentrations in groundwater at the S-3 Site exceed ARARs for inorganic and organic chemicals in drinking water.

S-3 Site conceptual model. At the S-3 Site, contaminated groundwater in the Nolichucky Shale is the main source of contaminants to downgradient receptors: more contaminant mass flux is discharging to the creek than is leaching from waste materials that remain in the former ponds. Historically, during operations at the S-3 Ponds, most of the acidic waste water probably migrated rapidly to the main stem of Bear Creek, NT-1, and Upper East Fork Poplar Creek via shallow groundwater flow. At the present time, contaminants in this plume are migrating in shallow and deep groundwater and discharging to Bear Creek, NT-1, and NT-2 (Fig. ES.5).

Contaminants have undergone differential retardation that has resulted in different distributions and exit pathways for the primary contaminants: nitrate, metals, uranium, ⁹⁹Tc, and PCE. Uranium and some metals are made relatively immobile by geochemical reactions and have been held up in the residuum and shallow groundwater close to the S-3 Site. The exit pathway for these contaminants is via discharge of shallow groundwater to Bear Creek. Nitrate, ⁹⁹Tc, PCE, and the more mobile metals have contaminated bedrock groundwater. The main pathway for these contaminants is along strike flow in the intermediate and deep groundwater intervals, followed by upwelling and/or diffusion to the shallow groundwater interval and discharge to NT-1 and NT-2. Nitrate is least retarded and has traveled the farthest from the S-3 Site — its occurrence in groundwater marks the maximum extent of contamination resulting from the S-3 Site.

All contaminants in groundwater at the S-3 Site have been retarded by matrix diffusion. A reservoir of contaminants in the matrix porosity now exists at the S-3 Site, where these contaminants flow and/or diffuse from the rock matrix into the active flow fractures in each pathway.

The maximum concentrations of PCE found at S-3 Site (> 1% of PCE solubility) indicate the potential for PCE bearing DNAPL in the bedrock formations beneath the ponds.

The plume of contaminated groundwater derived from the S-3 Site can be traced in the Nolichucky Shale as far west as NT-2. However, although the extent west of the plume in shallow groundwater is well known, no data points exist until downgradient of SL 1 to identify the leading edge of the plume in intermediate and deep groundwater. Increasing concentrations of nitrate in shallow wells near the NT-2 catchment over the past 10 years suggest that the center of mass of the nitrate plume may be moving along strike to the west in groundwater below 30 m (100 ft) depth. The probable condition is that the plume in deep groundwater extends no further west than the plume in shallow groundwater and that much of the contaminant mass flux in the plume is discharged to NT-2.

Oil Landfarm Functional Area

The OLF FA encompasses the soils, groundwater, and surface water at and immediately downgradient of four sites: OLF, BYBY, Hazardous Chemicals Disposal Area (HCDA), and SL 1.

Sources and contaminants. Both solid and liquid wastes were disposed of at the OLF FA. There are three primary locations of solid wastes: (1) buried waste materials at BYBY, (2) buried waste materials in the SL 1 trench, and (3) contaminated soils on the former OLF plots. In addition, disposals of liquid wastes at BYBY, HCDA, and OLF have resulted in plumes of volatile organic compound (VOC) -contaminated groundwater.

Contamination at the OLF FA is diverse, including metal, radionuclide, and VOC contamination in groundwater, surface water, soils, and waste materials. Frequently detected contaminants in the OLF FA are as follows:

- At BYBY and HCDA: (1) mercury, beryllium, manganese, nickel, vanadium, PCE, trichloroethene (TCE), 1,2-dichloroethene (DCE), and uranium isotopes in groundwater; (2) mercury, lithium, and uranium isotopes in surface water; and (3) mercury, cadmium, copper, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phthalates, uranium isotopes, and ⁹⁹Tc in soils.

- At OLF: (1) PCBs and uranium in soils and wastes, and (2) 1,1,1-trichloroethane (TCA), 1,1-dichloroethane (DCA), 1,1-DCE, 1,2-DCE, PCE, and TCE in groundwater. There is no surface water contamination that can be attributed to OLF.
- At SL 1: (1) mercury, copper, nickel, PCB-1254, and ²³⁵U in soils and wastes, and (2) 1,1-DCA, 1,2-DCE, and vinyl chloride in groundwater. There is no surface water contamination that can be attributed to SL 1.

OLF FA conceptual model. The conceptual models for both OLF and SL 1 are that soils surrounding the waste sites are relatively uncontaminated. Groundwater below and immediately downgradient of each waste area is contaminated with VOCs as a result of liquid waste disposals.

At BYBY, uranium leaches from waste materials (some of which are most likely inundated with groundwater) and contaminated soils to groundwater, which subsequently discharges to surface water in NT-3. Uranium in groundwater that has leached from fill material in the southern portion of BYBY probably migrates directly to the Maynardville Limestone and Bear Creek via shallow groundwater flow (Fig. ES.5). Fate and transport modeling indicates that most inorganic and radiological contaminants in NT-3 have probably reached peak concentrations; however, the presence of a continuous source (leaching from waste materials) suggests that these peak values would be maintained over several hundred years.

The VOC plume at BYBY is partly located in residuum above the Maynardville Limestone and, like uranium, VOCs probably migrate directly into the Maynardville Limestone or Bear Creek. Although VOCs entering groundwater from HCDA or the Burnyard may discharge to surface water in NT-3, the extent of this discharge is low, hence, VOCs volatilize almost immediately.

Bear Creek Burial Grounds Functional Area

Sources and contaminants. At the BCBG FA, both solid and liquid wastes were disposed of in a series of unlined trenches. The waste trenches are grouped into areas BG-A, -B, -C, -D, -F, and Walk-in-Pits (WIP). Uranium dominates the wastes disposed of in each area with a total estimated mass of 18.6 million Kg. Disposals of liquid wastes have also resulted in DNAPL (PCE and TCE) in groundwater that may have reached depths of 180 m (600 ft). Dissolution of DNAPL results in plumes of VOC-contaminated groundwater.

Contamination in the BCBG FA includes VOCs and metals in groundwater, and VOCs, metals, and radionuclides in surface water, soils, waste materials, and leachate from waste trenches. In general, organic contamination of environmental media at BCBG is more widespread than inorganic and radionuclide contamination. Primary contaminants detected at the BCBG are: (1) boron, PCE, TCE, 1,1,1-TCA, and 1,2-DCE in groundwater; (2) beryllium, 1,1,2-TCA, 1,1-DCE, 1,2-DCA, vinyl chloride, 1,1-DCA, 1,1,1-TCA, chloroethane, and uranium isotopes in surface water; (3) arsenic, vanadium, PCBs, acetone, and toluene in soils surrounding the waste areas; and (4) uranium, beryllium, PCBs, TCE, and PCE in wastes. Contaminant concentrations in groundwater at BCBG exceed ARARs for inorganic and organic chemicals in drinking water at many locations.

Contamination of groundwater and surface water is dominated by VOCs at the BCBG FA. Three groundwater plumes were identified: (1) the BG-A plume is dominated by PCE, TCE, and 1,2-DCE, and includes DNAPL; (2) the WIP plume is dominated by PCE; and (3) the plume at the NT-8 catchment is dominated by 1,2-DCE, with lesser concentrations of vinyl chloride.

Radiological contamination is virtually absent from groundwater wells in the BCBG, but uranium is consistently detected in surface water. Collection of leachate in the NT-7 and NT-8 catchments has significantly reduced the concentration of radiological and other contaminants in surface water.

Radiological contamination occurs in soils in the NT-8 floodplain and is probably related to past deposition of contaminated sediments derived from drainage of the BG-B, -C, and -D areas.

BCBG conceptual model. The distribution of contaminants at BCBG reflects the type of waste materials that were disposed. The organic wastes were dense liquids and were disposed of directly into groundwater; uranium is in the solid form and is slowly leaching from trenches. The dominance of the hydrogeologic system by shallow flow restricts inorganic and radionuclide contamination to short flow paths in the shallow groundwater interval, whereas the density-driven flow of DNAPL provides a mechanism for organic contamination to enter the shallow, intermediate, and deep bedrock intervals (Fig. ES.5).

Oils and solvents were disposed of in the BG-A area by pouring the liquids into standpipes in debris- and waste-filled trenches. The bulk of these liquids migrated laterally to surface water and downward to groundwater, ultimately reaching depths of up to 180 m (600 ft) as DNAPL. Free-phase liquids occur in bedrock and probably remain in the trenches as residual droplets that have adhered to waste materials and minerals. Dissolved VOCs in the BG-A and NT-8 plumes have undergone limited chemical or biological degradation. A plume of dissolved PCE is migrating along strike in the Nolichucky Shale to the west of BG-A South. Fate and transport modeling suggests that a PCE plume may take a few hundred years to migrate along strike as far as NT-8.

Maynardville Limestone and Bear Creek Functional Area

The Maynardville Limestone and Bear Creek FA includes (1) soils and sediments in the Bear Creek floodplain, (2) groundwater in the Maynardville Limestone, and (3) surface water in the main stem of Bear Creek and in floodplain springs.

Sources and contaminants. The environmental media in this FA represent the downgradient pathways and receptors of contaminants migrating away from the sources on the Nolichucky Shale. The primary sources of contaminant input to Bear Creek and the Maynardville Limestone from the source sites are:

- S-3 Site: nitrate, radionuclides, and high TDS via discharge from NT-1 and NT-2, shallow groundwater discharges to Bear Creek, and shallow groundwater discharges directly to the Maynardville Limestone.
- BYBY: uranium via discharge from NT-3 and direct runoff to the Floodplain, and uranium and VOCs by shallow groundwater discharge into the Maynardville Limestone.
- SL 1: VOCs via shallow groundwater discharge into the Maynardville Limestone.
- BCBG: VOCs and uranium via discharge from NT-7 and NT-8.
- Past releases of TCE and 1,2-DCE from an unknown site east of BYBY FA or Rust Spoil Area.

- Past releases of TCE and 1,2-DCE from the Fire Training area in the neighboring Upper East Fork Poplar Creek (Fig. ES.1) hydrogeologic regime that may have migrated in karst in the Maynardville Limestone into the Bear Creek hydrogeologic regime at Spoil Area 1.

In addition, the Creekside Debris Burial area and the Bear Creek Road Debris Burial area are two waste areas, first identified during field operations for the BCV RI, with soil contamination on the Floodplain. These sites do not currently contribute to groundwater contamination but may have done so in the past. Primary contaminants in the Maynardville Limestone and Bear Creek FA are:

- nitrate, boron, uranium, strontium, barium, PCE, TCE, 1,2-DCE, and ^{99}Tc in groundwater; concentrations of these contaminants exceed ARARs for drinking water at many locations in the valley upgradient of BCK 9.47;
- barium, cadmium, manganese, uranium, boron, strontium, TCE, 1,2-DCE, and ^{99}Tc in springs and surface water upstream of BCK 9.47;
- nitrate, boron, strontium, and uranium in surface water downstream of BCK 9.47; and
- cadmium, uranium, and PCBs in Floodplain soils and sediments at a few locations [in general, contaminant concentrations are higher in sediments than in soils, and the highest concentrations in soils occur in the top 10 cm (4 in.) of soil].

Nitrate, uranium, and ^{99}Tc contamination occurs close to the S-3 Site and continues west as far as BCK 9.47 and Picket A. Nitrate contamination in groundwater occurs 2590 m (8500 ft) west of Picket A in Picket W, but uranium and ^{99}Tc have not reached this far west. TCE- and 1,2-DCE contaminated groundwater occurs in groundwater wells at the Spoil Area 1 and Rust Spoil Area. Concentrations of TCE and 1,2-DCE in groundwater increase downgradient of Rust Spoil Area at Picket C and adjacent to BYBY. The furthest west that TCE is detected in groundwater is in Picket B; however, discharge to SS-5 is contaminated with trace concentrations of TCE, which may indicate the presence of the leading edge of the TCE plume at Picket A.

Maynardville Limestone conceptual model. At monitoring points downgradient of BYBY (groundwater and surface water), the plumes from the S-3 Site and BYBY source areas are completely commingled (Fig. ES.5). It is only possible to identify BYBY as a contributor to the inorganic and organic Maynardville Limestone contaminant plumes because of the relative concentrations of contaminants in groundwater, surface water, and springs. Progressive changes in relative concentrations of contaminants in groundwater along the valley reflect the inputs to the Bear Creek/Maynardville Limestone system and suggest that after entering Bear Creek contaminants can migrate downward into the Maynardville Limestone (Fig. ES.5).

Surface water in Bear Creek and shallow groundwater in the Maynardville Limestone are closely interrelated and constitute 96% of water flowing along the valley. Contaminants in these media pathways are quickly diluted by rapid recharge of rainwater and inputs from noncontaminated tributaries. Concentrations of contaminants in the intermediate and deep groundwater pathways [30 to 90 m (100 to 300 ft) depth] are not attenuated as rapidly as those in shallow groundwater because this interval is somewhat isolated from inputs from recharge and tributaries. Plumes of groundwater contaminated above maximum contaminant levels in the 30 to 90 m (100 to 300 ft) depth interval are more continuous and extend further along the valley.

Groundwater contamination at Picket W is attributed both to diffuse contamination as a result of infiltration of contaminated surface water in Bear Creek and along strike migration of contaminated groundwater in intermediate and deep groundwater.

ES.4 CONTAMINANT FATE AND TRANSPORT PATHWAYS

The principal contaminant sources in BCV are located on the outcrop of the Nolichucky Shale (S-3 Site, BYBY, and BCBG), a carbonate-rich fractured shale with low permeability. Solid and liquid waste disposals have caused shallow groundwater contamination. Leaching of solid materials, particularly uranium, is a current source of shallow groundwater contamination. Where dense liquids were disposed of at the S-3 Site and BCBG, contamination of deep groundwater in the Nolichucky Shale has occurred. Contaminants migrate away from the waste disposal units using the following pathways (Fig. ES.5):

- Contaminated shallow groundwater at sources on the Nolichucky Shale migrates through fractures along geological strike and discharges to tributaries or directly to Bear Creek causing the tributaries and Bear Creek to become contaminated.
- Contaminants in deep groundwater in the Nolichucky Shale also migrate through fractures along strike and discharge to tributaries. However, contaminant pathways in the deep groundwater can underflow proximal tributaries and/or springs and be a source of contamination in neighboring tributary subwatersheds.
- After entering tributaries, contaminants migrate in surface water directly to Bear Creek. Bear Creek intermittently loses and gains water from groundwater in the Maynardville Limestone throughout the length of the valley. Losing reaches of Bear Creek cause groundwater contamination in the Maynardville Limestone. Gaining reaches of Bear Creek are associated with large springs at the base of Chestnut Ridge, some of which have contaminated discharge (SS-1, -4, -5, and -6).
- Surface water in Bear Creek and shallow groundwater in the Maynardville Limestone constitute 96% of water flowing along the valley. Contaminants in these media pathways are quickly diluted by rapid recharge of rainwater and inputs from noncontaminated tributaries.
- Deep groundwater in the Maynardville Limestone [30 to 90 m (100 to 300 ft) depth] constitutes <4% of water flowing along the valley. Concentrations of contaminants in this and in the deep groundwater pathway are not attenuated as rapidly as those in shallow groundwater; this pathway is an important source of long distance groundwater transport along the valley.
- Contaminant concentrations in shallow groundwater in the Nolichucky Shale and the Maynardville Limestone and in surface water are diluted by recharge during storm events and show seasonal trends of lower concentrations during periods of high rainfall.

Contaminants migrating from the waste sites in BCV converge at BCK 9.47/SS-5 — more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater.

ES.4.1 Integrator Point/Plane Assessment

To determine the contribution of each FA to the valley-wide contaminant flux migrating off site from the BCVA, an IP assessment was completed at BCK 9.47/SS-5. Using a mass balance calculation, 69% of uranium measured at BCK 9.47 and SS-5 was measured at monitoring stations in tributaries to Bear Creek (gauged flux on Fig. ES.3). The remaining 31% was not measured in the RI (engaged flux) but is expected to be derived from migration of uranium directly to Bear Creek and the Maynardville Limestone via shallow groundwater at the BYBY and S-3 Site sources.

Assuming a similar distribution of the engaged flux as the gauged flux, then ~ 61% of the uranium found in surface water and groundwater at the IP is derived from BYBY. The S-3 Site is the second major contributor of uranium (26%), and this site contributes approximately 94% of the nitrate contamination at the IP. At the IP, 13% of the uranium is derived from BCBG. VOCs at the IP are mainly derived from BCBG; however, most VOCs (82%) discharged to surface water at source areas volatilize before reaching BCK 9.47. Boron was not measured in tributaries in the RI but is probably mostly derived from the BCBG where it was reported to be a contaminant in waste liquids that accompanied uranium tailings disposal and is found in the current leachate at BCBG.

Using these flux data, the portion of the total risk to human health and total hazard at the IP contributed by each waste site was calculated (Fig. ES.6). BYBY contributes most to the human health risk to the IP (38.5%), followed by BCBG (23.0%), and the S-3 Site (17.4%). Engaged uranium fluxes contribute 20.7% of risk at the IP. As discussed above, most of the engaged uranium flux originates in the BYBY (assumed 70%) and the S-3 Site (assumed 30%).

ES.4.2 Anticipated Future Changes

In the absence of remedial action and assuming maintenance of the current leachate collection system at BCBG, contaminant concentrations in most pathways are expected to remain at concentrations similar to those currently observed with four exceptions. These exceptions are:

- Concentrations of uranium and some metals in groundwater discharged to NT-1 are expected to increase in the foreseeable future (100 to 200 years). Concentrations of VOCs and nitrate may have peaked in this pathway but are expected to remain close to current levels for the next 100 years.
- Concentrations of nitrate, uranium, and some metals in groundwater discharged to NT-2 are expected to increase in the foreseeable future (100 to 1000 years).
- Along strike migration in the Nolichucky Shale of a plume of PCE-contaminated groundwater at BCBG may result in discharge of contaminated groundwater to NT-8 in the next 100 years. However, it is anticipated that volatilization of most of the VOCs in surface water, as is observed today, will lessen the impact of this discharge.
- Along strike migration in the Maynardville Limestone of a plume of TCE- and 1,2-DCE-contaminated groundwater at BCBG may result in discharge of increasingly contaminated groundwater at SS-5 and BCK 9.47 for the next 500 years. In addition, migration of this plume to BCK 9.47/SS-5 may result in unacceptable risk from use of groundwater at these locations and cause additional groundwater ARARs to be exceeded in the future.

Figure ES.6. Relative contributions from source areas to potential risks and hazards at the IP.

In the absence of remedial actions, the resulting effect of these changes on contaminant fluxes will be to increase the fluxes of uranium, nitrate, some metals, and VOCs at the IP during the foreseeable future. The leading edge of the nitrate plume in BCV has reached Picket W wells ~ 2.3 km west of BCK 9.47 (Fig ES.1). Increased fluxes of contaminants at the IP will most likely result in extension of the plumes of contaminated groundwater west of BCK 9.47 and increased concentrations of contaminants at Picket W.

ES.5 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARARs and to-be-considered guidance that may be applicable to BCV have been identified so that remedial actions planned for BCV can be fully protective of human health and the environment. Chemical-specific guidance for the BCV include:

- Environmental Protection Agency's (EPA's) insufficient yield criterion for groundwater classification;
- Safe Drinking Water Act maximum contaminant levels;
- National Secondary Drinking Water Standards secondary maximum contaminant levels;
- EPA rule for natural attenuation of contaminants in groundwater in cases where active remediation is not appropriate; and
- Tennessee Department of Environment and Conservation ambient water quality criteria.

Chemical-specific ARARs for soils and sediments and location- and action-specific ARARs applicable to sensitive resources are usually invoked during remedial action. Thus, these ARARs will be analyzed and discussed as remedial alternatives are screened in the BCV FS.

ES.6 BASELINE RISK ASSESSMENT

ES.6.1 Baseline Human Health Risk Assessment

Conclusions on potential human health risks in BCV are based on four hypothetical land uses for which risks to human health were calculated; these are current hypothetical "unprotected" site maintenance workers at the source areas, future industrial workers, future recreational receptors downstream of BCK 9.47, and future residential receptors (Figs. ES.7 and ES.8).

At BCBG, S-3 Site, and OLF, there is an important distinction between contamination due to buried waste materials and soil contamination resulting from mobilization of contaminants in wastes (secondary contamination). In general, although secondary contamination is present in soils immediately surrounding the wastes, the concentrations of contaminants in these soils are lower and pose potential risks that are orders of magnitude less than those from the neighboring waste materials. Soils surrounding waste units generally pose risks to potential future residents but little risks to potential future industrial or unprotected maintenance workers; whereas exposure to contaminants in wastes poses high risks for potential future residents and future industrial workers. With the exception of BYBY and BG-D, -E, and -J, waste materials are buried and covered with multilayer RCRA caps; therefore, the scenario for exposure of future residents and industrial workers assumes degradation of these caps and eventual uncovering of the wastes.

Figure ES.7. Distribution of risks posed to potential future residents and recreational users in Bear Creek Valley.

Figure ES.8. Distribution of risks posed to potential future industrial workers and unprotected maintenance workers in Bear Creek Valley.

Current “unprotected” maintenance worker. Risks from exposures to an unprotected maintenance worker (rather than a worker having the level of protection currently required for access at BCV sites) were evaluated to provide a conservative estimate of current risk. Assuming that existing caps at the waste areas are maintained, the only risks exceeding 10^{-4} identified for an unprotected maintenance worker at any of the BCV sites are through exposure to three chemicals of concern (COCs) (^{234}U , ^{235}U , and ^{238}U) found in hot spot soils, where waste material was exposed at the surface, at BYBY, and at BCBG (Fig. ES.8).

Future industrial worker. Risks/hazards to a future industrial worker can occur from exposure to 33 COCs:

- buried and capped wastes at the S-3 Site contain 12 COCs (beryllium, PCB-1248, and radionuclides);
- soils adjacent to the OLF cap contain 4 COCs (arsenic and radionuclides);
- soils at BYBY contain 12 COCs (metals, PAHs, and radionuclides);
- soils adjacent to caps, hot spot soils near BG-D East, and buried wastes at BCBG contain 12 COCs (metals, PCBs, VOCs, and radionuclides); and
- inventoried soils at the Disposal Area Remedial Action (DARA) Solids Storage Unit and the OLF Storage Pad contain 6 COCs (dioxins, PCB-1254, and uranium isotopes) and 4 COCs (beryllium, PCBs, and uranium isotopes), respectively.

Future recreational receptor. Risks to a future recreational user of BCV were evaluated for the BCV Floodplain, starting just west of the BCBG (BCK 9.47) and ending near Highway 95. Only one pathway was estimated to pose potential risks under this scenario: ingestion of fish that have bioaccumulated mercury (i.e., methylmercury) and PCBs (Fig. ES.7). However, there is uncertainty whether the fish analyzed in the assessment were exposed to contamination only from Bear Creek. No COCs associated with exposure to surface water, floodplain soils, and sediments were identified.

Future resident. Although a residential exposure scenario at the source areas is unlikely, it was evaluated to obtain a reasonable maximum exposure estimate of the risk to future human receptors in BCV.

West of BCK 9.47 and Picket A, total pathway risks from aggregated data do not exceed 10^{-4} (Fig. ES.7). Two individual locations have COCs associated with them. These are:

- 1 COC, PCB-1254, in soils at SP04 near Highway 95 in the BCV Floodplain;
- 4 COCs, arsenic, chromium, manganese, and PCB-1254 in sediments in Bear Creek near NT-9 and NT-11; and
- 2 COCs, boron and strontium, considered as naturally occurring and not related to activities in BCV, were identified for well GW-711 at Picket W.

In addition, low activities (< 7 pCi/L) of radium, ^{137}Cs , and ^{228}Th in groundwater at Picket W and arsenic, ^{137}Cs , and ^{238}U in surface water in Bear Creek downstream of BCK 9.47 pose risk between 10^{-6} and 10^{-4} . However, there is a high degree of uncertainty associated with these radiological data, and the lack of other radionuclides usually associated with contamination in BCV (e.g., U and ^{99}Tc) in these wells makes their occurrence at Picket W suspect.

At the IP, total pathway risks are between 10^{-4} and 10^{-6} . Specific risks and hazards are as follows:

- Ingestion of isotopic uranium in groundwater in GW-684 poses a risk between 10^{-6} and 10^{-4} to future residents. Nitrate and uranium in groundwater in this well also result in a potential HI = 1 for future residents.
- Ingestion of PCE, TCE, ^{99}Tc , ^{137}Cs , ^{237}Np , and isotopic uranium in surface water poses a potential risk between 10^{-6} and 10^{-4} to future residents. Ingestion of uranium in surface water at the IP also results in an HI > 1 for future residents with boron, fluoride, and nitrate also contributing to the hazard.
- Soils at transect TS4, located at the confluence of NT-8 and Bear Creek (Fig. ES.1), pose a potential risk > 10^{-4} to future residents via incidental ingestion or external exposure from beryllium, PCB-1260, or isotopic uranium.

East of BCK 9.47, risks and hazards posed to potential future residents are numerous, and at nearly all locations cumulative pathway risks exceed 10^{-4} and/or HIs exceed 1 via exposure to waste, soil, groundwater, or surface water (Fig. ES.7). Potential risks/hazards to future residents can occur from exposure to 94 COCs:

- at the S-3 Site FA: 34 COCs in groundwater, 13 COCs in surface water, 2 COCs in soils, and 17 COCs in buried/capped waste;
- at the OLF FA: 28 COCs in groundwater and 11 COCs in surface water, 10 COCs in OLF soils, 6 COCs in OLF Storage Pad soils, 12 COCs in SL 1 soils, and 22 COCs in BYBY soils;
- at the BCBG FA: 23 COCs in groundwater, 14 COCs in surface water, 41 COCs in leachate, 11 COCs in soils adjacent to caps and in hot spots, 16 COCs in buried waste, 7 COCs in DARA soils; an
- for the Maynardville Limestone and Bear Creek FA: 13 COCs in Bear Creek Road Debris Burial area, and 16 COCs in Creekside Debris Burial area.

In addition to the risk/hazard associated with exposure to chemicals in BCV, the BCBG site presents potential physical hazards associated with the burial of pyrophoric and explosive agents. An incompatibility study conducted in 1984 concluded that it is reasonable to expect that excavation at BCBG would foster additional reactions through re-exposure to air and unavoidable mixing as wastes are handled.

ES.6.2 Ecological Risk Assessment

Ecological risk was estimated for fish, benthic invertebrate, soil invertebrate, and plant communities and representative organisms of populations of small mammals (mice and shrew), piscivores (mink and kingfisher), large herbivores (deer), and predator/scavengers (hawks and fox). The baseline ecological risk assessment identified significant ecological risks from chemicals in water, sediment, soil, and shallow groundwater for one or more receptors. Metals and PCBs are the primary contaminants of potential ecological concern, and source area and floodplain soils, including transects west of 9.47, contribute to these risks (Fig. ES.9).

In characterizing risk to the assessment endpoints established for the BCV baseline ecological risk assessment (e.g. species richness and abundance), a 20% or greater reduction in one of the

Figure ES.9. Distribution of risks posed to aquatic and terrestrial biota in Bear Creek Valley.

endpoint properties measured in the field or a 20% reduction in survivorship, growth, or reproduction in a toxicity test was considered to be potentially significant. The assessment endpoints and their associated risks for the BCV are:

Reduction in species richness or abundance in fish communities resulting from toxicity. Risks to fish communities were evaluated for Bear Creek, which was divided into four reaches for the baseline ecological risk assessment (Fig. ES.1), and for tributaries NT-2 through NT-8. Both dissolved phase and total concentrations of metals were used in the exposure assessment for fish. The weight of evidence suggests that water from Bear Creek and NT-2 through NT-8 does not pose a significant risk of a 20% reduction in fish species richness or abundance or in the Tennessee dace population due to a toxic effect.

Reduction in species richness or abundance of benthic macroinvertebrate communities resulting from toxicity. Benthic invertebrates exposed primarily to surface water in erosional areas were evaluated separately from those exposed primarily to fine sediments in depositional areas. For benthic invertebrates in erosional areas, the weight of evidence suggests that water in Reaches 1 and 2, NT-2, SS-1, and SS-4 poses a significant risk of a 20% reduction in species richness and abundance due to a toxic effect from high concentrations of calcium, cadmium, manganese, nickel, and uranium. For benthic invertebrates in depositional areas, the weight of evidence suggests that sediment from 3 of 18 sites poses a significant risk due to a toxic effect, probably from manganese and, potentially, selenium and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). However, it is unlikely that the soft-sediment benthic invertebrate community as a whole is reduced by 20% in species richness or abundance.

Reduction in production of soil/litter invertebrates resulting from toxicity. Risk to soil invertebrates was evaluated for four source areas (S-3 Site, BYBY, combined SL 1 and OLF, and BCBG) and for the Bear Creek Floodplain. Risks of a toxic effect to soil invertebrates from mercury and, possibly, chromium, copper, and zinc, are estimated to be significant in the S-3 Site, SL 1/OLF, BYBY, Creekside Debris Burial area, and Bear Creek Road Debris Burial area.

Reduction in production of terrestrial plant communities resulting from toxicity. The plant communities in the BYBY area near HCDA are probably adversely affected by metals in shallow groundwater if they are exposed by root uptake. Soils at isolated locations along two Floodplain transects in Upper Bear Creek (transects TS3 and TS4, Fig. ES.1)) appear to pose a significant risk to plants.

Reduction in abundance or production of terrestrial wildlife populations resulting from toxicity. Risks to wide-ranging species were evaluated for the BCV as a whole. Risks to small mammals, which have more limited spatial requirements, were evaluated within the source areas and for BCV as a whole. Among the wide-ranging species, only fox were estimated to be significantly at risk of a 20% reduction in population production; this risk results from soil contamination by: antimony at BYBY; mercury at S-3 Site, BYBY, OLF, and Floodplain transect TS1; and PCBs in BCBG and Floodplain transects TS4 and TS10. Shrews are estimated to be significantly at risk of a 20% reduction in population production from high soil concentrations of metals at S-3 Site, BYBY, and OLF and PCBs at BCBG. Shrews are also estimated to be at risk from elevated chromium and PCBs in Floodplain soils in transects west of BCK 9.47. There were no risks to shrew, mouse, deer, hawk, and fox from uptake of radionuclides.

Reduction in abundance or production of piscivorous wildlife populations resulting from toxicity. Because piscivorous wildlife are highly mobile, risks to piscivores were evaluated for the BCV as a whole. Kingfishers inhabiting the watershed were estimated to be significantly at risk of a 20% reduction in population production because of mercury in fish.

ES.6.3 Conclusions about Potential Risk

At nearly all locations in BCV east of the IP, potential cumulative pathway risks posed to future residents exceed 10^{-4} and/or HIs exceed 1 via potential exposure to contaminants in waste, soil, groundwater, or surface water (Fig. ES.7). Cumulative pathway potential risks posed to future industrial workers or unprotected maintenance workers vary between 10^{-6} and 10^{-1} via exposure to buried waste and contaminated soil at hot spots (Fig. ES.8). Contamination both at the waste areas and in the floodplain poses risks to wide ranging predatory animals, fish-eating wildlife, small mammals, soil invertebrates, and plant communities (Fig. ES.9). Contaminants in surface water upstream of BCK 9.47 and in sediments in NT-2, NT-6, and reach 4 of Bear Creek pose risks to benthic invertebrates (Fig ES.9). In addition, ARARs are exceeded in groundwater at many locations east of the IP.

At the IP, potential human health risks posed from use of groundwater or surface water exceed 10^{-6} or an HI>1. The COCs at the IP are uranium, nitrate, boron, and fluoride. In addition, ARARs for nitrate, uranium, and VOCs are most likely exceeded in groundwater.

In the portion of the valley west of the IP, environmental media are contaminated as a result of releases from the waste areas east of the IP, but contamination is slight and poses relatively little risk (Figs. ES.7 to ES.8). West of the IP, the most prevalent contaminants in groundwater and surface water are chloride, fluoride, nitrate, boron, strontium, and uranium, but contamination does not exceed ARARs. For a potential future residential receptor, four COCs (As, Cr, Mn, and PCB-1254) were identified in sediments from Bear Creek at two locations, and one COC (PCB-1254) in soils at one location in the Bear Creek floodplain.

ES.7 REMEDIAL GOAL OPTIONS

Media- and chemical-specific RGOs have been developed for each chemical of concern in BCV. RGOs are target cleanup goals to be used in identifying effective remedial technologies. They are not proposed final cleanup levels. RGOs were calculated for the following three criteria:

- Chemicals of concern identified in the baseline human health risk assessment. For these chemicals of concern, RGOs were calculated to be protective of human health at target risk levels of 10^{-4} , 10^{-5} , and 10^{-6} and target HIs of 0.1, 1, and 3.
- Chemicals of concern identified in the baseline ecological risk assessment. For these chemicals of concern, RGOs represent benchmarks, probable effects levels, ambient water quality criteria, and naturally occurring background levels.
- Chemicals of concern identified as chemicals that exceed ARARs. For these COCs, RGOs represent the ARAR.

In addition, results of fate and transport modeling were used to identify chemicals that are likely to exceed ARARS or preliminary remediation goals as a result of leaching from soils to groundwater

or transport to surface water in the future. These chemicals are also considered chemicals of concern, and the RGOs for these chemicals are considered the maximum contaminant level or preliminary remediation goal in the receptor medium.

The ability to meet RGOs for primary risk drivers will be evaluated in the FS. Based on the results of the baseline risk assessments, primary risk drivers include uranium, nitrate, and VOCs in the upper third section of BCV.

ES.8 TECHNICAL CONSIDERATIONS FOR REMEDIAL ACTIONS

Contamination in groundwater and surface water at, and west of, the IP is derived from migration away from the source sites. A remedial strategy with the goal of reducing contaminant fluxes at the IP to acceptable levels will have two general options: (1) take actions at the IP to mitigate exposures downstream, or (2) take actions upstream and east of the IP that will result in achieving the remedial goals at the IP.

Actions taken at the IP would be groundwater and surface water capture/treatment type actions. Actions taken upstream of the IP would involve interception of contaminant pathways to tributaries (i.e., actions taken closer to the sources) that would result in remediation of nitrate and uranium in contaminated surface water in Bear Creek and groundwater in the Maynardville Limestone. These actions may also be groundwater and surface water treatment actions taken closer to the sources, but could also include source isolation/treatment/removal to mitigate three pathways. In addition, a plume of VOC-contaminated water in the Maynardville Limestone that has no apparent source would also need to be addressed.

The following physical, chemical, and hydrological parameters will need to be addressed to achieve the remedial action objectives for BCV.

ES.8.1 Considerations for Remedial Actions for Groundwater and Surface Water at the Sources

- Large volumes of contaminated groundwater exist in the Nolichucky Shale at the contaminant sources ($7.1 \times 10^6 \text{ m}^3$ at the S-3 Site, $0.4 \times 10^6 \text{ m}^3$ at BYBY, and $4.0 \times 10^6 \text{ m}^3$ at BCBG). Due to the fractured nature of the Nolichucky Shale, < 10% of this contaminated volume occurs in fractures that are accessible for withdrawal of water. More than 90% of this volume occurs in the very low permeability matrix and contains the highest concentrations of contaminants. The mechanism for migration of contaminants from the matrix to flowing fractures is by chemical diffusion and is termed matrix diffusion. The result of matrix diffusion is that, if pump and treat technology is used to remediate a plume in fractured bedrock, many times the contaminated volume of water will require pumping before acceptable concentrations can be achieved.
- DNAPL occurs at two locations in the Nolichucky Shale, the S-3 Site and BCBG (Fig. ES.5). The nature of migration of DNAPL in the subsurface means that small droplets of residual DNAPL exist rather than large and identifiable pools of liquids. Thus, identification and extraction of DNAPL is not possible. Dissolution of DNAPL at these sites will, therefore, act as a dispersed source of contamination to groundwater.

- Some of the solid waste at BYBY, BCBG, and most likely at the S-3 Site is inundated by shallow groundwater and will be a continuing source for groundwater contamination unless it is hydraulically isolated from groundwater.
- Contaminated shallow and deep groundwater in the Nolichucky Shale migrates rapidly through discrete fractures or preferential pathways along geological strike to discharge to tributaries or directly to Bear Creek. Most of the groundwater flux most likely flows through a few discrete fracture zones; however, the specific locations and depths of these fracture zones are not known at this time and may be difficult to ascertain.
- Flow in shallow groundwater and tributaries is "flashy." For example, flow in NT-3 varies from extremes of 0 L/s to over 150 L/s (2400 gpm). Average baseflow in NT-3 varies from 0 L/s in summer to almost 10 L/s (160 gpm) during winter months.

ES.8.2 Considerations for Remedial Actions for Groundwater and Surface Water in the Maynardville Limestone

- Water flows through a network of interconnected cavities and fractures up to 150 m (500 ft) deep in the Maynardville Limestone. Most of the groundwater flux most likely flows through a few discrete cavities, however, the flux through these cavities and the specific locations and depths of these cavities are not known at this time and may be difficult to ascertain.
- The total flux of groundwater flow at the IP was calculated as 54,000 m³ during the 10-month monitoring period for the RI (~65,000 m³/a or 52.5 acre ft/a).
- Flow in Bear Creek at BCK 9.47 is flashy and varies from extremes of < 1 L/s (~16 gpm) to over 10,000 L/s (16,000 gpm). Average baseflow varies from < 1 L/s in summer to 100 L/s (1,600 gpm) during winter months. Flow in SS-5 is more steady than in Bear Creek and varies from extremes of < 3 L/s (~48 gpm) to over 100 L/s (1600 gpm). Average baseflow varies from < 3 L/s in summer to 10 L/s (160 gpm) during winter months.
- Concentrations of contaminants in BCK 9.47 and SS-5 are relatively dilute. For example, at BCK 9.47, uranium ranges from 52 to 152 µg/L and nitrate ranges from < 1 mg/L to 46.2 mg/L.

ES.8.3 Considerations for Remedial Actions for Soils at Sources

- Large volumes of buried waste materials exist at the BCBG, some of which are potentially pyrophoric or explosive. In addition, large volumes of waste materials and contaminated fill exist at BYBY, SL 1, and the S-3 Site.
- At some locations in BCBG and BYBY, and probably at the S-3 Site, waste materials are inundated by shallow groundwater.
- At some locations in BYBY and BCBG, waste materials occur at the surface of the soil. These locations constitute the most likely areas where direct exposure to waste could occur with unrestricted use.
- Many of the source areas are covered with RCRA caps that limit the possibility of direct exposure to waste materials under the current land use.

ES.8.4 Consideration for Remedial Actions for Soils/Sediments in the Bear Creek Floodplain

- The sampling strategy for floodplain soils and sediments was, by intention, biased towards likely sediment accumulation areas. The relatively small number of samples for the area of land that constitutes the Bear Creek floodplain means that volumes of contaminated soils are not well defined. The data indicate that contaminant concentrations are low and soil volumes are small (most likely < 1000 m³).

ES.8.5 Relative Importance of Pathways

For actions taken close to the sources, the relative importance of the pathways with regard to the contaminant mass flux is a consideration for which remedial actions will be most effective from a watershed perspective. The following parameters, therefore, also need to be considered:

- Figure ES.3 shows the potential human health risk/hazard from surface water and groundwater at the IP posed by exposure to the individual COCs. Figure ES.3 also lists the relative proportions of the flux of the two principal COCs, nitrate and uranium, derived from sources in BCV. Based on this ranking of source contributions to the total potential risk/hazard at the IP (refer to Sect. 3.2.7 and Appendix E), most of the potential risk/hazard is from uranium migrating from BYBY and the S-3 Site. In addition, most of ungauged flux is most likely from BYBY and the S-3 Site, further increasing the proportion of uranium flux derived from these sites. Nitrate is the second most important COC at the IP and is 94% derived from the S-3 Site.
- Reduction of the contaminant mass flux through shallow groundwater and/or surface water discharge in tributaries at BYBY and S-3 Site will reduce the overall mass flux of uranium and nitrate at the IP and achieve a reduction of potential risks and hazards at this location. For example, a reduction of 70% in the uranium flux from NT-3 and a similar reduction in the ungauged flux derived from this site (assumed to be 70% of the total ungauged flux) would result in a 43% reduction in the total uranium flux at the IP. A reduction of 70% in the contaminant flux from S-3 Site (NT-1 and NT-2) and a similar reduction in the ungauged flux derived from this site (assumed to be 30% of the total ungauged flux) would result in an 18% reduction in the total uranium flux at the IP, and a 66% reduction in the total nitrate flux.
- COCs for ecological receptors in Bear Creek are mainly metals in reaches 1 and 2 that are derived from discharge in NT-1, -2, and -3 (with the exception of mercury for which no sources have been defined in BCV). It can be expected that actions taken to reduce the contaminant flux in any of these pathways will result in a reduction of ecological impacts in Bear Creek east of the IP and reduce impacts to piscivores in all of BCV.

ES.9 DOCUMENT LAYOUT

The BCV RI Report is contained in six volumes. Volume 1, the RI Report, summarizes the extensive data analysis and interpretation that have been completed for the RI. The eight chapters of the Report address (1) the strategy used to satisfy the regulatory requirements in BCV; (2) physical and hydrogeological properties of BCV; (3) results of environmental investigations conducted to determine the nature, extent, fate, and transportation of contamination; (4) ARARs; (5) results of baseline human health risk assessment; (6) results of baseline ecological risk assessment; (7) RGOs derived from the RI; and (8) conclusions.

The RI Report is supported by seven appendices (A through G), contained in five volumes, that provide detailed analysis and discussion corroborating the information provided and conclusions reached in Volume 1. Volume 2 contains three appendices addressing (A) the operational histories of BCV waste sites and detailed analysis of inventory records of the BCBG; (B) the historical database for BCV and a detailed description of the field activities conducted during 1994 and 1995; and (C) the valley-wide hydrogeological conceptual model for BCV. Volumes 3 through 6, each containing one appendix, address (D) nature and extent of contamination in BCV; (E) fate and transport of contaminants in BCV; (F) baseline human health risk assessment; and (G) baseline ecological risk assessment.

APPENDIX A

WASTE SITES, SOURCE TERMS, AND WASTE INVENTORY

Appendix A provides detailed information about waste disposal areas encompassed by the Bear Creek Valley (BCV) Characterization Area (CA) Remedial Investigation (RI). This information includes descriptions of waste areas and estimates of the current compositions of the wastes (source terms). These descriptions of the waste areas include the types of wastes disposed of, disposal methods used, timing of disposals, and treatment or clean-up activities that have been completed. Estimates of source terms were calculated in one of two ways: (1) from inventory of waste types and volumes or (2) from historical analytical data for the waste material.

BCV contains the watersheds of three creeks: Bear Creek, Grassy Creek, and Upper East Fork Poplar Creek. The BCV RI focuses primarily on the watershed of Bear Creek and, to a lesser extent, that of Grassy Creek. The Upper East Fork Poplar Creek watershed is covered in a separate RI report.

This appendix, like the overall BCV RI Report, presents a nonclassified analysis of data in the BCV. Where possible, declassified summaries of classified material were prepared and included in the appendix. Materials that could not be declassified are available for review by appropriately cleared individuals and have been included in an on-site record; they are not included in the off-site record.

A.1 SITE DESCRIPTION

BCV encompasses the Oak Ridge Y-12 Plant and its supporting facilities. The main facilities of the Y-12 Plant lie on the valley floor, primarily within the Upper East Fork Poplar Creek watershed (Fig. A.1). Auxiliary facilities, including several waste disposal areas, are located along Chestnut Ridge and in the Bear Creek watershed. The primary waste disposal areas included in the BCV CA and described in this report (Fig. A.2) are:

- S-3 Site,
- Oil Landfarm (OLF),
- Boneyard/Burnyard (BYBY) [including the Hazardous Chemical Disposal Area (HCDA)],
- Sanitary Landfill 1 (SL 1), and
- Bear Creek Burial Grounds (BCBG).

These five waste areas were known sources of contamination in BCV. Many smaller sites in BCV, listed in Table A.1 and identified on Fig. A.2, are known waste disposal or storage sites and may also be source areas.

A.1.1 GEOGRAPHICAL INFORMATION

About 18 km (11 miles) long, BCV trends E-W along the center of the Oak Ridge Reservation (ORR). As shown in Fig. A.1, the valley's west end is bounded by the Clinch River at the Grassy Creek Embayment on Watts Bar Lake, and its east end becomes Union Valley at Scarboro Road. BCV is bounded to the north by Pine Ridge and on the south by Chestnut Ridge.

As shown in Fig. A.3, Bear Creek originates in the southeast corner of the former S-3 Ponds (S-3 Site) near the western margin of the Y-12 Plant (Plates A.1 and A.2). The creek flows west

for about 8 km (5 miles), turns north through a water gap in Pine Ridge, and flows for 4.5 km (3 miles) to its confluence with Lower East Fork Poplar Creek.

A.1.2 BACKGROUND INFORMATION

The Oak Ridge Y-12 Plant was built by the U.S. Army Corps of Engineers in 1943 as part of the Manhattan Project. The original mission of the Plant was to separate the fissionable isotope of uranium (^{235}U) using an electromagnetic separation process. After World War II, this process was discontinued in favor of a more economical gaseous diffusion process conducted at the nearby Oak Ridge K-25 Site (Welch 1989).

Since its inception, the Y-12 Plant has developed into a sophisticated manufacturing and developmental engineering facility. Its mission is to serve as a key manufacturing technology center for developing and demonstrating unique materials, components, and services important to the Department of Energy (DOE) and the nation. Activities have included the reclamation and storage of nuclear materials, manufacture of nuclear materials, manufacture of components for the nation's defense capabilities, support to national security programs, and services provided to other customers as approved by DOE.

A.1.3 OPERATIONAL INFORMATION AND DESCRIPTION OF WASTE AREAS

The S-3 Ponds, BYBY, OLF, SL 1, and BCBG are the primary contaminant sources in BCV (Fig. A.2). Smaller sites in the Bear Creek watershed, identified as solid waste management units or listed in the Federal Facilities Agreement, are listed in Table A.1 along with a brief description of their status.

The following subsections describe the wastes managed in the five primary contaminant sources as well as information about their generation, disposal methods, and any subsequent treatment or clean-up activities that have been conducted. Where records are available, estimates of the current conditions in the source areas are included. These source data were used as input to the fate and transport modeling (Appendix E) and risk assessment (Appendix F) portions of the RI.

A.1.3.1 S-3 Ponds

Introduction

The S-3 Ponds source area consists of four unlined ponds formerly used for industrial waste treatment, which were neutralized, drained, filled, and capped during Resource Conservation and Recovery Act (RCRA) closure in 1988. Operations at the former S-3 Ponds are documented in the RCRA closure reports for the facility, with the primary source being the *RCRA Post Closure Permit Application for the Bear Creek Valley Hydrogeologic Regime at the Y-12 Plant* (Energy Systems 1992a).

S-3 Ponds Operational History

The S-3 Ponds, which were formerly a part of the S-3 Waste Management Area, are located adjacent to the west end of the Y-12 Plant (Fig. A.3). Activities at the S-3 Ponds are listed

chronologically in Table A.2. Constructed in 1951, the four unlined impoundments covered an area of $\sim 120 \times 120$ m (400×400 ft) (Plate A.3). The original pond excavations penetrated residual soil and fill materials but are assumed, based on the depth of bedrock in wells surrounding the site, not to have extended down to the bedrock. Each pond was ~ 5 m (17 ft) deep and, while in operation, each pond had a storage capacity of 9.5 million L (2.5 million gal).

Three different types of wastes are known to have been disposed of in the S-3 Ponds: (1) liquid wastes generated by Y-12 Plant operations and other facilities; (2) sludges generated from the in situ neutralization and bionitrification of the pond waters and sludges generated from the treatment of acid raffinate; and (3) contaminated sediments from two lagoons (known as the "Blue Lagoons") in Upper Bear Creek. Waste products were discharged into the ponds from tank trucks, small containers, and an underground nitric acid pipeline, which was abandoned and plugged in 1983. The liquid wastes generated by the Y-12 Plant consisted primarily of nitric acid, nitrate waste, pickling and plating wastes, and miscellaneous liquid wastes associated with routine clean-up operations (e.g., mop water). Other wastes included dilute acid, machine coolants, caustic solutions, and acids with a pH of <2.0 . During the mid-1950s, uranyl nitrate solutions containing small amounts of plutonium were discharged into the ponds. In the 1970s, aerosol cans (very small paint cans such as used for touch-up work) were placed in the northeast pond, and some small amounts (probably $<10\%$) were put in the southeast pond.

From 1951 to 1976, the ponds received liquid wastes from the uranium operations at the Y-12 Plant. Wastes from areas in the plant handling enriched uranium constituted the largest volumes [about 7.6 million L (2 million gal) of liquid per year]. These liquids were sent to the ponds through the pipeline in small batches [about 760 L (200 gal)]. Of the total waste stream, about 5.7 million L (1.5 million gal) per year were called "condensate" and were 0.1 to 4.0% nitric acid aqueous solutions. The other stream [about 1.9 million L (0.5 million gal) per year] was "raffinate" and was a mixture of about 20% aluminum nitrite in 1 to 4% nitric acid aqueous solutions.

During the 1950s to 1970s, the uranium assay in the ponds was monitored carefully. Depleted uranium nitrate solution (30% uranium nitrate aqueous) was pumped through the pipeline to the ponds to maintain an assay of $<0.7\%$ ^{235}U . The ponds generally had an assay of $<0.4\%$ ^{235}U . The volume of this stream was usually 1900 to 3800 L (500 to 1000 gal) per year and was generated from spent pickle baths used for cleaning depleted uranium metal. The acid cleaning bath also was occasionally used for cleaning copper metal, but this was not a common practice.

In 1976, a recycle and nitrate recovery system was developed and installed for the condensate and raffinate streams. The amounts of nitrate that were being released to the ponds from the plant decreased significantly, but the volumes of waste liquids going to the ponds remained approximately the same. However the amounts of depleted uranium being released did not decrease.

During the late 1970s, mop waters (soap and water) that had previously been discharged in BCBG were diverted to the S-3 Ponds. This waste stream reportedly did not contain any uranium. In the late 1970s and early 1980s, the ponds received sludge from the scrubbing of waste fluoride gas from the K-25 Site. The sludge was a mixture of potassium carbonate, potassium hydroxide, and potassium fluoride with a small amount of ^{99}Tc . The sludge contained about 40% solids and 60% water. Liquid waste discharges into the ponds were terminated in March 1984.

While in operation, the now-abandoned nitric acid pipeline also transported liquid wastes originating from sources outside of Oak Ridge Y-12 Plant, including raffinate from DOE's Savannah River Site and Idaho National Engineering Laboratory. The wastes from these facilities contained, at a minimum, the following radionuclides: ^{137}Cs , ^{57}Co , ^{60}Co , californium, americium, iodine isotopes, ^{237}Np , ^{95}Nb , nickel isotopes, ^{238}Pu , ^{239}Pu , ^{106}Ru , ^{90}Sr , ^{228}Th , ^{230}Th , ^{232}Th , ^{234}Th , ^{99}Tc , ^{95}Zr , and uranium daughters. These radionuclides were present in the waste streams in the parts per billion (ppb) range and possibly the low parts per million (ppm) range. The ponds also received liquid waste from the K-25 Site and Oak Ridge National Laboratory in Oak Ridge, but these were transported by truck in small batches (usually in 55-gal drums).

Several studies of water and sludges in the S-3 Ponds (Jeter 1983; Kimbrough and Turner 1987) concluded that, although the pond water chemistry varied from pond to pond and from year to year, it generally remained highly acidic. Nitric acid was the primary acid constituent. Major metallic ion constituents were calcium, magnesium, potassium, aluminum; moderately high concentrations of other trace metals were present. The few organic analyses available for the pond waters indicate that concentrations of organics could have been highly variable over the period of operation.

S-3 Ponds Treatment and Closure

In situ treatment of wastewater in the S-3 Ponds consisted of (1) neutralization in all four ponds between May and November 1983 and (2) in situ biodenitrification processes from May 1983 to September 1984 (Fig. A.3). This biodenitrification treatment decreased nitrate levels in the pond water to <50 ppm. Nutrients continued to be added to the ponds to maintain the bioreaction, and the sludge was agitated to denitrify residuals.

After denitrification, the contents of the ponds were allowed to settle and form a sludge layer ranging from 0.6 to 1.5 m (2 to 5 ft) thick. Supernatant liquids were pumped to the S-3 Ponds Treatment Facility (Fig. A.2) for removal of trace metals and organics. Treated effluent was discharged to East Fork Poplar Creek in accordance with a National Pollutant Discharge Elimination System permit. The supernatant treatment began in 1985 and was completed by the spring of 1986.

Immediately before structural stabilization and filling of the S-3 Ponds (Plate A.4) in preparation for facility closure in 1988 (Energy Systems 1988a), sediment that had accumulated in the two Blue Lagoons in Upper Bear Creek was placed in the southwest cell of the S-3 Ponds. Turner and Kamp (1984) characterized this material in place before removal from the lagoons, and each truckload of sediment was sampled and analyzed before it was placed in the ponds (McMahon 1988). The data from the 1988 sampling and characterization have been tabulated in Appendix A of the BCV OU 1 RI Work Plan (DOE 1994a) and are summarized in Table A.3 with the estimated current composition of materials located in the former ponds.

It should be noted that when the given thorium activities for the S-3 Ponds and the uranium activities were "back calculated" (using the isotopes' specific activities) to concentrations (mg/kg), the calculated values do not match the concentrations shown for total thorium and total uranium under the inventory's metals listing. For example, the measured S-3 Ponds ^{232}Th activity alone represents 818.7 mg/kg ^{232}Th . Yet the total thorium metal concentration for the S-3 Ponds was measured at 204 mg/kg. This apparent mismatch is probably due to the use of different analytical methods to measure total metals and isotopic activities. To address these data gaps in a manner most protective of human health, it was decided to calculate activities for three thorium isotopes

(^{228}Th , ^{230}Th , and ^{232}Th) for the Blue Lagoon assuming the same measured isotopic distribution as shown for the S-3 Ponds and by using the Blue Lagoon measured exposure concentration of 10.1 mg/kg. Similarly, the activities for four uranium isotopes (^{234}U , ^{235}U , ^{236}U , and ^{237}U) were calculated for the S-3 Ponds by assuming the same measured isotopic distribution as shown for the Blue Lagoon and by using the S-3 Ponds measured exposure concentration of 1020 mg/kg.

The S-3 Ponds Hazardous Waste Disposal Unit (HWDU) was granted interim status under TN Rule 1200-1-11-.07(3) in December 1984 and is, therefore, subject to the groundwater monitoring requirements described in TN Rule 1200-1-11-.05. Before this date, groundwater monitoring at the S-3 Ponds was conducted in accordance with two DOE monitoring programs: historical and characterization monitoring. Characterization monitoring was conducted at the S-3 Ponds from 1983 to 1986 in response to the Memorandum of Understanding (MOU) signed by DOE, the Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation (TDEC). The historical program was initiated in 1975 to monitor groundwater quality in and around waste disposal sites in the BCBG. The program was expanded in the early 1980s to include other sites, including the S-3 Ponds.

Continued investigations were performed between 1986 and 1989 to support RCRA groundwater monitoring requirements. Groundwater quality assessment monitoring was performed in lieu of RCRA detection monitoring in accordance with a formal Groundwater Quality Assessment Plan issued in 1987 (Geraghty and Miller 1987).

The 1988 RCRA closure of the S-3 Ponds Site included installing a multilayered cap and covering the site with asphalt to create a parking lot. TDEC granted final closure certification of the S-3 Ponds in November 1990 and issued a RCRA postclosure permit for the S-3 Ponds HWDU on September 30, 1991 (Energy Systems 1992b). The permit was appealed by DOE and Martin Marietta Energy Systems, Inc. (Energy Systems) on October 30, 1991. A revised application was submitted to TDEC in November 1992 (Energy Systems 1992b). The 1992 version satisfied the appeal, and in April 1993 a "consent order" related to the RCRA postclosure permit for the S-3 Site was signed by TDEC, DOE, and Energy Systems. With the consent order, the parties agreed to proceed with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as the lead regulatory program and RCRA as an applicable or relevant and appropriate requirement. The consent order was further used as a model for all remaining postclosure permits.

A.1.3.2 Oil Landfarm

Introduction

The OLF source area consists of a former landfarming plot that was used for the biological degradation of industrial waste oil and machine coolants. It was closed as a landfill with a multilayered engineered cap in 1990. Operations at the OLF are documented in the RCRA closure reports for the facility, with the primary source being the *RCRA Postclosure Permit Application for the Bear Creek Valley Hydrogeologic Regime at the Y-12 Plant* (Energy Systems 1992a). Primary sources concerning sampling and analysis of soils at the OLF are Herbes (1989) for characterization of soils before excavation and closure and Bohrman (1989) for characterization of soils after excavation.

OLF Operational History

The OLF is located ~2.4 km (1.5 miles) west of the Y-12 Plant and north of SL 1 and Bear Creek Road (Plate A.5). Activities at the site are listed chronologically in Table A.4. Between 1973 and 1982 the facility was used for biological degradation of waste oil and machine coolants through landfarming, a process involving the application of waste oils and coolants to nutrient-adjusted soil during the dry months of the year (April to October). After application, the plots were cultivated frequently to maintain aerobic conditions to enhance biodegradation of the wastes. During its 9 years of operation, the OLF received ~3.8 million L (1 million gal) of liquid wastes (Turner et al. 1991), including:

- waste oils,
- coolants,
- mop waters,
- tanker oils from the K-25 Site,
- wastes from cooling towers,
- oils from the Oil Retention Ponds (ORPs) in BCBG, and
- unidentified miscellaneous liquid wastes.

The oils and coolants disposed of at the OLF are known to have been contaminated with beryllium compounds, depleted uranium, polychlorinated biphenyls (PCBs), tetrachloroethene, and 1,1,1-trichloroethane.

The composition and volume of liquid waste applied to the OLF varied from plot to plot (BNI 1983). For example, beryllium-contaminated oil, tanker oils, and coolants were applied to Plots ½ through 15/16 (Fig. A.4) as follows:

• Beryllium-contaminated oils	Plots ½ (50% of total), 7/8 (25%), and 9/10 (25%)
• Tanker oils	Plots 3/4 and 5/6 (with lighter applications to other plots)
• Coolants	Plots 3/4, 5/6, 11/12, 13/14, and 15/16 (with lighter applications to other plots)

In general, the east plots received greater volumes of total liquid waste than the west plots, which in turn received greater volumes than the north plots.

Tables A.5 and A.6 summarize the types and amounts of waste oils and waste coolants disposed of in the plots during the operating period (Union Carbide 1984). Although waste oils typically consisted of crankcase, hydraulic, gear, vacuum pump, mineral, and machine coolant oils, the oils disposed of during 1974 and 1975 included ~57,000 L (15,000 gal) of oil skimmed from the surface of ORP-1, located in the BCBG (see Sect. A.1.3.5). The machine coolants included nonsoluble oils and water-soluble mixtures consisting of ~5% oil and 95% water.

The typical composition of waste oils and coolants disposed of in the OLF plots is considered representative of that of the waste oils and coolants generated at the Y-12 Plant, which is summarized in Appendix A of the BCV OU 1 RI Work Plan (DOE 1994a). The waste oils contained uranium concentrations ranging from ~20 to 80 ppm as well as elevated concentrations of calcium, iron, sodium, silicon, phosphorous, chlorine, zinc, and lead. The coolants show a similar composition, except that barium concentration in the coolants are 10 to 50 times higher

than those in the oils. Waste disposed of during 1980 also included 3800 L (1000 gal) of dye penetrant, which could act as a potential artifact in future dye-tracer studies.

Before 1979, waste oils and coolants were not specifically analyzed for contaminants before they were applied to the OLF. However, analytical results for samples of oil collected from the surface of one ORP in the BCBG and applied to the OLF in 1979 indicated the presence of PCBs. Thereafter, oils were analyzed for uranium, beryllium, thorium, and PCBs before being applied to the OLF. The Y-12 Plant established a maximum permissible concentration level of 5 mg/L PCBs in waste oils to be landfarmed. Oils containing >5 mg/L of PCBs were shipped for commercial disposal if uranium concentrations were less than permissible limits established for such disposal. If uranium concentrations were greater than the established permissible limits, waste oils containing >5 mg/L of PCBs were placed in storage for future incineration at the K-25 Site Toxic Substances Control Act Incinerator.

In December 1981, the analyses of wastes to be landfarmed were expanded to include chlorinated hydrocarbons. A maximum permissible concentration of 3% was established for chlorinated solvents in the waste oils. Since 1981, sampling and analysis of waste oils for chlorinated solvents have shown that landfarmed waste oils have contained concentrations of <3% chlorinated hydrocarbons.

OLF Treatment and Closure

In 1984, TDEC issued an order requiring DOE to permit or close the OLF site under RCRA, although the actual "closure" wasn't initiated until ~1988. In March 1994, DOE resubmitted the postclosure permit application with a modification to add the OLF to the BCV permit (Energy Systems 1994). Between 1984 and 1988, preparations for closure included extensive soil sampling, involving collection of 200 soil samples in a randomized block design, to delineate the extent of soils contaminated with >25 µg/g PCB (Herbes 1989). PCB concentrations above this action level were identified in several areas of the OLF plots; the highest concentration measured was 60.5 µg/g. Ten depth profiles revealed that the PCB contamination was principally confined to the upper 6 in. of soil, with concentrations declining by more than 90% between the surface (0- to 6-in. interval) and the 12- to 18-in. interval. The highest PCB concentrations were found in the east and west plots (Herbes 1989). Analysis of the same soil samples for uranium showed that uranium concentrations were also highest in the east and west plots and that they declined rapidly with soil depth. The highest mean uranium concentration observed was 204 µg/g (in Plot 7/8). Lowest concentrations were between 13 and 27 µg/g and occurred in the north plot group.

Soils found to be contaminated with >25 µg/g PCB were excavated in 1989, before construction of the OLF cap, and placed on the OLF soils contaminant pad (Fig. A.2), and post-excavation sampling was conducted to confirm that the <25 µg/g standard had been attained (Bohrman 1989). Table A.7 provides a summary of geotechnical and chemical analysis of soils placed on this storage pad, and Table A.8 lists the results of postevacuation confirmatory sampling of soils-in-place at the OLF. Note that although the soils-in-place samples were not analyzed for metals, it is expected that the concentrations of metal contaminants in the in-place samples would be equal to or less than the concentrations of metal contaminants in the evacuated soils placed in the OLF soils contaminant pad. Details of the current nature and extent of PCB and uranium soil contamination below the OLF cap were calculated using data from the Herbes 1989 and Bohrman 1989 reports.

The OLF HWDU was granted interim status under TN Rule 1200-1-11-.07(3) in December 1984 and is, therefore, subject to the groundwater monitoring requirements described in TN Rule 1200-1-11-.05. Before this date, groundwater monitoring at the OLF was conducted in accordance with two DOE groundwater monitoring programs. Historical monitoring at the site was conducted from 1975 to 1987 as part of a program to identify groundwater contamination sources at the Y-12 Plant. Characterization monitoring began in 1983 in response to the MOU signed by DOE, EPA, and TDEC and continued until 1986.

Groundwater quality data collected during historical and characterization monitoring verified the presence of contaminants in groundwater at the OLF. Therefore, interim status assessment monitoring was implemented at the site in lieu of detection monitoring, as required under TN Rule 1200-1-11-.05(6)(a)4. Assessment monitoring was initiated at the OLF in January 1986.

TDEC acceptance of certification of final closure of the OLF was granted in November 1990. The site was closed as an HWDU and is subject to postclosure care under TN Rule 1200-1-11-.06(7)(g) and (h). Pursuant to TN Rule 1200-1-11-.06(1)(c), a postclosure permit modification adding the OLF site to the BCV postclosure permit was issued in June 1995, thus groundwater monitoring requirements under TN Rule 1200-1-11-.06 apply to this site (Energy Systems 1994).

A.1.3.3 Boneyard/Burnyard

The BYBY, located east of the OLF, consists of three sites: Boneyard, Burnyard, and HCDA (Fig. A.5 and Plate A.5). Information concerning operations at this site is sparse. The primary source documents used for this section are the *RCRA Postclosure Permit Application for the Bear Creek Valley Hydrogeologic Regime at the Y-12 Plant* (Energy Systems 1992a), and the *Remedial Investigation Work Plan for Bear Creek* (Turner et al. 1991). Activities at the BYBY are listed chronologically in Table A.9.

The Boneyard, which consisted of a series of unlined earthen trenches, was an active waste disposal site from the mid-1940s to the mid-1970s. Site wastes have been characterized as ranging from ignitable and radioactive to inert. They are known to have included organics, metals, debris, acids, and beryllium, but the total quantity of material is unknown. The primary waste that went to the Boneyard in the late 1950s to the late 1960s was depleted uranium metal chips. These were placed into an open pit and were burned without being covered. Some waste oil or waste paper was used to start the burning, which was usually done once a week.

Magnesium chips were disposed of in the southwest corner of the Boneyard, south of the gravel road. The metal chips were placed in burn pans in unlined earthen trenches, and ignitable waste solvents were used to initiate the burn. The residue remaining in the trenches was covered with soil and compacted until the trenches were filled, after which they were covered with topsoil and seeded with grass. The remaining land in the Boneyard was used to dispose of construction spoil material such as concrete and rebar.

The Burnyard consisted of two trenches ~90 m (300 ft) long and 12 m (40 ft) wide (Plate A.6). The site is no longer visible because the HCDA was built on top of it and subsequently capped (Fig. A.5). An active waste site from 1943 to 1968, the Burnyard is estimated to have received ~90 m³ (350 yd³) per month [1000 m³ (4000 yd³) per year] of sanitary refuse, including solids, liquids, and sludges, from plant operations. The waste materials, which may have contained empty pesticide containers, metal shavings, solvents, oils, and laboratory

chemicals, were placed in unlined earthen trenches and burned. Oils and other flammable liquids, possibly transformer oils containing PCBs, were used to start and sustain combustion. Dioxin/furan contamination could have resulted from this burning of PCBs at relatively low temperatures. After the trenches became filled, they were covered with soil. No collection or treatment systems, other than burning, are known to have been used on this site.

The HCDA is located on top of the former Burnyard site (Fig. A.5 and Plate A.5). The site is estimated to have received $<3.8 \text{ m}^3$ (5 yd^3) of solid, liquid, and gaseous waste materials a year from 1975 to 1981 (Turner et al. 1991). The material was broadly characterized as ignitable, reactive, corrosive, toxic, highly flammable, or in some instances inert (Energy Systems 1987b).

Generally, the HCDA received wastes from two sources that posed safety hazards within the Y-12 Plant: (1) gas cylinders with leaking or damaged valves and (2) laboratory chemicals considered to be reactive or explosive. Gas cylinders containing noncorrosive gases were allowed to leak into the atmosphere or were bled off to expedite the process. Those containing corrosive gases were bled through neutralizing slurries. Empty gas cylinders were either destroyed or transported to another location for repair. The lab chemicals included acids, bases, organics, water-reactive compounds, and explosive compounds such as picric acid, benzoyl peroxide, and ether. Bottles of chemicals were broken under water spray in a concrete vessel that was open to the atmosphere. After the explosion or chemical reaction had taken place, the effluent was discharged into a small unlined surface impoundment and allowed to percolate through the soil (Plate A.5). The chemical residue remaining in the concrete vessel was removed periodically and transported to the BCBG (Energy Systems 1987b).

In 1989, the HCDA was covered with a cap of RCRA multilayer type construction (Energy Systems 1991); however, no actions to remediate soils were conducted before capping. This cap is not included in the BCV postclosure permit.

A.1.3.4 Sanitary Landfill 1

SL 1 is located $\sim 1.3 \text{ km}$ (0.8 mile) west of the Y-12 Plant, just north of Bear Creek and immediately south of the OLF (Fig. A.5 and Plate A.5). Little recorded information exists for the SL 1 site. The principal references for operational information are the same as those for BYBY: Energy Systems (1987b) and Turner et al. (1991). SL 1 was used between 1968 and 1983 for the disposal of combustible and decomposable solid wastes. The landfill was permitted for materials such as paper and cardboard, plastics, rubber, wood, brush, animal bedding, organic garbage, textile products, and asphalt roofing materials. Although administrative controls were used to exclude the disposal of toxic chemicals and other contaminated materials, some of these materials may have been disposed of in the landfill. Events at SL 1 are listed chronologically in Table A.10.

The trench at SL 1 was excavated to a depth of $\sim 6 \text{ m}$ (20 ft) and backfilled to $\sim 4.5 \text{ m}$ (15 ft) above grade. About $27,000 \text{ m}^3$ ($35,315 \text{ yd}^3$) of refuse were disposed of at the landfill during its 15 years of operation. SL 1 was closed in 1985 by grading the site to promote drainage, capping it with 0.6 m (2 ft) of clay and topsoil, and establishing a vegetation cover (Energy Systems 1987b).

A.1.3.5 Bear Creek Burial Grounds

Introduction

The BCBG were used from about 1955 to 1991 to dispose of industrial wastes that were composed of or contaminated with uranium. Most of the available information about the operations at the BCBG was compiled from the waste inventory records (see Supporting Information for Appendix A) and the RCRA closure documents for this facility (Energy Systems 1988b).

During the early years of Y-12 Plant operation, the Maintenance Division was responsible for waste disposal, including waste disposals at the BCBG. Waste materials disposed of in the BCBG came not only from the Y-12 Plant but also from Oak Ridge National Laboratory, K-25 Site, and facilities outside Oak Ridge.

Materials delivered to the BCBG were segregated and disposed of in particular areas. Initially, there were only two areas: Burial Ground 1 and Burial Ground 2 (BG-1 and BG-2). These areas were later subdivided, with BG-1 becoming Burial Ground A (BG-A) and BG-2 being divided into multiple areas: BG-B, -C, -D, -E, and -J (Figs. A.6 and A.7).

Trenches were dug in each area as needed, with each trench receiving its own identification number. For example, the number BG-A3E referred to the east end of trench #3 in the A area. Several areas were set aside for particular materials: carbon foam (BG-A8FOAM), aerosol cans (BG-A11AERCAN), asbestos (BG-A12ASBP), crucible oxides (BG-BCRUCOX and BG-CCRUCOX), depleted uranium alloys (BG-BDEPUCPD), depleted uranium (BG-BD38 and BG-CD38), and thorium (BG-BTHOR).

BCBG Operational Information

The BCBG, located ~3.2 km (2 miles) west of the Y-12 Plant (Fig. A.2 and Plate A.7), consist of:

- several principal waste disposal units designated as BG-A, -B, -C, -D, -E, and -J;
- Walk-In Pits (WIP);
- Uranium Vaults (Fig. A.8); and
- ORP-1 and -2.

Each waste disposal unit consisted of a series of trenches, 4.2 to 7.5 m (14 to 25 ft) deep (Energy Systems 1988b), which were used for disposal of solid and liquid wastes (Figs. A.6 and A.7). Events at the BCBG are listed chronologically in Table A.11.

A detailed inventory of waste materials in the BCBG has been constructed and is summarized here. Further details are contained in Supporting Information for Appendix A. Most of the wastes disposed of at the BCBG were composed of or contaminated with uranium (Fig. A.9). These wastes included:

- uranium-contaminated waste material,
- large pieces of uranium metal (machined parts),
- uranium tailings and chips generated by milling the machined parts, and
- uranium saw fines generated by fabrication methods.

In general, the contaminated material and tailings were placed in the A trenches (Plates A.8 and A.9), and the large uranium parts/pieces were placed in E and J trenches. Some of the tailings were also placed in 1-B trenches, as well as in the C to J trenches. The locations at which these various uranium forms were disposed of are discussed in more detail in Sect. A.6 of Supporting Information for Appendix A.

Unpublished reports and photographs (Plates A.7 and A.8) indicate that, after disposal, uranium tailings exposed to air often oxidized rapidly, causing uranium fires. The most pyrophoric form of uranium disposed of in the BCBG, saw fines and chips, was disposed of in the WIP in a manner that prevented rapid oxidation and subsequent fires. In addition, photographs also reveal that wastes in many branches were submerged (Plates A.9 and A.10).

Mercury, which is a known potential contaminant throughout the Y-12 complex, is also found in the BCBG. Because actual quantities of mercury disposed of at Y-12 were not routinely recorded, no estimates of mercury masses or concentrations have been attempted in this review.

Before 1968, oils (including those contaminated with PCBs) were burned for disposal in the BCBG. PCBs were also used in the plant in transformers and as a coolant component for the M-Wing and the Z-oil system. These original coolants, as well as subsequent non-PCB coolant change-out fluids, were deposited in the BCBG. Waste oils and coolants, which contained varying amounts of organic compounds (potentially with PCB content), were used to bathe uranium chips before disposal.

Actual quantities and identities of materials deposited in the BCBG have a high degree of uncertainty. Small amounts of unrecorded material may also have been buried in these areas.

Area A

Area A-South was the initial disposal site within the BCBG and was operational for about 6 years before other areas were opened.

Uranium is a major contaminant in every BCBG area. Area A was targeted primarily for waste types identified as containing depleted uranium contamination. A wide variety of contaminated debris and wastes were deposited in Area A, and small amounts of waste contaminated with enriched uranium may also have been disposed of here. Areas A-16 through A-18 are relatively recent burial sites designated strictly for uranium-contaminated trash; they are assumed to contain no other waste types. Other radioactive materials disposed in Area A-North include a one-time disposal of thorium-contaminated sludge from outside the Y-12 complex and technetium.

Area A also received nonradioactive wastes. Large quantities of waste oils and machine coolants were deposited in the trenches of A-South and A-North, either directly in the trenches or as burn residues. Disposal records available for the purposes of this report quantitatively documented the disposal of PCB materials only in relation to BCBG Areas A-North and A-South as well as WIP #1 (North). Specific PCB compounds cited are Therminol-FR-0 and Pyranol, manufactured by Monsanto and General Electric, respectively. The PCB concentration in Therminol-FR-0 during the 1960s was 80% Aroclor-1242, while Pyranol, a component in transformer oil during the 1960s, was manufactured as an Aroclor series (1242–1260) containing 45 to 100% PCBs, depending on the particular Aroclor (Mappes 1995).

The Isolation Area of A-South received thousands of gallons of organic solvent wastes and fuel-contaminated waters (gasoline/water mixtures) between 1970 and 1979. Similar quantities may have been discarded throughout the A-South area before 1970. Area A-North contains a segregated location for asbestos-containing materials. Such segregation was not implemented until 1978; therefore, asbestos-containing waste materials are assumed to have been deposited throughout Area A before 1978.

Areas B, D, E, and J

These areas were designated for disposal of uranium chip, metal, and oxide wastes. Almost 70% of the total uranium deposited in the BCBG is estimated to have been placed in these areas (Supporting Information, Sect. A.7.3). Although Area E is physically small, a relatively high percentage of the total BCBG uranium has been assigned to the area because of the reported type and size of uranium-containing objects deposited there. Area D designated trenches actually appear in three separate geographical locations of the BCBG and thus are addressed separately in the inventory review tables (D-East, D-West, and D-South). Area D-West, Area E, and Area J trenches form a geographically contiguous group and were combined to estimate uranium concentrations. An estimated quantity of thorium is also assumed to be deposited in Area B.

Area C

Area C was designated for the disposal of industrial wastes contaminated with beryllium, enriched uranium, thorium, and technetium. Indications are that only a minor amount of material potentially contaminated with enriched uranium was deposited in this area. However, review records contained definite reference to amounts of materials, metals, chips, and oxides contaminated with depleted uranium being deposited in Area C. Therefore, in addition to estimates for beryllium and thorium, this review has assumed a uranium contribution to the waste inventory of Area C. Records also indicated that lithium compounds were deposited in the C area (Supporting Information, Tables A.19 and A.20).

Walk-In Pits

Three WIP locations are mentioned in inventory information (see Supporting Information for Appendix A). The records indicate that these pits were contiguous with Area B and that WIP 1 (North) received most of the recorded material (78% of the recorded entries other than uranium saw fines). These areas were used for the disposal of laboratory and industrial chemicals of all types; however, uranium metal saw fines were a primary contribution to these locations. About 15% of the total BCBG uranium has been assumed to be uranium material in these areas.

As indicated in the BCBG waste inventory (see Supporting Information for Appendix A), there is an extensive list of chemicals that could have been placed in these areas. The quantities of most of these miscellaneous chemical deposits are assumed to be relatively small (on the order of milliliters). However, many common solvents (acetone, alcohols, carbon tetrachloride, cyclohexane, methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylenes), which were listed on inventories for these sites without associated quantities, may have been discarded in significant amounts. Several compounds, such as picric acid, ether, and chromic acid, were deposited in these WIP locations because they were old, partially crystallized or radioactively contaminated reagents, constituting an explosive hazard.

Oil Retention Ponds

ORP-1 and -2 were constructed to prevent downstream transport of oil in NT-6 and NT-7 (Fig. A.2 and Plate A.11). Although overflow of mop water from standpipes had occurred previously, oil was first observed seeping from the west ends of trenches in BG-A into NT-7 and from the soil surface above the oil disposal pits between 1969 and 1971. At this time, oil disposal in the BG-A South trenches was discontinued (Bailey 1979). To prevent oil transport down NT-7 to Bear Creek, ORP-1, with maximum dimensions of 55 m (180 ft) in length, 34 m (110 ft) in width, and 2 m (6 ft) in depth, was constructed at the southwest corner of BG-A in May 1971. The pond was equipped with underflow pipes to permit water discharge while retaining floating oils in the impoundment. Simultaneously, a drainage ditch was constructed about 18 to 30 m (60 to 100 ft) west of and parallel to the tributary, which rejoined NT-7 about 15 m (50 ft) south of the pond, to divert uncontaminated surface runoff around the pond. A sump was later dug at the western end of one of the trenches east of ORP-1 to collect oil, which was pumped into the pond. This sump has been backfilled with dirt (Bailey 1979). A pipe was also installed between the end of a second trench and the pond to permit direct oil transfer to the pond (Bailey 1979).

ORP-2 was constructed in a similar fashion to ORP-1, but located northeast of BCBG A North (Fig. A.2). It was capped at the same time as BCBG-A.

BCBG Treatment and Closure

Areas A, B, C, D, E, J, and WIP

BG-A and BG-C West were closed in place as landfills and covered with a RCRA cap in 1989. BG-B and the WIP North and South were covered with a RCRA cap in 1994 and closed. Although BG-B did not receive RCRA wastes, it was covered with a RCRA cap due to its location between WIP North and South. BG-C East also did not receive RCRA-regulated wastes, and was closed in 1994 with a .6-m (2-ft) clay cover.

The BCBG were granted interim status in December 1984 and, therefore, are subject to the groundwater monitoring requirements described in TN Rule 1200-1-11-.05. Before this date, groundwater monitoring at the site was conducted in accordance with two DOE monitoring programs. Historical monitoring at the site was conducted from 1975 until 1987 as part of a program to identify groundwater contamination sources at the Y-12 Plant. Characterization monitoring at the BCBG began in 1983 in response to the MOU signed by DOE, EPA, and TDEC and continued until 1986.

Groundwater quality data collected during historical and characterization monitoring verified the presence of contaminants in groundwater at the BCBG. Therefore, interim status assessment monitoring was implemented at the site in lieu of detection monitoring. TDEC granted approval in November 1990 for the final closure of BG-A. The site was closed as an HWDU and is subject to postclosure care. BCBG C West was certified in May 1993 (Energy Systems 1992c), and the WIP and BCBG B were certified by the State of Tennessee in February 1995.

In April 1995, DOE submitted a postclosure permit application modification to add the WIP to the BCBG permit, and in September 1995, TDEC issued a revised postclosure permit incorporating the WIP (Energy Systems 1995).

Oil Retention Ponds

In 1974, ~57,000 L (15,000 gal) of oil were removed from the surface of ORP-1 and sent to the Oil Landfarm (Sect. A.1.3.2). An additional 19,000 L (5000 gal) were removed in early 1975 and sprayed onto nearby trees. In 1979, another 68,000 L (18,000 gal) of oil were removed (Battelle 1986). Oil seepage was observed on a steep slope above NT-6 at the eastern end of trenches A-14 and A-15 before 1972 (Bailey 1979). In May 1972, a smaller impoundment, ORP-2, was constructed on NT-6 in the northeast corner of BG-A. No significant oil accumulation was reported on the surface of ORP-2 from 1975 to closure of the pond in 1989 (Battelle 1986).

Both ORPs were closed and capped under an approved RCRA closure plan in 1989. During closure operations, 3060 m³ (4,000 yd³) of sludge, sediment, and soil were excavated from ORP-1, ORP-2, and NT-7 (Collins 1990a) (Plate A.11). This waste was placed in the Disposal Area Remedial Action (DARA) facility located to the west of ORP-1 (Fig. A.2). A total of 980 screening samples (rapid turnaround) were taken during excavation to guide removal activities. A total of 287 certification samples of remaining soils were taken, and all but one of the contaminated areas in ORP-1, ORP-2, and NT-7 were certified to have <25 µg/g PCBs. In one area, the seepage area (Seep 1, Fig. A.6) to the west of BG-A North, higher than anticipated concentrations of PCBs were encountered during excavation (1,200 µg/g). This area was closed without achieving the 25 µg/g acceptance criteria. Table A.12 gives a summary of the analytical results from the soil samples taken from soils stored in the DARA facility. The ponds and the section of NT-7 north of ORP-1 were then covered with an engineered multilayered cap. The portion of NT-7 below ORP-1 was capped with a clay cap at this time. A new channel was constructed for NT-7, and this tributary was rerouted ~15 m (50 ft) to the west of its original course.

Seepage zones from adjacent burial areas have been observed on all three tributaries draining the BCBG: NT-6, NT-7, and NT-8 (Fig. A.8), and seepage collection systems were installed on NT-7 and -8 catchments during closure of the BG-A and BG-C, and just before the initiation of WIP closure, respectively. Collection system A, located on NT-7, collects an average of 2 L/min (0.5 gpm) from Seep 1 (Fig. A.8). Collection system B, known as the Leachate Collection System (Seeps 2, 3, and 4), is located on NT-8. Flow in system B is variable and may reach 76 L/min (20 gpm) in rainy weather, whereas flow in system A shows little variation.

A.2 RELEASES

Numerous releases of hazardous and/or radioactive chemicals to the environment occurred during operation of the waste disposal sites in BCV. These releases were the result of either working practices that were approved at the time (such as injection of waste oils into standpipes in the BCBG) or accidental releases. The instances of releases through working practices are described in this Appendix, and the released contaminants are described in detail in Appendix D.

A.3 REFERENCES

- Bailey, J. K. 1979. *History: Y-12 Oil Disposal*, Y-12 File Report, Union Carbide Corporation, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Bailey, J. K. 1983a. *Bear Creek Burial Grounds Inventory*, Y/DS-171, Parts 1 through 10, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Bailey, J. K. 1983b. *Waste Disposal Notes*, Y-12 File Report, Union Carbide Corp., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Bailey, J. K. 1995. Fax transmittal to J. H. Moyer dated May 9, subject: Information relating to PCB contamination in the Bear Creek Valley Burial Grounds.
- Battelle (Battelle, Inc.). 1986. *Geologic Report and RCRA Closure Plan for Oil Retention Ponds, DOE Y-12 Plant, Oak Ridge, Tennessee*, Columbus, Ohio.
- Battelle PNL. 1994. *PEIS Solid Waste Report for Y-12*, Y-12-S0001-001, February.
- BNI (Bechtel National, Inc.). 1983. *Preliminary Characterization and Remedial Action Plan for the Y-12 Plant Oil Landfarm*, Y/Sub/83-47974C/1, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, October.
- Bohrman, D. E. 1989. *Oil Landfarm Summary of Closure Under Rules Governing Hazardous Waste Management in Tennessee*, Y/TS-394/2, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, November.
- Collins, E. T. 1990a. *Oil Retention Ponds (T-008, T-009) Summary of Closure Under Rules Governing Hazardous Waste Management in Tennessee*, Y/TS-392/2, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, May.
- Collins, E. T. 1990b. *Bear Creek Burial Ground C-West Summary of Closure Under Rules Governing Hazardous Waste Management in Tennessee*, Y/TS-395/3, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, December.
- DOE (Department of Energy). 1988. *Historical Radionuclide Releases from Current DOE Oak Ridge Operations Office Facilities*, OR-890, May.
- DOE. 1993. *Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 1 (S-3 Ponds, Boneyard/Burnyard, Oil Landfarm, Sanitary Landfill I, and the Burial Grounds, Including Oil Retention Ponds 1 and 2) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1161/V1&D1.
- DOE. 1994a. *Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 1 (S-3 Ponds, Boneyard/Burnyard, Oil Landfarm, Sanitary Landfill 1, and the Burial Grounds, Including Oil Retention Ponds 1 and 2) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volumes 1. Main Text and 2. Appendices*, DOE/OR/01-1161/V1&D2, V2&D2, March.

- DOE. 1994b. *Preliminary Assessment Report for the Study Areas and Proposed No Further Investigation Sites for the Y-12 Plant at Oak Ridge, Tennessee*, Y/ER-164/R0, April.
- Energy Systems (Lockheed Martin Energy Systems, Inc.). 1987a. *Post-Closure Permit Application for the S-3 Ponds Hazardous Waste Disposal Unit at the Y-12 Plant*, Y/Sub/87-00206C/12, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1987b. *Post-Closure Permit Application for the Oil Landfarm Hazardous Waste Disposal Unit at the Y-12 Plant*, Y/Sub/87-00206C/10, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1988a. *Revised RCRA Closure Plan for the S-3 Ponds*, Y/TS-393, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, February.
- Energy Systems. 1988b. *Post-Closure Permit Application for the Burial Grounds Hazardous Waste Disposal Unit at the Y-12 Plant*, Y/Sub/87-00206C/11/R2, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1991. *Oak Ridge Reservation Environmental Report for 1990*, ES/ESH-18/V1&V2, Oak Ridge, Tennessee, September.
- Energy Systems. 1992a. *RCRA Postclosure Permit Application for the Bear Creek Hydrogeologic Regime at the Y-12 Plant*, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, November.
- Energy Systems. 1992b. *Post-Closure Permit Application for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: S-3 Ponds*, Y/ER/Sub/91-ALV96/1.
- Energy Systems. 1992c. *Post-Closure Permit Application for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: Bear Creek Burial Grounds*, Y/ER/Sub/91-ALV96/3, Rev. 2.
- Energy Systems. 1992d. *Environmental Restoration Remedial Action Surveillance and Maintenance Program Plan*, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1993. *Pages Excerpted from Documents Pertaining to Bear Creek Burial Grounds Inventory*, Y/SA-839, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, August.
- Energy Systems. 1994. *Post-Closure Permit Application for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: Oil Landfarm Hazardous Disposal Unit*, Y/ER/Sub/91-ALV96/2, Rev. 2.
- Energy Systems. 1995. *Post-Closure Permit Application for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: Walk In Pits*, Y-12/ER/Sub/91-ALV96/3, Rev. 2, Addendum.
- Energy Systems. 1996. Interviews with J. K. Bailey and C. Smith of Y-12 Waste Management conducted by N.A. Luedtke, Science Applications International Corporation, and J. A. Moyer, Lockheed Martin Energy Systems.
- Geraghty and Miller. 1987. *Proposed RCRA Groundwater Quality Assessment Plan for the S-3 Ponds Hazardous-Waste Disposal Unit at the Y-12 Plant*, Y/Sub/87-00206C/4, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

- Herbes, S. E. 1989. *PCBs, Uranium, and Oil/Grease in Soil at the Oak Ridge Y-12 Plant Oil Landfarm: Results of a 1985-1986 Sampling and Analysis Program*, Y/TS-538, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Jeter, I. W. 1983. *The Chemical and Radiological Characterization of the S-3 Ponds*, Y/MA-6400, Union Carbide Corporation Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Kimbrough, C. W. and R. R. Turner. 1987. *Field Notebook: Sampling and Analysis of Sludges in the S-3 Ponds at the Y-12 Plant*, Y/TS-294, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- McCauley, L. L. 1984. *Inventory of Existing Contamination in the Y-12 Plant Bear Creek Valley Oil Landfarm Area*, Y/IA-166, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- McMahon, L. W. 1988. *Sampling and Analysis to Support Excavation of Blue Lagoon Sediment Build-up*, Y/TS-481, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Mappes, G. 1995. Personal communication of Gary Mappes (Monsanto, St. Louis) to J. H. Moyer (Oak Ridge National Laboratory, Oak Ridge) on May 22, 1995.
- Mynatt, F. 1991. Letter dated February 1, 1991 to R.R. Nelson. (SWIMS). Subject: Historical Radionuclide Release Report Update.
- Turner, R. R. and G. E. Kamp. 1984. *Characterization and Remedial Alternatives for Sediments in Upper Bear Creek*, Y/TS-56, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Turner, R. R., M.A. Bogle, R. B. Clapp, K. Dearstone, R. B. Dreier, T.O. Eary, S. E. Herbes, J. M. Loar, P.D. Parr, and G. R. Southworth. 1991. *Remedial Investigation Work Plan for Bear Creek (Y02-S600) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, ES/ER-19&D2 (Y/ER/Sub-90/99928/2), Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, June.
- Union Carbide (Union Carbide Corporation-Nuclear Division). 1984. *Inventory of Existing Contamination in the Y-12 Plant Bear Creek Valley Oil Landfarm Area*, Y/IA-166, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, January 31.
- Welch, S. H. 1989. *RCRA Facility Investigation Plan General Document Y-12 Plant, Oak Ridge, Tennessee*, Y/TS-352, Vol. 1 (Rev. 1), Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, April.

A.4 FIGURES

Fig. A.1. Location map for BCV.

- 1 ABANDONED NITRIC ACID PIPELINE
- 2 S-3 TREATMENT FACILITY
- 3 S-3 SITE
- 4 WEST END TREATMENT FACILITY
- 5 INTERIM REACTIVE WASTE TREATMENT AREA
- 6 SPOIL AREA 1
- 7 RUST ENGINEERING STORAGE YARD
- 8 SY-200 YARD
- 9 WASTE OIL/SOLVENT STORAGE FAC.
AND TRANSFORMER FLUID STORAGE FAC.
- 10 RUST SPOIL AREA
- 11 LIQUID ORGANIC WASTE
STORAGE FACILITY (OD10)
- 12 HAZARDOUS CHEMICAL DISPOSAL AREA
- 13 OIL LANDFARM

- 14 OIL LANDFARM CONTAMINANT PAD
- 15 SANITARY LANDFILL 1
- 16 OIL RETENTION POND NO. 2
- 17 BEAR CREEK BURIAL GROUNDS
- 18 OIL RETENTION POND NO. 1
- 19 DARA LIQUID STORAGE AND TREATMENT UNIT
- 20 DARA SOLID STORAGE FACILITY
- 21 NaK BURN FACILITY
- 22 M.K. FERGUSON LAYDOWN AREA
- 23 BEAR CREEK ROAD SITE
DEBRIS BURIAL AREA
- 24 CREEKSIDE DEBRIS BURIAL AREA
- 25 MERCURY CONTAMINATED CONSTRUCTION
..... SPOIL PILE
- 26 BONEYARD/BURNYARD

SAC CAD DWG: 94020\DWGS\2785H4U
REV. 1 / 07-17-96

Fig. A.2. Locations of waste storage areas

BEAR CREEK VALLEY KEY MAP

Y-12 PLANT NORTH

0 400 800
SCALE: 1" = 800'

LEGEND:

-ROADS
- BEAR CREEK & TRIBUTARIES
- 900 20' CONTOUR
- (22)SITE IDENTIFIER

BEAR CREEK VALLEY
WASTE STORAGE AND
DISPOSAL AREAS

l treatment and storage facilities in BCV.

Fig. A.3. Map of the S-3 Site.

Fig. A.5. Site map for the Oil Landfarm Area, including the Oil Landfarm, the Boneyard/Burnyard, and SL 1.

Fig. A.9. Estimated uranium concentrations in Burial Grounds.

A5. PLATES

Plate A.1. Upper Bear Creek and the Y-12 Plan, circa 1947.

Plate A.2. Upper Bear Creek, circa late 1980s.

Plate A.3. Ponds during neutralization and bionitrification, circa 1983.

Plate A.4. Ponds during closure, filling, and structural stabilization, circa late 1980s.

Plate A.5. Foreground: OLF Area HCDA in operation, with small percolation pond in SW corner. Background: OLF, SL 1, and NT-3, circa 1980s.

Plate A.6. Trench, possibly located at BYBY.

Plate A.7. Burial Grounds, circa 1980s. (Note possible uranium fire in the BG-D area)

Plate A.8. Unidentified trench in BG-A South, circa 1980s. (Note the heat haze from uranium tailings fire)

Plate A.9. Unidentified trench in BG-A South, circa 1980s. (Note burn pit in foreground with firebricks)

Plate A.10. Unidentified trench, probably located in area D, E, or J.

Plate A.11. ORP 1 (Burial Grounds), circa 1980s. Picture taken after draining the pond during closure operation. Equipment in background is oil/water separator.

A6. TABLES

Table A.1. Sites considered in this RI report that are listed in the FFA or have been identified as solid waste management units

Site ^a	Status/service history	Reference
Bear Creek Burial Grounds (Fig. A.2 #17)	FFA Area of Concern in BCV CA	YD-024
HCDABoneyard Burnyard (Fig. A.2 #12)	FFA Area of Concern in BCV CA	YD-024-HC
Sanitary Landfill 1 (Fig. A.2 #15)	FFA Area of Concern in BCV CA	YD-101
Bear Creek Groundwater, Creek Sediments, and Floodplain Soils	FFA Area of Concern in BCV CA	YS-600
S-3 Ponds (Fig. A.2 #3)	FFA Area of Concern in BCV CA	YT-004
Oil Retention Pond 1 (Fig. A.2 #18)	FFA Area of Concern in BCV CA	YT-008
Oil Retention Pond 2 (Fig. A.2 #16)	FFA Area of Concern in BCV CA	YT-009
Oil Landfarm (Fig. A.2 #13)	FFA Area of Concern in BCV CA	YT-014
Oil Landfarm Soil Containment Pad (Fig. A.2 #14)	FFA Area of Concern in BCV CA. The site is used as a storage facility for contaminated soils from the closure of the Oil Landfarm. Site contains soils that are contaminated with PCBs, organics, and uranium. A RCRA Part B permit application has been submitted.	YS-050
DARA Solids Storage Facility (Fig. A.2 #20)	FFA Area of Concern in BCV CA. Bldg. 9720-60 is designed to dewater soils by gravity flow to sumps. Collected liquids are pumped to the DARA Liquid Storage Facility—a RCRA Permit by Rule Unit. The soil and liquids were products of the excavation and closure of the oil retention ponds and associated tributaries. Radioactive mixed waste, PCBs, uranium, and organic are among the contaminants present at this site. Site has had a RCRA permit application submitted.	YS-051
Abandoned Nitric Acid Pipeline (ANAP) (Fig. A.2 #1)	Operable Unit (ANAP). Received CERCLA NFA ROD 9/12/94. Also located in UEFPC CA.	YS-601
Rust Spoil Area (Fig. A.2 #10)	FFA Area of Concern in BCV CA - originally part of Bear Creek OU 2 but incorporated into BCV CA due to minor groundwater contamination.	YD-106

Table A.1 (continued)

Site ^a	Status/service history	Reference
Spoil Area 1 (Fig. A.2 #6)	Operable Unit (BCV OU 2) SA-1 and SY-200 yard (below) were included in BCV OU 2, and received a "status quo" ROD of maintaining existing caps on these sites. The ROD is due to EPA and TDEC April 1996. There is no groundwater contamination associated with SA-1 or SY-200 Yard.	YD-107
SY-200 Yard (Fig. A.2 #8)	Operable Unit (BCV OU 2) (see above).	YD-125
Contaminated Construction Spoil Pile (Fig. A.2 #25)	FFA Area of Concern in BCV CA — This soil was excavated during construction of the first tank farm for WETF. It has low levels of mercury contamination, similar to other soil in the area.	YS-027 (Y/TS-473)
S-3 (or Decant) Treatment Facility (Fig. A.2 #2)	FFA Area of Concern in BCV CA. Formerly operated under RCRA Permit by Rule — Treatment of denitrified supernatant from S3 Ponds; denitrified supernatant from West End Treatment Facility tanks from 1985 to 1989. No longer in operation.	YT-044
Waste Oil/Solvent Storage Facility (Fig. A.2 #9)	Active Waste Management Area (Alias OD-9) — The site is designed to store organics, PCBs, PCB-contaminated waste oil containing various concentrations of organic solvents and uranium. The site has a current RCRA permit.	YS-039
Liquid Organic Waste Storage Facility (Fig. A.2 #11)	Active Waste Management Area (Alias OD-10) — Used for storage of various chlorinated and non-chlorinated organics and PCBs. The site has a current RCRA permit.	YS-040
DARA Liquids Storage and Treatment Unit (Fig. A.2 #19)	Active Waste Management Area operated under RCRA Permit by Rule [Accumulation Area AA-137, Alias LSF Diked Area (YS-826)] — Liquids collected from dewatering soils within the DARA soils storage facility are pumped to this DARA liquid storage facility. The liquids go through an oil/water separator and then are tankered to the GWTF adjacent to WETF. These liquids/soils originated from excavation and closure of the oil retention ponds and associated tributaries (Trib 7), and from the seep collection trench (Trib 8).	YS-052
Rust Engineering Storage Yard (Fig. A.2 #7)	Active Process Storage Area — Storage of various types of concrete finishing and coating compounds from 1975 to present.	YS-401

Table A.1 (continued)

Site ^a	Status/service history	Reference
West End Treatment Facility (Fig. A.2 #4)	Active Waste Management Area [Also includes 9616-7, GWTF - Accumulation Area AA-133 (YS-822) and Groundwater Treatment Facility (YT-053) (RCRA Permit by Rule Unit)] — Treatment of nitrate-bearing wastes including biodenitrification sludge, plating solutions, mopwaters, evaporator condensates, acids, caustics, and heavy metals including depleted and enriched uranium from 1985 to present.	YT-007
Interim Reactive Waste Treatment Area (Fig. A.2 #5)	Active Waste Management Area (Interim Status IT-42) — This site treats water that may be contaminated with volatile and nonvolatile organics from the water stored at DARA Liquid Storage Facility (YS-052).	YT-150
NaK Burn Facility (Fig. A.2 #21)	Former Waste Management Area. Area where NaK alloys were ignited. Located between NT-5 and NT-6.	
9720-58 Transformer Fluid Storage Facility (Fig. A.2 #9)	Active Waste Management Area. RCRA Permitted Storage Facility. This facility stores PCB-contaminated waste and equipment.	YS-
M.K. Ferguson Laydown Area (Fig. A.2 #22)	Active Process Storage Area. Radiologically contaminated demarcated area	
Above Grade Storage Pads	Active Waste Management Area. Currently active under a state agreement	
Johnson Controls 90-Day Accumulation Area	Active Waste Management Area. RCRA 90-day Accumulation Area	YS-
Bear Creek Road Debris Burial Area (Fig. A.2 #23)	New found site on Bear Creek Floodplain. History unknown. Decision on inclusion in FFA is pending.	
Creekside Debris Burial Area (Fig. A.2 #24)	New found site on Bear Creek Floodplain. History unknown. Decision on inclusion in FFA is pending.	

^aLocations of sites identified on Fig. A.2.

Source: DOE 1994b.

Table A.2. Chronological list of events at the S-3 Ponds

Year	Event	Reference
1951	The S-3 Ponds were constructed. They consisted of four unlined surface impoundments with a total storage capacity of 38 million L (10 million gal)	Energy Systems 1992d
Mid-1950s	Uranyl nitrate solutions containing small amounts of plutonium were discharged into ponds	
1951–1983	Primary waste disposed of in S-3 Ponds consisted of nitric acid, nitrate waste, pickling and plating wastes, and miscellaneous liquid wastes associated with routine cleanup operations. Other wastes included dilute acid, machine coolants, depleted uranium, technetium, caustic solutions, biodenitrification sludges, and acids with pH of <2.0	
1976	The nitric acid recovery system became operational	
1983	Annual liquid waste entering the ponds was reported to be ~10.3 million L (2.7 million gal)	
1983	The underground nitric acid pipeline used to transport waste to the S-3 Ponds was plugged and abandoned	Energy Systems 1987a
March 1983	All waste discharges into the ponds were terminated	
1983	Characterization monitoring at the S-3 Ponds began in response to a Memorandum of Understanding (MOU) signed by DOE, EPA, and TDEC	Jeter 1983 and Turner et al. 1991
1983	In situ treatment of wastewater in the ponds began	
May–November 1983	Liquid in all four ponds was neutralized	
May 1983–September 1984	Biodenitrification of liquids occurred. Nitrate levels in the pond water decreased to ~100 ppm	
September 1984	In situ treatment of wastewater was completed. Nitrate levels were maintained below 50 ppm	
December 1984	S-3 Ponds HWDU ^a was granted interim status under TN Rule 1200-1-11-.07(3)	

Table A.2 (continued)

Year	Event	Reference
1985	Supernatant treatment to remove trace metals and organics began. The supernatant was pumped to the S-3 Ponds Treatment Facility where processes that included pH adjustment, precipitation, coagulation, flocculation, carbon absorption, filtration and chlorination were conducted. The treated effluent was discharged to EFPC in accordance with an NPDES ^b permit	
January 1986	Assessment monitoring was initiated at the S-3 Ponds	
Spring 1986	Supernatant treatment processes were completed	
March 1987	The formalized Groundwater Quality Assessment Plan for the site was submitted to TDEC	Geraghty and Miller 1987
1988	Sediment from the two "lagoons" in upper Bear Creek was placed in the southwest cell of the S-3 Ponds. The sediment was characterized in place and after being disposed (Turner and Kamp 1984). Data are reported in McMahon 1988	Energy Systems 1988a
February 1988	RCRA Closure Plan was revised	Energy Systems 1988a
1988	The S-3 Ponds were closed with a multilayered RCRA cap. Currently, the site is covered with asphalt and used as a parking lot	
November 15, 1990	Final closure of the S-3 Ponds was accepted by TDEC	
September 30, 1991	TDEC issued a RCRA postclosure permit for the S-3 Ponds	
October 31, 1991	DOE and Energy Systems appealed permit on basis of inapplicability of RCRA Corrective Actions toward an NPL with an FFA in place. As a result, all subsequent postclosure permit applications were put on hold pending determination of appeal.	
November 30, 1992	DOE resubmits postclosure permit application with reference to CERCLA for any groundwater remediation.	

Table A.2 (continued)

Year	Event	Reference
April 1993	DOE, TDEC, and Energy Systems go before state board with consent order signed by all parties agreeing to CERCLA reference, and agree to use S-3 Site postclosure permit application language as a model for all subsequent applications.	

^aHWDU = Hazardous Waste Disposal Unit.

^bNPDES = National Pollutant Discharge Elimination System.

Table A.3. Source term characterization for S-3 Site

Constituents	Exposure concentration ^a Blue Lagoon	Exposure concentration ^a S-3 Ponds	S-3 site source term ^b concentrations
<i>Anions (mg/kg)</i>			
Nitrate	NA	6100	6100
Nitrate-Nitrogen	NA	1130	1130
Sulfate	NA	2200	2200
Total kjeldahl nitrogen	NA	460	460
<i>Metals (mg/kg)</i>			
Aluminum	49800	20800	22134.00
Arsenic	16.1	0.4	1.12
Barium	206	130	133.50
Beryllium	1.95	2.78	2.74
Boron	34.3	37.8	37.64
Cadmium	2.45	5.02	4.90
Calcium	21800	43200	42215.60
Cerium	53.3	6	8.18
Chromium	33.6	138	133.20
Chromium (VI)		0.2	0.19
Cobalt	14.5	2.94	3.47
Copper	50	94.5	92.45
Cyanide		6.24	5.95
Gallium	9.33	6	6.15
Iron	15000	3100	3647.40
Lanthanum	14.8	2	2.59
Lead	31.4	36	35.79
Lithium	48.4	77	75.68
Magnesium	9020	1600	1941.32
Manganese	493	80.7	99.67
Mercury	12.3	1.8	2.28
Molybdenum	2.66	15.8	15.20
Nickel	38.5	575	550.32
Niobium	5.65	21.6	20.87
Phosphorus	246	987	952.91
Potassium	9000	1270	1625.58
Scandium	5.24	1	1.20
Selenium	0.116	0.8	0.77
Silver	2.46	1.84	1.87
Sodium	694	2820	2722.20
Strontium	45.6	35	35.49
Thallium		0.349	0.33
Thorium	10.1	204	195.08
Tin		1.65	1.57
Titanium	1530	344	398.56
Uranium	405	1020	991.71
Vanadium	30.9	5.93	7.08
Yttrium	17.5	3.84	4.47
Zinc	88.8	56.8	58.27
Zirconium	51.7	499	478.42

Table A.3 (continued)

Constituents	Exposure concentration ^a Blue Lagoon	Exposure concentration ^a S-3 Ponds	S-3 site source term ^b concentrations
<i>Organics (µg/kg)</i>			
1,1,2-Trichloroethane	0	79	75.37
1,1,2,2-Tetrachloroethane	0	402	383.51
1,1,2-Trichloro-1,2,2-trifluoroethane	32.4	3	4.35
1-(2-Butoxyethoxy)-Ethanol	0	1100	1049.40
2-Butoxyethanol	0	2400	2289.60
2-(2-Butoxyethoxy)-Ethanol	0	2000	1908.00
2-Hexanol	0	310	295.74
3-(1,1-Dimethylethyl)-Phenol	0	6330	6038.82
Acetone	499	0	22.95
Aroclor 1248	0	5940	5666.76
Diethylphthalate	0	548	522.79
Methylene chloride	10.6	0	0.49
Phenol	0	7700	7345.80
Phosphoric acid	0	810	772.74
Tetrachloroethene	5.54	831	793.03
Toluene	5.97	0	0.27
Trichloroethene	6.13	0	0.28
Trichlorofluoromethane	8.29	0	0.38
<i>Radionuclides (pCi/g)</i>			
Alpha activity	202	960	925.13
Beta activity	310	1980	1903.18
Americium-241	0.17		0.01
Cesium-137	0	5	4.77
Neptunium-237	0.506	10.3	9.85
Plutonium-238	1.25	26.5	25.34
Plutonium-239/240	0.104	2.66	2.54
Ruthenium-106		34.9	33.29
Strontium-90	0.377	13.5	12.90
Technetium-99	61.1	7880	7520.33
Tritium	15.1		0.69
Thorium-228	3.48 ^c	280	267.28
Thorium-230	7.02 ^c	570	544.10
Thorium-232	1.13 ^c	91.7	87.53
Uranium-234	77.1	126.31 ^c	124.05
Uranium-235	4.92	8.21 ^c	8.06
Uranium-236	4.89	7.81 ^c	7.68
Uranium-238	207	338.30 ^c	332.26

^a Exposure concentrations represent 95% upper confidence limit of the mean.

^b Source terms for S-3 Site represent weighted average (based on 95.4% S-3 Ponds sludge and 4.6% Blue Lagoon sludge) of exposure concentrations for the S-3 Ponds and the Blue Lagoon.

^c Activities for Blue Lagoon and S-3 Ponds are calculated (not measured) on the basis of the isotopic distributions shown for thorium in the S-3 Ponds and for uranium in the Blue Lagoon, respectively.

Table A.4. Chronological list of events at the Oil Landfarm

Year	Event	Reference
1973	Landfarming activities began at the site. Waste oils and coolants that contained beryllium compounds, depleted uranium, PCBs, and chlorinated organic compounds, mop waters, tanker oils from the K-25 Site, wastes from cooling towers and the Burial Grounds, and unidentified miscellaneous liquid wastes were disposed of at the site	Energy Systems 1991
1974–1975	57,000 L (15,000 gal) of oil skimmed from the surface of the Oil Retention Pond -1 in BG-A were disposed of in the Landfarm. An additional 19,000 L (5,000 gal) were removed and sprayed onto nearby trees	
1975	Historical monitoring at the site began as part of DOE monitoring programs	
1979	Analyses of waste were implemented before application to the Landfarm. The analytical results for oil samples collected from the surface of one of the ponds in the Burial Grounds indicated the presence of PCBs	
1979	Oils were analyzed for uranium, beryllium, thorium, and PCBs. Permissible concentration levels of 5 mg/L were established for PCBs. Waste oils containing PCBs at concentrations >5 mg/L and uranium concentration levels greater than permissible limits were placed in storage for incineration at the K-25 Site TSCA incinerator. An additional 68,000 L (18,000 gal) of oil were removed from ORP-1	Battelle 1986
1981	Analyses of waste were expanded to include chlorinated hydrocarbons with a maximum permissible concentration of 3% in waste oils	
1982	Landfarm activities ceased. Approximately 3.8 million L (1 million gal) of liquid waste were disposed of during the operational history. A total of 2.2 million L (583,500 gal) of waste coolant and 1.6 million L (430,800 gal) of waste oil were reported to be disposed of at the site (Union Carbide 1984)	Turner et al. 1991
1983	Groundwater characterization monitoring began in response to the MOU signed by DOE, EPA, and TDEC	
1983	Core samples from perimeter monitoring wells were analyzed for organic contaminants	
September 1983	Composite soil samples were collected from plots 1-12, 13-18, and 19-24 and analyzed for VOCs, acid- and base-neutral extractables, inductively coupled plasma metals, and pesticide/PCBs	

Table A.4 (continued)

Year	Event	Reference
1983–1984	Water and sediment samples were collected at tributaries NT-3 and NT-4. Levels of VOCs, phenols, and beryllium were all below detection limits	Turner et al. 1991
December 1984	Oil Landfarm was granted interim status under TN Rule 1200-1-11.07(3)	
1985	A total of 200 soil samples were collected in a randomized block design to delineate areas containing PCB levels >25 µg/g. Samples were also analyzed for uranium	Herbes 1989
January 1986	DOE characterization monitoring ended	
January 1986	Interim status assessment monitoring was initiated at the site in lieu of detection monitoring as required under TN Rule 1200-1-11-.05(6)(a)4 due to the detection of contaminants in groundwater	
1986–1987	Groundwater samples from three monitoring wells bordering the Oil Landfarm were analyzed for total and dissolved toxic metals and gross radioactivity	
1987	DOE historical monitoring at the site ended	
February 1988	RCRA Closure Plan was revised	
1989	305.8 m ³ (400 yd ³) of soils with PCB concentrations >25 µg/g excavated from soils at Oil Landfarm and placed in the OLF Soils Containment Pad	Bohrman 1989
November 1990	Oil Landfarm was closed as a landfill with a multilayered engineered cap pursuant to TN Rule 1200-1-11.05(14)(e)	Bohrman 1989
December 1990	Final RCRA closure for the site was certified by TDEC	Bohrman 1989
March 31, 1994	As a result of agreements made during issuance of the S-3 portion of the BCV Hydrogeologic Regime postclosure permit application, DOE resubmits OLF postclosure permit application to TDEC	
June 30, 1995	TDEC issues modification to BCV permit adding OLF section	

Table A.5. Summary of waste coolant disposals at the Y-12 Plant Oil Landfarm

Calendar year	No. of disposals	Volume (gal)	Active plots (acres)	Description
1973	12	34,800	0.9	Coolants
	8	22,500	0.9	Coolants and mop waters
	2	9,700	0.9	Water contaminated with nitrate
1974	22	104,000	1.6	Coolants
	6	21,000	1.6	Coolants and mop waters
1975	21	97,500	2.0	Coolants
1976	25	107,000	2.0	Coolants
	3	9,400	2.0	Water
1977	23	114,000	1.6	Coolants
1978	15	62,600	1.4	Coolants
1979	NA	NA	1.4	No disposals
1980	1	1,000	1.4	Dye penetrant
1981	NA	NA	1.4	No disposals
1982	NA	NA	1.4	No disposals
TOTAL	138	583,500		

Source: Union Carbide 1984.

Table A.6. Summary of waste oil disposals at the Y-12 Plant Oil Landfarm

Calendar year	Origin	No. of disposals	Volume (gal)	Active plots (acres)	Description
1973	Y-12	11	42,800	0.4	Waste oil
1974	Y-12	14	53,300	1.0	Waste oil
1975	Y-12	4	14,600	1.0	Waste oil
1976	Y-12	9	25,600	1.0	Waste oil
	NR ^a	5	17,700	1.0	No record
1977	NR	5	14,000	1.4	No record
1978	Y-12	12	36,000	1.7	Waste oil
	ORGDP	1	1,000	1.7	Mineral oil
1979	Y-12	4	16,500	2.6	Waste oil
	ORGDP	16	63,900	2.6	Waste oil
1980	Y-12	22	72,400	2.6	Waste oil
	Y-12	5	17,800	2.6	Mineral oil
	ORGDP	7	22,300	2.6	Waste oil
1981	NA ^b	NA	NA	2.6	No disposals
1982	Y-12	9	32,900	2.6	Waste oil
TOTAL		124	430,800		

^aNR = no record.^bNA = not applicable.

Source: Union Carbide 1984.

Table A.7. OLF storage pad soil data summary

Analysis	Units	Minimum	Maximum	Mean	N
Aluminum	ppm	9600	18000	13882.5	40
Antimony	ppm	2.2	34733	870.78	40
Arsenic	ppm	2.2	2.8	2.51	40
Barium	ppm	5.2	160	86.96	40
Beryllium	ppm	0.71	13	4.66	40
Boron	ppm	3.5	5.7	4.13	40
Cadmium	ppm	0.22	0.46	0.28	40
Calcium	ppm	1600	26000	6340	40
Chlorides	ppm	5	402	110.33	40
Chromium	ppm	15	37	21.7	40
Cobalt	ppm	7	14	9.65	40
Copper	ppm	9	25	14.93	40
Cyanide	ppm	0.5	0.5	0.5	40
Fluorides	ppm	5	24	13.28	40
Iron	ppm	14000	29000	18650	40
Lead	ppm	7.1	33	15.42	40
Lithium	ppm	660	830	750.75	40
Magnesium	ppm	8.9	9400	3292.72	40
Manganese	ppm	64	970	343.8	40
Mercury	ppm	0.09	0.73	0.39	40
Molybdenum	ppm	1.8	2.2	2.01	40
Nickel	ppm	11	23	14.88	40
PCBs	ppm	0.17	92.5	15.56	40
Phosphates	ppm	5	490	107.8	40
Phosphorus	ppm	150	1100	404.25	40
Selenium	ppm	2.2	3	2.52	40
Silicon	ppm	1300	2100	1725	40
Silver	ppm	0	0.28	0.24	40
Sodium	ppm	220	280	250.75	40
Strontium	ppm	5.2	22	9.83	40
Tin	ppm	2.2	2.8	2.51	40
Titanium	ppm	97	160	127.18	40
Uranium	ppm	16	151	66.13	40
Uranium 234	pCi/g	9.18	32.4	20.81025	40

Table A.7 (continued)

Analysis	Units	Minimum	Maximum	Mean	N
Uranium 235	pCi/g	0.351	2.7	1.38915	40
Uranium 238	pCi/g	5.13	45.9	20.12175	40
Uranium Total	pCi/g	14.9	80.35	42.32	40
Vanadium	ppm	15	26	19.85	40
Water	wt	16	30	23.03	40
Zinc	ppm	24	49	37.15	40
Zirconium	ppm	3.1	8	5.45	40
Ash	wt	62.9	73.7	68.7	40
Flash Point	°C	85	99	96.15	40
Site > 20 mesh		19	64	41.15	40
Specific Gravity	—	1.5	2.7	1.89	40

Table A.8. OLF soils-in-place analytical results summary

Analysis	Unit	Phase I light ^a	Phase I dark ^a	Phase II ^b	Verification ^c
Oil and grease	%	5.2	12.3	3.5	
PCB-1254	mg/kg	8.4	5.5	4.2	
PCB-1260	mg/kg	ND	10.8	5.3	
Percent solids	%	82.5	82.3	80.5	
Total Uranium	mg/kg	48.6	63.3	74.5	
Total PCBs	mg/kg				8.3

^aPhase I = Initial comparison of light versus dark stained areas.

^bPhase II = Investigation by plot of entire OLF area.

^cVerification = Confirmatory samples collected at each soil removal site.

ND - not detected.

Table A.9. Chronological list of events at the Boneyard/Burnyard

Year	Event	Reference
1943	The Boneyard was used as a disposal site for waste from the Y-12 Plant. Burning and disposal of debris and sanitary, metallic, chemical, and radioactive wastes are known to have occurred. In the southwest corner of the Boneyard, metal chips were placed in pans in unlined earthen trenches and burned. The residue remaining in the trench was covered with topsoil and compacted until the trench was filled. The trench was then covered with topsoil and seeded with grass	Energy Systems 1991
1943	The Burnyard received ~1000 m ³ (4000 yd ³ /year) of sanitary refuse from plant operations including solids, liquids, and sludges. The wastes were placed in two unlined earthen trenches and burned. When filled, the trenches were covered with soil	
1968	Disposal of waste at the Burnyard was discontinued	
1970	Disposal of waste at the Boneyard site was discontinued	
1975–1981	A Hazardous Chemical Disposal Area was established on ~2 acres in the southeastern portion of Boneyard/Burnyard on top of the Burnyard. The area was used to burn or neutralize liquid and gaseous wastes. The material was broadly characterized as ignitable, reactive, corrosive, toxic, highly flammable, or in some instances inert	Energy Systems 1991 Energy Systems 1987b
1985	An investigation conducted by Bechtel National, Inc. on sediment samples collected downstream of the Boneyard indicated levels of mercury, uranium, several polynuclear aromatic hydrocarbons, and phthalates	Energy Systems 1987b
1989	The Hazardous Chemical Disposal Area was covered with a RCRA-type cap	Energy Systems 1991

Table A.10. Chronological list of events at SL 1

Year	Event	Reference
1968–1983	The site was used for the disposal of combustible and decomposable solid wastes. A total of ~27,000 m ³ (35,315 yd ³) of refuse was disposed of at the landfill	
1983	Waste disposal at the site was terminated	
1985	The site was closed by grading, capping with 0.6 m (2 ft) of clay, and establishing a vegetative cover	

Table A.11. Chronological list of events at the Burial Grounds

Year	Event	Reference
August 1955	Disposal at the Burial Grounds began with the disposal of solid waste in Unit A. The Burial Grounds consisted of waste disposal units A, B, C, D, E, and J. Each unit consisted of a series of trenches, 4.3 to 7.6 m (14 to 25 ft) deep, that were used for the disposal of liquid and solid wastes	Turner et al. 1991
July 1959	Large volumes of solvent-contaminated water and oils began being disposed of in BG-A	Turner et al. 1991
1959–1979	An estimated 2.3 million L (600,000 gal) of mop water were disposed of annually in BG-A	Turner et al. 1991, Battelle 1994
1961	A surface tank was installed in BG-A to hold waste oils and coolants; accumulations were burned. Liquids that did not burn were drained into trenches. An estimated 684,000 L (180,000 gal) of oil and coolants were disposed of by this method	
1962	BG-B was opened and used for disposal of depleted uranium metal and oxides	Turner et al. 1991
1962	BG-C was opened for the disposal of asbestos beryllium, beryllium oxide, lithium, technetium, thorium, and solid waste contaminated with these materials. Other materials contaminated with enriched uranium were also disposed of in BG-C	Turner et al. 1991
1966	The WIP were established in the Burial Grounds. The area was used to dispose of chemicals and uranium metal saw fines	Turner et al. 1991
1968	Burning of waste oils and coolants was terminated in BG-A	
1968	BG-B reached waste disposal capacity	
1968	BG-D was opened. The area was used to replace BG-B and received depleted uranium metals and oxides waste	
1969–1971	Oil was first observed seeping from the ends of trenches in BG-A into Tributary NT-7 and from the soil surface above the oil disposal pits	
January 1969	Oil and coolants were poured into standpipes that were installed in the trenches	Fig. A.7
1970–1981	Approximately 380,000 L (100,000 gal) of waste solvents were poured into rock piles and into waste-filled trenches in the southern part of BG-A	Turner et al. 1991
May 1971	ORP-1 was constructed with dimensions of 55 m (180 ft) long, 34 m (110 ft) wide, and 2 m (6 ft) deep	Bailey 1979
1971–1972	Approximately 497,403 L (131,400 gal) of oil and mop waters were sumped into a standpipe in the northeast corner of BG-D.	Bailey 1983b

Table A.11 (continued)

Year	Event	Reference
May 1972	ORP-2 was constructed on Tributary NT-6 at the northeast corner of BG-A	Bailey 1979
1974–1975	Approximately 57,000 L (15,000 gal) of oil were skimmed and removed from the surfaces of ORP-1 for disposal on the Oil Landfarm	
1975	Approximately 132,450 L (35,000 gal) of oil were collected from ORP-2 and placed on the OLF plots	Bailey 1983
1975	Since 1975, no significant accumulation of oil has occurred on surface of ORP-2	Bailey 1983
1975–1987	Historical monitoring at the site began as part of a program to identify groundwater contamination sources at Y-12 Plant	
1979	There were 68,400 L (18,000 gal) of oil removed from ORP-1	
1979	The disposal of mop water in BG-A was terminated	Turner et al. 1991
1979	Oil disposal ceased in the Burial Grounds	
1980	Trenches and disposal areas in the Burial Grounds that received hazardous wastes were designated and given interim status	
1980, 1982	A series of soil cores were collected along transects from the perimeter of ORP-1 for PCB analysis	
1981	After 1981, the WIP were used for disposal of uranium metal saw-fines, organics, and laboratory wastes	
1983	Water and sediment samples collected from sites in NT-6 and NT-7 were analyzed for VOCs, metals, cyanide, phenols, and a number of conventional water quality parameters. Several VOCs principally including 1,1-dichloroethane, tetrachloroethylene (PCE), trans-1,2-dichloroethylene, and trichloroethylene (TCE) were found in the sediments of ORP-1 and in both water and sediments of NT-7 downstream of the pond. VOCs were not detected in a water sample collected north of ORP-1, which indicated that the VOC source differed from that of PCBs	Turner et al. 1991
September 1983	Sediment samples collected from ORP-1 and NT-7 downstream of the pond did not show elevated levels of toxic metals, cyanide, or phenols in comparison to the control site on NT-7 upstream of the Burial Grounds	
September 1983	Samples from ORP-1 were found to contain PCBs ranging from 3 to 31 mg/L	
1983, 1984	Concentrations of PCBs in NT-7 channel sediments at the confluence with Bear Creek were reported to range from 5.2 to 28.2 mg/g	McCauley 1984

Table A.11 (continued)

Year	Event	Reference
December 1984	The Burial Grounds were granted interim status and therefore became subject to the groundwater monitoring requirements described in TN Rule 1200-1-11-.05	
1985–1988	Extensive sediment sampling throughout the tributary system showed that PCBs were present in concentrations of several hundred milligrams per gram in surface sediments of NT-7 between ORP-1 and the visible area of oil seepage at the west end of Burial Trench A-14 but declined below 25 mg/g by a depth of 60 cm (24 in.)	
October 1985	Five cores were collected from the bottom of ORP-1 and subdivided into 15-cm (6-in.) intervals for analysis. Concentrations of PCBs in surface sediments ranged as high as 710 mg/g but declined to 3 mg/g or less at a depth of 67.5 cm (27 in.)	Herbes 1989
February 1988	RCRA Closure Plan was revised	
1989	3060 m ³ (4,000 yd ³) of sludge and soils were excavated and placed in DARA Soil Storage Facility from ORP-1, ORP-2, and NT-7. An engineered cap was constructed over each pond and NT-7 under an approved RCRA closure plan. A new channel was constructed for NT-7, and this tributary was rerouted ~15 m (50 ft) west of its original course	Collins 1990a
1989	BG-A and BG-C west were closed in place as a landfill and covered with an engineered cap under RCRA	Collins 1990b
November 1990	TDEC granted approval for the final closure of BG-A	
1993	WIP and BG-B closure plan approved	
Fall 1993	Trib 8 collection system complete	
May 1994	WIP closure complete	
February 1995	WIP closure certified by State of Tennessee	
April 1995	DOE submits postclosure permit application modification to add WIP to BCV permit	
September 1995	TDEC issues revised BCV Hydrogeologic Regime postclosure permit incorporating WIP	

Table A.12. DARA soil data summary

Chemical	Units	N Sample	N > Quan. Limit	Min	Max	Average
<i>Detected Constituents</i>						
1,2,4,5-Tetrachlorobenzene	mg/kg	32	1	0.19	25	6.511
2,4-Dimethylphenol	mg/kg	32	12	0.19	5.1	1.06
Acetone	mg/kg	21	10	0.012	0.36	0.071
Anthracene	mg/kg	32	1	0.26	5.1	1.507
Antimony	mg/l	32	7	0.012	0.018	0.013
Barium	mg/l	32	1	5	5.1	5
Benao(a)anthracene	mg/kg	32	1	0.4	5.1	1.481
Cadmium	mg/l	32	1	0.01	0.012	0.01
Carbon disulfide	mg/l	21	5	0.003	0.01	0.007
Chloroethane	mg/kg	21	1	0.006	0.043	0.014
Chrysene	mg/kg	32	1	0.4	5.1	1.486
Ethyl ether	mg/kg	21	2	0.005	0.21	0.068
Fluoranthene	mg/kg	32	2	0.23	5.1	1.468
Lead	mg/l	32	1	0.05	0.41	0.061
Methanol	mg/l	32	3	0.5	3.87	0.725
Methyl isobutyl ketone	mg/kg	21	2	0.012	0.043	0.016
Naphthalene	mg/kg	32	1	0.21	5.1	1.505
Pentachlorobenzene	mg/kg	32	3	0.071	25	5.518
Pentachlorodibenzo-p-dioxins	µg/kg	32	2	0.04	0.39	0.137
Phenanthrene	mg/kg	32	6	0.079	5.1	0.852
Pyrene	mg/kg	32	5	0.14	5.1	0.889

Table A.12 (continued)

Chemical	Units	N Sample	N > Quan. Limit	Min	Max	Average
Tetrachlorodibenzo-p-dioxins	µg/kg	32	2	0.067	2.4	0.275
Trichlorofluoromethane	mg/kg	21	2	0.001	0.021	0.007
bis(2-Ethylhexyl)phthalate	mg/kg	32	13	0.073	5.1	1.25
<i>Analytical Results</i>						
1,2,4-Trichlorobenze	mg/kg	32	19	0.057	4.9	0.423
Aroclor-1254	mg/kg	32	32	14.5	103	49.963
Ethyl benzene	mg/kg	21	11	0.002	0.021	0.007
Hexachlorodibenzo-furans	µg/kg	32	27	0.098	2.92	1.065
Hexachlorodibenzo-p-dioxins	µg/kg	32	22	0.017	2.65	0.194
Methylene chloride	mg/kg	21	21	0.005	0.3	0.26
Nickel	mg/l	32	32	0.012	0.069	0.03
Pentachlorodibenzo-furans	µg/kg	32	31	0.17	3.41	0.799
Tetrachlorodibenzo-furans	µg/kg	32	32	0.12	6067	2.074
Toluene	mg/kg	21	11	0.004	0.062	0.011
Total Uranium	pCi/gm			9.78	199.55	47.24
Uranium-234	pCi/gm	32	32	5.527	114.2	26.59
Uranium-235	pCi/gm	32	32	0.241	4.911	1.031
Uranium-236	pCi/gm	32	32	0.099	3.532	0.0603
Uranium-238	pCi/gm	32	32	3.913	76.91	18.9
Xylene	mg/kg	21	13	0.001	0.024	0.01

**A7. SUPPORTING INFORMATION FOR APPENDIX A:
BEAR CREEK BURIAL GROUNDS WASTE INVENTORY**

A.7.1 INTRODUCTION

During planning for the BCVR RI, DOE, Energy Systems, and the regulators agreed that a detailed waste analysis, resulting in development of a waste inventory, would be conducted in lieu of sampling in the BCBG. Factors contributing to this decision included:

- existing caps prevented sampling of large areas of the BCBG;
- direct sampling of the wastes could be potentially dangerous because of the presence of pyrophoric materials; and
- collection of representative, statistically valid samples would have required an extensive, costly sampling program (involving millions of samples) because of the tremendous variability of waste materials in the BCBG.

The purpose of developing the waste inventories was to identify the primary waste types, waste quantities, and potential source term quantities of chemicals to support the human health risk assessment and contaminant plume modeling phases of the BCVR RI. The inventories provide suspected locations of waste disposals and estimates of waste quantities and should not be interpreted as presenting actual disposal history. Additionally, it should be noted that this inventory may not be complete; data gaps exist from the probability that nonradioactive waste inventory estimates were poorly maintained or never recorded and that other hazardous materials weren't recorded. There were also uncertainties associated with the waste inventory documents (e.g., the volume estimates varied, etc.). Nonetheless, the information presented in this section provides useful estimates for the modeling and human health risk assessment phases of the RI.

As noted in the introduction to Appendix A, classified information is not included in the BCVR RI Report or its appendixes. Classified elements and compounds potentially present in the BCBG are addressed in the separate Classified Operable Unit Assessment.

A.7.2 WASTE DISPOSAL RECORDS

Disposals at the BCBG between the 1950s and 1980 can be categorized according to the following three distinct disposal practices:

- **Blanket Disposals** (accounting for about two-thirds of the wastes delivered to BCBG). Operating areas in the Y-12 Plant initiated "blanket requests" to the Maintenance Division for routine pickups of their waste. A separate blanket request was required for each type of waste, and each request was valid only for the period of time (months or years) during which that particular type of waste was being generated. About 350 blanket requests have been active at one time or another since the early 1960s.
- **Debris Disposals** (accounting for about one-third of the wastes delivered to BCBG). One-time disposals were made of materials that pose no particular hazard. These materials included cans, bottles, boxes, glass, discarded equipment, and other miscellaneous items that are generated routinely during industrial operations.
- **Hazardous Disposals** (accounting for a small proportion of the total wastes). Nonroutine disposals of hazardous (e.g., toxic, explosive, reactive) materials were made several times a

day. UNC-2109 forms (i.e., Request for Hazardous Materials Disposal forms) or UNC-6538 forms (i.e., Request for Classified Materials Disposal forms), which describe the hazards and handling requirements involved in the disposal, as determined by the requester, were submitted to the Maintenance Division with each disposal.

The Y-12 Plant records maintained for these disposals provided a basis for developing a BCBG waste inventory for use in the BCBV RI. These records included:

- Activity Reports - In 1963 the Maintenance Division's Activity Reports began recording the number of blanket disposals made each month. These reports show that about 50,000 blanket disposals were made from 1963–1983.
- Kardex Blanket File - Of the 50,000 blanket disposals recorded on the Activity Reports, about 40,000 (80%) are described on Kardex Blanket File cards. The Kardex Blanket File cards for the remaining 10,000 (20%) blanket disposals have not been located. Although the amounts of waste disposed of via these 10,000 disposals are unknown, the types of wastes are assumed to have been similar to those listed on the existing cards. Only the data provided on the recovered Kardex Blanket files were included in the BCBG waste inventory used for the BCBV RI. Because blanket disposals account for about two-thirds of the total BCBG disposals, the available blanket disposal data included in the inventory represent about half (80% of two-thirds) of the wastes disposed of at the BCBG since 1963.
- Requests for Hazardous/Classified Disposals (forms 2109s/6538s) - Hazardous disposals make up a very small amount of the total material sent to the BCBG (Energy Systems 1993). The great variety of materials found through tabulation of 2109s and 6538s does not lend itself to a summary inventory such as that presented for blanket disposals. However, the number of 2109s found corresponds closely with the number of individual hazardous disposals mentioned in the Maintenance Division's Activity Reports, so the records presented in this area are essentially complete for the time period covered.
- Nuclear Materials Control and Accountability Waybill Records - These records document the movement of accountable nuclear materials such as uranium. In general, disposals documented in this system are also recorded in the various Maintenance Division records. However, a type of waybill known as a "741" allows separate identification of material that was shipped to the Y-12 Plant from other installations for disposal since 1977.
- Waste Management Inventory-Manifest System - In 1983 a classified inventory of waste materials delivered to the BCBG between the 1950s and 1980 was developed (Bailey 1983). A declassified version of the classified inventory was prepared (Energy Systems 1993), and all disposal information was collected in a computerized database known as the Waste Management Inventory-Manifest System.

The BCBG waste inventory developed and used for the BCBG is based on review of (1) 50,000 disposals tabulated from existing records, (2) 15,000 disposals included in the Waste Management Inventory-Manifest System, and (3) hundreds of pages of historical text. Despite the available documentation, the inventory is incomplete: many records were routinely discarded under approved procedures, and many items of information were never recorded. The primary data gaps are:

- No records have been found detailing the composition of disposals made in the initial trenches of Burial Ground 1. (These trenches later became Burial Ground A, trenches #1 through #5.)
- An inventory of materials placed in the B and C areas during the early 1960s comes from an engineering drawing (E-CV-62373). Data from 1960 to 1964 are not accounted for in any other data source. Data after 1964 probably overlap with other reported information, but the extent of this overlap is impossible to determine.

A.7.3 INVENTORY REVIEW

The BCBG have been segmented into seven primary areas for presentation of this inventory review: Area-A, Area-B, Area-C, Area-D, Area-E, Area-J, and WIP. Inventory data are summarized, by area or sub-area, in Tables 1 through 15. Each table presents the primary waste constituents, estimated inventory mass (Kg), estimated concentration (mg/Kg), general physical form of the material, assumptions leading to the mass and concentration estimates, and a source reference for the estimates. Brief narratives regarding each area are presented in Sect. A.1.3.5.

Reference documentation used as resource material in compiling this information includes a 10-volume, classified waste inventory summary (up to 1982), computerized waste inventory records (1982 through 1989), personnel interviews, and additional classified and nonclassified records and documents (Energy Systems 1983 through 1988).

Tables A.13 through A.17 provide the inventory estimates and primary constituent concerns for Area A. Areas B, D, E, and J are dominated by uranium disposals, as shown in Tables A.18, A.21, A.22, and A.23. Area C was designed for the disposal of beryllium, enriched uranium, thorium, and technetium contaminated industrial wastes, with inventory estimates presented in Tables A.19 and A.20. The WIP were used for the disposal of a wide variety of laboratory and industrial chemicals, as indicated in Tables A.24 and A.25.

A.7.4 PRIMARY ASSUMPTIONS

As described in Sect. A.4, a detailed waste inventory analysis was conducted in lieu of sampling in the BCBG. To obtain equivalent concentrations needed for the risk assessment, a number of assumptions about the waste inventory had to be made. The primary assumptions implemented in this review and accumulation of data are itemized in the following subsections.

A.7.4.1 General Assumptions

- All concentrations have been derived based on the assumption that the quantity of contaminant is distributed equally throughout the trenched area of each location.
- Trench weights have been determined based on the volume of the trench, an assumed soil density of 2.2 g/cc, and an assumed void volume of 40% (based on close-pack spherical particles). The assumed weight of uranium was then added to this mass to obtain a total weight for trench material in the area.

- For those wastes identified through inventory records in gallons, the general assumption has been made that there are 8 lb/gal and 2.2 lb/Kg. Actual compound densities, when they were considered, are noted.

A.7.4.2 Disposal Area Volume Estimates

- These estimates are calculated from trench dimensions provided in Appendix B of the RI Work Plan for Bear Creek OU 1 (DOE 1993):

Area A South	61,122 yd ³	1,650,300 ft ³
Area A North	86,095 yd ³	2,324,600 ft ³
Area A16	44,000 yd ³	1,188,000 ft ³
Area A17	68,000 yd ³	1,836,000 ft ³
Area A18	34,000 yd ³	918,000 ft ³
Area B	14,468 yd ³	390,600 ft ³
Area C East	11,546 yd ³	311,700 ft ³
Area C West	30,100 yd ³	812,700 ft ³
Area D East	10,670 yd ³	288,100 ft ³
Area D West	1,100 yd ³	29,700 ft ³
Area D South	85 yd ³	2,300 ft ³
Area E	3,516 yd ³	94,900 ft ³
Area J	5,278 yd ³	142,500 ft ³
WIP North	21,404 yd ³	577,900 ft ³
WIP South	13,692 yd ³	369,700 ft ³

A.7.4.3 Uranium Assumptions

- Uranium is assumed to be in the form of UO₂, with a density of 10.96 g/cc and a percent uranium of 88.15. Other options, not used, are uranium as U₃O₈, with a density of 8.30 g/cc and a percent uranium of 84.09, and pure uranium metal with a density of 19.05 g/cc.
- The Y-12 Kardex Blanket File disposal records were used to estimate the total mass of uranium buried in the entire BCBG. Nineteen of these disposal records, encompassing major bulk uranium types (e.g., chips, saw fines, alloy, parts) over a 17-year period, totaled 26.2×10^6 lb of uranium materials. This volume is equivalent to 11.9×10^6 Kg as UO₂ or 10.5×10^6 Kg as uranium. A per-year estimate of 620,000 Kg/year of uranium, multiplied by a 30-year site history, provides an estimate of 18.6×10^6 Kg of uranium sent to the BCBG.
- Uranium chips (material varying from fine metallic filings to machine shop turnings and large chunks of metal) went primarily to Areas B, D, and J, when these areas were open.
- Area E received uranium metal parts.
- Areas D-West, E, and J form a geographically contiguous group of trenches and have been combined to estimate a uranium concentration for that area. Area D-West comprises trenches D-44, -45, -46, and -47.

- Although Areas C-East and C-West had been designated for thorium and beryllium disposals, a certain amount of depleted uranium-contaminated material and uranium metals were also deposited in these areas according to Kardex Blanket File records and other inventory records, it is assumed some enriched uranium was also deposited in this area as well.
- WIP areas are assumed to contain uranium saw fines. As with any fine particle metallic material, these were and potentially still are, highly combustible and explosive.
- Disposal Areas A-16 through A-18 contain contaminated wastes and debris from more recent year activities (about 1985 through 1991). As a result of increased awareness, recycling, and reuse, the quantities of uranium contained in these materials are assumed to be significantly lower than for other Area A locations.
- Mop water contains ~80 ppm uranium (Turner et al. 1991).
- Machine coolant/waste oil contains ~40 ppm uranium (Turner et al. 1991).
- The contribution of each burial ground to the total uranium deposited in the BCBG is assumed to be:

Assumed percentage by weight (%)

Area A South	5.0
Area A North	5.0
Area A16-A18	0.5
Area B	33.0
Area C East, West	5.0
Area D East, West, South	20.0
Area E	6.5
Area J	10.0
Walk-In North	9.0
Walk-In South	6.0

- For risk assessment purposes, a natural uranium isotopic distribution should be assumed for all uranium forms in the BCBG.

A.7.4.4 Thorium Assumptions

- Most thorium metals and contaminated materials were disposed of in Area C, with a smaller amount being associated with Area B, Area A-North, and WIP North. Before these areas were opened, thorium waste was not knowingly taken to the BCBG.
- Historical release reports indicate 18.4 Ci of thorium was deposited in the BCBG, and the assumption has been made that these disposals are distributed as follows:

Area C-East	37.5%
Area C-West	57.5%
Area B	5.0%

- A one-time thorium sludge disposal of 276 Kg of thorium was made to Area A North.
- WIP North has a recorded inventory estimate for thorium.
- Thorium should be assumed to be ^{232}Th , the thorium isotope that is most abundant and has the longest half-life.

A.7.4.5 Technetium Assumptions

- Most technetium was disposed of in Area C-West (80%), with the remaining 20% being associated with Area A-North. Before these areas were opened, technetium waste was not knowingly taken to the BCBG.
- Historical release reports indicate that 10.7 Ci of technetium was deposited in the BCBG, and the assumption has been made that these disposals are distributed according to the above percentages.
- Technetium is assumed to be ^{99}Tc .

A.7.4.6 Beryllium Assumptions

- All beryllium oxide and contaminated debris disposals went to Areas C-East and C-West from 1962 through 1989. Kardex Blanket File records divided beryllium disposals into two categories: beryllium oxide and beryllium-contaminated materials.
- Quantities of solid and scrap beryllium material in three Kardex Blanket File records over a 15-year period of time were totaled and then divided by 15 to obtain an estimated average yearly disposal rate of 1,650 Kg beryllium per year.
- Area C is assumed to have received this material over a 28-year time period, yielding a total beryllium mass of 28 years times 1,650 Kg/year.
- Beryllium-contaminated debris contains 0.05% beryllium by weight. Quantities of beryllium-contaminated debris in eight Kardex Blanket File records over a 15-year period of time were totaled and then divided by 15 to obtain the estimated average yearly disposal rate of 90 Kg beryllium per year.
- Area C is assumed to have received this material over a 28-year time period, yielding a total beryllium mass of 28 years times 90 Kg/year.
- These two estimates are then added to obtain an estimated 48,700 Kg of beryllium deposited in Area C.
- Mop water contains ~0.04 ppm beryllium (Turner et al. 1991).
- Machine coolant/waste oil contains ~12 ppm beryllium (Turner et al. 1991).

A.7.4.7 Lithium Assumptions

- Lithium disposals are recorded for Areas A and C.
- Estimates from Kardex Blanket File records indicate 12,000 Kg of lithium disposed of in Area C.
- Exact lithium compound composition can not be determined; however, most of the compound types disposed of can be assumed to have oxidized and hydrolyzed. Therefore, the lithium is assumed to be in the form of LiOH.
- Mop water contains ~2 ppm lithium (Turner et al. 1991).
- Machine coolant/waste oil contains ~4.5 ppm lithium (Turner et al. 1991).

A.7.4.8 Asbestos Assumptions

- Asbestos was not recognized as a hazardous substance until the mid-1970s. Therefore, its disposal before that time was not documented or quantitated and cannot be determined.
- Based on Kardex Blanket File records, 20,000 Kg/year of asbestos is assumed to have been taken to Area A-North between 1977 and 1990 (13 years).
- The location in Area A-North designated as the Asbestos Area has been assumed to include A-8E pit #s 22 through 27, A-9E pit #s 28 through 33, and A-10E pit #s 17 through 21. The estimated volume of these pits is 95,100 ft³.

A.7.4.9 PCB Assumptions

- Recorded disposals and removals for Area BG-A are summarized in Table A.26.
- Unless specified in the disposal records (Bailey 1995), PCB disposals to Area A were assumed to be divided equally between Areas A-South and A-North.
- Recorded oil removals from BG-A were considered in calculating the PCB at the site. Because PCBs sorb well to soil particulates, 85% of any unit volume of PCBs is assumed to have remained, only 15% being present in the removed liquids.
- Volumes of waste oils/coolants disposed of in Area A were adjusted to reflect that PCB-containing oils burned during the 1950s and until 1968 or 1969. About 25% of the volume of waste oils and coolants described in the chemical inventory tables is assumed to have been disposed of by burning. This value represents the assumption that 50% of the oils/coolants burned from 1958 through 1968 remained (and that 50% of the original PCB remained as well).
- Many potential sources and disposals of PCB-containing wastes were never documented. Therefore, estimates for PCBs are considered minimum contents. Records of Z-oil system disposals could not be identified to estimate this source of PCB disposal. Significant amounts of PCB-containing liquids may have been disposed of in the BCBG, which are unaccounted for in this report.

- Pyranol (trade name for PCB oil) transformer oil contains 50% PCBs.
- All Therminol (trade name for PCB oil) disposals were considered to be disposals of Therminol-FR-0.
- The following densities were assumed for all PCB estimations:

Aroclor-1242	density = 1.41 g/cc
non-PCB component of transformer oil	density = 1.2 g/cc
non-PCB component of Therminol	density = 0.82 g/cc
non-PCB component of other oils	density = 1.2 g/cc

A.7.4.10 Mop Water Assumptions

- Equal distribution of mop water disposal between Areas A-South and A-North is assumed.
- Disposal of an estimated 600,000 gal/year is assumed, based on records between 1971 through 1978. Records were not kept for previous years.
- The same quantity is assumed for all years up to 1979, when liquid disposal ended (20 years).

A.7.5 TOTAL URANIUM ESTIMATE COMPARISONS

A comparison to disposal estimates acquired and reported under the SWIMS (Mynatt 1991) program provides a level of confidence to the order of magnitude estimated through this review. Table A.27 and Fig. A.9 present the total uranium estimated by this review (18.6×10^6 Kg as uranium) and compare that total to a 1989 historical release report total (17.3×10^6 Kg) (DOE 1988).

A8. SUPPORTING INFORMATION FOR APPENDIX A—TABLES

Table A.13. Estimated disposals at Burial Ground A-South
Active: 1956 - 1981. Disposal Area Volume: 61,122 cu. yd.

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	0.93 × 10 ⁶ Kg as U		contaminated debris	Estimated uranium content based on assumption that 5% of the total uranium disposals went to Area A-South	i
	2,000 Kg as U		solid particle in oil or water	Waste oil and mop water estimated uranium contribution	ii, iii
Total Uranium	0.93 × 10 ⁶ Kg as U	15,000 mg/Kg as U			
Lithium	72 Kg	1.1 mg/Kg as Li	particle in oil or water	Waste oil and mop water estimate	ii, iii
Beryllium	75 Kg	1.2 mg/Kg	particle in oil or water	Waste oil and mop water estimate	ii, iii
Vythene (1,1,1-trichloroethane or TCA)	60,000 Kg	960 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Varsol	59,000 Kg	940 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Perchloroethylene	56,000 Kg	890 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Freon	30,000 Kg	480 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Benzene	8,500 Kg	140 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Trichloroethylene	5,300 Kg	85 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii

Table A.13 (continued)

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Methyl ethyl ketone	3,900 Kg	62 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Alcohol ^a	24,000 Kg	380 mg/Kg	liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
Fuel-water ^b	57,000 Kg		liquid	Isolation area inventory (1970-79) was doubled to account for all years of potential disposal in the A-South area	ii
PCBs	1,400 Kg	21 mg/Kg	liquid	Estimate based on recorded inventory information	iv, v
Asbestos ^c					
Waste oils and coolants ^d	1,700,000 gal		liquid	Estimate based on inventory from 1969-79 doubled to cover 1958-79	ii
Mop waters	6,000,000 gal		liquid	Estimate 600,000 gal/yr disposal from 59-79. Assume equal distribution of mop water disposal between A-South and A-North	ii

^a Assume this to be methanol.

^b Assume a gasoline/water mixture, with primary contaminants of Benzene, Toluene, Ethylbenzene, Xylene.

^c Asbestos was not recognized as a hazardous substance until the mid-1970s, therefore, its disposal prior to that time was not documented or quantitated and cannot be determined.

^d These comprise system coolant oils and liquids, machine oils, vehicle oils, etc. — on the entire spectrum of industrial oil and coolant materials that may have been employed at the plant.

Sources:

i. Energy Systems 1996.

ii. Battelle 1994.

iii. Turner et al 1991.

iv. Bailey 1995.

v. Mappes 1995.

Table A.14. Estimated disposals at Burial Ground A-North
Active: 1969 - 1981. Disposal Area Volume: 86,095 cu. yd.

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	0.93 × 10 ⁶ Kg as U		contaminated debris	Estimated uranium content based on assumption that 5% of the total uranium disposals went to Area A-North	i
	1,800 Kg as U		solid particle in oil or water	Waste oil and mop water estimated uranium contribution	ii, iii
Total Uranium	0.93 × 10 ⁶ Kg as U	11,000 mg/Kg as U			
Lithium	53 Kg as Li	0.6 mg/Kg as Li	solid particle in oil or water	Waste oil and mop water estimate	ii, iii
Thorium	280 Kg as Th	3.1 mg/Kg as Th	sludge material	One time large volume sludge disposal	i
Beryllium	27 Kg as Be	0.3 mg/Kg as Be	solid particle in oil or water	Waste oil and mop water estimate	ii, iii
Technetium	0.13 Kg	0.0014 mg/Kg		Estimate based on total Tc-99 of 10.7 Ci	iv, i
Asbestos	260,000 Kg	73,000 mg/Kg	debris	Kardex blanket estimate of 20,000 Kg/yr from 1977-90. Asbestos disposal area of 95,100 ft ³ assumed	v
PCBs	110,000 Kg	1,300 mg/Kg	liquid	Estimate based on recorded inventory information	vi, vii
Waste oils and coolants ^a	590,000 gal		liquid	Estimate based on inventory from 1971-79	ii
Mop waters	6,000,000 gal		liquid	Assume equal distribution of mop waters between A-North and A-South	ii

^a These comprise system coolant oils and liquids, machine oils, vehicle oils, etc. and represent the entire spectrum of industrial oil and coolant materials that may have been employed at the plant.

Sources:

- i. Energy Systems 1996.
- ii. Battelle 1994.
- iii. Turner et al. 1991.
- iv. DOE 1988.
- v. Bailey 1983.
- vi. Bailey 1995.
- vii. Mappes 1995.

Table A.15. Estimated disposals at Burial Ground A-16
Active: 1983 - 1987. Disposal Area Volume: 44,000 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	27,000 Kg as U	610 mg/Kg as U	contaminated debris	Estimated uranium content based on assumption that 0.5% of the total uranium disposals went to Areas A16-A18	i

Table A.16. Estimated disposals at Burial Ground A-17
Active: 1983 - 1987. Disposal Area Volume: 68,000 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	42,000 Kg as U	610 mg/Kg as U	contaminated debris	Estimated uranium content based on assumption that 0.5% of the total uranium disposals went to Area A16-A18	i

Table A.17. Estimated disposals at Burial Ground A-18
Active: 1988 - 1991. Disposal Area Volume: 34,000 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	21,000 Kg as U	610 mg/Kg as U	contaminated debris	Estimated uranium content based on assumption that 0.5% of the total uranium disposals went to Area A16-A18	i

Source:

i. Energy Systems 1996.

Table A.18. Estimated disposals at Burial Ground B
Active: 1962 - 1968. Disposal Area Volume: 14,468 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Total Uranium	6.14×10^6 Kg as U	300,000 mg/Kg as U	metallic chips	Estimated uranium content based on assumption that 33.0% of the total uranium disposals went to Area B	i
Thorium	0.84×10^4 Kg	410 mg/Kg as Th	saw fines	Estimated based on assumption that 5.0% of a total 18.4 Ci of thorium was equally distributed in Area B	ii, i
PCB ^a					

^a Existing disposal records are inadequate to provide relevant quantities and concentrations for this area of the Burial Grounds. It is recommended available groundwater and surface water analysis be employed to develop risk assessment estimates for PCB contamination.

Sources:

- i. Energy Systems 1996.
- ii. DOE 1988.

Table A.19. Estimated disposals at Burial Ground C-East
Active: 1962 - 1989. Disposal Area Volume: East = 11,546 yd³; West = 30,100 yd³; Total = 41,646 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	0.25 × 10 ⁶ Kg as U	21,000 mg/Kg as U	debris and chips	Estimated uranium content based on assumption that 5.0% of the total uranium disposals went to Area C ^a	i
Asbestos ^b					
Lithium	3,400 Kg as Li	280 mg/Kg as Li	compounds	Estimate from Y/DS-171, Parts 4 & 5.	i
Beryllium	13,000 Kg as Be		metallic materials (chips)	Kardex blanket estimate of 1,650 Kg/year estimated for 28 years.	i
	700 Kg as Be		contam. material	Kardex blanket estimate of 90 Kg/year assuming material contamination of 0.05% Be.	i
Total Beryllium	14,000 Kg as Be	1,100 mg/Kg as Be			
Thorium	6.33 × 10 ⁴ Kg	5,300 mg/Kg as Th	chips	Estimated based on assumption that 37.5% of a total 18.4 Ci of thorium was equally distributed in Area C-East	ii, iii

^a A volume proportional distribution has been assumed between sections east and west.

^b Asbestos was not recognized as a hazardous substance until the mid-1970s, therefore, its disposal prior to that time was not documented or quantitated and cannot be determined.

Sources:

i. Bailey 1983.

ii. DOE 1988.

iii. Energy Systems 1996.

Table A.20. Estimated disposals at Burial Ground C-West
Active: 1962 - 1989. Disposal Area Volume: East = 11,546 yd³; West = 30,100 yd³; Total = 41,646 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium	0.68 × 10 ⁶ Kg as U	22,000 mg/Kg as U	debris and chips	Estimated uranium content based on assumption that 5.0% of the total uranium disposals went to Area C ^a	i
Asbestos ^b					
Lithium	8,600 Kg as Li	280 mg/Kg as Li	compounds	Estimate from Y/DS-171, Parts 4 & 5.	i
Thorium	9.71 × 10 ⁴ Kg as Th	3,100 mg/Kg as Th	contam. debris and solid material (chips)	Estimated based on assumption that 57.5% of a total 18.4 Ci of thorium was equally distributed in Area C-West	ii, iii
Beryllium	33,000 Kg as Be		metallic materials (chips)	Kardex blanket estimate of 1,650 Kg/year estimated for 28 years.	i
	1,800 Kg as Be		contam. material	Kardex blanket estimate of 90 Kg/year assuming material contamination of 0.05% Be.	i
Total Beryllium	35,000 Kg as Be	1,100 mg/Kg as Be			
Technetium	0.50 Kg	0.016 mg/Kg		Estimated based on assumption that 80% of a total 10.7 Ci of technetium was equally distributed in Area C-West	ii, iii

^a A volume proportional distribution has been assumed between sections east and west.

^b Asbestos was not recognized as a hazardous substance until the mid-1970s, therefore, its disposal prior to that time was not documented or quantitated and cannot be determined.

Sources:

i. Bailey 1983.

ii. DOE 1988.

iii. Energy Systems 1996.

Table A.21. Estimated disposals at Burial Ground D-East
Active: 1968 - 1989. Disposal Area Volume: 10,670 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Total Uranium	3.35 × 10 ⁶ Kg as U	240,000 mg/Kg as U	metallic chips	Uranium estimates ^a	i

Table A.22. Estimated disposals at Burial Ground D-South
Active: 1988 - 1990. Disposal Area Volume: 85 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Total Uranium	0.03 × 10 ⁶ Kg as U	240,000 mg/Kg as U	metallic chips	Uranium estimates ^a	i

Table A.23. Estimated disposals at Burial Grounds D-West, E, and J
Active: 1983 - 1990. Disposal Area Volume: "D-West" = 1,100 yd³; "E" = 3,516 yd³; "J" = 5,278 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Uranium Area D-West	0.35 × 10 ⁶ Kg as U		metallic chips	Uranium estimates ^a	i
Uranium Area E	1.21 × 10 ⁶ Kg as U		metallic blocks	Estimated uranium content based on assumption that 6.5% of the total uranium disposals went to Area E	i
Uranium Area J	1.86 × 10 ⁶ Kg as U		metallic chips	Estimated uranium content based on assumption that 10.0% of the total uranium disposals went to Area J	i
Total Uranium	3.34 × 10 ⁶ Kg as U	260,000 mg/Kg as U		Areas are geographically contiguous and have been considered as one unit	i

^a Estimated uranium content based on assumption that 20.0% of the total uranium disposals went to Area D and Area D disposals were proportionally distributed between east, west, and south by volume.

Source:

i. Energy Systems 1996.

Table A.24. Estimated disposals at Burial Ground Walk-In Pit 1 (North)

Active: 1966 - 1989. Disposal Area Volume: 21,404 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Total Uranium	1.67 × 10 ⁶ Kg	72,000 mg/Kg as U	metallic fines	Estimated uranium content based on assumption that 9.0% of the total uranium disposals went to WIP North	i
Acetic acid	14 Kg	0.6 mg/Kg	liquid	Inventory accounting	ii
Acetone ^a					i
Alcohols ^b					i
Alizarin	0.03 Kg	0.001 mg/Kg	solid	Inventory accounting	i
Aluminum	7 Kg	0.3 mg/Kg	solid	Inventory accounting	i
Ammonia compounds ^c	11 Kg	0.5 mg/Kg	solid	Inventory accounting	i
Arsenic	0.1 Kg	.004 mg/Kg	solid	Inventory accounting	i
Asbestos ^d					i
Benzene	3,000 Kg	130 mg/Kg	liquid	Inventory accounting	i
Benzidine	730 Kg	31 mg/Kg	liquid	Inventory accounting	i
Beryllium	610 Kg	26 mg/Kg	solid	Inventory accounting	i
Bromine	23 Kg	1.0 mg/Kg	liquid	Inventory accounting	i
Carbon tetrachloride ^a					i
Chloroform	0.25 Kg	0.01 mg/Kg	liquid	Inventory accounting	i
Chromium compounds ^e	100 Kg as Cr	4.4 mg/Kg	liquid	Inventory accounting	i
Cyanide	0.48 Kg	0.02 mg/Kg	liquid	Inventory accounting	i
Cyclohexane ^a					i

Table A.24 (continued)

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
DDT	110 Kg	4.9 mg/Kg	liquid	Inventory accounting	i
Epoxys ^f	2,200 Kg	95 mg/Kg	liquid	Inventory accounting	i
Ether ^g	14 Kg	0.6 mg/Kg	liquid	Inventory accounting	i
Ethyl alcohol	2.6 Kg	0.1 mg/Kg	liquid	Inventory accounting	i
Formaldehyde	10 Kg	0.4 mg/Kg	liquid	Inventory accounting	i
Hydrazine	2.2 Kg	0.09 mg/Kg	liquid	Inventory accounting	i
Lead	140 Kg	6.0 mg/Kg	solid	Inventory accounting	i
Lithium compounds ^h	68 Kg	2.9 mg/Kg	solid	Inventory accounting	i
Mercuric chloride	400 Kg	17 mg/Kg	solid	Inventory accounting	i
MEK ^a					i
MIBK ^a					i
Nickel	120 Kg	5.2 mg/Kg	solid	Inventory accounting	i
Phenol	1,100 Kg	47 mg/Kg	liquid	Inventory accounting	i
Picric acid ⁱ					i
PCBs	40 Kg	1.7 mg/Kg	liquid	Inventory accounting with estimations	iii, iv
Thorium	14,000 Kg	580 mg/Kg	saw fines	Inventory accounting	i
Toluene ^a					i
Trichloroethane	180 Kg	7.7 mg/Kg	liquid	Inventory accounting	i
Waste oils	1,800 Kg	77 mg/Kg	liquid	Inventory accounting	i
Xylene ^a					i

Table A.24 (continued)

- ^a These various common laboratory solvents were listed in records without associated quantities. They have been included here to identify their potential presence and will be dealt with qualitatively in further evaluations.
- ^b Methanol can be assumed.
- ^c Ammonium bifluoride and ammonium fluoride are recorded in the inventory.
- ^d Asbestos was not recognized as a hazardous substance until the mid-1970s, therefore, its disposal prior to that time was not documented or quantitated and cannot be determined.
- ^e This can be assumed to be Hexavalent chromium. Compounds were probably of a chromic acid type and were placed in the WIP due to their highly oxidative and explosive nature.
- ^f Assume these epoxys are comprised of a polyolefin oxidized with peracetic acid.
- ^g Assume this to be partially crystallized ethyl ether with explosive potential.
- ^h Exact lithium compound composition cannot be determined, however, it can be assumed most of the compound types disposed would have oxidized and hydrolyzed. Therefore, the assumption can be made that the lithium is LiOH.
- ⁱ Initially, picric acid residues were disposed of in WIP North as an explosive waste; later, when space became limited they were taken to WIP South. Amount could not be estimated from existing information.

Sources:

- i. Energy Systems 1996.
- ii. Bailey 1983.
- iii. DOE 1988.
- iv. Mappes 1995.

Table A.25. Estimated disposals at Burial Ground Walk-In Pits 2 and 3 (South)
Active: 1966-1989. Disposal Area Volume: 13,692 yd³

Waste constituent	Estimated inventory mass	Estimated concentration in the unit	General form	Assumptions	Ref.
Total Uranium	1.12 × 10 ⁶ Kg	75,000 mg/Kg as U	metallic fines	Estimated uranium content based on assumption that 6.0% of the total uranium disposals went to WIP South	i
Mixed acids ^a	1200 Kg	80 mg/Kg	liquid	Inventory accounting	ii
Chromium ^b	700 Kg	47 mg/Kg	solids	Inventory accounting	ii
Mercury	31 Kg	2 mg/Kg	solids	Inventory accounting	ii

^a Mixture includes hydrochloric acid, nitric acid, picric acid (potentially partially crystallized), plus others. Since the exact mixture is unknown, the most toxic acid should be assumed for risk assessment.

^b This can be assumed to be Hexavalent chromium. Compounds were probably of a chromic acid type and were placed in the WIP due to their highly oxidative and explosive nature.

Sources:

- i. Energy Systems 1996.
- ii. Bailey 1983.

Table A.26. BG-A - Summary of recorded PCB disposals and removals

Area	Disposals ^{a,b}	Removal ^c
A-North	<p>131,440 gal oil (1971-1972), assumed: 16% PCB (equivalent of 20% Therminol)</p> <p>220 gal M-Wing coolant (known: 20% Therminol, 10% mineral oil, 70% PCE)</p> <p>97.5 gal transformer oil (1971) (Pyranol) (assumed: 50% PCBs)</p> <p>385 gal M-Wing coolant (1970) (known: 30% PCE, 10% mineral oil, 60% Therminol)</p> <p>990 gal M-Wing coolant with Therminol (1971) (assumed: 10% mineral oil, 70% PCE, 20% Therminol)</p> <p>4.9E+05 gal waste oils/coolants (1969-1979) (includes above)</p>	<p>35,000 gal collected oil (1975) sent to Oil Landfarm plots</p>
A-South	<p>220 gal M-Wing coolant (known: 20% Therminol, 10% mineral oil, 70% PCE)</p> <p>385 gal M-Wing coolant (1970) (known: 30% PCE, 10% mineral oil, 60% Therminol)</p> <p>97.5 gal transformer oil (1971) (Pyranol) (assumed: 50% PCBs)</p> <p>1.28E+06 gal oils/coolants (1969-1979) (includes above)</p>	<p>15,000 gal (1974) to Oil Landfarm plots</p> <p>18,000 gal (1979) to underground storage tanks</p>

^a Volumes were calculated using the assumption that (unless specified) "drums" cited in records are 55 gal.

^b Non-PCB component of Therminol assumed to have the same density as mineral oil (0.822 g/cc), and the non-PCB portion of the total waste oils/coolants disposed in each area was assumed to have a density of 1.2 g/cc.

^c 5000 gallons of oil were removed from ORP-1 in 1975; because they were sprayed on trees adjacent to the pond, this volume was not considered as a removal.

PCE - perchloroethene

Table A.27. Summary of estimated uranium quantities by Burial Grounds area^a

Area	Assumed % of total Kardex estimated	Estimated Uranium mass (Kg)	Estimated Uranium concentration (mg/Kg)
A-South	5.0	0.93×10^6	15,000
A-North	5.0	0.93×10^6	11,000
A-16 thru 18	0.5	0.09×10^6	610
B	33.0	6.14×10^6	300,000
C	5.0	East 0.25×10^6	21,000
		West 0.68×10^6	22,000
D	20.0	East 3.35×10^6	240,000
		South 0.03×10^6	240,000
		West 0.35×10^6	260,000
E	6.5	1.21×10^6	260,000
J	10.0	1.86×10^6	260,000
Walk-In North	9.0	1.67×10^6	72,000
Walk-In South	6.0	<u>1.12×10^6</u>	75,000

18.6×10^6 Kg as uranium

Kardex File Total Estimate

Nineteen Kardex Blankets over a 17-year period totaled 26.2×10^6 lbs of uranium type materials. This is equivalent to 11.9×10^6 Kg as UO_2 or 10.5×10^6 Kg as U. A per-year estimate then becomes 620,000 Kg/year of uranium, multiplied by a 30-year site history provides a total estimate of 18.6×10^6 Kg as uranium.

Comparison (DOE 1988)

17.3×10^6 Kg of uranium

The "Historical Radionuclide Releases, May 1988" reports a total of 19.3×10^6 Kg buried, corrected for overestimates of uranium mass due to water weight (1.5×10^6 Kg) and uranium transported to X-10 Site (522,000 Kg), provides the final estimate above uranium. This includes pre-1972 liquid materials containing uranium that were not actually placed in the landfill but were transferred off-site or to S-3 Ponds, which were considered as solid material entering the landfill.

^aReference is also made to Fig. A.9.

APPENDIX B

DESCRIPTION OF THE FIELD ACTIVITIES AND REPORT DATABASE

B.1 INTRODUCTION

An extensive database of environmental data for the Bear Creek Valley (BCV) Characterization Area (CA) was derived from (1) recent remedial investigation (RI) field activities conducted during 1994 and 1995 and from (2) historical field studies conducted during the 1980s and early 1990s. The extent and quality of this environmental database are summarized in this appendix. This appendix also presents information about the number and location of samples collected, the analytes examined in those samples, and the extent of data validation or data quality review. The focus is on the type and extent of environmental sampling in BCV, rather than the results of analyses.

This appendix is subdivided into six sections. Section B.2 summarizes the historic database, and Sect. B.3, B.4, and B.5 describe the sampling activities conducted during 1994 and 1995 for:

- BCV Operable Unit (OU) 1 — field activities addressing the source waste sites;
- BCV OU 4 — field activities addressing the main hydrological pathways for contaminant migration in BCV;
- floodplain soil/sediment (FPSS) investigation — field activities addressing secondary contamination in the BCV floodplain and pathways to ecological receptors within the valley; and
- biota sampling — addressing transfer of contaminants from physical media to plants and animals.

An evaluation of the data quality is presented in Sect. B.6 for the historic groundwater data and in Sect. B.7 for the data from the three recent field activities.

B.2 SUMMARY OF HISTORICAL DATA FOR BCV

Historical data for the 1995 BCV RI are defined as those data collected within the BCV before 1994 and not as part of the recently completed OU 1, OU 4, or FPSS investigations. This definition encompasses historical characterization and monitoring activities, ongoing monitoring activities, and special investigations. The types of historical data that exist include physical and chemical analyses of the primary environmental media (surface water, groundwater, soil, sediment waste) plus biological, ecological, geological, and meteorological data for a host of sites within the valley. Also included are the waste disposal records maintained from the 1950s to 1980, which were used to develop the waste inventory for the Bear Creek Burial Grounds (BCBG) (Supporting Information for Appendix A, Sect. A.6).

Literally thousands of samples have been collected from the BCV CA during the last 40 years as part of nearly 100 studies. Although some monitoring was conducted as early as the 1950s and 1960s, most of the historical data have been generated since 1982. These investigations have been conducted by the Oak Ridge Y-12 Plant, Oak Ridge National Laboratory (ORNL), Tennessee Valley Authority, U.S. Geological Survey (USGS), and companies under subcontract to Union Carbide or Lockheed Martin Energy Systems, Inc. (Energy Systems).

Table B.1 lists the historical studies that were reviewed for the BCV RI Report. The studies for which data are included in the BCV RI electronic database are shaded entries (although in some cases, only some of the data were captured). The electronic historical database includes results from more than 10,000 samples. Of particular note for their excellent summaries of historical sampling events and data collected from Bear Creek are:

- 1991 BCV RI Work Plan (Turner et al. 1991), which provide the most comprehensive coverage available;
- sampling history for the Oil Landfarm (OLF) area (Herbes 1989); and
- sampling history for the Oil Retention Ponds (ORPs)-1 and -2 (Herbes 1988).

The methodologies used in the historical studies for BCV vary widely. Sampling and analytical methods, including quality control measures, have changed over the years as techniques and protocols have evolved. In some cases, documentation of procedures is unavailable. Differing sampling designs, study goals, and companies performing the work also add variability to the historical data record for BCV. For the most part, however, the historical data that exist for Bear Creek and its environs were collected and analyzed by trained technicians using approved procedures. Furthermore, as noted by Turner et al. (1991), a general concordance of results over the years lends credibility to the historical data for this site.

The following subsections summarize the sources of historical data for BCV by medium:

- groundwater,
- soil,
- floodplain soil/sediment,
- surface water, and
- other.

Sources of historical data are identified by reference citation and/or a number (#) correlating to the numbers in Table B.1, which presents the details (sampling stations, dates, types of analyses performed) about each study. Table B.2 lists the frequency of analytes for each project and each medium in the historic database. Figure B.1 shows the locations of historic data sampling points in BCV.

B.2.1 GROUNDWATER

More than 300 groundwater monitoring wells and piezometers, ranging from shallow water table wells to deep bedrock wells, have been installed in the BCV watershed; screened intervals exist in the shallow and deep groundwater aquifers and for most of the formations present in BCV. Most of the wells are located near the waste disposal sites in upper Bear Creek (Fig. B.1).

Most of the wells in BCV were installed by Y-12 Plant subcontractors as part of the Groundwater Protection Program (GWPP); others were installed and monitored by the USGS. A substantial amount of groundwater data was made available from as early as 1983, when Bechtel National, Inc. (BNI) was subcontracted to install a group of wells near the waste sites (#20). The Roy F. Weston company also conducted an extensive groundwater sampling and analysis campaign in 1987-88, including Appendix IX analyses (#40) that have been validated to the extent possible, documented, and are available in the Bechtel Environmental Information Data Management System (BEIDMS). The Weston data are well documented and considered to be of good quality, but only a portion has been previously published (Turner et al. 1991).

The Y-12 Plant Groundwater Monitoring Program electronic database dates back to 1986. The data obtained under this program include water level measurements and a suite of organic and inorganic chemical analytical results (#41). Radiological analytical results are more sporadic, and the radionuclides reported vary.

B.2.2 SOIL

Historical soils data for BCV are derived primarily from cores that were sampled during drilling of groundwater wells or sampling of the OLF prior to closure. Not all of the well cores have been sampled, but McCauley (1985) includes data for ~50 boreholes. Sampling at the OLF was restricted to the individual treatment plots but included more than 300 composite samples (Herbes 1989; Bohrman 1989; #39 and #51). Some soil samples were collected by Y-12 Plant Waste Management from the excavated soils stored at the OLF Storage Pad (#61) and the Disposal Area Remedial Action facility (#69). These samples received the most comprehensive analyses, including analysis using Toxicity Characteristic Leaching Procedures. A number of surface and subsurface soil samples have also been collected in upper Bear Creek around the Rust Spoil Area (Energy Systems 1995; #57, #66), Storage Yard 200 (Energy Systems 1995; #54, #66), Spoil Area I (Energy Systems 1995; #58, #66), and the soil pile excavated during construction of the West End Tank Farm in 1984 (Turner 1988; #35).

B.2.3 FLOODPLAIN SOIL/SEDIMENT

Stream sediments and floodplain soils of Bear Creek and its tributaries have also been sampled extensively. Stream sediments were included in the sampling campaigns of BNI and the

Roy F. Weston company in the early 1980s (Geraghty and Miller 1985; #21, #40). Areas in and around the BCBG are the most intensively characterized; hundreds of samples were collected to characterize the North Tributary (NT)-7, NT-8, and the ORP sites during remediation. Sediment samples from other tributaries and for Bear Creek are less extensive. However, reference samples of sediment were also collected at Grassy Creek, NT-2, and NT-14 for use as background values in various studies.

Floodplain soil samples (as opposed to in-stream sediments) have been collected more sporadically, generally as part of larger investigations. Available data are limited to several sites in lower Bear Creek; the Blue Lagoon area in upper Bear Creek; the bridge site near Bear Creek Kilometer (BCK) 9.42; and areas of NT-6, -7, and -8 that drain the BCBG.

B.2.4 SURFACE WATER

Limited surface water data are available from as early as the 1960s (McMaster 1967). Sampling during the 1970s, especially in the headwaters, was associated primarily with the monitoring and eventual closure of the former S-3 Pond, which was completed in 1984. In the early 1980s, surface water was sampled in and around the waste disposal sites by Roy F. Weston (#40), BNI (#19), and the Y-12 Plant (#41). In addition to general chemistry, these samples were analyzed for a suite of analytical parameters. Surface water monitoring of Bear Creek has continued since that time, and sampling and analysis of both Bear Creek and its tributaries have been the focus of numerous special investigations, including an NT-8 study (Bogle and Turner 1993; #59), National Pollutant Discharge Elimination System monitoring (#3), and Environmental Sciences Division flow monitoring project (Clapp et al. 1990; #25).

In addition, surface water from the former ORPs was sampled and analyzed for a variety of contaminants during the 1980s (#16, #36, #50, #53). These ponds were eventually drained and excavated. The most recent study in the historical surface water dataset is a 1994 seep-and-spring survey conducted by the USGS (SAIC Project File 1995e; #71). Although the surveyors for this study did not collect samples for laboratory analysis, they did measure field parameters at more than 700 seeps, springs, and stream locations along Bear Creek, Grassy Creek, and their tributaries.

B.2.5 OTHER STUDIES

Other types of studies conducted within the Bear Creek watershed include meteorological monitoring, sampling of the waste sludge in the former S-3 Ponds (Kimbrough and Turner 1987; #26), leachate collection at BG-C (#64), sampling of liquids in standpipes in the burial trenches (McCauley 1985; #22), ecological and biological sampling, endangered species surveys, dye tracer tests, and various geological studies.

Water and sediment at the former S-3 Ponds were sampled in the 1970s and 1980s before the ponds were neutralized in 1983, as were the sludges resulting from the neutralization process (Kimbrough and Turner 1987; #26). Sediment from Blue Lagoon, a ponded area in Bear Creek just downstream of the ponds, was excavated in the late 1980s and transferred to the southwest cell of the S-3 Ponds just before they were closed. This sediment was sampled during the excavation and analyzed for contamination by the Y-12 Laboratory (McMahon 1988; #49).

The meteorology data for the vicinity of BCV date back to the 1950s, and rain gauges were installed in the valley during the 1980s. The rain gauges and meteorological monitoring stations provide information on the rainfall, solar radiation, and wind patterns within BCV and the surrounding areas.

Ecological and biological data have been collected primarily by ORNL, most notably by the Biological Monitoring and Abatement Program, which focuses on stream ecology and toxicity (Hinzman et al. 1995; #30). Other ecological monitoring activities have included mapping and characterization of wetlands and other sensitive areas and documentation of endangered species populations.

B.3 BCV OU 1 RI FIELD ACTIVITIES

B.3.1 SUMMARY OF FIELD INVESTIGATIONS

The BCV OU 1 field activity addressing the source sites in BCV was implemented in the Fall of 1994. It included sampling of surface and subsurface soils, groundwater, and/or surface water at the following sites:

- S-3 Site (Fig. B.2),
- OLF (Fig. B.3),
- Boneyard/Burnyard (BYBY) [including the Hazardous Chemical Disposal Area (HCDA)],
- Sanitary Landfill 1 [SL 1 (Fig. B.3)], and
- BCBG, including BG-A, -B, -C, -D, -E, and -J; ORP-1 and -2; and Walk-in Pits (Fig. B.4).

In addition, radiation and geophysical surveys were conducted at various sites, and groundwater head monitoring was conducted at the S-3 Site.

The rationale and procedures for collecting environmental samples and field data are presented in the BCV OU 1 RI Work Plan (DOE 1994a) and *Environmental Technical Support for Bear Creek Valley Operable Unit 1 Remedial Investigation Field Activities Manual* (SAIC 1994a). This manual includes procedures consistent with those in *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990) and investigation-specific procedures developed for sampling and field data collection methods not addressed by published Energy Systems procedures. Field procedures used during the RI and referred to in Sect. B.3 are referenced by procedure numbers correlating with those listed, along with the corresponding titles presented in SAIC (1994a), in Table B.3.

B.3.2 DEVIATION FROM THE SAMPLING AND ANALYSIS PLAN

Modifications to the original sampling and analysis plan (SAP) made during the course of the RI changed the scope of work for the field activities. Most of these changes to the SAP were made to accommodate site-specific conditions (e.g., change in sample location). These modifications are summarized in Table B.4.

B.3.3 SITE SAMPLING ACTIVITIES

The unique disposal histories of the various BCV OU 1 sites required the development of the site-specific sampling schemes presented in the RI Work Plan (DOE 1994a). The sampling schemes were designed to incorporate each applicable medium and to achieve the data quality objectives (DQOs) set forth in the RI Work Plan. The following sections summarize the field activities by sampling type: surface soil radiation surveys, geophysical surveys, surface soil, subsurface soil, groundwater, surface water, stormflow monitoring, and groundwater head monitoring.

B.3.3.1 Surface Soil Radiation Surveys

Radiation surveys were conducted to define areas of elevated activity in surface soils. Survey results were used in part to optimize sampling locations.

The Ultrasonic Ranging and Data System (USRADS) survey technology used for the surveys provides precise and real-time geographical location of collected data. The system includes a (1) movable base station containing a host microcomputer and a master receiver and (2) data pack consisting of electronic data gathering and positioning instrumentation. The data pack interfaces between the sensor meters and the master receiver located at the base station. The USRADS software automatically and instantaneously correlates the collected data to the actual location of the surveyor. The location and corresponding data value(s) are then plotted on a grid map displayed on the host microcomputer.

The USRADS equipment was mounted either in a backpack carried by the surveyor or on an all-terrain vehicle (ATV) driven by the surveyor. The instrumentation in the backpack carried by the surveyor included:

1. A Model 44-2, 2.5- × 2.5-cm (1- × 1-in.) sodium iodide detector probe (NaI scintillation crystal) coupled to a Ludlum Model 3 count rate meter for near-surface γ detection.
2. A Ludlum Model 44-9 open-window Geiger-Mueller pancake detector, mounted as close as possible to the surface, coupled with a Ludlum Model 3 count rate meter for near-surface β detection.
3. A Bicron MicroRem Model Tissue Equivalent Survey Meter, carried ~1 m (3 ft) above the ground surface, to detect low-level, tissue-equivalent dose rates in $\mu\text{rem/h}$.

The instrumentation for the ATV, which was used to survey the larger, open areas, was equipped with the following instrumentation:

1. Three Ludlum Model 3 Survey Meters equipped with Ludlum Model 44-2, 2.5-cm (1-in.) NaI scintillation crystal probes, spaced 30.5 cm (12 in.) apart, for near-surface γ detection.
2. Two Ludlum Model 12 ratemeters with Model 43-37 Gas Flow Proportional Floor Monitors, spaced equally across a 1-m (3-ft) frame, for near-surface β/γ detection.
3. One Bicron MicroRem Model Tissue Equivalent Survey Meter for low-level, tissue-equivalent dose-rate measurement.

In either configuration, the radiological instruments were used to record data during a single pass over each survey grid. For the surveyor-carried surveys, the γ and β ground surface probes were held about 15.2 to 30.5 cm (6 to 12 in.) above the ground surface and swung in a 1-m (3-ft) path across the survey transect. The surveyor traversed each survey grid at a rate of 1 m/s (3 ft/s) on parallel transects spaced ~1 m (3 ft) on center. For the surveys conducted with the ATV, the vehicle traveled at ~6.5 km/h (4 mph) on parallel transects spaced ~1 m (3 ft) on center.

Radiation surveys were conducted at three of the BCV OU 1 areas: BYBY, SL 1, and BCBG.

BYBY. Radiation surveys were conducted at the BYBY to identify areas of elevated activity in surface soils to target subsequent sampling activities. The large aerial coverage (Fig. B.3) and low topographic relief of the site required the use of the ATV. Vegetation in the area was cut back to allow the instrument to be suspended low enough to allow readings to be taken about 15.2 to 30.5 cm (6 to 12 in.) above the ground surface.

SL 1. A surveyor carrying a backpack surveyed the northern, western, and southern perimeters of the SL 1 capped area. Figure B.3 shows the extent of coverage of the radiological survey.

BCBG. Radiation surveys using both backpack- and ATV-mounted instruments were conducted at BCBG and on the Bear Creek floodplain in the vicinity of BCBG. Figure B.4 shows the extent of coverage of the radiological survey.

B.3.3.2 Geophysical Surveys

Geophysical surveys were conducted with a Geonics EM-31 terrain conductivity meter and a Geometrics G-822L Cesium Vapor Magnetometer. The EM-31 simultaneously measured two components of the induced magnetic field: a quadrature-phase component giving the ground conductivity and an in-phase component sensitive to metallic objects. The sensors were oriented in the vertical di-pole orientation and measured the components to a depth of ~5.5 m (18 ft) below the surface. The Geometrics G-822L Cesium Vapor Magnetometer used a directly locked oscillator that was proportional to the earth's magnetic field and was tolerant to noise and gradient changes. According to manufacturer specifications, the instrument is capable of detecting buried drums at a depth of 9.1 m (30 ft) or a pound of metal at a depth of 3 m (10 ft).

The EM-31 was connected to the USRADS equipment to allow output signals from the quadrature- and in-phase modes to be recorded simultaneously with geographic data from USRADS. The EM-31 was carried by the surveyor at a height of ~1 m (3 ft) above ground surface on parallel paths spaced ~3 m (10 ft) apart, first in a north-south direction and then in an east-west direction. Readings were usually taken about 15.2 to 30.5 cm (6 to 12 in.) above the ground surface.

The surveyor walked the G-822L surveys on ~1-m (3-ft) paths on center, swinging the instrument from side to side and holding the probe ~15.2 cm (6 in.) above the ground surface. The data collected by the GL-822L were output via RS-232 connections to the USRADS datapack, which immediately transmitted the data and location to the host computer.

Geophysical surveys were conducted in only one BCV OU 1 area: the BYBY.

BYBY. The BYBY surveys were conducted to define anomalies associated with buried objects and, consequently, the trenches. The survey data were subsequently used to determine optimal sampling locations for determining the nature and extent of contamination in the BYBY. The extent of the geophysical survey coverage is shown in Fig. B.3.

B.3.3.3 Surface Soil Sampling

Surface soil was collected for chemical analysis from the S-3, BYBY, SL-1, OLF, and BCBG sites to aid in determining the nature, extent, and likely contribution of surface erosion to contamination within the OU. Hand augers and scoops were used to collect soil samples from

<1 ft below ground surface (bgs). Surface radiation surveys were used to direct sampling activities, and levels of activity were monitored and recorded during sampling.

Surface soil samples were initially submitted for laboratory-based screening analyses of metals, polychlorinated biphenyls (PCBs), and uranium. These screening analyses were not validated. Screening results were reviewed by Energy Systems and Science Applications International Corporation (SAIC) project management to determine concentration and contaminant distribution. This evaluation was used to select those locations requiring additional analytical data collection with validation. The selected locations were resampled, and the collected samples were analyzed for metals, organics, semivolatiles, pesticides, and radioactivity (Table B.5).

Surface soil sampling was conducted at all five BCV OU 1 areas: S-3 Site, BYBY, SL 1, OLF, and BCBG.

S-3 Site. Surface soil samples were collected from four locations (SS3-01 through -04) at the S-3 Site and submitted for screening analysis (Fig. B.2). The results of screening analysis showed no concentrations of contaminants sufficient to warrant further sampling for more detailed analyses.

BYBY. Surface soil samples were taken at 27 locations (SBY-01 through -26 and -28) at the BYBY for screening analysis (Fig. B.3). Based on the results of screening analysis, six locations were resampled for more complete analysis (SBY-13, -16, -17, -20, -21, and -22) (Table B.5). An additional sample (SBY-27) was taken from material in a half-buried and ruptured drum located south of the BYBY, which exhibited radioactive contamination (>400,000 cpm). Because of its radioactive nature, this sample was submitted to the Y-12 Laboratory for analysis rather than to an off-site laboratory.

SL 1. Surface soil samples were taken at 14 locations (SSL-01 through -14) at the SL 1 for screening analysis (Fig. B.3). Results of the screening analysis showed that only SSL-13 required resampling for more complete analysis.

OLF. Surface soil samples were collected at two locations (SOL-1 and SOL-2) at the OLF (Fig. B.3) for screening analysis. The results of screening analysis showed no concentrations of contaminants sufficient to warrant further sampling for more detailed analyses.

BCBG. Surface soil samples were collected from 44 locations at BCBG (Fig. B.4). Screening analysis was performed on 41 of the samples (SBG-01 through -41). Of these locations, five were resampled for more complete analysis (SBG-07, -11, -20, -25, and -33). Surface soil samples from SBG-43 and -44 were each sampled for screening analysis and for complete analysis during one event due to time constraints and the need to have analyses consistent with previous sampling. The sample collected at SBG-42 came from an area of soil with yellow discoloration and high β and γ radiation (>400,000 cpm) that was discovered during reconnaissance of the area. Because of its radioactive nature, this sample was submitted to the Y-12 Laboratory for analysis rather than to an off-site laboratory.

B.3.3.4 Subsurface Soil Sampling

Depending on the sample site and the soil lithology, subsurface soil samples were collected using Geoprobe™ sampling techniques, hollow-stem auger and split barrel samplers, and Little Beaver™/hand auger sampling techniques.

Subsurface soil samples were analyzed for metals, volatile organic compounds (VOCs), PCBs, and radioactivity (Table B.5). At the BYBY site and selected locations at the BCBG, samples were also analyzed for semivolatile organic compounds (SVOCs) (dioxins and furans). Subsurface soil samples were also collected, using Shelby tubes for geotechnical analysis. These samples were analyzed for percent moisture, grain size diameter, hydraulic conductivity, mineral composition, distribution coefficient, shear strength, total organic carbon, and cation exchange capacity. Soil samples were analyzed for the list of parameters in Table B.5, and the Shelby tubes were analyzed for the list of parameters in Table B-6.

To ensure worker health and safety during field activities, environmental monitoring was conducted from within the breathing zone and for sample media. During the subsurface soil sampling, the presence and concentrations of VOCs, mercury vapor, combustible gases, and radioactivity were monitored and recorded.

S-3 Site. Subsurface soil samples were collected continuously at ten locations (S3-01 through -10) from the surface to auger refusal using a hollow-stem auger and split barrel samplers (Fig. B.2). Shelby tube samples were collected through the hollow-stem auger from two borings (S3-02 and -07).

BYBY. Continuous subsurface soil samples were collected from nine locations at the BYBY (BYBY-01 through -09) using Geoprobe™ sampling techniques (Fig. B.3). Sample depth intervals are shown on the lithologic logs for each boring (Supporting Information for this appendix). Shelby tubes were collected through a hollow-stem auger at two locations (BY-05 and -07).

SL 1. Subsurface soil samples were taken from two locations at SL 1 (SL1-01 and -02) using Geoprobe™ sampling techniques (Fig. B.3). Sample depth intervals are shown on the lithologic logs presented in the Supporting Information for this appendix. Soil samples and Shelby tube samples were analyzed for the parameters listed in Table B.6.

OLF. Subsurface soil samples were taken from five locations at the OLF (OLF-01 through -05) using Geoprobe™ sampling techniques (Fig. B.3). Sample depth intervals are shown on the lithologic logs presented in the Supporting Information for this appendix. Shelby tubes were collected through a hollow-stem auger at two locations (OLF-03 and -04). Soil samples and Shelby tube samples were analyzed for the parameters listed in Table B.6.

BCBG. Subsurface soil samples were taken from 15 locations at BCBG (BG-01 through BG-15) (Fig. B.4). Geoprobe™ sampling techniques were used at 12 of these locations (BG-01 through -06, -08, and -10 through -14). A Little Beaver™ power auger and hand-bucket augers were used to collect samples from BG-07, -15, and -16 because of difficulty in accessing these sites with a mechanical drilling rig. Sample depth intervals are shown on the lithologic logs presented in the Supporting Information for this appendix. Shelby tubes were collected through a hollow-stem auger at four locations (BG-02, -06, -11, and -15).

B.3.3.5 Groundwater

Groundwater samples were collected using Geoprobe™ groundwater sampling techniques from each Geoprobe™ sample location at which groundwater was identified during the subsurface soil sampling activities. The samples were analyzed for VOCs and SVOCs, metals, pesticides, and radioactivity (Table B.7). Temperature, pH, and conductivity of each sample were measured at

time of collection along with organic vapor concentration in the breathing zone, which was measured for health and safety concerns.

Wet zones were identified during subsurface soil sampling and targeted for groundwater sampling in a Geoprobe™ hole adjacent to the soil sampling hole. The Geoprobe™ groundwater sampling system used a 0.6-m (2-ft) screen that was deployed from the bottom of the pushrods. It was often necessary to retract the pushrods 0.6 m (2 ft) to sample water because of slow recharge or slight differences in water levels from soil sample stations to the adjacent groundwater station.

Groundwater was sampled at three BCV OU 1 areas: BYBY, SL 1, and BCBG.

BYBY. Groundwater grab samples were taken from seven of the nine Geoprobe™ borings at BYBY (BYBY-01 through -06 and BYBY-09) (Fig. B.3). Sample intervals ranged from 2 to 10.8 m (7 to 35.5 ft) bgs across the site (Table B.8). No water was encountered in the other two sample stations (BYBY-07 and BYBY-08).

SL 1. One groundwater sample was taken from the 3.7 to 4.3 m (12 to 14 ft) bgs interval (Table B.8) of boring SL1-01 (Fig. B.3). Boring SL1-02 was not sampled because no groundwater was encountered.

BCBG. Groundwater was collected from seven locations in the BCBG (BG-01 through -05, -12, and -13) (Fig. B.4). Stations BG-07 and -15 were inaccessible by groundwater sampling equipment. No water was encountered at BG-06, -08, -10, -11, or -14. The sample intervals ranged from 2.4 to 9.8 m (8 to 32 ft) bgs (Table B.8).

B.3.3.6 Surface Water

Surface water samples were obtained using a dipper. Before sample collection, each location was scanned for surface radioactivity to ensure worker health and safety, and temperature, pH, and conductivity of each sample were measured at time of collection. The collected samples were analyzed for VOCs and SVOCs, metals, PCBs, pesticides, and radioactivity (Table B.7).

Surface water samples were taken after a rainfall event at two locations in the upper reaches of NT-8 (SW-01 and SW-02) in BCBG (Fig. B.4). These locations were selected because they were likely to have received surface runoff from multiple sources within the BCBG.

B.3.3.7 Stormflow Monitoring

Stormflow tubes were installed at ten locations within the BCBG (SF-01 to SF-10) to establish the existence of flow in the shallow subsurface zone (Fig. B.4). Water level measurements in each stormflow tube were taken once a week for a period of 8 weeks. When applicable, measurements were obtained as soon as possible after a rain event during each week.

B.3.3.8 Groundwater Head Monitoring

Groundwater levels in selected wells and temporary piezometers were monitored continuously. Groundwater head measurements were recorded every 30 min for ~6 weeks using data loggers and pressure transducers.

Temporary piezometers were installed at the S-3 Site in borings S3-01, -03, -05, -06, -07, and -08 by placing a slotted polyvinyl chloride pipe in the hole after withdrawing the auger and filling the annulus space with drill cuttings. Groundwater levels were measured in each of these temporary piezometers and in monitoring wells GW-101, -127, and -276. Monitoring well GW-276 was monitored for a shorter period (~4 weeks) because a scheduled, quarterly sampling of the well could not be completed with the head monitoring equipment in place.

B.4 BCV OU 4 FIELD ACTIVITIES

B.4.1 SUMMARY OF FIELD INVESTIGATIONS

The BCV OU 4 field activities addressing the hydrology of BCV and the exit pathways from the source sites to potential off-site receptors included (1) sampling surface water at tributaries draining from the source sites into Bear Creek and (2) monitoring groundwater head, stormflow, and surface water flow to refine the hydrologic conceptual model for BCV. OU 4 sampling locations are shown in Fig. B.5.

The collection of environmental samples and field data followed procedures outlined in the BCV OU 4 RI Work Plan (DOE 1993) and presented in *Environmental Technical Support for Bear Creek Valley Operable Unit 4 Remedial Investigation Field Activities Manual* (SAIC 1994b) (Table B.9). This manual includes procedures consistent with those in *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990) and investigation-specific procedures developed for sampling and field data collection methods not addressed by published Energy Systems procedures.

The work plan for the BCV OU 4 RI was approved on September 29, 1993, and field activities began on March 1, 1994.

B.4.2 DEVIATIONS FROM THE SAMPLING ANALYSIS PLAN

Modifications to the original SAP, made after a review of preliminary data, changed the scope of work for the field activities. The major modifications to the BCV OU 4 SAP included:

- The original SAP included sampling of groundwater from 25 wells in BCV. The decision was later made not to sample groundwater because sufficient data for defining groundwater chemistry and contaminants are available from the annual sampling of monitoring wells in BCV for the Groundwater Quality Report (GWQR) (e.g., HSW 1995) (DOE 1994b — BCV DQO meeting minutes).
- Although the SAP identified 14 stream and spring sample sites, sampling equipment was available for only 6 of the 14 sites at the project start. Therefore, 6 priority sites were identified and monitored from project start, with the 8 remaining sites equipped and brought on line for sampling during May 1994.
- The original SAP called for surface water sampling to be conducted by using flow-proportional samplers to take weekly composites of surface water. However, experience in taking the initial two samples at each site revealed that taking composites over a 7-d period would not be practical and, furthermore, might bias the database towards high-flow periods.

The flow-proportional samplers, which take a volume of sample that is proportional to the total volume of water that has passed through the site, automatically switched off once the sample containers were full. To gain a representative sample of one week's flow, a field team had to set the sample rate at the start of each sample so that the sampler would operate for the whole week. In cases where water flow was higher than predicted when programming the

sampler, the sampler would switch off before the end of the week period. Conversely, in cases where flow was lower than anticipated, an insufficient sample would be taken. Most often, the samplers filled up and switched off during storm events before the end of the week sampling period. Unfortunately, weather forecasting could only give the sample teams the probable weather condition for 5 d in advance, which was insufficient to project total flow through the samplers for a full week. The sample strategy was therefore changed to obtain representative samples during different periods of the hydrograph: stormflow, storm regression, and baseflow. Sample periods were generally shorter than 1 week and ranged from 1 to 6 d, depending on the conditions and the targeted sample period. This change in strategy also resulted in fewer samples being needed to define the flux of contaminants at each site. The total number of sample events was therefore changed from the original 28 to 21.

- The SAP called for three tracer tests — one at each of the main waste sites in — BCV to be conducted. After obtaining additional expert opinion suggesting that the tracer tests would probably not work because there was little likelihood that any tracer would be identified in the monitoring wells, the sample strategy was changed to eliminate the tracer tests (DOE 1994b).
- The SAP called for three pressure pulse tests — one at each of the main waste sites in BCV — to be conducted. The same expert opinion that questioned the value of the tracer tests also suggested that the pulse tests should not be conducted. As a result, the sample strategy was changed to complete only one of the pulse tests (DOE 1994b).
- The SAP did not address lithium. However, because new data made available during the RI showed the potential toxicity of lithium, it was added to the list of analytes for the seven surface water sample events after September 1994.

Other minor modifications to the original SAP are summarized in Table B.10.

B.4.2.1 Comprehensive Radiological Characterization Monitoring

In addition to the modifications to the original SAP discussed above, a Statement of Work was issued July 14, 1995 (revised July 24, 1995) by Energy Systems to conduct groundwater sampling and analysis of radiochemical parameters in support of the ongoing RI in BCV. This task involved sampling and analysis of groundwater from selected wells and springs within the Bear Creek Hydrogeologic Regime for radiochemical parameters of concern to determine the nature and extent of radiogenic contamination and to perform a baseline human health risk assessment.

Radiochemical contaminants of potential concern were identified during a review and evaluation of the Y-12 Plant GWPP historical analytical database, radiological waste inventory data for the sludges in the S-3 Ponds and wastes in the BCBG, and radionuclides detected as part of the BCV OU 1 and OU 4 sampling events. The contaminants of potential concern selected include ^{241}Am , ^{137}Cs , ^3H , ^{237}Np , ^{238}Pu , $^{239/240}\text{Pu}$, $^{223,224,226}\text{Ra}$, ^{228}Ra , total Sr, ^{99}Tc , $^{228,230,232}\text{Th}$, $^{233/234}\text{U}$, ^{235}U , ^{238}U , gross α , and gross β .

Sampling locations were selected to determine the nature and extent of radiogenic contamination to the degree necessary to evaluate risk to human health and to evaluate the feasibility of implementing various remedial alternatives. Sampling locations are shown on Fig. B.6 and include source areas (the S-3 Site, BYBY, and BCBG), exit pathways for

contaminant migration (Bear Creek and the Maynardville Limestone), and background locations upgradient of any waste disposal sites.

B.4.3 SITE SAMPLING ACTIVITIES

Table B.11 lists the sampling activities conducted for BCV OU 4. Tables B.12 to B.28 list additional parameters for the BCV OU 4 activities that are referenced in Table B.11. The following subsections briefly describe the RI sampling activities by OU 4 sample group: surface water sampling, continuous surface water monitoring, continuous stormflow monitoring, and continuous groundwater monitoring.

B.4.3.1 Surface Water Sampling

A continuous automatic sampler was used in conjunction with a bubbler-flow meter to take flow-proportional samples for inorganic and radiological analyte groups. VOC samples cannot be taken using these samplers because of their volatility; instead, VOC samples were taken as grab samples when the flow-proportional samples were retrieved from the automatic sampler.

The flow-proportional samples were composited into a 15-L nalgene carboy packed with ice each day that the sampler was in operation. Samples were taken after completion of the sample program in each sampler was completed. Duplicate samples were taken by installing a second complete automatic sampler at one site in BCV for each sample event and programming the samplers for the same parameters. The duplicate site was changed for each sample event. Equipment rinsates were taken by rinsing a nalgene collection bottle at intervals specified in the work plan. No equipment rinsates were taken for VOC samples because the sample bottle was dipped directly in the stream and no sampling equipment was used. Samples were analyzed for the analytes listed in Table B.12.

As discussed in Sect. B.4.2, the total number of samples collected at each surface water monitoring site was reduced from the SAP-specified number because insufficient equipment was available to sample all sites from the start of the project. The 14 sample sites in BCV comprised of 9 surface water sampling sites (NT-1 through NT-8 and BCK-S3) and 5 surface water sampling sites at springs (SS-1, -4, -5, -6, and -8) (Fig. B.6) were sampled between 12 and 22 times. Each sample represents a unique sampling period, which depended on stream flow at that site. Table B.13 lists the total period over which flow was monitored at each site. Tables B.14 through B.26 list the time periods of sampling for each site, and Figs. B.7 through B.46 show the flow hydrographs for each sample. The one exception to this strategy occurred at SS-8, where the shape of the channel prohibited flume installation or continuous recording of flow. Instead, samples were taken for a fixed time period with fixed time intervals.

Surface water samples were analyzed for inorganics, organics, and radionuclides according to the list of analytes in Table B.12. Although all samples were analyzed for gross α , gross β , and isotopic uranium, only those samples that had gross α activities >15 pCi/L and gross β activities >50 pCi/L were to be analyzed for other isotopes to determine the isotopic nature of the radiological contamination. However, because more samples than anticipated had results greater than the specified screening values, only a representative number of samples were analyzed for isotopes other than uranium.

Two additional grab samples of surface water were obtained at sites without flow composite samplers (Table B.11). Although these sites were not included in the original SAP, they were added later because the RI technical team determined that samples from the sites were necessary to evaluate the nature and extent of contamination. This decision was based on results from sampling surface water at the planned sites. The two grab samples were performed on April 12, 1994, at BCK S3 and on December 20, 1994, at SS-6b. They were analyzed for the same analytes that the composite surface water samples were analyzed for (Table B.12). The locations of the two grab sample sites are shown on Fig. B.6.

B.4.3.2 Continuous Monitoring of Surface Water

Surface water stage was recorded continuously for the specified sampling period at each surface water sampling site, except for SS-8 (Table B.11) where the shape of the stream channel prevented flume installation. The stage at each site was measured using a bubbler-flow meter. Portable H-type flumes were installed at each site, except for BCK 9.4 and BCK 12.36. At BCK 9.4, where the stream channel is too large for a portable flume, a rating curve developed by USGS was used to calculate flow. BCK 12.36, where the stream is contained in two culvert pipes, required monitoring the stage in each pipe separately and combining the two flows to derive the total. Flow was calculated for each pipe using the Manning equation for a round pipe (slope = 0.001 and radius = 2.5 ft) and a roughness coefficient for corrugated steel pipe (Fig. B.47). Table B.13 lists (1) the time periods over which surface water flow was recorded at each site and (2) the stage-to-flow conversion calculation for each site. The rating curve for BCK 9.47 is listed in Table B.27 and illustrated in Fig. B.48.

Conductivity and temperature were measured at NT-2, NT-3, and SS-6. Although these measurements were not included in the original SAP, they were added later to investigate the relationship between flow rates and concentration. The two parameters were monitored using a probe placed in the tributary or spring, and data were recorded using a datalogger.

Sampling operations at NT-2 revealed that a major outfall from a contaminated groundwater plume occurs in NT-2. The RI technical team decided that the location of the sample site in NT-2 relative to the contaminated groundwater discharge needed to be determined to ensure that the samples from NT-2 were representative of tributary conditions. The location was delineated by measuring the conductivity at 25 locations spaced 15.2 m (50 ft) apart along NT-2.

B.4.3.3 Continuous Monitoring of Stormflow

Stormflow tubes were installed at six locations in upper BCV following the construction details in Moore (1992). Water level in these tubes was recorded continuously using a Druck PDCR 940 pressure transducer and an Omnidata Easylogger™ 900 Series datalogger (Table B.11). The sites were visited every 2 weeks to download data and check the calibration of the pressure transducer. Additional visits to each site were made to ensure that battery levels were sufficient for logger operation. The water level in each tube was monitored from March 16 to October 6, 1994.

B.4.3.4 Continuous Monitoring of Groundwater

Piezometric head, conductivity, and temperature were monitored in each well for the three well groupings located at each of the main waste areas in the valley (Table B.11). Piezometric head was monitored using a pressure transducer that was suspended in the well a distance below

the water table equal to about half of the pressure transducer's range, thus giving maximum allowance for rising or falling groundwater head. The sites were visited each week to download data, check the calibration of the pressure transducer, and verify that groundwater head had remained within the range of the transducer. Table B.28 lists the monitoring wells in each group and the time frame for monitoring each well.

B.5 FIELD DATA COLLECTION — FLOODPLAIN SOILS AND SEDIMENTS

B.5.1 SUMMARY OF FIELD INVESTIGATIONS

The BCV FPSS field activity addressed the potential impact of contaminant releases from numerous upstream sources and future releases due to erosion of the sediments and soil. Implemented in the Spring of 1995, the investigation consisted of four parts:

- large-scale characterization of floodplain sediments,
- fine-scale characterization of floodplain sediments,
- ecological sampling, and
- stream sediment sampling.

Figure B.49 is a flow chart that outlines the sampling activities for the Bear Creek floodplain investigation.

The BCV FPSS investigation was performed in accordance with the *Soil Sampling and Analysis Plan for the Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (DOE 1995a) and its procedures presented in the *Environmental Technical Support Bear Creek Valley Operable Unit 1 and Floodplain Soil Sampling Field Technical Procedures, Rev. 5* (SAIC 1995a). This manual includes procedures consistent with those in the *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990) and investigation-specific procedures developed for sampling and field data collection methods not addressed by published Energy Systems procedures.

All sample locations for the various media were surveyed by a certified land surveyor, recorded on the BCV map, and marked with a stake and flagging (Fig. B.50). In addition, all locations identified during the field screenings as areas for further investigation (AFIs) were staked, flagged with a unique identifier, and photographed so that they could easily be relocated during the subsequent ecological sampling. Stream sediment sampling locations were marked on the adjacent stream bank and supporting field notes were taken to ensure relocation.

In addition to samples specified in the SAP, three samples identified by Energy Systems Environmental Restoration were taken to further characterize floodplain soils. Other minor changes to the SAP were made during implementation to account for field conditions. These changes are detailed in the field change orders for this project and are summarized in Table B.29.

B.5.2 BACKGROUND DETERMINATIONS (REFERENCE SAMPLES AND VALUES)

Reference activities and concentrations were established for the list of analytes to provide a basis of comparison with BCV FPSS analytical results. A number of different types of samples were collected outside the Bear Creek floodplain to serve as reference samples.

B.5.2.1 Floodplain Soil Screening Reference Samples

Soil screening during the large- and fine-scale characterizations involved PCB, radiometric, and VOC screening techniques. The screening reference value for PCBs was originally set to satisfy risk assessment needs (0.05 ppm), but was reduced to the analytical detection limit of the selected field screening method (0.5 ppm). The screening reference value for γ radiation was determined by locating 10 sites outside of the Bear Creek floodplain but within geologic and soil units similar to those of the floodplain (e.g., sites along tributaries to Bear Creek that did not drain waste disposal sites) (Fig. B.50). Three locations at each reference site were sampled to yield a total of 30 measurements. Each sample was collected from depths of 0.0 to 81.0 cm (0.0 to 32.0 in.) bgs and homogenized before screening. The reference value for γ radiation used for comparison purposes during subsequent sampling was the 95% upper confidence level arithmetic average of all readings from all sites.

B.5.2.2 Floodplain Soil Radiological and Chemical Reference Values

The reference values against which soil radiological and chemical analyses were compared came from the Background Soil Characterization Project (BSCP) (Energy Systems 1993e) for soils of similar type and origin. These reference values were only for inorganic elements and compounds and radionuclides. Organic analytes are assumed not to occur naturally and, therefore, have no reference concentrations.

B.5.2.3 Ecological Reference Samples

Soil samples were collected from BSCP sites ORR-11, -23, and -33 for toxicity and geotechnical analysis to supplement the historical chemical and radiological data attained during the BSCP (Energy Systems 1993e). Samples were collected in accordance with procedures described in later sections.

B.5.2.4 Stream Sediment Reference Samples

Three stream sediment samples were collected for chemical, radiological, and geotechnical analysis from areas in Bear Creek tributaries NT-11, -13, and -15 not affected by contamination (Fig. B.50). They were collected in accordance with the procedures described in later sections, composited in equal amounts for sediment toxicity testing, and analyzed for the full radiological and chemical analyte list.

B.5.3 SOIL SAMPLING

B.5.3.1 Large-Scale Characterization of the Bear Creek Floodplain

The large-scale characterization of floodplain soil was conducted using a sequenced approach:

- Soil samples were collected with a backsaver™ sampler along the length of Bear Creek, beginning at BCK 12.10 and ending at the intersection between White Wing Road and Oak Ridge Turnpike, and screened. Results of the field screening analyses were compared with predetermined screening criteria (sampling action levels). If a screening sample from any borehole exceeded a sampling action level, that borehole location was classified as an AFI.

- After the initial screening survey was complete, the sampling strategy team evaluated the screening data to identify those AFIs that needed to be sampled in more detail. Additional soil samples were taken from each AFI, as described below, and submitted for more complete radiological and chemical analysis and toxicity testing. Additional screening tests for uranium were conducted on a split from each sample sent for further analysis.
- After laboratory analytical data were returned, the sampling strategy team used toxicological benchmarks to identify the biota samples to be collected within the vicinity of a subset of the AFIs.

Details of this approach are presented in the following subsections. The large-scale characterization sample location and analysis matrix is shown in Table B.30.

Floodplain soil screening. Thirteen transects in depositional areas of the Bear Creek floodplain were designated for sampling (Fig. B.50). These transects were located in areas of the floodplain most likely to have accumulated sediment and therefore contaminants. The locations were selected by field geologists and were based upon both floodplain morphology and previous sampling experience in BCV. Each transect consisted of a total of six sample locations: one in the creek berms on either side of Bear Creek and two more in the backmarsh on either side of the creek (where adequate floodplain existed on both sides of creek). The backmarsh locations were spaced evenly over the entire width of the floodplain. Each sample location was sampled at three different depth intervals: 0 to 10 cm (0 to 4 in.), 10 to 41 cm (4 to 16 in.), and 41 to 81 cm (16 to 32 in.) bgs or to sampler refusal, whichever came first.

Samples collected from each interval were homogenized, field-screened for VOCs and for γ -radiation, and sent to the Y-12 Laboratory for PCB screening. VOCs were screened using a hand-held photoionization detector to detect head-space concentrations of an undisturbed sample, and γ -radiation was screened using a sodium iodide (NaI) scintillator.

The screening level constituents and values that were selected during the development of the SAP were:

- PCBs - 0.5 ppm,
- VOCs - 0.5 mg/kg, and
- β/γ radioactivity - the lesser of two standard deviations or 100 cpm above background.

The PCB field screening criterion was originally set at 0.5 ppm, the detection limit on the lowest PCB screening method available. The screening level was mistakenly changed to 0.05 ppm by team members familiar with human health risk needs and not field screening methods. When the disconnect between the field screening capabilities and risk needs was identified, the project team decided that all AFI and confirmatory samples collected for laboratory analysis would be analyzed for PCBs using a CLP method having a detection level ≤ 0.05 ppm.

The radiological sampling action level was defined as 247 cpm, which is the lesser of two standard deviations or 100 cpm above the average activity of radiological control samples of uncontaminated soil of similar origin to those found in the Bear Creek floodplain (i.e., local background).

Samples from locations with PCB concentrations >0.5 ppm (the PCB sampling action level), γ radiation >247 cpm, and/or VOC levels >5 mg/kg (based on detector resolution) were classified

as AFIs. These areas were included in a second round of sampling, with samples from depth intervals exceeding the sampling action levels sent for laboratory radiological and chemical analysis (Table B.30).

AFI floodplain soil samples. The sampling strategy team identified the 14 AFIs that needed to be sampled and analyzed in more detail (Table B.30). (The SAP had limited this sampling and analysis effort to a maximum of 26 AFIs, with a maximum of two AFIs located on one transect.)

Sampling crews then returned to the 14 locations classified as AFIs to perform additional sampling. These AFIs were located by referring to the BCV map (Fig. B.50), photographs taken of the locations (e.g., Plates B.1 and B.2), and stakes and flagging used to delineate the AFI during the screening effort. For each AFI, only those depth intervals that exceeded the sampling action levels were sampled.

Sample collection at each AFI required collecting enough adjacent soil samples to provide a sufficient sample volume for laboratory analysis and toxicity testing (Table B.30). Because of the large volume of sample needed from the 0- to 10-cm (0- to 4-in.) and 10- to 41-cm (4- to 16-in.) intervals, multiple samples were collected immediately adjacent to [within a 0.3-m (1-ft) radius of] the location where the sampling action level was exceeded until an adequate sample volume was recovered. The samples were completely homogenized before collection of individual analytical samples.

Sampling began by clearing the forest litter, grasses, and forbs from the ground surface. Initially, samples were collected from the 0- to 10-cm (0- to 4-in.) deep interval using a hand auger. Samples for VOC analysis were taken directly from the first auger bucket from each interval sampled. The remaining sample was homogenized and the resulting sample was split: one split was sent for laboratory radiological and chemical analysis, and the other split was used for toxicity testing. Roots, rocks, and invertebrates were removed from the sample and returned to the sample location.

Following sampling of the initial 0- to 10-cm (0- to 4-in.) interval, two more intervals were sampled at each AFI, as appropriate: 10- to 41-cm (4- to 16-in.) interval and 41- to 81-cm (16- to 32-in.) interval. The 10- to 41-cm (4- to 16-in.) interval was homogenized and split as described for the 0- to 10-cm (0- to 4-in.) interval. One split was sent to a laboratory for more complete radiological and chemical analysis, and the other split was composited proportionally with a split from the 0- to 10-cm (0- to 4-in.) interval [composite was based on volume such that one part from the 0- to 10-cm (0- to 4-in.) interval and three parts from the 10- to 41-cm (4- to 16-in.) interval were combined to yield a sample representative of the 0- to 41-cm (0- to 16-in.) interval] and homogenized for use in toxicity testing. The 41- to 81-cm (16- to 32-in.) interval was sampled only when the sampling action level was exceeded in that interval during screening and if the 0- to 10-cm (0- to 4-in.) and 10- to 41-cm (4- to 16-in.) interval of the same boring did not exceed sampling action levels. The 41-cm to 81-cm (16- to 32-in.) interval was not tested for toxicity but was homogenized and submitted to the laboratory for more detailed radiological and chemical analyses.

The analytes for chemical analysis and the isotopes whose activities were determined during radiological analysis are listed in Table B.31. Gamma radiation field screening analyses were performed on splits from all soil samples that were sent to the laboratory for analysis to allow correlation of laboratory results with the field screening techniques. In addition, an aliquot of each sample sent for laboratory radiological and chemical analysis was sent to a geotechnical laboratory

for analysis of moisture content, pH, particle size distribution, and organic content using American Society for Testing and Materials (ASTM) or *Methods of Soil Analysis* procedures.

Toxicity testing was conducted on a maximum of two samples per transect from 11 AFIs. Toxicity tests were not performed on transects TS11 and TS12 because no contaminants were found above background concentrations in these transects. Sample locations for toxicity tests were determined after a review of screening data with emphasis on PCB results. PCBs were used to select the toxicity test sampling locations because they are more toxic to earthworms and vegetation than radionuclides or VOCs. If no samples in a transect exceeded the detection limit for the PCB screening test, then selection of samples for toxicity testing was based on radiological results. Concern for VOCs in toxicity tests is minimal. The procedures for toxicity testing are described in two separate addendums to the *Soil Sampling and Analysis Plan for the Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (DOE 1995a). Samples to be tested for toxicity to earthworms and plants were sieved coarsely (i.e., through a 1-cm mesh or screen) to remove pebbles, twigs, etc.

Biota sampling at AFIs. Biota were sampled at the AFIs to determine the degree of bioaccumulation of contaminants in small mammals and the potential for accumulation or biomagnification into higher trophic levels. Chemical analyses of soil samples were used to identify locations where small mammals, earthworms, and vegetation would be collected and the contaminants for which they would be analyzed.

Benchmarks for exposure of small mammals to soil contaminants were derived by assuming that contaminants are ingested directly and are transferred from soil to food. Exposure parameters for white-footed mouse (*Peromyscus leucopus*) and short-tailed shrew (*Blarina brevicauda*) included daily soil and food ingestion rates (Sample and Suter 1994) and soil-to-plant and soil-to-earthworm uptake factors taken from the Reservation-wide ERA (DOE 1995b). Toxicity benchmarks (Opresko, Sample, and Suter 1994) were used to compute soil exposure benchmark concentrations. Observed soil concentrations were compared to the calculated exposure benchmarks to identify sites in the AFIs where small mammals were exposed to potentially toxic contaminant concentrations. Any site where a contaminant concentration exceeded background and a screening benchmark for mice or shrews became a candidate for small mammals sampling. Because of the relatively large ranges of small mammals, only one trapping system was set up per soil transect. Small mammals were collected at transects G01 (5 individuals), G02 (5 individuals), G03 (3 individuals), G04 (4 individuals), and G07 (3 individuals).

Soil exposure benchmarks for earthworms were taken from Will and Suter (1994). Sites that exceeded background and the benchmark value for a contaminant became candidates for earthworm sampling. A team of scientists reviewed the screening results to determine the maximum number of samples to be taken and the optimal sampling locations. Because one purpose of sampling was to develop site-specific bio-uptake factors, sampling sites were chosen to provide as wide a range of soil exposure concentrations as possible. Earthworm samples were collected at transects G01 (2 samples), G02 (1 sample), G03 (2 samples), G04 (2 samples), G07 (2 samples), and G09 (1 sample). Plants were sampled in the vicinity of AFIs where earthworm samples were collected. Browse, canopy, and herbaceous vegetation (two samples of each for every earthworm sample collected) were collected at each site.

Reference samples of small mammals (16), earthworms (3), and plants (9 each of browse, canopy, and herbaceous vegetation) were collected at sites where the soil was similar to that in the AFIs.

Biota were analyzed only for contaminant groups (e.g., inorganics, PCBs) for which at least one soil exposure benchmark was exceeded. Plants were analyzed for inorganics and radionuclides, whereas earthworms and small mammals were analyzed for inorganics, radionuclides, and PCBs.

Confirmatory samples. Confirmatory sampling was conducted at 15% of the sample locations not classified as AFIs (Fig. B.50, Table B.30). Locations and intervals to be sampled were determined by the sampling strategy team on the basis of the field screening and analytical data. Of the confirmatory samples, 50% were collected from the 0- to 41-cm (0- to 16-in.) interval, represented by a composite sample from the 0- to 10-cm (0- to 4-in.) and 10- to 41-cm (4- to 16-in.) interval, and 50% from the 41- to 81-cm (16- to 32-in.) interval. The sampling plan for the confirmatory soils was identical to that for sampling the AFIs. Biota sampling at confirmatory locations was conducted when the laboratory radiological or chemical analyses of soils demonstrated that toxicological benchmarks for small mammals had been exceeded.

Additional floodplain soil samples. In addition to samples defined in the SAP, three additional samples identified by Energy Systems Environmental Restoration were taken to further characterize floodplain soils:

- a stream sample taken from a quiescent pool in the tributary draining the White Wing Gap Scrapyard,
- surface soil composite collected from previously unknown source area adjacent to the Rust Spoil Area (subsequently named the Bear Creek Road Debris Burial Area), and
- surface soil composite collected from previously unknown source area adjacent to West End Tank Farm (subsequently named the Creekside Debris Burial Area) (Appendix A, Table A.1).

All three samples were analyzed only for chemical and radiological constituents. No toxicity, geochemical, or γ screening analyses were performed. Because of the high radiological readings for the composite from the Bear Creek Road Debris Burial, just west of Rust Soil Area, the composite was diluted with lower-activity soil from the same area at a ratio of one part elevated-activity soil to four parts lower-activity soil to enable shipment to the laboratory.

B.5.3.2 Fine-Scale Characterization of the Bear Creek Floodplain

The fine-scale characterization of the Bear Creek floodplain was conducted because, at location BCK 4.70, the two primary contaminants, uranium and PCBs, were found to be concentrated near the creek's berm and within discrete strata in the floodplain (Turner et al. 1991) (Fig. B.50). To confirm this finding and to characterize the extent to which the pattern exists throughout the whole floodplain, the fine-scale characterization strategy was devised. In addition to defining the locations of contaminants in the soil column, this characterization was also valuable in confirming the findings of the large-scale characterization and in providing information for understanding the mechanisms for contaminant transport and deposition. The sampling strategy team had the option of reevaluating and modifying the characterization strategy if laboratory results indicated that uranium and PCBs were not the only contaminants of potential concern. Table B.32 shows the fine-scale and stream sediment sample locations and analysis matrix.

The investigation began at BCK 4.70 with a hand-dug, sediment profile excavation into the floodplain in the vicinity of coring sites W1 and W2 (Turner et al. 1991). Excavation dimensions

were $3 \times 1 \times 1$ m ($9.8 \times 3.3 \times 3.3$ ft). Each layer was described in sufficient detail to allow layers of similar type and origin to be recognized. Characteristics included in the profile description were color; relative amounts of coarse, fine, and organic material; depth in the profile; and general descriptions of overlying and underlying layers. Discrete layers were then sampled and screened for γ radioactivity, PCBs, and VOCs, as in the large-scale characterization. If any layer exceeded the sampling action levels for γ radiation, PCBs, or VOCs, then sufficient sample for radiological and chemical analysis was collected from the exposed excavation walls.

After the sediment profile excavation at BCK 4.70 was completed, a modified version of the excavation was used to investigate 17 locations in the Bear Creek floodplain between BCK 1.0 and BCK 11.09 (Fig. B.50, Table B.32). A soil sample was taken on or proximal to the berm to a depth equal to the bottom of the creek channel, a maximum of 1 m (3.3 ft), or sampler refusal, whichever came first. Sample layers were inspected for similarities to those recognized as contaminant-bearing layers during the sediment profile characterization at BCK 4.70. Any layers that matched the physical descriptions were screened for γ radiation, PCBs, and VOCs. If any layer exceeded the sampling action levels, then sufficient sample was collected from the layer for laboratory analysis of the radiological and chemical constituents. In addition, the sample location was classified and subsequently investigated as an AFI. This investigation included soil samples for chemical and radiological analysis [0 to 10 cm (0 to 4 in.), 10 to 41 cm (4 to 16 in.), and 41 to 81 cm (16 to 32 in.) as appropriate], toxicity tests, and biota samples for ecological testing.

All soil sampling for the BCV FPSS investigation was conducted using applicable, media-specific standard operating procedures provided or approved by Y-12 Plant Environmental Restoration and consistent with the Energy Systems *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990). Any deviations from these operation procedures were documented on a field change order form as outlined in the Field Quality Assurance Project Plan for the SAP.

Soil screening samples were collected with a 3.2-cm (1.25-in.) inside-diameter backsaver™ sampler. Bulk soil sampling in the floodplain was conducted using a 7.6-cm (3-in.) hand auger in accordance with Energy Systems procedures (Kimbrough et al. 1990). Additional technical procedures used during the course of the BCV FPSS investigation are presented in Table B.33.

B.5.4 BEAR CREEK STREAM SEDIMENT CHARACTERIZATION

Whole sediment samples from 17 locations along Bear Creek and from tributaries and springs that feed Bear Creek were collected from specified locations in the field and analyzed for specified constituents (Fig. B.50, Table B.31). They were also tested at the ORNL Environmental Sciences Division Aquatic Toxicology Laboratory for toxicity to surrogate benthic invertebrates. Sample splits were sent to a second laboratory for bulk sediment characteristics. Data obtained from the toxicity tests were used in the BCV Environmental Risk Assessment as one of several lines of evidence to evaluate the ecological condition of BCV.

All stream sediment sampling for the BCV FPSS investigation was conducted using, as applicable, media-specific standard operating procedures provided or approved by Y-12 Plant Environmental Restoration and consistent with the Energy Systems *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990) and with *Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance*

Manual (EPA 1991). Any deviations from the standard operating procedures were documented on a field change order form as outlined in the Field Quality Assurance Project Plan for the SAP.

Specifically, stream sediment sampling in Bear Creek was conducted using a 1-L, hand-operated Ponar-style dredge. Sampling was conducted in accordance with Energy Systems procedure ESP-304-1 (Kimbrough, Long, and McMahon 1990). Additional information for stream sediment sampling procedures using the Ponar dredge can be found in SOP-29 of the Environmental Sciences Division Toxicology Laboratory Quality Assurance Manual—Collection of Surface Sediment Samples. Other technical procedures to be used during the course of the BCV FPSS investigation are presented in Table B.33.

One 3-L sample volume was collected at each designated stream sediment sampling site. In the field, large gravel and debris were removed from the whole sediment samples that were homogenized. One 1-L split portion (for toxicity testing) was placed into labeled 1-L, high-density polyethylene sample containers covered with 2.5 cm (1 in.) of stream water and placed on ice. Another 1-L split portion (for bulk analysis) was placed into containers with volumes appropriate for use in laboratory analysis and stored on ice. All samples were shipped on ice to either the laboratory for chemical and radiological analysis or to the Environmental Sciences Division Aquatic Toxicology Laboratory for toxicity testing. In addition, a 1-L sample split was sent to a geotechnical laboratory for analysis of moisture content, pH, particle size distribution, and organic content using ASTM or *Methods of Soil Analysis* procedures.

B.5.5 SOURCE TERM ECOLOGICAL CHARACTERIZATION

Comprehensive characterization of the full ecological impact of any potential contaminants in BCV required an investigation of the impact of potential source areas. Most of the source areas for the Bear Creek drainage reside in OU 1. The RI for OU 1 was conducted during the Fall of 1994, prior to the BCV FPSS. Hence, by the time the BCV FPSS investigation was under way, many source soil samples had been collected and sent to the laboratory for radiological and chemical analyses.

Biota were sampled at the source areas to determine the degree of bioaccumulation of contaminants in small mammals and the potential for accumulation or biomagnification into higher trophic levels. Chemical analyses of soil samples were used to identify locations where small mammals, earthworms, and vegetation would be collected and the contaminants for which they would be analyzed. Identification of potential locations was carried out as described in Sect. B.5.3.1 (Biota sampling at AFIs), and included evaluation of the accessibility of potential sites. No intrusive sampling was done in capped sections of the source areas.

Small mammals were collected at the BYBY site BY17 (4 individuals). Earthworm samples were collected at BYBY sites BY17 (1 sample) and BY22 (1 sample). Plants were sampled in the vicinity of AFIs where earthworm samples were collected. Browse, canopy, and herbaceous vegetation (two samples of each for every earthworm sample collected) were collected at each site. Reference samples of small mammals (16), earthworms (3), and plants (9 each of browse, canopy, and herbaceous vegetation) were collected at sites where the soil was similar to that in the AFIs.

Biota were analyzed only for contaminant groups (e.g., inorganics, PCBs) for which at least one soil exposure benchmark was exceeded. Plants were analyzed for inorganics and

radionuclides, whereas earthworms and small mammals were analyzed for inorganics, radionuclides, and PCBs.

Other sample locations in OU 1 that were identified by this screening process were not sampled for biota. Screening benchmarks for earthworms and mice were not exceeded at the S-3 Ponds, OLF, or SL 1; at the BCBG area, benchmarks were not exceeded for mice and were exceeded at only one location for earthworms. In the case of the S-3 functional area, the soil boring location had subsequently been converted to a gravel parking area, which did not provide suitable habitat for plants or small mammals. Samples that exceeded screening benchmarks for shrews at locations in the BCBG functional area and at most locations in the BYBY functional area were not taken because access to those locations had been restricted because of potential radiological hazards to site workers. Toxicity testing was not done on soils from the source areas because of health and safety concerns for laboratory personnel.

B.6 FIELD DATA COLLECTION — BIOTA SAMPLING

BCV biota sampling addressed the impact of contaminant releases from numerous sources on biota in source areas and in the BCV floodplain. The data were also used to evaluate potential exposure of herbivores, insectivores, omnivores, and wide-ranging predators to contaminants in their food.

B.6.1 PROCEDURES

Any site where a contaminant concentration exceeded background and a screening benchmark for mice or shrews became a candidate for terrestrial biota sampling. Benchmarks for exposure of small mammals to soil contaminants were derived by assuming that contaminants are ingested directly and are transferred from soil to food. Exposure parameters for white-footed mouse (*Peromyscus leucopus*) and short-tailed shrew (*Blarina brevicauda*) included daily soil and food ingestion rates (Sample and Suter 1994) and soil-to-plant and soil-to-earthworm uptake factors taken from the Reservation-wide ERA (DOE 1995b). Toxicity benchmarks (Opresko, Sample, and Suter 1994) were used to compute soil exposure benchmark concentrations. Observed soil concentrations were compared to the calculated exposure benchmarks to identify sites in the AFIs where small mammals were exposed to potentially toxic contaminant concentrations. Because of the relatively large ranges of small mammals, only one trapping system was set up per soil transect.

The collection of biota samples and field data followed procedures outlined in the BCV OU 4 RI Work Plan (DOE 1993) and presented in *Environmental Technical Support for Bear Creek Valley Operable Unit 4 Remedial Investigation Field Activities Manual* (SAIC 1994b). This manual includes procedures consistent with those in *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990) and investigation-specific procedures developed for sampling and field data collection methods not addressed by published Energy Systems procedures. Procedures used to sample biota are listed in Table B.34.

B.6.1.1 Small Mammals

Small mammals were collected using snap-traps or Sherman live traps set along transects identified as AFIs. Traps were baited with peanut butter and rolled oats and were checked daily. The number of samples collected at each transect is presented in Table B.35.

The species, age, and sex of each sample were determined, and body measurements (weight, tail length, head/body length) were taken. Whole-body samples were washed with nonionic detergent to remove external contamination and were thoroughly rinsed with deionized water. Samples were stored at -20°C in a freezer prior to submission for laboratory analysis.

B.6.1.2 Earthworms

Earthworms were sampled by using a mustard solution (Gunn 1992) as an expellant (Bechtel 1994). This method is nonintrusive, minimizes personnel exposure to contaminants, and is not as labor intensive as hand sorting. A mustard and water suspension was applied slowly to the ground surface using a watering can to obtain even spread and minimal ponding. Surfacing earthworms were collected with forceps until no additional earthworms emerged (~20 to 25 min).

Earthworms were rinsed in the field with deionized water to remove soil and expellant, and put in a Petri dish that was then sealed and put in a cooler. All earthworms were kept moist, intact, and alive, and handling was minimized. Parameters recorded for each earthworm included sample location, sample site, date collected, total weight of earthworms collected at each site (measured in the laboratory), presence of clitellum, and general physical condition including overt signs of lesions or other abnormalities. In addition, a running total of earthworms collected since the time expellant was added (in 2-min intervals) was recorded. All earthworms were maintained in the laboratory for 3 d to allow voiding of intestinal contents (depuration) before being analyzed for radiological and chemical parameters.

B.6.1.3 Vegetation Sampling

Vegetation collected included tree foliage, herbaceous ground cover (i.e., grasses and forbs) and woody browse plants [e.g., Japanese honeysuckle (*Lonicera japonica*)]. Vegetation was collected from the same locations as earthworms. One composite sample of each type of vegetation was collected at each location. Leaves from a given tree were counted as a single sample. Ground cover and woody browse were sampled by compositing both leaves and stems at each sampling point.

Vegetation samples were rinsed with deionized water in the laboratory to remove external contamination, air dried, and stored at -20°C in a freezer prior to submission for laboratory analysis.

B.6.1.4 Fish Sampling

Field data collection for fish was not done as a part of the RI. Instead, historical data reported by the Bear Creek Biological Monitoring Program (Hinzman et al. 1995) were used. Sampling locations for this study are shown in Fig. B.50.

B.6.2 SOURCE TERM ECOLOGICAL CHARACTERIZATION

Comprehensive characterization of the full ecological impact of any potential contaminants in BCV required an investigation of the impact of potential source areas. Most of the source areas for the Bear Creek drainage reside in OU 1. The RI for OU 1 was conducted during the Fall of 1994, prior to the BCV FPSS. Hence, by the time the BCV FPSS investigation was under way, many source soil samples had been collected and sent to the laboratory for radiological and chemical analyses.

Biota were sampled at the source areas to determine the degree of bioaccumulation of contaminants in small mammals, earthworms, and plants and the potential for accumulation or biomagnification into higher trophic levels. Chemical analyses of soil samples were used to identify locations where small mammals, earthworms, and vegetation would be collected and the contaminants for which they would be analyzed. Identification of potential locations was carried out as described in Sect. B.5.3.1 (AFI floodplain soil samples), and included evaluation of the accessibility of potential sites. No intrusive sampling was done in capped sections of the source areas.

The numbers of samples and the locations at which they were taken are presented in Table B.35, and sample locations are also indicated in Figure B.3. Small mammals were collected

at the BYBY site BY17 (4 individuals). Earthworm samples were collected at BYBY sites BY17 (1 sample) and BY22 (1 sample). Plants were sampled in the vicinity of AFIs where earthworm samples were collected. Browse, canopy, and herbaceous vegetation (two samples of each for every earthworm sample collected) were collected at each site.

Biota were analyzed only for contaminant groups (e.g., inorganics, PCBs) for which at least one soil exposure benchmark was exceeded. Plants were analyzed for inorganics and radionuclides, whereas earthworms and small mammals were analyzed for inorganics, radionuclides, and PCBs.

Other sample locations in OU 1 that were identified by this screening process were not sampled for biota. Screening benchmarks for earthworms and mice were not exceeded at the S-3 Ponds, OLF, or SL 1; at the BCBG area, benchmarks were not exceeded for mice and were exceeded at only one location for earthworms. In the case of the S-3 functional area, the soil boring location had subsequently been converted to a gravel parking area, which did not provide suitable habitat for plants or small mammals. Samples that exceeded screening benchmarks for shrews at locations in the BCBG functional area and at most locations in the BYBY functional area were not taken because access to those locations had been restricted because of potential radiological hazards to site workers. Toxicity testing was not done on soils from the source areas because of health and safety concerns for laboratory personnel.

B.6.3 BIOTA SAMPLING AT FLOODPLAIN AFIs

Biota were sampled at the floodplain AFIs to determine the degree of bioaccumulation of contaminants in small mammals and the potential for accumulation or biomagnification into higher trophic levels. Chemical analyses of soil samples were used to identify locations where small mammals, earthworms, and vegetation would be collected and the contaminants for which they would be analyzed.

The numbers of samples and the locations at which they were taken are presented in Table B.35, and sample locations are also indicated in Figure B.50. Small mammals were collected at transects T01 (5 individuals), T02 (5 individuals), T03 (3 individuals), T04 (4 individuals), and T07 (3 individuals).

Soil exposure benchmarks for earthworms were taken from Will and Suter (1994). Sites that exceeded background and the benchmark value for a contaminant became candidates for earthworm sampling. A team of scientists reviewed the screening results to determine the maximum number of samples to be taken and the optimal sampling locations. Because one purpose of sampling was to develop site-specific bio-uptake factors, sampling sites were chosen to provide as wide a range of soil exposure concentrations as possible. Earthworm samples were collected at transects T01 (2 samples), T02 (1 sample), T03 (2 samples), T04 (2 samples), T07 (2 samples), and T09 (1 sample). Plants were sampled in the vicinity of AFIs where earthworm samples were collected. Browse, canopy, and herbaceous vegetation (two samples of each for every earthworm sample collected) were collected at each site.

Biota were analyzed only for contaminant groups (e.g., inorganics, PCBs) for which at least one soil exposure benchmark was exceeded. Plants were analyzed for inorganics and radionuclides, whereas earthworms and small mammals were analyzed for inorganics, radionuclides, and PCBs.

B.6.4 ECOLOGICAL REFERENCE SAMPLES

Soil samples were collected from BSCP sites ORR-11, -23, and -33 for toxicity and geotechnical analysis to supplement the historical chemical and radiological data attained during the BSCP (Energy Systems 1993e). Samples were collected in accordance with procedures described in later sections.

Reference samples of small mammals (16), earthworms (3), and plants (9 each of browse, canopy, and herbaceous vegetation) were collected at sites where the soil was similar to that in the AFIs.

B.7 GWQR DATA QUALITY ASSESSMENT

B.7.1 PURPOSE

This section of the RI report serves two purposes:

- document acceptance criteria for groundwater analytical results developed during BCV RI planning, identifying specific areas of uncertainty relative to these criteria; and
- assess the level of confidence associated with the GWPP groundwater geochemistry database, identifying specific areas of uncertainty (e.g., holding times, reporting units, and analytical method types).

The largest area of uncertainty in the GWPP data in BEIDMS is caused by the lack of laboratory quality control data and associated usability flags that would more adequately confirm data quality. These data would include such items as laboratory control samples, surrogate spike results, and matrix spike results. This uncertainty, however, can be largely overcome by using the available data in an informed manner. The massive volumes of data obtained through long-term monitoring over multiple years and the general consistency of results reduce the uncertainty.

B.7.2 SCOPE

This data quality assessment focuses on the Y-12 Plant groundwater data for 1986 through 1994, published in the annual GWQRs (e.g., HSW 1995).

B.7.3 RI DATA QUALITY OBJECTIVES

Objectives for data quality for BCV RI are summarized below. Data not meeting these criteria were determined to be unusable for the RI. As a result, 2,000 of 147,750 (1.3%) data records from the Y-12 Plant groundwater database have been eliminated from consideration. This dataset meets overall completeness objectives, except for radiochemical isotopic data. While areas of uncertainty exist, overall data quality is acceptable and is described in Sect. B.7.4.

B.7.3.1 Screening Criteria

To initiate the data screening process, certain steps were taken to eliminate non-representative data:

- **Mis-identified data.** Information derived from GWPP documents and individuals who participated in GWPP sampling activities show two mis-identified samples: 931108-106 from SS-6 and 931108-110 from BCK 9.4. These two samples are reported to have been switched in the laboratory and thus were eliminated from the RI dataset.
- **Well location.** Based on their locations, 266 monitoring wells located in the BCV hydrogeological regime were identified for use in the BCV RI.

- **Rule of four.** Characterization of current conditions in the Bear Creek hydrology requires use of data that are as complete and recent as possible. Thus, a screening criterion known as the *rule of four* was applied to data collected from each well.

GWPP sampling strategy from 1986 to 1990 involved quarterly sampling of all wells located within or near the source of the contaminant plume. After 1990, sampling focused on wells located at the periphery of the contaminant plumes, with few wells located in the center of plumes being sampled.

The *rule of four* selects data in the following manner: if a well was sampled at least four times since 1990, only those data collected since 1990 were considered during the investigation; if a well was sampled less than four times since 1990, all available data from those wells were used. Appendix D, Table D.6, lists all wells identified for use in the BCV RI along with the range of sampling dates available, well depth, and the source of data used in the investigation (1990 through 1994 or all available).

After this initial data screening process was completed, more specific criteria were used to eliminate (1) additional nonrepresentative and/or potentially inaccurate data and (2) data that do not meet sensitivity requirements established for the BCV RI. These criteria include:

- **ICP vs. GFAA.** The GWQR dataset contains metals values determined by inductively coupled plasma (ICP) methodologies and graphite furnace atomic absorption (GFAA) methodologies. A decision was made to retain only one set of metals data, as described in Sect. B.7.4.3, for inclusion in the BCV RI working dataset.
- **Elevated detection limits.** Nondetected values for diluted samples having quantification limits greater than five times the associated method detection limit were determined to be unusable for the BCV RI. Application of this criterion eliminated a total of 897 inorganic records (~1.3%) and 755 organic records (0.9%).
- **High suspended solids or interfering elements.** Results from wells with high total suspended solids, high sodium, and/or high chloride, as determined by GWQR, were also eliminated from consideration (See Sect. B.7.4).
- **Dissolved vs. total.** Where the percent difference between dissolved (filtered) metals concentrations and total (unfiltered) metals concentrations was $\geq 10\%$, metals data for that element were omitted.
- **Charge balance.** For the purposes of the BCV RI, an acceptance limit for ionic charge balance of 20% was determined. Any record with a calculated charge balance $>20\%$ was not considered during the investigation.
- **Radiochemical screening criteria.** Radiochemical counting uncertainties or minimum detectable activities exceeding the corresponding analytical value were determined to be unusable for the RI. Procedures used to collect historical radiological data as a best management plan did not specify the count times and associated minimum detectable activities/counting errors that were suitable for baseline risk assessment. Consequently, 80% of historical radiochemical data were determined unusable for the RI. In addition, the remaining data collected (H&R Technical Associates, Inc. 1995) were intended to provide a radiochemical review of selected isotopic data to determine if all isotopes of concern were

being evaluated. This did not require screening or validation as part of the evaluation and was therefore not useable in the RI.

Based on the above data, the decision was made to eliminate all radiochemical data from consideration and retain only gross α and gross β determinations that meet the above criteria. A supplemental sampling program was designed and implemented to provide new radiochemical isotopic data for use in the RI.

B.7.4 DATA UNCERTAINTY

This section uses sensitivity, precision, accuracy, representativeness, completeness, and comparability (SPARCC) parameters to assess data uncertainty and usability relative to the criteria presented in Sect. B.7.3. The assessment is limited by available information and can provide only a *general* overview of data quality. Individual results should be evaluated for their usability by comparing them to other relevant data and considering the cautions noted in this report.

Most of the uncertainty associated with the GWPP data can be attributed to the fact that the intended purpose of the GWPP data was monitoring, not RI support. Data collected for the GWPP did not undergo CLP-type data validation and are not stored with their corresponding laboratory quality control data.

B.7.4.1 Sensitivity

Determination of minimum detectable values allows an investigation to assess the relative confidence that can be placed in a value relative to the magnitude or level of analyte concentration observed. The closer a measured value comes to the minimum detectable concentration, the less confidence and more variation the measurement will have.

Sensitivity-based RI Criteria

Applicable sensitivity-based criteria established for acceptable data include the “five times” rule, which eliminates from consideration any data that are reported as a “less than” or “non-detected” value for which the associated number exceeds five times the associated quantitation limit.

Of the 897 inorganic results eliminated from consideration according to this criterion, more than half (460) were from the S-3 aggregate (5% of the S-3 data). These elevated quantitation limits occurred primarily in sulfate data from wells GW-244, -245, -246, -247, -276, -277, and -346. Antimony, beryllium, chloride, cobalt, copper, iron, molybdenum, nickel, sulfate, thorium, and vanadium in wells GW-101, -243, -345, -526, -537, and -615 were also eliminated based on this criterion.

Another 227 inorganic results were omitted from consideration in the BCBG aggregate based on this criterion. These results occurred primarily in wells GW-117, -118, -119, -626, -625, and -705. An additional 22 results were eliminated from the OLF aggregate, and 188 from the Maynardville groundwater aggregate (Table D.6), predominantly from wells GW-710 and -711.

A total of 755 (0.9%) nondetected organic values were considered unusable by the investigation based on the “five times” criterion. Of the 755 values, 236 were from well GW-243

at the S-3 Site. Contaminant levels associated with this source would require dilution of samples to bring particular analytes into the quantitation range of the laboratory instrument, thus raising the associated detection limits for other analytes.

Within the BCBG aggregate, 18 organic data values were omitted from consideration, as follows:

- one sample each from GW-014, -288, and -289;
- two samples each from GW-027, -046, -259, and -624;
- three samples from GW-626; and
- four samples from GW-623.

Other organic data eliminated from consideration based on this criterion included 27 results in the OLF aggregate (sample 891206-037 from GW-376) and 21 results primarily from GW-225 (sample 911102-025) in the Maynardville aggregate.

Application of sensitivity-derived criteria also resulted in the elimination of all GWPP radiochemical isotopic data from consideration during the RI. If an associated gross α or gross β minimum detectable activity level exceeded a sample value, data were further rejected for use in the investigation.

Blanks

Overall project sensitivity can be further evaluated by reviewing field blank information. These actual sample analyses may provide a comprehensive look at the combined sampling and analysis sensitivity attained by the project. Quality control blanks for the program, collected from 1991 to 1993, included (1) equipment rinsate blanks, (2) trip blanks, (3) field blanks, and (4) laboratory volatile blanks. Data for these types of samples analytical detection levels cannot be assumed for all results, and some data may require higher detection levels to be assigned. As a result, positively reported data associated with contaminated blanks were evaluated for false positive results.

Equipment rinsate samples were collected by pouring water over decontaminated sampling equipment. These samples were then analyzed for VOCs, metals, and radiochemical parameters. These blank samples were not analyzed for SVOCs, pesticide/PCBs, or indicator parameters (e.g., alkalinity, anions, pH). For a complete list of methods by year, refer to GWQR reports (e.g., HSW 1995) and Table B.36. VOC analytes were not detected in these rinsates at significant or consistent levels, indicating the decontamination process was effective for these compounds. Metals contaminants that were routinely identified included aluminum, boron, calcium, iron, magnesium, manganese, silicon, sodium, strontium, and zinc. These constituents were recognized to be associated with the deionized water used as the source for the rinsate samples. The deionized source was located in an active laboratory facility at the Oak Ridge K-25 Site where columns were not changed frequently enough to maintain high-quality deionized water. This problem was resolved in 1993 when the source unit was moved to a "clean area," and a more stringent maintenance schedule was instituted. Equipment rinsates were planned to be collected during each sampling event consisting of no more than 10 wells (generally). Equipment rinsates were collected at a rate of 13 to 17% across the three years, which would seem to be consistent with the RI DQOs.

Trip blanks were to be sent with each batch of samples for VOC analysis. In 1991, 271 trip blanks were collected across 238 dates; in 1992, 258 trip blanks were collected across 237 sampling dates; and in 1993, 250 trip blanks were collected across 217 sampling dates. These data indicate that a sufficient number of trip blanks were collected during these three years to document contamination during transport of samples.

Field quality control samples appear to have been collected at rates that provide an adequate description of potential artifact contamination. The current dataset contains flags that indicate the presence of volatiles contamination.

Laboratory volatile blanks are presumed to have been required at a rate of at least 1 in 20 (1/20) environmental samples, or 5%. Such blanks were actually reported at a rate of 23 to 27%, indicating that some sample delivery groups contained <20 samples.

Data Usability

Nondetected analytes

Nondetected analytes or data that are flagged "<" or "U" must be used accordingly. Both flags mean "less than" the associated value; for example, a value reported "<20.0" or "20.0 U" would be interpreted "less than" 20 or as not detected within the detection limit of 20. The inability to detect a particular analyte in a sample, however, does not necessarily mean the analyte is not present. Each analytical method has a method detection limit; concentrations below this limit cannot be detected with any confidence. For a complete list of analytes and detection limits, refer to Tables B.37, B.38, B.39, and B.40. Thus, although undetected, an analyte could be present in a concentration less than the detection limit. In the above example (<20.0 or 20.0 U), the analyte could be present at less than 20 units. This concept becomes especially important when an "action" or "trigger" level (the level at which contamination is considered to be present) is exceeded by the associated value. If the associated value (e.g., <20.0) is greater than an "action" level (e.g., 10.0), contamination may or may not be present above the action level.

In the statistical analysis of data, such values can be treated several ways. They can be considered "0," or 1/2 the detection limit, or even the detection limit. In calculating statistics for the groundwater aggregates, nondetects were set to 1/2 the detection limit except for radionuclide analyses. Regardless of the statistical use, the user must interpret individual data points according to the above information.

Positive identification

For a single sample to be considered positive, the Environmental Protection Agency (EPA) recommends that the value of the reported concentration should be significantly greater than any reported in the background samples or field quality assurance samples. EPA further defines "significant" as follows:

- For constituents present only in environmental samples and not detected in background samples or quality assurance samples (field or lab), a "three times" detection limit rule is used.
- If the background sample contains the constituent of concern, a concentration of at least five times background is required in the sample.

- Where quality control has uncommon contaminants, use a “five times” rule; for common contaminants, use a “ten times” rule.

Where a value meets any of these three criteria, it is considered positively identified. If not, EPA guidance uses a “three times” rule, wherein a value must exceed three times the analytical detection limit.

As a concentration approaches the analytical detection limit, the confidence associated with those values diminishes. As with human vision, one simply cannot “see” anything smaller or farther than a particular standard; as the limit of vision is approached, vision becomes less accurate and less precise. Therefore, a value very close to the analytical method detection limit is not as accurate as one several times larger.

Further, analytical methods are limited by matrix interferences, matrix heterogeneity, analytical precision, analytical accuracy, and many other factors. For this reason, an analytical value cannot be interpreted as an “absolute” number. A value reported as an analytical concentration could have an associated analytical error of as much as two to five times the method detection limit. Therefore, where a method detection limit is 10, a reported value of 15 should be considered to be between 0 and 65; however, as the reported value approaches 50 (for a detection limit of 10), confidence in a positive identification increases.

B.7.4.2 Precision

Precision is defined as the reproducibility or degree of agreement among duplicate measurements under a given set of conditions. The closer the measurements approach one another, the more precise the measurement. The level of precision is generally determined by calculating the relative percent difference (RPD) between two measurements. Field duplicates are collected to assess the precision of sample collection procedures, matrices, and analytical procedures. Similarly, analytical laboratory precision can be measured by the analysis of sub-samples of an aliquot. Sample homogeneity, analytical method performance, and the quantity of the analyte being measured all contribute to this measure of analytical precision.

Contribution to variability resulting from the combination of environmental media, sampling consistency, and analytical precision is measured by analyzing field duplicate samples. Field duplicate samples are samples collected at the same time and from the same point (e.g., well) as the original sample. EPA data validation guidelines call for the estimation of all associated data where laboratory precision exceeds 20%. When field duplicate pairs are simultaneously collected from a single well, precision usually approaches laboratory precision. As indicated above, the quantity of the analyte being measured contributes to the measure of precision. For this reason, criteria apply only where both the original and duplicate samples are >5 times the quantitation limit goal.

The GWPP dataset contains 15,201 field duplicate pairs. Of these data, 1130 pairs (7%) exceed 20% RPD. More than 70% of these values with 20% RPD are associated with the following metals analytes: aluminum, manganese, boron, iron, and zinc. Four wells (GW-190, -255, -191, and -262) account for 45% of the values with >20% RPD. Radiochemical analytical precision is calculated without considering analytical counting uncertainty.

The precision of organic and radiochemical GWPP data was concluded to be acceptable without qualification, and the precision of inorganic GWPP data was concluded to be largely acceptable, with the possible exception of the four wells noted above.

B.7.4.3 Accuracy

Accuracy is a measure of the difference between a measured value and its true value. Analytical accuracy is evaluated by measuring the agreement between an analytical result and its known or true value. This is generally determined through the use of laboratory control samples, matrix spike analysis, and performance evaluation samples. Factors that contribute to analytical accuracy include method accuracy, analyst error, instrument accuracy, and sample-specific matrix interferences. Any combination of these factors can and frequently does cause a result to be significantly biased, yielding a measured value that is either higher or lower than the actual value.

Accuracy-based RI Criteria

Accuracy-based criteria established during the BCV RI prompted the decision to (1) eliminate either the GFAA or ICP data where both existed and (2) eliminate data for which the associated charge balance exceeded 20% (Sect. B.7.3).

ICP versus GFAA

Although ICP values were generally comparable to available GFAA data, the ICP values for arsenic, cadmium, chromium, lead, selenium, and silver were excluded from the working dataset and replaced by GFAA values. Conversely, the GFAA values for barium and beryllium were excluded from consideration and were replaced by ICP values.

Chromium values reported by ICP are consistently higher than comparable GFAA data. Several factors may contribute to this anomaly. ICP methods are used more routinely than GFAA methods. Additionally, chromium is not completely soluble in nitric acid, which is the sole reagent used to prepare aqueous samples that are to be analyzed by GFAA. Samples to be analyzed by ICP are prepared using both nitric and hydrochloric acids. Therefore, the ICP data would be expected to be higher.

Determining which set of data (ICP vs. GFAA) is the most accurate for assigning chromium values is hampered by the lack of calibration and matrix spike data. However, based on the above discussion and the fact that the use of ICP data in this case yields the higher values, the use of ICP chromium data is believed to be more conservative than the use of GFAA data. It should be noted that prior to 1994, matrix interference may have produced falsely elevated or repressed values for ICP chromium, lead, and cadmium.

Charge balance

The calculation of charge balance is applicable for checking the correctness of analyses of water samples for which relatively complete mineral analyses are made. Theoretically, the sum of the anions, expressed in me/L, must equal exactly the sum of the cations, in me/L, in any sample. In practice, the sums are seldom equal because of unavoidable variations in the analysis. This inequality increases as the ionic concentrations increase. If values of differences of the sums fall outside acceptable limits, at least one of the determinations should be rechecked (APHA 1975).

GWPP samples having an unusually high or low charge balance have zeros reported for one or more parameters (usually calcium, magnesium, potassium, or sulfate) or high nitrate values. As nitrate is a contaminant of concern in the BCV regime, these samples should not be considered "out of balance." Where no value was reported, the calculation includes a zero value. This can sometimes throw the charge seemingly out of balance when, in fact, not enough information is known to establish a charge balance for that sample. No trends were observed that would suggest a need to eliminate a whole block of data from use. However, the user is encouraged to note those samples for which charge balance was determined to be "out of balance" and to consider individual cation or anion values that may seem to be significantly biased based on the history of that analyte in that well.

A total of 175 records (~0.2% of the database) were eliminated from consideration during the BCV RI as a result of charge balance results as follows: 18 from the OLF groundwater aggregate, 68 from the Maynardville groundwater aggregate, 41 from the BCBG groundwater aggregate, and 48 from the S-3 Site groundwater aggregate.

Laboratory data reporting

Accuracy of analytical data can be greatly affected by laboratory data reporting in addition to the analysis of samples. Accurate reporting and use of data include consideration of data quality flags, units of measure, and other factors.

Data quality flags. Data reported by a laboratory usually contain flags to indicate those samples that failed laboratory quality control requirements. All electronic datasets were searched for the presence of such laboratory flags. The only laboratory flags available for these data are the > and < symbols, indicating "greater than" and "less than" the corresponding value. Data with these flags should be used appropriately.

Units of measure. Also indicated as crucial to accurate data reporting are the analytical units of measure. In a dataset that has been collected over a long period, parameters are often reported in different units during different time periods. Units should always be noted by the user during data interpretation. Datasets for 1986 through 1994 were checked for consistency in reporting units and were found to be standard throughout the database with the following exceptions:

- Some radioisotopes are reported in bq/L as well as pCi/L.
- 1994 conductivity units have two spellings: $\mu\text{mho}/\text{cm}$ and $\mu\text{mhos}/\text{cm}$.

Other data

Radiochemical data have been reported in many different ways during the life of the GWPP. Various data have been reported with the "<" flag, with associated uncertainty, and with negative (less than zero) values. The appropriate and accurate use of radiochemical data depends in part upon these reporting techniques. The user should be aware of these differences in reporting techniques during data interpretation, particularly in association with statistical calculations.

The analysis of water samples for nitrogen can be reported in several ways. Data can be calculated as nitrate, nitrite, nitrogen, or both nitrate and nitrite. In any given year, data may have been reported under as many as three different parameters. All, however, were performed by the same ion chromatography method (EPA 300.0). These data should be used with appropriate caution for interpretation according to the intended analyte.

Isotopic uranium is reported as $^{234}\text{U}/^{235}\text{U}$ and ^{235}U alone. Although isotopic separation is possible, it is not easily or usually done unless specifically requested. Such data should be treated appropriately. Either ^{234}U or ^{235}U or both could occur in the BCV since ^{234}U occurs naturally at about 0.71%, ^{235}U was generated by Y-12 Plant uranium enrichment activities during or after World War II, and both have long half-lives.

B.7.4.4 Representativeness

Representativeness, which expresses the degree to which data accurately reflect the analyte or parameter of interest for the environmental site, is the qualitative term most concerned with the proper design of the sampling program (EPA 1987). Factors that affect the representativeness of analytical data include proper preservation, analytical holding times, use of standard sampling and analytical methods, and determination of matrix or analyte interferences.

RI Criteria Associated with Representativeness

Factors considered during the BCV RI include (1) total versus dissolved analyses and (2) elevated concentration of potential interferant.

Total vs. dissolved analyses

GWPP metals samples were collected in duplicate, with one fraction being filtered in the field before preservation. Because the dissolved fraction is a subset of the total fraction, analysis is expected to yield equal or higher results in the total fraction. Where the dissolved fraction was greater and the percent difference exceeded 10%, the total vs dissolved comparisons were considered unacceptable for the BCV RI because the values are suspected of being erroneously reported. A total of 108 data points (~0.1% of the database) were considered unusable for this reason. Of these 108 data points, 35 came from the S-3 Site aggregate, 44 from the Maynardville aggregate, and 29 from the BCBG aggregate.

Elevated concentrations of interferant

Data for samples with elevated concentrations of total suspended solids, sodium, or chloride were eliminated from consideration in the BCV RI as discussed in Sect. B.7.3. Eliminated analyses are listed in Table B.41. Total analytical results for samples with high levels of suspended solids might indicate a high concentration of a contaminant of concern in the water sample when, in fact, the contaminant is not present in the water but in suspended material. In this case, the use of dissolved, rather than total, data is desirable.

The presence of certain metals and cations (e.g., sodium, chloride, magnesium, calcium, potassium) in high concentrations can interfere with the analysis of other metals by ICP. This problem can be overcome by using interelement correction factors in the calculation of metals results.

Analytical Holding Time and Methods

The purpose of an environmental field investigation is to collect data that are representative of the site at the time of the investigation. Therefore, the preservation of environmental samples and completion of the required analyses according to standard analytical methods in a timely manner are critical. For analytical methods, refer to the GWQR reports (e.g., HSW 1995).

Samples are preserved by adding chemical preservative, controlling sample exposure to environmental factors such as light and air, and controlling the temperature at which the samples are stored. Protocol for sample preservation has been established for the GWPP, and routine assessments are conducted to ensure compliance. Therefore, sample preservation is not considered a source of uncertainty.

Table B.42 lists appropriate preservatives and analytical holding times for VOC, SVOC, pesticide/PCB, metals, cyanide, and radiochemical analyses. Analytical holding time is measured from the time of sample collection to the time of preparation and/or analysis. GWPP data in BEIDMS include the date of collection for all samples, but have only a date of analysis for volatile analyses. This information can be used to determine that all volatile analyses were performed within the routine analytical holding time of 14 d. However, data are not available to evaluate the analytical holding time of other parameters. Holding times are not likely to have been excessive for metals or radiochemical analyses. However, they could possibly have been exceeded for SVOC, pesticide/PCB, and mercury analyses. This lack of data introduces further uncertainty into the GWPP dataset.

The lack of holding time and preservation information, while introducing some uncertainty, does not present an unacceptable amount of uncertainty. The rejection of data for these reasons is rare and, therefore, unlikely to have affected a significant portion of samples.

Statistical Outliers

A value considered to be statistically “out of range” is not necessarily analytically inaccurate. Individual data points that seem suspect should be evaluated against other data from the same well under similar conditions to determine the data usability.

The effects of matrix interferant in water samples, while not as severe as in soil samples, can severely impact the representativeness of a dataset. As discussed in reference to analytical accuracy, data for measuring these effects were not available at the time of this review. Therefore, an unknown amount of uncertainty is introduced into the representativeness of the dataset. Apparent outliers might be compared to data, such as the BCV OU 2, OU 4, OU 1, or FPSS data, which have undergone a thorough CLP-type data validation process, including evaluation of matrix spike and laboratory control samples.

B.7.4.5 Completeness

Completeness of a dataset is an assessment of the quantity of samples collected and analyzed and the resulting data considered to be usable. Usable data are defined as those data that pass individual scrutiny during a review process (usually a data validation effort) and are accepted for unrestricted application to a human health risk assessment or equivalent applications.

The GWPP generated an abundance of data, a subset of which was selected for use in the BCV RI. Stations GW-196, -197, -237, and -509 were determined to have insufficient data and were eliminated from the data set. For other stations not having a minimum of four data points from 1990 through 1994, all available data were included in the RI. These and other criteria described in Sect. B.7.3 resulted in the rejection of 2000 of 147,750 (1.3%) GWPP data points. In addition to this 1.3%, all isotopic radiochemical data were rejected.

B.7.4.6 Comparability

Comparability is a qualitative term relative to a project dataset as an individual. A dataset comparable to other relevant datasets would possess narrowly defined sampling methods, site audits/surveillances, use of standard sampling devices, uniform training, documentation of sampling, standard analytical protocols/procedures, quality control checks with standard control limits, and universally accepted data reporting units to ensure comparability to other datasets.

Although sampling and analysis protocols may have changed as techniques have improved, the GWPP maintains standards and controls that provide data comparability. A more detailed review of comparability is provided in the BCV integrating data quality assessment (Sect. B.8).

B.7.5 CONCLUSIONS

The 1986 through 1994 GWPP dataset is judged adequate for use in the BCV RI, however, several specific areas of uncertainty, such as holding times, reporting units, and reporting analytical method types, are noted. The primary cause for rejecting 1.3% of the GWPP data for use in the BCV RI was elevated quantitation limits. Other causes for rejected data include a preference of methodology, elevated concentrations of interferant, unacceptable charge balance information, and unacceptable total comparisons with dissolved analyses.

The 1994 values for the benzene, ethylbenzene, toluene, and xylene parameters, as well as chromium values produced by GFAA methodologies, should also be rejected. Other data may be considered usable with caution as described herein.

B.8 BCV INTEGRATING DATA QUALITY ASSESSMENT

B.8.1 PURPOSE

The purpose of this integrating data quality assessment is to evaluate quality assurance/quality control results associated with the BCV RI dataset to confirm that data used in the RI report meet the stated objectives. This assessment included evaluations of field collection activities and laboratory analysis. The effect of field collection activities on analytical data was assessed by examining completeness, field quality control sample results, and quality assurance program findings. The effect of laboratory analysis on data quality was assessed by examining quality assurance program findings and evaluating SPARCC parameter results and goals.

Both quantitative measures and qualitative assessments were performed to characterize these data as having sufficient quality to satisfy stated objectives. As demonstrated in the following subsections, this assessment concluded that data originating from the BCV OU 4, BCV OU 1, and BCV FPSS field investigations can withstand scientific scrutiny (for its intended purposes), are technically defensible, and are of a known and acceptable precision and accuracy. Further, these data were compared to the previously assessed GWPP data to provide a comprehensive discussion of all data used for the BCV RI.

B.8.2 SCOPE

For purposes of this discussion of the integration data quality assessment, the available data and their sources have been categorized into quantitative and qualitative information. Table B.43 presents an index of the available numbers of samples from each source and medium providing qualitative or quantitative information.

Data from BCV OU 4, BCV OU 1, and BCV FPSS field investigations are evaluated against established, project-specific SPARCC criteria. General data quality are then summarized, noting areas that merit caution relative to data usability.

The GWPP groundwater data, which were also used to characterize the nature and extent of contamination in the BCV, have been previously evaluated (Sect. B.6) and thus are noted only for summary purposes.

B.8.3 DATA ACCEPTABILITY

More than 75,000 discrete soil, sediment, groundwater, and surface water analyses were accumulated for use in the BCV RI during the OU 4, OU 1, and FPSS field investigations. Of these, only 672 are considered to have sufficient problems with data quality to merit being flagged unacceptable (R).

The acceptability of analytical data to a project is determined by the criteria established for that project. In all BCV RI field investigations, CLP data validation criteria were selected as the criteria for comparison during the analytical data validation effort. Application of these criteria resulted in the rejection of <1% of all collected data for all three field investigations for use during the analytical data validation process. These data, which include those that failed CLP or

project-specific criteria, are flagged with an “R.” Following is an assessment of the impact of these rejections on each of the three projects.

BCV OU 4

Less than 1% of OU 4 surface water data were rejected during the data validation effort. These rejected data are primarily radiochemical data exhibiting severe matrix interferences. The rejected radiochemical data include 12 of 255 total gross α values ($>150\%$), 18 of 255 total gross β values, and 17 of 255 dissolved gross β values. The rejected values, which must be considered extremely positively biased, can be used for qualitative purposes only; they are unacceptable for quantitative use.

Matrix interferences also affected individual isotopic analyses. Of 10 ^{241}Am values, 2 were rejected because chemical recovery was $<20\%$. Additionally, 1 out of 46 isotopic thorium values was rejected because of low surrogate recovery. Other values for isotopic thorium and isotopic uranium were also rejected because chemical recovery was $<20\%$.

Some of these data should be eliminated from consideration entirely, while others can be used for qualitative purposes only. Data that can be used on a limited basis include total gross β values for SB1020 and SN3020 and dissolved gross β for SB1021. In all of these cases, the values are sufficiently elevated to warrant the interpretation of gross β activity, even though the laboratory control sample and matrix spike recovery were extremely elevated. Additionally, the SN3002 total gross α value may be used for qualitative purposes. Again, the associated value is elevated and may be considered indicative of some level of gross β contamination, regardless of the extremely high matrix spike value.

Several isotopic uranium values, which have been qualified “R,” may also be usable for limited purposes: SN3019, $^{233,234}\text{U}$ and ^{238}U ; SN3020, total and dissolved ^{234}U ; and SN3020, total and dissolved ^{238}U . As with the gross values discussed above, reported values are sufficiently elevated to warrant the interpretation of some radiochemical contamination, although quantitation of those values is impossible because of matrix interferences.

BCV OU 1

About 1.5% of all the BCV OU 1 data were rejected for use during the data validation effort. These data were predominantly BCBG soil data, rejected primarily because of antimony results exhibiting extremely poor accuracy. All pesticide/PCB data in three samples were rejected because of poor surrogate recovery.

BCV FPSS

Less than 1% (40 data points) of all FPSS data were flagged as unusable during the analytical data validation effort. Three of the rejected data points were reference points for antimony, which were considered critical to the BCV RI. However, existing nonrejected data were sufficient to calculate background values; therefore, the RI was not impacted as a result of the rejected antimony reference points.

The other 37 rejected data points were for:

- antimony,
- N-nitrosodiphenylamine, and
- americium, curium, and uranium.

All antimony soil and sediment data were qualified because of poor matrix spike recovery. Although matrix interferences to antimony are common in soil and sediments, recovery was sufficiently poor (18.8 to 50.4%) to warrant rejection of some and estimation of most associated antimony data points. In general, soil antimony data should be considered extremely negatively biased, and the 8 of 46 soils and 5 of 26 sediment samples qualified with an "R" should be considered unusable for any purpose. Associated antimony values are reported as non-detects. Values reported as non-detects in conjunction with a negative analytical bias result in inconclusive data, which should not be used for any purpose.

The rejection of three organic soil data points is associated with variation in instrument calibration. These rejected data points were all non-detected values for N-nitrosodiphenylamine, which is not a contaminant of concern in the BCV.

Rejected radiochemical data include seven uranium, two curium, and one americium soil data points. Poor surrogate recovery in these analyses warrants the rejection of these data for all purposes.

The only significant impact of rejected data in the FPSS dataset is that associated with the soil/sediment antimony data.

Summary of Data Acceptability

The overall quality of all OU 4, OU 1, and FPSS data is acceptable: <1% (672/78,455) of the data were found (through the analytical data validation process) to have sufficient quality problems to preclude their use for any purpose. The overall impact of rejected data to the BCV RI is minimal, with the relatively largest impact being radiochemical and metals data for soils and sediments. By far the greatest challenge to data interpretation is not insufficient or unacceptable data, but, rather, the appropriate use of available data. Therefore, this assessment will focus on data that, because of their quality, present a challenge to data usability.

B.8.4 QUALITY ASSURANCE PROGRAM

Each field investigation project establishes a project-specific quality assurance program that provides procedures and criteria that ensure an endproduct of data of known and defensible quality. Such procedures/criteria include DQOs, analytical methodologies, laboratory deliverables, data review, field change order documentation, Non-Conformance Report (NCR)/Analytical Data Non-Conformance Report (ADNCR) documentation, and others. DQOs generally include acceptance criteria for SPARCC parameters. Following is a description of the quality assurance programs and their project-specific criteria and/or procedures.

B.8.4.1 Sample Collection Activities

Quality assurance of sample collection activities for each field investigation includes audits and surveillances. These audits/surveillances include thorough internal and external reviews of adherence to established procedures for sample collection, chain of custody, field instrument calibration, preventive maintenance, and other activities. Field investigations supporting this RI report were subjected to ten internal surveillances and three client (Energy Systems and/or Department of Energy) audits. Table B.44 summarizes project audits and surveillances for each field investigation supporting this RI.

B.8.4.2 Laboratory Deliverables

Project quality assurance plans for the three field investigations outlined requirements for laboratory instrument preventive maintenance, zero calibration, data reduction, and reporting. Each project required the analytical laboratory to provide comprehensive deliverables, including data summary forms (EPA CLP-type forms or their equivalent), raw data, and instrument calibration information necessary for a thorough review of all data. This type of deliverable is equivalent to the former EPA Level IV data deliverable. Each project also required analytical laboratories to provide electronic data deliverables, thus eliminating the need for extensive data entry and the associated potential for data error.

B.8.4.3 Analytical Data Review

Data were reviewed for accuracy and precision during the laboratory data generation phase of the projects and then by SAIC analytical chemists during the data validation/evaluation process. The data validation approach used for all three projects involved a comprehensive review of 10% of the data and a summary review of the remaining 90%. The summary review did not include an evaluation of matrix spike data. Therefore, appropriate use of the data required conclusions to be drawn on the basis of this assessment and other available information, as well as the data validation qualifiers in the dataset. Only the BCV OU 4 dataset was flagged for poor sensitivity associated with field quality control blank samples.

B.8.4.4 Data Quality Objectives

Each project established objectives for data quality using SPARCC parameters, as summarized in Table B.45. Section B.8.5 compares data quality to these established objectives.

B.8.4.5 Quality Assurance Reports

Quality assurance reports such as SAIC's NCR/ADNCRs, corrective action reports, and field change orders were used to document deviations from established procedures or criteria. Copies of individual reports were routed through the project organization as appropriate.

A total of 40 field change orders and 134 NCR/ADNCRs were generated during these investigations. ADNCRs document nonconformance issues related to analytical data, while NCRs document all other types of nonconformance issues. All NCR/ADNCRs have been satisfactorily concluded. All problems, as well as their root causes and corrections, where applicable, are documented in the project file.

B.8.5 DATA EVALUATION

B.8.5.1 Completeness

The combined recent and historical BCV RI database includes analytical data for groundwater, surface water, surface soil, sediment, subsurface soil, waste, and biota. The primary BCV studies are the BCV OU 4, BCV OU 1, BCV FPSS, and GWPP. The BCV OU 1 and FPSS field investigations established individual project completeness objectives requiring 90% of all planned samples to produce valid analytical data. Background or reference locations were considered critical to both projects and required 100% completeness. Specific goals were not defined for the BCV OU 4 and GWPP investigations.

BCV OU 4

The BCV OU 4 project was evaluated during implementation as an ongoing process. Some originally planned segments were eliminated, and others were added to accommodate the evolving approach to a valley-wide investigation (Fig. B.51). Evaluation of established completeness goals is not appropriate under these circumstances. However, based on the interpretation of data in Appendices C, D, and E, the amount of data collected meets project needs.

BCV OU 1

The BCV OU 1 field activity investigated four separate areas: BYBY, OLF, S-3 Ponds, and SL 1. Project-specific criteria for the BCV OU 1 field investigation called for 90% of all planned data to be collected and validated for all four areas.

A total of 349 samples were planned for the OU 1 project. Of these, 295 (85%) were collected, with <2% (458/31,151 data points) then being rejected during the data validation process. Planned versus collected samples are summarized in Fig. B.52.

Because of the uncollected samples, each site except for SL 1 was <90% complete. Twelve locations are not represented by any data: BG-09 (soil) and BG-06, -07, -08, -09, -10, -11, -14, -15, BY-07, BY-08, and SL1-02 (all groundwater).

BCV FPSS

The same completeness criteria established for BCV OU 1 were applied to BCV FPSS. Of all planned samples, 83% (364/437) were collected (Fig. B.53). Uncollected samples included 16 sediment samples and 57 soil samples. All surface water and reference samples were collected.

Less than 1% (40 data points) of all data were then flagged as unusable during the data validation effort. The 40 rejected data points were primarily metals soils/sediment data. Three of the 40 points were reference points for antimony. These antimony and other rejected metals data were considered unacceptable because of extremely poor accuracy.

Summary of BCV RI Data Completeness

The compilation of these datasets creates a summary dataset that represents multiple media in the BCV regime and provides adequate data from which to draw conclusions about the extent of contamination related to each source.

B.8.5.2 Accuracy

Laboratory control samples, matrix spike analysis, and performance evaluation samples were used to assess the accuracy of data resulting from the BCV OU 1, BCV OU 4, and FPSS investigations. Data validation of matrix spikes was limited to those data packages that were comprehensively reviewed as described in Sect. B.8.2.

BCV OU 4

All organic and inorganic laboratory control samples indicate the non-radiochemical laboratory analytical processes were in control. However, data for several metals and radiochemical parameters had to be qualified because of poor accuracy, suggesting that their stable chemistry analyses were inhibited by matrix interferants.

Organic data

Out of the 253 chloroethane values, 170 (67%) are qualified as estimated because of poor laboratory instrument calibration. This qualification indicates that the instrument used for analysis of these samples was not operating properly, introducing a degree of uncertainty for these data.

Inorganic data

Inorganic analytes that merit close attention to potential bias include mercury, cyanide, antimony, aluminum, iron, lithium, and silver. Mercury matrix spike recoveries ranged from 55% to 137%; cyanide recoveries ranged from 41% to 110%; and antimony, aluminum, iron, lithium, and silver recoveries ranged from <1% to 144%. All of these analytes have associated unacceptable matrix spike values in at least some cases and a tendency towards low matrix spike/matrix spike duplicate recovery. This pattern indicates a potential for negative bias in these data.

Radiochemical data

Of 33 ^{234}U data points, 15 (45%) were qualified as estimated because of high matrix spike recoveries, and 17 (52%) were estimated because of low matrix spike recoveries. Therefore, almost all ^{234}U data that were evaluated based on matrix spike recoveries are considered to be highly variable and potentially biased.

Radiochemical data were also estimated because of laboratory control samples and surrogate recovery. Of 24 ^{238}Pu and $^{239}\text{Pu}/^{240}\text{Pu}$ data points, 5 were qualified as estimated because of low surrogate recovery. These data should be considered negatively biased. Of 41 ^{90}Sr values, 12 are considered estimated because of low laboratory control samples recovery, as are 12 of 36 ^{99}Tc values. Again, these data should be considered low estimates of true values.

BCV OU 1

Groundwater

As with OU 4, OU 1 stable chemistry laboratory control samples data indicate that analytical processes were in control, but apparent matrix interferences resulted in qualification of some data. Of 15 groundwater samples, 4 were qualified as estimated because of elevated recovery for

aluminum and depressed recovery for antimony in the matrix spike. Therefore, aluminum values are considered positively biased, and antimony negatively biased.

Additionally, 7/9 groundwater data points for 2,4-dinitrophenol are considered to be inaccurate (flagged as estimated) because of fluctuations in the calibration of the analytical instrument.

Soil

Soil data were qualified because of poor matrix spike recovery for antimony as well as poor laboratory control samples recovery for radiochemical parameters and fluctuations in analytical instrument calibration.

All OU 1 antimony soil data should be considered negatively biased. A significant portion of all radiochemical soil data is qualified "UJ" (estimated) because of low laboratory control samples recovery. These data should be considered negatively biased.

Two organic analytes (2,4-dinitrophenol and chloroethane) exhibit significant fluctuations in calibration information that may cause data to be of less than desirable accuracy. Of the 75 2,4-dinitrophenol soils data points, 70 are qualified "UJ," and of the 205 chloroethane soil data points, 46 are qualified "UJ."

Surface water

Similar to the soil data, 15/16 surface water chloroethane data points are qualified as estimated because of poor calibration of the analytical instrument.

BCV FPSS

Process control

Laboratory control soil sample data for barium, potassium, and sodium indicate analytical processes may not have been in control for these analyses. Analyte recovery for these parameters ranged from 92% (lowest value for all three analytes) to 133% for barium, 232% for potassium, and 632% for sodium. Because potassium, barium, and sodium are common elements that occur in most soil samples at quite variable concentrations, these analytical variations will cause minimal impact on data confidence.

Matrix spikes

Matrix spike recovery for mercury, lithium, manganese, and antimony exceeded the project criterion of $\pm 20\%$. In most cases, recoveries ranged from $<80\%$ to $>120\%$. This broad range of analyte recovery indicates a similarly broad range of accuracy in these analytes.

This tendency is particularly exaggerated in antimony soil data. All antimony soil data were qualified because of poor recovery in the matrix spike. Recovery was sufficiently poor (18.8% to 50.4%) to warrant the rejection of some associated antimony data points. Soil antimony data should be considered extremely negatively biased, and those qualified with an "R" should be considered unusable for any purpose.

Serial dilutions

Serial dilutions are performed during ICP analysis to further evaluate potential matrix interferences. When analyzed at a 10-fold dilution, interferants are expected to be significantly reduced or eliminated. Therefore, diluted results, when multiplied by the appropriate dilution factor, should agree within 10%. In 34 out of 46 FPSS soil samples, associated serial dilution results fail to agree within 10% of the original value for zinc, suggesting the presence of a matrix interferant, and are thus qualified as estimated. In all cases, the diluted sample had a higher value for zinc than the original. Therefore, zinc soil values for FPSS should be considered negatively biased.

Summary of BCV RI Data Accuracy

Accuracy in the BCV dataset is summarized in Table B.46, which presents an overall perception of data accuracy based on that portion of data receiving comprehensive validation. The table also indicates those analyte data that have poor accuracy and little confidence and whether they have been flagged in the data set.

Most problems seem to be attributable to matrix interferences in metals data. Exceptions would be the negatively biased cyanide data and ^{234}U in the surface water. Uranium-234 matrix spike recovery resulted in the qualification of 32/33 surface water data points.

B.8.5.3 Precision

Field duplicate samples, collected along with environmental samples during the BCV OU 1, BCV OU 4, and FPSS investigations, were analyzed to assess analytical precision. Assessment results are presented in following paragraphs.

*BCV OU 4**Organic and inorganic data precision*

Field duplicates indicate acceptable overall precision for all organic and inorganic analytes, except for total and dissolved aluminum, total iron, and total manganese. The average RPD for each of these analytes exceeds 35%. Of the 255 total and 255 dissolved aluminum values, 50 (19.6%) total and 80 (31%) dissolved values are qualified as estimated because of poor precision. Of the 255 total iron values, 70 are similarly qualified, and of the 255 total manganese values, 78 are flagged with a "J." Therefore, these analytes should be used with caution throughout the OU 4 dataset.

Radiochemical data precision

OU 4 gross α data must also be used with caution. Of 255 total and 255 dissolved gross α data points, 53 total and 52 dissolved data points are qualified "J" because of a poor laboratory duplicate error ratio. Additionally, 71/255 ^{235}U values are considered estimated because of poor laboratory precision.

BCV OU 1

Precision of analytical data is consistently acceptable across the BCV OU 1 project.

BCV FPSS**Soil**

Inorganic field duplicate RPDs for soil samples range from 3.6% (mercury) to 88.7% (cadmium). Laboratory duplicates for arsenic and manganese fail to meet CLP criteria. However, very few samples required qualification for these reasons. Overall precision of soil data is acceptable.

Sediment

Sediment sample RPDs for inorganic parameters range from 0.75% (magnesium) to 49.93% (lead). Analytes for which the average RPD exceeds 20% include aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, and potassium. Where this criterion is exceeded, data are qualified as estimated. All organic RPDs for sediment field duplicates are acceptable.

Precision of radiochemical field duplicates was evaluated by calculating the duplicate error ratio. Precision is considered acceptable where the duplicate error ratio is <1 . In the only sediment duplicate pair, the duplicate error ratios for ^{99}Tc , ^{228}Th , ^{230}Th , ^{232}Th , ^{234}U , ^{235}U , and ^{238}U fail this criterion. Although sediment data for these analytes are not qualified because of field precision, they should be considered estimated.

Summary of BCV RI Data Precision

The overall impact of poor precision on the BCV RI dataset is summarized in Table B.47, which shows that precision-related factors did not contribute significantly to poor data quality. Radiochemical precision is affected only in sediment and surface water data. Of these, all surface water data points, which are considered estimated because of laboratory precision, are qualified. The user is cautioned in the use of ^{99}Tc , ^{228}Th , ^{230}Th , ^{232}Th , ^{234}U , ^{235}U , and ^{238}U sediment data because, although not qualified, they may be significantly impacted by poor precision.

Inorganic data affected by poor precision include (1) very few arsenic and manganese soil values; (2) aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, and potassium sediment values; (3) aluminum, iron, and manganese in OU 4 surface waters; and (4) dissolved aluminum in OU 4 and OU 1 surface water.

B.8.5.4 Sensitivity

Required sensitivities vary across the three BCV projects, in some cases significantly so. In addition to this variability in sensitivity, the requested detection limits were not always obtained. Such is the case with ^{99}Tc data for NT-3 surface water samples. These data have associated minimum detectable activities (sensitivity) of ~50 to 60 pCi/L, which far exceeds the requested project detection limit of 1 pCi/L. Although the reported activities for the NT-3 surface water samples are all less than the 50- to 60-pCi/L minimum detectable activity, they nevertheless exceed the requested 1-pCi/L detection limit in some cases. Therefore, these data should be rejected for all use.

Another reason detection limits may exceed those required by the project is that contamination in the laboratory method blank may have caused the elevation of that detection

limit during data validation. Contamination in an associated laboratory blank can result in a “U” qualifier being applied to a result, thus adjusting the reported detection limit to the associated value. For example, a value reported as 27 µg/L for which the laboratory detection limit is 5 µg/L and in which the associated blank for that analyte reports 20 µg/L might be flagged “U.” In this case, the detection limit has effectively been adjusted from 5 to 27 µg/L. A significant portion of acetone and methylene chloride data is affected in this manner. Additionally, metals, including dissolved aluminum, iron, copper, cadmium, lithium, and sodium, are also frequently affected. Di-n-butylphthalate and ²³⁴U complete the list of parameters significantly affected by method blank contamination.

BCV OU 4

In the BCV OU 4 project, dissolved aluminum data were qualified because of laboratory blank contamination in 80/255 surface water samples. Contamination in associated blanks with dissolved iron and total copper qualified an additional 90 and 95 samples, respectively. Organic blank contamination for this project resulted in elevating 74/253 methylene chloride surface water detection limits. Radiochemical contamination of blanks with ²³⁴U resulted in 9/33 samples being qualified as estimated.

BCV OU 1

The only parameter for which a significant portion of data had elevated detection limits because of associated laboratory method blank contamination was di-n-butylphthalate. Of 75 soil data points, 66 were so qualified.

BCV FPSS

Metals contamination of associated laboratory method blanks led to the adjustment of detection limits for cadmium, lithium, and sodium soil samples, resulting in qualification of 10/46 cadmium soil data points, 11/46 lithium soil data points, and 12/46 sodium soil data points. Organic contamination of soil blanks resulted in 24/46 acetone soil data points and 46/46 (100%) methylene chloride soil data points receiving adjusted detection limits.

Sediment data were also qualified for metals and organic blank contamination in a significant portion of samples. Laboratory method blank contamination resulted in 11/26 cadmium samples and 8/26 sodium samples being qualified “U.” Of 26 herbicide samples, 19 were qualified “U” for all three herbicide parameters. An additional 16/26 acetone and 26/26 (100%) methylene chloride sediment data points also were so qualified.

Further, a significant number of radiochemical data are estimated because of contamination in an associated laboratory method blank. As a result, 19/46 ²⁴³Cm soils, 59/72 ²²⁸Th soils and sediments, 14/46 ²³⁰Th soils, and 21/72 ²³²Th soils and sediments are considered estimated.

Summary of BCV RI Data Sensitivity

Laboratory blank contamination resulted in elevated detection limits and/or qualification of data as either estimated or not detected for some data points in all BCV datasets. Analyses affected were primarily organics and metals, but radiochemical results for ²³⁴U, ⁹⁹Tc, ²⁴³Cm, and isotopic thorium were also impacted. Field blank results indicate that sample handling and

equipment decontamination procedures were effective in preventing sample contamination during field activities for all three BCV projects.

Field Blank Contamination

Overall project sensitivity can be evaluated by reviewing the three types of field quality control blanks used for the BCV OU 1, BCV OU 4, and FPSS projects:

- Trip blanks — No contamination of trip blanks, which would indicate that artifacts had been introduced into samples during shipment, was significantly detected for the three BCV projects.
- Field blanks — Field blanks collected during the BCV RI field investigations included samples of (1) the potable water source used during decontamination and (2) analyte-free water used as the final water rinse of the process. Field blanks indicate that the decontamination process used for all three BCV RI projects was effective.
- Equipment rinsate blanks — BCV OU 4 and FPSS project equipment rinsates indicate that the decontamination of field equipment was successful. Equipment rinsate EQR020 from the BCV OU 1 project, however, had 91.7 µg/L cyanide present. Sample S07011, which was collected immediately after this rinsate with the same equipment, had 1.4 mg/kg cyanide. Therefore, any contamination introduced through the sampling equipment was not significant.

B.8.5.5 Representativeness

Sample preservation techniques, analytical holding times, and sampling and analytical methods used for the BCV OU 1, BCV OU 4, and FPSS projects, along with matrix or analyte interferences, were assessed to determine representativeness of the BCV RI data.

BCV OU 4

Holding times

Of 253 OU 4 VOC analyte samples, 15 are estimated because of insufficient preservation. These data are considered to be negatively biased.

Statistical outliers

The statistical analysis of data suggests that some BCV OU 4 data points significantly exceed the rest of the population of values for that analyte and matrix and thus are not representative of conditions in the BCV.:

- The filtered ²³⁵U value for SN3010 (98 pCi/L) is not representative of conditions at the BCV OU 4 NT-3 site. This dissolved data point should be eliminated from consideration, based on several factors: (1) the duplicate SN3110 filtered sample values were not high, (2) the gross rad counts of the sample and duplicate were not high, and (3) the total (unfiltered) ²³⁵U value was 7.4 pCi/L.
- SB9115 2-butanone also has a field duplicate for which the associated 2-butanone value is 24 µg/L. Other values for this analyte at this station, coupled with the discrepancy in the two

surface water field duplicates for which precision is expected to approach 20%, suggest this value is questionable. Therefore, SB9115 2-butanone should not be used for any purpose.

- Lead in SS8009 should also be eliminated from consideration because of potential nonrepresentativeness of data. A dissolved value of 37.1 µg/L is associated with a total value of 2 µg/L. Furthermore, the next highest value at that station is 11.4 µg/L.

Samples possibly mis-identified during analysis

Evaluation of gross and total isotopic analyses, along with total and dissolved analyses, suggests that data from four samples (SS6008, SN5008, SB9017, and SN3016) may be mislabeled. All four samples were sent simultaneously to a single laboratory for analysis of total gross α , total gross β , total isotopic uranium, dissolved gross α , dissolved gross β , and dissolved isotopic uranium. Data for these samples are presented in Table B.48.

Total isotopic uranium results reported for SS6008 and SN5008 are more consistent with gross values and dissolved U values reported for the other two samples, and vice versa. Other data at the locations substantiate the theory that the samples were mislabeled. Because the theory cannot be proven or disproven, total isotopic uranium data for all four samples were eliminated from consideration during data interpretation.

Calculated charge balance

Calculation of ionic charge balance provides a general geochemical check of cations and anions in solution. Of 20 OU 4 samples, 6 have a calculated charge balance exceeding 20%. However, these results seem to be attributable to the turbidity of samples rather than the validity of the data itself. Therefore, no BCV RI data should be excluded from consideration based on charge balance information.

BCV OU 1

All indications point to a high degree of representativeness in the BCV OU 1 dataset, especially in aqueous samples. This finding is supported by acceptable charge balance ratios for all aqueous samples, comparable conductivity measurements between the field and laboratory, and agreement between most total/dissolved analyses. The only exception is for ^{212}Pb in sample B01511, which showed a dissolved value eight times that of the total. Because these ^{212}Pb values may not be representative of actual conditions at BCV, neither should be included in data interpretation.

BCV FPSS

Project data seem to be generally representative of conditions in the BCV, with the following exceptions:

- W00221 and W00321 copper values are highly questionable and should not be used for any purpose. In both cases, the copper values for the total analyses are non-detects (0.7U), while the dissolved analysis is ~5 times the detection limit (3.4 and 4.6 µg/L, respectively).

- Analyses of several soil samples for pesticides/PCBs and/or SVOC analytes were performed outside of analytical holding time. As a result, 11/46 pesticides/PCBs and 13/46 SVOC soil data points are estimated.
- Exceedance of analytical holding times also leads to the estimation of 1/26 herbicide, 3/26 pesticide/SVOC, and 1/26 VOC sediment samples during the validation effort. These data should be considered negatively biased and, therefore, not completely representative of conditions at the BCV floodplains.

Summary of BCV RI Data Representativeness

Overall representativeness of the BCV RI dataset is judged to be very good. Analysis outside holding times and insufficient preservation resulted in qualification of 15/253 surface water VOC samples, 24/92 soil SVOC or pesticide/PCB samples, and 5/78 sediment VOC or pesticide/herbicide samples. These data are qualified as estimated and considered to be negatively biased. Other factors affecting representativeness resulted in the elimination of a total of only 11 results from consideration.

B.8.5.6 Comparability

Each of the three BCV projects evaluated, as well as the GWPP data source for groundwater, used narrowly defined sampling methods, which were audited both internally and by Energy Systems/Department of Energy. Additionally, the projects used standard sampling devices, uniform training, documentation of sampling, standard analytical methods, quality control checks with standard control limits, and universally accepted data reporting units.

Analytes

Analyte lists were not common across all projects. Project-specific analytes are presented in the discussion of each project (Sects. B.3, B.4, and B.5).

Reporting of nitrogen

The analysis of water samples for nitrogen can be reported in several ways. Data can be calculated as nitrate, nitrite, nitrogen, or both nitrate and nitrite. In any given year, GWPP data may have been reported under as many as three different parameters. All, however, were analyzed using the same ion chromatography method (EPA 300.0). Current BCV RI data (OU 4, OU 1, and FPSS) are consistently reported as nitrogen as nitrate and were analyzed using the EPA 353.2 colorimetry method. Although the methodologies are not consistent, data are expected to be comparable in quality. However, these data should be used with appropriate caution to ensure that they are interpreted in terms of the intended analyte.

Reporting of isotopic uranium

Isotopic uranium is reported as $^{234}\text{U}/^{235}\text{U}$ and ^{235}U alone. Although isotopic separation is possible, it is not easily or usually done unless specifically requested. Either ^{234}U or ^{235}U or both could occur in the BCV because ^{234}U occurs naturally at about 0.71%. The reader should treat such data appropriately.

B.8.6 CONCLUSIONS

More than 75,000 discrete soil, sediment, groundwater, and surface water analyses were accumulated for use in the BCV RI during the three BCV field investigations. Overall quality of all OU 4, OU 1, and FPSS data are acceptable, with <1% (672/78,455) of the data having sufficient quality problems to be considered unacceptable.

Those data whose quality presents a challenge to data usability are summarized in Table B.49 and are discussed in the following subsections, which present the data by matrix.

B.8.6.1 Soil

Soil and sediment data present the greatest challenge to data usability because of the heterogeneity and matrix-related interferences inherent to these matrices. The OU 1 and FPSS projects combine to produce 41,282 discrete data points of which <1% are considered unusable.

The only inhibitors to usability of organic soil data are the 11/46 FPSS pesticide/PCB values, which should be considered negatively biased because analytical holding times were exceeded.

Additionally, two copper values from BCV OU 1 (samples W00221 and W00321) should be eliminated from consideration because they were not representative of actual conditions at OU 1.

B.8.6.2 Sediment

BCV RI sediment values were obtained from the FPSS and OU 1 investigations. Matrix-related interferences and inherent heterogeneity contributed to variability in sediment metals data. Arsenic and manganese data precisions at FPSS are generally poor. Additionally, zinc values are generally positively biased across both projects, while antimony at both sites and selenium and silver from the FPSS are generally biased low.

Sediment organic data are affected as follows: one herbicide and VOC sample, as well as three pesticides and SVOC samples, have been negatively impacted because analytical holding times were exceeded. These values are usable but should be considered negatively biased.

Remaining challenges to usability of sediment data in the BCV RI are attributable to matrix heterogeneity. Technetium-99, isotopic thorium, and isotopic uranium radiochemical data are of poor precision. Metals data similarly affected include aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, and potassium. These radiochemical and metals parameters should be considered estimates of true concentrations in the FPSS samples.

B.8.6.3 Groundwater

Minimal challenges to data usability are associated with BCV RI groundwater data provided by OU 1. The exceptions are aluminum values, which are positively biased, and antimony data, which are negatively biased. Data should be used accordingly.

B.8.6.4 Surface Water

BCV RI surface water data were obtained from the OU 4 and OU 1 field investigations.

A single organic value (SB9115, 2-butanone) should be eliminated from data interpretation because it far exceeds any other 2-butanone value at that station or in the corresponding field duplicate sample (SB9015). Additionally, 15/253 OU 4 VOC samples are negatively biased due to insufficient preservation.

Inorganic data precision and accuracy merit some caution. Total (OU 4) and dissolved (OU 1) aluminum, iron (OU 4), and manganese (OU 4) are of poor precision and thus exhibit a high degree of variability. Additionally, mercury, cyanide, antimony, aluminum, iron, lithium, and silver are generally biased low in the OU 4 dataset.

The lead value for SS8009 should be eliminated from consideration. The dissolved value for this analyte is 37.1 $\mu\text{g/L}$, while the total is only 2 $\mu\text{g/L}$. Further, the next highest lead value at the SS-8 station is 11.4 $\mu\text{g/L}$.

Challenges to radiochemical data quality include gross α , isotopic uranium, isotopic thorium, and ^{99}Tc data. Total and dissolved gross α and ^{235}U values at OU 4 exhibit poor precision. The accuracy of ^{234}U data from OU 4 is in question. Data should be considered according to data validation flags.

The sample B01511 ^{212}Pb result seems to be nonrepresentative of actual conditions at BCV OU 1 and should therefore be eliminated from consideration. Likewise, SS6008, SN5008, SB9017, and SN3016 isotopic uranium values are not usable for any purpose as these data do not seem to be representative of actual conditions at OU 4. Finally, ^{99}Tc data from NT-3 are unusable because of poor sensitivity.

B.9 REFERENCES

- APHA (American Public Health Association). 1975. *Standard Methods for the Analysis for Water and Wastewater*.
- Anonymous. 1983. *Bear Creek Characterization Study, December 1981 through March 1983*, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Bailey, J. K. 1980. *Compliance with PCB Regulations—Y-12 Burial Ground Pond*, Memorandum to M. Sanders, Union Carbide Corporation, Inc., Oak Ridge Y-12 Plant, February 21.
- BNI (Bechtel National, Incorporated). 1983. *Preliminary Characterization and Remedial Action Plan for the Y-12 Plant Oil Landfarm*, Y/Sub/83-47974C/1, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, October.
- Bohrman, D. E. 1989. *Oil Landfarm Summary of Closure under Rules Governing Hazardous Waste Management in Tennessee*, Y/TS-394/2, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, November.
- Bogle, M. A., R. R. Turner, and S. D. Easterling. 1991. *Characterization of Contamination Along the Upper Reaches of the East Fork of Tributary 8 at Burial Ground C in Bear Creek Valley*, Y/TS-720, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, February.
- Bogle, M. A. and R. R. Turner. 1993. *Comparison of water quality at BCK-12.46 and BCK-11.97 in upper Bear Creek, February 1989—June 1992*, Y/TS-945, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, May.
- Burson, Z. G. 1976. *Aerial Radiological Surveys of ERDA's Oak Ridge Facilities and Vicinity (Survey Period: 1973-1974)*, EG&G-1183-1682, Las Vegas, Nevada.
- Clapp, R. B., D. K. Cox, J.R. Jones, W. C. Kyker, J. A. Watts, and B.J. Fredrick. 1990. *Surface Water Discharge Data for the Bear Creek Watershed, Oak Ridge, Tennessee, 1984-1988*, Y/TS-407, Martin Marietta Energy Systems, Inc., prepared for Y-12 HSEAD, Oak Ridge, Tennessee, October.
- Collins, E. T. 1990. *Water Sample results from Upper West Forks Tributary 7 and Tributary 8*, Internal Martin Marietta Energy Systems, Inc., Correspondence to Distribution, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, July.
- DOE (Department of Energy). 1993. *Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 4 (Shallow Groundwater in Bear Creek Valley) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1115&D3, September.
- DOE. 1994a. *Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 1 (S-3 Ponds, Boneyard/Burnyard, Oil Landfarm, Sanitary Landfill 1, and the Burial Grounds, Including Oil Retention Ponds 1 and 2) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volumes 1. Main Text and 2. Appendices*, DOE/OR/01-1161/V1&D2, V2&D2, March.

- DOE. 1994b. Bear Creek Valley Data Quality Objectives Meeting Minutes.
- DOE. 1995a. *Soil Sampling and Analysis Plan for the Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant, Oak, Ridge, Tennessee*, DOE/OR/01-1322&D2, March.
- DOE. 1995b. *Preliminary Assessment of the Ecological Risks to Wide-Ranging Wildlife Species on the Oak Ridge Reservation*, DOE/OR/01-1407&D1.
- Dreier, R. B., T. O. Early, and H. L. King. 1993. *Results and Interpretation of Groundwater Data Obtained from Multiport-Instrumented Coreholes (GW-131 through GW-135); Fiscal Years 1990-1991*, Y/TS-803, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Dreier, R. B. and A. Caldanaro. 1993. *Installation Summary for the DNAPL Characterization Multiport Wells, GW-726, GW-727, GW-729, GW-730, and GW-790*, Y/ER-117, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Energy Systems (Lockheed Martin Energy Systems, Inc.) 1987a. *Environmental Surveillance of the U.S. Department of Energy Oak Ridge Reservation and Surrounding Environs During 1986*. ES/ESH-1/V1 & V2, Oak Ridge, Tennessee.
- Energy Systems. 1987b. *Analytical Results: Groundwater Samples Collected from Selected Wells at the Y-12 Plant Site*, Y/TS-218/2, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1990. *Oak Ridge Y-12 Plant Groundwater Protection Program Management Plan*, Y/TS-633, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Energy Systems. 1993a. *Resource Management Plan for the Oak Ridge Reservation: Volume 29: Rare Plants on the Oak Ridge Reservation*, ORNL/NERP-7, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Energy Systems. 1993b. *Resource Management Plan for the Oak Ridge Reservation: Volume 30: Oak Ridge National Environmental Research Park Natural Areas and Reference Areas—Oak Ridge Reservation Environmentally Sensitive Sites Containing Special Plants, Animals, and Communities*, ORNL/NERP-8, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Energy Systems. 1993c. *Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 2 (Rust Spoil Area, SY-200 Yard, Spoil Area 1) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR-1060&D3, ES/ER-43/&D3, Y/ER/Sub/91/99069/1, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, May.
- Energy Systems. 1993d. *Oak Ridge Environmental Report for 1992. Volume 1: Narrative*. ES/ESH-31/V1, Oak Ridge, Tennessee, September.
- Energy Systems. 1993e. *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee: Results of Phase I Investigation*, DOE/OR/01-1136 (ES/ER/TM-43), Oak Ridge, Tennessee, May.

- Energy Systems. 1995. *Remedial Investigation Report on Bear Creek Valley Operable Unit 2 (Rust Spoil Area, Spoil Area 1, and SY-200 Yard) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01/1273/V1&D2/A1, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, April.
- ERDA (Energy Research and Development Administration). 1975. *Preliminary Draft Environmental Analysis Oak Ridge Operations*, Vol. VI, Section 2.5.5.
- EPA (Environmental Protection Agency). 1987. *Data Quality Objectives for Remedial Response Activities Development Process*, EPA/540/G-87/003.
- EPA. 1991. *Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual*.
- Evaldi, R. D. 1984. *Streamflow and Specific Conductance Data for Selected Sites, February 15 through April 9, 1984, Near the Y-12 Plant, the Oak Ridge Reservation, Tennessee*, USGS Open File Report 84-625.
- Evaldi, R. D. 1985. *Streamflow and Specific Conductance Data for Bear Creek, August 13, 1985, Oak Ridge Reservation, Tennessee*, USGS Open File Report 85-682.
- Francke, H.C. 1973. *Nitrate Effluents and Their Effect on the Environment as Related to the Y-12 Plant*, Y/DA-5085, Union Carbide Corporation Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Geraghty and Miller, Inc. 1985. *Remedial Alternatives for the Bear Creek Valley Waste Disposal Area*, Y/Sub/85-00206C/3, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Geraghty and Miller, Inc. 1987. *Hydrogeologic Investigation of the S-3 Pond Area at the Y-12 Plant*, Y/Sub/87-00206C/18, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Geraghty and Miller. 1989. *Tracer Study of the Hydrologic System of Upper Bear Creek, Y-12 Plant, Oak Ridge, Tennessee*, Y/Sub/89-00206C/4, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- H&R Technical Associates, Inc. 1995. Letter Report: *Radiological Analysis of Oak Ridge Y-12 Plant Groundwater Data*, Y/Sub/95-TK532C/1, prepared for Lockheed Martin Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, June 22.
- Haase, C. S. and H. L. King. 1990. *Report and Preliminary Assessment of the Occurrence of Dense Nonaqueous Phase Liquids in the Bear Creek Burial Grounds Hazardous Waste Disposal Unit at the Oak Ridge Y-12 Plant*, Y/TS-629, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Hatcher, R. D., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leitzke, W. M. McMaster, J. L. Foreman, and S. Y. Lee. 1992. *Status Report on the Geology of the Oak Ridge Reservation*, ORNL/TM-12074, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- Herbes, S. E. 1988. *PCB Contamination in the Sediments of the Oil Retention Ponds and Associated Tributary Channels at the Burial Grounds of the Oak Ridge Y-12 Plant*, Y/TS-431, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Herbes, S. E. 1989. *PCBs, Uranium, and Oil/Grease in Soil at the Oak Ridge Y-12 Oil Landfarm: Results of 1985 - 1986 Sampling and Analysis Program*, Y/TS-538, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Hinzman, R. L., J. J. Beauchamp, C. F. Cada, S. W. Christiansen, M. J. Peterson, T. L. Phipps, W. K. Roy, E. M. Schilling, J. G. Smith, M. R. Smith, G. R. Southworth, A. J. Stewart, L. F. Wicker, and J. A. Wojtowicz. 1995. *Report on the Biological Monitoring Program for Bear Creek at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, 1989-1994, Draft*, ORNL/TM-12334, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Hoffman, F. O., B. G. Blaylock, K. E. Couser, K. L. Daniels, C. C. Travis, and C. W. Weber. 1984. *Preliminary Screening of Contaminants in Sediments*, ORNL/TM-9370, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- HSW (HSW Environmental Consultants, Inc.). 1991. *Groundwater Quality Assessment for the Bear Creek Hydrogeologic Regime at the Y-12 Plant, 1990: Data Interpretations and Proposed Modifications*, Y/Sub/91-YP507C/1 Part 2, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- HSW. 1992. *Groundwater Quality Assessment for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: 1991 Groundwater Quality Data Interpretations and Proposed Program Modifications*, Y/Sub/92-YP507C/1/P1&P2, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, August.
- HSW. 1995. *Calendar Year 1994 Groundwater Quality Report for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: 1994 Groundwater Quality Data Interpretations and Proposed Program Modifications*, Y/Sub/95-EAQ10C/1/P2, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, August.
- Jeter, I. W. and Napier, J. M. 1978. *Chemical Analysis of the S-3 Disposal Ponds (April 1978)*, Y/DA-7794, Union Carbide Corporation—Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Jeter, I. W. 1983. *The Chemical and Radiological Characterization of the S-3 Ponds*, Y/MA-6400, Union Carbide Corporation—Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Kimbrough, C. W. and R. R. Turner. 1987. *Field Notebook: Sampling and Analysis of Sludges in the S-3 Ponds at the Y-12 Plant*, Y/TS-294, Martin Marietta Energy Systems, Inc., Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Kimbrough, C. W. 1988. *Characterization of the Tributary 7 Oil Retention Pond No. 1 and Associated Seep in Bear Creek Watershed*, Y/TS-458, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, August.

- Kimbrough, C. W., L. W. Long, and L. W. McMahon. 1990. *Environmental Surveillance Procedures Quality Control Program*, ESH/Sub/87-21706/1, Rev. 1, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tennessee, January.
- Lowery, J. F. 1987. *Water Resources Data for Tennessee, Water Year 1986*, Report USGS/WRG/HD-86/216, USUS, Nashville, Tennessee.
- McCauley, L. L. 1984a. *Sediment Assessment and Inventory of Existing Contamination and Biological Data of Two Oil Retention Ponds in the Y-12 Plant, Bear Creek Valley Waste Disposal Area*, Y/IA-165, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- McCauley, L. L. 1984b. *Inventory of Existing Contamination in the Y-12 Plant Bear Creek Valley Oil Landfarm Area*, UCC-ND Report Y/IA-166, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, January.
- McCauley, L. L. 1985. *Analytical Results for Water, Sediment, and Soil Samples Collected in the Y-12 Plant Bear Creek Valley Waste Disposal Areas*, Y/TS-112, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- McClain, G. R. 1972. *Preliminary Aquatic Survey of East Fork Poplar Creek, 1972*. Report to Pollution Control Branch, U.S. Atomic Energy Commission, Oak Ridge, Tennessee, 18 pp.
- McElhaney, R. J. 1982. *PCB in Fish from East Fork Poplar Creek and Bear Creek*, Memorandum from R.J. McElhaney, Y-12 Plant, to W. Van Winkle, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 22.
- McMahon, L. W. 1988. *Sampling and Analysis to Support Excavation of Blue Lagoon Sediment Build-up*, Y/TS-481, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- McMaster, W. M. 1967. "Hydrologic Data for the Oak Ridge Area, Tennessee," *U.S. Geological Survey—Water Supply Paper No. 1838-N*, U.S. Government Printing Office, Washington, D.C.
- Moore, E. K. 1992. *Hydrograph Analysis in Fractured Rock Terrace*, Groundwater, Vol. 30, no. 3, pp. 390-395.
- Napier, J. M., C. W. Hancher, G. E. Harris, M. E. Johnson, and B. C. Padgett. 1988. *Treatability Studies for Waters in Oil Pond No. 1, Oil Pond No. 2, and the Oil Seep*, Y/DZ-392, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Opresko, D. M., B. E. Sample, and G. W. Suter II. 1994. *Toxicological Benchmarks for Wildlife: 1994 Revision*, ES/ER/TM-86/R1, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Pulliam, Pamela J. 1985a. *Water-quality Data for 34 Sites, April and June 1984, Near the Y-12 Plant, The Oak Ridge Reservation, Tennessee*, U.S. Geological Survey Open File Report 85-165.

- Pulliam, Pamela J., 1985b. *Water Quality Data for 35 Sites, September, 1984, Near the Y-12 Plant, The Oak Ridge Reservation, Tennessee*, U.S. Geological Survey Open File Report 85-553.
- Reece, J. H. 1973. *Preliminary Aquatic Survey of East Fork Poplar Creek and Bear Creek, 1973*, Report to Environmental Protection Branch, U.S. Atomic Energy Commission, Oak Ridge, Tennessee, 26 pp.
- Rosensteel, B. A. and C. C. Trettin. 1993. *Identification and Characterization of Wetlands in the Bear Creek Watershed*, Y/TS-1016, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- SAIC (Science Applications International Corporation). 1985. SAIC Project File. Project information consisting of hard copy of lab data sheets received from Chris Smith, Lockheed Martin Energy Systems, Inc.
- SAIC. 1994a. *Environmental Technical Support for Bear Creek Valley Operable Unit 1 Remedial Investigation Field Activities Manual*, prepared for RI Field Team.
- SAIC. 1994b. *Environmental Technical Support for Bear Creek Valley Operable Unit 4 Remedial Investigation Field Activities Manual*, prepared for RI Field Team.
- SAIC. 1995a. SAIC Project File. *Environmental Technical Support, Bear Creek Valley Operable Unit 1 and Floodplain Soil Sampling Field Technical Procedures, Rev. 5*.
- SAIC. 1995b. SAIC Project File. Project information consisting of diskette and letter received from Roger Clapp, Lockheed Martin Energy Systems, Inc.
- SAIC. 1995c. SAIC Project File. Project information consisting of hard copy of printed data summary received from Chris Smith, Lockheed Martin Energy Systems, Inc.
- SAIC. 1995d. SAIC Project File. Project information consisting of paper and electronic copies of survey results received from Chemrad, Inc.
- SAIC. 1995e. SAIC Project File. Project information consisting of electronic files received from John Robinson, USGS.
- Sample, B. E. and G. W. Suter II. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants*, ER/ES/TM-125, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Southworth, G. R., J. A. Burris, J. M. Loar, M. G. Ryon, J. G. Smith, A. J. Stewart, and J. A. Burris. 1992. *Ecological Effects of Contaminants and Remedial Actions in Bear Creek* ORNL/TM11977, ESD Publication No. 3810, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- TVA (Tennessee Valley Authority). 1986. *Instream Contaminant Study: Task 5 Summary Report*, ZZ-86-06-08, prepared for U.S. Department of Energy, Oak Ridge, Tennessee, under Interagency Agreement No. DE-AI05-85OR.

- Taylor, P. A. 1981. *Sampling of Oil Farm Plots*. Memorandum to M. Sanders, December 16.
- Turner, R. R. and G. E. Kamp. 1984. *Characterization and Remedial Alternatives for Sediments in Upper Bear Creek*, Y/TS-56, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Turner, R. R. 1988. *Sampling and Analysis of Soil from 1985 Tank Farm Excavations Near S-3 Ponds, Y-12 Plant, Oak Ridge, Tennessee*, Y/TS-473, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, September.
- Turner, R. R., M. A. Bogle, R. B. Clapp, K. Dearstone, R. B. Dreier, T. O. Early, S. E. Herves, J. M. Loar, P. D. Parr, and G. R. Southworth. 1991. *Remedial Investigation Work Plan for Bear Creek (Y02-S600) at the Oak Ridge Y-12 Plant*, ES/ER-19&D2, Y/ER/Sub-90/99928/2, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- U.S. Atomic Energy Commission (USAEC). 1953. *A Meteorological Survey of the Oak Ridge Area. Final Report Covering the Period 1948-1952*, ORO-99, Weather Bureau, Oak Ridge, Tennessee.
- Van Winkle, W., R. W. Counts, J. E. Dorsey, J. W. Eldwood, V. W. Lowe, Jr., R. McElhaney, S. D. Schlotzhauer, F. G. Taylor, Jr., and R. R. Turner. 1984. *Mercury Contamination in East Fork Poplar Creek and Bear Creek*, ORNL/TM-8894, ESD-2051, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Walker, B. A. and Saylor, R. E., eds., Low Level Waste Disposal Development and Demonstration (LLWDDD) Program. 1988. *Data Package for the Low-Level Waste Disposal Development and Demonstration Program Environmental Impact Statement*, ORNL/TM-10939/V1&V2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Will, M. E. and G. W. Suter II. 1994. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process*, ES/ER/TM-126, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Y-12 HSEAD (Health, Safety, Environmental, and Accountability Division). 1984a. *Preliminary Assessment of Existing Contamination in Bear Creek Valley Watershed Area and Potential Remedial Actions for Mitigating Its Impact on Bear Creek*, Y/TS-51/1, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Y-12 HSEAD. 1984b. *Appendices: Preliminary Assessment of Existing Contamination in Bear Creek Valley Watershed Area and Potential Remedial Actions for Mitigating its Impact on Bear Creek*, Y/TS-51/2, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, June.
- Y-12 HSEAD. 1987. *Post-Closure Permit Application for the Oil Landfarm Hazardous Waste Disposal Unit at the Y-12 Plant*, Y/Sub/87-00206C/10, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

B10-1

B.10 FIGURES

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Fig. B.2. Locations of OU 1 sampling activities at the S-3 Site.

Fig. B.3. Locations of OU 1 sampling activities at BYBY, Oil Landfarm, and SL 1.

BEAR CREEK VALLEY KEY MAP

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 10' CONTOUR
- ⊕ SBB-25 SURFACE SOIL SAMPLE
- △ BG-7 SOIL BORING LOCATION
- ▲ BG-3 SOIL BORING LOCATION WITH GROUNDWATER SAMPLE
- SW-02 SURFACE WATER SAMPLE
- SF-9 STORM FLOW TUBES
- RADIOLOGICAL SURVEY AREA

BURIAL GROUNDS
BEAR CREEK VALLEY

Fig. B.4. Locations of OU 1 sampling activities at BCBG.

B10-9

Fig. B.5. Locations of OU

BEAR CREEK VALLEY

0 900 1800
SCALE: 1" = 1800'

LEGEND:

- ROADS
- NT-1 BEAR CREEK & TRIBUTARIES
- 900 10' CONTOUR
- ▲ NT-1 WATER SAMPLE LOCATION
- ▼ SFT-1 FLOW TUBE LOCATION
- SS-1 OU4 SURFACE WATER SAMPLE AT SPRINGS
- GW-101 PULSE TEST WELL SITE

sampling activities in BCV.

BEAR CREEK VALLEY
RADIOLOGICAL MONITORING

Y-12 PLANT NORTH

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES

● RADIOLOGICAL SAMPLE LOCATION

SAIC CAD DWG 94020\DWGS\345RAD
REV : / 07-17-96

B10-10

Fig. B.6. Surface water and groundwater sampling locations for August 1995 radiological sampling task in BCV.

Fig. B.7. Surface water hydrographs showing flow during sampling periods for samples 2 through 7 at BCK 12.38 N Tunnel.

Fig. B.8. Surface water hydrographs showing flow during sampling periods for samples 8 through 11, 13, and 17 at BCK 12.38 N Tunnel.

Fig. B.9. Surface water hydrographs showing flow during sampling periods for samples 18 through 21 at BCK 12.38 N Tunnel.

Fig. B.10. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at BCK 12.38 S Tunnel.

Fig. B.11. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at BCK 12.38 S Tunnel.

Fig. B.12. Surface water hydrographs showing flow during sampling periods for samples 13, 14, 16, through 19 at BCK 12.38 S Tunnel.

Fig. B.13. Surface water hydrographs showing flow during sampling periods for samples 20 and 21 at BCK 12.38 S Tunnel.

Fig. B.14. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-2.

Fig. B.15. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at NT-2.

Fig. B.16. Surface water hydrographs showing flow during sampling periods for samples 13 through 18 at NT-2.

Fig. B.17. Surface water hydrographs showing flow during sampling periods for samples 19 through 21 at NT-2.

Fig. B.18. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-3.

Fig. B.19. Surface water hydrographs showing flow during sampling periods for samples 7 through 9 and 14 through 16 at NT-3.

Fig. B.20. Surface water hydrographs showing flow during sampling periods for samples 17, 18, 20, and 21 at NT-3.

Fig. B.21. Surface water hydrographs showing flow during sampling periods for samples 2 through 7 at NT-4.

Fig. B.22. Surface water hydrographs showing flow during sampling periods for samples 8 through 12 at NT-4.

Fig. B.23. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-5.

Fig. B.24. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at NT-5.

Fig. B.25. Surface water hydrographs showing flow during sampling periods for sample 13 at NT-5.

Fig. B.26. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at NT-6.

Fig. B.27. Surface water hydrographs showing flow during sampling periods for samples 7, 8, and 12 through 15 at NT-6.

Fig. B.28. Surface water hydrographs showing flow during sampling periods for samples 18 through 21 at NT-6.

Fig. B.29. Surface water hydrographs showing flow during sampling periods for samples 2 and 4 through 8 at NT-7.

Fig. B.30. Surface water hydrographs showing flow during sampling periods for samples 9 through 14 at NT-7.

Fig. B.31. Surface water hydrographs showing flow during sampling periods for samples 15 through 17, and 20 and 21 at NT-7.

Fig. B.32. Surface water hydrographs showing flow during sampling periods for samples 2 through 5, and 9 and 10 at NT-8.

Fig. B.33. Surface water hydrographs showing flow during sampling periods for samples 11 and 12 at NT-8.

Fig. B.34. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at BCK 9.47.

Fig. B.35. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at BCK 9.47.

Fig. B.36. Surface water hydrographs showing flow during sampling periods for samples 14 through 18, and 22 at BCK 9.47.

Fig. B.37. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at SS-1.

Fig. B.38. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at SS-1.

Fig. B.39. Surface water hydrographs showing flow during sampling periods for sample 13 at SS-1.

Fig. B.40. Surface water hydrographs showing flow during sampling periods for samples 1 through 6 at SS-4.

Fig. B.41. Surface water hydrographs showing flow during sampling periods for samples 7 through 12 at SS-4.

Fig. B.42. Surface water hydrographs showing flow during sampling periods for sample 13 at SS-4.

Fig. B.43. Surface water hydrographs showing flow during sampling periods for samples 1 through 3 and 5 through 7 at SS-5.

Fig. B.44. Surface water hydrographs showing flow during sampling periods for samples 8 through 13 at SS-5.

Fig. B.45. Surface water hydrographs showing flow during sampling periods for samples 1, 3, and 6 through 9 at SS-6.

Fig. B.46. Surface water hydrographs showing flow during sampling periods for samples 10, 12, and 13 at SS-6.

Manning Equation

$$Q = \frac{A \cdot 1.49 \cdot R^{2/3} \cdot S^{1/2}}{n}$$

$$L = \sqrt{r^2 - (r - h)^2}$$

$$\Theta = \text{Arc Tan} \left(\frac{L}{(r - h)} \right) \text{ where } \Theta \text{ is in radians}$$

$$\text{Wetted Perimeter (WP)} = 2Qr$$

$$A = \Theta r^2 - (r - h)L$$

$$R = A / WP$$

Fig. B.47. Diagrammatic representation of the method for calculating flow from stage at BCK 12.38.

Fig. B.48. Rating curve for BCK 9.47.

*Review of data will occur as data packages arrive from the analytical laboratory.
Reevaluation of the sampling strategy may occur any time during the sampling activities.

**No further action

Fig. B.49. Flowchart outlining sampling activities for BCV Floodplain soils investigation.

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Fig. B.51. Summary of samples collected for the BCV OU 4 RI field activities by matrix, site, and analyte group.

Fig. B.52. Summary of samples taken for the BCV OU 1 RIFA by matrix, site, and analyte group.

Fig. B.53. Summary of samples taken for the FPSS field activities by matrix, site, and analyte group.

B11-1

B.11 PLATES

Plate B.2. Photograph showing the floodplain soil sample at transect 3.

Plate B.1. Photograph showing the floodplain soil sample at transect 2.

B12-1

B.12 TABLES

Table B.1. Historical data from special studies, subcontractor sampling events, and monitoring activities within BCV. Datasets captured for use in this RI are highlighted

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
1.	Early meteorological data	Beginning in 1948	NA ^a	NA	Oak Ridge Townsite: (011) BCV: (008, 018) Pine Ridge, K-25, X-10	Extensive meteorological monitoring including radioactivity	USAEC 1953
2.	U.S. Geologic Survey (USGS) hydrologic monitoring of Bear Creek and its tributaries	1958 to present	NA	Surface water	03538256 03538260 035382672 035382673 035382677 03538270 03538272 03538273 03538275	Flow	McMaster 1967; Lowery 1987; Clapp et al. 1990; Turner et al. 1991
3.	National Pollution Discharge Elimination System (NPDES) monitoring by Y-12 at BCK-4.55	1971 to present	ND ^b	Surface water	NPDES-304	Flow, anions, inorganics, miscellaneous constituents ^c	Environmental Surveillance Reports e.g., Energy Systems 1987a; Energy Systems 1993d

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
4.	Characterization of the S-3 Ponds before neutralization	1973-1983	ND	Pond water, sediment	ND	Inorganics, uranium, PCBs, nitrate, pH	Francke 1973; Jeter and Napier 1978; Jeter 1983; Saunders and Napier 1986; Turner et al. 1991
5.	Analysis of waste oil generated at the Y-12 Plant	Before 1974	NA	Oily wastes	NA	Density, % carbon, % hydrogen, uranium	Turner et al. 1991
6.	Aerial gamma survey of the White Wing Scrap Yard	Nov 1974	NA	NA	NA	Radioactivity	Burson 1976
7.	Early studies of the ecology and water quality of upper Bear Creek	1972-1973	ND	Ecological communities, surface water	ND	Ecological data, pH	McClain 1972; Reece 1973;
		1974-1975				Quantitative fish and benthic invertebrate sampling, pH	ERDA 1975;
		1981-1983				pH, inorganics, PCBs	Anonymous 1983; McElhaney 1982

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
8.	Analysis of oily wastes sent to the Oil Landfarm	Before 1979	NA	Oily wastes	NA	Inorganics	Turner et al. 1991
		After 1979	NA	Oily wastes	NA	Inorganics, PCBs	
		Dec 1981 - 1982	NA	Oily wastes	NA	Inorganics, PCBs, chlorinated hydrocarbons	
9.	Soil samples from transects on the perimeter of Oil Retention Pond 1 (ORP-1)	1980, 1982	14 19	Soil cores	ND	PCBs	Bailey 1980; Herbes 1988
10.	Meteorological data collected by the National Oceanic and Atmospheric Administration (NOAA)	1980-present	NA	NA	NA	Precipitation, temperature, relative humidity, wind speed and direction	Energy Systems 1993d
11.	Station 8 ambient air monitoring by Y-12 near the plant's west end	Early '80s to present	ND	Air	8	Gross α , gross β , isotopic U, mercury	Turner et al. 1991; Energy Systems 1993d
12.	Y-12 Plant Lab analysis of soil from the Oil Landfarm	Oct 1981 Nov 1982	45 3	Soil composites	Plots 1/2, 3/4, 5/6, OF-East OF-Middle OF-West	Oil and grease, total carbon, PCBs, inorganics, nitrates, uranium	Taylor 1981; BNI 1983; Geraghty and Miller 1985; Herbes 1989

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
13.	TVA study of contaminants at OR-DOE facilities--Oak Ridge Interagency Task Force evaluation	1982-84	56	Surface water	7.40 (baseflow), 0.55 (stormflow)	Flow, inorganics, PCBs, radionuclides, organics	Van Winkle et al. 1984;
			15	Sediment	7.40, 2.80, 2.75, 0.55, 0.4, L2		TVA 1986; Turner et al. 1991
			26	Aquatic biota			
14.	Preliminary screening of contaminants in Bear Creek sediments	Oct 1983	3 (BC-FP-1 = 12 cores)	Floodplain soil, sediment	BCK-4.68 (BC-FP-1) BC-1 BC-2	Organics, inorganics, radionuclides	Hoffman et al. 1984; Geraghty and Miller 1985
15.	Weekly surface water monitoring at BCK-12.46 and BCK-11.97	July 1983 to present (11.97 est Feb 1989)	ND	Surface water	BCK-12.46 BCK-11.97 (BCK-12.36 3/88—5/88)	Inorganics, PCBs, VOCs, rads, TSS, TDS, DO, pH	Turner et al. 1991; Bogle and Turner 1993
16.	Subsurface water samples collected from beneath the surface oil layer on ORP-1	Sept 1983	2	Pond water	10A, 16A	PCBs, phenols, inorganics, cyanide, uranium	McCauley 1984a; McCauley 1985
17.	Composite study of "dark" and "light" areas within the Oil Landfarm to investigate correlations between PCB contamination and soil color.	Sept 1983	5	Soil composites	01D, 01L, 13L, 13D, 19L	Organics, inorganics, pesticides, PCBs	BNI 1983; Herbes 1989; McCauley 1985
			1	Sediment	SEDGRAB		

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
18.	Background samples collected for comparison to Bear Creek data during the early 1980s	1983-1986	14 14	Surface water, sediment	GCK-1.4 GCK-2.4 NT-2	Inorganics, radionuclides, VOCs, PCBs, pesticides, miscellaneous constituents ^d	Turner et al. 1991
19.	Monitoring of Bear Creek Valley surface water and sediment in the early 1980s (BNI)	1983-1984	16 26	Surface water, sediment Surface water, sediment	Oil Landfarm: 1-16 Burial Grounds: 1A- 26A	Inorganics, organics PCBs, radionuclides, anions, miscellaneous constituents ^e	BNI 1984; McCauley 1984b; McCauley 1985; Y-12 HSEAD 1984a; Y-12 HSEAD 1984b; Y-12 HSEAD 1987
20.	Analysis of soil cores from groundwater wells installed by BNI (S-3 Ponds, Burial Grounds, Oil Landfarm)	1983-1984	732	Soil cores	GW-1... GW-53A, GW-100... GW-103	Organics, inorganics, pesticides, PCBs, miscellaneous constituents ^f	BNI 1983; Herbes 1989

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
21.	Monitoring of Bear Creek Valley groundwater in the early to mid 1980's (BNI)	1983-1987	233	Groundwater	GW-series wells	Organics, inorganics, radionuclides, pesticides, PCBs, anions, miscellaneous constituents ^g	Y-12 HSEAD 1987; Geraghty and Miller 1985
22.	Collection of "source term liquids and solids" from the Burial Grounds and Oil Landfarm	1983-1984	40	Standpipe liquids, filter residue	BG-BCP, BG-CCP, SPC2... SPC10, SP2A, SP3B, STP1...STP3, BG-BIN BG-BIS BG-B3S BG-B6S BG-B8N	Organics, Inorganics, Radionuclides, Pesticides, PCBs, Miscellaneous Constituents ^h	McCauley 1985
23.	Toxicity tests of surface water	1984-1988	69	Minnow larvae	BCK-12.36	Toxicity	Turner et al. 1991

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
24.	Weekly water levels measured at monitoring wells in BCV (wells not shown on Plate B.1)	1984-1988	16,981	Groundwater	Y-12 monitoring wells: 1000-series, GW-001... GW-338, USGS#1 USGS#2 USGS#3	Water level	DOE 1995a

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
25.	Oak Ridge National Laboratory (ORNL) hydrologic monitoring of sites in Bear Creek watershed [by the Environmental Sciences Division (ESD)]	March 1984-1988	NA	Surface water	BCK-12.46 BCK-12.39 BCK-12.38 BCK-11.96 BCK-11.68 BCK-11.67 BCK-11.64 BCK-11.59 BCK-11.17 BCK-11.15 BCMS2-- (11.64) BCK-10.78 BCK-10.41 BCK-9.99 BCMS5-- (9.53) BCK-9.53 BCK-9.45 BCK-9.41 BCK-7.87 BCK-6.23 BCK-4.70 BCK-4.56 BCK-4.55	Flow, water quality: temperature, conductance, turbidity, pH, dissolved oxygen	McCauley 1985; Clapp et al. 1990; Turner et al. 1991

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
26.	S-3 Pond characterization after neutralization of pond waters	1984	4 Composites	Sludge	NW, NE, SW, SE	Organics, inorganics, TCLP, anions, permeability, radionuclides	Kimbrough and Turner 1987
27.	Characterization of sediments in upper Bear Creek, including two samples from the "Blue Lagoon" area	1984	4	Sediment	UBC-2 UBC-3 UBC-4 UBC-FPI	Organics, inorganics, PCBs, radionuclides	Turner and Kamp 1984; McMahon 1988
28.	Y-12 Plant study of sediments in Bear Creek and tributary channels to investigate contaminant transport away from the disposal areas	March and September 1984	31	Sediment surface water	BCK-11.5, 2.8, 4.8, 7.5, GCK-1.4, 2.4, SPR-1... SPR-4, 1-1 2-1...2-5 3-1...3-3 4-1...4-3 6-1...6-3 7-1...7-3 8-1...8-8 9-1	PCBs, VOCs, inorganics, radionuclides	McCauley 1985; Herbes 1988

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
29.	USGS water quality studies in the Bear Creek watershed	1984-1985 (and other years)	32 (in 1984)	Surface water	9.77, 9.70, 9.63, 9.60, 9.65, 9.52, 9.46, 9.45, 9.31, 9.18, 9.16, 14.3, 14.5, 14.9, 11.2	Inorganics, gross β , gross α , anions, miscellaneous constituents ⁱ	Evaldi 1984; Pulliam 1985a; Pulliam 1985b; Evaldi 1985; Lowery 1987
30.	Biological Monitoring and Abatement Program (BMAP) sampling in BCV	1984-present	ND	Aquatic biota, surface water	BCK-3.3, 5.1, 7.8, 9.4, 9.9, 10.3, 11.0, 11.8, 12.3, NT-14 (0.3)	Ecological parameters, water quality	Hinzman et al. 1995
31.	Recent ecological characterizations of BCV	1984-1993	ND	ND	ND	ND	Southworth et al. 1992; Walker and Saylor 1988
						Environmentally sensitive sites, natural areas, and reference areas	Energy Systems 1993b, Resource Mgmt Plan, Vol. 30
						Rare plants	Energy Systems 1993a, Resource Mgmt Plan, Vol. 29

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
32.	ORNL ESD preliminary evaluation of contaminants in Bear Creek and East Fork Poplar Creek floodplains	April 1985	104	Sediment, floodplain soil	BCK-1.05 BCK-4.70 BCK-9.91 BCK-11.09 BCK-12.10	Radionuclides, inorganics	Turner et al. 1991
33.	Soil samples collected by R. R. Turner from NT-7 and surrounding area	April 1985	5	Soil	RRT-1... RRT-5	PCBs	Herbes 1988
34.	Y-12 subsampling and analysis of archived soil cores from wells installed in Burial Ground A	April 1985	16	Soil	GW-14 GW-15 GW-16 GW-18 GW-20 GW-21 GW-22 GW-46 GW-47 GW-53A	PCBs, radionuclides, inorganics	Herbes 1988; Turner et al. 1991

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
35.	Soil sampling from spoils pile created during construction of the West End Tank Farm (located just west of the Tank Farm)	May 1985	31	soil	Base, perimeter, 10A...10E, 30A...30C, 65A...65D, 145A...145C, 220A...220C, 275A...275C, 320A...320E, 350A...350C	Radionuclides, inorganics, EP toxicity, total uranium	Turner 1988
36.	Soil study at ORP-1 (west pond) and ORP-2 (east pond), including depth profiles of contamination	July 1985	72	Soil	East Pond, Transects 1-3: e.g., E1E1 West Pond, Transects 1-6: e.g., W1E1	% solids, PCBs	Herbes 1988
37.	Sediment study at ORP-1	Oct 1985	24	Sediment	Cores 1-5	% solids, PCBs	Herbes 1988
38.	Sediment and soil samples collected at the bridge site near BCK-9.42	Nov 1985	6	Sediment, floodplain soil	C1, C2, C3, C4, C5, C6	Inorganics, radionuclides, PCBs	Turner et al. 1991

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
39.	Analysis of soil from the Oil Landfarm: Phase I and Phase II studies	Sept 1985 -April 1986	56	Soil composites	Phase I-- dark/light: 1/2 5/6 9/10 East/West dark/light: 3/4 Phase II-- A/B/C/D: 1/2 5/6 7/8 9/10 11/12 13/14 15/16 17/18 19/20 21/22 23/24 A/B/C: 3/4	% solids, PCBs, uranium, oil and grease	Herbes 1989
			144				

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
40.	Extensive sampling of groundwater, surface water, and sediment in BCV by the Roy F. Weston company (wells not shown on Plate B.1)	1985-1987	ND	Surface water groundwater, spring water, sediment	(Partial listing:) NT-7 GW-103 GW-225 SS-1-5,7,8 BCK 5.15 BCK-9.43 BCK-12.46	Pesticides, PCBs, inorganics, organics	Turner et al. 1991; Southworth et al. 1992; Geraghty and Miller 1987
41.	Y-12 groundwater monitoring program data (wells not shown on Plate B.1)	1985-present	ND	Groundwater, surface water	GW-series wells, Tribes: NT-1, NT-13, Bear Crk: BCK-0.63, 4.55, 9.40, 11.97, 12.36, Springs: SS1, SS4, SS5, SS6, SS8	Anions, organics, inorganics, radionuclides, pesticides, PCBs	Energy Systems 1987b; Energy Systems 1990; Annual Groundwater Quality Assessment Reports, e.g., HSW 1991 or 1992; Bogle and Turner 1993
42.	Groundwater quality assessment program investigation using three wells around the Oil Landfarm	1986-1987	3	Groundwater	ND	Total and dissolved inorganics, radionuclides	Turner et al. 1991

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
43.	Soil and sediment samples collected from Bear Creek tributaries NT-6, NT-7, and NT-8	April 1986	84	Floodplain soil, sediment	NT6, transects 1-8, W,C,E NT7, transects 1-12, W,C,E NT8, transects 1-5 W,C,E	% solids, PCBs, uranium	Herbes 1988
44.	Study of contamination in seeps near the Oil Retention Ponds	April 1986	33	Soil	S1-1...S1-6 S2-1...S2-9 S3-1...S3-6 S4-1...S4-6	PCBs, oil and grease, uranium	Herbes 1988
45.	Depth profiles of sediment contamination in tributaries NT-6 and NT-7	Sept 1986	19 23	Sediment	E1, E2, W, C	PCBs, mercury, uranium	Herbes 1988
46.	Soil samples from transects parallel to Tribs 6 and 7, between the ends of BG-A trenches and the stream channels: potential seep positions in Burial Ground A	Nov 1986	78	Floodplain soil, Sediment	T1-1.T1-16 T2-1.T2-12 T3-1...T3-5 T4-1...T4-6	% solids, PCBs, Uranium	Herbes 1988

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
47.	Surface water monitoring at six sites at the Low Level Waste Disposal Development Demonstration (LLWDDD) site in west Bear Creek	1987	24	Surface water	FL-270 FL-272 FL-273 FL-672 FL-673 FL-677	Flow, inorganics, anions, gross α , gross β , total uranium	Walker and Saylor 1988
48.	Golden and Associates hydrogeologic characterization of west Bear Creek LLWDDD area	1987	45 piezo-meters	NA	ND	ND	Walker and Saylor 1988
49.	Characterization of sediment excavated from two lagoons (Blue Lagoon) and placed in the SW cell of the S-3 Ponds	1987-1988	54	Sediment, water	Trucks and Tankers (from the Blue Lagoon)	Organics, inorganics, radionuclides	McMahon 1988
50.	Characterization of Trib 7 seep, ORP-1, and ORP-2	1987-1988	ND	Surface water	ORP-1, ORP-2, Seep 1	PCBs, VOAs, inorganics	Napier et al. 1988
51.	Confirmatory samples collected from the Oil Landfarm after excavation of PCB-contaminated areas (where 80% confidence limit > 25ppm)	1988	186	Soil	EA1-001...012 EA2-001...012 EA3-001...080 EA4-001...006 EA5-001...034 EA6-001...042	PCBs	Bohrman 1989

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
52.	Post-excavation core study of Blue Lagoon area soils	April-June 1988	32	Soil cores	EBL-1...19 WBL-1...13	Inorganics, radionuclides, VOCs	McMahon 1988; Turner et al. 1991
53.	Follow-up sampling from ORP-1 and the Trib 7 seep	June 1988	6	Pond water, seep water soil	1,2,3,4 1 1	PCBs, VOAs, total uranium, inorganics	Kimbrough 1988
54.	Storage Yard 200 (SY-200) soil characterization	July 1986	4 2	Surface soil, subsurface soil	EP-1...EP-3 1,2	Mercury, TCLP metals, PCBs	Energy Systems 1993c (OU 2 RI)
		Jan 1988	15	Soil cores	B-1...B-5	Gross α , gross β , gamma, PCBs, selected metals, TCLP metals	(OU 2 RI)
		Jan 1989	22	Soil composites from excavated berm material	1,2...22	Thorium, uranium, % ^{235}U , mercury	
55.	Dye tracer study in upper Bear Creek to investigate hydrogeology	Oct 1988	NA	Water	MS-1... MS-13	Flow, water quality	Geraghty and Miller 1989

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
56.	Investigation of Dense Non-Aqueous Phase Liquids (DNAPLs) found at the bottom of groundwater wells near the Burial Grounds	Jan, Feb 1990	ND	Groundwater from bottom of well	GW-045, 046, 047, 068, 071, 072, 094 GW-117 GW-118, 119, 126, 237, 374, 375 GW-625, 628, 629	Visual inspection for oil phase PCBs, VOCs, total phenols PCBs, total phenols PCBs, VOCs, total phenols	Haase and King 1990
57.	Rust Spoil Area (RSA) soil characterization	Sept 1990	24	soil cores	RSA-1... RSA-7	Inorganics, VOCs, cyanide, asbestos, radionuclides	Energy Systems 1993c (OU 2 RI)
58.	Spoil Area 1 (SA-1) soil characterization	Aug 1990	60	soil cores	SAI-1... SAI-6	organics, inorganics, cyanide, radionuclides	Energy Systems 1993c (OU 2 RI) (OU 2 RI)

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
59.	Characterization of Trib. 8 soils, sediment, and surface water prior to remediation	Jan 1990	100	Sediment, floodplain soil, surface water	P1...P23 S1...S10 W1...W9	Organics, inorganics, radionuclides, PCBs, % moisture	Bogle et al. 1991
60.	Groundwater data from deep, multi-port instrumented (Westbay) wells	1990-present	ND	Groundwater	GW-131... GW-135, GW-722, GW-726, GW-727, GW-730, GW-790	Hydraulic head, anions, inorganics, organics	Dreier et al. 1993; Dreier and Caldanaro 1993
61.	Characterization data from soils stored at the Oil Landfarm Storage Pad (excavated from the Oil Landfarm plots)	1990	40	Soil composites	1-40	Inorganics, anions, PCBs, cyanide, organics	SAIC Project File 1985
62.	Water samples from the upper west forks of NT-7 and NT-8 in preparation for future closure activities	April 1990	8	Surface water	1,2,3,4 on each tributary	TSS, pH, conductivity, inorganics, PCBs, VOAs, α , β , gamma, Total U, % ^{235}U	Collins 1990
63.	Geology and soil description of BCV	1992	NA	NA	NA	Geological survey	Hatcher et al. 1992; Energy Systems 1993d

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
64.	Analysis of leachate collected from the Burial Ground C leachate collection system installed at several seeps draining burial trenches	1993	ND	Leachate	Trib 8: Seeps 2, 3, 4 and C-West Toe Slope Trib 7: Seep 1	Organics, inorganics, radionuclides, pesticides, PCBs	SAIC Project File 1995a
65.	ORNL ESD rainfall data from a rain gage located at the Burial Grounds	1993-1995	hourly	Precipitation	BUR	Rainfall	SAIC Project File 1995b
66.	Operable Unit 2 Remedial Investigation (RSA, SAI, SY-200)	1993	285	Soil	SB-1...SB-64, SS01...SS09	Organics, inorganics, radionuclides	Energy Systems 1995
67.	Wetlands delineation in Bear Creek Valley	1993	NA	NA	NA	Wetlands survey	Rosensteel and Trettin 1993
68.	NPDES monitoring by Y-12 of effluent from ORP-1	ND	ND	Surface water	NPDES-305	ND	Turner et al. 1991
69.	Characterization data from soils stored at DARA (excavated from Trib. 7 and the Oil Retention Ponds)	ND	32	Soil	ND	TCLP and non-TCLP: organics, inorganics, cyanide, radionuclides, PCBs, herbicides, dioxin/furans	SAIC Project File 1995c

Table B.1 continued

No.	Description of study	Dates	Number of samples	Media sampled	Sampling stations	Analyses performed	Selected references to these data
70.	Radiological and geophysical surveys of the Burial Grounds and BYBY areas by CHEMRAD	1994	NA	NA	NA	EM-31, pancake probe, NaI Probe, magnetometer	SAIC Project File 1995d
71.	USGS seep and spring survey (sites not shown on Plate B.1)	1994	approx. 1400	Surface water	01005... 22060 (N = 702)	Flow, water quality ^k	SAIC Project File 1995e

^a NA: Not Applicable.

^b ND: Not Determined.

^c pH, Conductivity, Temperature, Dissolved Oxygen (DO), Surfactants, Oil and Grease, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS).

^d pH, Conductivity, Temperature, BOD, COD, TSS, Redox, Alkalinity, Ammonia-N, Total Kjeldahl Nitrogen, Nitrate, Phosphate, Sulfate.

^e pH, Conductivity, Temperature, BOD, COD, TSS, Redox, Alkalinity, Ammonia-N, Total Kjeldahl Nitrogen, Nitrate, Oil and Grease, Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), Particulate Organic Carbon (POC).

^f Ammonia-N, Nitrate-N, Ortho Phosphate, Cation Exchange Capacity (CEC), TOC.

^g Water Level, pH, Conductivity, Temperature, COD, TSS, TDS, Redox, Alkalinity, Ammonia-N, Total Kjeldahl Nitrogen, Nitrate, Phosphate, Sulfate, Turbidity, Conductance, Hardness, Coliform, Phenols, TOC, Total Organic Halides (TOH).

^h pH, Conductivity, Temperature, BOD, COD, TSS, Redox, Alkalinity, Ammonia-N, Total Kjeldahl Nitrogen, Nitrate, Oil and Grease, Plate Counts, Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC).

ⁱ Total Carbon, Dissolved Carbon, Alkalinity, Nitrogen, TDS, Oil and Grease.

^j Specific Conductance, pH, Temperature.

^k pH, DO, Temperature, Conductivity.

Table B.2. Summary of number of samples per analyte per project and medium

Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
Anions												
ALKALINITY (CO3)	70				70							
ALKALINITY (HCO3)	70				70							
BROMIDE						11						
CHLORIDE	70	56	26		70	74						
CONDUCTIVITY	70				70							
DISSOLVED SOLIDS	70				70							
FLUORIDE	70	56			70	74						
NH3 AS N			11									
NITRATE						74					4	
NITRATE AS N	70				70							
NITRATE AS NITROGEN		230										
NITRATE, AS NITROGEN							1					
NITRATE-NITROGEN											5	
NITRATE/NITRITE (NO3/NO2-N)			11									
NITROGEN, NO2/NO3			15									
NITROGEN, TOTAL			11									
PH	70				70							
SULFATE	70	56	26		70	72					5	
SUSPENDED SOLIDS	70				70							
TURBIDITY	70				70							
Inorganics												
ALUMINUM	139	56		10	140	74	1	79	6	11	6	52
ANTIMONY	139				140	14			6			
ARSENIC	139	56	11	10	140	73	1	79	6	11	5	53
BARIUM	139	56	26	10	140	74	1	79	6	11	6	53
BERYLLIUM	139	56	26	10	140		1	79	12	11	6	52
BORON	139	56		10	140	74	1	79	6	11	6	51

Table B.2 (continued)

Media Sampled		River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project	GWQAR Sites		NPDES	USGS Water Quality			Trib 8	Westbay Groundwater Data		Blue Lagoon Sediment	Trib 8	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
	CADMIUM	139	56	26	10	140	73	1	79	12	11	6	53	
	CALCIUM	139	56	26	10	140	74	1	79	6	11	6	52	
	CERIUM		56		10			1	79	6	11	6	51	
	CHROMIUM	139	56	26	10	140	73	1	79	12	11	6	53	
	CHROMIUM (VI)											4		
	COBALT	139	56	24	10	140	73	1	79	6	11	6	51	
	COPPER	139	56	26	10	140	73	1	79	12	11	6	51	
	CYANIDE			26						6		5		
	GALLIUM		56		10			1	79	6	11	6	51	
	IRON	139	56	26	10	140	74	1	79	6	11	6	52	
	LANTHANUM				10			1	18	6	11		51	
	LANTHANUM											6		
	LEAD	139	56	26	10	140	73	1	79	12	11	6	53	
	LITHIUM		56	26	10			1	79	6	11	6	50	
	MAGNESIUM	139	56	26	10	140	74	1	79	6	11	6	52	
	MANGANESE	139	56	14	10	140	73	1	79	6	11	6	52	
	MERCURY	134	56	25	10	135		1	79	6	11	5	53	
	MOLYBDENUM	139	56	25	10	140	72	1	79	6	11	6	50	
	NICKEL	139	56	11	10	140	73	1	79	12	11	6	52	
	NIOBIUM		46		10			1	79	6	11	6	50	
	ORTHOPHOSPHORUS			11										
	PHOSPHORUS		5	26	10			1	79	6	11	6	50	
	POTASSIUM	139	56	26	10	140	74	1	79	6	11	6	52	
	SCANDIUM				10				79	6	11	6	50	
SELENIUM	139	56	11	10	140	73	1	79	6	11	5	53		
SILICON	50				50	31								
SILVER	139	56		10	140	73	1	79	12	11	6	53		
SODIUM	139	56	26	10	140	74	1	79	6	11	6	52		

Table B.2 (continued)

Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
STRONTIUM	139	56	24	10	140	73	1	79	6	11	6	52
THALLIUM		56							6		5	
THORIUM	139	56		10	140	73	1	79	6	11	6	50
TIN											5	
TITANIUM		56		10			1	79	6	11	6	50
URANIUM			7								5	
VANADIUM	139	56	25	10	140	73	1	79	6	11	6	50
YTTRIUM							1	79	6	11	6	50
ZINC	139	56	25	10	140	72	1	79	12	11	6	50
ZIRCONIUM		56		10			1	79	6	11	6	52
Miscellaneous												
ALKALINITY			17			74						
ALPHA RADIOACTIVITY											5	
ALUMINUM						1						
ARSENIC											5	
BARIUM											5	
BETA RADIOACTIVITY											5	
BIOLOGICAL OXYGEN DEMAND (BOD)		229										
CADMIUM											5	
CHEMICAL OXYGEN DEMAND (COD)		230										
CHROMIUM											5	
CONDUCTIVITY	69				70							
DISSOLVED OXYGEN	69				70							2
ENDRIN											5	
IRON						1						
LEAD											5	
LINDANE											5	
MERCURY											5	

Table B.2 (continued)

[illegible]

Table B.2 (continued)

[illegible]

Table B.2 (continued)

Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
BETA-BHC									6			
CHLORDANE									6			
DELTA-BHC									6			
DIELDRIN									6			
ENDOSULFAN I									6			
ENDOSULFAN II									6			
ENDOSULFAN SULFATE									6			
ENDRIN									6			
ENDRIN ALDEHYDE									6			
HEPTACHLOR									6			
HEPTACHLOR EPOXIDE									6			
LINDANE									6			
PCB, TOTAL				10				79				
PCB-1016									6	11		
PCB-1221									6			
PCB-1232									6			
PCB-1242									6			
PCB-1248									6			
PCB-1254									6			
PCB-1260									6			
TOTAL PCB									6		4	
TOXAPHENE									6			
Semi-volatile Organics												
1,2,4-TRICHLOROBENZENE									6			
1,2-DICHLOROBENZENE									6			
1,2-DIPHENYLHYDRAZINE									6			
1,3-DICHLOROBENZENE									6			
1,4-DICHLOROBENZENE									6			

Table B.2 (continued)

Media Sampled		River/Stream Water	River/Stream Water	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project		GWQAR Sites				Trib 8	GWQAR Sites	Westbay	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
1-(2-BUTOXYETHOXY)-ETHANOL															
2 BUTOXYLETHANOL															
2(2-BUTOXYETHOXY)-ETHANOL															
2,4,6-TRICHLOROPHENOL															
2,4-DICHLOROPHENOL															
2,4-DIMETHYLPHENOL															
2,4-DINITROPHENOL															
2,4-DINITROTOLUENE															
2,6-DINITROTOLUENE															
2-CHLORONAPHTHALENE															
2-CHLOROPHENOL															
2-HEXANOL															
2-NITROPHENOL															
3,3'-DICHLOROBENZIDINE															
3-(1,1-DIMETHYLETHYL)PHENOL															
4-BROMOPHENYL PHENYL ETHER															
4-CHLORO-3-METHYLPHENOL															
4-CHLOROPHENYLPHENYL ETHER															
4-NITROPHENOL															
A DIMETHYLPHENOL															
A METHYL PHENOL															
ACENAPHTHENE															
ACENAPHTHYLENE															
ANTHRACENE															
BENZIDINE															
BENZO(A)ANTHRACENE															
BENZO(A)PYRENE															
BENZO(B)FLUORANTHENE															

Table B.2 (continued)

	Project	Media Sampled
	GWQAR Sites	River/Stream Water
	NPDES	River/Stream Water
	USGS Water Quality	River/Stream Water
	Trib 8	River/Stream Water
	GWQAR Sites	Spring/Seep Water
	Westbay Groundwater Data	Monitoring Well
	Blue Lagoon Sediment	Water sample from truck tank
	Trib 8	Soil
	UBC Sediment (1984)	Sediment
	Trib 8	River/Stream Sediments
	S-3 Pond Sludge	Impoundment Pond Sediments/Sludge
	Blue Lagoon Sediment	Impoundment Pond Sediments/Sludge
BENZO(GH)PERYLENE		
BENZO(K)FLUORANTHENE		
BIS(2-CHLOROETHOXY)METHANE		
BIS(2-CHLOROETHYL) ETHER		
BIS(2-CHLOROISOPROPYL) ETHER		
BIS(2-ETHYLHEXYL)PHTHALATE		
BUTYLBENZYLPHTHALATE		
CHRYSENE		
DI-N-BUTYLPHTHALATE		
DI-N-OCTYLPHTHALATE		
DIBENZ(A,H)ANTHRACENE		
DIETHYL PHTHALATE		
DIETHYLPHTHALATE		5
DIMETHYLPHTHALATE		
DIPHENYLAMINE		
FLUORANTHENE		
FLUORENE		
HEXACHLOROBENZENE		
HEXACHLOROBUTADIENE		
HEXACHLOROCYCLOPENTADIENE		
HEXACHLOROETHANE		
INDENO(1,2,3-CD)PYRENE		
ISOPHORONE		
N-NITROSO-DI-N-PROPYLAMINE		
N-NITROSODIMETHYLAMINE		
NAPHTHALENE		
NITROBENZENE		
O-CRESOL, 4,6-DINITRO		

Table B.2 (continued)

	Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
	Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
OCTAMETHYL-CYCLOTETRASILOZANE												2	
PENTACHLOROPHENOL										6			
PHENANTHRENE										6			
PHENOL										6		5	
PHOSPHORIC ACID												2	
PYRENE										6			
TRIPHENYL ESTER												2	
UNIDENTIFIED (POSSIBLE SILANE)												5	
UNIDENTIFIED METHYLESTER												4	
1,1'-THIOBIS-ETHANE					1								
1,1,1-TRICHLOROETHANE		71			10	69	52		79	6	11		49
1,1,2,2-TETRACHLOROETHANE		71			10	69	52		79	6	11	5	49
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETH					10				79		1		38
1,1,2-TRICHLOROETHANE		71			10	69	52		79	6	11	1	48
1,1-DICHLOROETHANE		71			10	69	52		79	6	11		49
1,1-DICHLOROETHENE		71			10	69	52		79	6	11		49
1,2-DICHLOROETHANE		71			10	69	52		79	6	11		49
1,2-DICHLOROETHENE							52						
1,2-DICHLOROETHENE (TOTAL)		71				69							
1,2-DICHLOROPROPANE		71			10	69	52		79	6	11		49
2-BUTANONE		71			10	69	52		79		4		5
2-CHLOROETHYL VINYL ETHER					10				79	6	11		49
2-HEXANONE		71				69	52						
2-PROPANOL									1				
2-PROPENYL BENZENE									2				
3-CHLORO-1-BUTYNE					1								
4-METHYL-2-PENTANONE		71			10	69	52		79		1		
ACETONE		71			10	69	52		79				14

Table B.2 (continued)

Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
ACROLEIN									6			
ACRYLONITRILE									6			
ALL OTHER VOLATILES TOTAL											5	
BENZENE	71			10	69	52		79	6	11		48
BROMODICHLOROMETHANE	71			10	69	52		79	6	11		47
BROMOFORM	71			10	69	52		79	6	11		48
BROMOMETHANE	71			10	69	52		79	6	11		49
CARBON DISULFIDE	71				69	52						
CARBON TETRACHLORIDE	71			10	69	52		79	6	11		48
CHLOROBENZENE	71			10	69	52		79	6	11		49
CHLOROETHANE	71			10	69	52		79	6	11		49
CHLOROFORM	71			10	69	52		79	6	11		49
CHLOROMETHANE	71			10	69	52		79	6	11		49
CIS-1,2-DICHLOROETHENE				7				43				
CIS-1,3-DICHLOROPROPENE	71			10	69	52		79	6	11		49
DIBROMOCHLOROMETHANE	71			10	69	52		79	6	10		49
DIBROMODICHLOROMETHANE										1		
DIETHYL DISULFIDE				2						3		
ETHYL METHYL BENZENE				2								
ETHYLBENZENE	71			10	69	52		79	6	11		49
ISOPHORONE												2
METHYLENE CHLORIDE	71			10	69	52		79	6	11		49
STYRENE	71				69	52						
SUBSTITUTED BENZENES								1		4		
TETRACHLOROETHENE	71			10	69	52		79	6	11	5	49
TOLUENE	71			10	69	52		79	6	11		49
TOTAL XYLENES	71				69							
TRANS-1,2-DICHLOROETHENE				10				79	6	11		49

Table B.2 (continued)

Media Sampled		River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge	
Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment	S-3 Pond Sludge	
														GWQAR Sites
	TRANS-1,3-DICHLOROPROPENE	71			10	69	52	79	6	11				49
	TRICHLOROETHENE	71			10	69	52	79	6	11				49
	TRICHLOROFLUOROMETHANE				10			79	6	11				49
	TRIMETHYL BENZENE				2									
	VINYL ACETATE	71				69	52							
	VINYL CHLORIDE	71			10	69	52	79	6	11				49
	XYLENE (TOTAL)													1
	XYLENE, TOTAL				10	52	79	4						
Radiological														
ALPHA ACTIVITY								1	6				53	
ALPHA RADIOACTIVITY														
AMERICIUM-241	20				20			1	6			4	44	
BETA ACTIVITY														
BETA RADIOACTIVITY												4	53	
CESIUM-137														
COBALT-60												5		
GAMMA ACTIVITY														
GROSS ALPHA	71			10	70				79		11			
GROSS ALPHA U-NAT			10						79		11			
GROSS BETA	71			10	70				79					
GROSS BETA CS-137			10											
GROSS BETA SR/Y-90			10											
LEAD-212														
NEPTUNIUM-237	20				20					5			44	
PLUTONIUM-238										6		5	7	
PLUTONIUM-239/240								1		6		5		
PU-239/240								1		6		5	4	

Table B.2 (continued)

	Media Sampled	River/Stream Water	River/Stream Water	River/Stream Water	River/Stream Water	Spring/Seep Water	Monitoring Well	Water sample from truck tank	Soil	Sediment	River/Stream Sediments	Impoundment Pond Sediments/Sludge	Impoundment Pond Sediments/Sludge
	Project	GWQAR Sites	NPDES	USGS Water Quality	Trib 8	GWQAR Sites	Westbay Groundwater Data	Blue Lagoon Sediment	Trib 8	UBC Sediment (1984)	Trib 8	S-3 Pond Sludge	Blue Lagoon Sediment
RUTHIUM-106												5	
STRONTIUM-90		24				24		1				5	52
TECHNETIUM-99		24				24		1		5		5	52
THALLIUM-208										4			
THORIUM-228												4	
THORIUM-230												4	
THORIUM-232												4	
TOTAL URANIUM (FLUOROMETRIC)		139				140							
TRITIUM		24				24		1					52
U-235					10				79		11		
U-238									79				
URANIUM				18	10				79	6	11		
URANIUM - 235 %												5	
URANIUM, TOTAL								1					51
URANIUM-234		50				50		1		6			53
URANIUM-235		45				45		1		6			53
URANIUM-236								1					51
URANIUM-238		50				50		1		6			53
ZIRCONIUM-95												4	
ZR95/NB95										3			

Table B.3. Procedure numbers and titles for BCV OU 1 RIFA

Procedure number	Subject activity	Issue date	Revision
<i>Activity series 301: surface water sampling</i>			
ESP-301-1	Water sampling using a dipper	8/30/88	0
ESP-301-4	Grab sampling with Kemmerer bottles	8/30/88	0
ESP-301-5	Stream flow measurements	8/30/88	0
<i>Activity series 302: groundwater sampling</i>			
ESP-302-1	Water level measurements using a water level indicator	8/29/88	0
ESP-302-5	Using a bladder pump	8/29/88	0
FTP-352	Groundwater sampling procedures: using a hydropunch	6/30/93	0
FTP-357	Groundwater sampling using micropurge and low flow sampling	TBA	
FTP-616	Installation, development, and abandonment of temporary piezometers	TBA	
<i>Activity series 303: soil sampling</i>			
ESP-303-1	Soil sampling with a spade and scoop	8/30/88	0
ESP-303-2	Soil sampling with an auger	9/01/88	0
ESP-303-3	Soil sampling with a trier	8/31/88	0
ESP-303-4	Penetration testing and split-barrel sampling	8/24/88	0
ESP-303-5	Subsurface soil sampling with shelby tubes	8/30/88	0
FTP-551	Soil sampling by direct push	TBA	
<i>Activity series 304: sediment sampling</i>			
ESP-304-1	Streambeds	8/29/88	0
<i>Activity series 307: field measurements</i>			
FTP-880	Field measurement procedures: pH, temperature, and conductance	8/29/88	0
ESP-307-5	Oxidation/reduction potential of water	8/29/88	0
FTP-750	Field measurement procedures: organic vapor detection	8/29/88	0
FTP-451	Field measurement procedures: operation of radiation survey instruments	1/31/90	0
FTP-701	Field measurement procedures: using a proton magnetometer	TBA	
FTP-710	Field measurement procedures: using the EM-31	TBA	

Table B.4. List of changes to SAP for OU 1

FCO NO.	DATE ISSUED	DESCRIPTION OF CHANGE
BCVOU1-001	10/13/94	Changes to Health and Safety Plan. See attached list.
BCVOU1-002	10/19/94	Use of Little Beaver Auger Tool: For borings that cannot be accessed by the Geoprobe or auger rig, a Little Beaver will be used.
BCVOU1-003	10/19/94	Use of 60 ml glass bottles for soil VOC samples: VOC soil samples will be collected in 60 ml glass bottles instead of 125 ml containers.
BCVOU1-004	10/19/94	If unable to collect enough soil sample to fill sample jars when using the Geoprobe or Auger Rig, the sample interval will not be collected.
BCVOU1-005	10/19/94	During subsurface soil collection activities using the split spoon, at times it will be necessary to use a 3 in. diameter split spoon instead of the 2 in. diameter split spoon that is specified in the SAP.
BCVOU1-006	10/21/94	Page 9-28 Section 0.2.5.2 of the Health and Safety Plan Work Plan Addendum. General Employee Training will not be required for surveyor, CHEMRAD, Ogden, and Geomarine subcontractors.
BCVOU1-007	10/18/94	Replace the use of ESP-800 with ER/C-P2302 IAD, ESP 801 with ESP-900, ESP-802 with ESP-901, ESP-307-6 with FTP-750, ESP-307-7 with FTP-451 and disregard procedure ESP-301-6.
BCVOU1-008	10/21/94	Changes to Health and Safety Plan need to accommodate use of the Little Beaver Auger. Table 9.3 page 9-10, item 2 should be revised to include: "lifting" in the hazard column, add "The Little Beaver will have at least one kill switch" in controls column.
BCVOU1-009	11/28/94	The following changes should be made to the Sampling and Analysis Plan due to location accessibility problems (see attached).
BCVOU1-010	10/19/94	The BCV OU1 Project will allow a change to the quantitation level goals specified in the Work Plan by changing the Hg soil level to 0.1 µg/gm and the Molybdenum level to 4 µg/gm.
BCVOU1-011	10/21/94	Reference: Section 9.1.5.5 "Decontamination and Contamination Control" Health and Safety Plan. Insert "Personnel exiting from a radiological controlled area will be monitored as per procedure Y50-66HP-124" at end of first paragraph.
BCVOU1-012	10/21/94	Reference: Waste Management Plan Chapter 10.1 Paragraph 6. Procedure K/HS-410 will not be used to scan protective clothing and other sanitary waste. Instead SAIC will package this waste in plastic bags and Y-12 ER will be responsible for the waste's final disposition.
BCVOU1-013	10/14/94	The BCV OU1 Project will allow determination of metals utilizing SuperTrace ICP technology in place of GFAA. This can only be implemented when the laboratory can meet quantitation level goals identified in the SAP for these elements.

Table B.4. (continued)

FCO NO.	DATE ISSUED	DESCRIPTION OF CHANGE
BCVOU1-014	11/3/94	Waive Hazwoper zoning requirement for groundwater sampling in boreholes previously soil probed. Sites covered: SL-01; SL-02; OLF-01.
BCVOU1-015	11/1/94	Site Health & Safety Officer (SHSO) may waive equipment/personnel rad/con surveys at job completion and during job provided no HP measurements are above general area background on samples, geoprobe equipment.
BCVOU1-016	11/3/94	Waive Hazwoper zoning requirement on SL-01, SL-02, OLF-01 Geoprobe sites for water sampling (groundwater).
BCVOU1-017	11/3/94	Will take VOA water samples from geoprobe boreholes using the tubing water is pumped through. Tubing extends into borehole and is connected to peristaltic pump. Water will be drawn through tubing, up to pump and tubing will then be disconnected from pump, water captured by putting thumb/finger over tubing, tubing removed from borehole, VOAs filled by letting water out of tubing.
BCVOU1-018	11/15/94	Change work plan from "borehole will be abandoned to 4 ft of surface" to "boreholes will be abandoned to about 4 ft of surface."
BCVOU1-019	11/15/94	Not necessary to scan geoprobe borehole location with Mercury Vapor analyzer on 11/15/94.
BCVOU1-020	11/15/94	Collect one trip blank per day instead of one trip blank per crew. All VOA samples will be shipped to lab in same cooler as trip blank. Trip blanks will be alternated between teams daily.
BCVOU1-021	11/14/94	Replace FTP-616 with BCV OU1-615. Delete references to the following procedures in the QAPJP and/or the Health and Safety Plan in the Work Plan Addendum: ESP-302-5, ESP-303-3, ESP-304-1, ESP-307-5, FTP 352, FTP 357, FTP 551, FTP 701 and FTP 710.
BCVOU1-022	11/15/94	Reference: Waste Management Plan Chapter 10, page 10-1, paragraph 6. Delete the use of procedure K/HS-410. SAIC Health and Safety Officer will scan protective clothing and other sanitary waste prior to leaving the sampling location and before bagging the PPE and sanitary waste. (This FCO affects FCO BCV OU1-012.)
BCVOU1-023	11/15/94	If unable to collect enough soil sample to fill sample jars when homogenizing a 4 ft interval using the geoprobe or auger rig then a 6 ft interval will be homogenized. If there is still not enough sample then the sample jars will be filled following the analyte priority list. (This FCO affects BCV OU1-004.)
BCVOU1-024	11/16/94	Boring locations around S-3 Ponds may have to be moved due to overhead and underground obstructions. Mitch Guinn will assist and concur on any moved boreholes.
BCVOU1-025	11/16/94	Piezometers are being installed around S03 ponds and boreholes are being backfilled with soil cuttings. top 5 feet of borehole will be backfilled with bentonite to prevent surface water going down borehole.

Table B.4. (continued)

FCO NO.	DATE ISSUED	DESCRIPTION OF CHANGE
BCVOU1-026	11/28/94	Clarification for BCV OU1 Addendum to RI Work Plan Chapter 8 page 8-2. Calibration of field screening instruments (such as pH and conductivity meters should be done once in the morning and once in the afternoon when using the equipment all day. However, if only using the instruments once during the day, it is only necessary to calibrate it immediately before use. All H&S monitoring equipment (HNus, Radmeters, etc.) will only be required to be calibrated once per day before use.
BCVOU1-027	11/23/94	Waive Hazwoper zoning requirements [(e.g., support zone, CR2 zone, exclusion zone) since previous field monitoring indicated no contaminants present] for pushing Shelby tubes; area to be marked as "construction area". Area will be "Hazwoper" zoned if any field monitoring results indicate contaminants present.
BCVOU1-028	11/23/94	Change the Waste Management Plan. At soil boring S-3-8 and S-3-7 all the soil would not go back down the borehole. Because the soil at S-3-8 was found to have a low pH (<3) and the soil at S-3-7 was found to have high beta/gamma readings (500 cpm), a decision was made <u>not</u> to spread the remaining soil on top of the ground around the borehole. Steve Walker requested that we dig a hole next to the boreholes and bury the excess soil and cover it with the soil removed from the hole that was dug.
BCVOU1-029	11/29/94	Increase the type and number of Field Blanks (FB) to be collected on the project. See the attached definition for the type of field blank to be collected. The field blanks will be collected at a frequency of 1/20 or 5% per area (BG, S-3 Ponds, (SL-1, BY/By and the Oil Landfarm). This increase is being implemented at the request of Hugh Newsom and was approved by Judy Hodgins. Collecting the additional samples will cause an increase to the analytical costs. However, the cost is unknown by this requestor because the laboratory is subcontracted directly to Energy Systems.
BCVOU1-030	12/1/94	Waive Hazwoper zoning requirement for sites in the Burial Ground, Boneyard / Burnyard and Oil Landfarm Area. These sites have previously been drilled / probed with only background radiological contamination detected, 0% LEL, .000 m ³ /m ³ Hg, and) ppm PID readings. The SHSO will continue to perform real-time monitoring and will post the area as a "Hazwoper site" (e.g., exclusion zone, contamination reduction zone, support zone) as conditions warrant.
BCVOU1-031	11/18/94	Addendum to BCV OU1 Health and Safety Plan and Sampling and Analysis Plan. This should include the sampling of one opened 55 gallon drum radiologically contaminated (e.g., 100,000 pm beta gamma, 0 cpm alpha). Sample to be collected and shipped to Y-12 laboratory. SAIC will collect the additional sample and Steve Walker will transport the sample to the Y-12 Exclusion Area. Radiochemical laboratory; qualified (Rad worker II, Resp. Qualified) SAIC personnel will perform sampling/packaging.
BCVOU1-032	2/6/95	Will monitor water level in GW-276 for approximately 5 weeks versus 8 weeks as outlined in Work Plan.

Table B.5. List of analytes and reported quantitation limits for surface and subsurface soils in BCV OU 1

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Inorganics (mg/kg)</i>		
Aluminum		
Antimony		
Arsenic	0.38	0.38
Barium		
Beryllium	0.12	2.20
Boron		
Cadmium	0.27	0.57
Calcium	35.70	263.00
Chromium		
Cobalt		
Copper	3.70	24.70
Cyanide	0.48	57.30
Iron		
Lead		
Magnesium		
Manganese		
Mercury	0.04	0.08
Molybdenum	0.49	16.20
Nickel		
Potassium		
Selenium	0.48	4.10
Silver	0.47	3.70
Sodium	20.60	811.00
Thallium	0.33	0.72
Tin	1.90	16.60
Vanadium		
Zinc	7.10	7.10

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Pesticides/PCBs/Dioxins (µg/kg)</i>		
2378-TCDD (pg/g)	2.15	5.40
Aroclor-1016	38.00	43.00
Aroclor-1221	76.00	87.00
Aroclor-1232	38.00	43.00
Aroclor-1242	38.00	43.00
Aroclor-1248	38.00	43.00
Aroclor-1254	38.00	43.00
Aroclor-1260	38.00	43.00
4,4'-DDD	3.30	42.00
4,4'-DDE	3.30	42.00
4,4'-DDT	3.30	42.00
Aldrin	1.70	21.00
Aroclor-1016	33.00	420.00
Aroclor-1221	67.00	850.00
Aroclor-1232	33.00	420.00
Aroclor-1242	33.00	420.00
Aroclor-1248	33.00	420.00
Aroclor-1254	33.00	47.00
Aroclor-1260	33.00	420.00
Dieldrin	3.30	42.00
Endosulfan I	1.70	21.00
Endosulfan II	3.30	42.00
Endosulfan sulfate	3.30	42.00
Endrin	3.30	42.00
Endrin aldehyde	3.30	42.00
Endrin ketone	3.30	42.00
Heptachlor	1.70	21.00
Heptachlor epoxide	1.70	21.00
Toxaphene	170.00	2100.00
α-BHC	1.70	21.00
α-Chlordane	1.70	21.00

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
β-BHC	1.70	21.00
Δ-BHC	1.70	21.00
γ-BHC (Lindane)	1.70	21.00
γ-Chlordane	1.70	21.00
p,p'-Methoxychlor	17.00	210.00
<i>Semivolatile Organics (μg/kg)</i>		
1,2,4-Trichlorobenzene	360.00	2000.00
1,2-Dichlorobenzene	360.00	2000.00
1,3-Dichlorobenzene	360.00	2000.00
1,4-Dichlorobenzene	360.00	2000.00
2,2'-oxybis(1-Chloropropane)	360.00	2000.00
2,4,5-Trichlorophenol	900.00	4900.00
2,4,6-Trichlorophenol	360.00	2000.00
2,4-Dichlorophenol	360.00	2000.00
2,4-Dimethylphenol	360.00	2000.00
2,4-Dinitrophenol	900.00	4900.00
2,4-Dinitrotoluene	360.00	2000.00
2,6-Dinitrotoluene	360.00	2000.00
2-Chloronaphthalene	360.00	2000.00
2-Chlorophenol	360.00	2000.00
2-Methylnaphthalene	360.00	750.00
2-Methylphenol	360.00	2000.00
2-Nitroaniline	900.00	4900.00
2-Nitrophenol	360.00	2000.00
3,3'-Dichlorobenzidine	360.00	2000.00
3-Nitroaniline	900.00	4900.00
4,6-Dinitro-2-methylphenol	900.00	4900.00
4-Bromophenyl-phenylether	360.00	2000.00
4-Chloro-3-methylphenol	360.00	2000.00
4-Chloroaniline	360.00	2000.00
4-Chlorophenyl-phenylether	360.00	2000.00
4-Methylphenol	360.00	2000.00

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
4-Nitroaniline	900.00	4900.00
4-Nitrophenol	900.00	4900.00
Acenaphthene	360.00	750.00
Acenaphthylene	360.00	2000.00
Anthracene	360.00	750.00
Benzo(a)anthracene	360.00	750.00
Benzo(a)pyrene	360.00	750.00
Benzo(b)fluoranthene	360.00	750.00
Benzo(g,h,i)perylene	360.00	750.00
Benzo(k)fluoranthene	360.00	750.00
Butylbenzylphthalate	360.00	2000.00
Carbazole	360.00	750.00
Chrysene	360.00	750.00
Di-n-butylphthalate	82.00	2000.00
Di-n-octylphthalate	360.00	4000.00
Dibenzo(a,h)anthracene	360.00	750.00
Dibenzofuran	360.00	750.00
Diethylphthalate	360.00	4000.00
Dimethylphthalate	360.00	2000.00
Fluoranthene	360.00	750.00
Fluorene	360.00	750.00
Hexachlorobenzene	360.00	4000.00
Hexachlorobutadiene	360.00	4000.00
Hexachlorocyclopentadiene	360.00	4000.00
Hexachloroethane	360.00	4000.00
Indeno(1,2,3-c,d)pyrene	360.00	750.00
Isophorone	360.00	4000.00
N-Nitroso-di-n-propylamine	360.00	4000.00
N-Nitrosodiphenylamine	360.00	4000.00
Naphthalene	360.00	750.00
Nitrobenzene	360.00	4000.00
Pentachlorophenol	900.00	9800.00

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Phenanthrene	360.00	750.00
Phenol	360.00	2000.00
Pyrene	360.00	750.00
bis(2-Chloroethoxy)methane	360.00	2000.00
bis(2-Chloroethyl)ether	360.00	4000.00
bis(2-Ethylhexyl)phthalate	360.00	2000.00
<i>Volatile Organics (µg/kg)</i>		
1,1,1-Trichloroethane	5.00	33.00
1,1,2,2-Tetrachloroethane	5.00	33.00
1,1,2-Trichloroethane	5.00	33.00
1,1-Dichloroethane	5.00	33.00
1,1-Dichloroethene	5.00	33.00
1,2-Dichloroethane	5.00	33.00
1,2-Dichloroethene	5.00	33.00
1,2-Dichloropropane	5.00	33.00
2-Butanone	10.00	66.00
2-Hexanone	10.00	66.00
4-methyl-2-Pentanone	6.00	23.00
Acetone	11.00	170.00
Benzene	5.00	33.00
Bromodichloromethane	5.00	33.00
Bromoform	5.00	33.00
Bromomethane	10.00	66.00
Carbon disulfide	5.00	33.00
Carbon tetrachloride	5.00	33.00
Chlorobenzene	5.00	33.00
Chloroethane	10.00	66.00
Chloroform	5.00	33.00
Chloromethane	10.00	66.00
Dibromochloromethane	5.00	33.00
Ethylbenzene	5.00	33.00
Methylene chloride	5.00	85.00

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Styrene	5.00	33.00
Tetrachloroethene	5.00	12.00
Toluene	6.00	33.00
Trichloroethene	5.00	33.00
Trichlorotrifluoromethane	10.00	66.00
Vinyl chloride	10.00	66.00
Xylene, Total	5.00	33.00
cis-1,3-Dichloropropene	5.00	33.00
trans-1,3-Dichloropropene	5.00	33.00

Radionuclides (pCi/g)

Antimony-125

Americium-241

Bismuth-212

Cerium-144

Cesium-134

Cesium-137

Chromium-51

Cobalt-57

Cobalt-58

Cobalt-60

Gross α Gross β

Iron-59

Manganese-54

Lead-212

Neptunium-237

Niobium-95

Potassium-40

Plutonium-238

Plutonium-239/240

Ruthenium-106

Thallium-208

Table B.5 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Sodium-22		
Strontium-90		
Technetium-99		
Thorium-228		
Thorium-230		
Thorium-232		
Uranium-234		
Uranium-235		
Uranium-238		
Zinc-65		
Zirconium-95		

^aParameters which were never reported as less than the quantitation limit have no statistics for minimum or maximum quantitation limit

Table B.6. Geotechnical and physical parameters for soil samples taken in BCV OU 1 RIFA

Analytical parameter	Analytical method
Permeability	SW 846 Method 9100
Hydraulic conductivity	SW 846 Method 9100
Porosity	EM 1110-2-1906
Grain size (sieve)	ASTM D422
Grain size (hydrometer)	ASTM D422
Mineral composition	X-ray diffraction/electron spectroscopy
Bulk density	ASTM D4531-86
Cation exchange capacity	SW 846 Method 9081
pH	SW 846 Method 9045
Total organic carbon (bulk)	SW 846 Method 9060 ^a
Total organic carbon (<75 µm)	SW 846 Method 9060 ^a
Distribution coefficient	ASTM Method 4646
Moisture content	ASTM D4959-89
Atterburg limits	ASTM D4318-84
Shear strength	ASTM D4318-84

^a As modified for solid media per laboratory-specific methodology. Laboratory method will be submitted for review and approval.

Table B.7. List of analytes and reported quantitation limits for groundwater and surface water in BCV OU 1

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Anions (mg/l)</i>		
Chloride		
Fluoride	0.05	0.05
Nitrate/Nitrite (NO ₃ /NO ₂ -N)	0.10	0.10
Sulfate		
<i>Inorganics (total, µg/l)</i>		
Aluminum		
Antimony	0.90	0.90
Arsenic	1.70	1.70
Barium		
Beryllium	0.30	1.50
Cadmium	1.40	3.30
Calcium		
Chromium	1.70	9.90
Cobalt	2.30	6.10
Copper	4.60	53.90
Cyanide	10.00	10.00
Iron		
Lead	3.90	3.90
Magnesium		
Manganese		
Mercury	0.20	0.20
Molybdenum	2.40	45.80
Nickel	3.50	3.50
Potassium		
Selenium	2.50	4.00
Silver	2.40	2.40
Thallium	1.70	1.70
Tin	9.90	9.90

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Vanadium	2.30	8.10
Zinc	6.40	53.40
<i>Inorganics (dissolved, µg/l)- surface water only</i>		
Aluminum	22.40	22.40
Arsenic		
Barium		
Beryllium	0.30	0.30
Cadmium	1.40	1.40
Calcium		
Chromium	1.70	1.70
Cobalt	2.30	2.30
Copper	3.10	5.20
Iron	12.40	12.40
Magnesium		
Manganese	1.20	1.20
Mercury	0.20	0.20
Molybdenum	2.40	2.40
Nickel	3.50	3.50
Potassium		
Selenium		
Silver	2.40	2.40
Thallium		
Tin	9.90	9.90
Vanadium	2.30	2.30
Zinc	6.30	6.30
<i>Pesticides/PCBs (µg/l)</i>		
4,4'-DDD	0.10	0.19
4,4'-DDE	0.10	0.19
4,4'-DDT	0.10	0.19
Aldrin	0.05	0.09
Aroclor-1016	0.98	1.90
Aroclor-1221	1.90	3.80

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Aroclor-1232	0.98	1.90
Aroclor-1242	0.98	1.90
Aroclor-1248	0.98	1.90
Aroclor-1254	0.98	1.90
Aroclor-1260	0.98	1.90
Dieldrin	0.10	0.19
Endosulfan I	0.05	0.09
Endosulfan II	0.10	0.19
Endosulfan sulfate	0.10	0.19
Endrin	0.10	0.19
Endrin aldehyde	0.10	0.19
Endrin ketone	0.10	0.19
Heptachlor	0.05	0.09
Heptachlor epoxide	0.05	0.09
Toxaphene	4.80	9.40
α -BHC	0.05	0.09
α -Chlordane	0.05	0.09
β -BHC	0.05	0.09
Δ -BHC	0.05	0.09
γ -BHC (Lindane)	0.05	0.09
γ -Chlordane	0.05	0.09
p,p'-Methoxychlor	0.48	0.94
<i>Semi-volatile organics ($\mu\text{g/l}$)</i>		
1,2,4-Trichlorobenzene	10.00	17.00
1,2-Dichlorobenzene	10.00	17.00
1,3-Dichlorobenzene	10.00	17.00
1,4-Dichlorobenzene	10.00	17.00
2,2'-Oxybis(1-Chloropropane)	10.00	17.00
2,4,5-Trichlorophenol	25.00	42.00
2,4,6-Trichlorophenol	10.00	17.00
2,4-Dichlorophenol	10.00	17.00
2,4-Dimethylphenol	10.00	17.00

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
2,4-Dinitrophenol	25.00	42.00
2,4-Dinitrotoluene	10.00	17.00
2,6-Dinitrotoluene	10.00	17.00
2-Chloronaphthalene	10.00	17.00
2-Chlorophenol	10.00	17.00
2-Methylnaphthalene	10.00	17.00
2-Methylphenol	10.00	17.00
2-Nitroaniline	25.00	42.00
2-Nitrophenol	10.00	17.00
3,3'-Dichlorobenzidine	10.00	17.00
3-Nitroaniline	25.00	42.00
4,6-Dinitro-2-methylphenol	25.00	42.00
4-Bromophenyl-phenylether	10.00	17.00
4-Chloro-3-methylphenol	10.00	17.00
4-Chloroaniline	10.00	17.00
4-Chlorophenyl-phenylether	10.00	17.00
4-Methylphenol	10.00	17.00
4-Nitroaniline	25.00	42.00
4-Nitrophenol	25.00	42.00
Acenaphthene	10.00	17.00
Acenaphthylene	10.00	17.00
Anthracene	10.00	17.00
Benzo(a)anthracene	10.00	17.00
Benzo(a)pyrene	10.00	17.00
Benzo(b)fluoranthene	10.00	17.00
Benzo(g,h,i)perylene	10.00	17.00
Benzo(k)fluoranthene	10.00	17.00
Butylbenzylphthalate	10.00	17.00
Carbazole	10.00	17.00
Chrysene	10.00	17.00
Di-n-butylphthalate	10.00	17.00
Di-n-octylphthalate	10.00	17.00

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Dibenzo(a,h)anthracene	10.00	17.00
Dibenzofuran	10.00	17.00
Diethylphthalate	10.00	17.00
Dimethylphthalate	10.00	17.00
Fluoranthene	10.00	17.00
Fluorene	10.00	17.00
Hexachlorobenzene	10.00	17.00
Hexachlorobutadiene	10.00	17.00
Hexachlorocyclopentadiene	10.00	17.00
Hexachloroethane	10.00	17.00
Indeno(1,2,3-c,d)pyrene	10.00	17.00
Isophorone	10.00	17.00
N-Nitroso-di-n-propylamine	10.00	17.00
N-Nitrosodiphenylamine	10.00	17.00
Naphthalene	10.00	17.00
Nitrobenzene	10.00	17.00
Pentachlorophenol	25.00	42.00
Phenanthrene	10.00	17.00
Phenol	10.00	17.00
Pyrene	10.00	17.00
Bis(2-Chloroethoxy)methane	10.00	17.00
Bis(2-Chloroethyl)ether	10.00	17.00
Bis(2-Ethylhexyl)phthalate	10.00	17.00

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Volatile Organics (µg/l)</i>		
1,1,1-Trichloroethane	5.00	14.00
1,1,2,2-Tetrachloroethane	5.00	5.00
1,1,2-Trichloroethane	5.00	5.00
1,1-Dichloroethane	5.00	5.00
1,1-Dichloroethene	5.00	5.00
1,2-Dichloroethane	5.00	5.00
1,2-Dichloroethene	5.00	5.00
1,2-Dichloropropane	5.00	5.00
2-Butanone	10.00	10.00
2-Hexanone	10.00	10.00
4-Methyl-2-Pentanone	10.00	10.00
Acetone	10.00	150.00
Benzene	5.00	5.00
Bromodichloromethane	5.00	5.00
Bromoform	5.00	5.00
Bromomethane	10.00	10.00
Carbon disulfide	5.00	5.00
Carbon tetrachloride	5.00	5.00
Chlorobenzene	5.00	5.00
Chloroethane	10.00	10.00
Chloroform	5.00	5.00
Chloromethane	10.00	10.00
Dibromochloromethane	5.00	5.00
Ethylbenzene	5.00	5.00
Methylene chloride	5.00	58.00
Styrene	5.00	5.00
Tetrachloroethene	5.00	5.00
Toluene	5.00	5.00
Trichloroethene	5.00	5.00
Trichlorotrifluoromethane	10.00	10.00
Vinyl chloride	10.00	10.00

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Xylene, total	5.00	5.00
Cis-1,3-Dichloropropene	5.00	5.00
Trans-1,3-Dichloropropene	5.00	5.00
<i>Radionuclides (pCi/l)</i>		
Antimony-125		
Americium-241		
Bismuth-212		
Cerium-144		
Cesium-134		
Cesium-137		
Chromium-51		
Cobalt-57		
Cobalt-58		
Cobalt-60		
Gross α		
Gross β		
Iron-59		
Manganese-54		
Lead-212		
Neptunium-237		
Niobium-95		
Potassium-40		
Plutonium-238		
Plutonium-239/240		
Ruthenium-106		
Thallium-208		
Sodium-22		
Strontium-90		
Technetium-99		
Thorium-228		
Thorium-230		

Table B.7 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Thorium-232		
Uranium-234		
Uranium-235		
Uranium-238		
Zinc-65		
Zirconium-95		

^aParameters which were never reported as less than the quantitation limit have no statistics for minimum or maximum quantitation limit

Table B.8. Groundwater sample intervals for groundwater collected during BCV OU 1 RIFA

Sample ID	Sample interval (ft bgs)
<i>BYBY</i>	
Y01616	16 to 18
Y02616	30 to 32
Y03616	33.5 to 35.5
Y04616	7 to 9
Y05616	18 to 20
Y06616	12.5 to 15.5
Y09616	9 to 12
<i>OLF</i>	
L01611	12 to 14
<i>BCBG</i>	
B01611	16 to 18
B02611	30 to 32
B03611	18 to 22
B04611	8 to 13
B05611	23 to 26.5
B12611	30 to 34
B13611	10 to 14.5

Table B.9. Technical sampling procedures used during BCV OU 4 RIFA

Procedure number	Subject activity	Issue date	Revision
<i>Groundwater sampling</i>			
ESP-302-1	Water level measurements using a water level indicator	9/26/94	0
ESP-302-2	Guidelines for well pumping	9/26/94	0
ESP-302-3	Using a bailer	9/26/94	0
ESP-302-4	Using a gas-driven piston pump	9/26/94	0
<i>Surface water sampling</i>			
ESP-301-1	Water sampling with a dipper	9/26/94	0

Table B.10. List of minor changes to the BCV OU 4 RIFA

FCO NO.	DESCRIPTION OF CHANGE
OU4-001	Modifications to Appendix C (Environmental Restoration Program Site Specific Health and Safety Plan) of the Remedial Investigation Work Plan (RIWP) for Bear Creek Valley Operable Unit 4 (BCV OU4, DOE/OR/01-1115&D3). The attached modifications show the revisions to the Hazard Evaluation, Personal Protective Equipment, Training, Monitoring, and spill response aspects of this plan.
OU4-002	Clarify the identities of Site Health and Safety Officer as described in section 10.1 of the Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 4 (DOE/OR/01-1115&D3). The stream water sampling task performed by Y-12 personnel will be performed under the oversight of Y-12 health and safety personnel. In other words, Y-12 will supply an SHSO(s), as needed, for this task. SAIC observers will comply with the requirements of these Y-12 health and safety personnel. For the installation of storm flow tubes performed by SAIC personnel and groundwater sampling performed by Y-12 personnel will be carried out under the direct oversight of SAIC health and safety personnel. Tasks that do not involve any potential for significant hazard (site survey, data downloading, tracer testing) will be performed under general oversight of an SAIC SHSO but the SHSO will not be present at all times. The primary SAIC SHSO will be Gary Seaver. The alternate SAIC SHSOs are Mike Crenshaw and Steve Davis or other suitably trained personnel.
OU4-003	Modify section 10.7 of the Remedial Investigation Work Plan for Bear Creek Valley Operable Unit 4 (DOE/OR/01-1115&D3) to require that on-site workers use a buddy system.
OU4-004	Replace the use of ESP-800 Packaging Environmental Samples for Transportation throughout the BCV OU4 Work Plan with ER/C-P2302 Sample Classifying, Packaging, Marking Labeling, and Shipping for Analysis through the K-25 and Y-12 Environmental Restoration Programs.
OU4-005	Change Field Blank Frequency to: [Surface Water - one per lot number of ASTM water, one rinsate water at the start, middle, and end of sampling] [Groundwater - one per lot number of ASTM water, one per event of rinsate water] [Bromide - one per twenty ASTM water]. Change Equipment Rinsate Blank Frequency to: [Surface water - one for grab sample equipment per twenty samples, one for filtration equipment per twenty samples, six initially from the dedicated samplers, two at the midpoint from the dedicated samplers, two at the end from the dedicated samplers.] [Groundwater - one per twenty samples per event, two per event from the filtration equipment.
OU4-006	Change the metals CRDL's to the following: Silver from 3 ppb to 4 ppb Thallium from 2 ppb to 3 ppb Lead from 2 ppb to 3 ppb Arsenic from 2 ppb to 3 ppb
OU4-007	The workplan states a 2 ppb detection limit for selenium. Change this to 3 ppb.

Table B.10. (continued)

FCO NO.	DESCRIPTION OF CHANGE
OU4-008	Modification to Appendix C (Environmental Restoration Program Site Specific Health and Safety Plan) of the Remedial Investigation Work Plan (RIWP) for Bear Creek Valley Operable Unit 4 (BCV OU4, DOE/OR/01-1115 & D3). Task 7.2 will also include intrusive in addition to non-intrusive types of work. Intrusive work will be associated with the installation and removal of stormflow tubes.
OU4-009	Modify the Bear Creek Valley OU4 Work Plan to reduce groundwater sampling from four quarters to two events. The list of wells remains the same.
OU4-010	Modification of the Sampling Plan in BCV OU4 RI Work Plan (DOE/OR/01-1115 & D3). Add a surface water sampling point in the uppermost reach of Bear Creek near the S-3 Ponds, at a new BCK 12.5. The sampling type at this location will be a grab sample, and sampling will be carried out twice, once at high flow and once at low flow conditions. Surface water will be analyzed for the same parameters as surface water samples are being analyzed for in the current plan.
OU4-011	Change to NCR reporting process as contained in section 8 of the RIWP: When an NCR is recognized and documented on the NCR form, that form will be submitted to the SAIC NCR Coordinator and the Y-12 ER BCV OU4 Project Management and QAS will be notified. The NCR Coordinator will enter the information into the NCR database.
OU4-012	Substitute GW-651 for GW-118 as a monitoring point for the pulse test being performed at the Burial Grounds.
OU4-013	Substitute GW-629 for GW-117 as a monitoring point for the pulse test to be performed at the Burial Grounds.
OU4-014	Bear Creek Valley OU4 RIFA Work Plan states that handling of waste will be described in procedure ESP-1000. Procedure ESP-1000 is not the most current procedure, and will be replaced by ESP-105.
OU4-015	Variances during the field sampling program from approved operating procedures in the BCV OU4 RI Work Plan, SAP, QAPJP, or H&S plan will be documented through filing of a "Field Change Order (FCO)" according to procedure ER/C-P1719 "Controlling and Documenting Field Changes to Approved Field Sampling Plans."
OU4-016	Replace procedure TP-307-8 (LWA 1990) with ESP-307-1, ESP-307-2, and ESP-307-8.
OU4-017	In the BCV OU4, RIFA Work Plan, it states that ground water sampling will follow procedures ESP-302-3 and ESP-302-4. These procedures will be replaced by ESP-302-5.
OU4-018	Allow for the taking of surface water VOA grab samples by immersing the sample container in the stream. A project specific procedure for this sampling procedure will be generated, and will serve as an alternate method to ESP-301-1, "Water Sampling Using a Dipper."

Table B.10. (continued)

FCO NO.	DESCRIPTION OF CHANGE
OU4-019	Add procedure number ESP-308-1, "Composite Procedures" to the BCV OU4 RIFA Procedure Manual.
OU4-020	Change the well list for the Oil Landfarm Pulse Test. The Work Plan well list was GW-073, GW-097, GW-098, GW-120, GW-225, GW-226, GW-229, GW-368, GW-369 and GW-601. The revised list of wells is as follows: GW-537, GW-086, GW-085, GW-076, GW-225, GW-226, GW-725, GW-736, GW-346 and GW-526.
OU4-021	Metals analytes originally to be analyzed by GFAA will now be analyzed by ICP Trace per APO approval of this methodology. quantitation limit goals will not change.
OU4-022	Change mercury quantitation limit goal from 0.1 µg/l to 0.2 µg/l.
OU4-023	Change procedure number BCV OU4-353, Section 6.3: During calibration of pressure transducer, the deeper set point as outlined in 6.3.6 should be performed before the shallower set point outlined in 6.3.5. Also, it is not necessary for transducer to equilibrate for a minimum of 5 minutes. The transducers equilibrate in less than 2 minutes. Section 6.4.14: Delete this section. Once the sensors have been installed, it is impossible to cap the well. These changes are being incorporated in Revision 1 of this procedure.
OU4-024	Procedure number BCV OU4-353, Section 6.4.12 - For installations at monitoring wells, excess cable will be coiled and hung from an approximately 1 ft length of PVC pipe horizontally secured to the top of the well casing. The data logger will be located on the concrete pad that supports the casing stick-up. If the data logger is placed more than 10 ft from the well the sensors are installed in, but within the area secured by the well's protective posts, the cables will be run through PVC pipe for the length between the data logger and the well head. If the data logger must be installed outside the area secured by the protective posts, the cable will be buried in a 6 in. trench and flags placed along trench pathway.
OU4-025	Modifications to section 7.4.5.3, Ecological data, on page 7-26 and Table 7.5 on page 7-36 of the Remedial Investigation Work Plan (RIWP) for Bear Creek Valley Operable Unit 4 (BCV OU4, DOE/OR/01-1115&D3). Water and fish samples from the Biological Monitoring and Abatement Program (BMAP) reference site on Hinds Creek will be collected to provide supplemental ecological data for the risk assessment. Water samples will be collected for two toxicity tests and fish samples will be collected during one sampling event.
OU4-026	Modification to Table 7.4 (Numbers of samples and quality control for water quality samples) on page 7-26 of the Remedial Investigation Work Plan (RIWP) for Bear Creek Valley Operable Unit 4 (BCV OU4, DOE/OR/01-1115&D3). Modifications include the elimination of field blanks and equipment rinsate blanks. The QC requirements for the toxicity testing will include one field split sample from a randomly selected test site for each of the two test periods.

Table B.10. (continued)

FCO NO.	DESCRIPTION OF CHANGE
OU4-027	A duplicate ISCO water sampler at NT-3 did not collect enough water for a duplicate sample that was scheduled to be taken at that site. There was sufficient water collected by the dedicated sampler at the site to provide sample volume for both the regular sample and the duplicate. The duplicate sample was, therefore, a split sample. The sampling event occurred on 7/19/94. (After review this FCO was deemed unnecessary and was cancelled)
OU4-028	Modify the Bear Creek Valley OU4 Field Quality Assurance Project Plan Section 8.4 Sample Custody Procedures, paragraph 3, last sentence and the Laboratory Quality Assurance Project Plan Section 9.4, first paragraph, last sentence to read: "The BCV OU 4 project manager will be responsible for ensuring that the original or a copy of the chain-of-custody form is submitted to the Document Management Center."
OU4-029	Revise the list of wells to be monitored at the S-3 Pond Site for water level elevation, temperature, and conductivity. The wells to be monitored will be: GW-101, GW-122, GW-124, GW-345, GW-526, GW-615, GW-616.
OU4-030	Change to required field apparel worn by SAIC field personnel involved in surface water sampling. This change will allow wearing of shorts or similar hot weather clothing as an option to company issued coveralls. Field personnel handling preservatives (acids and bases) must wear a chemical resistant apron in addition to splash prevention PPE originally specified in the project Health and Safety Plan.
OU4-031	Stormflow tubes will be downloaded and calibrated on a biweekly schedule as opposed to weekly. In the week between the downloads, battery levels and instrument checks will be performed to confirm datalogger operation.
OU4-032	Table 7.4 (Numbers of samples and quality control for water quality samples) on page 7-26 of the Remedial Investigation Work Plan (RIWP) for Bear Creek Valley Operable Unit 4 (BCV OU4, DOE/OR/01-1115&D3) indicates numbers of environmental and quality control samples for the following categories: Surface water/springs, Groundwater, Groundwater Tracer Test, and Ecological. (Continued on page 2).

Table B.10. (continued)

FCO NO.	DESCRIPTION OF CHANGE
OU4-033	<p>Change procedure number BCV OU4-353 Sections 1.0 and 2.0: The Hydrolab H20® G Multiprobe which is used on BCV OU4 to measure and record specific conductance (conductivity) and temperature of groundwater in wells can also be used to record these parameters in surface water bodies such as streams, springs, and ponds. There is no change to the procedure with the exception of the following: In Section 6.4 where there is a reference to a well, add "or stream, spring, or pond sample site". Section 6.4.4 and 6.4.9 do not apply. Add to 6.4.10 "If installing a probe into a stream, pond or spring, locate the probe such that the sensor is covered with water."</p>
OU4-034	<p>Section 7.4.5.1 (p. 7-22) of the project work plan calls for samples exceeding MCLs to be analyzed for radiochemical isotopes including Strontium-90. Identified samples will be analyzed for Total Strontium instead of Strontium-90.</p>

Table B.11. List of activities completed for BCV OU 4 RIFA

Group	Media	Analysis type	Sample type	Stations	Comments
1	Surface water	Chemistry	Flow proportional composite	NT-2, NT-3, NT-4, NT-5, NT-6, NT-7, NT-8, BCK 12.36, BCK 9.4, SS-1, SS-4, SS-5, SS-6, SS-8	Filtered and unfiltered inorganics, volatile organics, anions, and filtered and unfiltered radiological. See Table B.12 for a detailed list of analytes.
2	Surface water	Chemistry	Grab	BCK-S3, SS-6b	Filtered and unfiltered inorganics, volatile organics, anions, and filtered and unfiltered radiological. See Table B.12 for a detailed list of analytes.
3	Surface water	Chemistry	Continuous	NT-2, NT-3, SS-6	Conductivity and temperature.
4	Surface water	Chemistry	Grab	NT-2	Conductivity profile.
5	Surface water	Flow	Continuous	NT-2, NT-3, NT-4, NT-5, NT-6, NT-7, NT-8, BCK 12.36, BCK 9.4, SS-1, SS-4, SS-5, SS-6	See Table B.13 for a list of monitoring periods.
6	Stormflow	Water level	Continuous	SFT-1, SFT-2, SFT-3, SFT-4, SFT-5, SFT-6	Monitored between March and October 1994.
7	Groundwater	Chemistry	Continuous	GW-045, GW-053, GW-094, GW-095, GW-126, GW-624, GW-626, GW-629, GW-651.	Conductivity and temperature. Burial Grounds group of wells. See Table B.28 for a list of monitoring periods.
8	Groundwater	Water level	Continuous	GW-045, GW-053, GW-094, GW-095, GW-126, GW-624, GW-626, GW-629, GW-651.	Burial Grounds group of wells. See Table B.28 for a list of monitoring periods.

Table B.11 continued

Group	Media	Analysis type	Sample type	Stations	Comments
9	Groundwater	Chemistry	Continuous	GW-076, GW-085, GW-086, GW-227, GW-228, GW-346, GW-526, GW-537, GW-725, GW-736.	Conductivity and temperature. Oil Landfarm group of wells. See Table B.28 for a list of monitoring periods.
10	Groundwater	Water level	Continuous	GW-076, GW-085, GW-086, GW-227, GW-228, GW-346, GW-526, GW-537, GW-725, GW-736.	Oil Landfarm group of wells. See Table B.28 for a list of monitoring periods.
11	Groundwater	Chemistry	Continuous	GW-101, GW-122, GW-124, GW-345, GW-526, GW-615, GW-616.	Conductivity and temperature. S-3 Site group of wells. See Table B.28 for a list of monitoring periods.
12	Groundwater	Water level	Continuous	GW-101, GW-122, GW-124, GW-345, GW-526, GW-615, GW-616.	S-3 Site group of wells. See Table B.28 for a list of monitoring periods.
13	Groundwater	Water level	Continuous	GW-710, GW-711, GW-712, GW-714.	Western Picket group of wells. See Table B.28 for a list of monitoring periods.

Table B.12. List of analytes and reported quantitation limits for surface water in BCV OU 4

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Anions (mg/l)</i>		
Chloride	1.00	1.00
Fluoride	0.10	0.10
Nitrate/Nitrite (NO ₃ /NO ₂ -N)	0.10	0.10
Sulfate	5.00	20.00
<i>Inorganics (dissolved, µg/l)</i>		
Aluminum	16.50	235.00
Antimony	1.30	2.90
Arsenic	1.50	2.60
Barium	49.10	173.00
Beryllium	0.30	0.80
Cadmium	0.80	11.80
Calcium		
Chromium	1.70	7.80
Cobalt	2.10	7.20
Copper	2.10	14.80
Iron	4.80	260.00
Lead	0.70	4.00
Lithium	1.10	8.70
Magnesium		
Manganese	0.90	13.20
Mercury	0.10	0.20
Molybdenum	3.60	3.60
Nickel	2.80	21.30
Selenium	2.10	5.20
Silver	2.40	4.10
Sodium	1450.00	8020.00
Thallium	1.70	3.70
Tin	13.30	13.30
Vanadium	2.10	17.10
Zinc	2.00	19.70
<i>Inorganics (total, µg/l)</i>		
Aluminum	17.00	700.00

Table B.12 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Antimony	1.30	1.80
Arsenic	1.50	2.60
Barium	118.00	125.00
Beryllium	0.30	0.61
Cadmium	0.80	8.90
Calcium		
Chromium	1.70	11.40
Cobalt	2.10	8.40
Copper	2.10	26.30
Cyanide	10.00	10.00
Iron	6.30	357.00
Lead	1.00	1.50
Lithium	1.10	1.50
Magnesium		
Manganese	3.80	56.70
Mercury	0.10	0.20
Molybdenum	3.60	7.80
Nickel	2.80	34.40
Potassium	4910.00	4910.00
Selenium	2.10	3.30
Silver	2.40	4.10
Sodium	2010.00	8030.00
Thallium	1.70	3.30
Tin	13.30	13.30
Vanadium	2.10	18.60
Zinc	3.60	58.00
<i>Volatile Organics (µg/l)</i>		
1,1,1-Trichloroethane	5.00	5.00
1,1,2,2-Tetrachloroethane	5.00	10.00
1,1,2-Trichloroethane	5.00	10.00
1,1-Dichloroethane	5.00	5.00
1,1-Dichloroethene	5.00	5.00
1,2-Dichlorobenzene	5.00	10.00

Table B.12 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
1,2-Dichloroethane	5.00	10.00
1,2-Dichloroethene	5.00	5.00
1,2-Dichloropropane	5.00	10.00
1,3-Dichlorobenzene	5.00	10.00
1,4-Dichlorobenzene	5.00	10.00
2-Butanone	5.00	10.00
2-Hexanone	5.00	10.00
4-methyl-2-Pentanone	4.00	10.00
Acetone	5.00	41.00
Benzene	5.00	10.00
Bromodichloromethane	5.00	10.00
Bromoform	5.00	10.00
Bromomethane	5.00	10.00
Carbon disulfide	5.00	10.00
Carbon tetrachloride	5.00	10.00
Chlorobenzene	5.00	10.00
Chloroethane	5.00	10.00
Chloroform	5.00	5.00
Chloromethane	5.00	12.00
Dibromochloromethane	5.00	10.00
Ethylbenzene	5.00	10.00
Methylene chloride	3.00	23.00
Styrene	5.00	10.00
Tetrachloroethene	5.00	5.00
Toluene	5.00	10.00
Trichloroethene	5.00	5.00
Trichlorofluoromethane	5.00	10.00
Vinyl chloride	5.00	5.00
Xylene, total	5.00	10.00
cis-1,3-Dichloropropene	5.00	10.00
trans-1,3-Dichloropropene	5.00	10.00

Radionuclides (pCi/l)

Americium-241

Table B.12 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Curium-243		
Curium-244		
Cesium-137		
Plutonium-238		
Plutonium-239/240		
Strontium-90		
Technetium-99		
Thorium-228		
Thorium-230		
Thorium-232		
Uranium-234		
Uranium-235		
Uranium-238		

^aParameters which were never reported as less than the quantitation limit have no statistics for minimum or maximum quantitation limit

**Table B.13. Time periods and the stage to flow conversions
for each surface water site in BCV OU 4**

Site	Monitoring period		Flow measurement method	Flow calculations ^a
	Start	End		
BCK 12.6 ^b	3/29/94	1/30/95	5-ft diameter corrugated pipe	Manning ^c
NT-2	3/22/94	1/30/95	1.5-ft H-flume	$Q(\text{cfs}) = 2.11 \times h^{2.31}$
NT-3	3/22/94	1/30/95	1.0-ft H-flume	$Q(\text{cfs}) = 1.95 \times h^{2.31}$
NT-4	5/31/94	1/30/95	1.0-ft H-flume	$Q(\text{cfs}) = 1.95 \times h^{2.31}$
NT-5	5/19/94	1/30/95	1.5-ft H-flume	$Q(\text{cfs}) = 2.11 \times h^{2.31}$
NT-6	3/22/94	1/30/95	2.0-ft H-flume	$Q(\text{cfs}) = 2.23 \times h^{2.31}$
NT-7	3/29/94	1/30/95	2.0-ft H-flume	$Q(\text{cfs}) = 2.23 \times h^{2.31}$
NT-8	6/2/94	1/30/95	2.0-ft H-flume	$Q(\text{cfs}) = 2.23 \times h^{2.31}$
BCK 9.4	3/22/94	1/30/95	Open channel	Rating curve ^d
SS-1	5/19/94	1/30/95	1.0-ft H-flume	$Q(\text{cfs}) = 1.95 \times h^{2.31}$
SS-4	5/19/94	1/30/95	2.0-ft H-flume	$Q(\text{cfs}) = 2.23 \times h^{2.31}$
SS-5	5/19/94	1/30/95	1.5-ft H-flume	$Q(\text{cfs}) = 2.11 \times h^{2.31}$
SS-6	5/19/94	1/30/95	1.0-ft H-flume	$Q(\text{cfs}) = 1.95 \times h^{2.31}$
SS-8	5/19/94	1/30/95	NA	

^a For H-flumes the stage to flow conversion is an empirical formula supplied by the manufacturer.

^b At this site, flow is through two 5-ft diameter corrugated pipes.

^c Manning equation was used to calculate flow from stage:

$$Q = \frac{1.49 \times A \times R^{2/3} \times S^{1/2}}{n}$$

where:

- Q = the flow,
- A = the cross-sectional area of flow,
- R = the hydraulic radius defined as the ratio of A to the total length of the wetted perimeter (see Fig. B.47),
- S = the slope (0.001),
- n = the Manning roughness coefficient (0.017).

^d The USGS-supplied rating curve for BCK 9.41 was used to convert stage to flow. See Table B.27 for the rating curve.

h - stream stage

cfs - cubic feet/second

**Table B.14. Flow monitoring periods, total flow, and average flow
for the monitoring station at BCK 12.38**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1*	22-MAR-94	12:00	27-MAR-94	13:15	253436.97	1.16	32.89
2	29-MAR-94	10:25	04-APR-94	03:30	241285.65	0.53	15.14
3	05-APR-94	09:20	06-APR-94	14:35	177524.43	2.05	58.16
4	07-APR-94	08:25	10-APR-94	10:35	118874.98	0.45	12.76
5	12-APR-94	16:55	14-APR-94	07:10	112591.01	3.71	105.02
6	16-APR-94	06:05	20-APR-94	05:25	197048.35	0.58	16.40
7	20-APR-94	06:40	22-APR-94	06:20	61170.08	0.36	10.15
8	24-APR-94	05:45	26-APR-94	06:05	48441.85	0.28	7.96
9	20-MAY-94	06:45	24-MAY-94	07:05	42982.92	0.13	3.57
10	26-MAY-94	07:35	31-MAY-94	09:05	48636.82	0.17	4.70
11	03-JUN-94	08:00	07-JUN-94	08:30	41526.31	0.12	3.43
12	14-JUN-94	12:05	16-JUN-94	06:40	4241.20	0.06	1.57
13	16-JUN-94	07:50	21-JUN-94	07:10	49350.90	0.13	3.81
14	23-JUN-94	07:05	26-JUN-94	21:20	40228.64	0.26	7.31
15	03-JUL-94	07:35	07-JUL-94	07:20	14702.48	0.11	3.25
16	07-JUL-94	11:20	12-JUL-94	07:10	10587.53	0.06	1.69
17	15-JUL-94	05:45	19-JUL-94	18:45	56393.01	0.26	7.37
18	08-AUG-94	15:00	11-AUG-94	07:35	22756.93	0.10	2.85
19	29-SEP-94	05:40	04-OCT-94	13:10	35849.39	0.08	2.39
20	21-JAN-95	06:30	24-JAN-95	08:55	57613.82	0.22	6.14
21	27-JAN-95	19:05	28-JAN-95	16:00	60365.13	0.88	24.97

* During this period only the north tunnel was operational. The average flow for the north tunnel was doubled to estimate the average flow for both tunnels

**Table B.15. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-2**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	22-MAR-94	10:10	27-MAR-94	06:05	180294.40	0.43	12.24
2	29-MAR-94	11:00	04-APR-94	06:55	235526.48	0.47	13.24
3	06-APR-94	06:30	06-APR-94	22:20	154557.65	2.71	76.79
4	07-APR-94	10:10	11-APR-94	03:05	330169.67	1.03	29.21
5	12-APR-94	17:20	12-APR-94	22:05	95666.90	5.59	158.44
6	16-APR-94	07:25	20-APR-94	07:30	123039.57	0.36	10.07
7	20-APR-94	07:50	22-APR-94	07:15	30369.47	0.18	5.04
8	24-APR-94	07:00	26-APR-94	06:30	24332.81	0.14	4.03
9	20-MAY-94	07:35	24-MAY-94	07:00	6345.59	0.02	0.52
10	26-MAY-94	07:20	28-MAY-94	14:15	13881.01	0.07	1.99
11	03-JUN-94	08:25	07-JUN-94	07:45	8947.09	0.03	0.74
12	14-JUN-94	11:25	16-JUN-94	09:20	7505.47	0.05	1.29
13	16-JUN-94	09:55	21-JUN-94	06:00	8867.61	0.02	0.60
14	23-JUN-94	06:25	26-JUN-94	13:20	16729.11	0.06	1.67
15	03-JUL-94	07:25	07-JUL-94	08:00	1014.06	0.00	0.08
16	07-JUL-94	08:35	11-JUL-94	13:00	2500.54	0.01	0.20
17	15-JUL-94	06:55	15-JUL-94	19:05	9000.82	0.21	5.82
18	08-AUG-94	16:30	11-AUG-94	07:45	1286.69	0.01	0.16
19	29-SEP-94	07:25	03-OCT-94	08:30	1302.11	0.00	0.11
20	21-JAN-95	08:10	24-JAN-95	06:35	16689.87	0.07	1.86
21	27-JAN-95	08:25	28-JAN-95	13:25	45733.39	0.44	12.41

**Table B.16. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-3**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	22-MAR-94	13:20	27-MAR-94	07:55	142396.62	0.35	9.78
2	29-MAR-94	11:30	02-APR-94	07:10	160015.81	0.48	13.73
3	05-APR-94	09:55	06-APR-94	04:25	58375.01	0.88	24.82
4	07-APR-94	11:15	10-APR-94	10:35	104611.75	0.41	11.54
5	12-APR-94	17:25	13-APR-94	00:35	98120.51	3.80	107.70
6	16-APR-94	07:40	20-APR-94	06:50	170090.48	0.50	14.06
7	20-APR-94	09:40	22-APR-94	08:05	22610.47	0.14	3.83
8	24-APR-94	07:40	26-APR-94	07:20	17405.67	0.10	2.87
9	20-MAY-94	08:50	24-MAY-94	07:45	3927.76	0.01	0.33
10*	26-MAY-94	08:00	31-MAY-94	08:05		0.01	0.28
11*	03-JUN-94	09:40	06-JUN-94	09:00		0.00	0.02
12*	15-JUN-94	08:30	16-JUN-94	09:20		0.05	1.35
13*	16-JUN-94	10:00	21-JUN-94	06:55		0.02	0.71
14	23-JUN-94	05:45	26-JUN-94	18:55	8429.96	0.03	0.78
15	03-JUL-94	07:00	07-JUL-94	07:15	5215.68	0.02	0.43
16	07-JUL-94	08:45	10-JUL-94	11:55	2659.26	0.01	0.28
17	15-JUL-94	06:10	15-JUL-94	19:05	3803.10	0.08	2.32
18	08-AUG-94	15:50	11-AUG-94	07:05	3073.31	0.01	0.38
19*	30-SEP-94	04:40	03-OCT-94	09:15		0.00	0.06
20	21-JAN-95	09:25	24-JAN-95	16:20	32594.57	0.11	3.25
21	27-JAN-95	09:50	28-JAN-95	15:25	42303.46	0.40	11.25

* Flow not recorded electronically. Average flow calculated from field printouts.

**Table B.17. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-4**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	26-MAY-94	08:55	28-MAY-94	06:40		0.02	0.62
2	03-JUN-94	09:55	06-JUN-94	10:05	867.14	0.00	0.09
3	14-JUN-94	13:20	15-JUN-94	15:35	4525.49	0.05	1.36
4	16-JUN-94	10:15	24-JUN-94	11:10	1587.48	0.00	0.11
5	24-JUN-94	11:20	24-JUN-94	20:20	6610.73	0.21	5.83
6	03-JUL-94	10:25	07-JUL-94	12:35	1524.67	0.00	0.14
7	08-JUL-94	01:30	10-JUL-94	10:00	1200.11	0.01	0.17
8	15-JUL-94	08:30	15-JUL-94	19:55	12419.89	0.30	8.56
9	08-AUG-94	18:15	11-AUG-94	15:10	786.36	0.00	0.09
10*	29-SEP-94	9:15	03-OCT-94	09:45		0.00	0.05
11	21-JAN-95	10:20	24-JAN-95	10:05	13403.69	0.05	1.47
12	27-JAN-95	10:10	28-JAN-95	09:35	40738.75	0.48	13.69

* Flow not recorded electronically. Average flow calculated from field printouts.

**Table B.18. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-5**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	20-MAY-94	07:30	24-MAY-94	07:15	3557.82	0.01	0.29
2	26-MAY-94	06:55	28-MAY-94	06:35	3731.71	0.02	0.62
3	03-JUN-94	08:05	07-JUN-94	08:25	1831.58	0.01	0.15
4	14-JUN-94	11:55	16-JUN-94	11:00	9769.09	0.06	1.63
5	16-JUN-94	11:40	21-JUN-94	10:25	7262.76	0.02	0.48
6	23-JUN-94	06:00	26-JUN-94	12:55	16424.33	0.06	1.64
7	03-JUL-94	08:05	07-JUL-94	09:30	3258.30	0.01	0.26
8	07-JUL-94	10:35	11-JUL-94	21:10	4381.96	0.01	0.32
9	15-JUL-94	06:40	15-JUL-94	18:00	9515.60	0.23	6.60
10	08-AUG-94	16:40	11-AUG-94	08:00	2526.17	0.01	0.31
11	29-SEP-94	07:30	03-OCT-94	14:35	2846.25	0.01	0.22
12	21-JAN-95	09:15	25-JAN-95	15:05	36550.13	0.10	2.82
13	27-JAN-95	19:20	28-JAN-95	14:25	38180.64	0.56	15.74

**Table B.19. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-6**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	24-MAR-94	10:05	27-MAR-94	05:45	111672.11	0.46	12.98
2	29-MAR-94	14:00	03-APR-94	23:30	116192.13	0.25	7.06
3	05-APR-94	13:50	05-APR-94	23:40	11702.88	0.33	9.36
4	07-APR-94	13:20	10-APR-94	11:35	52369.41	0.21	5.86
5	12-APR-94	17:35	12-APR-94	22:15	22592.23	1.34	38.08
6	16-APR-94	08:00	20-APR-94	08:45	81509.69	0.23	6.63
7	20-APR-94	12:00	21-APR-94	06:00	2026.61	0.03	0.89
8	24-APR-94	07:45	26-APR-94	07:20	3245.71	0.02	0.54
9*	20-MAY-94	10:55	24-MAY-94	09:25		0.00	0.07
10*	26-MAY-94	09:15	26-MAY-94	19:00		0.07	2.09
11*	03-JUN-94	11:45	06-JUN-94	09:30		0.00	0.00
12	14-JUN-94	13:25	15-JUN-94	16:15	1743.89	0.02	0.51
13	16-JUN-94	13:00	20-JUN-94	09:15	606.37	0.00	0.05
14	23-JUN-94	07:45	26-JUN-94	14:15	9753.97	0.03	0.98
15	03-JUL-94	09:45	07-JUL-94	10:20	637.01	0.00	0.05
16*	07-JUL-94	11:05	11-JUL-94	00:50		0.00	0.08
17*	15-JUL-94	08:10	15-JUL-94	18:45		0.12	3.33
18	08-AUG-94	18:05	11-AUG-94	09:30	290.93	0.00	0.04
19	29-SEP-94	11:15	03-OCT-94	13:10	215.92	0.00	0.02
20	21-JAN-95	10:55	24-JAN-95	01:35	8943.70	0.04	1.12
21	27-JAN-95	10:30	28-JAN-95	11:25	39609.71	0.44	12.51

* Flow not recorded electronically. Average flow calculated from field printouts.

**Table B.20. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-7**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1*	22-MAR-94	17:15	27-MAR-94	04:15		0.70	19.77
2	01-APR-94	08:20	05-APR-94	13:05	39762.11	0.11	3.10
3	05-APR-94	15:15	05-APR-94	23:10	34411.20	1.19	33.84
4	07-APR-94	13:55	10-APR-94	11:35	38381.72	0.15	4.33
5	12-APR-94	17:45	12-APR-94	23:45	45241.64	3.51	99.32
6	16-APR-94	08:15	20-APR-94	08:05	76150.63	0.22	6.25
7	20-APR-94	10:30	22-APR-94	09:50	6340.44	0.04	1.05
8	24-APR-94	07:50	26-APR-94	09:50	3218.91	0.02	0.51
9	20-MAY-94	09:10	24-MAY-94	10:55	2492.08	0.01	0.20
10*	26-MAY-94	08:45	26-MAY-94	17:50		0.22	6.35
11	03-JUN-94	09:35	07-JUN-94	12:35	1117.53	0.00	0.09
12	14-JUN-94	13:40	15-JUN-94	14:10	1538.14	0.02	0.49
13	16-JUN-94	13:30	21-JUN-94	09:50	2826.10	0.01	0.19
14	23-JUN-94	07:50	24-JUN-94	17:20	4487.48	0.04	1.05
15*	03-JUL-94	10:05	07-JUL-94	10:40		0.00	0.00
16	07-JUL-94	11:15	11-JUL-94	13:25	4272.96	0.01	0.34
17	15-JUL-94	08:45	15-JUL-94	19:05	20452.27	0.55	15.57
18*	08-AUG-94	18:45	11-AUG-94	10:25		0.00	0.00
19*	29-SEP-94	09:05	03-OCT-94	12:05		0.00	0.00
20	21-JAN-95	10:05	24-JAN-95	09:50	7292.24	0.03	0.80
21	27-JAN-95	10:00	28-JAN-95	07:20	27016.95	0.35	9.96

* Flow not recorded electronically. Average flow calculated from field printouts.

**Table B.21. Flow monitoring periods, total flow, and average flow
for the monitoring station at NT-8**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1*	26-MAY-94	09:00	Timed - 40 min				
2	03-JUN-94	08:45	07-JUN-94	11:55	4745.58	0.01	0.38
3	14-JUN-94	12:55	16-JUN-94	15:40	3408.42	0.02	0.53
4	16-JUN-94	16:25	21-JUN-94	11:10	4864.57	0.01	0.33
5	23-JUN-94	07:05	24-JUN-94	18:25	8853.25	0.07	1.97
6*	03-JUL-94	09:30	07-JUL-94	12:55			
7*	07-JUL-94	13:30	11-JUL-94	19:30			
8*	15-JUL-94	07:55	16-JUL-94	18:35			
9	08-AUG-94	17:55	11-AUG-94	11:00	557.16	0.00	0.09
10	29-SEP-94	07:40	03-OCT-94	10:55	503.89	0.00	0.07
11	21-JAN-95	09:25	24-JAN-95	12:05	27724.78	0.10	2.92
12	27-JAN-95	09:15	28-JAN-95	06:55	27013.97	0.35	9.81

* Flowmeter malfunction resulted in no flow record for this time period

**Table B.22. Flow monitoring periods, total flow, and average flow
for the monitoring station at BCK 9.47**

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	23-MAR-94	16:15	27-MAR-94	05:05	1765423.56	5.78	163.71
2	29-MAR-94	16:15	31-MAR-94	08:30	1215668.05	8.39	237.60
3	31-MAR-94	09:15	03-APR-94	14:45	1251661.04	4.49	127.05
4	05-APR-94	15:55	06-APR-94	00:40	567102.64	18.00	509.85
5	07-APR-94	14:35	10-APR-94	11:15	987316.38	3.99	113.11
6	12-APR-94	14:05	12-APR-94	22:30	2369073.41	77.42	2192.55
7	16-APR-94	06:45	19-APR-94	19:45	2267823.13	7.41	209.88
8	20-APR-94	13:00	22-APR-94	10:05	350530.77	2.16	61.16
9	24-APR-94	08:05	26-APR-94	10:25	246698.33	1.36	38.56
10	20-MAY-94	09:10	25-MAY-94	07:15	112261.45	0.26	7.48
11	26-MAY-94	09:20	31-MAY-94	06:55	126110.03	0.30	8.44
12	03-JUN-94	09:15	06-JUN-94	08:45	46951.82	0.18	5.17
13*	15-JUN-94	12:10	16-JUN-94	16:35			
14	16-JUN-94	17:10	20-JUN-94	06:35	42128.92	0.25	7.05
15	23-JUN-94	07:55	26-JUN-94	20:35	380563.23	1.25	35.36
16	03-JUL-94	10:15	07-JUL-94	13:35	80121.76	0.22	6.35
17	07-JUL-94	15:00	11-JUL-94	17:25	88519.77	0.25	7.07
18	15-JUL-94	08:25	15-JUL-94	21:15	178234.89	3.86	109.26
19*	08-AUG-94	18:45	11-AUG-94	12:30			
20	29-SEP-94	08:45	03-OCT-94	13:40	63262.05	0.17	4.93
21	21-JAN-95	10:25	24-JAN-95	12:20	98860.27	0.54	15.25
22	27-JAN-95	09:40	28-JAN-95	22:10	688576.14	5.24	148.41

* Flowmeter malfunction resulted in no flow record for this time period

Table B.23. Flow monitoring periods, total flow, and average flow for the monitoring station at SS-1

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	20-MAY-94	06:20	24-MAY-94	05:20	2587.11	0.01	0.21
2	26-MAY-94	06:30	30-MAY-94	23:35	2391.10	0.01	0.17
3	03-JUN-94	07:15	07-JUN-94	06:35	1095.59	0.00	0.09
4	14-JUN-94	10:15	16-JUN-94	08:00	1112.95	0.01	0.19
5	16-JUN-94	08:30	21-JUN-94	04:25	2498.32	0.01	0.17
6	23-JUN-94	05:15	26-JUN-94	19:55	4684.54	0.02	0.43
7	03-JUL-94	05:50	07-JUL-94	06:40	3023.18	0.01	0.25
8	07-JUL-94	07:40	12-JUL-94	04:20	2126.20	0.01	0.14
9	15-JUL-94	05:50	16-JUL-94	01:25	1583.03	0.02	0.64
10	08-AUG-94	15:20	11-AUG-94	06:35	1152.95	0.01	0.14
11	29-SEP-94	06:15	03-OCT-94	03:00	638.63	0.00	0.05
12	21-JAN-95	07:00	24-JAN-95	06:45	5152.37	0.02	0.56
13	27-JAN-95	07:05	29-JAN-95	01:30	4910.98	0.03	0.91

Table B.24. Flow monitoring periods, total flow, and average flow for the monitoring station at SS-4

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	20-MAY-94	07:45	24-MAY-94	07:40	62033.50	0.18	5.09
2	26-MAY-94	07:25	31-MAY-94	00:35	62377.25	0.15	4.34
3	03-JUN-94	08:15	07-JUN-94	08:50	45364.00	0.13	3.69
4	14-JUN-94	12:10	16-JUN-94	11:50	33095.95	0.19	5.46
5	16-JUN-94	12:35	21-JUN-94	07:30	75927.90	0.18	5.20
6	23-JUN-94	06:25	27-JUN-94	10:25	82996.93	0.23	6.53
7	03-JUL-94	08:35	07-JUL-94	09:45	64137.49	0.18	5.19
8	07-JUL-94	10:35	12-JUL-94	07:35	64468.59	0.15	4.33
9	15-JUL-94	07:05	16-JUL-94	19:10	33620.77	0.26	7.33
10	08-AUG-94	16:45	11-AUG-94	03:15	31376.52	0.15	4.22
11	29-SEP-94	09:25	03-OCT-94	08:50	32001.93	0.09	2.64
12	21-JAN-95	08:45	24-JAN-95	09:05	93191.22	0.36	10.14
13	27-JAN-95	08:45	30-JAN-95	05:40	81838.63	0.33	9.34

Table B.25. Flow monitoring periods, total flow, and average flow for the monitoring station SS-5

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	20-MAY-94	08:35	24-MAY-94	11:00	100482.64	0.28	8.03
2	26-MAY-94	08:25	31-MAY-94	13:00	106123.63	0.24	6.71
3	03-JUN-94	09:00	07-JUN-94	12:45	62245.43	0.17	4.91
4*	14-JUN-94	14:00	16-JUN-94	15:00		0.30	8.42
5*	16-JUN-94	15:40	21-JUN-94	10:05		0.24	6.81
6	23-JUN-94	07:25	26-JUN-94	21:00	120253.08	0.39	11.05
7	03-JUL-94	09:55	07-JUL-94	13:05	79003.76	0.22	6.27
8	07-JUL-94	13:55	12-JUL-94	11:15	77770.33	0.18	5.21
9	15-JUL-94	08:05	16-JUL-94	14:15	36998.24	0.34	9.65
10	08-AUG-94	18:20	11-AUG-94	11:50	50204.00	0.21	6.03
11	29-SEP-94	08:20	03-OCT-94	11:55	65654.59	0.18	5.19
12	21-JAN-95	09:45	24-JAN-95	12:40	217218.80	0.81	22.81
13	27-JAN-95	10:10	29-JAN-95	10:35	146734.43	0.84	23.84

* Flow not recorded electronically. Average flow calculated from field printouts.

Table B.26. Flow monitoring periods, total flow, and average flow for the monitoring station at SS-6

Sample #	Start Date	Start Time	End Date	End Time	Total Flow (cf)	Average Flow (cfs)	Average Flow (L/s)
1	20-MAY-94	09:10	25-MAY-94	07:15	15990.89	0.04	1.07
2*	26-MAY-94	09:20	31-MAY-94	06:45		0.04	1.22
3	03-JUN-94	09:20	06-JUN-94	08:45	5106.53	0.02	0.56
4*	15-JUN-94	14:10	16-JUN-94	17:25		0.03	0.77
5*	16-JUN-94	17:10	20-JUN-94	06:30		0.02	0.68
6	23-JUN-94	09:55	26-JUN-94	22:35	5147.79	0.03	0.88
7	03-JUL-94	10:15	07-JUL-94	13:30	3659.84	0.01	0.29
8	07-JUL-94	15:05	11-JUL-94	17:25	2498.64	0.01	0.21
9	15-JUL-94	08:25	15-JUL-94	21:15	1692.93	0.04	1.04
10	08-AUG-94	18:45	11-AUG-94	12:35	357.52	0.00	0.05
11*	29-SEP-94	08:45	03-OCT-94	13:35		0.00	0.00
12	21-JAN-95	10:25	24-JAN-95	12:20	75874.48	0.29	8.08
13	27-JAN-95	09:40	28-JAN-95	22:10	31216.19	0.24	6.73

* Flow not recorded electronically. Average flow calculated from field printouts.

Table B.27. Rating curve for Bear Creek at BCK 9.47

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
0.0	0.000	2.6	101.6
0.85	0.155	2.7	114.8
0.87	0.171	2.8	129.1
0.9	0.177	2.9	144.7
1.0	0.285	3.0	161.5
1.1	0.98	3.1	179.6
1.2	2.16	3.2	199.0
1.3	4.43	3.3	219.9
1.4	7.40	3.4	242.2
1.5	11.12	3.5	266.0
1.6	15.72	3.6	291.5
1.7	20.90	3.7	318.5
1.8	26.99	3.8	347.2
1.9	34.37	3.9	377.7
2.0	42.05	4.0	410.0
2.1	49.61	4.1	442.5
2.2	58.07	4.2	476.7
2.3	67.50	4.3	512.7
2.4	77.95	4.4	550.0
2.5	89.45	4.5	586.0

**Table B.28. List of monitoring wells and monitoring periods
for BCV OU 4 RIFA head monitoring activities**

Well	Depth (ft bgs)	Formation	Start monitoring	End monitoring	Pressure head measurement	K/T ^a measurement
<i>BCBG</i>						
GW-045	15.2	Cn	3/15/94	4/18/95	X	X
GW-053	39.7	Cm	3/15/94	4/18/95	X	X
GW-094	131	Cm	3/14/94	4/18/95	X	X
GW-095	156	Cm	3/15/94	4/18/95	X	X
GW-126	105	Cn	3/14/94	4/18/95	X	X
GW-624	27.2	Cn	3/15/94	4/18/95	X	X
GW-626	78	Cn	3/19/94	4/18/95	X	X
GW-629	262.3	Cn	3/14/94	4/18/95	X	X
GW-651	52	Cm	3/14/94	4/18/95	X	X
<i>OLF</i>						
GW-076	81	Cn	4/28/94	6/2/94	X	X
GW-085	62	Cn	5/3/94	6/1/94	X	
GW-086	33.5	Cn	5/3/94	6/1/94	X	X
GW-227	30	Cm	4/28/94	5/30/94	X	X
GW-228	80	Cm	4/27/94	5/29/94	X	X
GW-346	65	Cn	4/29/94	6/3/94	X	X
GW-526	101	Cn	4/28/94	6/2/94	X	X
GW-537	24.5	Cn	5/3/94	5/30/94	X	X
GW-725	132.5	Cm	5/2/94	6/3/94	X	X
GW-736	102	Cm	5/2/94	6/2/94	X	X
<i>S-3 Site Group</i>						
GW-101	17.5	Cn	7/18/94	8/4/94	X	X
GW-122	92	Cm	7/8/94	8/4/94	X	X
GW-124	100	Cm	7/5/94	8/4/94	X	X
GW-345	26	Cn	7/8/94	8/4/94	X	X
GW-526	101	Cn	7/8/94	8/4/94	X	X

Table B.28 continued

Well	Depth (ft bgs)	Formation	Start monitoring	End monitoring	Pressure head measurement	K/T ^a measurement
GW-615	222	Cn	7/8/94	8/4/94	X	X
GW-616	219	Cn	7/8/94	8/4/94	X	X
<i>Western Picket</i>						
GW-710	539	Cm	11/1/94	1/4/95	X	
GW-711	616	Cm	11/1/94	1/4/95	X	
GW-712	451	Cm	11/1/94	1/4/95	X	
GW-713	305	Cm	11/1/94	1/4/95	X	
GW-714	113	Cm	11/3/94	1/4/95	X	
GW-715	75	Cm	11/3/94	1/4/95	X	

^a Indicates that water conductivity and temperature were monitored.

Cn - Nolichucky Shale

Cm - Maynardville Limestone

bgs - below ground surface

Table B.29. List of minor changes to the BCV FPSS field activities

FCO NO.	DATE ISSUED	DESCRIPTION OF CHANGE
BCVFPSS-001	3/27/95	Change (PPE requirement) for shoes from steel-toe boots to "Filed Boots" in Bear Creek Valley Flood Plain Soil Sampling Health and Safety Plan for field team members.
BCVFPSS-002	3/28/95	Add the use of Procedure No. ESP-900, Cleaning and Decontaminating sample containers and sampling devices, to the BCV FPSS SAP in Section 4, Table 4.1. In addition, in Attachment 2 of the procedure in Section II.4 delete the requirement to have the equipment air dry for 24 hours.
FPSS-003	3/28/95	Delete the requirement to grout the upper 4 ft of each borehole in Table 9.1 under waste stream.
FPSS-004	4/3/95	1. Pages 8 - 14 of Section 8 in the Health & Safety Plan - Section 8.1.8 Emergency Preparedness - change the location of nearest plant phone from the green trailer at SL-1 to west end guard portal at Bear Creek Rd. 2. Change Table 8.3 from respiratory protection for site visitor from "V" to "X". 3. Clarify Section 8.1.5 on page 8-8 for admin contracts - chemicals will be brought on site within their original containers, however some chemicals may need to be in an aliquot type container. These containers will be labeled using the Hazardous Materials Identification Diamond.
FPSS-005	4/3/95	Add to Section 4.1 page 4-1 2nd paragraph - soil sampling will be conducted using a 1.25 in. or 3-in. manual sampler.
FPSS-006	4/11/95	When transporting environmental samples collected on Bear Creek to the Y-12 laboratory for analysis on the BCV FPSS Project, it will not be necessary to line the cooler with vermiculite, tape the cooler shut with strapping tape and custody seals, or to have Y-12 survey technicians conduct radiological surveys to green tag the cooler and sample as stated in procedure no. ER/C-P2302 IAD, Rev. 0.
FPSS-007	4/21/95	Change the screening level criteria for PCB's from 0.05 mg/kg (ppm) to 0.5 ppm (mg/kg) throughout the BCV Floodplain Sampling and Analysis Plan.
FPSS-008	5/8/95	Delete isopropanol rinse from decontamination procedure for the Ponar dredge.
FPSS-009	5/4/95	Modifications to screen 4.5, Stream Sediment Sampling, on page 4-3 and section 6.6, Stream Sediment Toxicity Testing, on page 6-3 of the Soil Sampling and Analysis Plan for Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant (DOE/OR/ 01-1322 & D1) are detailed in the attached document: Addendum to the Soil Sampling and Analysis Plan for the Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant. Details concerning sediment sampling, toxicity testing, data analysis and data quality assurance issues are specified for the sediment sampling and sediment toxicity testing sections. Specific criteria for data quality assurance and quality control are detailed.

Table B.29. (continued)

FCO NO.	DATE ISSUED	DESCRIPTION OF CHANGE
FPSS-010	5/3/95	Modifications to section 4.1, Floodplain Sediment Sampling, on page 4-1 and section 6.5, Floodplain Sediment Toxicity Testing, on page 6-2 of the Soil Sampling and Analysis Plan for Bear Creek Valley Floodplain at the Oak Ridge Y-12 Plant (DOE/OR/01-1322&D1); an addendum to the Remedial Investigation Work Plan (RIWP). Details concerning sampling, testing, and data quality assurance issues are provided for the sediment sampling and sediment toxicity testing sections. Specific criteria for data quality assurance and quality control are detailed. A complete description of the aforementioned changes can be found in the attached addendum.
FPSS-011	5/12/95	The procedure that will be used for the measurement of the physical parameters in the field are SAIC's FTP-451, FTP-750, FTP-753 and FTP-880. This change is being written to clarify and specify which procedures will be used. In section 7.2.3 of the BCV SAP, DOE/OR/01-1322&D2, the use of <u>which</u> SAIC procedures is not clearly identified.
FPSS-012	6/12/95	2 - Chloroaniline should be changed to 4- Chloroaniline, as listed in CLP OLM 3.0 and as listed in previous Bear Creek projects.

Table B.30. Large-scale characterization sample location and analysis matrix

Sample Location and Depth	Floodplain Soil Screening						Floodplain Soil Sampling AFIs						Confirmatory Soil Sampling					
	Station Number						Station Number						Station Number					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Transect: 1																		
0-4 in	S	S	S	S	S	S		C,G,Sr				C,G,Sr						
4-16 in	S	S	S	S	S	S		C,G,Sr				C,G,Sr						
0-16 in Comp								T,B				T,B						
16-32 in	S		S	S	S	S												
Transect: 2																		
0-4 in	S	S	S	S	S	S								C,G,Sr				
4-16 in	S	S	S	S	S	S								C,G,Sr				
0-16 in Comp														T,B				
16-32 in			S	S	S	S												
Transect: 3																		
0-4 in	S	S	S	S	S	S			C,G,Sr	C,G,Sr								
4-16 in	S	S	S	S	S	S			C,G,Sr	C,G,Sr								
0-16 in Comp									T,B	T,B								
16-32 in		S		S	S	S												
Transect: 4																		
0-4 in	S	S	S	S	S	S	C,G,Sr	C,G,Sr										
4-16 in	S	S	S	S	S	S	C,G,Sr	C,G,Sr										
0-16 in Comp							T,B	T,B										
16-32 in	S	S	S	S	S	S												
Transect: 5																		
0-4 in	S	S	S	S	S	S	C,G,Sr											
4-16 in	S	S	S	S	S	S	C,G,Sr											
0-16 in Comp							T,B											
16-32 in	S	S	S	S	S	S												
Transect: 6																		
0-4 in	S	S	S	S	S	S			C,G,Sr	C,G,Sr								
4-16 in	S	S	S	S	S	S			C,G,Sr	C,G,Sr								
0-16 in Comp									T,B	T,B								
16-32 in	S	S	S	S	S	S			C,G,Sr	C,G,Sr								
Transect: 7																		
0-4 in	S	S	S	S			C,G,Sr		C,G,Sr									
4-16 in	S	S	S	S			C,G,Sr		C,G,Sr									
0-16 in Comp							T,B		T,B									
16-32 in	S	S	S	S														
Transect: 8																		
0-4 in	S	S	S	S	S	S											C,G,Sr	
4-16 in	S	S	S	S	S	S											C,G,Sr	
0-16 in Comp																	T,B	
16-32 in	S	S	S	S	S	S												
Transect: 9																		
0-4 in	S	S	S	S	S	S								C,G,Sr				
4-16 in	S	S	S	S	S	S								C,G,Sr				
0-16 in Comp														T,B				
16-32 in	S	S	S	S	S													
Transect: 10																		
0-4 in	S	S	S	S	S	S			C,G,Sr									
4-16 in	S	S	S	S	S	S			C,G,Sr									
0-16 in Comp									T,B									
16-32 in	S	S	S	S	S	S					C,G,Sr							
Transect: 11																		
0-4 in	S	S	S	S	S	S												
4-16 in	S	S	S	S	S	S												
0-16 in Comp																		
16-32 in	S	S	S	S	S	S						C,G,Sr						
Transect: 12																		
0-4 in	S	S	S	S	S	S												
4-16 in	S	S	S	S	S	S												
0-16 in Comp																		
16-32 in	S		S	S										C,G,Sr				
Transect: 13																		
0-4 in	S	S	S	S	S	S			C,G,Sr									
4-16 in	S	S	S	S	S	S			C,G,Sr									
0-16 in Comp									T,B									
16-32 in	S	S	S	S		S												

S - PCB, VOC, RAD Screen

Sr - Rad Screen only

T - Toxicity

B - Biota

C - Organic/Inorganic and Radiological Analysis

G - Geotechnical Analysis

Table B.31. List of analytes and reported quantitation limits for soils and sediment in BCV FPSS

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Inorganics (mg/kg)</i>		
Aluminum		
Antimony	0.44	1.00
Arsenic	0.94	1.00
Barium		
Beryllium	0.36	0.63
Cadmium	0.07	0.84
Calcium		
Chromium		
Copper		
Cyanide	0.57	1.40
Iron		
Lead		
Lithium	4.90	13.00
Magnesium		
Manganese	0.93	0.93
Mercury	0.10	0.26
Nickel		
Potassium		
Selenium	1.10	1.50
Silver	0.12	0.27
Sodium	149.00	306.00
Thallium	1.00	2.50
Vanadium		
Zinc		
<i>Herbicides (µg/kg)</i>		
2,4,5-T	25.00	65.00
2,4,5-TP (Silvex)	25.00	150.00
2,4-D	99.00	610.00

Table B.31 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Pesticides/PCBs (µg/kg):</i>		
4,4'-DDD	3.60	26.00
4,4'-DDE	3.60	26.00
4,4'-DDT	3.60	26.00
Aldrin	1.90	13.00
Aroclor-1016	36.00	260.00
Aroclor-1221	73.00	530.00
Aroclor-1232	36.00	260.00
Aroclor-1242	36.00	260.00
Aroclor-1248	36.00	260.00
Aroclor-1254	40.00	260.00
Aroclor-1260	36.00	260.00
Dieldrin	3.60	26.00
Endosulfan I	1.90	13.00
Endosulfan II	3.60	26.00
Endosulfan sulfate	3.60	26.00
Endrin	3.60	26.00
Endrin aldehyde	3.60	26.00
Endrin ketone	3.60	26.00
Heptachlor	1.90	13.00
Heptachlor epoxide	1.90	13.00
Methoxychlor	19.00	130.00
Toxaphene	190.00	1300.00
alphaα-BHC	1.90	13.00
α-Chlordane	1.90	13.00
β-BHC	1.90	13.00
Δ-BHC	1.90	13.00
γ-BHC (Lindane)	1.90	13.00
γ-Chlordane	1.90	13.00

Table B.31 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
<i>Semivolatile Organics (µg/kg)</i>		
1,2,4-Trichlorobenzene	330.00	800.00
1,2-Dichlorobenzene	330.00	800.00
1,3-Dichlorobenzene	330.00	800.00
1,4-Dichlorobenzene	330.00	800.00
2,2'-oxybis(1-Chloropropane)	330.00	800.00
2,4,5-Trichlorophenol	830.00	2000.00
2,4,6-Trichlorophenol	330.00	800.00
2,4-Dichlorophenol	330.00	800.00
2,4-Dimethylphenol	330.00	800.00
2,4-Dinitrophenol	830.00	2000.00
2,4-Dinitrotoluene	330.00	800.00
2,6-Dinitrotoluene	330.00	800.00
2-Chloronaphthalene	330.00	800.00
2-Chlorophenol	330.00	800.00
2-Methylnaphthalene	330.00	800.00
2-Methylphenol	330.00	800.00
2-Nitroaniline	830.00	2000.00
2-Nitrophenol	330.00	800.00
3,3'-Dichlorobenzidine	330.00	800.00
3-Nitroaniline	830.00	2000.00
4,6-Dinitro-2-methylphenol	830.00	2000.00
4-Bromophenyl-phenylether	330.00	800.00
4-Chloro-3-methylphenol	330.00	800.00
4-Chloroaniline	330.00	800.00
4-Chlorophenyl-phenylether	330.00	800.00
4-Methylphenol	330.00	800.00
4-Nitroaniline	830.00	2000.00
4-Nitrophenol	830.00	2000.00
Acenaphthene	330.00	800.00
Acenaphthylene	330.00	800.00
Anthracene	330.00	800.00

Table B.31 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Benzo(a)anthracene	330.00	800.00
Benzo(a)pyrene	330.00	800.00
Benzo(b)fluoranthene	330.00	800.00
Benzo(g,h,i)perylene	330.00	800.00
Benzo(k)fluoranthene	330.00	800.00
Butylbenzylphthalate	330.00	800.00
Carbazole	330.00	800.00
Chrysene	330.00	800.00
Di-n-butylphthalate	110.00	800.00
Di-n-octylphthalate	330.00	800.00
Dibenzo(a,h)anthracene	330.00	800.00
Dibenzofuran	330.00	800.00
Diethylphthalate	330.00	800.00
Dimethylphthalate	330.00	800.00
Fluoranthene	330.00	800.00
Fluorene	330.00	800.00
Hexachlorobenzene	330.00	800.00
Hexachlorobutadiene	330.00	800.00
Hexachlorocyclopentadiene	330.00	800.00
Hexachloroethane	330.00	800.00
Indeno(1,2,3-c,d)pyrene	330.00	800.00
Isophorone	330.00	800.00
N-Nitroso-di-n-propylamine	330.00	800.00
N-Nitrosodiphenylamine	330.00	800.00
Naphthalene	330.00	800.00
Nitrobenzene	330.00	800.00
Pentachlorophenol	830.00	2000.00
Phenanthrene	330.00	800.00
Phenol	330.00	800.00
Pyrene	330.00	800.00
bis(2-Chloroethoxy)methane	330.00	800.00
bis(2-Chloroethyl)ether	330.00	800.00

Table B.31 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
bis(2-Ethylhexyl)phthalate	330.00	800.00
<i>Volatile Organics (µg/kg)</i>		
1,1,1-Trichloroethane	6.00	12.00
1,1,2,2-Tetrachloroethane	6.00	12.00
1,1,2-Trichloroethane	6.00	12.00
1,1-Dichloroethane	6.00	12.00
1,1-Dichloroethene	6.00	12.00
1,2-Dichloroethane	6.00	12.00
1,2-Dichloroethene	6.00	12.00
1,2-Dichloropropane	6.00	12.00
2-Butanone	6.00	12.00
2-Hexanone	6.00	12.00
4-methyl-2-Pentanone	6.00	12.00
Acetone	6.00	83.00
Benzene	6.00	12.00
Bromodichloromethane	6.00	12.00
Bromoform	6.00	12.00
Bromomethane	6.00	12.00
Carbon disulfide	6.00	12.00
Carbon tetrachloride	6.00	12.00
Chlorobenzene	6.00	12.00
Chloroethane	6.00	12.00
Chloroform	6.00	12.00
Chloromethane	6.00	12.00
Dibromochloromethane	6.00	12.00
Ethylbenzene	6.00	12.00
Methylene chloride	6.00	97.00
Styrene	6.00	12.00
Tetrachloroethene	6.00	12.00
Toluene	6.00	12.00
Trichloroethene	6.00	12.00
Vinyl chloride	6.00	12.00

Table B.31 (continued)

Analyte	Minimum quantitation limit ^a	Maximum quantitation limit ^a
Xylene, total	6.00	12.00
cis-1,3-Dichloropropene	6.00	12.00
trans-1,3-Dichloropropene	6.00	12.00
<i>Radionuclides (pCi/g)</i>		
Americium-241		
Cesium-137		
Curium-243		
Curium-244		
Plutonium-238		
Plutonium-239/240		
Strontium-90		
Technetium-99		
Thorium-228		
Thorium-230		
Thorium-232		
Uranium-234		
Uranium-235		
Uranium-238		

^aParameters which were never reported as less than the quantitation limit have no statistics for minimum or maximum quantitation limit

Table B.32. Fine-scale characterization, stream sediment and soil reference, sample location, and analysis matrices

Fine-scale characterization			Stream sediment characterization		Stream sediment reference		Floodplain soil radiological and chemical references	
Sample location	Initial sample analyses	AFI analyses	Sample location	Sample analyses	Sample location	Sediment analyses	Sample location	Sample analyses
<i>Sediment profile excavation</i>			1	C, G, T	1	C, G	1	
1	S		2	C, G, T	2	C, G	0-16 in. comp	G, T, B
2	S		3	C, G, T	3	C, G	2	
3	S		4	C, G, T	1, 2, 3 comp	T	0-16 in. comp	G, T, B
4	S, C		5	C, G, T			3	
5	S		6	C, G, T			0-16 in. comp	G, T, B
<i>Fine-scale sediment</i>			7	C, G, T				
1			8	C, G, T				
2			9	C, G, T				
3			10	C, G, T				
4	S		11	C, G, T				
5			12	C, G, T				
5: 0-4 in.		C, G, Sr	13	C, G, T				
5: 4-16 in.		C, G, Sr	14	C, G, T				
5: 10-28 in.	S	C, G	15	C, G, T				
5: 0-16 in. comp		T, B	16	C, G, T				
6			17	C, G, T				
7	S							
8	S							
9								
10								
11								
11: 16-32 in.		C, Sr						
11: 18-34 in.	S	C						
12	S							
13	S							
14	S							
15	S							
16	S							
17	S							

S = PCB, VOC, rad screen

Sr = Rad screen only

T = Toxicity

B = Biota

C = Organic/inorganic and radiological analyses

G = Geotechnical analysis

**Table B.33. Technical sampling procedures used in the course
of BCV Floodplain investigation**

Procedure number ^a	Subject activity	Issue date	Revision
<i>Soil sampling</i>			
ESP-303-1	Soil sampling with a spade and scoop	8/30/88	0
ESP-303-2	Soil sampling with an auger	9/1/88	0
TP-303-8	Subsoil sampling with a JMC backsaver soil sampling system	10/2/91	1
<i>Stream sampling</i>			
ESP-304-1	Sediment sampling procedures: stream beds	10/29/90	1
<i>Biota sampling</i>			
TP-309-9	Terrestrial vegetation sampling collection	5/8/92	0
TP-309-9	Terrestrial small mammal sampling	10/15/91	0
K-901-1062	Terrestrial subsurface macroinvertebrate collection	9/14/94	0

^a SAIC 1995a. *Environmental Technical Support, Bear Creek Valley Operable Unit One and Floodplain Soil Sampling Field Technical Procedures.*

Table B.34. Technical procedures for collection of BCV biota samples

Procedure number	Subject activity	Issue date	Revision
TP-309-3	Terrestrial small mammal sampling	10/15/91	0
K-901-1062	Terrestrial subsurface macroinvertebrate collection	9/14/94	0
TP-309-9	Terrestrial vegetation sample collection	5/8/92	0

Table B.35. Biota samples collected for the BCV RI

Location	Small mammals	Earthworm	Herbiage	Browse	Canopy
BYBY (BY17)	4 individuals	1 composite	1 composite	1 composite	1 composite
BYBY (BY22)		1 composite	1 composite	1 composite	1 composite
Transect 1	5 individuals				
TS012		1 composite	1 composite	1 composite	1 composite
TS016		1 composite	1 composite	1 composite	1 composite
Transect 2	5 individuals				
TS023		1 composite	1 composite	1 composite	1 composite
Transect 3	3 individuals				
TS033		1 composite	1 composite	1 composite	1 composite
TS034		1 composite	1 composite	1 composite	1 composite
Transect 4	4 individuals				
TS041		1 composite	1 composite	1 composite	1 composite
TS042		1 composite	1 composite	1 composite	1 composite
Transect 7	3 individuals				
TS071		1 composite	1 composite	1 composite	1 composite
TS073		1 composite	1 composite	1 composite	1 composite
Transect 9, TS092		1 composite	1 composite	1 composite	1 composite

Table B.36. Summary of analytical methods used for the GWQR dataset

Parameter	Method 1986	Method 1987	Method 1988	Method 1989	Method 1990	Method 1991	Method 1992	Method 1993
VOA	EPA 8240	EPA 8240	EPA 8240	EPA 8240	EPA 8240	EPA 8240	EPA 8240	EPA 8240
SVOA	EPA 8270	EPA 8270	EPA 8270	EPA 8270	EPA 8270	EPA 8270	EPA 8270	EPA 8270
Pesticides/PCBs	EPA 8080	EPA 8080	EPA 8080	EPA 8080	EPA 8080	EPA 8080	EPA 8080	EPA 8080
Alkalinity	TP-1822	SM-403	SM-403	SM-403	SM-403	SM-403	SM-403	SM-2320B
Alkalinity	TP-1822	SM-403	SM-403	SM-403	SM-403	SM-403	SM-403	SM-2320B
Ammonia	EPA 350.3	EPA 350.3	EPA 350.3	EPA 350.3	EPA 350.3			
Chloride	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0
Conductivity	EPA 120.1	EPA 120.0	EPA 120.0	EPA 120.1	EPA 120.1		EPA 9050	EPA 9050
Fluoride	TP-1835	EPA 340.2	EPA 340.2	EPA 340.2	EPA 340.2		EPA 340.2	EPA 340.2
Kjeldahl	EPA 351.3	EPA 351.1	EPA 351.3	EPA 351.3	EPA 351.3			
Nitrate	EPA 300.0	EPA 300.0						
Nitrate as N	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0		EPA 300.0	EPA 300.0
Nitrite	EPA 300.0							
pH	EPA 150.0	EPA 150.1	EPA 150.1	EPA 150.1	EPA 150.1	EPA 9040	EPA 9040	EPA 9040
Phenols	EPA 420.1	EPA 420.1	EPA 420.1	EPA 420.1	EPA 420.1	EPA 9065		
Sulfate	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0
Suspended	TP-1818	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2	EPA 160.2
Total	SM-909	SM-909	SM-909	SM-909	SM-909			
Total	TP-1837	TP-183708	TP-183708	TP-183708	TP-183708	EC-1910	EC-1910	EC-1910
Turbidity	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1?	EPA 180.1	EPA 180.1

Table B.36 continued

Parameter	Method 1986	Method 1987	Method 1988	Method 1989	Method 1990	Method 1991	Method 1992	Method 1993
Metals	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010
Total	EPA 415.1	EPA 415.1	EPA 415.1	EPA 415.1	EPA 415.1			
Gross	TP-1602	EPA 900.0	EPA 900.0	EPA 300.0	EPA 300.0	EPA 9310	EPA 9310	EPA 9310
Nitrite		EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0			
Total		EPA 415.2	EPA 415.2	EPA 415.2	EPA 415.2			
Dissolved				EPA 160.1	EPA 160.1		EPA 160.1	EPA 160.1
Petroleum					At X-10	At X-10	At X-10	At X-10

Table B.37. Minimum and maximum non-detects for groundwater in the S-3 aggregate^a

Analyte	Units	Minimum non-detect	Maximum non-detect
<i>Inorganics</i>			
Aluminum	mg/L	0.02	0.04
Ammonia nitrogen	mg/L	0.2	0.2
Antimony	mg/L	0.05	0.25
Arsenic	mg/L	0.005	0.005
Barium	mg/L	.	.
Beryllium	mg/L	0.0003	0.0006
Boron	mg/L	0.004	0.02
Cadmium	mg/L	0.002	0.01
Calcium	mg/L	.	.
Chloride	mg/L	1	5
Chromium	mg/L	0.01	0.01
Cobalt	mg/L	0.005	0.025
Copper	mg/L	0.004	0.02
Fluoride	mg/L	0.1	0.1
Iron	mg/L	0.004	0.01
Kjeldahl nitrogen	mg/L	0.1	0.2
Lead	mg/L	0.004	0.02
Lithium	mg/L	.	.
Magnesium	mg/L	.	.
Manganese	mg/L	0.001	0.005
Mercury	mg/L	0.0002	0.00026
Molybdenum	mg/L	0.01	0.05
Nickel	mg/L	0.01	0.05
Niobium	mg/L	0.007	0.007
Nitrate	mg/L	0.2	0.5
Nitrite	mg/L	6.7	100
Potassium	mg/L	0.6	0.6
Selenium	mg/L	0.005	0.03
Silicon	mg/L	.	.
Silver	mg/L	0.01	0.01
Sodium	mg/L	.	.

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Strontium	mg/L	.	.
Sulfate	mg/L	1	5
Thallium	mg/L	0.01	0.01
Thorium	mg/L	0.2	1
Tin	mg/L	0.01	0.01
Titanium	mg/L	0.003	0.003
Total Uranium	mg/L	0.001	0.001
Vanadium	mg/L	0.005	0.025
Zinc	mg/L	0.001	0.004
Zirconium	mg/L	0.005	0.005
<i>Organics</i>			
1,1,1-Trichloroethane	µg/L	0.8	10
1,1,2,2-Tetrachloroethane	µg/L	5	10
1,1,2-Trichloroethane	µg/L	5	10
1,1-Dichloroethane	µg/L	5	10
1,1-Dichloroethene	µg/L	5	10
1,2,4-Trichlorobenzene	µg/L	5	10
1,2-Dichlorobenzene	µg/L	5	10
1,2-Dichloroethane	µg/L	5	10
1,2-Dichloroethene	µg/L	5	10
1,2-Dichloropropane	µg/L	5	10
1,3-Dichlorobenzene	µg/L	5	10
1,4-Dichlorobenzene	µg/L	5	10
2,4,5-Trichlorophenol	µg/L	25	50
2,4,6-Trichlorophenol	µg/L	5	10
2,4-D	µg/L	1	1
2,4-Dichlorophenol	µg/L	5	10
2,4-Dimethylphenol	µg/L	5	10
2,4-Dinitrophenol	µg/L	25	50
2,4-Dinitrotoluene	µg/L	5	10
2,6-Dinitrotoluene	µg/L	5	10
2-Butanone	µg/L	6	10

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
2-Chloroethylvinyl ether	$\mu\text{g/L}$	10	10
2-Chloronaphthalene	$\mu\text{g/L}$	5	10
2-Chlorophenol	$\mu\text{g/L}$	5	10
2-Hexanone	$\mu\text{g/L}$	10	10
2-Methyl-4,6-Dinitrophenol	$\mu\text{g/L}$	25	50
2-Methylnaphthalene	$\mu\text{g/L}$	5	10
2-Methylphenol	$\mu\text{g/L}$	5	10
2-Nitrobenzenamine	$\mu\text{g/L}$	25	50
2-Nitrophenol	$\mu\text{g/L}$	5	10
3,3'-Dichlorobenzidine	$\mu\text{g/L}$	10	20
3-Nitrobenzenamine	$\mu\text{g/L}$	25	50
4,4'-DDD	$\mu\text{g/L}$	0.1	0.1
4,4'-DDE	$\mu\text{g/L}$	0.1	0.1
4,4'-DDT	$\mu\text{g/L}$	0.1	0.1
4-Bromophenyl phenyl ether	$\mu\text{g/L}$	5	10
4-Chloro-3-Methylphenol	$\mu\text{g/L}$	5	10
4-Chlorobenzenamine	$\mu\text{g/L}$	5	10
4-Chlorophenylphenyl ether	$\mu\text{g/L}$	5	10
4-Methyl-2-Pentanone	$\mu\text{g/L}$	1	10
4-Methylphenol	$\mu\text{g/L}$	5	10
4-Nitrobenzenamine	$\mu\text{g/L}$	25	50
4-Nitrophenol	$\mu\text{g/L}$	25	50
Acenaphthene	$\mu\text{g/L}$	5	10
Acenaphthylene	$\mu\text{g/L}$	5	10
Acetone	$\mu\text{g/L}$	1	10
Aldrin	$\mu\text{g/L}$	0.05	0.05
α -BHC	$\mu\text{g/L}$	0.05	0.05
α -Chlordane	$\mu\text{g/L}$	0.5	0.5
Aniline	$\mu\text{g/L}$	10	10
Anthracene	$\mu\text{g/L}$	5	10
Benzene	$\mu\text{g/L}$	5	10
Benzenemethanol	$\mu\text{g/L}$	5	10

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Benzidine	$\mu\text{g/L}$	80	80
Benzo(a)anthracene	$\mu\text{g/L}$	5	10
Benzo(a)pyrene	$\mu\text{g/L}$	5	10
Benzo(b)fluoranthene	$\mu\text{g/L}$	5	10
Benzo(ghi)perylene	$\mu\text{g/L}$	5	10
Benzo(k)fluoranthene	$\mu\text{g/L}$	5	10
Benzoic Acid	$\mu\text{g/L}$	25	50
β -BHC	$\mu\text{g/L}$	0.05	0.05
Bis(2-chloroethoxy)methane	$\mu\text{g/L}$	5	10
Bis(2-chloroethyl) Ether	$\mu\text{g/L}$	5	10
Bis(2-chloroisopropyl)ether	$\mu\text{g/L}$	5	10
Bis(2-ethylhexyl)phthalate	$\mu\text{g/L}$	5	10
Bromodichloromethane	$\mu\text{g/L}$	5	10
Bromoform	$\mu\text{g/L}$	5	10
Bromomethane	$\mu\text{g/L}$	10	10
Butylbenzylphthalate	$\mu\text{g/L}$	5	10
Carbon Disulfide	$\mu\text{g/L}$	5	10
Carbon Tetrachloride	$\mu\text{g/L}$	5	10
Chlorobenzene	$\mu\text{g/L}$	5	10
Chloroethane	$\mu\text{g/L}$	10	10
Chloroform	$\mu\text{g/L}$	0.8	10
Chloromethane	$\mu\text{g/L}$	10	10
Chrysene	$\mu\text{g/L}$	5	10
Cis-1,3-dichloropropene	$\mu\text{g/L}$	5	10
Δ -BHC	$\mu\text{g/L}$	0.05	0.05
Di-n-butylphthalate	$\mu\text{g/L}$	5	10
Di-n-octylphthalate	$\mu\text{g/L}$	5	10
Dibenzo(a,h)anthracene	$\mu\text{g/L}$	5	10
Dibenzofuran	$\mu\text{g/L}$	5	10
Dibromochloromethane	$\mu\text{g/L}$	5	10
Dieldrin	$\mu\text{g/L}$	0.1	0.1
Diethylphthalate	$\mu\text{g/L}$	5	10

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Dimethylbenzene	$\mu\text{g/L}$	5	10
Dimethylphthalate	$\mu\text{g/L}$	5	10
Endosulfan I	$\mu\text{g/L}$	0.05	0.05
Endosulfan II	$\mu\text{g/L}$	0.1	0.1
Endosulfan Sulfate	$\mu\text{g/L}$	0.1	0.1
Endrin	$\mu\text{g/L}$	0.1	0.1
Endrin Ketone	$\mu\text{g/L}$	0.1	0.1
Ethylbenzene	$\mu\text{g/L}$	0.7	10
Fluoranthene	$\mu\text{g/L}$	5	10
Fluorene	$\mu\text{g/L}$	5	10
γ -BHC	$\mu\text{g/L}$	0.05	0.05
γ -Chlordane	$\mu\text{g/L}$	0.5	0.5
Heptachlor	$\mu\text{g/L}$	0.05	0.05
Heptachlor Epoxide	$\mu\text{g/L}$	0.05	0.05
Hexachlorobenzene	$\mu\text{g/L}$	5	10
Hexachlorobutadiene	$\mu\text{g/L}$	5	10
Hexachlorocyclopentadiene	$\mu\text{g/L}$	5	10
Hexachloroethane	$\mu\text{g/L}$	5	10
Indeno(1,2,3-cd)pyrene	$\mu\text{g/L}$	5	10
Isophorone	$\mu\text{g/L}$	5	10
Methoxychlor	$\mu\text{g/L}$	0.5	0.5
Methylene Chloride	$\mu\text{g/L}$	1	16
N-nitroso-di-n-propylamine	$\mu\text{g/L}$	5	10
N-nitrosodimethylamine	$\mu\text{g/L}$	10	10
N-nitrosodiphenylamine	$\mu\text{g/L}$	5	10
Naphthalene	$\mu\text{g/L}$	5	10
Nitrobenzene	$\mu\text{g/L}$	5	10
PCB-1016	$\mu\text{g/L}$	0.5	0.5
PCB-1221	$\mu\text{g/L}$	0.5	0.5
PCB-1232	$\mu\text{g/L}$	0.5	0.5
PCB-1242	$\mu\text{g/L}$	0.5	0.5
PCB-1248	$\mu\text{g/L}$	0.5	0.5

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
PCB-1254	$\mu\text{g/L}$	1	1
PCB-1260	$\mu\text{g/L}$	1	1
Pentachlorophenol	$\mu\text{g/L}$	25	50
Phenanthrene	$\mu\text{g/L}$	5	10
Phenol	$\mu\text{g/L}$	5	10
Phenols	mg/L	0.001	0.03
Pyrene	$\mu\text{g/L}$	5	10
Silvex	$\mu\text{g/L}$	0.1	0.1
Styrene	$\mu\text{g/L}$	5	10
Tetrachloroethene	$\mu\text{g/L}$	5	10
Toluene	$\mu\text{g/L}$	0.6	10
Toxaphene	$\mu\text{g/L}$	1	1
Trans-1,2-dichloroethene	$\mu\text{g/L}$	5	10
Trans-1,3-dichloropropene	$\mu\text{g/L}$	5	10
Trichloroethene	$\mu\text{g/L}$	5	10
Vinyl acetate	$\mu\text{g/L}$	10	10
Vinyl chloride	$\mu\text{g/L}$	10	10

RADS

Americium-241

Cesium-137

Gross α Gross β

Neptunium-237

Plutonium-238

Plutonium-239/240

Radium-228

Technetium-99

Thorium-228

Thorium-230

Thorium-232

Total Radioactive Strontium

Total Radium α

Table B.37 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Tritium			
Uranium-234			
Uranium-235			
Uranium-238			

^a Refer to Table D.6 in Appendix D for a list of wells and sample dates for this aggregate.

Table B.38. Minimum and maximum non-detects for groundwater in the OLF aggregate^a

Analyte	Units	Minimum non-detect	Maximum non-detect
<i>Inorganics</i>			
Aluminum	mg/l	0.02	0.02
Antimony	mg/l	0.05	0.05
Arsenic	mg/l	0.005	0.005
Barium	mg/l	.	.
Beryllium	mg/l	0.0003	0.0003
Boron	mg/l	0.004	0.004
Cadmium	mg/l	0.002	0.002
Calcium	mg/l	.	.
Chloride	mg/l	1	1
Chromium	mg/l	0.01	0.01
Cobalt	mg/l	0.005	0.005
Copper	mg/l	0.004	0.004
Fluoride	mg/l	0.1	0.2
Iron	mg/l	0.004	0.005
Lead	mg/l	0.004	0.004
Lithium	mg/l	0.004	0.004
Magnesium	mg/l	.	.
Manganese	mg/l	0.001	0.001
Mercury	mg/l	0.0002	0.00026
Molybdenum	mg/l	0.01	0.01
Nickel	mg/l	0.01	0.01
Niobium	mg/l	0.007	0.007
Nitrate	mg/l	0.1	1
Potassium	mg/l	0.6	0.6
Selenium	mg/l	0.005	0.005
Silicon	mg/l	.	.
Silver	mg/l	0.01	0.01
Sodium	mg/l	.	.
Strontium	mg/l	.	.
Sulfate	mg/l	1	1

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Thallium	mg/l	0.01	0.01
Thorium	mg/l	0.2	0.2
Titanium	mg/l	0.003	0.003
Total Uranium	mg/l	0.001	0.001
Vanadium	mg/l	0.005	0.005
Zinc	mg/l	0.001	0.002
Zirconium	mg/l	0.005	0.005
<i>Organics</i>			
1,1,1-Trichloroethane	µg/l	0.8	10
1,1,2,2-Tetrachloroethane	µg/l	5	10
1,1,2-Trichloroethane	µg/l	5	10
1,1-Dichloroethane	µg/l	5	10
1,1-Dichloroethene	µg/l	5	10
1,2,4-Trichlorobenzene	µg/l	10	10
1,2-Dichlorobenzene	µg/l	10	10
1,2-Dichloroethane	µg/l	5	10
1,2-Dichloroethene	µg/l	5	10
1,2-Dichloropropane	µg/l	5	10
1,3-Dichlorobenzene	µg/l	10	10
1,4-Dichlorobenzene	µg/l	10	10
2,4,5-Trichlorophenol	µg/l	50	50
2,4,6-Trichlorophenol	µg/l	10	10
2,4-D	µg/l	1	1
2,4-Dichlorophenol	µg/l	10	10
2,4-Dimethylphenol	µg/l	10	10
2,4-Dinitrophenol	µg/l	50	50
2,4-Dinitrotoluene	µg/l	10	10
2,6-Dinitrotoluene	µg/l	10	10
2-Butanone	µg/l	3	20
2-Chloroethylvinyl ether	µg/l	10	10
2-Chloronaphthalene	µg/l	10	10

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
2-Chlorophenol	µg/l	10	10
2-Hexanone	µg/l	10	20
2-Methyl-4,6-Dinitrophenol	µg/l	50	50
2-Methylnaphthalene	µg/l	10	10
2-Methylphenol	µg/l	10	10
2-Nitrobenzenamine	µg/l	50	50
2-Nitrophenol	µg/l	10	10
3,3'-Dichlorobenzidine	µg/l	20	20
3-Nitrobenzenamine	µg/l	50	50
4,4'-DDD	µg/l	0.1	0.1
4,4'-DDE	µg/l	0.1	0.1
4,4'-DDT	µg/l	0.1	0.1
4-Bromophenyl phenyl ether	µg/l	10	10
4-Chloro-3-Methylphenol	µg/l	10	10
4-Chlorobenzenamine	µg/l	10	10
4-Chlorophenylphenyl ether	µg/l	10	10
4-Methyl-2-Pentanone	µg/l	1	20
4-Methylphenol	µg/l	10	10
4-Nitrobenzenamine	µg/l	50	50
4-Nitrophenol	µg/l	50	50
Acenaphthene	µg/l	10	10
Acenaphthylene	µg/l	10	10
Acetone	µg/l	1	49
Aldrin	µg/l	0.05	0.05
α-BHC	µg/l	0.05	0.05
α-Chlordane	µg/l	0.5	0.5
Anthracene	µg/l	10	10
Benzene	µg/l	5	10
Benzenemethanol	µg/l	10	10
Benzo(a)anthracene	µg/l	10	10
Benzo(a)pyrene	µg/l	10	10

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Benzo(b)fluoranthene	µg/l	10	10
Benzo(ghi)perylene	µg/l	10	10
Benzo(k)fluoranthene	µg/l	10	10
Benzoic acid	µg/l	50	50
β-BHC	µg/l	0.05	0.05
Bis(2-chloroethoxy)methane	µg/l	10	10
Bis(2-chloroethyl)ether	µg/l	10	10
Bis(2-chloroisopropyl)ether	µg/l	10	10
Bis(2-ethylhexyl)phthalate	µg/l	10	10
Bromodichloromethane	µg/l	5	10
Bromoform	µg/l	5	10
Bromomethane	µg/l	10	20
Butylbenzylphthalate	µg/l	10	10
Carbon Disulfide	µg/l	5	10
Carbon Tetrachloride	µg/l	5	10
Chlorobenzene	µg/l	5	10
Chloroethane	µg/l	10	20
Chloroform	µg/l	0.8	10
Chloromethane	µg/l	10	20
Chrysene	µg/l	10	10
Cis-1,3-Dichloropropene	µg/l	5	10
Δ-BHC	µg/l	0.05	0.05
Di-n-butylphthalate	µg/l	10	10
Di-n-octylphthalate	µg/l	10	10
Dibenzo(a,h)anthracene	µg/l	10	10
Dibenzofuran	µg/l	10	10
Dibromochloromethane	µg/l	5	10
Dieldrin	µg/l	0.1	0.1
Diethylphthalate	µg/l	10	10
Dimethylbenzene	µg/l	5	10
Dimethylphthalate	µg/l	10	10

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Endosulfan I	$\mu\text{g/l}$	0.05	0.05
Endosulfan II	$\mu\text{g/l}$	0.1	0.1
Endosulfan Sulfate	$\mu\text{g/l}$	0.1	0.1
Endrin	$\mu\text{g/l}$	0.1	0.1
Endrin Ketone	$\mu\text{g/l}$	0.1	0.1
Ethylbenzene	$\mu\text{g/l}$	5	10
Fluoranthene	$\mu\text{g/l}$	10	10
Fluorene	$\mu\text{g/l}$	10	10
γ -BHC	$\mu\text{g/l}$	0.05	0.05
γ -Chlordane	$\mu\text{g/l}$	0.5	0.5
Heptachlor	$\mu\text{g/l}$	0.05	0.05
Heptachlor Epoxide	$\mu\text{g/l}$	0.05	0.05
Hexachlorobenzene	$\mu\text{g/l}$	10	10
Hexachlorobutadiene	$\mu\text{g/l}$	10	10
Hexachlorocyclopentadiene	$\mu\text{g/l}$	10	10
Hexachloroethane	$\mu\text{g/l}$	10	10
Indeno(1,2,3-cd)pyrene	$\mu\text{g/l}$	10	10
Isophorone	$\mu\text{g/l}$	10	10
Methoxychlor	$\mu\text{g/l}$	0.5	0.5
Methylene Chloride	$\mu\text{g/l}$	0.6	17
N-nitroso-di-n-propylamine	$\mu\text{g/l}$	10	10
N-nitrosodiphenylamine	$\mu\text{g/l}$	10	10
Naphthalene	$\mu\text{g/l}$	10	10
Nitrobenzene	$\mu\text{g/l}$	10	10
PCB-1016	$\mu\text{g/l}$	0.5	0.5
PCB-1221	$\mu\text{g/l}$	0.5	0.5
PCB-1232	$\mu\text{g/l}$	0.5	0.5
PCB-1242	$\mu\text{g/l}$	0.5	0.5
PCB-1248	$\mu\text{g/l}$	0.5	0.5
PCB-1254	$\mu\text{g/l}$	1	1
PCB-1260	$\mu\text{g/l}$	1	1

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Pentachlorophenol	$\mu\text{g/l}$	50	50
Phenanthrene	$\mu\text{g/l}$	10	10
Phenol	$\mu\text{g/l}$	10	10
Phenols	mg/l	0.001	0.03
Pyrene	$\mu\text{g/l}$	10	10
Silvex	$\mu\text{g/l}$	0.1	0.1
Styrene	$\mu\text{g/l}$	5	10
Tetrachloroethene	$\mu\text{g/l}$	5	10
Toluene	$\mu\text{g/l}$	0.7	10
Toxaphene	$\mu\text{g/l}$	1	1
Trans-1,2-Dichloroethene	$\mu\text{g/l}$	5	5
Trans-1,3-Dichloropropene	$\mu\text{g/l}$	5	10
Trichloroethene	$\mu\text{g/l}$	5	10
Vinyl acetate	$\mu\text{g/l}$	10	20
Vinyl chloride	$\mu\text{g/l}$	10	20

RADS

Americium-241

Cesium-137

Gross α Gross β

Neptunium-237

Plutonium-238

Plutonium-239/240

Radium-228

Technetium-99

Thorium-228

Thorium-230

Thorium-232

Total Radioactive Strontium

Total Radium α

Tritium

Table B.38 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Uranium-234			
Uranium-235			
Uranium-238			

^a Refer to Table D.6 in Appendix D for a list of wells and sample dates for this aggregate.

Table B.39. Minimum and maximum non-detects for groundwater in the BCBG aggregate^a

Analyte	Units	Minimum non-detect	Maximum non-detect
<i>Inorganics</i>			
Aluminum	mg/L	0.02	0.
Antimony	mg/L	0.05	0.25
Arsenic	mg/L	0.005	0.005
Barium	mg/L	.	.
Beryllium	mg/L	0.0003	0.000
Boron	mg/L	0.003	0.004
Cadmium	mg/L	0.002	0.002
Calcium	mg/L	.	.
Chloride	mg/L	1	5
Chromium	mg/L	0.01	0.05
Cobalt	mg/L	0.004	0.025
Copper	mg/L	0.004	0.02
Fluoride	mg/L	0.1	0.1
Iron	mg/L	0.004	0.005
Lead	mg/L	0.004	0.02
Lithium	mg/L	0.001	0.001
Magnesium	mg/L	.	.
Manganese	mg/L	0.001	0.001
Mercury	mg/L	0.0002	0.0002
Molybdenum	mg/L	0.01	0.05
Nickel	mg/L	0.01	0.05
Niobium	mg/L	0.007	0.007
Nitrate	mg/L	0.11	1
Potassium	mg/L	0.6	0.6
Selenium	mg/L	0.005	0.005
Silicon	mg/L	.	.
Silver	mg/L	0.01	0.01
Sodium	mg/L	.	.
Strontium	mg/L	.	.
Sulfate	mg/L	0.2	1

Table B.39 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Thallium	mg/L	0.01	0.01
Thorium	mg/L	0.2	1
Titanium	mg/L	0.003	0.003
Total uranium	mg/L	0.001	0.001
Vanadium	mg/L	0.004	0.025
Zinc	mg/L	0.001	0.002
Zirconium	mg/L	0.001	0.005
<i>Organics</i>			
1,1,1-Trichloroethane	µg/L	0.8	25
1,1,2,2-Tetrachloroethane	µg/L	1	25
1,1,2-Trichloroethane	µg/L	5	25
1,1-Dichloroethane	µg/L	5	25
1,1-Dichloroethene	µg/L	5	25
1,2-Dichloroethane	µg/L	5	25
1,2-Dichloroethene	µg/L	5	25
1,2-Dichloropropane	µg/L	5	25
2,4,5-T	µg/L	0.1	0.1
2,4-D	µg/L	1	1
2-Butanone	µg/L	2	50
2-Chloroethylvinyl ether	µg/L	10	10
2-Hexanone	µg/L	1	50
4,4'-DDD	µg/L	0.1	0.1
4,4'-DDE	µg/L	0.1	0.1
4,4'-DDT	µg/L	0.1	0.1
4-Methyl-2-Pentanone	µg/L	1	50
Acetone	µg/L	1	50
Aldrin	µg/L	0.05	0.05
α-BHC	µg/L	0.05	0.05
α-Chlordane	µg/L	0.5	0.5
Benzene	µg/L	5	25
β-BHC	µg/L	0.05	0.05

Table B.39 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Bromodichloromethane	$\mu\text{g/L}$	5	25
Bromoform	$\mu\text{g/L}$	5	25
Bromomethane	$\mu\text{g/L}$	10	50
Carbon Disulfide	$\mu\text{g/L}$	1	25
Carbon Tetrachloride	$\mu\text{g/L}$	5	25
Chlorobenzene	$\mu\text{g/L}$	5	25
Chloroethane	$\mu\text{g/L}$	10	50
Chloroform	$\mu\text{g/L}$	0.8	25
Chloromethane	$\mu\text{g/L}$	10	50
Cis-1,3-Dichloropropene	$\mu\text{g/L}$	5	25
Δ -BHC	$\mu\text{g/L}$	0.05	0.05
Dibromochloromethane	$\mu\text{g/L}$	5	25
Dieldrin	$\mu\text{g/L}$	0.1	0.1
Dimethylbenzene	$\mu\text{g/L}$	5	25
Endosulfan I	$\mu\text{g/L}$	0.05	0.05
Endosulfan II	$\mu\text{g/L}$	0.1	0.1
Endosulfan Sulfate	$\mu\text{g/L}$	0.1	0.1
Endrin	$\mu\text{g/L}$	0.1	0.1
Endrin Ketone	$\mu\text{g/L}$	0.1	0.1
Ethylbenzene	$\mu\text{g/L}$	5	25
γ -BHC	$\mu\text{g/L}$	0.05	0.05
γ -Chlordane	$\mu\text{g/L}$	0.5	0.5
Heptachlor	$\mu\text{g/L}$	0.05	0.05
Heptachlor epoxide	$\mu\text{g/L}$	0.05	0.05
Methoxychlor	$\mu\text{g/L}$	0.5	0.5
Methylene chloride	$\mu\text{g/L}$	0.6	25
PCB-1016	$\mu\text{g/L}$	0.5	0.5
PCB-1221	$\mu\text{g/L}$	0.5	0.5
PCB-1232	$\mu\text{g/L}$	0.5	0.5
PCB-1242	$\mu\text{g/L}$	0.5	0.5
PCB-1248	$\mu\text{g/L}$	0.5	0.5

Table B.39 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
PCB-1254	$\mu\text{g/L}$	1	1
PCB-1260	$\mu\text{g/L}$	1	1
Phenols	mg/L	0.001	0.05
Silvex	$\mu\text{g/L}$	0.1	0.1
Styrene	$\mu\text{g/L}$	5	25
Technical Chlordane	$\mu\text{g/L}$	0.5	0.5
Tetrachloroethene	$\mu\text{g/L}$	5	10
Toluene	$\mu\text{g/L}$	0.3	25
Toxaphene	$\mu\text{g/L}$	1	1
Trans-1,2-Dichloroethene	$\mu\text{g/L}$	5	5
Trans-1,3-Dichloropropene	$\mu\text{g/L}$	5	25
Trichloroethene	$\mu\text{g/L}$	5	25
Vinyl acetate	$\mu\text{g/L}$	2	50
Vinyl chloride	$\mu\text{g/L}$	10	50

RADS

Americium-241

Cesium-137

Gross α Gross β

Neptunium-237

Plutonium-238

Plutonium-239/240

Radium-228

Technetium-99

Thorium-228

Thorium-230

Thorium-232

Total Radioactive Strontium

Total Radium α

Tritium

Uranium-234

Table B.39 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Uranium-235			
Uranium-238			

^a Refer to Table D.6 in Appendix D for a list of wells and sample dates for this aggregate.

Table B.40. Minimum and maximum non-detects for groundwater in the Maynardville aggregate^a

Analyte	Units	Minimum non-detect	Maximum non-detect
<i>Inorganics</i>			
Aluminum	mg/l	0.02	0.1
Ammonia Nitrogen	mg/l	0.2	0.2
Antimony	mg/l	0.05	0.25
Arsenic	mg/l	0.005	0.005
Barium	mg/l	.	.
Beryllium	mg/l	0.0003	0.0006
Boron	mg/l	0.004	0.004
Cadmium	mg/l	0.002	0.003
Calcium	mg/l	.	.
Chloride	mg/l	1	1
Chromium	mg/l	0.01	0.05
Cobalt	mg/l	0.005	0.025
Copper	mg/l	0.004	0.02
Fluoride	mg/l	0.1	0.1
Iron	mg/l	0.004	0.005
Kjeldahl Nitrogen	mg/l	0.05	0.06
Lead	mg/l	0.004	0.02
Lithium	mg/l	0.004	0.004
Magnesium	mg/l	.	.
Manganese	mg/l	0.001	0.001
Mercury	mg/l	0.0002	0.00026
Molybdenum	mg/l	0.01	0.05
Nickel	mg/l	0.01	0.05
Niobium	mg/l	0.007	0.007
Nitrate	mg/l	0.11	1
Nitrite	mg/l	1	10
Potassium	mg/l	0.6	0.6
Selenium	mg/l	0.005	0.005
Silicon	mg/l	.	.
Silver	mg/l	0.01	0.01
Sodium	mg/l	.	.

Table B.40 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Strontium	mg/l	.	.
Sulfate	mg/l	1	5
Thallium	mg/l	0.01	0.01
Thorium	mg/l	0.2	1
Tin	mg/l	0.01	0.01
Titanium	mg/l	0.003	0.003
Total uranium	mg/l	0.001	0.003
Vanadium	mg/l	0.005	0.025
Zinc	mg/l	0.001	0.004
Zirconium	mg/l	0.005	0.005
<i>Organics</i>			
1,1,1-Trichloroethane	$\mu\text{g/l}$	0.8	25
1,1,2,2-Tetrachloroethane	$\mu\text{g/l}$	2	25
1,1,2-Trichloroethane	$\mu\text{g/l}$	5	25
1,1-Dichloroethane	$\mu\text{g/l}$	5	25
1,1-Dichloroethene	$\mu\text{g/l}$	5	25
1,2-Dichloroethane	$\mu\text{g/l}$	5	25
1,2-Dichloroethene	$\mu\text{g/l}$	5	25
1,2-Dichloropropane	$\mu\text{g/l}$	5	25
2-Butanone	$\mu\text{g/l}$	2	50
2-Chloroethylvinyl ether	$\mu\text{g/l}$	10	10
2-Hexanone	$\mu\text{g/l}$	1	50
4-Methyl-2-Pentanone	$\mu\text{g/l}$	1	50
Acetone	$\mu\text{g/l}$	1	50
Benzene	$\mu\text{g/l}$	2	25
Bromodichloromethane	$\mu\text{g/l}$	5	25
Bromoform	$\mu\text{g/l}$	5	25
Bromomethane	$\mu\text{g/l}$	10	50
Carbon disulfide	$\mu\text{g/l}$	2	25
Carbon tetrachloride	$\mu\text{g/l}$	5	10
Chlorobenzene	$\mu\text{g/l}$	5	25
Chloroethane	$\mu\text{g/l}$	10	50

Table B.40 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Chloroform	$\mu\text{g/l}$	0.6	25
Chloromethane	$\mu\text{g/l}$	10	50
Cis-1,3-Dichloropropene	$\mu\text{g/l}$	5	25
Dibromochloromethane	$\mu\text{g/l}$	5	25
Dimethylbenzene	$\mu\text{g/l}$	5	25
Ethylbenzene	$\mu\text{g/l}$	1	25
Methylene chloride	$\mu\text{g/l}$	0.5	25
Phenols	mg/l	0.001	0.05
Styrene	$\mu\text{g/l}$	5	25
Tetrachloroethene	$\mu\text{g/l}$	4	20
Toluene	$\mu\text{g/l}$	0.4	25
Trans-1,2-Dichloroethene	$\mu\text{g/l}$	5	10
trans-1,3-Dichloropropene	$\mu\text{g/l}$	5	25
Trichloroethene	$\mu\text{g/l}$	4	10
Vinyl acetate	$\mu\text{g/l}$	10	50
Vinyl chloride	$\mu\text{g/l}$	10	50

RADS

Americium-241

Cesium-137

Gross α Gross β

Neptunium-237

Plutonium-238

Plutonium-239/240

Radium-228

Technetium-99

Thorium-228

Thorium-230

Thorium-232

Total Radioactive Strontium

Total Radium α

Tritium

Table B.40 (continued)

Analyte	Units	Minimum non-detect	Maximum non-detect
Uranium-234			
Uranium-235			
Uranium-238			

^a Refer to Table D.6 in Appendix D for a list of wells and sample dates for this aggregate.

Table B.41. Analyses eliminated for use due to high total suspended solids, sodium, or chloride

Well	Analysis
GW-005	Aluminum, iron, cadmium, lead, mercury, strontium, uranium
GW-040	Aluminum, iron
GW-042	Cadmium
GW-071	Boron
GW-075	Boron
GW-085	Strontium
GW-086	Aluminum, iron
GW-117	Molybdenum
GW-118	Iron, strontium
GW-119	Molybdenum, strontium
GW-211	Strontium
GW-343	Aluminum, iron
GW-344	Strontium
GW-371	Strontium
GW-531	Aluminum, iron
GW-537	Barium, strontium
GW-623	Boron
GW-705	Boron, copper, iron, lead, manganese, zinc

Table B.42. Analytical holding times and preservatives

Parameter	Analytical holding time	Preservative
Volatile organic analytes	14 d	HCl to pH <2 Cool to 4° C
Semivolatile organic analytes	7 d ^a 40 d ^b	Cool to 4° C
Pesticides/PCBs	7 d ^a 40 d ^b	Cool to 4° C
Metals (except mercury)	180 d	HNO ₃ to pH <2
Mercury	28 d	HNO ₃ to pH <2 Cool to 4° C
Radiochemical parameters	180 d	HNO ₃ to pH <2

^a Represents holding times from sampling to extraction.

^b Represents holding times from sampling to analysis.

Table B.43. Index of available numbers of samples from each source and media providing qualitative or quantitative information

Data source	Media					
	Groundwater	Surface water	Soil	Sediment	Waste	Biota
BCV OU 1	QN(16) ^a	QN(2)	QN(277)		QN(1)	
BCV OU 4		QN(231)				
Floodplain soil			QN(276)	QN(23)	QL	
Ecological						QN ^b /QL
Historical	QN(5000)	QN(450); QL	QL	QL	QL	

^a Approximate number of samples shown in parentheses.

^b In progress.

QL - Qualitative

QN - Quantitative

Table B.44. Audits and surveillances of Bear Creek field activities

Audit/surveillance	Project	Type of audit/surveillance and activity observed	Findings/issues
ETS-94-017	BCV OU 1	QA—Soil sampling and documentation	None.
ETS-93-009	BCV OU 2	QA—Soil sampling, sample packaging and shipment, chain-of-custody implementation, decontamination of sampling devices, operation of safety equipment.	<p>To ensure that adequate sample volumes are collected, as often as possible, 3-in. diameter spoons should be used.</p> <p>To reduce the chance of cross-contamination between collected samples and clean sampling equipment, at least one additional table should be obtained for the storage of clean equipment. One table should be dedicated solely to sample collection.</p> <p>To ensure traceability of instrument readings to the instruments, all information pertaining to screening instruments required in the Cooler Shipping Log should be obtained and recorded.</p>
ETS-93-010	BCV OU 2	QA—Decontamination pad, calibration for HNU organic vapor meter and MX-261 combustible gas meter.	None.
ETS-93-015	BCV OU 2	QA—Groundwater sampling.	None.
ETS-93-016	BCV OU 2	QA—Sediment sampling.	None.
Sept. 20, 1993	BCV OU 2	QA—Assess implementation of requirements of work plan; hollow stem auger split spoon sampling, equipment decontamination.	Unapproved substitution of High Performance Liquid Chromatography (HPLC) water in place of American Society for Testing and Materials (ASTM) Type II water used in the final rinse for decontaminating sampling equipment.
ETS-94-005	BCV OU 2	QA—Field crew decontamination of sampling equipment.	None.
ETS-94-006	BCV OU 2	QA—Soil sample collection using shelby tubes, well installation.	None.
ETS-94-007	BCV OU 2	QA—Surface water sampling using a dipper.	None.

Table B.44 continued

Audit/surveillance	Project	Type of audit/surveillance and activity observed	Findings/issues
ETS-94-008	BCV OU 4	QA—Installation of stormflow tubes.	From the procedure, it is unclear as to whether sand poured in the annular space is to act as a true sand pack, or to just provide support for the tube. If the sand is to act as a true pack, an alternative method of emplacement may be required. Theoretical calculations of the amount of sand needed to fill the annular space and measures of actual amounts used may provide an indication of sand "pack" quality.
ETS-94-010	BCV OU 4	QA—Collection of surface water sampling using a dipper and automatic sampler.	<p>Currently, the rate at which "flow-paced" samples are collected is determined and programmed in the field by Energy Systems Field Team Members based on anticipated stream flow conditions. It is recommended that a field change order be written to document that this is the required methodology.</p> <p>It is recommended that a field change order be written to allow for the collection of VOC fractions by the dipping method. If the dipping method is used, however, great care must be taken to insure that the preservative is not lost from the sample container during sample collection.</p> <p>Currently there is no compositing procedure in the project-specific procedures manual. It is recommended that the procedure used for compositing be added to the procedures manual.</p>
ETS-94-011	BCV OU 4	QA—Ensure presence of required records on-site; assess sample packaging and shipment; ensure required completion of sample tags, labels, and chain-of-custody forms; ensure proper completion of logbooks pertaining to surface water sample shipping.	None.
ETS-94-012	BCV OU 4	QA—Setup of the decontamination line, performance of the decontamination procedure, and the completion of decontamination logbook.	None.

Table B.44 continued

Audit/surveillance	Project	Type of audit/surveillance and activity observed	Findings/issues
Y-12/ER-94-006	BCV OU 4	QA—Sample collection and decontamination.	<p>There is no assurance now that all procedures have been reviewed and approved for use by Y-12 ER because the procedures manual, which was updated by the 2/23/94 sheet stating that all procedures were reviewed and approved for use by Y-12 ER, is out-of-date.</p> <p>RECOMMENDATION: Either mark a procedure indicating that it is the subject of a field change or file the change orders with the appropriate procedure(s).</p> <p>Field change logs are not being kept up-to-date.</p> <p>Original chain-of-custody forms are not returned from the analytical labs; thus, the original records are not available for project archiving.</p>
ER/Y-95-002	BCV FPSS	QA—Maintaining Temperate Cooler log, calibration of field measurement instrumentation, project management.	<p>The cooler log on 3/30/95 indicates a time gap in checking the cooler temperature of 2 hours and 18 minutes (occurred between 11:50 and 14:08).</p> <p>Positive response verification checks were not performed as often as specified in the above requirements.</p> <p>Discrepancies appear to exist in COC versus field logbooks about times when samples were delivered to the Y-12 Plant laboratory.</p> <p>Legibility of logs is not maintained through the copying process.</p> <p>Apparent incorrect date entries made in the temperature cooler log.</p>

Table B.44 continued

Audit/surveillance	Project	Type of audit/surveillance and activity observed	Findings/issues
ER/Y-95-002 (continued)			<p>Copies of Project Nonconformance Reports are not being provided to the Y-12 ER Quality staff in a timely manner.</p> <p>Field Change Requests are not being filed to provide project specific directions, i.e., to progress from purposely generic and vague directions from the Sampling and Analysis Plan.</p> <p>Complete information is not being provided via the logs when an unscheduled event (and/or variations from the norm) occurs, or what the final resolution was (e.g., 3/30/95 failure of counter).</p>
ER/Y-95-005	BCV Floodplain SS	QA—Data handling.	None.
ETS-95-008	BCV Floodplain SS	QA—Subsoil sampling using a JMC Backsaver soil sampler.	<p>Clarification to Procedure ER/C-P2302 as written should specify the type of glove to be worn during sampling, depending on anticipated site conditions.</p> <p>It was stressed that a sampling spoon be used only for the sample depth interval taken from that spoon. Sample spoons from associated overlying sample intervals will be used if a boring has to be deepened before a sample is taken. This will ensure that, if additional sample is needed for analysis from the intermediate or lowest sample interval, the spoon for that sample will not have been used to remove overlying soil.</p>
ETS-95-010	BCV Floodplain SS	QA—Observe control and documentation of field changes to approved Field Sampling Plans.	None.

Table B.44 continued

Audit/surveillance	Project	Type of audit/surveillance and activity observed	Findings/issues
ETS-95-011	BCV FPSS	QA—Sample classification, packaging, marking, and shipping.	By definition in the procedure, transportation of environmental screening samples within the plant boundary is considered as an off-site shipment and the requirements for shipment are the same as if the samples were being sent to an off-site, contracted laboratory. Based on this, deficiencies were observed and documented on the attached Procedures Checklist. These samples are hand-carried and in custody of the sampling team until transfer to the Y-12 Analytical Laboratory.
ETS-95-012	BCV FPSS	QA—Manual chain-of-custody and field logbook procedures.	A deficiency was noted in the designation of QC samples (in particular the duplicate samples). No duplicate samples are being taken during initial screening sampling at the transverses.
ETS-95-013	BCV FPSS	QA—Observe decontamination procedures of sampling devices and equipment.	A final rinse with organic-free water, as listed on the attached Procedure Checklist, was not done. Sufficient time was allowed for the isopropanol from the previous rinse to evaporate before the sampling equipment was used. This is consistent with the requirements of ESP-801.

ASTM - American Society for Testing and Materials
 FPSS - Floodplain soil/sediment
 HPLC - High Performance Liquid Chromatography
 QA - Quality assurance
 QC - Quality control

Table B.45. SPARCC parameter criteria for BCV OU 4, OU 1, and FPSS projects

Parameter	BCV OU 4	BCV OU 1	BCV FPSS
Sensitivity	—	—	—
Precision	No criteria established	Laboratory duplicates ±20% RPD for rad/inorganic ±lab criteria for organic	Laboratory duplicates ±20% RPD for rad/inorganic ±lab criteria for organic
Accuracy	No criteria established	±20% recovery for rad/inorganic ±lab criteria for organic	±20% recovery for rad/inorganic
Representativeness	—	Qualitative parameters	
Comparability	—	—	—
Completeness	No criteria established	95% collection 90% overall 100% at background locations	95% collection 90% overall 100% at background locations

RPD - Relative percent difference

FPSS - Floodplain soil/sediment

Table B.46. Accuracy in the BCV OU 4, OU 1, and FPSS datasets

Matrix	Organic	Inorganic	Radiochemical
Soil	No significant problems with accuracy of data	<ul style="list-style-type: none"> • Zinc biased high (FPSS) • Antimony biased low (OU 1 and FPSS) • Selenium biased low (FPSS) • Silver biased low (FPSS) 	No significant problems with accuracy of data
Sediment		No significant problems with accuracy of data	
Groundwater		<ul style="list-style-type: none"> • Aluminum biased high (OU 1) • Antimony biased low (OU 1) 	
Surface water		<ul style="list-style-type: none"> • Mercury, cyanide, antimony, aluminum, iron, lithium, silver biased low (OU 4) 	<ul style="list-style-type: none"> • ^{234}U poor accuracy. Data can be biased in either direction (OU 4)

Table B.47. Overall precision in the BCV RI dataset

Media	Organic	Inorganic	Radiochemical
Soil	Precision considered acceptable.	Overall precision acceptable. Very few arsenic and manganese values qualified (FPSS) due to poor precision.	Precision considered acceptable.
Sediment		<ul style="list-style-type: none"> Minimal effects on precision indicated for aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, and potassium. Data qualified as necessary. (FPSS) 	<ul style="list-style-type: none"> ^{99}Tc, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, and ^{238}U FPSS sediment data of poor precision and not qualified in the dataset.
Groundwater		Precision considered acceptable.	Precision considered acceptable.
Surface water		<ul style="list-style-type: none"> Poor overall precision for OU 4 aluminum, iron, manganese, and dissolved aluminum. Dissolved aluminum precision estimated in OU 1 data as well. 	<ul style="list-style-type: none"> Total and dissolved gross α for OU 4 estimated due to poor precision ^{235}U OU 4 values estimated due to poor laboratory precision.

FPSS - Floodplain soil/sediment

Table B.48. BCV OU 4 samples that may have been mis-identified during analysis

Sample	Gross α (pCi/L)		$^{233}\text{U}/^{234}\text{U}$ (pCi/L)		^{235}U (pCi/L)		^{238}U (pCi/L)		Gross β (pCi/L)	
	Total	Dslvd	Total	Dslvd	Total	Dslvd	Total	Dslvd	Total	Dlvd
SS6008	1.9	-2	25.5	.4	2.05	-.03	50.3	0.5	2.89	0.8
SN5008	1.54	-3	35.6	0.2	4.96	0.2	71.3	0.3	1.36	-7
SB9017	107	59.5	0.36	26	0.29	.96	0.37	56	61.3	60.2
SN3016	766	450	0.68	181	0.12	14	0.88	41	214	254

Table B.49. Data usability in the BCV OU 4, OU 1, and FPSS datasets

Matrix	Organic	Inorganic	Radiochemical
Soil	<ul style="list-style-type: none"> • 11/46 pesticide/PCB values negatively biased due to exceedance of analytical holding time (FPSS) • Di-n-butylphthalate (OU 1) poor sensitivity • MeCl₂ and acetone sensitivity (FPSS) 	<ul style="list-style-type: none"> • Arsenic, cadmium, lithium, sodium, and manganese data poor sensitivity (FPSS) • Zinc generally biased high (FPSS) • Antimony generally biased low (OU 1 and FPSS) • Selenium generally biased low (FPSS) • Silver generally biased low (FPSS) • W00221 and W00321 copper non-representative of OU 1 	<ul style="list-style-type: none"> • B01511 ²¹²Pb non-representative of OU 1 • ²⁴³Cm, ²²⁸Th, ²³⁰Th, ²³²Th poor sensitivity (FPSS)
Sediment	<ul style="list-style-type: none"> • 1/26 herbicides and VOAs, 3/26 pesticides and SVOAs negatively biased due to exceedance of analytical holding time (FPSS) • Herbicides, acetone, and MeCl₂ poor sensitivity (FPSS) 	<ul style="list-style-type: none"> • Aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, potassium precision caused FPSS data to be estimated • Cadmium and sodium poor sensitivity (FPSS) 	<ul style="list-style-type: none"> • ⁹⁹Tc, isotopic thorium, isotopic uranium FPSS data of poor precision • ²²⁸Th, ²³²Th poor sensitivity (FPSS)
Groundwater	No significant, unqualified challenges to data usability.	<ul style="list-style-type: none"> • Aluminum positively biased (OU 1) • Antimony generally biased negatively (OU 1) 	No significant, unqualified challenges to data usability

Table B.49 continued

Matrix	Organic	Inorganic	Radiochemical
Surface water	<ul style="list-style-type: none"> • 15/243 VOAs negatively biased due to insufficient preservation (OU 4) • SB9115 2-butanone value considered non-representative of OU 4 • MeCl₂ poor sensitivity (OU 4) 	<ul style="list-style-type: none"> • Mercury, cyanide, antimony, aluminum, iron, lithium, and silver generally biased low (OU 4) • Aluminum, iron, manganese, and dissolved aluminum OU 4 data of poor precision • Dissolved aluminum OU 1 data of poor precision • SS8009 lead not representative of OU 4 • Dissolved aluminum and dissolved iron poor precision (OU 4) 	<ul style="list-style-type: none"> • Total and dissolved gross α estimated due to poor precision (OU 4) • SS6008, SN5008, SB9017, and SN3016 isotopic uranium values unusable • SN3009, and SN3010 non-representative ²³⁵U values (OU 4) • ²³⁴U generally poorly accurate and poor sensitivity for OU 4 samples • ²³⁴U OU 4 data estimated due to poor precision • ⁹⁹Tc sensitivity poor at NT3. Data considered unusable.

**B.13 SUPPORTING INFORMATION
FOR APPENDIX B—LITHOLOGIC LOGS**

LITHKEY

in.

ft above MSL

LOGGED BY

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

26.00

ft bgs

BOREHOLE NUMBER

LITHKEY

COORDINATES

BOREHOLE DIAMETER

in.

SAMPLING DEVICE

ELEVATION

ft above MSL

LOGGED BY

SAMPLE INFORMATION

DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water
---------------	--------------	------------------	-------------------------	-------

STRATA

LITHOLOGIC DESCRIPTION

ELEVATION
FEET

20

25

Weathered shale

Chert

Clay with rock fragments

No Recovery

Clay with chert fragments

Fill

Limestone

LOCATION

BCV OU 1

TOTAL DEPTH

11.50

ft bgs

BOREHOLE NUMBER

S3-01

COORDINATES N 30,427.20 E 52,537.40

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1010.80 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	S01011	11.0	150/80	MOIST		(0.0-1.0) Moderate yellowish brown (10YR5/4) clay-CL, contains some rootlets and some iron staining, very few small frag of olive grey (5Y 4/1) shale.	1010
						(1.0-1.5) Light brown (5YR5/6) clay-CL mottled w/ dark yellowish orange (10YR6/6) completely weathered chert, dry and brittle.
						(1.5-2.0) No recovery.	
	S01012	10.0	150/80	MOIST		(2.0-4.0) Light brown (5YR5/6) clay CL w/ approx 75% weathered (5Y4/1) olive grey to a dark yellowish brown (10YR4/2) shale. Moist shale has a moderate reddish brown (10R4/6) staining. Some shale has completely weathered to a very light grey (N8) clay. Shale is thinly laminated and micaceous.	1005
						(4.0-5.5) Same as above.

10	S01013	7.9	80/80	MOIST		(7.4-8.0) Same as above but slightly moist and exhibiting some black organic staining on bedding planes breaks up in larger frag. than top of spoon. (8.0-10.0) Same as above but large lenses of more silty shale (approx 10mm in width) also approx 5 mm in width layers of completely weathered very light grey (N8) shale-clay. Shale is more weathered and brittle, dry shale layers also exhibit undulating pattern.	1000

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/16/94** ENDED **11/16/94**

REMARKS S-3IN=SPLIT SPOON (3in.)

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1 TOTAL DEPTH 15.40 ft bgs

BOREHOLE NUMBER S3-02

COORDINATES N 30,062.00 E 52,391.80

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1001.80 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION

DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water	STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
						(0.0-1.0) Gravel.	
	S02011	4.2	60/60			(1.0-1.5) Silty clay -CL- moderate brown (5YR4/4) containing approx. 30% dark yellowish brown (10YR4/2) to light grey (N7) thinly laminated shale fragments dry.	1000
			60/60			(1.5-2.0) No recovery.	
			60/60			(2.0-3.5) Silty clay - CL dark yellowish brown (10YR4/2) clay w/ approx. 80% olive grey (5YR4/1) thinly laminated / micaceous shale exhibiting moderate brown (5YR4/4) weather staining. Some shale frag are a med. dark grey (N3 in color). The bottom 0.3 ft of the spoon contained large light grey (N7) limestone frag - fine grained micrite, dry.	
						(3.5-4.0) No recovery.	
5			60/60			(4.0-5.2) Same as above.	
	S02012		60/60	MOIST		(5.2-6.0) Fine clay -CL moderate yellowish brown (10YR5/4). At transition to clay shale is a dark greenish grey (5GY4/1) to a medium bluish grey (5B5/1) in color still micaceous. Bottom of clay is rather homogeneous except for occasional small pocket of organics (black clay). Bottom clay getting slightly moist.	995
			60/60			(7.0-8.0) Becomes 50% mottled w/light grey (N7) clay becomes more firm w/increased grey clay contact slightly moist.	
			60/60			(8.0-9.2) Clay (CL) moderate yellowish brown (10YR5/4) clay w/ 80% moderate brown (5YR3/4) to light grey (N7) thinly laminated micaceous weathered shale w/ moderate brown (5YR4/4) weathered staining (iron).	
10	S02013	NA	60/60	MOIST		(9.2-10.0) Moderate brown (5YR4/4) clay (CL) mottled w/ >60% light grey (N7) clay, slightly firm and slightly moist not as firm as bottom of last spoon.	
			60/60			(10.0-11.3) Silty clay -CL- dark yellowish brown (10YR4/2) thinly laminated micaceous shale (approx 80%) breaks into small pieces, crumbles dry.	
						(11.3-11.5) Contains approx 60% clay and it is mottled w/ grey (N7) clay.	
						(11.5-12.0) No recovery.	990
	S02014		60/60			(12.0-14.0) Same as bottom of last spoon w/ bottom 0.4 ft (13.6-14.0) becoming slightly lighter in color - pale brown (5YR5/2).	
			60/60			(14.0-15.4) Same as bottom of last spoon but only slightly weathered. Refusal - shale bedrock at 15.4 ft BGS.	

DRILLING CONTRACTOR OGDEN
 DRILLING METHOD HOLLOW STEM AUGER
 DRILLING EQUIPMENT CME-75

REMARKS S-3IN=SPLIT SPOON(3in.)

Coordinates are reported in Y-12 Grid

TOTAL DEPTH

SAMPLING DEVICE S-3IN

BOREHOLE DIAMETER 8 in.

LOGGED BY S.L.ABSTON

DRILLING CONTRACTOR	OGDEN		
DRILLING METHOD	HOLLOW STEM AUGER		
DRILLING EQUIPMENT	CME-75		
DRILLING STARTED	11/22/94	ENDED	11/22/94

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

22.90

ft bgs

BOREHOLE NUMBER

S3-04

COORDINATES N 30,136.50 E 51,853.40

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1004.50 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	S04011	NA	80/80	MOIST		(0.0-0.2) Small limestone gravel in 80% lime - moist sand. (0.2-0.4) Crusher run w/ larger limestone gravel frag. (0.4-2.0) (7.5YR4/4) brown clay w/75% brownish grey (5YR4/1) to medium grey (N5) micaceous thinly to medium bedded shale frag. Some shale exhibits moderate reddish brown (10R4/6) staining and (5YR4/4) moderate brown staining - dry. (2.0-3.0) Same as bottom of last spoon but w/ increasing amounts of olive grey (5Y4/1) shale.	1000
			80/80			(3.0-4.0) Asphalt (approx. 10%) bottom of spoon has a large concrete fragment approx. 3" in length w/pebbles in it, dry.	
5	S04012		80/80	MOIST		(4.0-6.0) Top .9 ft same as above w/transition into a moist dark greyish brown to a olive grey (5Y4/2) clay mottled w/ (10YR6/6) brownish yellow clay-turning into a more brittle, dry (10YR4/3) brown clay mottled w/some yellowish brown (10YR5/8) clay w/rootlets w/some small shale frag. brownish grey (5YR4/1).	
			80/80			(6.0-6.2) Same as bottom of last spoon. (6.2-7.1) Very weathered, brittle, dry, greyish red (10R4/2) shale micaceous exhibiting (10YR6/6) dark yellowish orange (10GY5/2) staining.	
			80/80	MOIST		(7.1-8.0) Slightly weathered greyish red (10R4/2) micaceous shale w/ dark yellowish orange (10YR6/6) and black staining dry. Some bedding planes exhibit a greenish grey surface. (8.0-10.0) Top 1.7 ft same as above grading into a more moist shale - greyish red (10R4/2) thinly bedded, micaceous w/some layers being light grey (N7) in color and completely weathered. Some surfaces have a (10R4/8) red color.	995
10	S04013		80/80			(10.0-10.3) Same as bottom of last spoon. (10.3-12.0) (7.5YR4/8) silty clay (CL) strong brown weathered shale w/60-70% (7.5YR6/1) grey clay- completely weathered shale layers. Some bedding planes exhibit (7.5YR6/8) reddish yellow staining, dry.	
			80/80			(12.0-13.0) Same as above.	
	S04014		80/80			(13.0-14.0) Same as above, becoming more competent, still brittle but only moderately weathered dry. Some bedding planes also exhibit black staining shale is micaceous. Only about <5% of the grey completely weathered shale. (14.0-16.0) Light brown (5YR5/6) weathered massive shale/siltstone w/ some layers (N7) light grey completely weathered shale. Black and dark yellowish orange (10YR6/6) staining predominant, dry.	

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/21/94** ENDED **11/22/94**

REMARKS **S-3IN=SPLIT SPOON(3in.)**

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1** TOTAL DEPTH **22.90** ft bgs
 BOREHOLE NUMBER **S3-04**
 BOREHOLE DIAMETER **8** in. SAMPLING DEVICE **S-3IN**
 LOGGED BY **S.L. ABSTON**

COORDINATES **N 30,136.50 E 51,853.40**ELEVATION **1004.50** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20		NA	80/80			(16.0-17.3) Same as last spoon w/grey clay being moist. (17.3-17.7) Very thinly laminated avulating dark yellowish brown (10YR4/2) shale with some layers of the (N7) light grey (completely weathered) shale clay. (17.7-18.0) Greyish red (10R4/2) thinly laminated brittle weathered shale. (18.0-20.0) Spoon wet - split spoon sample not same as above. Alternating w/10mm thick beds of very weathered (10YR5/4) moderate yellowish brown siltstone. .2mm thick layers of thinly laminated brittle weathered (10R4/2) shale. (20.0-21.5) Sample is saturated at the top greyish brown (5YR3/2) micaceous thinly laminated, moderately weathered shale, brittle, moist. (21.5-22.0) No recovery. (22.0-22.9) Split spoon refusal at 22.9 ft BGS. Same as above w/light brown (5YR5/6) and black weather staining less weathered only slightly dry.	985
				MOIST			
	S04015		80/80				
			80/80	WET			
			80/80				
	S04016		80/80

LOCATION BCV OU 1 TOTAL DEPTH 8.80 ft bgs

BOREHOLE NUMBER S3-05

COORDINATES N 30,380.70 E 51,801.90

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1005.00 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
5	S05011	NA	80/80			(0.0-0.2) Crushed limestone gravel and asphalt. (0.2-2.0) Crushed limestone gravel, crusher run -fill, dry.	1005	
			80/80			(2.0-4.0) Crusher run limestone gravel and crushed limestone fill, dry.		
	S05012		80/80	WET			(4.0-4.6) Same as above but wet.	
			80/80				(4.6-6.0) No recovery.		1000
	S05012		80/80	WET			(6.0-7.0) Same as above - more gravel size limestone toward the bottom, very wet.	
			80/80				(7.0-8.0) No recovery.	
	S05013		80/80				(8.0-8.2) Lime sand.	
			80/80	WET			(8.2-8.7) Coarse grainsize limestone w/some dolostone frag. (8.7-8.8) Very compacted dense crusher run w/ gravel wet. Split spoon refusal at 8.8 ft BGS.	

DRILLING CONTRACTOR OGDEN
 DRILLING METHOD HOLLOW STEM AUGER
 DRILLING EQUIPMENT CME-75
 DRILLING STARTED 11/21/94 ENDED 11/21/94

REMARKS S=SPLIT SPOON

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 2

LOCATION BCV OU 1 TOTAL DEPTH 18.80 ft bgs
 BOREHOLE NUMBER S3-06
 BOREHOLE DIAMETER 8 in. SAMPLING DEVICE S-3IN
 LOGGED BY S.L. Abston

COORDINATES N 30,424.60 E 51,936.50

ELEVATION 1011.60 ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
5	S06011	NA	80/80	MOIST		(0.0-1.6) (5YR5/6) yellowish red clay -CL- slightly moist w/ (N7) light grey weathered chert frag., rootlets throughout, slightly brittle to hard, some magnesium nodules - black - fill.	1010
						(1.6-2.0) No recovery.	
			80/80			(2.0-4.0) Same as above. Some chert completely weathered. Some fragments of coal. Bottom .2 ft limestone gravel (~80%) in a (10YR4/3) brown brittle, dry, clay - CL, fill.	1005	
			80/80	MOIST		(4.0-6.0) Same as bottom of last spoon w/ ~60% gravel and some brick frags. The bottom of spoon has large concrete frags. (concrete w/ gravel filler), slightly moist.		
			80/80			(6.0-7.3) All red brick frag. and light grey (5YR7/1) brick mortar - does not fizz w/HCL but is attached to the bricks. The bottom .05 ft. of the spoon had (10YR4/3) brown clay.
					(7.3-8.0) No recovery.		
	10		S06013	80/80	MOIST		(8.0-8.3) Same as bottom .05 ft of above spoon w/ smell, brick frag., brittle, dry. (8.3-9.5) (10YR6/6) brownish yellow clay mottled w/ traces of (10YR5/6) yellowish brown clay and black streaks of weathered chert, slightly moist.	1000
							(9.5-10.0) Darker (10YR4/2) dark greyish brown clay mottled w/ (10YR5/6) yellowish brown clay - slightly moist, grey clay are soft - CL. (10.0-10.3) Same as above.
				80/80			(10.3-12.0) Same as above w/ the grey clay becoming (10YR6/2) light brownish grey weathered shale w/ alot of black staining on bedding planes, slightly moist. Some shale layers are (N7) light grey completely weathered shale (clay), soft.	
				80/80			(12.0-14.0) Same as bottom of last spoon. Top .4 ft was 80% black weather stained. Increasing amounts of the grey (N7) chert frag, large, inside of chert is black w/ small reddish brown zone between the grey outside and black inside. Bottom .4 ft of spoon is a light olive brown (5Y5/6) slightly weathered shale - dry.	
	S06014					(14.0-15.8) Same as bottom of last spoon. Many bedding planes exhibit black weathered staining.		

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/28/94** ENDED **11/28/94**

REMARKS **S=SPLIT SPOON**

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 2

LOCATION BCV OU 1 TOTAL DEPTH 27.90 ft bgs
 BOREHOLE NUMBER S3-07
 BOREHOLE DIAMETER 8 in. SAMPLING DEVICE S-3IN
 LOGGED BY S.L. ABSTON

COORDINATES N 30,178.90 E 51,991.30

ELEVATION 1008.10 ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/gamma (cpm)	water			
5	S07011	8.6	60/60			(0.0-1.7) (5YR5/6) yellowish red clay - CL with rootlets some (2.5Y7/4) pale yellow clay and contains (7.5YR8/2) pinkish white weathered chert and medium dark grey (N4) limestone fragments.	1005
				MOIST		(1.7-2.0) Limestone gravel and crushed gravel (crusher run) slightly moist.	
				WET		(2.0-2.2) Crusher run, saturated.	
				MOIST		(2.2-2.7) (5YR5/6) yellow red, moist clay (CL) with (10YR8/4) very pale brown weathered chert.	
5	S07012	2.9	400/60			(2.7-3.3) (N4) medium dark grey shale.	1000
						(3.3-4.0) (10YR 4/3) brown clay with 50% limestone gravel fragments (this section is the 400 cpm b/gamma), wet.	
				WET		(4.0-4.6) Split spoon refusal at 4.6 ft BGS on concrete - same as bottom of last spoon, saturated (some asphalt).	
						(4.6-6.0) No recovery.	
10	S07013	4.1	200/60			(6.0-7.0) Same as above, saturated.	995
				WET		(7.0-7.2) Concrete. Top section had large asphalt fragments composite b/gamma 400 cpm.	
				MOIST		(7.2-8.0) (10YR5/6) yellowish brown silty clay - CL w/ weathered chert frag, olive green shale frag, asphalt, small limestone gravel, wood, slightly moist. 600 cpm.	
						(8.0-8.6) (5YR5/6) yellowish red clay - CL with limestone gravel fragments.	
10	S07014	35.0	2000/60	MOIST		(8.6-8.8) (10YR4/3) brown clay with rootlets (hottest with b/gamma meter). Traces of (5YR4/6) yellowish red (orange) fibrous material - very small probably plant material.	995
						(8.8-9.0) (5YR5/8) yellowish red clay mottled w/ (7.5YR5/4) brown clay, rootlets. Brown clay more moist than yellowish red clay.	
						(9.0-10.0) (10YR5/4) moderate yellowish brown thinly laminated shale, brittle, dry with moderate reddish brown (10YR4/6) staining. Spoons are wet on outside.	
						(10.0-10.8) Same as bottom of last spoon.	
10	S07014	35.0	150/60			(10.8-12.0) (5YR5/6) yellowish red clay layered with (7.5YR7/2) pinkish gray clay - CL completely weathered shale exhibiting bedding plane fabric - moist.	995
						(12.0-14.0) Same as bottom of last spoon with yellowish red becoming less weathered and having black staining on the bedding planes, slightly moist solvent odor.	
				MOIST		(14.0-14.4) Same as above.	
						(14.4-15.2) (5YR4/1) brownish grey thinly bedded with black weather stain on bedding planes shale.	

DRILLING CONTRACTOR OGDEN
 DRILLING METHOD HOLLOW STEM AUGER
 DRILLING EQUIPMENT CME-75
 DRILLING STARTED 11/29/94 ENDED 11/29/94

REMARKS S=SPLIT SPOON

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

27.90

ft bgs

BOREHOLE NUMBER

S3-07

COORDINATES N 30,178.90 E 51,991.30

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1008.10 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			150/60	MOIST		(15.2-16.0) Almost completely weathered (N8) light grey and light brown (5YR5/6) shale with black staining on bedding planes. Slightly moist about 70% grey and 30% brown.	
						(16.0-16.3) (5YR5/2) reddish gray silty, dry brittle clay -CL	
			200/60			(16.3-16.7) (10YR5/6) yellowish brown clay mottled with (7.5YR3/3) dark brown clay and (7.5YR8/2) pinkish white clay.	
						(16.7-18.0) Same as bottom of last spoon, solvent odor.	
	S07015	6.9	200/60			(18.0-20.0) Same as bottom of last spoon - moist solvent smell-odor.	990
20							
			200/60				
						(20.0-20.6) (7.5YR4/3) brown silty clay.	
			200/60	MOIST		(20.6-22.0) Moderate brown (5YR3/4) shale interbedded with moderate (5YR4/4) siltstone slightly weathered moist, solvent odor.	
	S07016	43.0				(22.0-24.0) Same as bottom of last spoon, brittle, slightly moist. Strong nitric odor.	
			200/60				985
						(24.0-25.8) Same as above. Not as strong of an odor. Very wet zone at 24.9 ft BGS.	
25			150/60	WET			
						(25.8-26.0) (5YR5/2) pale brown thinly bedded, slightly weathered shale.	
	S07017	4.6				(26.0-26.4) Same as bottom of last spoon.	
			100/60			(26.4-27.9) Split spoon refusal at 27.9 ft BGS. Dark yellowish brown (10YR4/2) thinly bedded only slightly weathered black on bedding planes shale.

SHEET 1 OF 1

LOCATION

BCV OU 1

TOTAL DEPTH

12.00

ft bgs

BOREHOLE NUMBER S3-08

COORDINATES N 30,173.30 E 52,368.30

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1006.00 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			80/80			(0.0-1.2) (10YR4/4) dark yellowish brown silty clay -CL- with rootlets, concrete fragments, limestone fragments (7.5YR4/3) shale fragments.	1005
						(1.2-1.5) Coal fragments and gravel layer.	
						(1.5-2.0) Dark reddish grey shale - slightly weathered, dry. (2.0-3.7) Same as bottom of last spoon.	
	S08011	4.7	80/80				
5			100/80	MOIST		(3.7-4.0) (10YR5/6) yellowish brown clay mottled w/ (2.5YR4/8) red and (10YR6/2) light brownish gray clay. Occasional layers of very weathered (10YR6/3) shale w/ black weather staining, plastic, slightly moist. (4.0-5.5) Same as above.	1000
	S08012	18.0				(5.5-5.8) Same as above with > 80% grey clay. (5.8-6.0) Same as above with > 50% grey clay, more plastic (completely weathered shale beds) slightly moist. (6.0-8.0) Geotechnical sample.	
	S08013		80/80			(8.0-9.2) Greyish red (10YR4/2), weathered, thinly laminated, brittle, shale w/ layers of (10YR6/2) light brownish grey, completely weathered shale - clay. (9.2-9.5) Brownish grey (5YR4/1) thinly laminated, micaceous, slightly brittle to hard shale. Some bedding planes exhibit (5YR5/6) light brown to orange iron staining, dry. Split spoon refusal at 9.5 ft BGS.	

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/17/94** ENDED **11/17/94**

REMARKS **S=SPLIT SPOON**

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 16.00

ft bgs

BOREHOLE NUMBER S3-09

COORDINATES N 30,656.50 E 52,080.10

BOREHOLE DIAMETER 8 in.

SAMPLING DEVICE S-3IN

ELEVATION 1018.00 ft above MSL

LOGGED BY S.L. ABSTON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	S09011	NA	60/60			(0.0-2.0) Silty clay (CL) light brown (5YR5/6) with rootlets, medium light grey (N6) limestone gravel fragments, moderate reddish brown (10Y4/6) weathered chert fragments and dark yellowish orange (10YR6/6) weathered shale, thinly laminated (~60-75% shale, bottom .5 ft), dry.	1015
			60/60			(2.0-4.0) Completely to moderately weathered shale light brown (5YR5/6) to pale yellowish brown (10YR6/2) mottled with organic shale layers. Shale almost weathered to clay, dry.	
	S09012		60/60	MOIST		(4.0-5.5) Same as above but moist and becoming more complete.	1010
						(5.5-6.0) No recovery.	
	S09013		MOIST		(6.0-6.4) Same as above. (6.4-7.4) Split spoon refusal at 7.4 ft BGS. Bottom of spoon light olive gray (5Y6/1) shale exhibiting (10YR5/4) moderate yellowish brown weathering staining. The shale is thinly bedded and micaceous, dry, brittle.	1005	
					(7.4-8.0) No recovery.		
			60/60				(8.0-9.2) Same as above, brittle. (9.2-9.5) Split spoon refusal at 9.5 ft BGS. Bottom of spoon is a light grey micaceous shale, much more resistant and only showing traces of weathering. (9.5-10.0) No recovery.
			60/60				(10.0-10.4) Same as above. (10.4-11.2) Very thinly bedded (N5) medium grey shale beds with staining (5YR5/6) light brown- occurring between bedding planes - bedding planes avolute and some exhibit black organic staining and appear to be at a high angle to the spoon.
	S09014		60/60	WET		(11.2-11.5) Exhibits a high angle of frac. in the split spoon core and having water it is a greyish brown (5YR3/2) highly silty clay-wet.	1005
			60/60	WET		(11.5-12.0) Resistant grayish brown (5YR3/2) shale exhibiting moderate brown (5YR4/4) and black weathering. Shale will break but not crumble. (12.0-13.4) Split spoon refusal at 13.4 ft BGS on a greyish brown (5YR3/2) shale exhibiting moderate brown (5 YR 4/4) and black weathering, wet. Refusal - only recovering shale and lab will not be able to run it.	

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/15/94** ENDED **11/15/94**

REMARKS S=SPLIT SPOON

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 1

LOCATION **BCV OU 1** TOTAL DEPTH **12.00** ft bgs
 BOREHOLE NUMBER **S3-10**
 BOREHOLE DIAMETER **8** in. SAMPLING DEVICE **S-3IN**
 LOGGED BY **S.L. ABSTON**

COORDINATES **N 29,781.00 E 50,793.00**ELEVATION **981.00** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	S10011	2.9	60/60			(0.0-2.0) Top .05 ft top soil- (10YR2/2) dusky brown silty clay CL-dark yellowish brown (10YR4/2) with (N6) (medium light gray) limestone fragments and siltstone - moderate brown (5YR4/4) -fill dry.	980
			60/60			(2.0-4.0) Silty clay -CL- (10YR4/2) dark yellowish brown with (N6) medium light gray limestone fragments and (5YR4/1) brownish grey thinly laminated shale fragments -fill, dry.	
	S10012	NA	60/60			(4.0-5.5) Same as above with some fragments (N3) dark grey calcareous thinly laminated shale fragments -fill, dry.	975
			60/60			(5.5-6.0) No recovery.	
10	S10013	NA	60/60			(6.0-8.0) Same as above- some shale appears micaceous- fill.	970
						(8.0-8.3) Same as above but softer.	
			60/60	MOIST		(8.3-9.1) Silty clay- moderate yellowish brown (10YR5/4) with large medium grey (N5) crystalline limestone fragments, dry and hard.	
				MOIST		(9.1-9.5) (5YR3/4) moderate brown clay, moist soft with plant rootlets, brick fragments, small thinly laminated micaceous (N3) dark grey shale fragments. (9.5-10.0) No recovery.	
						(10.0-11.3) Split spoon refusal @ 11.3 ft BGS. Same as above (bottom). Top very moist getting dry downward. Bottom contained concrete, coal, bricks, stems piece of wood, asphalt, and some greyish red (10R4/2) limestone fragments some (N3) dark grey thinly laminated shale fragments and some dark greenish grey (5 GY 4/1) shale fragments. Refusal at 11.8 ft BGS.	

DRILLING CONTRACTOR **OGDEN**
 DRILLING METHOD **HOLLOW STEM AUGER**
 DRILLING EQUIPMENT **CME-75**
 DRILLING STARTED **11/14/94** ENDED **11/14/94**

REMARKS **S=SPLIT SPOON**

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

35.00

ft bgs

BOREHOLE NUMBER

BG-01

COORDINATES N 29,638.60 E 43,459.60

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE

PROBE

ELEVATION 923.30 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B01011	NA	100			(0.0-2.0) Entire 2 ft. section (7.5YR5/6) strong brown, stiff, dry, clay with sparse frags of weathered white chert and (N3) very dark gray shale.	920
					(2.0-2.2) Same as above.		
	180			(2.2-4.0) (7.5YR5/2) brown weathered shale with bedding planes often filled with above brown clay, dry.			
					(4.0-4.2) (7.5YR5/6) strong brown clay.		
	B01012		180		(4.2-6.0) Same weathered shale as 2.2-4.0 ft section of above sample, dry.		
						(6.0-6.9) Same shale as above.	
	10		B01013	80		(6.9-8.0) Grades to (7.5YR5/8) strong brown clay mottled with < 20% (7.5YR7/1) light gray clay (completely weathered chert) (CL) dry.	915
						(8.0-8.3) Same as above.	
				80		(8.3-8.6) (2.5Y7/2) light gray silty clay. (8.6-10.0) (10YR7/8) yellow silty clay mottled with < 10% of gray clay above, dry.	
			B01014	80		(10.6-11.2) (10YR5/8) yellowish brown clay with large (~1.5 cm) frags of (10YR5/3) brown shale, dry.
					(11.2-12.0) No recovery.
	80			(12.0-13.5) (10YR4/3) brown slightly meta shale microcrystals observable with hand lens, weathered, dry.	910
				(13.5-14.0) No recovery.
				(14.0-15.2) Same as above.		

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 11/16/94 ENDED 11/17/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1** TOTAL DEPTH **35.00** ft bgs
 BOREHOLE NUMBER **BG-01**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 29,638.60 E 43,459.60**ELEVATION **923.30** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			80			(15.2-16.0) (10YR5/8) yellowish brown sandy clay, wet.	
						(16.0-18.0) Same as above, wet. (7.5YR5/3) brown shale layers 0.1 ft. thick at 16.2, 16.6 and 17.6 ft.	
			100	WET			
	B01015					(18.0-20.0) (7.5YR4/3) brown slightly weathered shale, dry.	905
			100				
20						(20.0-20.7) Same as above.	
			100			(20.7-21.6) (2.5Y7/4) pale yellow weathered shale, dry.	
	B01016	NA				(21.6-22.0) No recovery.	
			80			(22.0-24.0) (10YR4/3) brown weathered shale, dry.	900
						(24.0-25.0) Same as above, dry.	
25			80			(25.0-26.0) No recovery.	
	B01017					(26.0-27.0) (5YR5/2) reddish gray shale, dry, weathered.	
			80			(27.0-28.0) No recovery.	
						(28.0-29.0) Same as above.	895
			80			(29.0-29.4) (2.5Y4/2) dark grayish brown weathered shale.	
						(29.4-30.0) No recovery.	
30	B01018					(30.0-32.0) Same as above, dry.	
			80

TOTAL DEPTH	35.00	ft bgs
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BOREHOLE NUMBER BG-01

COORDINATES N 29,638.60 E 43,459.60

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE	PROBE
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ELEVATION 923.30 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
35	B01019	NA	80	WET		(32.0-32.6) Same as above, wet. Scattered frags of (5Y5/2) olive gray shale (< 1 cm).	890
						(32.6-34.0) No recovery.
						(34.0-34.6) Same as above.
						(34.6-35.0) Fragmented (7.5YR5/3) brown layered siltstone. Refusal at 35.0 ft BGS on siltstone.

SHEET 1 OF 3

LOCATION **BCV OU 1** TOTAL DEPTH **37.00** ft bgs
 BOREHOLE NUMBER **BG-02**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 29,655.00 E 43,746.60**ELEVATION **926.70** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5 <							

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/17/94** ENDED **11/18/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 37.00

ft bgs

BOREHOLE NUMBER BG-02

COORDINATES N 29,655.00 E 43,746.60

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 926.70 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			80				
						(15.5-16.0) No recovery.	
						(16.0-16.9) Same as above, dry.	
			80			(16.9-17.7) (10YR5/6) yellowish brown silty clay, wet.	910
	B02015			WET		(17.7-18.0) No recovery.	
						(18.0-20.0) (2.5Y5/4) light olive brown clay with micro layers of (10YR4/2) dark grayish brown stained zones, dry.	
20			80				
						(20.0-21.4) (10YR5/3) brown weathered shale, dry.	
			80			(21.4-21.8) (5Y5/3) olive, very weathered shale with infilling between layers with (2.5Y6/4) light yellowish brown clay, dry.	905
	B02016	NA				(21.8-22.0) No recovery.	
						(22.0-23.0) (7.5YR4/2) brown weathered shale, dry.	
			80			(23.0-24.0) No recovery.	
						(24.0-25.4) Same as above.	
25			80			(25.4-26.0) No recovery.	
	B02017					(26.0-27.5) (10YR4/2) dark grayish brown shale, moist. Some of same color clay. Moist to wet. Last 1.0 ft. very low resistivity to driving sampler.	900
			80	MOIST TO WET		(27.5-28.0) No recovery.	
						(28.0-30.0) (10YR5/1) gray weathered shale, dry.	
30			80			(30.0-31.5) (5Y5/2) olive gray shale, and above brown shale-mix (~50% each). Wet at 31.0 and 31.5 ft.	
	B02018						
			80			(31.5-32.0) No recovery.	895

LOCATION BCV OU 1

TOTAL DEPTH

37.00

ft bgs

BOREHOLE NUMBER BG-02

COORDINATES N 29,655.00 E 43,746.60

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 926.70 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
35	B02019	NA	80	WET		(32.0-33.0) (10YR4/3) brown weathered shale, wet.	890
						(33.0-34.0) No recovery.	
			80	WET		(34.0-35.4) Same as above - wet.	
						(35.4-35.5) (5Y5/4) olive shale frags, resistant, ~ 1.0 cm, wet.	
			80			(35.5-36.0) No recovery.	
				WET		(36.0-36.4) Same as above with 1 large frag (3 cm) of (N4) dark gray microcrystalline, wet. Refusal at 37.0 ft BGS (1410).

LOCATION **BCV OU 1**TOTAL DEPTH **20.25**

ft bgs

BOREHOLE NUMBER **BG-03**COORDINATES **N 29,701.80 E 44,208.10**BOREHOLE DIAMETER **1.25 in.**SAMPLING DEVICE **PROBE**ELEVATION **925.90** ft above MSLLOGGED BY **KEN SWAIN**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B03011	NA	<80			(0.0-1.0) (5YR5/8) yellowish red clay with yellow weathered chert. (1.0-2.0) (2.5Y6/6) olive yellow clay with (10YR5/3) weathered brown shale, dry.	925
					(2.0-3.0) (10YR5/3) brown shale with subordinate olive yellow clay (2.5Y6/6).	
			180		(3.0-3.2) (10YR5/8) yellowish brown clay with 5 mm frags of (10YR5/8) yellowish brown weathered chert. (3.2-4.0) No recovery.		
	B03012		<80			(4.0-4.5) (10YR5/2) grayish brown clay mottled with (5GY7/1) light greenish gray clay with one frag of weathered shale (5GY7/1). (4.5-5.0) (2.5Y5/4) light olive brown clay mottled with (7.5 YR 5/6) strong brown clay. (5.0-6.0) No recovery.	920
					(6.0-7.3) Same as above.	
			<80		(7.3-7.4) (5G6/1) greenish gray clay with (5YR5/8) yellowish red mottling (less than 10%). (7.4-8.0) No recovery.		
	B03013		<80	MOIST		(8.0-8.5) (2.5Y6/3) light yellowish brown clay, moist. (8.5-8.9) (5Y7/2) light gray silty clay, moist.
					(8.9-10.0) No recovery.	
			<80		(10.0-10.1) Same as above but dry.		
	B03014		<80			(10.1-12.0) Highly weathered (2.5Y6/6) olive yellow shale with sparse frags of brown weathered chert, dry.	915
					(12.0-12.8) Wet very weathered (2.5Y5/3) light olive brown shale.	
				WET MOIST	(12.8-13.0) (2.5Y5/2) grayish brown slightly weathered shale, moist. (13.0-14.0) (7.5YR4/2) brown highly fractured, weathered shale.		
				(14.0-16.0) (5YR4/2) dark reddish gray weathered shale entire 2 ft.			

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/21/94** ENDED **11/21/94**

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

TOTAL DEPTH

SAMPLING DEVICE	PROBE
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BOREHOLE DIAMETER 1.25 in.

LOGGED BY **KEN SWAIN**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20	B03015	NA	<80			(16.0-18.0) Entire sample (7.5YR5/2) brown weathered shale, dry.	910
			<80				
			<80			(18.0-20.0) No recovery - no resistance in pushing sampler.	
		WET		(20.0-20.2) Wet, (7.5YR3/4) dark brown, fractured shale. Refusal at 20.25 ft BGS.

LOCATION BCV OU 1

TOTAL DEPTH 12.50

ft bgs

BOREHOLE NUMBER BG-04

COORDINATES N 29,882.90 E 44,264.40

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 926.40 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
5	B04011	NA	<80	MOIST		(0.0-1.5) (2.5YR4/6) red clay, plastic, moist, with weathered (7.5YR5/1) gray chert (sparse). Black wood frags at 0.75 ft. (CL) moist.	925
						(1.5-2.0) No recovery.	
			<80	MOIST		(2.0-2.1) Same as above. (2.1-3.6) (10YR7/2) light gray silty clay mottled with < 10% (10YR7/6) yellow clay (CL). Grading from 2.1 soil to remainder as above. Entire sample slightly moist plastic.
						(3.6-4.0) No recovery.	
			<80			(4.0-4.3) Top 0.3 same as above with increased mottling to 25% (CL). (4.3-4.4) (5BG6/1) bluish gray plastic clay, dry. (CL).
						(4.4-6.0) No recovery.	
				<80			(6.0-7.3) (5Y7/2) light gray clay with (10YR7/6) yellow clay mottling up to 50% dry. (7.3-8.0) (10YR4/6) dark yellowish brown clay (CL), dry, crumbly.	920
					MOIST		(8.0-8.4) (2.5Y5/3) light olive brown clay, moist.	
	<80					(8.4-8.6) (2.5Y4/1) dark gray limestone frags, 100% dry. (8.6-9.0) (2.5Y6/6) olive yellow shale, highly weathered, bedding observable, dry.
						(9.0-10.0) No recovery.	
	10		B04013	<80			(10.0-11.8) (5Y6/2) light olive gray completely weathered shale with 1 layer (~ 1 cm thick) at 10.9 of (5B4/1) dark bluish gray friable shale, dry.	915
						(11.8-12.0) 100% weathered (2.5YR7/2) pale red chert and light gray limestone frags.	
<80		WET			(12.0-12.4) (5Y5/2) olive gray silty clay with (5B4/1) dark bluish gray shale fragments. (12.4-12.5) Refusal at 12.5 ft, wet.			

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 11/8/94 ENDED 11/8/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1** TOTAL DEPTH **26.50** ft bgs
 BOREHOLE NUMBER **BG-05**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,192.20 E 43,998.00**ELEVATION **952.10** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5 <							

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/22/94** ENDED **11/22/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 26.50

ft bgs

BOREHOLE NUMBER BG-05

COORDINATES N 30,192.20 E 43,998.00

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE	PROBE
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ELEVATION 952.10 ft above MSL

LOGGED BY **KEN SWAIN**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20	B05015	NA	<80	MOIST			935
			<80		(16.0-16.3) (10YR5/8) yellowish brown clay with very small weathered chert frags. (16.3-16.6) (10YR2/2) very dark brown clay with ~ 30% (2.5Y5/3) light olive brown chert with (10YR2/2) weathering rind, moist. (16.6-17.5) (2.5Y7/4) pale yellow silty clay, dry.		
					(17.5-18.0) No recovery.		
					(18.0-19.8) (2.5Y6/2) light brownish gray weathered shale.		
	<80		WET	(19.8-20.0) (10YR3/2) very dark grayish brown silty clay, wet. (20.0-20.6) (5BG6/1) greenish gray shale with interlayer (7.5YR5/6) strong brown staining. (20.6-21.6) (5G5/2) grayish green shale. (21.6-22.0) Same as 20.0-20.6 ft. Very bottom (N3) very dark gray bedded shale. (22.0-22.8) Same shale as above, dry.	930		
			<80	(22.8-24.0) No recovery.			
				WET		(24.0-24.2) Same as above, dry (24.2-24.5) Same shale but coated with (5YR4/6) yellowish red clay, wet. (24.5-25.5) (N4) dark gray shale, dry.	
						(25.5-26.0) No recovery.	
						(26.0-26.5) Same as above, dry. Refusal at 26.5 ft BGS.

LOCATION **BCV OU 1** TOTAL DEPTH **24.60** ft bgs
 BOREHOLE NUMBER **BG-06**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,298.00 E 44,437.80**ELEVATION **955.30** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	B06011	NA	<80			(0.0-0.8) (5YR6/6) reddish yellow clay, dry, abundant (5YR8/1) white chert frags.	955
						(0.8-1.2) (7.5YR5/2) brown silty clay, dry.	
						(1.2-2.0) No recovery.	
	B06012	NA	<80			(2.0-3.6) (10YR6/8) brownish yellow clay, dry.	
						(3.6-4.0) No recovery.	
						(4.0-4.4) (7.5YR5/8) strong brown clay, dry.	
5	B06012	NA	<80			(4.4-4.7) (10YR7/4) very pale brown weathered shale.	
						(4.7-5.0) (7.5YR4/2) brown silty clay, dry, micaceous.	
						(5.0-6.0) No recovery.	
	B06013	NA	<80			(6.0-7.6) (2.5Y7.6) yellow clay with 5 mm layers of (10YR4/4) dark yellowish brown silty clay at ~ every 0.3 ft.	
						(7.6-8.0) No recovery.	
						(8.0-9.0) Same as above.	
	B06013	NA	<80			(9.0-9.6) (7.5YR4/3) brown silty clay, dry.	
10						(9.6-10.0) No recovery.	
						(10.0-10.4) (10YR4/4) dark yellowish brown silty clay, moist.	
	B06014	NA	<80	MOIST		(10.4-11.6) (2.5Y6/6) olive yellow weathered shale, dry.	945
						(11.6-12.0) No recovery.	
						(12.0-14.0) (2.5Y5/3) light olive brown weathered shale, abundant Fe staining in jointing planes.	
	B06014	NA	<80			(14.0-15.9) Same as above.	

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/22/94** ENDED **11/28/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 24.60 ft bgs

BOREHOLE NUMBER BG-06

COORDINATES N 30,298.00 E 44,437.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 955.30 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			< 80				940
						(15.9-16.0) (7.5YR6/6) reddish yellow clay with (7.5YR4/2) brown residuum and (2.5Y5/2) grayish brown shale fragments.	
						(16.0-17.3) (2.5Y6/3) light yellowish brown weathered shale, dry.	
			< 80			(17.3-18.0) No recovery.	
	B06015	NA				(18.0-20.0) Same as above.	
			< 80				
20						(20.0-22.0) Piston rod broke in tube - can't extract sample.	935
			< 80				
	B06016					(22.0-23.2) (10YR3/2) very dark grayish brown moist fractured shale.	
			< 80	MOIST			
						(23.2-24.0) No recovery.	
			< 80	WET		(24.0-24.6) Wet large frag of shale above. Refusal at 24.6 ft BGS.

SHEET 1 OF 1

LOCATION BCV OU 1

TOTAL DEPTH 12.00 ft bgs

BOREHOLE NUMBER BG-07

COORDINATES N 30,614.40 E 44,569.90

BOREHOLE DIAMETER 6 in.

SAMPLING DEVICE BUCKET

ELEVATION 975.40 ft above MSL

LOGGED BY D. THOMPSON

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B07011	NA	< 60			(0.0-0.5) Yellowish brown clayey silt (7.5YR5/8); dry; soil class (CL).	975
						(0.5-1.5) No recovery.
			< 60			(1.5-2.0) Yellowish brown clayey silt (7.5YR4/6) dry; soil class (CL).
						(2.0-3.5) No recovery.
	B07012		< 60			(3.5-4.0) Yellowish brown clayey silt (7.5YR5/6) dry; soil class (CL).	970
						(4.0-5.5) No recovery.
			< 60			(5.5-6.0) Yellowish brown silty clay (7.5YR6/8 to 7.5YR5/8); mottled; increase in moisture content; weathered shale fragments.
						(6.0-7.5) No recovery.
	B07013		< 60			(7.5-8.0) Same as above. Very dry.	965
						(8.0-9.5) No recovery.
			< 60			(9.5-10.0) Same as above, but with increase in shale content. Very dry.
						(10.0-11.5) No recovery.
		< 60		(11.5-12.0) Same as above; weathered shale; very dry.			

DRILLING CONTRACTOR **SAIC**
 DRILLING METHOD **POWER HAND AUGER**
 DRILLING EQUIPMENT **LITTLE BEAVER AUGER**
 DRILLING STARTED **12/13/94** ENDED **12/13/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

14.50

ft bgs

BOREHOLE NUMBER

BG-08

COORDINATES N 31,013.60 E 43,360.20

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE

PROBE

ELEVATION 960.60 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B08011	NA	< 60			(0.0-0.4) (N3) very dark gray limestone frags (gravel fill).	960
						(0.4-1.3) (10YR5/6) yellowish brown silty clay.	
						(1.3-1.5) Same (N3) very dark gravel as 0.0-0.4	
						(1.5-1.7) 1.5-1.75 same as 0.4-1.3.	
						(1.7-2.0) No recovery.	
						(2.0-2.3) (2.5Y6/6) olive yellow silty clay (completely weathered shale).	
						(2.3-2.6) (10YR5/8) yellowish brown clay with some red residuum.	
						(2.6-2.8) (2.5Y6/4) light yellowish brown silty clay.	
						(2.8-3.0) (2.5Y7/3) pale yellow weathered shale.	
						(3.0-3.4) (10YR4/4) dark yellowish brown weathered shale.	
10	B08012	NA	< 60			(3.4-3.6) (5YR4/4) reddish brown weathered chert, dry.	955
						(3.6-4.0) No recovery.	
						(4.0-5.5) Entire 1.5 ft. (7.5YR5/4) brown silty clay with sparse (2.5YR4/6) red highly weathered chert ~ 1.5 cm.	
						(5.5-6.0) No recovery.	
						(6.0-6.4) Entire 0.4 ft (2.5Y5/4) silty clay, sandy clay (N4) gray limestone in very bottom 0.1 ft, with sparse areas of (10R6/1) reddish gray silty clay.	
						(6.4-8.0) No recovery.	
						(8.0-8.8) (10YR6/4) light yellowish brown silty clay with sparse small (2.5Y7/4) pale yellow chert frags.	
						(8.8-9.2) (7.5YR5/8) strong brown clay with abundant completely weathered (7.5YR2.5/1) black highly weathered chert frags.	
						(9.2-9.4) (10YR5/6) yellowish brown calcareous silty to sandy clay (weathering residuum), moist.	
						(9.4-10.0) No recovery.	
	B08013		< 60	MOIST		(10.0-11.2) (10YR4/6) dark yellowish brown weathered shale.	950
						(11.2-11.6) (10YR5/2) grayish brown weathered shale, dry.	
						(11.6-12.0) No recovery.	
						(12.0-12.5) (10YR5/4) yellowish brown wet clay.	
						(12.5-12.7) (10YR4/3) brown shale.	
						(12.7-13.4) (5YR5/1) gray weathered shale, dry, bedding observable.	
			< 60	WET		(13.4-14.0) No recovery.	
						(14.0-14.5) Refusal at 14.5 ft BGS on same gray shale as above.	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **11/7/94** ENDED **11/7/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1** TOTAL DEPTH **30.00** ft bgs
 BOREHOLE NUMBER **BG-10**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,935.60 E 42,739.00**ELEVATION **972.50** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	B10011		<80			(0.0-0.2) (10YR5/4) yellowish brown clay with (N6) gray limestone gravel. (0.2-2.0) (5YR5/8) yellowish red stiff clay with sparse 2 cm limestone frags, same as above, dry.	
			<80			(2.0-3.4) (10YR7/6) yellow clay with scattered fragments of (N8) white and (N3) very dark gray chert, dry.	970
						(3.4-4.0) No recovery.	
5	B10012		<80			(4.0-6.0) Same as above, dry.	
		NA	<80			(6.0-8.0) Same as above.	965
			<80			(8.0-10.0) Same as above.	
10	B10013		<80			(10.0-11.2) (7.5YR5/8) strong brown clay with same chert fragments (sparse).	
			<80			(11.2-12.0) (7.5YR7/8) reddish yellow clay with very small fragments of (10YR7/8) yellow weathered clay and black chert, dry. (12.0-13.0) Same as above.	960
			<80			(13.0-13.5) (10YR4/3) brown clay with (5B4/1) dark bluish gray shale fragments dry. (13.5-14.0) No recovery.	
	B10014					(14.0-15.0) (5YR5/2) reddish gray weathered shale, dry.	

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **12/1/94** ENDED **12/2/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1 TOTAL DEPTH 30.00 ft bgs
 BOREHOLE NUMBER BG-10
 BOREHOLE DIAMETER 1.25 in. SAMPLING DEVICE PROBE
 LOGGED BY KEN SWAIN

COORDINATES N 30,935.60 E 42,739.00

ELEVATION 972.50 ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			<80		X	(15.0-16.0) No recovery.	
			<80			(16.0-18.0) (5YR5/6) yellowish red clay with (10YR7/8) reddish yellow shale fragments and (10R4/8) red silty clay pockets (sparse and small).	955
	B10015					(18.0-20.0) (7.5YR5/4) brown clay with fragments of (7.5YR7/8) reddish yellow shale.	
			<80				
20							
		NA	<80			(20.0-21.4) Conglomerated mix of (5YR4/3) reddish brown (10YR7/8) yellow (2.5YR5/8) red (5GY7/1) light bluish gray weathered shale fragments in varying proportions and states of weathering.	
	B10016					(21.4-22.0) (10YR5/8) yellowish brown clay, dry.	
			<80			(22.0-24.0) (10YR7/2) light gray clay mottled with (5YR6/8) reddish yellow clay < 30%, dry.	950
25			<80	WET	X	(24.0-26.0) Sampler wet, no recovery.	
	B10017		<80	MOIST		(26.0-26.9) (10YR6/8) brown yellowish clay mottled with (5B7/1) light greenish gray clay.	
						(26.9-27.4) Moist (2.5Y6/4) light yellowish brown clay.	
						(27.4-28.0) (5Y5/3) olive clay.	945
						(28.0-28.3) (2.5Y6/6) olive yellow clay.	
			<80			(28.3-30.0) (2.5YR7/1) light reddish gray shale with some (2.5YR4/1) dark reddish gray shale. Refusal at 30.0 ft.	
30

SHEET 1 OF 2

LOCATION BCV OU 1 TOTAL DEPTH 15.90 ft bgs

BOREHOLE NUMBER BG-11

COORDINATES N 30,559.90 E 42,691.30

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 989.40 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
				MOIST		(0.0-0.2) (5YR5/8) yellowish red moist clay with large fragments of (N5) gray limestone. (0.2-2.0) No recovery.	
			< 80				
						(2.0-2.5) Same as above but small limestone. (2.5-4.0) No recovery.	
	B11011		< 80				
5			< 80			(4.0-5.5) (5YR5/2) reddish gray clay with (2.5YR3/3) dark reddish brown weathered shale fragments. Some greenish gray (5G5/1) silty clay coatings.	985
		NA	< 80			(5.5-6.0) (2.5Y5/6) weathered shale (completely) but layering observable, dry. (6.0-8.0) (10YR6/6) brownish yellow highly weathered shale with subordinate amounts of (10R5/6) red clay, dry.	
	B11012		< 80			(8.0-10.0) Same as above with 2 minute layers of (7.5YR3/1) very dark gray silty clay, oriented at ~ 60 degrees to horizontal.	980
10			< 80			(10.0-11.8) (2.5Y6/6) olive yellow clay with abundant (10YR4/3) brown weathering residuum. 2cm diagonal layer of (5GY7/1) light greenish gray sandy clay at 11.6 ft.	
	B11013		< 80			(11.8-12.0) (10YR4/3) brown silty clay with (10YR3/1) very dark gray silty clay subordinate, dry. (12.0-13.9) Equal amounts of (10YR7/6) yellow and (2.5Y6/2) light brownish gray silty clay with sparse frags of highly weathered (10YR4/2) dark greyish brown shale.	
	B11014		< 80			(13.9-14.0) (2.5Y7/3) pale yellow weathered shale. (14.0-15.9) (2.5Y5/3) light olive brown shale. Some weathered, most very resistant with sparse Fe staining, dry. Refusal at 15.9 ft BGS.	975

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 11/28/94 ENDED 11/28/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

[illegible]

LOCATION **BCV OU 1** TOTAL DEPTH **34.20** ft bgs
 BOREHOLE NUMBER **BG-12**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,264.50 E 42,913.30**ELEVATION **957.90** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	B12011	NA	<80			(0.0-0.7) (5YR5/8) yellowish red clay.	955
						(0.7-1.0) (N6) gray limestone gravel.	
						(1.0-1.2) (10YR4/3) brown silty clay with trace amounts of (5GY6/1) greenish gray clay, dry.	
						(1.2-2.0) No recovery.	
	B12012	NA	<80			(2.0-3.0) Same as above with greenish gray clay content increasing to 25%, dry.	950
						(3.0-4.0) No recovery.	
5						(4.0-5.1) Same as above with addition of (N6) gray limestone fragments.	
						(5.1-5.8) Same as above without limestone fragments and addition of sparse (7.5YR5/2) brown silty clay (weathered shale).	
	B12013	NA	<80			(5.8-6.0) No recovery.	945
						(6.0-6.6) (2.5Y5/4) light olive silty clay and highly weathered shale isolated pockets ~ 2 cm in length of (5YR5/8) yellowish red clay, dry.	
						(6.6-8.0) No recovery.	
						(8.0-9.6) Same as above with 8.9-9.1 ft having 50% (7.5YR5/4) brown silty clay dry.	
10	B12014	NA	140			(9.6-10.0) No recovery.	945
						(10.0-12.0) (2.5Y7/4) pale yellow weathered shale with subordinate (10YR6/8) brownish yellow and (5GY7/1) light greenish gray silty clays (weathered shale), dry.	
						(12.0-13.5) Same as above, dry.	
						(13.5-14.0) No recovery.	
	B12014	NA	<80			(14.0-14.7) Same as above.	945
						(14.7-15.6) (7.5YR3/2) dark brown silty clay with scattered fragments of (5YR8/4)	

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/28/94** ENDED **11/29/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

34.20

ft bgs

BOREHOLE NUMBER

BG-12

COORDINATES N 30,264.50 E 42,913.30

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE

PROBE

ELEVATION 957.90 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
20	B12015	7.0	<80			yellow shale, dry.	940	
			<80			(15.6-16.0) No recovery.		
						(16.0-16.5) (7.5YR4/3) brown silty clay with frags of (5Y7/3) pale yellow very weathered shale.		
						(16.5-17.2) (10YR5/8) yellowish brown weathered (slightly) shale with (10YR3/4) dark yellowish brown interlayer staining, dry.		
	B12016	NA	<80			(17.2-18.0) No recovery.		
			<80			(18.0-20.0) Same as above.		
						(20.0-20.5) (2.5Y5/4) light olive brown weathered shale, dry.		
						(20.5-21.3) (10YR6/6) brownish yellow weathered shale, dry.		
	B12017	NA	<80			(21.3-22.0) (5Y6/6) olive yellow silty clay (weathered completely) shale, dry.		
			<80			(22.0-22.6) (2.5Y5/4) light olive brown weathered shale, some Fe staining.		
						(22.6-23.3) (2.5YR2.5/2) very dusky red clay, not compact, moist 2-3 cm zones in above olive brown shale weathering residuum as above.		
						(23.3-24.0) No recovery.		
25	B12017	NA	<80		(24.0-25.7) (2.5Y6/4) light yellowish brown weathered shale with up to 40% (10YR4/4) silty clay.	935		
			<80				(25.7-26.0) No recovery.	
							(26.0-26.6) (2.5Y4/3) olive brown weathered shale.	
							(26.6-27.1) (2.5YR2.5/3) dark reddish brown silty clay.	
	B12018	NA	<80		(27.1-27.5) (10YR5/8) yellowish brown weathered shale, dry.			
			<80				(27.5-28.0) No recovery.	
							(28.0-29.2) Same shale as above with isolated pockets of (2.5YR2.5/3) dark reddish brown silty clay, dry.	
							(29.2-30.0) No recovery.	
30	B12018	NA	<80		(30.0-31.0) (10R3/2) dusky red shale, resistant fragments, wet, saturated.	930		
				(31.0-32.0) No recovery.				

ELEVATION 957.90 ft above MSL

[illegible]

LOCATION **BCV OU 1** TOTAL DEPTH **14.50** ft bgs
 BOREHOLE NUMBER **BG-13**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,335.20 E 42,212.30**ELEVATION **929.70** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
5	B13011	NA	<80			(0.0-0.9) (10YR6/8) brownish yellow clay with (N6) gray chert fragments and root fragments.	925
						(0.9-1.5) (N7) light gray limestone fragments (100%) dry.
						(1.5-2.0) No recovery.
						(2.0-2.9) (10YR6/6) brownish yellow plastic clay.
						(2.9-3.6) Same as above with small fragments (10YR7/6) yellow weathered shale dry.	
	B13012		<80		(3.6-4.0) No recovery.
					(4.0-5.8) (10YR6/8) brownish yellow clay with sparse fragments of (5GY5/1) greenish gray shale.
					(5.8-6.0) No recovery.
					(6.0-7.8) Same as above with addition of Fe staining.		
				B13013	<80			(7.8-8.0) (2.5Y5/4) light olive brown weathered shale, dry.
			(8.0-10.0) Same shale as above with addition of (10YR4/4) dark yellowish brown shale frags and associated residuum, dry.			
	MOIST					(10.0-10.6) (10YR3/1) very dark gray silty clay, moist.
						(10.6-11.6) (2.5Y4/3) olive brown shale with globular deposits of above silty clay moist.
	10		B13013	<80	MOIST			(11.6-12.0) No recovery.
MOIST						(12.0-13.7) Same as above with shale becoming (2.5Y4/2), dark grayish brown dry.		
		MOIST					(13.7-14.0) No recovery.	
B13014						<80	MOIST		(14.0-14.4) Same as above with fractured (N5) gray limestone.
		WET

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/2/94** ENDED **12/2/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 2

LOCATION BCV OU 1

TOTAL DEPTH 25.50 ft bgs

BOREHOLE NUMBER BG-14

COORDINATES N 30,388.10 E 42,151.00

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 946.00 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			< 80			(0.0-1.8) (7.5YR6/8) reddish yellow clay, stiff, dry.	945
	B14011		< 80			(1.8-2.0) (5YR7/3) pale yellow clay (weathered shale). (2.0-3.6) (10YR5/8) yellowish brown stiff clay, dry.	
			< 80			(3.6-4.0) Same as 1.8-2.0 ft BGS.	
5			< 80			(4.0-6.0) (5GY7/1) light greenish grey shale with interbed staining of (7.5YR6/8) reddish yellow, dry.	
	B14012		< 80			(6.0-7.0) Same as above, dry.	940
		NA	< 80			(7.0-8.0) No recovery.	
			< 80			(8.0-10.0) Grading from above to (5Y7/3) pale yellow silty clay (CL) with same (7.5YR6/8) reddish yellow staining, no observable bedding, dry.	
10			< 80			(10.0-11.9) Same as above.	935
	B14013		< 80			(11.9-12.0) Bedding (5BG6/1) greenish gray shale, highly weathered, dry. (12.0-14.0) Top 1 ft. same as above grading into (2.5Y6/6) olive yellow clay (weathered shale) with sparse (5YR4/6) yellowish red Fe staining.	
			< 80			(14.0-14.8) (2.5Y5/6) light olive brown clay.	
	B14014		< 80			(14.8-15.6) (5GY7/1) light greenish gray clay with 20% (10YR6/8) brownish yellow	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**

REMARKS

Coordinates are reported in Y-12 Grid

LOCATION **BCV OU 1**TOTAL DEPTH **25.50** ft bgsBOREHOLE NUMBER **BG-14**COORDINATES **N 30,388.10 E 42,151.00**BOREHOLE DIAMETER **1.25 in.**SAMPLING DEVICE **PROBE**ELEVATION **946.00** ft above MSLLOGGED BY **KEN SWAIN**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			<80			mottling, dry, crumbly.	
						(15.6-16.0) No recovery.	
						(16.0-17.0) (10YR5/8) yellowish brown clay, dry.	930
			100			(17.0-17.2) (5YR5/8) yellowish red clay.	
						(17.2-18.0) (5GY7/1) light greenish gray shale, dry. 50 ppm in 17.0-18.0 section when chopped up.	
						(18.0-20.0) Same (5GY7/1) greenish gray shale as above.	
		NA	100				
20	B14015					(20.0-20.4) Same as above.	
						(20.4-20.8) (2.5Y7/4) pale yellow silty clay.	
			<80			(20.8-21.2) Same as 20.0-20.4 ft BGS.	925
						(21.2-22.0) No recovery.	
	B14016					(22.0-23.8) (N6) gray weathered shale, observable bedding.	
			<80				
						(23.8-24.0) Sharp contact above to (7.5YR6/8) reddish yellow silty to sandy weathered shale residuum.	
						(24.0-25.3) Same as above with some Fe staining.	
25	B14017		<80			(25.3-25.5) Massive (5BG5/1) bluish grey low grade meta-shale, moist (slightly). Refusal at 25.5 ft BGS.	
				MOIST

SHEET 1 OF 1

LOCATION **BCV OU 1** TOTAL DEPTH **6.50** ft bgs
 BOREHOLE NUMBER **BG-15**
 BOREHOLE DIAMETER **6** in. SAMPLING DEVICE **BUCKET**
 LOGGED BY **D. THOMPSON**

COORDINATES **N 30,802.40 E 41,986.30**ELEVATION **941.00** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B15011	NA	< 60			(0.0-0.5) Silty clay; color - (7.5YR5/4); soil class.-(CL); dark brown.	940
						(0.5-1.5) No recovery.
			< 60			(1.5-2.0) Grayish brown clay; high organic content; weathered clasts of orange silt (orange appears to be weathering stain); soil class-(CL) color - clay - (5YR5/4); silt-(5YR6/8)
						(2.0-3.5) No recovery.
	B15012		< 60	WET		(3.5-4.0) Hit groundwater in this interval. Weathered bluish gray clay interbeds in dark brown clay; wet; moderate plasticity; color - dark brown - (7.5YR5/4); bluish gray - (5B6/1).	935
						(4.0-5.0) No recovery.
			< 60	WET		(5.0-5.5) Same above, with increasing amounts of bluish gray clay. Dry. Soil class - .
						(5.5-6.0) No recovery.
			< 60	WET		(6.0-6.5) Same as above. Refusal at 6.5 ft BGS.	

DRILLING CONTRACTOR **SAIC**
 DRILLING METHOD **POWER HAND AUGER**
 DRILLING EQUIPMENT **LITTLE BEAVER AUGER**
 DRILLING STARTED **12/12/94** ENDED **12/12/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1**TOTAL DEPTH **7.50**

ft bgs

BOREHOLE NUMBER **BG-16**COORDINATES **N 30,463.50 E 44,638.20**BOREHOLE DIAMETER **6** in.SAMPLING DEVICE **BUCKET**ELEVATION **943.60** ft above MSLLOGGED BY **D. THOMPSON**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	B16011	NA	< 60			(0.0-0.15) "A" soil horizon.	940
						(0.15-0.4) Reddish brown clay (5YR6/6) with pebble sized shale clasts.
						(0.4-0.5) Dark brown silty clay (10YR3/3); soil class - CL. .M=CLS
						(0.5-1.5) No recovery.
			< 60			(1.5-1.7) Same as dark brown silty clay above.
						(1.7-2.0) Gray clay with reddish brown clay clasts (gray clay - 10YR5/3 reddish brown clay - 5YR5/6). Soil class-CL.
						(2.0-3.5) Encountered water at ~ 3.00 ft.
			< 60	WET		(3.5-4.0) Same gray clay as above; very wet; observed oxidized root traces; this gray clay is interpreted as the wetland soil horizon (hydric zone).
						(4.0-5.5) No recovery.
			< 60	MOIST		(5.5-6.0) Grayish blue (5GY6/1) with large reddish brown clay clasts (7.5YR6/6 to 5/6); moisture is coming from water encountered at 3.0 ft in hole, but fresh sample is slightly moist. The silt is compact and appears to be weakly cemented.
						(6.0-7.0) No recovery.
			< 60			(7.0-7.5) Highly weathered greenish gray shale (5Y6/3). Sample is dry. "Little Beaver" auger refusal at 7.5 ft.	

DRILLING CONTRACTOR **SAIC**
 DRILLING METHOD **POWER HAND AUGER**
 DRILLING EQUIPMENT **LITTLE BEAVER AUGER**
 DRILLING STARTED **12/14/94** ENDED **12/14/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 2

LOCATION BCV OU 1 TOTAL DEPTH 16.00 ft bgs

BOREHOLE NUMBER SL1-01

COORDINATES N 29,632.80 E 48,082.70

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 953.00 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	L01011	NA	< 60/60			(0.0-0.5) Top 6 inches (5YR5/6) yellowish red clay. (0.5-2.0) (N6) grey shale completely weathered but layering still discernible in a (10YR5/4) clay matrix.	950
				MOIST		(2.0-2.5) Moist (5YR4/6) yellowish red clay mottled with small layers. (5YR4/1) dark grey clay with 1-2 cm fragments of (5YR3/1) very dark grey limestone.	
			< 60/60			(2.5-4.0) No recovery.	
5	L01012	22.0	< 60/60			(4.0-5.0) (10YR5/6) yellowish brown silty clay with very small oxidized rock frags. (5.0-5.8) Same as above with completely weathered iron stained rock frags ~ 1 cm.	945
			< 60/60	WET		(5.8-6.0) (10YR5/8) yellowish brown clay mottled with (N7) light gray clay. At 5.8 ft BGS, (7.5YR4/6) strong brown sand (result of weathering). (6.0-6.9) Same as above with addition of (5 YR 5/6) yellowish red clay. (6.9-7.5) Same as above with water present.	
			< 60/60	WET		(7.5-8.0) Weathered shale (2.5Y5/4) light olive brown. (8.0-8.6) Same as above - soupy - wet.	
10	L01013	6.0	< 60/60			(8.6-9.6) (5GY7/1) weathered shale with alternating layers of (10YR6/6) brownish yellow shale - layers ~ 1 cm thick.	940
			< 60/60			(9.6-10.0) No recovery.	
			< 60/60			(10.0-10.8) Same as above with a wedge of (5YR3/4) weathered shale, dry from 10.2-10.6 ft BGS. (10.8-12.0) No recovery.	
	L01014	NA	110/60			(12.0-13.0) 100% frags of (5Y5/3) shale and same (5YR3/4) dark reddish brown shale as above.	940
				WET		(13.0-14.0) Highly weathered (2.5Y5/2) grayish brown shale - higher red activity wet.	
			< 60/60			(14.0-14.5) (N5) gray limestone. (14.5-15.0) (5Y5/3) olive shale.	

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 10/25/94 ENDED 10/25/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

16.00 ft bgs

LOCATION BCV OU 1

TOTAL DEPTH

16.00 ft bgs

BOREHOLE NUMBER SL1-01

COORDINATES N 29,632.80 E 48,082.70

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE	PROBE
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ELEVATION 953.00 ft above MSL

LOGGED BY **KEN SWAIN**

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
						(15.0-16.0) Refusal at 16.0 ft BGS on (N5) gray limestone.

LOCATION **BCV OU 1** TOTAL DEPTH **26.00** ft bgs
 BOREHOLE NUMBER **SL1-02**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 29,409.90 E 46,994.50**ELEVATION **948.50** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	L02011	7.9	< 60/100			(0.0-0.2) (2.5YR3/4) dark reddish brown clay with recent forest litter. Bottom 0.15 ft (5GY5/1) greenish gray clay mottled with Fe stained clay (weathered) product. Second location, same as above.	945
						(0.2-0.8) Second location, same as bottom 0.15 ft above.	
						(0.8-2.0) No recovery.	
						(2.0-4.0) No recovery - will composite 0-2 and 4-6 to get needed volume.	
						(4.0-4.8) Whole sample wet, plywood fragments covered with (5GY5/1) greenish gray clay.	
10	L02012	NA	< 100	WET		(4.8-6.0) No recovery.	940
						(6.0-6.9) Entire section (10YR5/6) yellowish brown clay with styrofoam plastic and paper throughout and 2 cm frags of (N6) limestone. Wet.	
						(6.9-8.0) No recovery.	
				WET		(8.0-8.7) Same as above with mostly wood frags and sawdust.	
				MOIST		(8.7-8.9) Same clay with (N6) limestone coated with tarlike material, moist.	
15	L02013	NA	< 100/100			(8.9-10.0) No recovery.	935
						(10.0-10.7) (10YR5/6) yellowish brown clay with wood frags.	
						(10.7-11.8) (10YR6/8) brownish yellow clay with (10YR2/1) black completely weathered frags, (10YR5/8) yellowish brown chert frags < 5 mm, large piece of white gauze - very pungent odor; also black wood frags throughout.	
						(11.8-12.0) No recovery.	
						(12.0-13.0) Same as above.	
20	L02013	NA	< 100/100			(13.0-13.8) (10YR5/4) yellowish brown clay with large frags (2 cm) (N6) gray limestone and (N7) light gray shale, Fe stained pebbles (4 mm diameter).	935
						(13.8-14.0) No recovery.	
25	L02013	NA	< 100/100			(14.0-15.0) Same as above.	935

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/26/94** ENDED **12/26/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

26.00

ft bgs

BOREHOLE NUMBER

SL1-02

COORDINATES N 29,409.90 E 46,994.50

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 948.50 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20	L02014	NA	<100/100			(15.0-16.0) (10YR6/8) brownish yellow clay with abundant completely weathered (10YR2/2) very dark brown rock frags ~ 5 mm in diameter.	930
				WET		(16.0-17.0) Same as above, wet.	
			<100/100			(17.0-18.0) Same as above, dry, with addition of (10YR4/8) red brick (?) frags or weathered sandstone and (N7) light gray chert frags.	
						(18.0-19.6) Same as above, but saturated.	
	L02015		<100/100	WET		(19.6-20.0) No recovery.	
						(20.0-22.0) Entire sample (10YR5/8) clay mottled (10YR3/2) very dark grayish brown weathering residual (~10%).	
				WET		(22.0-22.5) Same as above, very wet, plastic.	
			<100/100			(22.5-24.0) No recovery.	
	L02016		<100/100	WET		(24.0-24.8) Sampler refusal at 25 ft BGS. Sample same as above. Bottom 0.1 (2.5Y5/4) light olive brown clay and refusal met on vuggy limestone.

SHEET 1 OF 2

LOCATION BCV OU 1 TOTAL DEPTH 16.00 ft bgs
 BOREHOLE NUMBER OLF-01
 BOREHOLE DIAMETER 1.25 in. SAMPLING DEVICE PROBE
 LOGGED BY KEN SWAIN

COORDINATES N 30,368.40 E 48,113.40

ELEVATION 973.60 ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
						(0.0-0.4) (10YR5/3) brown highly weathered shale (CL) (0.4-2.0) (2.5Y6/4) weathered shale, some Fe staining, dry.	
	001011		<80/80			(2.0-4.0) Same weathered shale as above, dry.	
			<80/80				
5			<80/80			(4.0-6.0) Same as above, dry.	970
	001012	NA	<80/80			(6.0-6.3) (7.5YR3/4) dark brown highly weathered shale with abundant Fe staining. (6.3-7.3) Same weathered shale as bottom of above sample.	
			<80/80			(7.3-7.6) (10YR6/4) light yellowish brown shale - very resistant, dry, no Fe staining.	
						(7.6-8.0) No recovery.	
						(8.0-8.3) Same as above.	
						(8.3-8.6) (10YR4/3) brown silty clay (weathered residuum).	965
			<80/80	WET		(8.6-9.6) (10YR5/8) yellowish brown weathered shale, some Fe staining, wet. Very bottom (~0.05 ft) (5Y5/2) olive gray, weathered shale, dry.	
10	001013					(9.6-10.0) No recovery.	
						(10.0-10.4) Same as bottom of above.	
				WET		(10.4-10.9) (10YR3/1) very dark gray sandy clay, wet, almost oily appearance.	
			<80/80			(10.9-12.0) (10YR6/1) gray weathered (clay) shale, dry.	
						(12.0-12.2) Cave-in.	
			<80/80			(12.2-13.6) Same gray shale as above.	
						(13.6-14.0) No recovery.	960
	001014		<80/80			(14.0-15.6) Same as above. Refusal at 16.0 ft BGS.	

DRILLING CONTRACTOR GEOMARINE, INC.
 DRILLING METHOD GEOPROBE
 DRILLING EQUIPMENT GEOPROBE
 DRILLING STARTED 11/2/94 ENDED 11/2/94

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE	PROBE
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COORDINATES N 30,368.40 E 48,113.40

ELEVATION 973.60 ft above MSL

LOGGED BY **KEN SWAIN**

[illegible]

SHEET 1 OF 2

LOCATION **BCV OU 1** TOTAL DEPTH **21.60** ft bgs
 BOREHOLE NUMBER **OLF-02**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,042.90 E 48,176.80**ELEVATION **963.10** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	002011	5.9	<80/80		(0.0-0.3) (7.5YR4/6) strong brown clay (N4) gray limestone (CL). (0.3-0.9) (N7) light gray limestone gravel.		
					(0.9-1.0) Black wood fragments (GP) dry. (1.0-2.0) No recovery.		
					(2.0-2.6) (5G6/1) greenish gray weathered shale (CL), dry.		
					(2.6-2.9) (5Y4/3) olive silty clay (CL), dry. (2.9-3.2) (5YR2.5/1) black silty clay (CL), dry.		960
					(3.2-4.0) No recovery.		
5	002012	NA	<80/80	MOIST	(4.0-4.7) (2.5Y4.1) dark gray silty clay (CL) moist.		
					(4.7-6.0) No recovery.		
				WET	(6.0-7.2) (2.5Y5/3) light olive brown clay, wet. Very bottom < 0.1 ft (2.5 5/2) grayish brown silty clay.		
					(7.2-8.0) No recovery.		
					(8.0-8.8) (10YR5/4) yellowish brown weathered shale, dry.		955
10	002013	NA	<80/80		(8.8-10.0) No recovery.		
					(10.0-10.9) (2.5 6/6) olive yellow silty clay (CL).		
					(10.9-11.3) (7.5YR4/4) brown weathered shale. (11.3-12.0) (10YR6/8) brownish yellow highly weathered shale.		
					(12.0-12.5) Same as above.		
					(12.5-14.0) (7.5YR5/2) brown, slightly weathered shale, dry.		950
					(14.0-16.0) Same as above, dry.		

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **GEOPROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **11/1/94** ENDED **11/1/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

21.60

ft bgs

BOREHOLE NUMBER

OLF-02

COORDINATES N 30,042.90 E 48,176.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 963.10 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20	O02014		<80/80	NA		(16.0-17.3) Same as above.	945
			<80/80			(17.3-18.0) Same but wet with Fe staining.	
	O02015		<80/80			(18.0-18.4) (10YR4/2) dark grayish brown clay.
						(18.4-18.8) (10YR4/3) brown weathered shale.
						(18.8-19.1) (2.5Y5/4) light olive brown highly weathered shale.
						(19.1-19.3) (10YR2/2) very dark brown weathered shale (dry) (2.5Y5/3) light olive brown weathered shale.
	<80/80		(19.3-20.0) No recovery.				
		WET		(20.0-20.5) Same as above.			
						(20.5-21.2) (2.5Y4/3) olive brown weathered shale, dry.	
						(21.2-21.6) Shale frags (100%) - hard frags, wet, same color as above, but not weathered. Refusal at 21.5 ft BGS.

LOCATION **BCV OU 1** TOTAL DEPTH **27.80** ft bgs
 BOREHOLE NUMBER **OLF-03**
 BOREHOLE DIAMETER **1.25 in.** SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 29,916.70 E 47,829.00**ELEVATION **964.70** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	003011		<80/80			(0.0-1.2) (2.5YR4/6) red compact, plastic clay, dry with very sparse weathered chert (2.5Y8/2) pale yellow frags up to 2 cm. Very bottom (2.5Y4/4) olive brown clay, slightly sandy < 10%, moist (CL).	960
						(1.2-2.0) No recovery.	
						(2.0-3.0) Same olive brown soil as bottom of above (0.8 ft).	
						(3.0-4.0) No recovery.	
						(4.0-4.8) Weathered (7.5YR4/3) brown highly weathered dry shale.	
	003012	NA	<80/80			(4.8-6.0) No recovery.	
						(6.0-7.0) Rod indicates 50% recovery. Core stuck in tube, beat out, same shale as above.	
						(7.0-8.0) No recovery.	
						(8.0-9.0) Same shale as above.	
						(9.0-10.0) (10YR6/6) brownish yellow silty clay. Sharp contact with overlaying shale. Some Fe stained in bedding planes.	
10	003013		<80/80	MOIST		(10.0-10.2) Same as above. (10.2-10.9) Same as above with 90% being Fe stained.	955
						(10.9-11.5) (5GY7/1) light greenish gray moist clay with some Fe staining, moist.	
						(11.5-11.8) (2.5Y3/1) very dark gray bedded shale, weathered, dry.	
						(11.8-12.0) No recovery.	
						(12.0-13.0) Same shale as above becoming lighter with depth.	
			<80/80	MOIST		(13.0-14.0) (5GY7/1) light greenish gray with isolated pockets of (7.5YR6/8) reddish yellow dry clay. Greenish clay slightly moist.	950
						(14.0-16.0) (5YR4/2) dark reddish gray highly weathered shale, dry, bedding evident.	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **10/31/94** ENDED **10/31/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

27.80

ft bgs

BOREHOLE NUMBER

OLF-03

COORDINATES N 29,916.70 E 47,829.00

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 964.70 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
20	O03014	NA	<80/80			(16.0-18.0) Same as above - extruded with hydraulic press.	945
			<80/80			(18.0-19.2) Same as above.	
	O03015		<80/80		(19.2-20.0) No recovery.		
			<80/80		(20.0-22.0) Same as above.		
	O03016			WET	(22.0-22.25) (2.5Y4/4) olive brown shale, weathered, wet (all 0.25 ft.)		
			<80/80		(22.25-24.0) No recovery.		
25				WET	(24.0-24.6) Wet (10YR3/4) dark yellowish brown sandy clay.	940	
			<80/80		(24.6-25.75) (2.5Y5/4) light olive brown weathered shale.		
		<80/80					(26.0-27.8) Refusal at 27.8 - had to beat sample out of the tube. Same as above. Refused on same.

SHEET 1 OF 1

LOCATION

BCV OU 1

TOTAL DEPTH

15.00

ft bgs

BOREHOLE NUMBER

OLF-04

COORDINATES N 29,971.30 E 47,160.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 951.10 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
						(0.0-1.0) (2.5YR4/6) red plastic clay with (N4) dark gray limestone gravel (10%).	
			< 60/60			(1.0-2.0) No recovery.	950
	004011					(2.0-3.7) (10YR6/6) brownish yellow dry clay with isolated iron-stained deposits < 1 cm in diameter, dry, (CL).	
			< 60/60			(3.7-4.0) No recovery.	
						(4.0-4.5) Same as above.	
5						(4.5-6.0) (5GY7/1) light greenish gray clay mottled with (10YR6/6) brownish yellow clay. 1-5 cm root. (CL).	
	004012		< 60/60			(6.0-6.4) Same as above.	945
						(6.4-6.5) (2.5Y8/1) white weathered limestone.	
			< 60/60			(6.5-7.6) Same clay as above.	
		NA				(7.6-7.65) Same limestone as above.	
						(7.65-8.0) Highly weathered (5G5/1) greenish gray shale, (CL).	
						(8.0-8.3) (10YR6/6) brownish yellow clay.	
						(8.3-9.1) (2.5Y6/4) light yellowish brown highly weathered shale, dry.	
10			< 60/60			(9.1-10.0) Grades from above to (2.5Y6/3) yellowish brown highly weathered shale, dry, (CL). Bedding observable.	
						(10.0-10.3) Same as above.	
						(10.3-11.2) (2.5Y5/4) light olive brown weathered shale.	
	004013		< 60/60			(11.3-11.6) (5YR4/4) reddish brown weathered shale (moist).	940
						(11.6-11.8) Same as 11.3 - 11.6 ft. Dry, crumbly.	
						(11.8-12.0) No recovery.	
						(12.0-14.0) Refusal at 15.0 ft on same shale as above. Slightly moist sample beat out of the sample tube.	
				MOIST			
						(14.0-15.0) Refusal at 15.0 ft.	

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 10/28/94 ENDED 10/28/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION **BCV OU 1** TOTAL DEPTH **12.00** ft bgs
 BOREHOLE NUMBER **OLF-05**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 30,109.10 E 46,920.20**ELEVATION **955.60** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET	
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water				
5	O05011	NA				(0.0-1.0) (5YR4/6) yellowish red clay with (N7) light gray limestone, dry.	955	
			< 80/60		(1.0-1.8) Fractured (N6) gray limestone frags and rock flour.			
			< 60/60		(1.8-2.0) (10YR5/4) yellowish brown clay, stiff, dry (CL). (2.0-2.6) Same as above. (2.6-3.5) (5YR5/6) yellowish red clay, dry.	950		
			< 60/60		(3.5-4.0) (5G6/1) greenish gray clay, stiff. (4.0-6.0) Entire sample (2.0 ft) (2.5Y6/4) light yellowish brown clay with (5G5/1) greenish gray weathered shale increasing in content % from ~ 10% at top to 50% at bottom.			
	< 60/60			(6.0-7.1) Same as above but with addition of (N6) limestone and highly variable shale content (0-20%).	945			
	< 60/60			(7.1-8.0) No recovery.				
	O05012		< 60/60			(8.0-8.2) (2.5Y6/4) light yellowish brown clay (CL). (8.2-8.3) Highly weathered (2.5 Y 5/4) light olive brown shale. (8.3-10.0) (2.5Y6/2) light brownish gray silty clay (weathered shale with a segment of less weathered Fe stained (2.5Y3/3) dark olive brown) shale.	945	
			O05013			< 60/60		(10.0-12.0) (2.5Y6/1) gray shale - refusal at 12.0 ft.

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **10/28/94** ENDED **10/28/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SHEET 1 OF 2

LOCATION

BCV OU 1

TOTAL DEPTH

17.00

ft bgs

BOREHOLE NUMBER

BY-01

COORDINATES N 29,614.00 E 48,644.90

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 957.50 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	Y01011	70.0	180	MOIST		(0.0-0.5) (5YR5/8) yellowish red silty clay with white weathered chert frags (~2mm) (CL)	955
						(0.5-1.0) (10YR4/3) brown sandy clay, moist (CL).	
						(1.0-2.0) No recovery.	
						(2.0-2.6) Refusal at 2.3 ft BGS - nothing in shoe to cause refusal. Second attempt - same as above with (2.5YR4/4) reddish brown brick frag, glass.	
5	Y01012	NA	<100	MOIST		(2.6-3.0) (7.5YR4/3) brown clay, sparse weathered chert.	950
						(3.0-3.2) (7.5YR3/1) very dark grey, glass frags.	
						(3.2-4.0) No recovery.	
						(4.0-4.2) Brick frags 50% with 50% (5Y4/2) olive gray moist, plastic clay. (CL)	
10	Y01013	NA	180	MOIST		(4.2-6.0) No recovery.	945
						(6.0-6.2) (5BG7/1) light greenish gray compact, plastic clay with an Fe wire running through the length of core (CL).	
						(6.2-8.0) No recovery.	
						(8.0-8.7) Same as above.	
	Y01013	NA	100	MOIST		(8.7-9.4) (2.5Y7/6) yellow clay with weathered black chert.	945
						(9.4-10.0) No recovery.	
						(10.0-10.8) (5GY7/1) light greenish gray clay.	
						(10.8-12.0) (7.5YR5/8) strong brown very stiff, plastic clay, dry. (CL)	
	Y01013	NA	100	MOIST		(12.0-14.0) Same clay as above with black chert frags (very small) dry (CL)	945
						(14.0-16.0) Same as above (CL).	

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 11/15/94 ENDED 11/15/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

17.00 ft bgs

BOREHOLE NUMBER BY-01

BY-01

BOREHOLE DIAMETER 1.25 in.

1.25 in.

SAMPLING DEVICE	PROBE
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PROBE

COORDINATES N 29,614.00 E 48,644.90

ELEVATION 957.50 ft above MSL

LOGGED BY **KEN SWAIN**

KEN SWAIN

[illegible]

SHEET 1 OF 2

LOCATION **BCV OU 1** TOTAL DEPTH **17.00** ft bgs
 BOREHOLE NUMBER **BY-02**
 BOREHOLE DIAMETER **1.25** in. SAMPLING DEVICE **PROBE**
 LOGGED BY **KEN SWAIN**

COORDINATES **N 29,560.60 E 48,361.70**ELEVATION **957.10** ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y02011	NA	<80			(0.0-0.6) (7.5YR5/8) strong brown clay with very small white chert frags.	955
						(0.6-1.3) Fill, glass and ceramic tile frags in (7.5YR3/2) dark brown silty clay with (N5) gray limestone frags (CL).	
						(1.3-2.0) No recovery.	
						(2.0-2.5) Same as above.	
						(2.5-3.5) 100% (N4) dark grey limestone (GW) gravel.	
						(3.5-4.0) No recovery.	
						(4.0-4.1) (10R3/6) dark red highly weathered shale.	
						(4.1-4.5) (10Y5/4) yellowish brown clay (CL).	
						(4.5-6.0) No recovery.	
						(6.0-7.0) (2.5Y6/4) light yellowish brown clay mottled with (5YR5/8) yellowish red clay (20%) with sparse black weathering residuum. Plastic, moist (CL).	
10	Y02012	NA	<80	MOIST		(7.0-8.0) No recovery.	950
						(8.0-8.5) Same as above (CL) dry, grades to (5G6/1) greenish gray clay with less red mottling.	
						(8.5-10.0) No recovery.	
						(10.0-10.4) Same (5G6/1) greenish grey clay (50% mottling).	
						(10.4-12.0) Grades to next 1.6 feet of (10YR6/8) brownish yellow clay (CL), very stiff, dry, no rock frags.	
						(12.0-13.5) (10YR5/8) yellowish brown clay, less than 5% (2.5Y6/6) olive yellow mottling. Very stiff, dry (CL).	
	Y02013	NA	<80			(13.5-14.0) No recovery.	945
						(14.0-14.25) Same as above.	
						(14.25-16.0) No recovery.	

DRILLING CONTRACTOR **GEOMARINE, INC.**DRILLING METHOD **PROBE**DRILLING EQUIPMENT **GEOPROBE**DRILLING STARTED **10/27/94** ENDED **10/27/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 18.60 ft bgs

BOREHOLE NUMBER BY-03

COORDINATES N 29,757.10 E 48,305.30

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 959.30 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y03011	88.0	400		(0.0-0.3) (N6) gray limestone gravel in a (10YR7/3) very pale brown clay matrix (GC)		955
					(0.3-0.9) Same (10YR7/3) clay mottled with (10YR7/6) yellow clay (CL).		
			400		(0.9-1.1) Dark yellowish brown clay with 60% broken glass of assorted colors.		
					(1.1-2.0) No recovery.		
					(2.0-2.5) Same clay as above - no large glass frags. wood chips at very top and very bottom. Large (N6) limestone (<2 cm) wedged in shoe (CL).		
10	Y03012	11.0	180		(2.5-4.0) No recovery.		950
					(4.0-4.3) (5Y4/2) olive gray clay mottled with (5Y7/6) yellow clay (CL).		
			200	WET	(4.3-4.7) (5Y3/1) very dark gray silty clay with 1 2-cm frag of (2.5YR3/4) dark reddish brown shale (CL).		
					(4.7-5.0) (2.5Y5/4) light olive brown silty clay, wet (CL).		
					(5.0-6.0) No recovery.		
15	Y03013	44.0	220	WET	(6.0-6.5) Wet (10YR5/6) yellowish brown clay with glass frags.		945
					(6.5-8.0) (10YR5/6) yellowish brown clay mottled with (10YR7/1) light gray clay up to 60% in 6.3-6.4 ft. less than 20% throughout rest of sample. (CL).		
			160	WET	(8.0-9.0) Wet (10YR6/8) brownish yellow clay with isolated black weathering residuum (<1 cm)(CL).		
					(9.0-10.0) (10YR6/8) brownish yellow clay mottled with (5Y7/2) light gray clay (<10%). Plastic, dry (CL).		
					(10.0-11.4) (7.5YR5/6) plastic, dry clay mottled with (5GY7/1) light greenish gray clay < 10% (CL).		
20					(11.4-12.0) No recovery.		
					(12.0-12.9) (5Y5/4) olive clay (totally weathered shale) with some (7.5YR6/6) reddish yellow residuum (CL).		
				MOIST	(12.9-13.0) (5Y7/4) pale yellow shale with Fe stained crusts. Moist.		
25					(13.0-14.0) No recovery.		
					(14.0-16.0) (10YR5/8) yellowish brown clay mottled w/ (2.5Y7/3) pale yellow clay w/sparse frags of (5Y6/2) light olive gray shales (~0.5 cm). Shale content increases to ~ 30% at bottom (GC) 15.0-15.2 was 100% of shale described above.		

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 11/14/94 ENDED 11/14/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

SHEET 1 OF 1

LOCATION

BCV OU 1

TOTAL DEPTH

14.20

ft bgs

BOREHOLE NUMBER

BY-04

COORDINATES N 30,247.70 E 48,385.30

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE

PROBE

ELEVATION 969.70 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y04011	14.0	500			(0.0-0.6) (10YR6/1) gray limestone frags and powdered limestone (GC).	965
				MOIST		(0.6-1.1) Black, apparently burned organic material with silica sand.	
						(1.1-1.3) (2.5YR4/8) red brick frags in (10YR4/3) brown sandy clay, moist. Fill.	
			150			(1.3-2.0) No recovery.	
						(2.0-2.4) (2.5Y4/4) olive brown sandy clay (CL).	
				MOIST		(2.4-3.1) (10YR5/6) yellowish brown weathered shale with associated weathering residuum.	
	Y04012	6.1	<80			(3.1-3.4) (N6) gray limestone frags in black clay, moist, 80% limestone frags (GC).	
				WET		(3.4-4.0) No recovery.	
						(4.0-4.3) (5GY4/1) dark greenish gray shale and same color clay, wet (CL).	
			150			(4.3-4.6) Same as above with white mortar, sandy with black burned residuum as described above (<15%).	
						(4.6-4.7) (7.5YR5/4) brown clay with (5G5/2) grayish green shale frags, wet. (CL).	
				WET		(4.7-6.0) No recovery.	
10	Y04013	NA	200			(6.0-6.5) (10YR5/4) yellowish brown silty sandy clay, same mortar.	960
				WET		(6.5-7.2) Dry, concrete and mortar.	
						(7.2-7.5) (5Y7/3) pale yellow chert frags (100%), very wet (GC)	
			<80			(7.5-7.7) Same black burn residuum described above with 50% (7.5YR4/1) dark gray microcrystalline limestone, dry. Metal frags throughout.	
				WET		(7.7-8.0) No recovery.	
						(8.0-8.3) 50% water, black burn residuum and limestone as above.	
	Y04014	3.7	<80			(8.3-10.0) No recovery.	
						(10.0-10.5) (5B6/1) bluish gray clay with (10R4/2) weak red sandstone fragments (up to 3 cm)	
						(10.5-12.0) (2.5Y5/6) light olive brown weathered shale, dry (CL).	
						(12.0-13.5) (2.5Y5/1) gray shale, dry.	
						(13.5-14.0) No recovery.	
						(14.0-14.2) Refusal at 14.2 ft BGS.	

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 12/6/84 ENDED 12/6/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1 TOTAL DEPTH 20.00 ft bgs

BOREHOLE NUMBER BY-05

COORDINATES N 30,259.60 E 48,578.20

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 973.90 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/gamma (cpm)	water			
5	Y05011	9.1	<80		(0.0-0.5) (N4) dark gray limestone gravel (GP).		970
					(0.5-1.0) (10YR5/4) yellowish brown clay mottled with (5Y5/3) olive clay ~40% (CL)		
					(1.0-2.0) No recovery.		
					(2.0-2.4) (10R4/8) brick and associated mortar.		
					(2.4-3.0) (2.5Y5/4) light olive brown weathered clay, dry (CL).		
10	Y05012	NA	<80	WET	(3.0-3.2) (5BY/1) dark greenish gray clay with (2.5Y5/4) woody fragments, dry. A copper wire. (CL).		965
					(3.2-4.0) No recovery.		
					(4.0-4.2) (2.5Y5/3) light olive brown clay and shale (CL)		
					(4.2-5.2) Same as 3.0-3.2 in above sample with alternating portions of same red brick as above. Some hairlike fibers ~ 2 cm in length.		
					(5.2-6.0) No recovery.		
15	Y05013	NA	<80	MOIST	(6.0-6.5) End of sampler wet. Crushed mortar with very small frags of (N6) limestone.		960
					(6.5-7.45) (2.5Y 6/4) light yellowish brown clay.		
					(7.45-7.5) Wet, all other moist, plastic (CL).		
					(7.5-8.0) No recovery.		
					(8.0-8.8) (5Y6/3) pale olive clay - wet from 8.4-8.7 ft.		
20	Y05013	NA	<80	MOIST	(8.8-9.15) (10YR5/8) yellowish brown clay - resistant, dry (CL).		960
					(9.15-9.2) (5GY7/1) light greenish gray clay (CL).		
					(9.2-10.0) No recovery.		
					(10.0-11.5) (5GY6/1) greenish gray shale and associated clay weathering residuum, some (5GY7/1) light greenish gray silty clay, moist. Very bottom (5Y5/3) olive very weathered shale, dry (CL).		
					(11.5-12.0) No recovery.		
25	Y05013	NA	<80	MOIST	(12.0-12.9) (2.5Y6/3) light yellowish brown weathered shale.		960
					(12.9-13.3) (10YR5/3) brown shale, dry (CL).		
					(13.3-14.0) No recovery.		
30	Y05013	NA	<80	MOIST	(14.0-15.6) (10YR5/1) gray weathered shale, dry.		960

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/5/94** ENDED **12/5/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 20.00 ft bgs

BOREHOLE NUMBER BY-05

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

COORDINATES N 30,259.60 E 48,578.20

ELEVATION 973.90 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	Y05014	NA	<80			(15.6-15.8) (10YR4/3) brown shale, wet.	
				WET		(15.8-16.0) No recovery.	
			<80			(16.0-17.3) (10YR4/2) dark grayish brown shale, bottom 0.2 ft, moist.	
				MOIST		(17.3-18.0) No recovery.	
	Y05015		<80	WET		(18.0-18.5) Same as above, wet. (18.5-18.8) (5B4/1) dark bluish gray shale, wet. Refusal at 20 ft BGS.

LOCATION

BCV OU 1

TOTAL DEPTH

16.60

ft bgs

BOREHOLE NUMBER

BY-06

COORDINATES N 30,458.70 E 48,460.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 976.80 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y06011	17.0	<80			(0.0-0.9) (7.5YR4/3) brown clay with abundant brick frags and (N4) dark gray shale (CL).	975
						(0.9-2.0) (10YR5/6) yellowish brown clay with brick frags, and (N4) dark gray shale, dry.	
						(2.0-2.5) Same as above.	
						(2.5-2.8) Black burn residuum with (N4) limestone frags with very small amounts of above yellowish brown clay.	
5	Y06012	7.2	<80	MOIST		(2.8-3.2) Red brick (10YR8/2) very pale brown mortar.	970
						(3.2-3.25) (10YR8/2) very pale brown quartzite frags.	
						(3.25-4.0) No recovery.	
						(4.0-5.5) (10YR7/1) light grey clay and (10YR5/1) gray clay with abundant brick and (N3) very dark gray shale frags (CL) dry.	
10	Y06013	NA	<80	WET		(5.5-6.0) No recovery.	965
						(6.0-6.25) Red brick with subordinate (5BG4/2) dark greenish gray shale frags and weathering residuum of same shale (clay) moist.	
						(6.25-8.0) No recovery.	
						(8.0-8.2) Same as above, wet with large piece of red brick.	
10	Y06013	NA	<80	WET		(8.2-10.0) No recovery.	965
						(10.0-10.7) Wet black clay ooze.	
						(10.7-11.1) Wood frags, natural color.	
						(11.1-11.4) (N4) dark gray plastic clay, moist, rootlets - pH of soil ~ 10.	
10	Y06013	NA	<80	MOIST		(11.4-12.0) No recovery.	965
						(12.0-14.0) No recovery - no resistance in pushing, sampler dripping water.	
						(14.0-14.9) Same clay as above, wet (CL).	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/6/94** ENDED **12/6/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION

BCV OU 1

TOTAL DEPTH

23.90

ft bgs

BOREHOLE NUMBER

BY-07

COORDINATES N 29,760.40 E 48,788.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 961.90 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y07011	53.0	200			(0.0-0.5) Refusal at 1 ft on (N7) light gray limestone gravel (GC). Moved 0.5 ft. east, refusal at 1.8 ft. Third attempt - (N7) light gray limestone, brick frags (10YR5/8) yellowish brown clay, wood fragments. Moved 6 ft. to east. Preprobed to 3 ft. Heavy resistance, but got through. (0.5-2.0) No recovery.	960
				MOIST		(2.0-2.6) (10YR5/3) brown clay with brick dust, moist (CL). (2.6-4.0) No recovery.	
			150			(4.0-6.0) No recovery.	
10	Y07012	16.0	150	MOIST		(6.0-8.0) (2.5Y6/4) light olive brown clay, moist. (8.0-8.9) Same as above.	955
			<80			(8.9-9.3) (5G7/1) light greenish gray clay mottled with black residuum and (10YR6/8) brownish yellow clay. Large fragment of white, granular chert, dry (CL). (9.3-10.0) No recovery.	
			<80			(10.0-10.5) (10YR5/8) yellowish brown becoming mottled with (5Y7/4) pale yellow clay (CL) (10.5-12.0) (5GY7/1) light greenish gray clay mottled with up to 40% (10YR6/8) brownish yellow clay, dry (CL).	
						(12.0-12.5) Same as above but shaley, dry, (CL). (12.5-13.2) (5G7/1) light greenish gray shale, very weathered.	
			100			(13.2-14.0) (2.5Y6/4) light yellowish brown weathered shale, dry.	
	Y07013	NA		MOIST		(14.0-14.5) Same as above grading to completely weathered to clay, moist. (14.5-14.7) (5YR5/8) yellowish red clay (CL).	950

DRILLING CONTRACTOR GEOMARINE, INC.

DRILLING METHOD GEOPROBE

DRILLING EQUIPMENT GEOPROBE

DRILLING STARTED 12/8/94 ENDED 12/8/94

REMARKS

Coordinates are reported in Y-12 Grid
See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH

23.90

ft bgs

BOREHOLE NUMBER BY-07

COORDINATES N 29,760.40 E 48,788.80

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 961.90 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
			100			(14.7-16.0) No recovery.	
	Y07014	5.0		WET		(16.0-16.7) (10YR6/8) brownish yellow clay, wet with small frags of (10YR6/2) light brownish gray shale (CL).	
			<80			(16.7-18.0) No recovery.	945
				MOIST		(18.0-18.2) Same clay as above mottled with 50% (10YR3/2) very dark grayish brown clay, plastic, moist (CL).	
			<80			(18.2-20.0) No recovery.	
20	Y07015	NA		MOIST		(20.0-20.4) Same as above.	
			<80			(20.4-22.0) (10YR6/8) brownish yellow clay. Wet from 21.2-21.6 ft BGS. At 22.0 ft BGS (10YR7/3) very pale brown silty clay, wet (CL).	
				WET			
				WET		(22.0-22.3) Same as above (CL). Refusal at 23.9 ft.	940
	Y07016		<80

LOCATION BCV OU 1

TOTAL DEPTH 6.40

ft bgs

BOREHOLE NUMBER BY-08

COORDINATES N 29,922.40 E 48,264.20

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

ELEVATION 967.40 ft above MSL

LOGGED BY KEN SWAIN

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
5	Y08011	460.0	2500			(0.0-1.0) (5YR5/8) yellowish red clay w/(N8) white chert frags (CL). < 80 cpm.	965
						(1.0-1.6) (5YR3/2) dark reddish brown clay with abundant glass, (5Y5/4) olive shale, very small frags of (5Y8/8) yellow material (glass) (CL) 2500 cpm.	
			2000			(1.6-2.0) No recovery.	
						(2.0-2.5) Mottled yellowish red clay as in 0.0-1.0 of above (CL)	
		(2.5-2.7) Apparent green salt.					
		(2.7-3.1) Same reddish brown clay with glassy shale as described in 0.0-0.2 (CL).					
	Y08012	880.0	3000			(3.1-4.0) No recovery.	
						(4.0-4.6) Same as above with metal frags, rusty colored tubular material, wire corrosion-looking material / (White) dry (CL).	
						(4.6-6.0) No recovery.	
			1000/ 5000			(6.0-6.2) Refusal at 6.4 ft. moving over and try again. From 6.0-6.2 ft BGS same as above. Second try at 6 - 8 approximately 0.5 ft east of original hole. Refusal at 6.4 ft again. Same material as before but apparently burned much blacker. Refusal at 6.0 after moving 4 ft to the west.	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/8/94** ENDED **12/8/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

LOCATION BCV OU 1

TOTAL DEPTH 16.00 ft bgs

BOREHOLE NUMBER BY-09

BOREHOLE DIAMETER 1.25 in.

SAMPLING DEVICE PROBE

LOGGED BY KEN SWAIN

COORDINATES N 29,893.60 E 48,204.70

ELEVATION 963.00 ft above MSL

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			
	Y09011	520.0	2500			(0.0-1.0) (10YR3/3) dark brown clay with frags of brick, glass and wood limestone gravel.	960
						(1.0-2.0) No recovery.	
			1000	WET		(2.0-2.6) Wet, same material.	
						(2.6-4.0) No recovery.	
		NA				(4.0-6.0) Wet, no recovery - 1 piece of magnesium turning on outside of sampler.	
				WET		(6.0-8.0) Water, no soil again.	
10	Y09013	33.0	300			(8.0-8.6) Wet, black organic burn residuum, wood and shale frags - color undeterminable due to black mud covering, wet.	955
						(8.6-10.0) No recovery.	
			500	WET		(10.0-11.0) (5Y4/1) dark gray clay, moist (CL). Top 0.6 ft wet, rest feels moist.	
				MOIST WET		(11.0-11.2) A sharp contact (10YR4/4) dark yellowish brown clay, wet (CL). (11.2-12.0) No recovery.	
	Y09014	3.2	200			(12.0-12.7) (10YR4/3) brown highly weathered clay, dry (CL).	950
						(12.7-12.9) (5GY6/1) greenish gray highly weathered shale. (12.9-13.0) Same shale, less weathered, with (2.5Y4/2) dark grayish brown interlayer staining.	
			200			(13.0-14.0) No recovery.	
						(14.0-15.8) (5YR4/2) dark reddish gray shale, dry. Refusal at 16.0 ft.	

DRILLING CONTRACTOR **GEOMARINE, INC.**
 DRILLING METHOD **GEOPROBE**
 DRILLING EQUIPMENT **GEOPROBE**
 DRILLING STARTED **12/9/94** ENDED **12/9/94**

REMARKS

Coordinates are reported in Y-12 Grid
 See key sheet for symbols and abbreviations used above.

SAMPLE INFORMATION					STRATA	LITHOLOGIC DESCRIPTION	ELEVATION FEET
DEPTH FEET	SAMPLE ID	U-238 (pCi/g)	beta/ gamma (cpm)	water			

APPENDIX C

CHARACTERIZATION OF HYDROGEOLOGIC SETTING

The purpose of this appendix is to describe the hydrogeologic conceptual model for Bear Creek Valley (BCV). This conceptual model is one of the principal components of the conceptual site models for contaminant transport in BCV, development of which is one of the goals of this Remedial Investigation (RI). The hydrogeologic conceptual model is a presentation of the working hypothesis, or theory, governing the physical aspect of water movement in BCV. In this respect, the hydrogeologic conceptual model provides the technical basis for interpreting the nature and extent of contamination (Appendix D) and the fate and transport of contaminants (Appendix E). It is important to note that hydrogeologic conditions at individual sites in BCV may vary from the generalized model but still retain the main components of the model (refer to Appendix D for individual site hydrogeologic conditions). Understanding the close interaction among the main components of the hydrogeologic conceptual model in a localized area is, therefore, the key to understanding groundwater flow at a site within that area.

In developing the hydrogeologic conceptual model, data collected during the RI Field Activities (RIFA) in BCV were combined with a wealth of past and ongoing studies that have been carried out in BCV or elsewhere on the Oak Ridge Reservation (ORR). Interest in contaminant transport associated with the waste disposal sites in BCV motivated the Oak Ridge Y-12 Plant to develop a large database of environmental data from studies of the disposal areas and of potential exit pathways. Ongoing work is summarized each year in the Groundwater Quality Report (GWQR) (e.g., HSW 1995). These studies include quarterly water level measurements summarized in the annual GWQR, data from RIs conducted in BCV during 1994 and 1995 (Appendix B), data from numerous previous studies carried out in BCV between 1984 and 1994 (e.g., Golder and Associates 1988a; Geraghty and Miller 1986), the Exit Pathway Monitoring Program (Shevenell et al. 1992), and other more specific studies carried out by the Environmental Sciences Division at Oak Ridge National Laboratory for the Groundwater Protection Program (GWPP) or the ORR Hydrology and Geology Studies (ORRHAGS) program (e.g., Dreier et al. 1993; Goldstrand 1995; Moline and Schreiber 1995, draft). Using these data, the resulting conceptual model builds on the previous theories and hypotheses for groundwater movement on the ORR (e.g., Solomon et al. 1992; Moore and Toran 1992).

Sections C.1 and C.2 of this appendix briefly describe the climate and topographical components of the hydrogeologic conceptual model, Sect. C.3 discusses the geological component, and Sect. C.4 presents the hydrogeological component. Conclusions of this appendix are also summarized into Section 2 of the RI Report.

C.1 CLIMATE

The climate of the region surrounding the Oak Ridge area is broadly classified as humid continental. The Cumberland Mountains to the northwest have a moderating influence by shielding the region from cold air masses that frequently extend far south over the plains of the central United States during the winter months. In the summer months, tropical air masses from the south provide warm and humid conditions that often produce thunderstorms; however, anticyclonic circulation around high-pressure systems centered in the western Gulf of Mexico can bring dry air from the southwestern United States into the region, which causes occasional periods of drought (Energy Systems 1994).

C.1.1 TEMPERATURE

The National Climatic Data Center calculates the area's "normal" temperatures each decade using climate data from a recent 30-year period. Recent climate normals (1963 through 1992 base period) were obtained from the Atmospheric Turbulence and Diffusion Laboratory of the National Oceanographic and Atmospheric Administration in Oak Ridge, which is the Center's source for local climate data. According to these data, the annual mean air temperature for the Oak Ridge area is 13.9°C (57.1°F). The coldest month is usually January, with temperatures averaging about 2.0°C (35.6°F) but occasionally falling as low as -27°C (-17°F) (Fig. C.1). July is typically the hottest month of the year, with average temperatures of 24.7°C (76.5°F) but occasionally rising to 41°C (105°F). Diurnal temperature changes are relatively consistent from month to month, ranging from 10 to 15°C (18 to 27°F) (Site & Facilities Planning Department 1994).

C.1.2 WINDS

The Oak Ridge area has relatively light winds compared to other parts of the United States. The Cumberland Mountains and Plateau to the northwest and west, combined with the local valley and ridge topography, divert severe storms and minimize air movement and wind impact. However, wind speed characteristics vary greatly over short distances in the Oak Ridge area, depending on the measuring site's location with respect to individual valley bottoms or ridges. According to a preliminary analysis of wind data from the Oak Ridge Site Survey (Eckman et al. 1992), ridge-top and valley sites in the Oak Ridge area (excluding the Cumberland Plateau) experience wind speeds <5 m/s (11.2 mph) over 90% of the time. Also, many valley-bottom sites experience winds <2 m/s (4.5 mph) over 70% of the time and calm winds about 25 to 30% of the time (Site & Facilities Planning Department 1994).

Prevailing wind directions in the Oak Ridge area are oriented parallel to the direction of the local ridge and valley terrain. Prevailing winds are either up-valley (northeasterly) day-time winds or down-valley (southwesterly) night-time winds (Energy Systems 1994). The general wind characteristics for Oak Ridge described above are observed in BCV, where prevailing winds are oriented along the valley with an average wind speed of 1.5 m/s (3.4 mph) (Fig. C.1).

C.1.3 PRECIPITATION

Detailed discussions of precipitation patterns for BCV can be found in Sect. 2.2 of *Ecological Effects of Contaminants and Remedial Actions in Bear Creek* (Southworth et al. 1992). Average precipitation in the Oak Ridge area varies by as much as 30%, depending on the location relative to local terrain. In the Oak Ridge area there is a rain shadow effect caused by the higher Cumberland Plateau to the west. The net result is slightly above average precipitation in the northwest portion of the Oak Ridge area and somewhat below average precipitation in the southeast portion (Site & Facilities Planning Department 1994).

The 40-year annual average precipitation for Oak Ridge is 137 cm (53.75 in.), including about 26 cm (10.4 in.) of snowfall (Fig. C.1). Precipitation in 1993 was 126 cm (49.6 in.), about 11 cm (4.3 in.) below the annual average. Precipitation in the region is greatest in the winter and spring months (January through April) and least during the fall months (September through November), when high-pressure systems are most frequent (Energy Systems 1994).

C.2 TOPOGRAPHY

The ORR lies within the Valley and Ridge Physiographic Province, which is characterized by steep-sided parallel ridges with broad intervening valleys, generally oriented in a northeast-southwest direction. BCV is bordered by Pine Ridge on the northwest and by Chestnut Ridge on the southeast (Fig. C.2). Topographic relief from the crest of Pine Ridge to the floor of BCV ranges from 79 to 91 m (260 to 300 ft); relief from the crest of Chestnut Ridge to the floor of BCV ranges from 85 to 122 m (280 to 400 ft). The average elevation of the ridges is ~335 m (1100 ft) above mean sea level (amsl), while elevation of the floor of BCV ranges from 244 to 305 m (800 to 1000 ft) amsl.

C.3 BCV HYDROGEOLOGIC CONCEPTUAL MODEL — GEOLOGY

The hydrogeologic system in BCV is governed by its main geologic features, including:

- lithology that is interbedded shale, sandstone, and limestone;
- geologic structure characterized by tilted stratigraphy, faults, and fractures; and
- geomorphology dominated by parallel ridges and valleys.

The key geologic features affecting transmission of groundwater in BCV are identified below and discussed in the following subsections. Further detailed reviews are available in Hatcher et al. (1992) and Solomon et al. (1992).

- The geology of BCV displays an inclined layer-cake-style stratigraphy. This stratigraphy is observed on a regional scale, where predominantly carbonate rock groups (Knox Group and the Maynardville Limestone) are interbedded with predominantly clastic groups (Conasauga Group and the Rome Formation). Interbedding is also observed on the scale of outcrops, where clastic beds are interlayered with carbonate beds (Figs. C.3 and C.4). This layering structure results in anisotropy of permeability and hydraulic conductivity, which exerts a strong influence on flow directions.
- The primary permeability of the rocks underlying BCV is very low. However, diagenesis, fracturing, and solution weathering of bedrock has resulted in secondary porosity and permeability through which most fluid movement occurs (Solomon et al. 1992; Shevenell 1994b; Goldstrand et al. 1995). In addition, orientations of well-connected fractures or solution conduits are predominantly parallel to geological strike and/or bedding planes, enhancing the effect of anisotropy caused by layering. As a result, groundwater flow paths parallel to geological strike and bedding predominate.
- Fracture aperture width generally decreases with depth in all formations and thus restricts the depth of active groundwater circulation. Hydraulically active fractures, and thus active groundwater circulation, occur at greater depths in the Knox Group and the Maynardville Limestone than in the Conasauga Group.
- Residuum (weathered bedrock) of variable thickness covers most of BCV. Thickest on the ridges of the Knox Group, it is thinner in the valleys and nearly disappears in stream channels. Residuum on the ridges formed by the Rome Formation has variable thickness. When the residuum occurs over clastic formations, it probably retains relict structures from the bedrock and maintains some of the hydraulic anisotropy.
- The surface morphology of the ORR is characterized by parallel ridges and intervening valleys formed by differential erosion of the steeply dipping resistant and less resistant rock units. Knox Group and Rome Formation rocks represent the competent units that, more resistant to erosion than the Conasauga Group, today constitute the ridge-forming units that define BCV.

C.3.1 BCV STRATIGRAPHY

The geology of the ORR is characterized by a folded and faulted assemblage of shales and limestones. This assemblage represents the deposition of a ~2.5-km (1.6-mile) layer of marine and

near-shore sediments during the entire Cambrian and Ordovician periods. BCV is underlain by rocks of three regionally important stratigraphic units: the Rome Formation, the Conasauga Group, and the Knox Group (Fig. C.4). For general descriptions of the stratigraphy of geological units in the ORR, see Hatcher et al. (1992) for an overview of the ORR geology; Haase et al. (1985) for the Conasauga Group and Rome Formation; and Lee and Ketelle (1987) for the Knox Group. Following are brief descriptions of these units.

Rome Formation

The Rome Formation crops out at the Y-12 Plant on Pine Ridge and dips beneath BCV. The oldest rock unit exposed in the ORR, it ranges in thickness from 122 to 183 m (400 to 600 ft). Maroon, green, and/or yellow-brown micaceous shale is the most common lithology in the Rome Formation. The formation consists of siltstone, sandstone, dolomitic sandstone, and dolomite interbedded with shale. Sandstones and siltstones are more abundant in the upper Rome Formation, which is capped by a 3- to 6-m (10- to 20-ft) thick sandstone bed. Some dolomite and dolomitic sandstone beds in the upper Rome Formation are laterally continuous.

Conasauga Group

The Conasauga Group outcrops above the Rome Formation on the southern flank of Pine Ridge. The average thickness of the Conasauga Group is 567 m (1860 ft). The Group is traditionally subdivided in central East Tennessee into the (1) Middle Cambrian Pumpkin Valley Shale, Rutledge Limestone [Friendship Formation in Hatcher et al. (1992)]; (2) Rogersville Shale, Maryville Limestone [Dismal Gap Formation in Hatcher et al. (1992)]; and (3) Upper Cambrian Nolichucky Shale, Maynardville Limestone.

Except for the Maynardville Limestone, the Conasauga in BCV is a monotonous sequence of shale, siltstone, and thin-bedded limestone. Some formations, however, include laterally continuous limestone beds up to several meters thick. Where karstification has enlarged fractures in the limestone beds, strata-bound, high-permeability zones may exist. The Maynardville Limestone is the uppermost member of the Conasauga Group, a massively bedded limestone and dolomite formation with extensive karstification.

The following are brief descriptions of the six formations in the Conasauga Group.

Pumpkin Valley Shale. Oldest of the Conasauga Group formations, the Pumpkin Valley Shale is predominantly an olive and maroon, massive, clay and shale unit with thin beds of siltstone and sandstone. The Pumpkin Valley Shale is gradational with the underlying Rome Formation but lacks the sandstone that is characteristic of the Rome Formation. Two members of the Pumpkin Valley Shale have been identified (Law Engineering 1975), the upper one being richer in shale than the lower one. The lower member exhibits units that are commonly bioturbated or have wavy parallel stratification. The Pumpkin Valley Shale exhibits low hydraulic conductivity (DuBuchanne and Richardson 1956), and the lack of continuous limestone beds also precludes the possibility of extensive karst development in this formation. The formation is ~94 to 109 m (308 to 358 ft) thick (Hatcher et al. 1992).

Rutledge Limestone [on the ORR referred to as the Friendship Formation by Hatcher et al. (1992)]. Predominantly a clastic unit (75% shale) with some limestone, the Rutledge Limestone in BCV ranges in thickness from 31 to 45 m (102 to 148 ft). The formation consists of light-grey to white, medium- to thin-bedded limestones and micritic limestones interbedded with mudstones and shales that become more calcareous higher in the succession. Some limestone beds are persistent and

serve as marker beds within the lower Conasauga Group. Increased amounts of limestone distinguish the Rutledge Limestone from the overlying and underlying formations. Although limestone is a minor lithology in this formation, laterally continuous beds may provide groundwater flow paths where karst has formed.

Rogersville Shale. The Rogersville Shale is ~36 m (118 ft) thick and is composed of massive to medium-bedded, noncalcareous mudstones, interbedded with brown shales. The shales and mudstones contain subordinate units of glauconitic and/or calcareous siltstones. A limestone-rich interval known as the Craig Limestone member, which outcrops throughout much of eastern Tennessee, occurs in the upper portion of the Rogersville Shale. Clastic sediments dominate the Rogersville Shale, and karst formation is probably not common, except possibly for the Craig Limestone member.

Maryville Limestone [referred to as the Dismal Gap Formation by Hatcher et al. (1992)]. The Maryville Limestone, ranging in thickness from 47 to 85 m (154 to 279 ft), consists of calcareous shales and shaley siltstones (~60 to 70 %) interbedded with light- to dark-grey, fine- to coarse-crystalline limestone (~30 to 40 %). This formation is informally divided into two members (Haase et al. 1985). The lower member consists of medium- to thin-bedded calcareous mudstone interbedded with pelloidal or oolitic calcareous siltstones. Limestones appear as discrete beds, 5 to 20 cm (2 to 8 in.) thick in coarsening upward cycles. Several relatively limestone-rich horizons ranging from 6 to 12 m (20 to 39 ft) thick, which are characteristic of the Maryville Limestone, occur throughout the lower member. The upper member of the Maryville Limestone is characterized by the presence of distinctive, flat, limestone-pebble conglomerates. In places, the intraclastic limestones are glauconitic or oolite-rich. The limestone units in this formation offer the potential for karst formation. Bedding in the clastic units is commonly wavy, which may result in poor development of bedding parallel fractures.

Nolichucky Shale (Foreman et al. 1991; Rothschild et al. 1984). The Nolichucky Shale, which is ~190 m (620 ft) thick, consists of shale interbedded with intraclastic limestone, thick fossiliferous limestone, and oolitic limestone. Shale is the dominant lithology, occurring in 2.5- to 3-m (8- to 10-ft) thick beds that are laterally continuous. Like all shales in the Conasauga Group on the ORR, the Nolichucky Shale has good fissility, and horizontal laminae are well preserved. The occasional limestone beds in the Nolichucky Shale may provide preferential flow paths for groundwater where karst has occurred.

Maynardville Limestone (Shevenell et al. 1992). The youngest formation of the Conasauga Group, the Maynardville Limestone, consists primarily of light-gray to tan, medium- to thin-bedded limestone with subordinate amounts of dolostone. Extensive study of the Maynardville Limestone during the Exit Pathway Monitoring Program in BCV (Shevenell et al. 1992) subdivided the Maynardville into seven different, informal lithologic zones (with zone 7 being stratigraphically highest) based on lithology and geophysical characteristics (Fig. C.5). Comparison with the stratigraphic nomenclature for the Maynardville Limestone shows that zones 4 through 7 correspond to the Chances Branch member, zones 2 and 3 correspond to the Low Hollow member, and zone 1 corresponds to the upper Nolichucky Shale.

In BCV, the thickness of the Maynardville Limestone varies from 67 to 136 m (220 to 445 ft). Thickest at the northeast end of the Y-12 Plant close to Scarboro Road, the formation thins considerably in BCV adjacent to the Bear Creek Burial Grounds (BCBG) (Table C.1 and Fig. C.5) (Shevenell et al. 1992). Zone 2, which varies considerably in thickness, is apparently absent opposite the BCBG; this absence reflects an overall thinning of the Maynardville Limestone along strike at the BCBG. The pinching out of zone 2 at the BCBG also appears to be accompanied by a thickening

of the upper Nolichucky Shale in this section and has been interpreted as an along-strike facies change (Shevenell et al. 1992).

Knox Group

The Knox Group underlies and forms Chestnut Ridge, the southern boundary of BCV. On the ORR, the Knox Group is divided into five separate units: the Copper Ridge Dolomite, the Chepultepec Dolomite, the Longview Dolomite, the Kingsport Formation, and the Mascot Dolomite. Total thickness of the Knox Group ranges between 600 and 900 m (1970 and 2950 ft), with the Copper Ridge Dolomite making up roughly one-third of the total.

The Knox Group is composed of a series of medium- to thick-bedded, massive, grey, green, and pink dolomite. The Copper Ridge and Longview Formation dolomites are siliceous, and these formations tend to be ridge formers in East Tennessee. All formations within the group contain subordinate amounts of chert, some in nodular form that characteristically remain in the soils after weathering of the dolomite matrix. The Knox Group, along with the Maynardville Limestone from the Conasauga Group, forms the regionally important Knox aquifer (Solomon et al. 1992). Although the dolomite lithologies have little primary matrix porosity, extensive karst formation (Shevenell and Beauchamp 1994) and dedolimitation (Goldstrand et al. 1995) have resulted in the development of secondary porosity and permeability. Sinkholes are common at outcrop, and springs and seeps are common features at the upper and lower geologic contacts.

Residuum

Overlying the bedrock on the ORR is unconsolidated material that consists of weathered bedrock (referred to as residuum), man-made fill, alluvium, and colluvium. With the exception of the areas close to the S-3 Site and Rust Spoil Area, most of the unconsolidated material in BCV west of the Y-12 Plant is residuum. The depths to unweathered bedrock differ throughout the ORR because of the different thicknesses of fill and alluvium and the particular weathering characteristics of the bedrock units. The total thickness of these materials typically ranges from 3 to 15 m (10 to 50 ft) (Hoos and Bailey 1986).

Overlying the bedrock throughout the ORR except in scattered outcrop areas, the residuum ranges from silty to sandy clay overlying shale units to a slightly sandy clay overlying limestone units. Predominant colors are shades of brown, orange, and grey. With increasing depth, the colors darken and the clay grades to weathered rock that has retained its structural characteristics (saprolite). Bedding planes and joint surfaces in the weathered bedrock commonly are marked by dark reddish-brown and yellow-brown oxide coloration, indicative of a high degree of weathering by circulating groundwater. Although hydraulic conductivities for residuum materials are low (10^{-7} - 10^{-4} cm/s; Moore 1988) because of the high proportion of clay minerals, conduits or preferential flow paths may exist that are related to this relict bedrock structure.

C.3.2 STRUCTURAL GEOLOGY OF THE ORR

According to Hatcher et al. (1992), the deformation that is characteristic of the geology of the ORR was created by compressional stresses during the Appalachian orogeny. A result of these tectonic forces is that, today, the rocks in the subsurface at BCV typically dip $\sim 45^\circ$ to the southeast except where interrupted locally by folds (Fig. C.4).

The stratigraphic section of the ORR is stacked along three major thrust faults — the Kingston, White Oak Mountain, and Copper Creek faults (Hatcher et al. 1992) — and therefore tends to be repetitive (Fig. C.6). All three faults parallel regional strike and dip because of detachment along lithologic planes of weakness during faulting. Y-12 Plant and BCV are underlain by the White Oak Mountain thrust sheet, which in turn is underlain by the White Oak Mountain thrust fault. This fault has not been historically active.

C.3.3 BCV BEDROCK STRUCTURES

Formation of secondary porosity and permeability is a major factor in groundwater movement through the formations underlying BCV. Bedrock structural features, such as fractures and solution cavities, provide the pathways for groundwater flow. These formations have little primary porosity or permeability.

Fractures. Because of the large-scale faulting and folding characteristic of ORR geology, all lithologic units in BCV are highly fractured. The most pervasive structural features are extensional, hybrid, and shear fractures. Corehole studies of fractures in bedrock along a transect across BCV near the head of Bear Creek (Lutz and Dreier 1988; Dreier and Davidson 1994) demonstrate the existence of several major fracture sets that are dominated by a strike-parallel set. Most fractures in ORR bedrock constitute a single cubic system (three orthogonal sets) of extension fractures (Dreier et al. 1987; Sledz and Huff 1981). One fracture set is formed by bedding planes, which have an average strike of $\sim N55^\circ E$; although variable, the dip commonly is ~ 30 to $40^\circ SE$ (Stockdale 1951). Two other fracture sets generally parallel strike and dip; at shallow depths, these sets are commonly angled ~ 50 to 60° below the horizon. These three fracture sets may occur in any locality, and other extension and shear fractures may also be present.

Fractures are abundant on rock outcrops. In general, fracture spacing is a function of lithology and bed thickness. Fractures in more massively bedded formations tend to have longer trace lengths and are more widely spaced. Dreier et al. (1987) measured an average fracture density of $\sim 200/m$ (60/ft) in saprolite of the Maryville Limestone and Nolichucky Shale. At the other extreme, Sledz and Huff (1981) measured a minimum of 5 fractures per meter (1.5 fractures per foot) in fresh rock. Fewer open fractures occur at deeper levels. As described by Haase et al. (1985), fracture frequency is variable, but most fractures observed in cores occur within limestone or sandstone layers >0.5 m (1.6 ft) thick, and many are filled or partly filled with secondary minerals.

Most fractures are short, a few centimeters to ~ 1 m (3.3 ft) in length (longest dimension). Sledz and Huff (1981) found that fracture length at outcrop is relatively uniform [~ 12 cm (5 in.)] in shale but increases with bed thickness in siltstone. Haase et al. (1985) observed numerous fractures ~ 0.1 to 1.5 m (0.3 to 5 ft) long in limestone and sandstone units of the Conasauga Group and the Rome Formation. In limestone, typical fracture spacings range from <5 cm (2 in.) for very thin beds to >3 m (10 ft) for very thick to massive beds. The size of fracture planes may be only a few square meters for thin to very thin beds, but pervious bedding-plane fractures may be 10^3 to 10^6 m² for medium to massive beds (Ford and Williams 1989).

Detailed logging of core from wells at the BCBG has provided information on the relative changes in densities of open (hydraulically active) fractures in the Nolichucky Shale compared to depth and lithology (Dreier and Davidson 1994). This information was supported by estimates of spacings for hydraulically active fractures from resistivity, temperature, and flow meter logs of the same borings. The resulting estimates ranged from ~ 0.9 m (3 ft) in the shallow intervals to more than 6 m (20 ft) in the deep intervals (Fig. C.7). The combination of hydrological data and fracture logging

in Dreier and Davidson (1994) also shows that changes in the vertical hydraulic gradient can be correlated to changes in the spacing of hydraulically active fractures. In the Nolichucky Shale, a strong vertical hydraulic gradient exists in well GW-726 over the upper 76 m (250 ft), where fracture spacings are ~0.9 m (3 ft) (Fig. C.7). Below this level, however, fracture spacings increase and the vertical head gradient decreases significantly, becoming flat with increasing fracture spacing (GW-727, Fig. C.7).

In addition to small-scale deformation features such as the fracture sets discussed above, large-scale features, such as fracture zones and faults, that would provide enhanced groundwater flow paths probably exist in the subsurface and influence groundwater flow in BCV. There are a number of lines of evidence that such faults exist; for example, the nearly parallel southerly flow of most tributaries draining the southern slope of Pine Ridge is characteristic of surface expressions arising from parallel fracture zones in the subsurface. The following cumulative evidence suggests the location of one such fracture zone at the BCBG:

- Goldstrand (1995) cites repeated sections of zone 5 of the Maynardville observed in well GW-790 as direct evidence for faulting. These sections, occurring between 55 and 65 m (180 and 212 ft) below ground surface (bgs), are associated with abundant cavities that have been demonstrated to be connected to cavities in GW-728, ~29 m (95 ft) to the north of GW-790.
- Dreier and Koerber (1990) have identified major fault zones at Y-12 Plant by connecting ridge offsets across BCV. Many of these ridge offsets are coincident with valleys on Chestnut Ridge and tributaries on Pine Ridge. One such offset occurs at the BCBG and is associated with a valley in Chestnut Ridge.
- The occurrence of major springs in BCV is associated with zones of major discharge from intermediate and deep groundwater flow paths (Fig. C.8) in the valley floor. These zones occur at five discrete locations along the valley (SS-2, -4, -5, -6, and -8; refer to Sect. C.4.5) and are probably related to structures that cut across formations that allow deep groundwater to come to the surface.

Cavities and Solution Openings. Fractures are often enlarged by solution. This effect is extensive in the Maynardville Limestone and the Knox Group; in BCV, only these formations display highly developed and well-connected cavity systems. Many of the smaller limestone or dolomite beds within the predominantly clastic formations, such as the Nolichucky Shale, also exhibit solution openings and cavities at shallow depth.

Cavities in rocks underlying the ORR in the Chickamauga Group were first described by Stockdale (1951, p. 41). Since then, cavities have been reported in most other formations with limestone units (Shevenell and Beauchamp 1994). A general principle of cavity occurrence is that the largest cavities are found in the purest and most massively bedded limestones. Cavities in the Conasauga Group have been reported in the Maryville Limestone, Nolichucky Shale, and Maynardville Limestone.

In BCV, 66% of wells drilled in the Maynardville Limestone and Copper Ridge Dolomite intercepted at least one cavity and 38% intercepted two (Shevenell and Beauchamp 1994). During drilling of the Maynardville Exit Pathway Picket Wells (Pickets A, B, C, and W; Fig. C.5), numerous cavities and water-bearing fractures were intercepted (Shevenell et al. 1992). Although no obvious correlation was found between stratigraphic zone and the occurrence of water-bearing zones and cavities in general, most water-bearing zones were intercepted in zones 2 and 6, and cavities were

more common in zone 6 (Shevenell et al. 1992; Shevenell and Beauchamp 1994; Goldstrand and Dreier 1993). Regardless of stratigraphic zone, 60% of cavities were encountered at depths of <30 m (100 ft) and nearly all were encountered above 90 m (300 ft).

Cavities encountered in the Maynardville Limestone range in size from <0.3 m (1 ft) to >3 m (10 ft) (Shevenell and Beauchamp 1994). In the Maynardville Limestone, 52% of measurable cavities were between 0.3 and 1.5 m (1 and 5 ft) in height, with 12% >1.2 m (5 ft) and 16% <0.3 m (1 ft) (20% were of unknown height). In the Chestnut Ridge Formation, cavities are generally larger, with 38% between 0.3 and 1.5 m (1 and 5 ft) height, 23% >1.5 m (5 ft), and 1% <0.3 m (1 ft) (38% of unknown size).

In addition to creating cavities and solution-enlarged fractures in the carbonate formations, water-rock chemical interaction in the Maynardville Limestone and Copper Ridge Dolomite has increased matrix porosity of these formations. Two diagenetic processes — dissolution of evaporite minerals and dedolimitization (Saunders and Toran 1994b) — have produced matrix porosities in these formations of between 1.3 and 2.1% in the Copper Ridge Dolomite and zone 6 of the Maynardville Limestone, and between 0.5 and 0.8% in zones 2 to 5 of the Maynardville Limestone (Goldstrand et al. 1995).

C.3.4 FORMATION HYDRAULIC CHARACTERISTICS

Hydraulic tests in BCV have been conducted by a number of researchers over the past decade (Law Engineering, Inc. 1983; Geraghty and Miller 1986; Lozier et al. 1987; Golder and Associates 1988a and b; King and Haase 1988) and have included pumping tests, slug tests, packer tests, and tracer tests. Results of these tests show that the Nolichucky Shale is anisotropic and heterogeneous and that semiconfined conditions exist to a depth of ~31 m (100 ft). Using the results from these tests, transmissivities calculated for the Nolichucky Shale range from 9.29×10^{-7} to 1.49×10^{-4} m²/s and storage coefficients range from 10^{-4} to 10^{-3} . Consistent with the dominance of strike-parallel fracture directions, pumping test results show that transmissivity in the strike-parallel direction is several times larger than in any other direction. Transmissivities calculated from hydraulic testing conducted in well GW-734, an open hole well in Maynardville Limestone, yielded transmissivities ranging from 6.12×10^{-5} to 5.87×10^{-4} m²/s (Shevenell 1994b).

C.4 BCV HYDROGEOLOGIC CONCEPTUAL MODEL — HYDROLOGY

The hydraulic component of the hydrogeologic conceptual model for BCV is presented here as the hypothesis that best describes the main observations of hydraulic parameters in BCV. Figures C.8 and C.9 depict the hydrogeologic conceptual model for the BCV; Fig. C.8 shows the overall model, and Fig. C.9 shows details of the shallow system.

One of the main points raised by the conceptual model is that although the largest mass of water (and consequently the largest mass of contaminants) exits BCV via surface water, groundwater is the principal pathway for contaminants leaving the waste units. The main flow and contaminant transport pathways in groundwater at the waste units is along strike with the discharge points at tributaries to Bear Creek. For the 10-month monitoring period of BCV Operable Unit (OU) 4 RIFA, it is estimated that 97% of water available for flow (precipitation - evapotranspiration) exited the upper section of the valley [above Bear Creek Kilometer (BCK) 9.47] as surface water flow (Sect. C.4.1; Fig. C.10). In addition, of water available for flow in the predominantly clastic formations outcropping on Pine Ridge, 94 % exited these formations via surface water in tributaries, and 6% via subsurface flow. Fluxes in flow paths at the waste units (overland flow, soil interflow, and groundwater flow) have not been quantified; however, hydraulic monitoring data show that overland flow and soil interflow are only important during storm events and recharge followed by groundwater flow to tributaries constitutes the main water flux pathway.

Hydrogeology differs significantly between predominantly clastic formations (such as the Nolichucky Shale) and carbonate formations (such as the Maynardville Limestone), to the extent that they can almost be treated as separate hydraulic entities. In BCV, the contact between the Maynardville Limestone and the Nolichucky Shale roughly corresponds to the axis of the valley (Fig. C.3) and marks a major transition from predominantly clastic formations in the Conasauga Group to carbonate dominant formations in the overlying Knox Group.

Flow in the predominantly clastic formations is mainly by way of fracture flow (Solomon et al. 1992; Moline and Schreiber 1995, draft). More than 95% of flow occurs through the shallow interval [<30 m (100 ft)] of the formations, principally in the water table interval at the bedrock/residuum interface (Sect. C.4.2). In this interval of the groundwater regime, flow rates can be very rapid (up to 40 m/d; Sanford and Solomon 1995; McKay et al. 1995) and may be even greater during transient storm events. The transient response of surface water streams to precipitation shows that both interflow through soils and groundwater flow through the water table interval are probably major components of the total flow during storm events.

Flow in the carbonate formations has components of both fracture flow and flow through solution-enlarged cavities and conduits (Shevenell 1994b). Although most flow in the carbonate dominant formations probably occurs in the shallow bedrock interval [<30 m (100 ft) depth], components of groundwater flow occur in deeper intervals [>30 m (100 ft) depth] (Solomon et al. 1992). The shallow interval [<30 m (100 ft) depth] of the Maynardville Limestone in BCV is dominated by a maze-like system of interconnected cavities and solution-enlarged fractures. Bear Creek can be considered as one of the primary conduits for flow in this cavity system.

The dynamic nature of the hydrology of BCV is extremely important, both for predominantly clastic and carbonate formations. The nature, rate, and direction of groundwater flow are transient and vary based on the climatological conditions. Variations occur on different scales: an annual cyclic variation resulting from seasonal climatic effects (Sect. C.4.3) and a short-term variation

resulting from the response to individual storm events (Sect. C.4.4). Head in groundwater wells and baseflow in streams relate both to the amount of precipitation and the rate of evapotranspiration. In general, flow in streams is greatest and groundwater elevations are highest during late winter and early spring because annual precipitation is greatest during this time period and moisture demand from plants is at a minimum. Conversely, during the summer and fall, precipitation is usually relatively low and evapotranspiration is high. During this time, flow in most tributaries to Bear Creek ceases, and groundwater elevations fall to their lowest levels.

Additional key features of the hydraulic component of the hydrogeologic conceptual model are as follows:

Flow in Predominantly Clastic Formations

- Although there are no clearly defined abrupt hydrogeologic changes in the clastic formations with depth, a general hydrogeologic stratigraphy can be defined that separates these formations into shallow-, intermediate-, and deep-flow regimes (Fig C.8; Solomon et al. 1992). The boundary between shallow and intermediate intervals is defined by a consistent change in groundwater geochemistry and ~30 m (100 ft) depth that indicates flow is considerably slower below this depth (Haase 1991; Dreier et al. 1993). The boundary between intermediate and deep intervals is poorly defined and is indicated by a change in groundwater geochemistry that has been observed between ~100 and 150 m (328 and 492 ft) depth (Solomon 1992; Haase 1991; Dreier et al. 1993). The deep interval probably relates to the base of effective flow in the clastic formations.
- Most flow occurs in the predominantly clastic formations in the shallow interval. This interval includes the water table interval that usually occurs close to the bedrock/residuum interface, where a high conductivity zone is hypothesized to exist. Most flow in the shallow interval is probably through this high conductivity zone or through other preferential flow pathways in the bedrock. Flow in the shallow interval is oriented predominantly along geological strike, with discharge occurring at the tributaries to Bear Creek.
- Geochemistry indicates that greater groundwater residence times and, thus, slower flow generally occur below 30 m (100 ft) in the intermediate interval (Sect. C.4.2). However, the distribution of contaminant plumes in BCV indicates that more rapid flow than predicted by major ion geochemistry may occur in an along strike direction along preferential pathways in this interval [nitrate from the S-3 Site has migrated ~1 km (0.62 mile) or more since 1950; refer to Appendix D].
- An upward hydraulic gradient occurs almost everywhere in the bedrock of the predominantly clastic formations that outcrop on the southern flank of Pine Ridge (Sect. C.4.2). This upward hydraulic gradient is a function of the anisotropy of the geological formations and the average 45° dip of the beds. Pressure head in bedrock is partially controlled by the elevation of the recharge zone, which correlates approximately to the elevation at outcrop of each stratigraphic zone. The elevations at outcrop of stratigraphic zones in the Nolichucky shale increases with depth, thus creating an upward hydraulic gradient.
- During rainfall events, the hydrological system in the predominantly clastic formations responds in changing ways to the influx of water (Sect. C.4.4):
 - The shallow portions of the soil profile become saturated, transmitting water laterally downslope to springs and seeps in the banks of streams as interflow.

- Fractures in the residuum also become saturated, transmitting water rapidly to the shallow groundwater table. As a result, the elevation of the water table rises rapidly during rainfall events.
 - The elevated water table increases the rate of groundwater flow in the water table interval and, subsequently, groundwater discharge to streams increases.
 - During the heaviest precipitation events, flow in streams increases very rapidly as overland flow enters the stream channels.
 - After precipitation has ceased, flow in streams reflects the rate of drainage from three reservoirs of water: overland flow, soil interflow, and groundwater flow. These components of the hydrologic system drain at varying rates: overland flow is the most rapid, stormflow is intermediate, and groundwater discharge declines at the slowest rate and reaches near pre-precipitation levels within a few days.
- Although flow through the porous matrix constitutes a minor component of flow volume in all formations, it plays an important role in contaminant migration because matrix diffusion will significantly slow down contaminant transport rates.

Flow in Carbonate Formations

- The Maynardville Limestone outcrops along the southern side of the BCV floor. This formation and Copper Ridge Dolomite act as a hydraulic drain for the valley. Flow in these formations is predominantly along strike, parallel to the maximum hydraulic gradient.
- The hydrostratigraphy in the carbonate formations is less well defined than that in the clastic formations (Fig C.8; Solomon et al. 1992). The definitions of shallow, intermediate, and deep regimes are not rigid and rely on cumulative evidence from cavity occurrence (Shevenell et al. 1992; Shevenell and Beauchamp 1994), hydraulic and geochemical responses during storms (Shevenell 1994b; Sect. C.6.2 in Supporting Information for Appendix C), and the distribution of contaminant plumes (Appendix D).
- The shallow interval includes groundwater to ~30 m (100 ft) depth. Flow in this interval occurs through a maze of interconnected solution conduits and cavities (Sect. C.3.3) and is closely associated with flow in Bear Creek (Sect C.4.5). The channel of Bear Creek can be considered conceptually as one of the main hydraulic conduits in this conduit system. In this interval, groundwater flow is relatively rapid and, during storm events, recharge to this interval occurs as a quickflow. Contaminants are easily flushed through this interval, and dilution effects that arise from rainfall/recharge and quickflow mean that contaminant plumes tend to attenuate rapidly along strike.
- The intermediate interval occurs between ~30 and 100 m (100 and 328 ft). Solution cavities and solutionally enlarged fractures exist in the Maynardville Limestone in this interval. This zone is known to have high flow rates where solution features have been encountered during drilling. Because of its depth, this zone is isolated from dilution effects seen in shallower zones and constitutes an important contaminant transport pathway.
- In the deep interval [>100 m (328 ft) depth], the flow through fractures dominates groundwater movement, and as fracture density decreases with depth, flow zones become less frequent.
- Bear Creek displays losing and gaining reaches where groundwater is recharged and discharged to the surface, respectively (Sect. C.4.5). Major gaining reaches along strike are associated with large springs in the floodplain of Bear Creek, which may be sites of upwelling groundwater

from deep flowpaths in the Maynardville Limestone. The locations of these springs may be controlled by large-scale geologic structure, such as across strike faults, or thinning of the Maynardville Limestone due to stratigraphic changes or faulting.

The features of the hydraulic component of the hydrogeological conceptual model listed above are discussed in detail in the following sections. Detailed analyses of hydraulic data taken during the BCV OU 4 RIFA are presented in the Supporting Information to this appendix.

C.4.1 WATER BALANCE MODEL FOR BCV

The detailed water balance of the upper section of the Bear Creek catchment in BCV (above BCK 9.47) establishes the dominant role that surface water flow plays in the overall mass flux of water out of the valley. The water balance model has been completed for only that portion of BCV that is upgradient of BCK 9.47 for a 10-month monitoring period between March 1994 and February 1995. This is the portion of the valley for which there is intensive flow monitoring provided from the RIFA (Appendix B, Sect. B.4).

The water balance attempts to balance the total volume of water entering this section of BCV (inflow) with the total volume of water flowing along strike in BCV at BCK 9.47 and SS-5 (outflow) for the 10-month monitoring period (Sect. C.6.5 in Supporting Information for Appendix C) using water fluxes that were measured during the RI (gaged) or have been calculated (ungaged). Inflow is by way of a single component: rainfall (gaged). The conceptual model for BCV has four outflow fluxes: evapotranspiration (ungaged), flow in BCV at BCK 9.47 (gaged), flow in SS-5 (gaged), and along strike flow in groundwater over a plane at BCK 9.47 (ungaged). Gaged fluxes were measured and have relatively little uncertainty associated with their values; for example, flow monitoring of the tributaries and Bear Creek provided data necessary to accurately define the surface water component of the water balance model with little uncertainty.

Of the parameters of the water balance model shown in Fig. C.10, the values of ungaged fluxes were derived in the following ways (refer to Supporting Information for Appendix C):

- Along strike flow in groundwater was estimated from the site-wide groundwater flow model for BCV (Jacobs Engineering 1995, in preparation).
- Evapotranspiration was calculated by a process of elimination, and the value obtained was compared to results of modeling evapotranspiration using the HELP model (Schroeder et al. 1994). It assumed that there is no net change in the volume of groundwater in this portion of BCV during the period of calculation. Evapotranspiration then becomes the only unquantified value in equation 1 on Fig. C.10. The total evapotranspiration flux over this 10-month period was calculated as $2.78 \times 10^6 \text{ m}^3$, which compares favorably with the modeled flux of $3.10 \times 10^6 \text{ m}^3$. The ~10% variance between these two values is a reasonable margin of error to expect from mass balance modeling of this type and suggests that the results of overall water balance model are reasonable.
- Across strike flow of groundwater was derived by a process of elimination using a water balance model for only the predominantly clastic formations (Fig. C.10). This model assumed that all available water for the siliceous formations (precipitation - evapotranspiration) either moves along strike (modeled) or flows into Bear Creek and/or the Maynardville Limestone. This parameter then becomes the only unquantified value in equation 2 on Fig. C.10.

Surface water flow leaving the upper section of the valley during the 10-month monitoring period constituted 40.5% of precipitation (flow at BCK 9.47 and SS-5 combined; Fig. C.10) or 97% of the water available for flow (precipitation - evapotranspiration). For the predominantly clastic formations underlying the southern flank of Pine Ridge, 94.% ($1.087 \times 10^6 \text{ m}^3$) of available water left as surface water flow in tributaries. Only 6% ($0.069 \times 10^6 \text{ m}^3$) of available water left these formations as groundwater and, of this amount, 0.6% ($0.007 \times 10^6 \text{ m}^3$) left by way of along strike flow and 5.4% ($0.062 \times 10^6 \text{ m}^3$) entered the Maynardville Limestone as ungaged subsurface flow. Thus, the model estimates that, during this 10-month period, 99.4% of water falling on the predominantly clastic formations in BCV flowed out of these formations into either Bear Creek or the Maynardville Limestone.

For the 94% of available water that flows in tributaries along the flank of Pine Ridge to Bear Creek, the pathways for water to arrive at the tributaries vary and include overland flow, soil interflow, and groundwater flow. These components of the total flow in the tributaries have not been quantitatively itemized in this water balance, but are discussed in more detail in the following sections. Of the 5.4% of precipitation falling on the flank of Pine Ridge that flows into the Maynardville Limestone, the depth at which this groundwater is flowing is not known; however, most probably flows through the shallow system into the Maynardville Limestone, with only a very small proportion of groundwater in the bedrock of the Nolichucky Shale flowing across strike into the Maynardville Limestone.

Of the total available water for Bear Creek and the Maynardville Limestone (precipitation-evapotranspiration plus inflow from the siliceous formations), 80.8% ($1.616 \times 10^6 \text{ m}^3$) leaves at BCK 9.47 via surface water flow, and an additional 16.2% ($0.323 \times 10^6 \text{ m}^3$) leaves as discharge to the surface water at SS-5. Only 2.7% ($0.054 \times 10^6 \text{ m}^3$) of flow along strike in BCV at BCK 9.47 is via groundwater flow in the Maynardville Limestone.

C.4.2 GROUNDWATER FLOW CHARACTERISTICS

The direction of groundwater movement generally is controlled by the potentiometric gradient and the permeability of the medium. In a completely isotropic aquifer, the flow direction of groundwater should be normal to the equipotential contours of the aquifer. However, in anisotropic formations such as those in the Conasauga and Knox Groups, flow directions are strongly controlled by the orientation of the bedding planes, fractures, and joints as well as by the distribution of solution cavities. Thus, a map of potentiometric contours based on observed head differences in wells in BCV indicates only the general direction of groundwater flow.

Tracer studies, potentiometric data, and geochemical data have been used to determine flow paths in BCV. These data are discussed in the following sections.

C.4.2.1 Tracer Studies

Tracer tests have revealed that groundwater flow directions in the shallow bedrock of the predominantly clastic formations may be oriented parallel to strike and almost perpendicular to the prevailing hydraulic gradient (Lee et al. 1992). In addition, tracer migration may undergo rapid and transient changes in direction during storm events, the net result of which may be increased dispersion and possible differing wet- and dry-season flow paths. Moline and Schreiber (1995, draft) report variations in hydraulic characteristics within individual wells located in shallow bedrock of the Nolichucky Shale in BCV that were equipped with multiport monitoring devices. Preliminary

results of this ongoing study suggest that, although flow dynamics are complex, groundwater flow is strongly controlled by lithology and bedding orientation.

In a tracer study conducted on the Nolichucky Shale in BCV (Lee et al. 1992), the rhodamine tracer, which was injected into the top 0.3 m (1 ft) of the water table, traveled only in the shallow water table interval. The initial breakthrough of this dye indicated a velocity of 5 m/d; however, after the initial breakthrough, the tracer test recorded migration rates of 0.04 to 0.09 m/d for the more concentrated plume. This pattern was interpreted as (1) rapid migration of the dye in transmissive fractures accompanied by diffusion of most of the tracer into poorly connected fractures, followed by (2) slow release of the tracer to the active fractures by matrix diffusion.

Recent work by Sanford and Solomon (1995), McKay et al. (1995), and Sanford et al. (1994) at the same site as the 1989 study (Lee et al. 1992) indicates that over the past 5 years the 10 parts per billion (ppb) contour for the dye tracer has hardly moved from the position in which it was located 3 months after the tracer injection. Analysis of residuum conducted during installation of new monitoring wells at this site indicates that the highest concentrations of dye are located at the centerline of the plume in an apparently laterally continuous zone ~1.5 m (5 ft) thick.

Results of a noble gas tracer study in the water table interval of BCV at the same site support the concept of a very active fracture-flow system at the water table (Sanford and Solomon 1995; McKay et al. 1995; Sanford et al. 1994). Using neon and helium as tracers and a passive gas sampling methodology to allow sampling of groundwater under ambient conditions, these studies recorded migration rates of up to 4 m/d in the shallow water table interval, very similar to those estimated from the initial release of the rhodamine dye tracer. Helium has a greater diffusivity than neon, and data from Sanford and Solomon (1995) indicate that the tracer plume is relatively enriched in neon resulting from the greater tendency for helium to diffuse into the matrix. In addition to noble gas tracers at this site, McKay et al. (1995) experimented with colloid tracers, which would not be expected to diffuse into the matrix to any great extent. Migration rates for these colloids appear to have reached 45 m/d at this site. These data indicate that migration rates in the water table interval depend on the characteristics of the migrating species and can be highly heterogeneous, varying by as much as four orders of magnitude.

C.4.2.2 Potentiometric Data

Water level data are collected, at a minimum, each time monitoring wells are sampled as part of the Y-12 Plant compliance program. Recent results reveal a groundwater piezometric surface (Figs. C.11 and C.12) sloping in from recharge areas on ridges to discharge along Bear Creek (e.g., HSW 1995). The piezometric surface indicates a groundwater divide just east of the S-3 and Spoil Area 1 sites. This divide is the eastern boundary of the Bear Creek Hydrogeologic Regime (BCHR).

Dreier et al. (1993) present detailed hydraulic head measurements from four deep coreholes (GW-132, -133, -134, and -135), the locations of which form a transect across BCV in the vicinity of the S-3 Site. Westbay™ multiport samplers installed in each of the coreholes allowed hydraulic head measurements, hydraulic testing, and water sampling in discrete intervals within the groundwater system. Figure C.13 is a hydrologic cross-section of hydraulic head contours across the head of the BCHR, which shows topographically driven recharge from adjacent ridges and convergent flow to the Maynardville Limestone in the axis of the valley (Note that these data also show a pressure bulge within the Nolichucky Shale at the S-3 Site, which is attributed to pond waste water that infiltrated from the S-3 Site when the ponds were active).

The hydraulic head distributions in well pairs in the Nolichucky Shale (Fig. C.14), combined with the studies Dreier et al. (1993; Fig. C.13) and Dreier and Davidson (1994; Fig C.7), indicate that on a valley-wide scale, vertical upward hydraulic gradients predominate in the Nolichucky Shale in the intermediate, deep, and shallow bedrock intervals [depths ranging from 14 to 152 m (45 to 500 ft)]. Hydraulic gradient vary from -0.22 and 0.35 (negative indicates downward gradients); however, downward gradients are only observed in wells between the water table interval and shallow bedrock wells, indicating local recharge to the shallow system. Water level data from the Maynardville Limestone indicate variable gradients ranging from -0.15 to 0.1 with predominantly downward gradients (Fig. C.14).

The predominance of vertically upward hydraulic gradients in the Nolichucky Shale is probably caused by the strong anisotropy of the formation, where conductivity oriented parallel to bedding planes may be one or two orders of magnitude greater than that across strike. Bedding in the Conasauga Group dips uniformly to the south, and recharge most likely flows downward in bedrock, parallel to dip. Pressure head at depth is, therefore, partly controlled by the elevation of the recharge zone, or outcrop of that stratigraphic zone, which is topographically higher up on Pine Ridge with increasing depth in the Nolichucky Shale.

C.4.2.3 Geochemical Data

Large-scale groundwater flow in BCV was studied using patterns of groundwater geochemistry observed at the BCBG by Haase (1991) and data from a series of deep [>305 m (1000 ft)] groundwater wells installed at the S-3 Site with multiport sampling devices (Dreier et al. 1993; Toran and Saunders 1992a and b; Saunders and Toran 1994a and b).

Haase (1991) reported three distinct groundwater geochemical facies in BCV and concluded that the major ion geochemistry of groundwater in BCV is a function of residence time and flow path length. Dreier et al. (1993) identify these facies in the deep multiport well transect of BCV and an additional facies (Figs. C.15 and C.16). Toran and Saunders (1992b) and Saunders and Toran (1994b) interpret the data from Dreier et al. (1993) to determine the mechanisms controlling chemical evolution of groundwater in BCV (Fig. C.17). A more rigorous cluster analysis of groundwater types completed as part of the BCV RI (Sect. 3.2; HSW 1995) confirmed the findings of the previous studies. The four identified groundwater facies were described as follows:

- **Calcium/magnesium bicarbonate (Ca/Mg HCO_3):** Groundwater from this facies type generally has total dissolved solids (TDS) <300 mg/L; has Ca/Mg ratios usually close to 1, but ranging from 0.50 to 14 (expressed as milliequivalents); and is usually saturated or slightly oversaturated with respect to calcite and dolomite (Toran and Saunders 1992b). This groundwater facies type generally occurs in water table and shallow bedrock wells in the predominantly clastic formations and in most wells in the carbonate formations in BCV (HSW 1995).
- **Sodium bicarbonate (Na-HCO_3):** Groundwater from this facies type typically has TDS >400 mg/L, very low Ca and Mg concentrations, and pH up to 9. It is usually saturated with respect to calcite and undersaturated to saturated with respect to dolomite, and occurs in wells in the siliceous dominant formations screened <30 m (100 ft) depth (HSW 1995). This facies type has been interpreted as being derived from Ca/Mg HCO_3 type groundwater by water-rock interaction with minerals in the shale formations. Toran and Saunders (1992b) suggested that the observed water types could be derived solely by mineral dissolution and precipitation reactions and that cation exchange reactions may not be important in deriving the bulk chemistry of this facies type (Fig. C.17).

- **Calcium/magnesium sulfate (Ca/Mg-SO₄):** Groundwater from this facies type typically has TDS >2000 mg/L, has pH <8, and is usually supersaturated with respect to calcite and dolomite. This groundwater facies type was identified in the multiport sampling wells installed at the S-3 Site (Dreier et al. 1993; Saunders and Toran 1994b). Building on the identification of gypsum nodules in core from these wells (Dreier et al. 1993), Saunders and Toran (1994b) interpret this facies type as being derived from dedolomitization reactions in discrete zones of the Maynardville Limestone and Copper Ridge Dolomite Formations resulting from dissolution of gypsum.
- **Sodium/calcium chloride/bicarbonate (Na/Ca-Cl/HCO₃):** This facies type exhibits high TDS (>3000 mg/L) and typically occurs in wells >122 m (400 ft) bgs. The major ion chemistry of this facies type varies; however, high concentrations of sodium and chloride are characteristic of this facies type. Toran and Saunders (1992b) interpret this facies type as resulting from the mixing of groundwater with a deeper brine, either by advective flow or by chemical diffusion. Identification of precipitates of barite (BaSO₄) and celestite (SrSO₄) in core from the multiport wells supports this hypothesis of Sr- and Ba-rich brines [brines with high concentrations of Ba and Sr are observed in Melton Valley (Switek et al. 1987)] mixing with a sulfate-rich groundwater.

In general, in the predominantly clastic formations, Ca/Mg HCO₃ type groundwater is associated with shorter residence time and shorter flow paths than the Na-HCO₃ type groundwater. The consistent change from Ca/Mg HCO₃ type groundwater to Na-HCO₃ type groundwater at 30 to 61 m (100 to 200 ft) in the predominantly clastic formations implies the existence of a distinctly younger water type in a more active flow system at depths <30 m (100 ft) compared to an older, less active, water type below 30 m (100 ft). For the carbonate formations, Ca/Mg HCO₃ type groundwater occurs at all depths, except for (1) gypsum-rich zones, where Ca/Mg SO₄ groundwater dominates, and (2) the deepest wells, where Na-Cl groundwater occurs.

C.4.3 TRANSIENT RESPONSES TO ANNUAL CHANGE

Piezometric head in groundwater wells and baseflow in tributaries and Bear Creek show seasonal changes in magnitude that relate both to the amount of precipitation and the rate of evapotranspiration (Figs. C.18 and C.19). In general, flow in streams is greatest and groundwater elevations are highest during late winter and early spring. This is because annual precipitation is greatest during this time period and moisture demand from plants is at a minimum. Conversely, during the summer and fall, precipitation is usually relatively low and evapotranspiration is high. During this time, flow in most tributaries to Bear Creek ceases and groundwater elevations fall to a minimum.

Detailed monitoring of groundwater wells in BCV during 1994 recorded both periods of rising groundwater levels and declining groundwater levels. Figure C.20 shows the piezometric head in three wells screened at the water table interval (GW-624), the shallow bedrock (GW-626), and deep bedrock (GW-629) intervals of the Nolichucky Shale during March and April 1994. These records show steadily increasing groundwater pressure at all depths in the Nolichucky Shale during a period of high rainfall. During this time period, BCV experienced a number of large storms [over 36 cm (14 in.) precipitation during one month], and rapid recharge shallow groundwater during each storm results in rapid changes in GW-624, as discussed above. The two deeper wells in this well group also display slight immediate changes in water level. In addition, the pressure head in these wells increases fairly uniformly by ~0.60 m (2 ft) over the period of monitoring in response to the period of heavy rain.

The converse effect can be observed in wells screened in the Maynardville Limestone that were monitored during May 1994. The hydrographs from wells GW-227, -228, -725, and -736 show a continuous declining trend over this period of monitoring [Fig. C.21; the greatest fall in head was recorded in GW-228 at 2.6 m (8.5 ft) and the smallest change in GW-725 of 0.98 m (3.2 ft)]. This time period contains three precipitation events [a total of 5.6 m (2.2 in.)], and these wells show little or no response to these events. The period of monitoring for these wells coincided with the time period of increasing water demand from plants during the leafing-out period.

C.4.4 TRANSIENT RESPONSES TO STORMS

Stream flow in Bear Creek and its tributaries is highly responsive to precipitation. At all tributary sites monitored during the OU 4 RIFA, flow in the stream channel increased rapidly after precipitation commenced in the valley (e.g., Figs. C.22 and C.23). After precipitation ceased, flow in the streams rapidly declined to baseflow within 2 or 3 d. This effect is termed *quickflow* (Shevenell 1994b). Understanding how quickflow operates in BCV is important to conceptualizing contaminant migration pathways in the valley. Quickflow during storms has a strong influence on contaminant migration from sources to tributaries draining Pine Ridge, and may also promote along-strike migration of contaminants in the Maynardville Limestone.

Three main components of the BCV hydrologic system (surface water flow, groundwater piezometric head, and soil saturation) were monitored during the BCV OU 4 RIFA to determine their responses to precipitation. Results and analysis of this monitoring are presented and discussed in the Supporting Information for this appendix. In general, during precipitation events, the components of the hydrogeologic regime showed these following responses (Figs. C.22 and C.23):

- first, water level in stormflow tubes increases immediately and ceases rising when precipitation ceases, indicating soil saturation and probable interflow during storms;
- then, flow in streams responds similarly to stormflow tubes by increasing immediately as precipitation starts and falling as precipitation ceases; and
- finally, the pressure head in shallow groundwater wells increases almost immediately during precipitation events and continues rising in some wells for up to 2 d after cessation of rainfall (Fig. C.23).

Figures C.22 and C.23 each show an example of the responses in these components to storms in BCV: Fig. C.23 from close to the S-3 Site during the summer low flow period and Fig. C.22 from the BCBG during the winter/spring high flow period. In each example, all components respond to precipitation rapidly and in almost the same sequence: first, soil saturation; then, surface water; and lastly, groundwater.

In addition, analysis of the regression hydrographs from streams, groundwater wells, and stormflow tubes provides an indication of the relative change that occurs in each of these components after precipitation has ceased. The regression section of the hydrograph depends on the rate of change of storage in the basin after a storm has stopped. In BCV, three types of water storage are included in the hydrogeologic conceptual model: overland flow, soil saturation, and groundwater. When plotted on semi-logarithmic axes, the slope of the regression curve (λ) is indicative of the rate of change of water storage in the hydrogeologic system upgradient of the monitoring point and indicates the flow pathways that are operating from soils to tributary streams (refer to Supporting Information for Appendix C).

C.4.4.1 Soil Saturation, Interflow, and Surface Runoff

Stormflow tubes were first to respond to precipitation, with soil becoming saturated (and the tubes starting to collect water) between 1 and 3.5 h after precipitation starts. At the BCBG, groundwater piezometric head and surface water start to rise almost simultaneously about 30 min after the stormflow tube reacts (Fig. C.23). At the S-3 Site, surface water starts to rise about 1 h after the stormflow tube and about 1 h before groundwater (Fig. C.22). This indicates that, before interflow or recharge begin, the upper layers of the soil need to reach a level of saturation that allows for flow through the soil.

The rapid response of stormflow tubes has been observed in previous studies (Moore 1988) and was hypothesized to result in interflow in the uppermost layers of the soil (Moore and Toran 1992). Moore (1988, 1992) and Solomon et al. (1992) suggested that a large proportion of flow on the ORR occurs as interflow through the soil and upper regolith, and referred to this process as *stormflow*. The *stormflow* zone corresponds approximately to the root zone, and infiltration tests indicate that this zone may be as much as 1000 times more permeable than the underlying vadose zone (Moore 1988). The rapid response to precipitation in shallow groundwater wells in BCV indicates that stormflow plays a lesser role in water movement in BCV and that flow in shallow groundwater accounts for a larger portion of the water flow.

C.4.4.2 Transient Response in Tributaries Draining Pine Ridge

Tributaries to Bear Creek draining Pine Ridge show rapid increases in flow during storm events. During the two storm events depicted in Figs. C.22 and C.23, surface water flow starts increasing slightly soon after rainfall and coincident with the stormflow tubes. However, after 30 to 60 min, surface water flow increases rapidly, which is interpreted as the start of overland runoff and soil interflow reaching the stream channels.

For tributaries in BCV, the rising limbs of hydrographs are very steep, and little delay occurs between peak rainfall intensity and peak discharge in the streams. In one extreme case, the level in North Tributary (NT)-5 rose by nearly 0.3 m (1 ft) over a 20-min period. As a result of the “flashy” nature of runoff in BCV, the flow hydrographs show a wide range in flow over short periods, with flow most of the time at baseflow level (e.g., as shown in the annual hydrograph for BCK 9.47, Fig. C.18), representing groundwater discharge.

This rapid response to precipitation is typical of streams draining low conductivity formations and can be explained by a combination of overland flow, soil interflow, and rapid shallow groundwater flow that operates only during, and immediately following, storms (Bras 1990).

For many storms in BCV, three segments of the surface water regression hydrograph with different linear slopes (λ) were identified in many storm hydrographs plotted on semi-logarithmic axes (Supporting Information for this appendix) and probably relate to different rates of drainage from the three components of the hydrogeologic conceptual model. These are:

- The steepest slope on the regression curve (a) occurs immediately after precipitation ceases and is interpreted as being derived predominantly from water drainage from surface water bodies (i.e., streams channels and ponded water). The mean values for λ for this initial segment of the regression curve range from 0.596 to 1.26 h⁻¹. In general, the highest values for λ for this segment of the hydrographs tend to coincide with the most intense precipitation events, probably as a result of greater ponding and surface runoff during the most intense rainfall. Due to the rate of decline of flow during this segment of the regression curve, this period is short-lived, ranging

from 1 to 6 h after cessation of precipitation for BCV tributaries and main stem. In some instances, where rainfall intensity is insufficient to saturate soils, this section of the regression curve is missing.

- The intermediate slopes in the regression curves (b) are interpreted as resulting from the decline in runoff and from the flow in the streams being dominated by runoff derived from soil drainage and quickflow drainage. The mean values for λ for this segment of the regression curve range from 0.061 h^{-1} to 0.167 h^{-1} . The section of the regression curve where soil drainage and quickflow dominate the flow in the streams in BCV lasts from 8 to 24 h, depending on the intensity of the storm.
- The lowest slopes in the regression curves (c) are interpreted as resulting from the decline in runoff derived from groundwater discharge alone. The mean values for λ for this segment of the regression curve range from 0.010 h^{-1} to 0.038 h^{-1} . This segment of the regression curve may continue for a number of days and is usually truncated by the next precipitation event or by the stream drying up.

C.4.4.3 Groundwater in Predominantly Clastic Formations

Shallow groundwater in the clastic formations responds rapidly to precipitation. During the two storm events depicted in Figs. C.22 and C.23, water levels in the shallow wells start increasing rapidly between 0.5 and 2 h after the stormflow tubes react, which is interpreted as the start recharge to groundwater after the soils reach close to saturation. The reaction to precipitation in GW-345 at the S-3 Site is delayed relative to that of GW-624 at the BCBG. The differences between these sites probably reflect the difference in the time of year during which the monitoring occurred. In addition, GW-624 generally shows more rapid and sharper responses to precipitation, indicating a well-connected fracture network.

Rapid transient response of groundwater pressure head in the Nolichucky Shale has been observed in this study (refer to Supporting Information for Appendix C) and elsewhere in BCV (Moline and Schreiber 1995, draft; Sanford et al. 1994). Rapid pressure responses to precipitation were observed in shallow wells with screened intervals <10 m (33 ft) depth [e.g., GW-127 at 7.3 m (24 ft) or GW-624 at 5.2 m (17 ft); Fig. C.24; Supporting Information, Sect. C.6.3]. The transient pressure response to precipitation in some shallow wells was accompanied by rapid changes in specific conductivity, indicating that newly recharged rainwater occurs in these wells a short time after initiation of rainfall. Pressure responses were observed in deeper wells, but, although the initial responses were rapid, the responses were smaller and slower to reach peak pressure than that observed in the shallow wells [e.g., GW-127 at 7.3 m (24 ft) or GW-624 at 5.2 m (17 ft), Fig. C.20; Supporting Information, Sect. C.6.3]. The deeper wells did not show specific conductivity response to precipitation.

The response of groundwater in the clastic formations can be explained by rapid recharge to the water table during the storm event and transmission of a pressure pulse to deeper intervals of the formations. The magnitude and rapidity of the observed rises in the water table imply that recharge occurs along discrete permeable features in the residuum that become saturated during rain events (Solomon et al. 1992). This creates localized and temporarily perched water tables where fractures are saturated even though surrounding pores may remain unsaturated and contain trapped air. During recharge events, flow paths in the vadose zone are probably complex and may be controlled by the orientation of structures, such as relict fractures.

C.4.4.4 Groundwater in Carbonate Formations

Rapid transient response of groundwater pressure head in the Maynardville Limestone has been observed by a previous study (Shevenell 1994b) and in this study (Fig. C.25; refer to Supporting Information for this appendix). Pressure pulses from precipitation events have been observed in wells as deep as 164.3 m (539 ft) (GW-710; Fig. C.25). The transient pressure response to precipitation in one shallow well [GW-715 at 13.6 m (45 ft)] is also accompanied by rapid changes in specific conductivity, indicating that newly recharged rainwater occurs in this well a short time after initiation of rainfall (Shevenell 1994b). Data taken during the BCV OU 4 RIFA from deeper wells or wells without observed cavities in the Maynardville Limestone [e.g., GW-094 at 39.1 m (128 ft) or GW-651 at 15.8 m (52 ft), Supporting Information, Sect. C.6.3] show similar pressure responses during storm events but do not have the accompanying specific conductivity change.

Shevenell (1994a) concluded that quickflow in response to precipitation occurred in the Maynardville Limestone and Copper Ridge Dolomite through cavities and fractures. The data from Shevenell (1994b) and this study (refer to Supporting Information for Appendix C) indicate that during precipitation a pressure pulse is transmitted rapidly through the carbonate dominant formations in BCV throughout the fracture and cavity network. The fracture and cavity network is vertically well-connected and pressure pulses are rapidly transmitted to depths >152 m (500 ft). The differences in responses by specific conductivity between shallow and deep wells indicate that water recharges rapidly and enters the cavity system in the most shallow [<30 m (100 ft)] intervals of these formations within a few hours after precipitation begins. Although these pressure pulses may induce a temporary change in the rate of flow in the deeper bedrock [>30 m (100 ft)] intervals, recharge water takes longer to reach these intervals.

The contrast between the transition of pressure pulses in the clastic formations and carbonate formations is striking. The pressure pulse in clastic formation at depths >10 m (33 ft) is subdued and diffuse, whereas the pulse in the Maynardville Limestone at depths over 152 m (500 ft) is relatively sharp. This is indicative of the much better connectivity of fractures and cavities in the carbonate formations than those in the clastic formations. However, the sharp rises in groundwater pressure head in shallow wells in the clastic formations indicate that fractures and/or cavities in this interval of the clastic formations may be well-connected.

C.4.4.5 Combined Hydrograph Analysis

Surface water, groundwater, and stormflow tubes all show multiple sloped hydrographs. Figure C.26 shows the ranges of slopes (or λ values) derived from hydrographs in both the Nolichucky Shale and the Maynardville Limestone. The slopes of hydrographs fall into four categories based on the values for λ , with an approximate order of magnitude difference between the λ values for each category. The categories can be associated with the probable type of flow that, for a time period after a storm, dominates the flow in the tributaries. These are overland flow, soil interflow, groundwater baseflow surge or *quickflow*, and groundwater baseflow. The characteristics of flow from these four components are:

- **Overland flow with λ values ranging from 0.596 to 1.26 h⁻¹.** As would be expected, the overland flow component is seen only in surface water hydrographs.
- **Soil interflow with λ values ranging from 0.058 to 0.208 h⁻¹.** This component of the hydrographs is seen in both surface water and stormflow tube hydrographs, indicating that surface water flow is dominated by soil interflow for a period of time after overland flow has ceased.

- **Quickflow with λ values ranging from 0.037 to 0.0067 h⁻¹.** This component is seen in surface water, stormflow tube, and groundwater well hydrographs. This may indicate that the rate of drainage from groundwater is strongly influenced by recharge from the soil layer for a period after precipitation has ceased. In addition, quickflow is the dominant component of stream flow after overland flow and soil interflow have ceased.
- **Long-term flow and regional baseflow discharge, with λ values ranging from 0.00576 to 0.00122 h⁻¹.** This component is seen only in groundwater well hydrographs and relates to the seasonal changes in groundwater elevations.

For hydrographs from shallow wells in clastic formations, the slopes for quickflow segments of the hydrographs are on the same order of magnitude as those determined by Shevenell (1994b) for the second and third segments of the Maynardville well regression hydrographs. These two segments were interpreted to represent drainage of (1) a well-connected fracture network in the Maynardville Limestone and (2) the matrix (including poorly connected fractures). This similarity in values between the initial regression slopes in the water table wells from the Nolichucky Shale and those in the Maynardville Limestone implies that the transmissivity of the water table interval in the Nolichucky Shale may be of a similar order of magnitude as the fracture networks in the Maynardville Limestone during high flow conditions. This interpretation supports the conceptual model of a high-conductivity zone at the water table interval that transmits most water during storm events.

C.4.4.6 Conceptual Model for Transient Response

Based on the above monitoring data, the conceptual model for water movement after impacting on the land surface is as follows (Fig. C.9):

- After precipitation begins, soil saturation increases.
- If precipitation continues, the soil eventually approaches complete saturation; water then ponds in the surface and is transmitted laterally downslope as overland flow and soil interflow to the nearest surface water channel. At the same stage, saturation of fractures in the vadose zone increases, and water is transmitted downward from the soil to the water table.
- Recharge elevates the level of the water table, and along-strike groundwater flow at the water table interval in clastic formations increases, resulting in an increase in the rate of discharge to tributary streams. At the same time, quickflow in carbonate formations occurs.
- After precipitation ceases, surface ponds drain rapidly and overland flow ceases.
- Soil saturation declines, and interflow and groundwater recharge slow and ultimately cease.
- The water table slowly declines, and baseflow returns close to pre-storm conditions.

The relative importance of components of this conceptual model varies depending on climate and therefore show seasonal variation. For example, during the high rainfall and low evapotranspiration period in late winter and early spring, soils are usually close to saturation, while overland flow, interflow, and groundwater recharge react rapidly to rainfall. During summer and late fall, when precipitation is lower and generally occurs in isolated storm events, soils are considerably drier and may not reach saturation in some rain events. Thus, overland flow occurs only during the most intense storms.

C.4.5 BEAR CREEK/MAYNARDVILLE LIMESTONE RECHARGE/DISCHARGE RELATIONSHIPS

The solution cavity system within the Maynardville Limestone conducts flow westward under Bear Creek and plays an important role in the surface water hydrology of BCV. The numerous springs that originate on the north slope of Chestnut Ridge are locations of discharge from this cavity system and are a dominant feature of the hydrograph of upper Bear Creek. This is especially so during drought periods when most of the flow in the main-stem Bear Creek is contributed by springs (Fig. C.27; Clapp et al. 1990).

During two relatively short periods (1 to 2 weeks) in 1994, the U.S. Geological Survey completed spring and seep surveys for Bear Creek and its tributaries and for Grassy Creek and its tributaries. The surveys were carried out at high baseflow (March 14 to March 19, 1994) and low baseflow (September 9 to September 16, 1994). Table C.1 summarizes all the data taken during the spring and seep surveys in BCV and Grassy Creek, and Fig. C.28 shows the results for flow.

The spring and seep survey identified reaches of Bear Creek and its tributaries that are either net-gaining or -losing reaches. Figures C.27 and C.28 depict detailed analyses of gaining and losing reaches in streams upgradient of BCK 9.47 during high- and low-flow periods, respectively. Figure C.29 shows west-east profiles along BCV of the flow and conductivity in the main stem. These profiles reveal that a number of gaining and losing reaches of the creek alternate down the valley.

In the headwaters of Bear Creek, between Y-12 Plant coordinates 52,000E and 47,500E, the creek gains flow during both the low- and high-flow periods. This segment corresponds approximately to the reach between the Rust Spoil Area and Sanitary Landfill 1 (SL 1), where the main influxes to the creek are NT-2, NT-3, SS-2, and SS-3. Of these four influxes, only SS-2 is perennial and has flow even during low-flow periods [0.02 cubic feet per second (cfs) during September and 0.23 cfs during March].

West of 47,500E, the creek loses flow: during the low-flow period the creek is dry in the reach adjacent to SL 1 and all the way downstream to the confluence with SS-4. Below SS-4, the creek flows for ~457 m (1500 ft) and then is dry until the confluence with NT-8 (41,250E). During the high-flow period, flow decreases downstream from SL 1 until the confluence with ST-1 (~46,000E) and steadily increases until the confluence with NT-8 at BCK 9.41. During the low-flow period, SS-4 provides the only influx of flow to Bear Creek between 47,500E and 41,250E; below the confluence with Bear Creek, this flow is lost to groundwater. During high-flow periods, flow is lost from the creek to groundwater for a distance of almost 762 m (2500 ft) downstream of NT-3, where it gains steadily with influxes from tributaries NT-5, -6, -7, -8, SS-4, and ST-1. For this reach of the creek, the influxes approximately balance the final outflow at BCK 9.41 (1.09 cfs in; 1.06 cfs out), suggesting little net interaction with groundwater over this reach of the creek.

In both the high- and low-flow periods, the flow in the creek increases dramatically between 41,250E and 40,000E: from 0.0 to 0.29 cfs in the low-flow period and from 0.44 to 2.01 cfs during the high-flow period. This increase in flow corresponds to the influx from SS-5; however, the flow from this spring alone cannot account for the increase, suggesting additional groundwater discharge directly to the creek bed along this reach. During the low-flow period, flow in the main stem increases from 0.01 to 0.29 cfs with an influx of 0.1 cfs from SS-5. This implies that an additional 0.18 cfs is derived from groundwater discharge. During the high-flow period, flow increases from 0.44 to 2.01 cfs, with 1.06 cfs from SS-5, which implies that an additional 0.51 cfs is derived from groundwater discharge.

Below 40,000E, Bear Creek is a perennial stream. Both the low- and high-flow periods exhibit a similar pattern, with a losing reach from 40,000E to 35,000E; a gaining reach from 35,000E to 32,500E (including the influx from SS-6); and a second losing reach over which almost half the flow is lost from Bear Creek between 32,500E and 30,000E. Below 30,000E, the creek veers to the north and steadily gains flow until the final sample point for the survey in the water gap in Pine Ridge. The losing reach between 32,500E and 30,000E is significant because, immediately below this reach, two major springs (SS-7 and SS-8) contribute a combined flow to Bear Creek that more than accounts for that lost along this reach.

In general, the flow in the creek varies in an alternating step-wise fashion down the valley. A major spring appears to be associated with each increase in flow (SS-2 and SS-3 at 48,500E; SS-4 at 43,500; SS-5 at 41,250; SS-6 at 35,250E; and SS-7 and SS-8 at 30,000E) and, in at least one case (SS-5), is probably associated with additional groundwater discharge to the creek on a similar order of magnitude as that from the spring itself. This finding indicates that the major springs in the floodplain of BCV may be associated with general groundwater discharge zones, not just the discharge from the individual spring.

C.5 REFERENCES

- Bras, R.L. 1990. *Hydrology: an Introduction to Hydrologic Science*, Addison-Wesley Publishing Company, Inc.
- Clapp, R.B., D.K. Cox, W.C. Kyker, J.R. Jones, J.A. Watts, and B.J. Frederick. 1990. *Surface Water Discharge Data for the Bear Creek Watershed, Oak Ridge, Tennessee, 1984-1988*, Y/TS-407, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, October.
- Dreier, R.B., D.K. Solomon, and C.M. Beaudoin. 1987. "Fracture Characterization in the Unsaturated Zone of a Shallow Land Burial Facility," in *Flow and Transport Through Fractured Rock*, American Geophysical Union Monograph, 42:51-59.
- Dreier, R.B. and S.M. Koerber. 1990. *Fault Zone Identification in the Area Surrounding the Y-12 Plant and Its Waste Management Areas*, Y/TS-656, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Dreier, R.B., T.O. Early, and H.L. King. 1993. *Results and Interpretation of Groundwater Data Obtained from Multiport-instrumented Coreholes (GW-131 through GW-135), Fiscal Years 1990 and 1991*, Y/TS-803, Martin Marietta Energy Systems, Inc., Y-12 Plant, Oak Ridge, Tennessee.
- Dreier, R.B. and G.L. Davidson. 1994. "Fracture Spacing and Connectivity Observed in Multiport Instrumented Wells," in *GSA Abstracts with Programs*, v. 25, no. 7, p. A-412.
- DuBuchanne, G.D. and R.M. Richardson. 1956. *Groundwater Resources of East Tennessee*, Bulletin 58, Part I, Division of Geology, State of Tennessee Department of Conservation.
- Eckman, R.M., R.J. Dobosy, and W.R. Pendergrass. 1992. *Preliminary Analysis of Wind Data from the Oak Ridge Site Survey*, Atmospheric Turbulence and Diffusion Laboratory of the National Oceanographic and Atmospheric Administration, Oak Ridge, Tennessee.
- Energy Systems (Lockheed Martin Energy Systems, Inc.). 1994. *Oak Ridge Reservation Annual Site Environmental Report for 1993*, ES/ESH-47, prepared for the U.S. Department of Energy, November.
- Ford, D.C. and P.W. Williams. 1989. *Karst Geomorphology and Hydrogeology*, Univin Hyman, Winchester, Massachusetts.
- Foreman, J.L., K.R. Walker, L.J. Weber, S.L. Driese, and R.B. Dreier 1991. "Slope and Basinal Carbonate Deposition in the Nolichucky Shale (Upper Cambrian), East Tennessee: Effect of Carbonate Suppression by Silicilastic Deposition on Basin-Margin Morphology," in *Mixed Carbonates-Silicilastic Sequences*, SEPM Core Workshop, No. 15, Dallas, Texas.
- Geraghty and Miller, Inc. 1986. *Aquifer Test Data and Design of Recovery Wells, S-3 Ponds*, Y/SUB/86-00206C/3, prepared for Martin Marietta Energy Systems, Inc., October.

- Golder and Associates, Inc. 1988a. *Geohydrologic Site Assessment and Computer Model Application, Bear Creek Valley, Oak Ridge Reservation, Contract #30X-SA706C, Tasks 1-6*, prepared for Martin Marietta Energy Systems, Inc.
- Golder and Associates, Inc. 1988b. *Task 2, Well Logging and Geohydrologic Testing, Site Characterization and Groundwater Flow Computer Model Application, Bear Creek Valley, Oak Ridge Reservation, Contract #30X-SA706C, Tasks 1-6*, prepared for Martin Marietta Energy Systems, Inc.
- Goldstrand, P.M. 1995. *Stratigraphic Variations and Secondary Porosity within the Maynardville Limestone in Bear Creek Valley, Y-12 Plant, Oak Ridge, Tennessee*, Y/TS-1093, Lockheed Martin Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.
- Goldstrand, P.M. and R.B. Dreier. 1993. "Stratabound Porosity in the Maynardville Limestone, Bear Creek Valley, Oak Ridge, Tennessee," Y/TS-1008, Abs, Abstract for submission to Geological Society of America Annual Meeting, Boston, Massachusetts, October 25-28.
- Goldstrand, P.M., L.S. Menefee, and R.B. Dreier. 1995. *Porosity Development in the Copper Ridge Dolomite and Maynardville Limestone, Bear Creek Valley, and Chestnut Ridge, Tennessee*, Y/SUB/95-SP912V/1, Lockheed Martin Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, December.
- Haase, C.S. 1991. *Geochemical Identification of Groundwater Flow Systems in Fractured Bedrock Near Oak Ridge, Tennessee*, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Haase, C.S., E.C. Walls, and C.D. Farmer. 1985. *Structural and Stratigraphic Data for the Conasauga Group and Rome Formation on the Copper Creek Thrust Sheet Near Oak Ridge, Tennessee: Preliminary Data from Test Borehole ORNL-Joy No. 2*, ORNL/TM-9159, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Hatcher, R.D., P.J. Lemiszki, R.B. Dreier, R.H. Ketelle, R.R. Lee, D.A. Leitzke, W.M. McMaster, J.L. Foreman, and S.Y. Lee. 1992. *Status Report on the Geology of the Oak Ridge Reservation*, ORNL/TM-12074, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Hoos, A.B. and Z.C. Bailey. 1986. *Reconnaissance of Surficial Geology, Regolith Thickness, and Configuration of the Bedrock Surface in Bear Creek and Union Valleys, Near Oak Ridge, Tennessee*, USGS Water-Resources Investigations Report 86-4165.
- HSW (HSW Environmental Consultants, Inc.). 1995. *Calendar Year 1994 Groundwater Quality Report for the Bear Creek Hydrogeologic Regime at the Y-12 Plant: 1994 Groundwater Quality Data Interpretations and Proposed Program Modifications*, Y/Sub/95-EAQ10C/1/P2, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, August.
- Jacobs Engineering. 1995. In preparation. *Regional Groundwater Flow Model, Construction and Calibration, Oak Ridge Reservation, Y-12/Bear Creek Valley Site*, October.
- Jones, S.B., B.K. Thompson, and S.M. Field. 1995. *Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge*

Reservation, Y/TS-881/R2, Lockheed Martin Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

- King, H.L. and C.S. Haase. 1988. *Summary of Results and Preliminary Interpretations of Hydrogeologic Packer Testing in Core Holes GW-131 through GW-135 and CH-157, Oak Ridge Y-12 Plant, Y/TS-495*, prepared by C-E Environmental, Inc./E.C. Jordan Company for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, December.
- Law Engineering (Law Engineering Testing Company). 1975. *Preliminary Safety Analysis Report for Nuclear Fuel Recovery and Recycling Center*, prepared for the Exxon Nuclear Company.
- Law Engineering. 1983. *Results of Ground-Water Monitoring Studies at Y-12 Plant, Y/SUB/83-47936/1*, prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, September.
- Lee, R.R. and R.H. Ketelle. 1987. *Stratigraphic Influence on Deep Groundwater Flow in the Knox Group Copper Ridge Dolomite on the West Chestnut Ridge Site*, ORNL/TM-10479, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Lee, R.R., R.H. Ketelle, J.M. Bownds, and T.A. Rizk. 1992. "Aquifer Analysis and Modeling in a Fractured, Heterogeneous Medium," *Groundwater*, 30(4):589-597, July-August.
- Lozier W.B., C.A. Spiers, and R. Pearson. 1987. *Aquifer Pump Test with Tracers*, ORNL/SUB/86-32136, prepared for Martin Marietta Energy Systems, Inc. by Golder and Associates, Inc., October.
- Lutz C. and R.B. Dreier. 1988. "Differences in Local Deformation History as Indicated by Fracture Orientations in Two Foreland Thrust Sheets," Abstract, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- McKay, L.D., W.E. Sanford, J. Strong-Gunderson, and V. DeEnriquez. 1995. "Microbial tracer experiments in a fractured weathered shale near Oak Ridge, Tennessee," presented at International Association of Hydrogeologists, Solutions '95 Conference, Edmonton, Alberta, Canada, June 4-10.
- Moline, G.R. and M.E. Schreiber. 1995. *FY94 Site Characterization and Multi-Level Well Installation at a West Bear Creek Valley Research Site on the Oak Ridge Reservation, Draft*, ORNL/TM-13029, Lockheed Martin Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee, August.
- Moore, G.K. 1988. *Concepts of Groundwater Occurrence and Flow Near Oak Ridge National Laboratory, Tennessee*, ORNL/TM-10969, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee, November.
- Moore, G.K. 1992. "Hydrograph analysis in fractured rock terrane," *Ground Water*, Vol. 30, no. 3, pp. 390-395.
- Moore, G.K. and L.E. Toran. 1992. *Supplement to a Hydrologic Framework for the Oak Ridge Reservation, Oak Ridge, Tennessee*, ORNL/TM-12191, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Rothschild, E.R., R.R. Turner, S.H. Stow, M.A. Boyle, L.K. Hyder, O.M. Sealand, and J.H. Wyrick.
1984. *Investigation of Subsurface Mercury at the Oak Ridge Y-12 Plant*, ORNL/TM-9092,
Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

C.6 FIGURES

(Source ORNL-DWG 94M-5238)

Wind rose produced from 1993 data from the eastern meteorological tower (MT5) at the Y-12 Plant.

Fig. C.1 Meteorological data of ORR. (Source NOA)

SAIC CAD DWG 94020\DWGS\2620U4
REV 1 / 07-11-96

Fig. C.2. Map of BCV showing topog

BEAR CREEK VALLEY

LEGEND:

- ROADS
- NT-1 BEAR CREEK & TRIBUTARIES
- 900 10' CONTOUR
- OU4 SURFACE
- ▲ NT-1 WATER SAMPLE LOCATION
- OU4 STORM
- ▼ SFT-1 FLOW TUBE LOCATION
- OU4 SURFACE WATER
- SS-1 SAMPLE AT SPRINGS
- MAYOR SPRINGS NOT
- SS-2 SAMPLED BY OU4

0 900 1800
SCALE: 1" = 1800'

Y-12 PLANT NORTH

ny, named tributaries, and springs.

Fig. C.3. Geological map of BCV and surrounding areas.

Fig. C.4. Geology of BCV. (Photograph of the Nolichucky Shale, courtesy of P. Lemiski)

Fig. C.5. Along-strike section of Maynardville Limestone in BCV. Source: Shevenell et al. 1992.

Fig. C.6. Stuctural cross section of the Oak Ridge area.

GW-726

Fig. C.7. Hydraulic head, fractures, and fracture characteristics in Nolichucky Shale from GW-726 and GW-727.
Source: Dreier and Davidson 1994.

BC-70

BC-12-03

Fig. C.8. Conceptual model for groundwater flow in BCV.

Fig. C.9. A schematic showing conceptual shallow groundwater flow for BCV.

Fig. C.10. Water balance model for BCV above BCK 9.47.

Fig. C.11. BCV groundwater elevations for January 10-13, 1994—groundwater piezometric head in BCV for water table and

ARM

LS

M

LEGEND:

GROUNDWATER ELEVATION
.....CONTOUR (ft mls)

DATA SOURCE:
CONTOURS FROM HSW
CONSULTANTS, INC. 1994

BEAR CREEK VALLEY
RI

GROUNDWATER
ELEVATIONS
JANUARY 10-13, 1994

REVISION	DRAWN BY	CHKD. BY	DATE
0	P. HOLM	XX	XX/XX/95
A	S. DUNLAP	XX	10/26/95

XREFERENCES	PLOT FILES
94020\XREF\XREFC9,10,11,12,13,14 94020\XREF\GWELS-J 94020\XREF\GWWT-J	94020\LOT\128GW1 PLOT

DRAWING # 94020\DWGS\128GW1 CAD FILE # ROT ANGLE

bedrock intervals during high-flow season.

Fig. C.12. BCV groundwater elevations for August 23-31, 1994—groundwater piezometric head in BCV for water table

M

TE BEDROCK INTERVALS
-31, 1994

LEGEND:

GROUNDWATER ELEVATION
..... CONTOUR (ft. mls)

DATA SOURCE:
CONTOURS FROM HSW
CONSULTANTS, INC. 1994

FARM

RVALS
94

bedrock intervals during low-flow season.

BEAR CREEK VALLEY
RI

GROUNDWATER
ELEVATIONS
AUGUST 23-31, 1994

REVISION	DRAWN BY	CHKD. BY	DATE
0	P. HOLM	XX	XX/XX/95
A	S. DUNLAP	XX	10/26/95

XREFERENCES	PLOT FILES
94020\XREF\XRCV9.10.11.12.13.1	94020\PL0T\12BGW1.PLT
94020\XREF\GWELS-J	
94020\XREF\GWWT-J	

DRAWING # 94020/DWGS/12BGW2A
CAD FILE # ROT ANGLE

Fig. C.13. Hydrologic cross section in strike-perpendicular section showing detailed hydraulic head measurements from four coreholes (GW-132, -133, -134, and -135). *Source:* Dreier et al. 1993. Cr = Rome Formation, Cpv = Pumpkin Valley Shale, Cr = Rutledge Limestone, Crg = Rogersville Shale, Cm = Maryville Limestone, Ch = Nolichucky Shale, Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

Fig. C.14. Frequency distribution of vertical hydraulic gradients in the Nolichucky Shale and Maynardville Limestone in BCV.

Fig. C.15. Water-type regimes in a strike-perpendicular cross section of BCV. *Source:* Dreier et al. 1993. Note that the effects of nitrate contamination in the vicinity of GW-134 have not been incorporated into the diagram. Cr = Rome Formation, Cp = Pumpkin Valley Shale, Crt = Rutledge Limestone, Crg = Rogersville Shale, Cm = Maryville Limestone, Cn = Nolichucky Shale, Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

Fig. C.16. Piper diagram illustrating groundwater geochemistry in BCV. Source: HSW 1995.

Fig. C.17. Reaction path model for groundwater in BCV. Source: Toran and Saunders 1992b.

Fig. C.18. Stream hydrograph from BCK 9.47 from March 1994 to January 1995.

Fig. C.19. Variation of head from instantaneous measurement in GW-227 and GW-228.

Fig. C.20. Hydraulic head monitoring in wells GW-624, -626, and -629 in the Nolichucky Shale.

Fig. C.21. Well hydrographs for GW-725 and GW-726 at BYBY, and for GW-227 and GW-228 at SL 1.

Fig. C.22. Monitoring of changes in soil saturation, stream flow, and groundwater at the BCBG for a storm on April 15, 1994.

Fig. C.23. Monitoring of changes in soil saturation, stream flow, and groundwater at the S-3 Site during storms on July 26-28, 1994.

Fig. C.24. Example well hydrographs for the water table interval of the Nolichucky Shale.

Fig. C.25. Hydraulic head monitoring in wells at the Western Picket in the Maynardville Limestone.

Fig. C.26. Relative magnitudes of λ for stream flow, stormflow tubes and groundwater in BCV.

*Gaining and Losing Reaches
during High Base Flow in 1994*

Fig. C.27. Identification of gaining and losing reaches in Bear Creek during a high-baseflow period in April 1994.

*Gaining and Losing Reaches
during Low Base Flow in 1994*

Fig. C.28. Identification of gaining and losing reaches in Bear Creek during a low-baseflow period in April 1994.

Fig. C.29. West-East profiles of Bear Creek showing flow and conductivity during the high and low baseflow spring and seep surveys (low-flow profile—September 1994 and high-flow profile—March 1995).

C.7 TABLES

Table C.1 Thickness of zones identified in the Maynardville Limestone^a

DOWNHOLE THICKNESS OF GEOLOGICAL UNITS							
Well Name	zone 7	zone 6	zone 5	zone 4	zone 3	zone 2	Total Est Cmn
PICKET A							
GW-685			68				NA
PICKET B							
GW-703		97					
GW-704		94	52				
GW-705			48	125	30	0	301
PICKET C							
GW-723	11	94	59	80			
GW-724			58	80	67		
GW-739	19	95	56				
GW-740	16						NA
PICKET J							
GW-722		97	56	145	94	192	
GW-733		142	63				619
PICKET W							
GW-710	23	93					
GW-711	31	92	55				
GW-712		116	59	84	84		
GW-713	20	95	55				NA
SUMMARY							
Well Name	zone 7	zone 6	zone 5	zone 4	zone 3	zone 2	Total Est Cmn
DOWNHOLE THICKNESS							
AVERAGE	21	100	54	106	74	148	491
STANDARD DEV	5	16	7	23	24	68	106
MAXIMUM	31	142	68	145	108	236	619
MINIMUM	11	83	39	76	24	0	301
# OF BOREHOLES	10	14	17	12	13	8	5

Table C.1 (continued)

Summary							
Well Name	zone 7	zone 6	zone 5	zone 4	zone 3	zone 2	Total Est Cmn
STRATIGRAPHIC THICKNESS (assume 43 degree dip)							
AVERAGE	16	73	39	78	54	108	359
STANDARD DEV	4	12	5	17	18	50	77
MAXIMUM	23	104	50	106	79	173	453
MINIMUM	8	61	29	56	18	0	220
# OF BOREHOLES	10	14	17	12	13	8	5

^aSource: Shevenell et al. 1992.

**Table C.2 Valley-wide summary of results from the BCV and
Grassy Creek spring and seep survey**

SUMMARY STATISTICS Y-12 PLANT											
High Base Flow						Low Base Flow					
	Q (cfs)	pH	K (uS/cm)	Temp C	DO (mg/l)		Q (cfs)	pH	K (uS/cm)	Temp C	DO (mg/l)
Maximum	6.89	8.4	1710	21	16	Maximum	0.76	8.3	2030	27	9.2
Minimum	0	5.0	1	4.5	0.6	Minimum	0	4.8	5	13.5	0.99
Average	0.23	7.0	164	10	7.4	Average	0.02	7.5	346	18	6.9
Median	0.01	7.1	90	11	7.4	Median	0.00	7.5	262	19	7.7
Std. Dev.	0.89	0.8	208	2	2.6	Std. Dev.	0.07	0.5	329	2	2.0

**C.8 SUPPORTING INFORMATION
FOR APPENDIX C—DETAILED ANALYSIS
OF HYDROGEOLOGIC MONITORING
DATA FOR BCV OU 4 RIFA**

INTRODUCTION

This section of the RI report contains detailed analysis of hydrogeologic data from BCV. The data analyzed include hydraulic head data from Y-12 Plant monitoring over the past 10 years: constant monitoring of hydraulic head, specific conductivity, and temperature in groups of wells from the OU 4 RIFA; constant monitoring of hydraulic head from temporary piezometers from the OU 1 RIFA; and continuous monitoring of surface water flow at 13 sites from the OU 4 RIFA.

In the first two subsections of this section, two important components of the BCV hydrogeologic conceptual model are discussed in detail: the nature of vertical hydraulic gradients in BCV and the response of hydrostatic pressure in monitoring wells to precipitation. Both of these components are important to understanding the migration of contaminants in BCV. Following this, results from recent surface water flow monitoring and stormflow tube monitoring in BCV are presented and discussed.

C.8.1 VERTICAL HYDRAULIC GRADIENTS

C.8.1.1 Historic Groundwater Potentiometric Data

Information on location and construction details for the wells discussed in this document is available in *Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge Reservation* (Jones et al. 1995). The locations of current groundwater monitoring wells in BCV that were used in this report are shown in Fig. D.1 (Appendix D).

The results of water level measurements throughout BCV are summarized in the annual GWQR (e.g., HSW 1995). Figures C.11 and C.12 in Appendix C show contours of the piezometric surface for the water table interval and the intermediate and deep bedrock intervals during the high-flow period in January 1994 and the low-flow period in August 1994, respectively. The maps show that hydraulic gradients in BCV vary little in slope and direction between high-flow and low-flow time periods. In addition, the magnitude and direction of hydraulic gradients do not vary significantly between water table interval and bedrock for either the low-flow or high-flow periods.

The potentiometric maps also show that there is a general upward hydraulic gradient in the Nolichucky Shale throughout the valley. In predominantly clastic formations of the Conasauga Group, the mean hydraulic gradient is upward in 76% of well pairs (Table C.3 and Fig. C.30). Mean gradients range in magnitude from -0.22 to 0.35 (negative indicates a downward gradient); however, most of the gradients are between 0.0 and 0.1 (66% of all well pairs). These data are supported by hydraulic head data for the bedrock interval at the S-3 Site recorded in the transect of multi-level monitoring wells (Dreier et al. 1993) that show upward hydraulic gradients in the upper 30 to 46 m (100 to 150 ft) of the Nolichucky Shale.

Out of the eight well pairs that recorded mean downward gradients in the Nolichucky Shale, six had one well that was screened in the residuum or at the bedrock/water table interval [depth ranges from 3.7 to 9 m (12 to 29 ft)]. This indicates that, where downward gradients exist in the Nolichucky Shale, they may be restricted to the shallowest interval, probably indicating a mechanism for shallow groundwater recharge. In nearly all cases, hydraulic gradients between wells screened in bedrock were upward.

Vertical hydraulic gradients in the Maynardville Limestone vary more than those in the Nolichucky Shale and fall in a smaller range of values. Of the 11 well pairs analyzed, the range of hydraulic gradients was -0.15 to 0.1 with a mean value of 0.02 (Table C.3 and Fig. C.30). Seven well pairs had downward gradients, and four pairs had upward gradients. At least one well in each well pair that showed mean upward gradients was screened at depths >46 m (150 ft). These observations are supported by hydraulic head data for the bedrock interval at the S-3 Site recorded in the transect of multi-level monitoring wells (Dreier et al. 1993) that showed downward hydraulic gradients in the Copper Ridge Dolomite and Maynardville Limestone formations to depths exceeding 300 m (1000 ft) below Chestnut Ridge. These same borings show increases in the hydraulic head with depth close to the transition between the Nolichucky Shale and Maynardville Limestone.

The general patterns of hydraulic head suggest that, in the predominantly clastic formations in BCV, vertically upward hydraulic gradients predominate in the bedrock intervals. Downward gradients occur in some sections of the shallow interval and, in many instances, in the water table interval of these formations. Vertical gradients differ between the carbonate and predominantly clastic formations. Downward gradients predominate in the carbonate formations, and upward gradients may only exist at depths in excess of 300 m (1000 ft) or in the Maynardville Limestone close to the transition to the Nolichucky Shale.

The predominance of vertically upward hydraulic gradients in the Nolichucky Shale probably arises as a result of the strong anisotropy of the formation where conductivity oriented parallel to bedding planes may be one or two orders of magnitude greater than that across strike. Bedding in the Conasauga Group dips uniformly to the south, and recharge flow paths in bedrock are most likely downward, parallel to dip. Pressure head at depth is, therefore, partly controlled by the elevation of the recharge zone, or outcrop of that stratigraphic zone, which is topographically higher up on Pine Ridge. The overall effect is the vertical hydraulic gradients as a single point; however, due to the very low across-strike conductivities, this vertical hydraulic gradient probably does not translate into significant upward flow except at locations where structural features provide a conduit for vertical flow. In essence, it is the low across-strike conductivity that maintains the vertical gradients.

C.8.1.2 Continuous Monitoring of Hydraulic Heads

During the recent RIFA activities, hydraulic head was monitored continuously for periods up to 1 month in four groups of wells and one group of temporary piezometers in BCV. The wells and piezometers were monitored for ranges in depth and in formation. Table B.28 in Appendix B contains a list of wells for which monitoring was completed and a summary of the monitoring that was carried out. Figures C.31 to C.68 show the results of monitoring at each individual well in relation to rainfall for that time period.

The continuous monitoring data from wells in the Nolichucky Shale support the observations of vertical upward gradients in this formation. Well pairs GW-085 and -086 at the Boneyard/Burnyard (BYBY) (Fig. C.69), GW-346 and -526 at the S-3 Site (Fig. C.69), and GW-624, -626, and -629 at the BCBG (Fig. C.20) are located close to each other and were monitored continuously for periods of ~1 month. The well groups located in the BCBG and at the S-3 Site show upward gradients throughout the monitoring period, whereas the well group at BYBY shows almost no gradient. These results are generally consistent with piezometric head data from the GWQR database.

The continuous monitoring data from wells in the carbonate dominant formations show mainly upward hydraulic gradients between the screened intervals that were monitored; this observation differs from the mostly downward gradients observed in the GWQR database. Well groups GW-045

and -095 at BCBG (Fig. C.70), GW-725 and -726 at BYBY (Fig. C.21), and GW-227 and -228 at the SL 1 (Fig. C.21) are wells located in pairs that were monitored continuously for periods of ~1 month.

Both the well pairs GW-045/-095 at the BCBG and GW-227/-228 at SL 1 show vertically upward hydraulic gradients for the period of monitoring. The vertical upward gradient in the GW-045/-095 pair is consistent with the head data from the GWQRs, which also show a mean vertical upward gradient of 0.05. However, GWQR data for the GW-227/-228 show a mean downward gradient between this well pair. A possible reason for this inconsistency is that the hydraulic gradient between this well pair may temporarily reverse during periods of high flow.

During the period of monitoring at this well pair, the head gradient between the wells screened decreased from 0.115 to 0.017, which coincided with a steady decline in head in both wells. This general head decline is also seen in other Maynardville Limestone wells during the same time period (GW-725 and -736) and corresponds to monitoring during a dry period immediately following a period of intense rainfall in March and April 1994. The rate of change of head in GW-228 is almost twice that in GW-227 and indicates that head variations in GW-228 are greater than those in GW-227. A hydraulic gradient reversal resulting in downward hydraulic gradients would occur between this well pair if the relative rates of decline in head observed in each well during the monitoring period were to continue for a further week. Figure C.19 shows the variation of hydraulic gradient between these two wells observed in instantaneous data from the GWQR database. The hydraulic gradient varies from -0.093 to 0.015, and the water levels in these wells mimic each other. Upward gradients were observed twice in this database, in July 1988 and in March 1989; vertical gradients at all other times were downward.

The anomaly between the results of these two monitoring efforts could be the result of the time period of monitoring: the GWQR data are instantaneous readings and were taken over a period of 5 years, irrespective of the current, or preceding weather, conditions. Whereas, the continuous monitoring occurred over a shorter 4-week period and was started immediately after a 2-month period in which almost 51 cm (20 in.) of precipitation was recorded in BCV. These data indicate that, although the vertical gradient between this well pair is generally downward, for short periods of time after periods of intense rainfall, upward gradients may temporarily exist.

The well pair GW-725/-736 shows almost no gradient between the well screens. This lack of difference in head between these wells is particularly notable because, during the period of monitoring, the head in both wells fell by ~0.9 m (3 ft). The open intervals for these wells are vertically only 9 m (30 ft) apart; due to their proximity, a significant difference in hydraulic head between these wells might not be expected. However, these data indicate that there are good hydraulic connections between these wells. This is consistent with the drilling records for the exit pathway program where both of these wells intersected cavities and water-bearing cavities in zone 2 of the Maynardville Limestone (Shevenell et al. 1992).

C.8.2 PRESSURE PULSES IN RESPONSE TO RAINFALL

C.8.2.1 Hydrograph Analysis

Shevenell (1994b) observed rapid rises in hydrostatic pressure in wells screened in the Maynardville Limestone in BCV during rainfall events. Similar rapid rises in hydrostatic pressure in wells screened in the Nolichucky Shale were observed during the BCV RI. These changes in hydrostatic pressure during rainfall events occur in parallel with changes in the saturation state of

soils and in the flow in creeks draining the siliceous dominant formations, providing insight into groundwater flow in each of these components (Appendix C).

Hydrograph analysis for surface water has been a standard method for estimating relative contributions to flow derived from groundwater, soil interflow, and overland flow in a stream catchment (Bras 1990). Moore (1988, 1992) and Shevenell (1994b) adapted these surface water methods to analysis of hydrographs derived from continuous monitoring of hydrostatic pressure in wells and stormflow tubes on the ORR. Shevenell (1994b) further developed these methods to allow quantitative analysis of well hydrographs in the Maynardville Limestone in BCV.

In general, the shape of the rising limb of a hydrograph (e.g., Fig. C.24) is controlled by factors such as rainfall intensity, rate of infiltration, rate of recharge, and effective porosity of the vadose zone. The slope of the regression limb of the hydrograph, however, relates to the rate of drainage of the reservoir of water upstream of the monitoring point. In the case of streams, the upstream reservoirs are ponded surface water, soil moisture, and groundwater storage; the rate of drainage is the combined rate of flow in each of these reservoirs. In the case of a well hydrograph, the upstream reservoir is groundwater storage in the aquifer, and the discharge rate is a function of the transmissivity and specific yield of the rock.

Moore (1992) identified segments of the stream hydrographs in Melton Valley that were related to drainage from soils (stormflow) and groundwater. Shevenell (1994b) identified two or three segments of the regression curve for hydrographs in the Maynardville Limestone that the study related to differential rates of drainage from conduits, fractures, and matrix porosity, respectively. These segments of the regression limb can be best identified by plotting the well hydrographs on semi-logarithmic axes.

A change in head in a well does not necessarily indicate flow to that well; rather, changes in head indicate transmittal of a pressure pulse in the aquifer. However, when the pressure pulse is accompanied by a change in specific conductivity and/or temperature of the water in the well, the change in head during a storm is the result of both transmittal of pressure and of quick flow to the well. When the pressure pulse is not accompanied by a change in specific conductivity and/or temperature of the water in the well, recharge has occurred at the water table interval and the pressure pulse has been transmitted to the monitoring well.

Regression Analysis

A hydrograph regression curve can be represented by the following equation:

$$Q = Q_0 e^{-\epsilon t}, \quad (1)$$

where Q is flow in the stream at time t , and ϵ is the exhaustion coefficient and is the slope of the hydrograph when plotted on $\log(Q)$ vs time axes. ϵ represents the capability of the upstream reservoir to release water; where ϵ is large, the formation has a poor ability to retain water, and groundwater will drain easily. The equivalent equation can be written for the pressure head hydrographs for wells or the stage hydrographs for streams:

$$h = h_0 e^{-\lambda t}, \quad (2)$$

where h is the groundwater head or stream stage and λ is the equivalent of ϵ in Equation 1. Shevenell (1994b) contains detailed analysis of hydrographs from wells screened in the Maynardville

Limestone in BCV. This section of the RI contains similar analysis of hydrographs from wells in BCV.

C.8.2.2 Wells Screened in Predominantly Clastic Formations

Wells screened in the Nolichucky Shale show responses to rainfall that are dependent upon the depth of the well screen. Shallow wells showed very rapid responses to rainfall events with rising hydraulic head and, in some cases, decreases in specific conductivity. Deeper wells, especially those screened below 30 m (100 ft), showed more subdued responses to rainfall in the form of steadily rising hydraulic heads. Changes in conductivity were not observed in the deep wells.

Water Table Interval and Shallow Bedrock

Table C.4 lists the storms that occurred during the monitoring periods for each well, which are identified on the rainfall hydrographs for each well. For each well, Table C.4 lists the minimum, maximum, and mean values for the following: the time lag between the initiation of rainfall and the initiation of the hydrograph response; the time lag between peak rainfall and peak of the hydrograph; and the rise of hydrostatic pressure recorded. The following are detailed descriptions of well hydrographs that show responses to storms.

GW-624. Well GW-624 is screened between 5.2 m (16.9 ft) and 8.3 m (27.2 ft) bgs and was monitored between March 15 and April 18, 1994 during a period of intense rainfall (Fig. C.51). During this period, there were six storms with a total of >35.5 cm (14 in.) of rain. The most intense rainfall during this period occurred on April 12 with an intensity of 1.35 in./h.

The responses to rainfall in this well were very rapid. The shape of the hydrographs shows a truncated peak for each storm event (Fig. C.51), with a maximum elevation for the hydrograph that does not vary between storms. Possible causes for this truncated peak are an overflow of the well casing, the level in the well exceeding the maximum pressure range for the transducer, or a natural aquifer effect that sets a maximum value on the elevation of groundwater in this region. The first two possible causes were discarded because the observed peaks were within the calibrated range of the pressure transducer, and the land elevation is ~0.7 m (2.3 ft) above the maximum value (Fig. C.20). The truncated nature of the hydrograph suggests that, at this elevation, groundwater is able to drain rapidly from the subsurface in this region. The well is located close to NT-7; therefore, it is possible that the maximum peak height is related to the elevation of an ephemeral spring or seep at this tributary and that this spring controls the maximum elevation of groundwater in this area.

In well GW-624, the time delay from peak rainfall intensity to hydrograph peak cannot be measured due to this truncating effect. However, the time lag between the initiation of rainfall and the initial rise in the hydrograph is an indication of the speed of groundwater recharge that causes these peaks. A short lag time between rainfall initiation and rise in the hydrograph is probably indicative of quickflow (Shevenell 1994b). Unfortunately, 14 d of data were lost from this datalogger after it was swamped with water during a storm; however, the rising limbs of three storms were recorded (Table C.4). The mean time lag between initiation of rainfall and initiation of the rising limb of the hydrograph for the three recorded storms was 2.5 h and was the shortest time period of all the wells analyzed.

Specific conductivity and temperature in well GW-624 both respond rapidly to rainfall (Fig. C.51). During storm events, specific conductivity drops ~200 μmhos and the temperature also drops 1 to 2°C. The changes in conductivity and temperature are coincident with the pressure pulses, indicating that the travel time for recharge to the well screen is very short. After the storm event, specific conductivity increases and almost returns to the pre-storm values. This is consistent with the

observations of Sanford and Solomon (1995); McKay et al. (1995); and Sanford et al. (1994) at the tracer test site in BCV where the concentration of tracers in the monitoring wells temporarily drops during transient storm events and rebounds to the previous values within a few days. In conclusion, the hydrograph record at this well demonstrates that very rapid recharge to groundwater occurs during precipitation events. In addition, these data show that the rate of drainage from the water table interval can be very rapid when the water table is elevated above the ambient levels.

GW-345. A second well screened in the shallow Nolichucky Shale (GW-345) also shows rapid response to rainfall with rising hydraulic heads (Fig. C.46). GW-345 is located close to NT-1 and is screened at 4.9 to 7.9 m (16 to 26 ft) bgs. The pressure responses to rainfall are not as immediate as those seen in GW-624; however, a true peak is seen for the hydrograph with no truncation. Two storms occurred during the monitoring period; the lag times between peak rainfall intensity and peak hydrograph are 13.5 and 14.5 h. The size of the storm peaks relative to ambient groundwater elevation was also smaller than in GW-624. Peak heights were both 23 m (0.77 ft).

S-3 Site. Three existing shallow wells screened in the Nolichucky Shale and six temporary piezometers close to the S-3 Site were monitored for a period of 2 months as part of the BCV OU 1 project. Hydrographs from the three wells (GW-101, -127, and -276) all show rapid response to rainfall events (Figs. C.37, C.38, C.42, C.45, respectively). The hydrographs in GW-127 and -276 show well-defined peaks and regression curves; whereas the hydrograph from GW-101 shows peaks during rainfall events but poorly defined regression curves. The temporary piezometers (S3-1, -3, -5, -6, -7, -8) show a mixed quality of hydrographs. Piezometer S3-5 (Fig. C.65) has well-defined peaks and regression curves in response to rainfall; S3-1 and -8 (Figs. C.63 and C.68) both show truncated peaks with poorly defined regression curves in response to rainfall; S3-6 and -7 (Figs. C.66 and C.67) show hydrographs that vary very rapidly but have seemingly little correlation to rainfall; and S3-3 (Fig. C.64) shows no response to rainfall and a general decline in head during the monitoring period.

The temporary piezometers were constructed without a screen or grout seals; and it is likely that the confused hydrographs of S3-6 and -7 are due to this incomplete construction. S3-1, -5, and -8 react to rainfall in a similar way to the shallow wells monitored during the same time period; S3-5 responds similarly to GW-127 and -276; and S3-1 and -8 respond in similar ways to GW-101. It is therefore probable that the construction of these piezometers did not compromise the quality of monitoring and that these hydrographs reflect the changes in the water table.

The hydrographs for S3-5, GW-127, and -276 have very similar responses to rainfall and are probably representative of the active groundwater flow systems in the water table interval at S-3 Site. The initiation lag times in each of these piezometers ranged from 1.5 to 6 h, and the peak lag times from 4.5 to 30 h.

Specific Conductivity Trends

With the exception of GW-624 (discussed above, Fig. C.51), the wells in the Nolichucky Shale do not show systematic changes in specific conductivity during the monitoring periods that can be attributed to real changes in groundwater chemistry. Only GW-101 (Fig. C.37) shows a distinct drop in specific conductivity immediately following rainfall between July 26 and July 27 that can probably be attributed to the precipitation event. Approximately 3 d after the cessation of rainfall, the specific conductivity in this well starts to rebound; 5 d after cessation of rainfall, the conductivity in the well is almost returned to its former values. Similar to GW-624, change in conductivity in GW-101 implies that the precipitation event resulted in flow of recent recharge to the well. The return of specific conductivity to its original value is consistent with the observations of Sanford and Solomon (1995); McKay et al. (1995); and Sanford et al. (1994) at the tracer test site in BCV, where

the concentrations of tracers in the monitoring wells temporarily drop during transient storm events and rebounds to the previous values within a few days.

Wells GW-345 (Fig. C.46), -616 (Fig. C.50), -526 (Fig. C.48), and -629 (Fig. C.53) each show anomalously high values of specific conductivity after the initial installation of the measuring probe, but have a rapid decrease to a stable value during the period of monitoring. This effect may be an artifact of installation of the hydrolab. None of the wells were purged before installing the hydrolabs, and this change in time could relate to the hydrolab equilibrating to the conditions at the well screen.

Regression Analysis

The hydrographs from wells GW-127, -276, -345, -537, and piezometer S3-5 have reasonably complete regression curves (Figs. C.42, C.45, C.46, C.49, and C.65), although the regression curve observed for GW-537 is derived from an artificially induced pressure pulse (see below). The hydrographs from these wells were analyzed following the methods outlined by Shevenell (1994b). Figure C.24 shows the hydrographs for GW-127, -276, and piezometer S3-5 plotted on semi-log axes. The plots are normalized to the lowest water level value for each well such that the plots are able to define the slope of the hydrograph more easily.

The hydrographs for GW-127, -276, -537, and S3-5 each show two distinct slopes during the regression from the peak water level after a storm. These two slopes (or values for λ) imply two pathways for drainage in the water table interval of the Nolichucky Shale with different transmissivities. The steeper slopes (corresponding to rapid drainage) for these wells have values for λ that range from $5.92 \times 10^{-3} \text{ h}^{-1}$ to $1.86 \times 10^{-2} \text{ h}^{-1}$ with a mean value of $8.06 \times 10^{-3} \text{ h}^{-1}$. The shallower slopes (corresponding to slow drainage) have values for λ that range from $7.74 \times 10^{-4} \text{ h}^{-1}$ to $4.84 \times 10^{-3} \text{ h}^{-1}$ with a mean of $2.05 \times 10^{-3} \text{ h}^{-1}$. The peaks for GW-345 only have one slope, and the λ values for these slopes were $2.79 \times 10^{-3} \text{ h}^{-1}$ and $7.55 \times 10^{-3} \text{ h}^{-1}$, respectively. These values are between the ranges of values for the steeper and shallower slopes observed for regression curves from GW-127, -276, -537, and S3-5.

Intermediate and Deep Bedrock Intervals

The well hydrographs from wells screened in the shallow, intermediate, and deep bedrock intervals of the Nolichucky Shale show more subdued responses to rainfall events than the water table wells. Well GW-076 (Fig. C.32) showed no immediate response to rainfall. Wells GW-126 (Fig. C.41), -346 (Fig. C.47), -526 (Fig. C.48), -616 (Fig. C.50), -626 (Fig. C.52), and -629 (Fig. C.53) show immediate but subdued responses to rainfall. In addition, the wells GW-626 and -629 show a longer-term increase in head over the period of monitoring in response to the high precipitation rate during the monitoring period. Head in both wells increases by $\sim 0.67 \text{ m}$ (2.2 ft) over the period of monitoring; this value is the same as the increase in the base groundwater level in well GW-624 (a water table well at the same location) over the same time period (Fig. C.20). This suggests that this period of high precipitation [over 36 cm (14 in.) during 1 month] caused a relatively uniform rise in the hydraulic head throughout the Nolichucky Shale and implies that, although fracture networks in the predominantly clastic formations may not be connected enough to transmit pressure pulses rapidly, the fractures are connected sufficiently to transmit longer-term pressure changes.

Cross Borehole Pressure Pulse Test in the Nolichucky Shale

A cross borehole pressure pulse test was carried out at the scrap metal salvage yard adjacent to BYBY. Water was injected into well GW-085 [19 m (62 ft)], and hydraulic head was monitored

continuously in the Oil Landfarm group of wells (Table B.27 in Appendix B). Two wells showed a response to the pressure injections, GW-086 and -537 (Figs. C.34 and C.49). The screen for well GW-086 is located 8.6 m (28.5 ft) vertically above the injection well screen, while well GW-537 is located 152 m (500 ft) east of the injection well and is screened at approximately the same depth as GW-086 [7.5 m (24.5 ft)]. Both groundwater pressure and specific conductivity responded to the injection of water in these two wells. This implies that a pressure pulse was transmitted to each well that also caused groundwater inflow to the wells from a different flow path than that usually monitored (the conductivity response does not necessarily mean a flow of injected water from the injection well to the monitoring wells, therefore, it is unlikely that injected water moved from GW-085 to -537 in the observed time frame).

During the injection test, after ~10 min of injection, the pressure in the injection well stabilized at 80 psi and the injection rate of 6 gal/min. After 61 min of injection, there was a sharp rise in the injection rate that was accompanied by a fall in the injection pressure that could be maintained. From the 67th minute of the test to the end of the test (85th minute), the injection rate was 110 gal/min with the pressure in the injection well at 60 psi. Although GW-085 responded to the initial injection of water almost immediately after the observed increase in flow rate in the injection well, the response in GW-085 increased rapidly and the response in GW-537 was observed almost immediately after that sharp increase in flow. These phenomena are consistent with the opening of a flow path from the injection well to the monitoring wells. It is possible that these phenomena were the result of a break in the grout seal above the screened interval of the injection well, thus opening a flow path up the well bore and into the water table interval. Another possibility is that the breakthrough occurred along the natural fracture network in the shallow bedrock. Although these data cannot be analyzed quantitatively, the response to injection in a well located 152 m (500 ft) along strike from the injection well implies that there exists good hydraulic connectivity along strike in the Nolichucky Shale. None of the other monitoring wells used in this test responded to the injection pulse.

C.8.2.3 Wells Screened in Carbonate Formations

Well hydrographs from wells screened in the shallow, intermediate, and deep intervals of the Maynardville Limestone showed responses to precipitation. Wells GW-045 (Fig. C.30), -053 (Fig. C.31), -094 (Fig. C.35), -095 (Fig. C.36), -122 (Fig. C.39), -124 (Fig. C.40), -651 (Fig. C.54), -710 (Fig. C.55), -711 (Fig. C.56), -712 (Fig. C.57), -713 (Fig. C.58), -714 (Fig. C.59), and -715 (Fig. C.60) have hydrographs that responded to rainfall during their respective monitoring periods. Table C.4 contains a summary of the peak responses from some of these wells. Each of these wells shows a similar response to precipitation, and the extent and rapidity of response appear to be irrespective of the depth of the well. In contrast to wells in the Nolichucky Shale, intermediate and deep wells show rapid responses to storm events. This is a consistent, well documented occurrence of a well-connected network of solution cavities and fractures in the Maynardville Limestone that extend to depths up to 106 m (350 ft) (Shevenell et al. 1992; Shevenell 1994b; Shevenell and Beauchamp 1994). The following is a description of key features of the monitoring data obtained for this RI.

Picket W. Hydrographs were recorded in each of the six wells at Picket W during a 2-month period between November 1994 and January 1995. During this time period, four major precipitation events were recorded, and all the wells in Picket W recorded responses to each event (except where technical difficulties were encountered). Table C.4 contains an analysis of the timing of the well hydrographs compared to the precipitation event. The responses of these wells to the same storms appear to fall into two broad groupings: one for deep wells and one for relatively shallow wells. Each of the wells has relatively sharp asymmetric peaks with a steeper rise than fall; however, the deep wells have peaks that are generally more rounded and slower to develop than those in the shallow

wells. This is reflected in the lag time between the initial rise of the hydrograph and the initial rainfall, and in the lag time between the peak hydrograph and peak rainfall. Wells GW-710 to -714 have mean peak lag times that range from 21 to 45 h and are two to three times the mean initiation lag time. The hydrograph peaks in these wells decrease with depth of the well; the mean values are 1.3 in GW-710 to -712, 1.6 in -713, and 2.4 in -714. GW-715 shows a very sharp initial peak response to rainfall followed by a more subdued response. The initial peaks in GW-715 reflect the precipitation rate very closely and, in events 10 and 11 where precipitation shows two peak intensities, this is matched by two separate peaks in the hydrograph. Shevenell (1994b) interpreted this as the result of this well being connected to a conduit system that transmits quick flow from two upstream conduits that converge into the single conduit tapped by this well.

Picket C and Vicinity

The hydrographs from wells GW-227, -228, -725, and -736 show a continuous declining trend over this period of monitoring; the greatest fall in head was recorded in GW-228 at 2.6 m (8.5 ft) and the smallest change in GW-725 of 0.98 m (3.2 ft). This time period contains three precipitation events [a total of 5.6 cm (2.2 in.)], and these wells show little or no response to these events. The period of monitoring for these wells coincided with the time period of increasing water demand from plants during the leafing-out period. The downward trend observed during this time period probably reflects a much lower rate of recharge over the valley as a whole and, with the increased water demand during this time period, it is not surprising that rapid recharge from precipitation was dramatically reduced.

Regression Analysis

The hydrographs from wells GW-094, -122, and -124 have reasonably complete regression curves (Figs. C.35, C.39, and C.40). The hydrographs from GW-124 and GW-094 show only one slope during the regression from the peak water level after storms (Fig. C.71). The slope (or value for λ) for these wells range from $3.45 \times 10^{-3} \text{ h}^{-1}$ to $4.14 \times 10^{-3} \text{ h}^{-1}$ for GW-094, and $5.3 \times 10^{-3} \text{ h}^{-1}$ to $5.96 \times 10^{-3} \text{ h}^{-1}$ for GW-124. Only one storm hydrograph was available for GW-122, and this peak showed two slopes on semi-log space (two values for λ); however, for this peak, the slope of the initial drainage regression curve was less than the later drainage. This is anomalous since it is expected that the more rapid drainage conduits will dominate the regression hydrograph at the early stages after the storm recharge subsides (Shevenell 1994b).

The slopes observed from these three wells are in the same order of magnitude as those determined by Shevenell (1994b) for the second and third segments of the Maynardville Limestone well regression hydrographs at Picket W. These segments were interpreted to represent drainage of the well-connected fracture network in the Maynardville Limestone and the matrix (including poorly connected fractures), respectively. Neither of these wells shows any characteristics of being connected to conduits, and these data are consistent with the absence of quickflow from these wells.

Specific Conductivity Trends

Some of the wells in the Maynardville Limestone also show immediate changes in conductivity that accompany the changes in pressure head. Wells GW-045 and -124 show responses, and Shevenell (1994b) reported that well GW-715 showed specific conductivity responses to precipitation. These three wells are screened at or above 30 m (100 ft) depth in the carbonate dominant formations; change in water conductivity implies that during precipitation events these wells are affected by quickflow in the carbonate dominant formations. Shevenell (1994b) reported that GW-715 intercepts known cavities, and drilling logs indicate that GW-124 intercepts a fracture

at 9 m (30 ft) depth (Jones et al. 1995). GW-045 is only 4.6 m (15 ft) deep, therefore, it is reasonable to assume that this well and GW-124 are connected to a fracture or conduit network that transmits quickflow, similar to the interpretation by Shevenell (1994b) for GW-715. The remaining Maynardville Limestone wells, for which conductivity was recorded and which show immediate response to precipitation in the hydrograph (GW-053, -94, -95, and -651), do not show immediate responses to precipitation in the specific conductivity record. This implies that these wells are not connected to quickflow conduits. Each of these wells is screened at >30 m (100 ft) depth, which may indicate an approximate maximum depth for quickflow to occur.

C.8.3 SURFACE WATER FLOW MONITORING DATA

Surface water stage was recorded continuously for the period of sampling in OU 4 RIFA at each of the surface water sampling sites, with the exception of SS-8. Details of the monitoring periods at each site and the calculation of flow from stage data are contained in Appendix B.

The tributary hydrographs, and those from the two locations on Bear Creek, show similar general patterns of flow in relation to rainfall. The shape of the rising limb of a hydrograph is usually dependent on the geometry of the basin and of the storm; however, for the tributary basins in BCV, the storm geometry probably is less influential due to the small sizes of the basins. For tributaries in BCV, the rising limbs of hydrographs are very steep, and there is little delay between peak rainfall intensity and peak discharge in the streams. In one extreme case, the level in NT-5 rose by nearly 0.3 m (1 ft) over a 20-min time period. This implies that there is relatively little recharge prior to developing runoff in these catchments. As a result of the “flashy” nature of runoff in BCV, the flow hydrographs show a wide range in flow over short-time periods and, during a high proportion of the time, flow is at baseflow level (e.g., the annual hydrograph for BCK 9.47, Fig. C.18).

The regression section of the hydrograph is dependent on the rate of change of storage in the basin after a storm has stopped. Similar to the regression analysis for the groundwater hydrographs, the shape of the regression curve may indicate different types of storage that drain at differing rates. On the ORR, three types of water storage are anticipated: overland flow, soil interflow, and groundwater baseflow.

Fifteen storms were identified for analysis in each tributary catchment and the two locations on Bear Creek (storms were labeled 01 - 15). The results of analysis are shown in Table C.5. In some cases, hydrographs for storms were missing or were uninterpretable due to gaps in the data record; where this has happened, the section on Table C.5 for that storm at that location is left blank. At least seven storms were analyzed at each location.

Three segments of the regression hydrograph with different linear slopes were identified in many of the storms (these segments were labelled a, b, and c). In some cases, only one or two segments could be identified because of insufficient rainfall intensity to generate overland flow, or truncation of the regression curve by a second rainfall event. In these cases, the section of the regression curve was allocated to one of the hydrograph segments based on the magnitude of the value for λ .

The steepest slope on the regression curve (a) occurs immediately after precipitation ceases and is interpreted as being derived from predominance of drainage from water in surface water bodies, i.e., streams channels and ponded water. The mean values for λ for this initial segment of the regression curve range from 0.596 to 1.26 h⁻¹. In general, the highest values for λ for this segment of the hydrographs tend to coincide with the most intense precipitation events; this is probably the

result of greater ponding and surface runoff during the most intense rainfall. Due to the rate of decline of flow during this segment of the regression curve, this time period is short-lived and, for BCV tributaries and main stem, ranges from 1 to 6 h after cessation of precipitation. In some instances, where rainfall intensity is insufficient to saturate soils, this section of the regression curve is missing.

The intermediate slopes in the regression curves (b) are interpreted as resulting from the decline in runoff and from the flow in the streams being dominated by runoff derived from soil drainage. The mean values for λ for this segment of the regression curve range from 0.061 to 0.167 h⁻¹. The section of the regression curve where soil drainage dominates the flow in the streams in BCV lasts from 8 to 24 h, depending on the intensity of the storm.

The lowest slopes in the regression curves (c) are interpreted as resulting from the decline in runoff derived from groundwater discharge alone. The mean values for λ for this segment of the regression curve range from 0.010 to 0.038 h⁻¹. This segment of the regression curve may continue for a number of days and is usually truncated by the next precipitation event or by the stream drying up.

C.8.4 STORMFLOW TUBE MONITORING

Stormflow tubes were installed at six locations in upper BCV following construction details in Moore (1988). Water level in these tubes was recorded continuously during OU 4 RIFA. Figure C.2 shows the location of the stormflow tubes in BCV, and the time periods for each tube are listed in Table C.6. Figures C.72 and C.73 show the hydrographs from April to October 1994 for SFT1 to SFT6.

Each of the stormflow tubes showed response to precipitation buildup of water in the tube, however, responses differ between tubes. The hydrographs are somewhat like the hydrographs derived from stream monitoring in that, during a storm event, there is a very rapid increase in the level of water in the tube (30 to 90 min to peak) and, after precipitation ends, the level of water falls in an exponential manner. The regression curve from these stormflow tube hydrographs can also be interpreted in a similar manner to regression curves from surface water and groundwater. The slope of the regression curve in this instance is indicative of the rate of drainage of the soils.

Tubes in this study exhibited up to three different slopes in the regression curve. Although the slopes of the regression curve relate to soil drainage characteristics, it is possible that the rate of regression in these tubes is also strongly influenced by the tube construction, small-scale heterogeneities in the soils, and local topography. Care was taken to select similar sites for location of the tubes; however, tubes located on Chestnut Ridge (SFT4 to SFT6) were located on steeper slopes than those on Pine Ridge (SFT1 to SFT3). In general, the tubes on Pine Ridge show slower drainage rates than those on Chestnut Ridge, which suggests that local effects strongly influence the hydrograph regression.

SFT1, SFT2, SFT3, and SFT5 responded to storms throughout the monitoring period, including precipitation during the summer months with the highest evapotranspiration rates. Peak heights varied depending on the intensity of the precipitation; however, each tube attained peaks <0.61 m (2 ft) [the length of the tube, therefore, the maximum peak height was 0.78 m (2.56 ft)], meaning that, in the highest intensity storms, the soils were saturated to within 15 cm (6 in.) of the surface. Two distinct segments of the regression curve were identified in most hydrographs from these sites. The initial steepest sections of the regression curves plotted on semi-log axes had mean values for λ

ranging from 0.058 h^{-1} to 0.209 h^{-1} . The second, less steep, slopes had values for λ ranging from 0.0067 h^{-1} to 0.037 h^{-1} . The initial segments, which occurred above 0.23 m (0.75 ft) to 0.66 m (1.5 ft) in the tube, lasted for 2 to 10 h and are interpreted as relating to dominance of the drainage by the upper sections of the soil profile. The lower slopes are interpreted as drainage from the lower soils in the soil profile.

SFT5 and SFT6 responded very rapidly to rainfall and drained equally rapidly after the precipitation event. The rate of drainage in each of these tubes indicates that the soils at these localities were more permeable than those at the other stormflow tube locations. It was not possible to analyze the regression curve of these hydrographs due to lack of sufficient data points.

C.8.5 WATER BALANCE CALCULATION METHODOLOGY

The water balance attempts to balance the total volume of water entering the section of BCV above BCK 9.47 (inflow) with the total volume of water flowing along strike in BCV at BCK 9.47 (outflow). Inflow is by way of a single component: rainfall (gaged). The conceptual model for BCV has five outflow fluxes: evapotranspiration, flow in BCV at BCK 9.47 (gaged), flow in SS-5 (gaged), along-strike flow in the carbonate dominant formations over a plane at BCK 9.47 (ungaged), and along-strike flow in the siliceous dominant formations over a plane at BCK 9.47 (ungaged).

The water balance can be summarized using the following equation:

$$\Delta S = (P - ET) \times A - S_r - G_r, \quad (1)$$

where:

- ΔS = the net change in water stored in BCV (m^3),
- P = precipitation (m),
- ET = evapotranspiration (m),
- S_r = surface water outflow (m^3),
- G_r = groundwater outflow (m^3).

If no net change in the volume of water stored in BCV over the period of the water balance ($\Delta S = 0$) is assumed, then the equation for this upper section of BCV can be written as follows:

$$(P - ET) \times A_{BCV} = SWG + SSG + SSU_{aqf} + SSU_{aqd}, \quad (2)$$

where:

- A_{BCV} = area of BCV up-gradient from BCK 9.47 (m^2),
- SWG = flow at BCK 9.47 (m^3),
- SSG = flow at SS-5 (m^3),
- SSU_{aqf} = subsurface along strike flow in the carbonate formations (m^3),
- SSU_{aqd} = subsurface along strike flow in the predominantly clastic formations (m^3).

For the water balance model to be more applicable to estimating fluxes from the source areas, the valley-wide water balance can be further refined into a balance for the predominantly clastic formations and a balance for the carbonate formations. This refinement is possible because (1) the total surface water flux from the siliceous formations to the carbonate formations was measured during this time period by gauging of the tributaries draining Pine Ridge and (2) the conceptual

model treats the predominantly clastic and carbonate formations as almost separate hydraulic regimes. The equations for each set of formations are as follows. For the siliceous dominant formations:

$$(P - ET) A_{aqd} = SWG_{Trib} + SSU_{xaqd} + SSU_{aqd}, \quad (3)$$

where:

- A_{aqd} = area of BCV upgradient from BCK 9.47 that is underlain by predominantly clastic formations (m^2),
- SWG_{Trib} = combined flow in the tributaries (m^3),
- SSU_{xaqd} = subsurface across-strike flow from the predominantly clastic formations to the carbonate dominant formations (m^3).

For the carbonate formations, this equation is:

$$(P - ET) \times A_{aqf} + SSU_{xaqd} + SWG_{Trib} = SWG + SSG + SSU_{aqf}, \quad (4)$$

where:

- A_{aqf} = area of BCV upgradient from BCK 9.47 that is underlain by carbonate formations (m^2).

These main components of the water balance model (P , ET , A_{BCV} , SWG , SSG , SSU_{aqf} , SSU_{xaqd} , and SWG_{Trib}) are shown on Fig. C.10, along with their calculated values for the 10-month period monitored between March 1994 and February 1995.

Of the parameters of the water balance model shown in Fig. C.10, the values were derived in the following ways:

- P , A_{BCV} , SWG , SSG , and SWG_{Trib} were all measured.
- SSU_{aqd} and SSU_{aqf} were estimated from the site-wide groundwater flow model for BCV.
- ET was calculated by a process of elimination because it is the only unquantified value in Equation (2) assuming that $\Delta S = 0$.
- SSU_{xaqd} was derived by a process of elimination because it is the only unquantified value in Equation (3) assuming that $\Delta S = 0$.

**C.9 SUPPORTING INFORMATION
FOR APPENDIX C—FIGURES**

Fig. C.30. Well hydrograph and specific conductivity for GW-045 at depth of 15.2 ft at BCBG for March 15 to April 18.

Fig. C.31. Well hydrograph and specific conductivity for GW-053 at depth of 39.7 ft.

Fig. C.32. Well hydrograph and specific conductivity for GW-076 at depth of 81 ft at OLF for April 28 to June 2.

Fig. C.33. Well hydrograph for GW-085 at depth of 62 ft at OLF for May 3 to June 1.

Fig. C.34. Well hydrograph and specific conductivity for GW-086 at depth of 33.5 ft at OLF for May 3 to June 1.

Fig. C.35. Well hydrograph and specific conductivity for GW-094 at depth of 131 ft at BCBG for March 14 to April 18.

Fig. C.36. Well hydrograph and specific conductivity for GW-095 at depth of 156 ft at BCBG for March 15 to April 18.

Fig. C.37. Well hydrograph and specific conductivity for GW-101 at depth of 17.5 ft at S-3 Site for July 18 to August 4.

Fig. C.38. Well hydrograph for GW-101 at depth of 17.5 ft at S-3 Site for January 18 to March 2.

Fig. C.39. Well hydrograph for GW-122 at depth of 92 ft at S-3 Site for July 18 to August 4.

Fig. C.40. Well hydrograph for GW-124 at depth of 100 ft at S-3 Site for July 8 to August 4.

Fig. C.41. Well hydrograph for GW-126 at depth of 105 ft at BCBG for March 14 to April 18.

Fig. C.42. Well hydrograph for GW-127 at depth of 24.0 ft at S-3 Site for January 18 to March 2.

Fig. C.43. Well hydrograph and specific conductivity for GW-227 at depth of 30 ft at OLF for April 28 to May 30.

Fig. C.44. Well hydrograph and specific conductivity for GW-228 at depth of 80 ft at OLF for April 27 to May 29.

Fig. C.45. Well hydrograph for GW-276 at depth of 18.5 ft at S-3 Site for February 3 to March 2.

Fig. C.46. Well hydrograph and specific conductivity for GW-345 at depth of 26 ft at S-3 Site for July 8 to August 4.

Fig. C.47. Well hydrograph and specific conductivity for GW-346 at depth of 65 ft at S-3 Site for April 29 to June 3.

Fig. C.48. Well hydrograph and specific conductivity for GW-526 at depth of 101 ft at S-3 Site for April 28 to June 2.

Fig. C.49. Well hydrograph and specific conductivity for GW-537 at depth of 24.5 ft at OLF for May 3 to May 30.

Fig. C.50. Well hydrograph and specific conductivity for GW-616 at depth of 219 ft at S-3 Site for July 8 to August 4.

Fig. C.51. Well hydrograph, specific conductivity, and temperature for GW-624 for March 15 to April 18.

Fig. C.52. Well hydrograph and specific conductivity for GW-626 at depth of 78 ft at BCBG for March 19 to April 18.

Fig. C.53. Well hydrograph and specific conductivity for GW-629 at depth of 262 ft at BCBG for March 14 to April 18.

Fig. C.54. Well hydrograph and specific conductivity for GW-651 at depth of 52 ft at BCBG for March 14 to April 18.

Fig. C.55. Well hydrograph for GW-710 at depth of 539 ft at Western Picket for November 1 to January 4.

Fig. C.56. Well hydrograph for GW-711 at depth of 616 ft at Western Picket for November 1 to January 4.

Fig. C.57. Well hydrograph for GW-712 at depth of 451 ft at Western Picket for November 1 to January 4.

Fig. C.58. Well hydrograph for GW-713 at depth of 305 ft at Western Picket for November 1 to January 4.

Fig. C.59. Well hydrograph for GW-714 at depth of 113 ft at Western Picket for November 3 to January 4.

Fig. C.60. Well hydrograph for GW-715 at depth of 75 ft at Western Picket for November 3 to January 4.

Fig. C.61. Well hydrograph and specific conductivity for GW-725 at depth of 132.5 ft at OLF for May 2 to June 3.

Fig. C.62. Well hydrograph and specific conductivity for GW-736 at depth 102 ft at OLF for May 2 to June 2.

Fig. C.63. Well hydrograph for S3-1 at depth of 11.5 ft at S-3 Site for January 17 to March 2.

Fig. C.64. Well hydrograph for S3-3 at depth of 6.0 ft at S-3 Site for January 18 to March 2.

Fig. C.65. Well hydrograph for S3-5 at depth of 12.0 ft at S-3 Site for January 18 to March 2.

Fig. C.66. Well hydrograph for S3-6 at depth of 18.8 ft at S-3 Site for January 17 to March 2.

Fig. C.67. Well hydrograph for S3-7 at depth of 27.9 ft at S-3 Site for January 18 to March 2.

Fig. C.68. Well hydrograph for S3-8 at depth of 95 ft at S-3 Site for January 18 to March 2.

Fig. C.69. Well hydrographs for GW-526 and GW-346 at S-3 Site and for GW-085 and GW-086 at BYBY.

Fig. C.70. Well hydrographs for GW-045 and GW-095 at BCBG.

Fig. C.71. Well hydrographs for GW-094, GW-122, and GW-124 plotted in semi-log space.

Fig. C.72. Hydrographs for stormflow tubes SFT 1, SFT 2, and SFT 3 from April to October 1994.

Fig. C.73. Hydrographs from stormflow tubes SFT 4, SFT 5, and SFT 6 from April to October 1994.

**C.10 SUPPORTING INFORMATION
FOR APPENDIX C—TABLES**

Table C.3 Vertical hydraulic gradients in the Nolichucky Shale in BCV.

Upper Well	Depth (ft)	Lower Well	Depth (ft)	Location	Number of Readings	Mean Head Difference (-ive =downward)	Mean Hydraulic Gradient
Nolichucky Shale Well Nests							
GW-086	33.50	GW-085	62.00	BYBY	9	0.21	0.01
GW-105	17.00	GW-106	75.00	S-3 (UEFPC)	15	2.45	0.04
GW-107	14.20	GW-108	58.60	S-3 (UEFPC)	14	-0.91	-0.02
GW-108	58.60	GW-109	147.60	S-3 (UEFPC)	15	2.79	0.03
GW-276	18.50	GW-277	77.40	S-3	14	0.78	0.01
GW-325	17.90	GW-324	80.00	S-3	19	1.27	0.02
GW-345	26.30	GW-346	65.30	S-3	7	1.54	0.04
GW-346	65.30	GW-526	101.00	S-3	7	5.03	0.14
GW-345	26.30	GW-526	101.00	S-3	16	5.35	0.07
GW-613	42.00	GW-614	90.00	S-3	15	6.86	0.14
GW-043	40.00	GW-044	70.00	OLF	19	0.88	0.03
GW-005	12.50	GW-076	81.00	OLF	5	1.79	0.03
GW-097	19.00	GW-098	104.00	OLF	11	-1.83	-0.02
GW-098	104.00	GW-120	130.00	OLF	10	9.23	0.36
GW-638	12.00	GW-637	27.50	OLF	12	-3.47	-0.22
GW-637	27.50	GW-636	98.50	OLF	12	4.90	0.07
GW-342	75.00	GW-343	185.00	BG	10	2.31	0.02
GW-343	185.00	GW-344	316.00	BG	10	5.87	0.05
GW-643	29.30	GW-372	51.60	BG	12	-1.69	-0.08
GW-372	51.60	GW-373	123.00	BG	24	1.67	0.02
GW-641	24.30	GW-640	47.40	BG	13	-0.14	-0.01
GW-640	47.40	GW-639	95.50	BG	13	2.10	0.02
GW-257	33.70	GW-248	62.00	BG	5	-0.27	-0.01
GW-259	33.50	GW-258	50.00	BG	8	1.73	0.10
GW-289	40.80	GW-288	60.00	BG	9	2.14	0.11

Table C.3 (continued)

Upper Well	Depth (ft)	Lower Well	Depth (ft)	Location	Number of Readings	Mean Head Difference (-ive =downward)	Mean Hydraulic Gradient
Nolichucky Shale Well Nests							
GW-249	35.10	GW-250	61.70	BG	5	-2.72	-0.10
GW-287	12.50	GW-286	32.30	BG	20	-0.50	-0.03
GW-291	19.68	GW-290	35.50	BG	10	2.14	0.13
GW-047	25.50	GW-374	124.60	BG	5	5.36	0.05
GW-078	21.10	GW-077	100.50	BG	5	0.51	0.01
GW-080	30.00	GW-079	65.00	BG	10	1.77	0.05
GW-072	101.40	GW-071	220.60	BG	11	1.53	0.01
GW-622	20.50	GW-623	274.50	BG	8	7.85	0.03
GW-626	78.00	GW-627	254.00	BG	16	2.20	0.01
Maynardville Limestone Well Nests							
GW-045	15.20	GW-095	156.00	BG	5	7.08	0.05
GW-057	25.00	GW-056	55.20	BG	12	-0.00	-0.00
GW-227	30.00	GW-228	80.00	OLF	15	-1.87	-0.04
GW-226	45.00	GW-225	150.00	OLF	21	-3.77	-0.04
GW-347	27.00	GW-348	81.00	S-3	21	-6.09	-0.11
GW-520	80.00	GW-366	102.00	OLF	13	-3.41	-0.15
GW-366	102.00	GW-367	125.00	OLF	12	-2.79	-0.12
GW-369	115.00	GW-368	225.00	OLF	7	11.28	0.10
GW-368	225.00	GW-601	319.00	OLF	6	15.46	0.08
GW-619	40.00	GW-620	75.00	S-3 (UEFPC)	19	-1.80	-0.05
GW-740	165.00	GW-739	289.00	PICKET C	9	-0.30	-0.00
GW-739	289.00	GW-723	340.00	PICKET C	9	1.27	0.02

Table C.4 Analysis of selected well hydrographs in BCV.

Well	Group	Depth (ft)	# Peaks	Delay to Start			Delay to Peak			Rise		
				Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
GW-045	BG		1,2,3,6	2.40	6.00	3.60	6.50	37.40	19.70	20.90	61.40	35.30
GW-094	BG		2,3,4,5,6	3.30	8.20	6.00	13.00	30.20	23.50	21.50	41.40	29.00
GW-095	BG		1,2,3	3.00	8.00	5.50	NA	NA	NA	NA	NA	NA
GW-126	BG		2	5.60	5.60	5.60	25.60	25.60	25.60	1.50	1.50	1.50
GW-624	BG		1,2,6	1.70	4.00	2.50	NA	NA	NA	NA	NA	NA
GW-629	BG		2,3,4,5,6	3.00	12.70	7.80	NA	NA	NA	NA	NA	NA
GW-251	BG		1*,2,3,4,6	3.00	7.40	5.90	41.50	41.50	41.50	1.97	1.97	1.97
GW-124	OLF		7,8	4.00	1.50	2.30	NA	NA	NA	NA	NA	NA
GW-345	OLF		7,8*	3.50	6.53	5.00	13.50	14.50	14.00	0.77	0.77	0.77
GW-710	Picket W		9,10,11,12	8.50	33.50	15.00	37.50	53.50	45.00	0.37	2.45	1.32
GW-711	Picket W		10,11,12	4.50	33.50	23.50	37.00	56.50	45.00	0.41	1.88	1.32
GW-712	Picket W		9,10,11,12	1.00	30.50	10.60	12.00	37.00	26.00	0.36	2.58	1.36
GW-713	Picket W		9,10,11,12	2.00	30.50	10.90	12.00	37.00	24.80	0.24	4.49	1.66
GW-714	Picket W		11,12	8.00	22.50	15.25	16.50	26.50	21.50	1.00	3.88	2.44
GW-715	Picket W		9,10,11	2.50	19.00	8.70	2.00	3.00	2.50	1.27	3.75	2.67
GW-127	OU 1 S-3		13,14	2.00	6.00	4.00	4.50	27.50	16.00	1.59	2.53	2.06
GW-276	OU 1 S-3		14	1.50	1.50	NA	26.50	26.50	NA	2.51	2.51	NA
S3-5	OU 1 S-3		13,14	2.00	5.00	3.50	26.00	30.00	28.00	1.81	2.53	2.17

C10-5

Table C.5 Analysis of selected stream hydrographs in BCV.

Regresion Segment	Storm Event															Maximum	Minimum	Mean
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15			
BCK 12.3																		
a	2.5E-01	5.7E-01	4.5E-01	2.9E-01	9.4E-01		4.1E-01	9.7E-01	9.8E-01	5.2E-01			9.5E-01		2.3E-01	9.8E-01	2.3E-01	6.0E-01
b	2.3E-02	9.1E-02	4.8E-02	2.1E-02	4.6E-02			2.9E-02	4.8E-02	1.5E-01			6.0E-02	9.1E-02	6.1E-02	1.5E-01	2.1E-02	6.1E-02
c	9.9E-03	1.9E-02	9.7E-03	5.3E-03	1.1E-02		1.4E-02		1.2E-02	5.9E-03			6.0E-03	8.3E-03		1.9E-02	5.3E-03	1.0E-02
BCK 9.4																		
a	2.6E-01		1.1E+00	3.0E-01		6.9E-01	4.0E-01	7.8E-01					1.2E+00			1.2E+00	2.6E-01	6.7E-01
b	5.4E-02					1.1E-01	2.1E-01	9.7E-02					2.2E-01		1.3E-01	2.2E-01	5.4E-02	1.4E-01
c	1.5E-02		2.1E-02	8.2E-03		2.6E-02										2.6E-02	8.2E-03	1.7E-02
NT-2																		
a	3.4E-01		2.6E-01	3.9E-01	1.5E+00	8.5E-01	2.5E+00	1.8E+00	1.6E+00	1.6E+00	1.1E+00	8.7E-01	1.2E+00	3.6E-01	7.8E-01	2.5E+00	2.6E-01	1.1E+00
b		2.0E-01	2.6E-02	6.4E-02		4.6E-02	3.8E-01	9.9E-02	6.7E-02	2.5E-01	6.3E-02	1.3E-01	1.0E-01		6.7E-02	3.8E-01	2.6E-02	1.2E-01
c	1.5E-02	1.3E-02	7.0E-03	1.2E-02	2.8E-02	1.9E-02	2.4E-02		2.7E-02			2.0E-02				2.8E-02	7.0E-03	1.8E-02
NT-3																		
a		2.9E-01	4.5E-01	1.9E-01	1.7E+00			9.1E-01		3.3E-01	6.7E-01	5.6E-01				1.7E+00	1.9E-01	6.4E-01
b	1.6E-01	3.8E-02	7.0E-02	5.8E-02	4.3E-01			3.2E-02	1.4E-01		1.3E-01	1.3E-01		5.1E-02	3.8E-02	4.3E-01	3.2E-02	1.2E-01
c	1.6E-02	1.3E-02	1.7E-02	4.8E-03	4.5E-02				1.5E-02	1.5E-02	2.3E-02	1.5E-02		1.1E-02	1.5E-02	4.5E-02	4.8E-03	1.7E-02
NT-4																		
a							1.0E+00	1.3E+00		9.9E-01	2.1E+00	5.8E-01	1.0E+00	2.9E-01		2.1E+00	2.9E-01	1.0E+00
b							4.9E-02	8.5E-02		2.0E-01	9.0E-02	1.9E-01	1.4E-01	1.7E-02		2.0E-01	1.7E-02	1.1E-01
c										3.3E-02		2.9E-02	5.1E-02			5.1E-02	2.9E-02	3.8E-02
NT-5																		
a						1.1E+00	1.0E+00	1.7E+00	1.2E+00	7.3E-01	1.7E+00	8.9E-01	2.5E+00		4.9E-01	2.5E+00	4.9E-01	1.3E+00
b						4.7E-02	8.9E-02	7.5E-02	6.4E-02	1.1E-01	9.9E-02	1.4E-01	8.3E-02	1.8E-01	2.6E-02	1.8E-01	2.6E-02	9.2E-02
c									3.0E-02	3.2E-02		2.2E-02	3.2E-02	1.0E-02		3.2E-02	1.0E-02	2.5E-02
NT-6																		
a				4.6E-01					5.2E-01	5.7E-01	1.1E+00	5.9E-01	8.9E-01			1.1E+00	4.6E-01	7.0E-01
b		1.3E-01	1.4E-01						1.5E-01	2.3E-01	1.4E-01	1.9E-01	1.8E-01	1.8E-01		2.3E-01	1.3E-01	1.7E-01
c		3.9E-02	3.3E-02	3.2E-02					5.2E-02			4.9E-02	3.2E-02	1.8E-02	4.2E-02	5.2E-02	1.8E-02	3.7E-02
NT-7																		
a	6.2E-01		6.3E-01	5.3E-01	2.1E+00	1.2E+00	1.2E+00	1.6E+00	1.5E+00	1.2E+00				4.0E-01	1.0E+00	2.1E+00	4.0E-01	1.1E+00
b	3.2E-02		7.3E-02	5.0E-02	5.9E-01	1.5E-01	2.0E-01	1.1E-01	1.3E-01	1.9E-01			1.6E-01	7.7E-02	2.1E-01	5.9E-01	3.2E-02	1.6E-01
c			3.0E-02	1.8E-02		2.4E-02			4.5E-02					2.9E-02	6.2E-02	6.2E-02	1.8E-02	3.5E-02
NT-8																		
a						1.1E+00	1.1E+00		1.3E+00		1.9E+00	1.2E+00	1.5E+00	4.8E-01	4.8E-01	1.9E+00	4.8E-01	1.1E+00
b							2.5E-01				1.1E-01	2.5E-01	1.5E-01		4.9E-02	2.5E-01	4.9E-02	1.6E-01
c						2.4E-02	7.1E-02		5.2E-02		4.1E-02	2.0E-02	3.4E-02	1.4E-02	1.0E-02	7.1E-02	1.0E-02	3.3E-02

C10-6

Table C.6 Analysis of selected stormflow tube hydrographs in BCV.

Regression Segment	Storm Event													Maximum	Minimum	Mean
	01	02	03	04	05	06	07	08	09	10	11	12	13			
SFT-1																
a		7.1E-02	7.8E-02										1.0E-01	1.0E-01	7.1E-02	8.4E-02
b	1.8E-02	1.4E-02	1.6E-02	2.2E-02		3.8E-02		3.5E-02	1.1E-02	1.4E-02	1.7E-02		1.4E-02	3.8E-02	1.1E-02	2.0E-02
c	5.1E-03	4.8E-03	5.7E-03	6.7E-03		9.1E-03		9.0E-03				6.6E-03		9.1E-03	4.8E-03	6.7E-03
SFT-2																
a		4.2E-02	3.8E-02						3.6E-02					1.2E-01	3.6E-02	5.8E-02
b	7.4E-03	1.0E-02	1.3E-02					1.8E-02	1.3E-02	1.4E-02				1.8E-02	7.4E-03	1.3E-02
SFT-3																
a	1.0E-01	1.4E-01	1.5E-01											1.5E-01	1.0E-01	1.3E-01
b	3.1E-02	4.4E-02	3.7E-02					3.6E-02						4.4E-02	3.1E-02	3.7E-02
SFT-4																
a		1.6E-01	2.6E-01											2.6E-01	1.6E-01	2.1E-01
b	4.1E-02													4.1E-02	4.1E-02	4.1E-02
SFT-5																
a		3.7E-01	1.6E-01										1.0E-01	3.7E-01	1.0E-01	2.1E-01
b	3.0E-02			2.2E-02		2.7E-02	5.1E-02	1.8E-02				1.3E-02	2.6E-02	5.1E-02	1.3E-02	2.7E-02
c	1.1E-02	7.2E-03	9.4E-03		9.8E-03	1.1E-02	9.4E-03	9.4E-03						1.1E-02	7.2E-03	9.6E-03

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