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TECHNICAL MEMORANDUM

FINAL WORK PLAN
OPERABLE UNIT NO. 7

PRESENT LANDFILL (IHSS 114) AND INACTIVE HAZARDOUS WASTE STORAGE AREA (IHSS 203)

VOLUME I - SECTIONS 1-8

Rocky Flats Environmental Restoration Project

SEPTEMBER 2, 1994

ADMIN RECORD

Technical Memorandum

Final Work Plan
Operable Unit No. 7 — Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203)

Volume I — Sections 1–8

September 2, 1994

U.S. Department of Energy
Rocky Flats Site
Golden, Colorado

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Final Work Plan
Operable Unit No. 7 — Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203) Technical Memorandum

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EXECUTIVE SUMMARY

This Operable Unit (OU) No. 7 Revised Work Plan Technical Memorandum presents the findings of the Phase I Resource Conservation and Recovery Act (RCRA) facility investigation/remedial investigation (RFI/RI); the results of the data quality objectives (DQO) process, which identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7; and the field sampling plan developed for the collection of these additional data. These activities are pursuant to the Interagency Agreement (IAG) signed by the U.S. Department of Energy (DOE), the Colorado Department of Public Health and Environment (CDPHE), and the U.S. Environmental Protection Agency (EPA), which addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues. CDPHE is the lead regulatory agency at OU 7.

OU 7 is one of 16 OUs at the Rocky Flats Environmental Technology Site in Jefferson County, Colorado. Each OU is made up of a number of individual hazardous substance sites (IHSSs). OU 7 comprises the Present Landfill (IHSS 114); the Inactive Hazardous Waste Storage Area (IHSS 203); and the East Landfill Pond and adjacent spray evaporation areas, which include IHSSs 167.2 and 167.3. Several IHSSs (166.1, 166.2, 166.3, and 167.1) located near OU 7 are being investigated as part of the RFI/RI for Operable Unit No. 6—Walnut Creek Priority Drainage. If the Baseline Risk Assessment for OU 6 indicates that remediation of these IHSSs is warranted, then the OU 6 IHSSs will be transferred to OU 7 and contaminated environmental media will be disposed in the Present Landfill (IHSS 114).

Operation of the Present Landfill (IHSS 114) for disposal of nonradioactive solid waste began in 1968 and will continue until the new landfill opens. Because records indicate that some hazardous waste was disposed in the landfill, it was designated as an interim status RCRA-regulated unit. Elevated tritium and strontium concentrations were detected in leachate draining from the landfill in 1973. Monitoring wells were installed in saturated landfill wastes, and samples were obtained and analyzed to locate the source of the tritium and strontium. The number of wells installed is referenced in previous reports and varies from 47 to 52. The highest measured concentration of tritium was 301,609 picocuries per liter (pCi/L). Although the approximate location was determined, the source of tritium was never removed. To control the migration of tritium, interim response actions were taken. Interim response activities included

construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill (West Landfill Pond and East Landfill Pond), a subsurface intercept system for diverting groundwater around the landfill, and a subsurface leachate-collection system. Two areas of spray evaporation of East Landfill Pond water, IHSSs 167.2 and 167.3, have been documented. Spray evaporation of water from the East Landfill Pond was conducted to prevent overflow of the pond and release of water downstream and to protect surface water and groundwater in the vicinity of the landfill. East Landfill Pond water is currently being transferred to the A-series ponds as an alternative water management practice.

The Inactive Hazardous Waste Storage Area (IHSS 203), located at the southwest corner of the Present Landfill, was used for storage of drummed liquids and solids in 1986 and 1987. It was also included as an interim status RCRA-regulated unit in the November 1986 RCRA Part B permit application for Rocky Flats. Because it is located within the Present Landfill, it will be remediated to meet requirements for closure of the unit at the same time as the landfill.

A presumptive remedy strategy for streamlined site characterization and site remediation for OU 7 has been adopted by DOE, CDPHE, and EPA. Source containment is the designated presumptive remedy for municipal landfills and consists of the following elements: a landfill cap, gas control and treatment, if necessary, leachate collection and treatment, and source area groundwater control. Institutional controls supplement these engineering controls. This streamlined approach, which is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements and is supported by guidance in the National Contingency Plan, eliminates the need for initial identification and screening of alternatives during the feasibility study and allows for acceleration of the schedule to implement remedial actions and achieve final closure.

The presumptive remedy strategy also streamlines the assessment of risk at the source by comparing contaminant concentration levels to standards that are potential chemical-specific applicable or relevant and appropriate requirements (ARARs). A focused risk assessment will be performed for areas other than the landfill itself. Data needed for the design of the presumptive remedies, assessment of the nature and extent of groundwater contamination, and the focused risk assessment will be collected in accordance with the field sampling plan included in this document. For purposes of streamlined site characterization and site remediation, OU 7 has been divided, roughly by media, into three decision-making areas: East Landfill Pond sediments and soils in spray evaporation areas adjacent to the pond, groundwater and

surface water, and the Present Landfill (IHSS 114) and the Inactive Hazardous Waste Storage Area (IHSS 203).

Data collected during the Phase I RFI/RI have undergone rigorous review and data-quality evaluation. Approximately 87 percent of all Phase I RFI/RI records have been reviewed and evaluated in accordance with EPA procedures for the documentation and validation of Level IV and V data. Less than 3 percent of these records have been rejected because the data did not meet the minimum quality assurance/quality control (QA/QC) requirements outlined in the General Radiochemistry and Routine Analytical Services Protocol (GRRASP). The valid data are considered usable for site characterization, human health and environmental risk assessments, remedial alternative evaluation, and engineering and remedial action design. Historical data collected from 1990 through 1993 were evaluated qualitatively; their usability was determined from laboratory qualifiers and validation codes.

The OU 7 Revised Work Plan Technical Memorandum describes the site physical features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology to characterize OU 7 within the Rocky Flats site framework. Results of the Phase I RFI/RI show that leachate within the landfill is primarily recharged by precipitation through the interim soil cover material. However, groundwater probably flows under the intercept system on the north side of the landfill.

Results of the Phase I RFI/RI were also used to characterize the primary sources of contamination at OU 7, which include landfilled wastes and associated leachate and gas. The landfill covers an area of approximately 27 acres. The total volume of landfilled material is approximately 415,000 cubic yards and consists of approximately 291,000 cubic yards of waste and 124,000 cubic yards of daily soil cover. The composition of landfill gas is variable and consists primarily of methane and carbon dioxide (associated with the decomposition of water) and trace amounts of volatile organic compounds (VOCs). Approximate average concentrations of methane and carbon dioxide are 60 and 40 percent, respectively, indicating anaerobic conditions. Concentrations of methane and carbon dioxide are highest in the eastern portion of the landfill where wastes are thickest and youngest. Approximately 96,000 cubic yards of landfill gas occupy the void and pore spaces in the landfill. In general, landfill-generated gases appear to be contained within the existing intercept system. Leachate is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through waste. Approximately 5,756,000 gallons of leachate are present in landfill debris within the intercept system above the unweathered bedrock, which is considered the underlying confining unit. Methane concentrations in leachate range from 0.003 to 31.4 milligrams per liter. Concentrations of VOCs are variable throughout the landfill.

Chemical concentration data from various environmental media sampled at OU 7 were evaluated with two distinct objectives: to identify potential contaminants of concern (PCOCs) and to describe the nature and extent of contamination. Data from OU 7 samples were compared to data from background samples for each media. Statistical comparisons for PCOC identification consisted of six steps: (1) a hot-measurement test, (2) the Gehan Test, (3) the Quantile Test, (4) the Slippage Test, (5) the t-test, and (6) professional judgment. Analytes having concentrations elevated relative to background concentrations, as indicated by any of the statistical tests, are considered PCOCs. Histograms and box-and-whisker plots were generated for each analyte from each media type for both site and background data. Isoconcentration maps were generated to evaluate the spatial distribution of contaminants.

On the basis of statistical evaluations, the following PCOCs were identified in surface soils from IHSS 203: calcium, copper, radium-226, americium-241, and uranium-235. Americium-241 and uranium-235 activities exceeded the UTL (upper tolerance limit) $_{99/99}$ value; calcium, copper, and radium-226 were identified using the inferential statistical tests. PCBs were detected at low concentrations in approximately 20 percent of the soil samples from IHSS 203 and are also considered PCOCs. PCOCs identified in surface soils from IHSS 114 include calcium; copper; strontium-89,90; and gross beta.

Calcium, strontium, and radium-226 were identified as PCOCs in surface soils from the East Landfill Pond area based on results of the inferential statistical tests. Arsenic, barium, calcium, lead, magnesium, selenium, sodium, vanadium, zinc, americium-241, radium-226, and nitrate/nitrite were identified as PCOCs based on $UTL_{99/99}$ comparisons. These exceedances were generally in the range of two to three times the maximum background concentration. However, the activity of one sample was 27 times the maximum background activity for americium-241. Radionuclides exceeded background activities only in the 0- to 2-inch soil horizon.

Seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-228) were identified as PCOCs in surficial geologic materials upgradient of OU 7; radium-226 was identified as a PCOC in upgradient bedrock material. Cesium-137 and uranium-238 were identified as PCOCs in surficial deposits located near the north groundwater intercept system discharge point. Uranium-238 was also identified as a PCOC in surface water from the intercept system discharge. These data suggest that the north groundwater intercept system discharge water may be a source of uranium-238 to geologic materials downgradient of the landfill. However, the ultimate source of uranium-238 may be located upgradient of the landfill, as indicated by the upgradient borehole data.

Statistical comparisons of East Landfill Pond sediments to background stream sediments identified metal, radionuclide, and inorganic analytes at concentrations significantly elevated with respect to background concentrations. In addition, 15 semivolatile organic compounds (SVOCs) were detected in East Landfill Pond sediments collected near the leachate seep. Their presence indicates that SVOC contamination of East Landfill Pond sediments has probably occurred. Cesium-137 was the only radionuclide found at activities higher than background. The highest activities of cesium-137 and other radionuclides were present in the sample collected from the west end of the pond, closest to the leachate seep.

VOCs and SVOCs were detected in surface-water samples from the leachate seep. The VOCs include benzene, toluene, ethylbenzene, xylene (BTEX compounds), and various chlorinated hydrocarbons and are similar to the VOCs detected as trace components of the landfill gas. Tritium activities were elevated relative to background activities in water from the leachate seep, the East Landfill Pond, and the southern groundwater-intercept discharge. Americium-241 was elevated above background in water from the East Landfill Pond, south groundwater-intercept discharge, and the north groundwater-intercept discharge. Uranium-235 and uranium-238 were both elevated relative to background in water from the pond and the north discharge point; only uranium-238 was elevated above background in water from the south discharge point. As may be expected, water in the East Landfill Pond is similar in quality to water from the leachate seep and from the groundwater intercept system. However, VOCs and SVOCs were detected more frequently in seep water.

Groundwater in the upper hydrostratigraphic unit (UHSU) at OU 7 contains metals, radionuclides, organic constituents, and nitrates at concentrations higher than background. Sources of radionuclides and chlorinated hydrocarbon contamination to UHSU groundwater may be located upgradient of the landfill (within OU 10) and within IHSS 166.1 (within OU 6). Groundwater contamination upgradient of the landfill will be addressed in the Phase I RFI/RI for OU 10, Other Outside Closures, and the Phase I RFI/RI for OU 6, Walnut Creek. The landfill appears to be the primary source of metals and BTEX compounds. Statistical comparisons of upgradient versus downgradient UHSU groundwater indicate statistically significant increases in downgradient concentrations of several metals and water-quality parameters. None of the radionuclides or VOCs show a statistically significant difference in upgradient versus downgradient concentrations. PCOCs were identified in groundwater from the lower hydrostratigraphic unit (LHSU). However, in LHSU groundwater collected downgradient of the landfill, radionuclide and VOC concentrations were not significantly higher than concentrations in LHSU groundwater from background wells.

The DQO process presented in the Interim Final Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process (EPA 1993c) was used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7.

Preliminary engineering design studies indicate that the landfill cap will extend to the East Landfill Pond embankment. Pond sediments and soils in adjacent spray evaporation areas will be covered by the landfill cap. To determine whether or not remediation of surface soils below the East Landfill Pond embankment is required, it is necessary to determine if concentrations of contaminants present risk to human health or the environment and, if so, the appropriate response action. PCOCs were identified in soils based on statistical comparisons and the hot-measurement test. UTL exceedances in soils were randomly distributed across the site. Additional surface soil sampling and analysis is recommended to describe contaminant distribution around sample locations where PCOC concentrations exceeded an ARAR or guidance to be considered (TBC).

In order to fully describe impacts to groundwater resulting from contaminant releases from the landfill, establish risk, and determine whether or not these impacts require a response action, the concentrations of PCOCs must be compared to chemical-specific ARARs. Available data indicate that some PCOCs clearly exceed draft OU-specific ARARs in groundwater from the UHSU and remediation of groundwater will be required. Phase I RFI/RI data were used to map the known extent of groundwater contamination associated with OU 7 sources. However, the full extent of groundwater contamination has not been described. Therefore, the installation of four additional wells at two locations is recommended to characterize potential contaminant migration pathways and improve descriptions of contaminant distribution downgradient of the East Landfill Pond in No Name Gulch.

Presumptive remedies dictate the remedial actions that will be taken at the Present Landfill and IHSS 203 and additional chemical characterization of affected media in those areas is not needed to make decisions about remediation. Other types of information will be required to design the landfill cap and the control systems for landfill-generated gas and leachate. Drilling boreholes is recommended to determine the depth to bedrock, collect samples, and perform geotechnical tests for remedial design. Measuring gas emission rates is recommended to evaluate the need for landfill gas control.

The specific objectives of the Phase II field investigation include the following:

- Investigate the distribution of analytes in surface soils below the East Landfill Pond dam where analyte concentrations exceeded draft numerical standards to delineate the area of soil contamination around each hotspot. Collect samples from the 0- to 2-inch horizon at three locations and the 0- to 3-inch horizon at one location. Collect four samples per location. Collect samples 25 feet from the original sample location where soils exceeded draft numerical standards, one each to the north, south, east, and west of the original location.

- Determine the depth to bedrock and thickness of the alluvial and weathered bedrock material along the potential slurry wall around the landfill, at the leachate seep, and on the slopes downgradient of the dam. Collect samples to determine the physical properties of the alluvium for the purpose of remedial design. Determine the load-bearing capability of the alluvium at the storage tank foundation. Perform a drawdown recovery test to estimate the hydraulic conductivity of the alluvium at the leachate seep.

- Characterize the valley-fill alluvium and determine the presence or absence of contamination in No Name Gulch by collecting and analyzing samples of the subsurface, geologic materials.

- Delineate the extent of groundwater contamination in the UHSU, determine the presence or absence of contamination in the LHSU, and improve the monitoring network along No Name Gulch by installing a group of three wells downgradient of the existing compliance wells and one well farther down No Name Gulch. Screen the group of wells across valley-fill alluvium, weathered bedrock, and bedrock. Screen the single well across valley-fill alluvium. Collect groundwater samples monthly for four months to characterize groundwater quality. Perform drawdown recovery tests to estimate the hydraulic conductivity of the screened units.

- Measure gas emission rates from the existing gas venting wells at the Present Landfill (IHSS 114).

Data collected during the Phase II investigation will be used to determine the contaminants in surface soils below the dam that present a risk to human health and the environment and the appropriate response action required to reduce those risks; describe the impacts to groundwater resulting from contaminant releases from the landfill and determine whether or not these impacts require a response action; support closure of the Present Landfill under CHWA and RCRA; design the landfill cap, leachate collection and

treatment system, gas control and treatment system and address source area groundwater control; and meet the IAG milestone of July 1997 for interim measure/interim remedial action (IM/IRA) implementation.

In accordance with a Resolution of the Senior Executive Committee of the IAG, two IM/IRAs will be required for OU 7. These include a separate IM/IRA for the collection of leachate from the East Landfill Pond and another IM/IRA for closure of the Present Landfill. The design for the leachate collection system remedial action will be submitted to the public in October 1994 as a proposed action memorandum. Construction is scheduled to begin in May 1995. The leachate collection system design will be consistent with the presumptive remedy for final landfill closure. The design for landfill closure will be submitted to the public as an IM/IRA decision document in December 1995. Construction is scheduled to begin in May 1997. The IM/IRA will be the final action for landfill closure.

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ACRONYMS AND ABBREVIATIONS

af	artificial fill
ANOVA	analysis of variance
ARARs	applicable or relevant and appropriate requirements
ASTM	American Society of Testing and Materials
BAT®	Bengt-Arne Torstensson
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTOB	below top of bedrock
C	runoff coefficient
CAMU	Corrective Action Management Unit
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHWA	Colorado Hazardous Waste Act
CI	confidence interval
CLP	Contract Laboratory Program
cm/sec	centimeters per second
COC	contaminant of concern
CPT	cone penetration test
CRDL	contract-required detection limit
cu ft	cubic feet
cu yd	cubic yard
CV	coefficient of variation
cy	cubic yards
DCA	dichloroethane
DCE	dichloroethene
DIL	dilution
DOE	U.S. Department of Energy
DQO	data quality objective

EIS	environmental impact statement
EMD	Rocky Flats Environmental Management Department
EPA	U.S. Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low-Energy Radiation
ft	feet
ft^3	cubic feet
$ft^3/day/ft^2$	cubic feet per day per square feet
ft/ft	feet per feet
ft/yr	feet per year
FWHM	full width at half maximum
gal	gallon
gal/min	gallons per minute
gal/month	gallons per month
GC	gas chromatogram
GC/MS	gas chromatography/mass spectrometry
GFAA	graphic furnace atomic adsorption
gpm	gallons per minute
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
hr/day	hours per day
HSU	hydrostratigraphic unit
IAG	Interagency Agreement
IDL	instrument detection limit
IDM	investigative-derived materials
IHSS	individual hazardous substance site
IM/IRA	interim measure/interim remedial action
in. Hg	inches of mercury
K	hydraulic conductivity
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone
ℓ	liter
lb	pound

LDRs	land disposal restrictions
LHSU	lower hydrostratigraphic unit
MDL	method detection limit
MG	million gallons
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MG/month	million gallons per month
min/hr	minutes per hour
mL	milliliter
mo	month
MS	matrix spike
MSD	matrix spike duplicate
NC	not calculated
NCP	National Contingency Plan
NDE	not deep enough
ND-GC	no data - gas chromatogram
NEPA	National Environmental Policy Act
NMOC	non-methane organic compound
NP	not performed
NP-ACC	not performed - access
NP-DRY	not performed - dry
NP-DUP	not performed - duplication of effort
NP-EQUIP	not performed - equipment
NP-REF	not performed - refusal
NPDES	National Pollutant Discharge Elimination System
NR-WP	not required - work plan
NS-DRY	not sampled - dry
NS-REF	not sampled - refusal
OU	operable unit
oz	ounce
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PCE	tetrachloroethene

pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
ppm	parts per million
PRG	preliminary remediation goal
psi	pounds per square inch
PU&D	Property Utilization and Disposal
PVC	polyvinyl chloride
QA	quality assurance
QAA	quality assurance addendum
QAPjP	quality assurance project plan
Qc	colluvium
QC	quality control
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium
%R	percent recovery
RCRA	Resource Conservation and Recovery Act
REP	replicate
REX	re-extraction
RFD	reference dose
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA facility investigation/remedial investigation
RPD	relative percent difference
SAP	sampling and analysis plan
SOPs	standard operating procedures
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TAL	target analyte list
TCA	trichloroethane
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids

TIC	tentatively identified compound
TOC	total organic carbon
TRG	target
TSS	total suspended solids
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
USCS	Unified Soil Classification System
UHSU	upper hydrostratigraphic unit
UTL	upper tolerance limit
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level
VOA	volatile organic analysis
VOC	volatile organic compound
WABS	water level below bottom of screen
wk	week
WQCC	Water Quality Control Commission
WSIC	Waste Stream Identification and Characterization
WSRIC	Waste Stream Residue Identification and Characterization

INFORMATION ONLY

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1. INTRODUCTION

Operable Unit (OU) No. 7 is one of 16 OUs at the Rocky Flats Environmental Technology Site in Jefferson County, Colorado. Each OU is made up of a number of individual hazardous substance sites (IHSSs). OU 7 comprises the Present Landfill (IHSS 114); the Inactive Hazardous Waste Storage Area (IHSS 203); and the East Landfill Pond and adjacent spray evaporation areas, including IHSSs 167.2 and 167.3.

As a result of the production of nuclear weapon components, processing of radioactive substances, and fabrication of metals, hazardous substances have been released at the Rocky Flats site. A Phase I Resource Conservation and Recovery Act (RCRA) facility investigation/remedial investigation (RFI/RI) was conducted at OU 7 in 1992 and 1993 to characterize the site physical features, describe contaminant sources, and determine the nature and extent of contamination in soils resulting from such releases. Data obtained during the Phase I RFI/RI, along with existing data, were to be used for developing and screening remedial alternatives and estimating the risks to human health and the environment posed by contaminant sources within OU 7. A Phase II RFI/RI was subsequently planned to characterize the nature and extent of contamination in surface water, groundwater, and air and evaluate contaminant migration pathways.

These activities were initiated pursuant to an Interagency Agreement (IAG) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) dated January 22, 1991 (DOE 1991a). The IAG program developed by DOE, EPA, and CDPHE addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues that pertain to the site. CDPHE is the lead regulatory agency at the site.

Prior to completion of the Phase I RFI/RI and initiation of Phase II, the focus of investigations at OU 7 changed due to the adoption of a presumptive-remedy strategy for streamlined site characterization and site remediation by DOE, CDPHE, and EPA. Source containment is the

designated presumptive remedy for municipal landfills (EPA 1993a). The containment presumptive remedy consists of the following elements: institutional controls, a landfill cap, landfill gas control and treatment, if necessary, source area groundwater control, and leachate collection and treatment. This streamlined approach, which is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements supported by guidance in the National Contingency Plan (NCP) and recent EPA guidance for landfills (EPA 1991a, EPA 1993a, EPA 1993b), eliminates the need for initial identification and screening of alternatives during the feasibility study and allows for acceleration of the schedule to implement remedial actions and achieve final closure.

As a result of this strategy, the Phase I RFI/RI report and comprehensive baseline risk assessment are no longer required. Data needed for the design of the presumptive remedies, an assessment of the nature and extent of groundwater contamination, and a focused risk assessment will be collected in accordance with the field sampling plan (FSP) included in this document. In accordance with a Resolution of the Senior Executive Committee of the IAG (DOE 1994), two interim measure/interim remedial actions (IM/IRAs) will be required for OU 7. These include a separate IM/IRA for the collection of leachate at the seep above the East Landfill Pond and another IM/IRA for closure of the Present Landfill.

The leachate is an FO39 listed waste that is currently discharged to the pond. The objective of the leachate collection remedial action is to stop discharge and limit downgradient migration of leachate from the source area thus minimizing exposure of receptors to contaminated leachate. Leachate will be collected by a French drain installed downgradient of the seep and pumped to onsite storage tanks. Leachate will be trucked to the sitewite OU 1/OU 2 facility for treatment. The design for this remedial action will be submitted to the public in October 1994 as a proposed action memorandum. Construction is scheduled to begin in May 1995.

The leachate collection system design will be consistent with the presumptive remedy for final landfill closure. The access manhole and pump will be designed so that they can be easily modified for continued collection during post-closure remediation. The manhole and all buried piping will be designed to maintain structural integrity under the increased load due to placement of fill and the final cap. Leachate storage tanks will be located outside the proposed extent of the cap so they can be used for groundwater storage during post-closure remediation.

The objective of the landfill closure remedial action is to contain the landfill waste, prevent leachate formation, control landfill gas, and collect and treat groundwater, if necessary. Components of the remedial action include a multiple-layer landfill cover that will extend to the East Landfill Pond embankment or to the outer edge of the contaminant plume, a slurry wall constructed under the footprint of the cover, and a groundwater collection system downgradient of the embankment. The design for this remedial action will be submitted to the public in December 1995 as an IM/IRA decision document. The construction process is scheduled to begin in May 1996. Actual construction of the IM/IRA will begin in May 1997 and must meet the IAG milestone of July 1997 for IM/IRA implementation. The IM/IRA will be the final action for a landfill closure.

On the basis of presumptive remediation, the scope of the risk assessment for OU 7 will be streamlined. The containment remedy addresses all pathways associated with the source. The threat of direct contact and surface water runoff is addressed by capping. Exposure to contaminated groundwater, the ingestion pathway, is addressed by groundwater treatment/control. Exposure to landfill gas, the inhalation pathway, is addressed by gas control or collection and treatment.

No quantitative risk assessment is required at the source. Justification for remedial action is the exceedance of chemical-specific ARARs in groundwater. Because the landfill cap will extend to the dam, no risk assessment on pond sediments and surrounding soils is required. Analyte concentrations in surface soils not under the cap will be compared to PRGs after landfill closure. An assessment of risk is required for groundwater contaminated by migrating leachate to determine the need for additional remedial action in areas beyond the cap. Residual risks will be evaluated after the closure of the landfill.

1.1 Purpose of Report

This OU 7 Revised Work Plan Technical Memorandum presents the findings of the Phase I investigation; the results of the data quality objective (DQO) process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7; and the FSP to collect these data.

1.2 Organization of Report

This section presents background information regarding the locations and operational histories of the IHSSs and associated areas that make up OU 7 (Section 1.3) and discusses previous investigations at the site (Section 1.4). Section 2 presents the site characterization, including surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology. Section 3 discusses data quality and usability. Section 4 presents the process for identifying potential contaminants of concern (PCOCs), including the methodologies for aggregating data and comparing site data to background data, presents the PCOCs at OU 7 based on assessment of existing data, and discusses the nature and extent of contamination. Section 5 discusses the DQOs for additional sampling. Section 6 presents the FSP. Section 7 presents the quality assurance (QA) and quality control (QC) objectives for data collection, analysis, validation, and reporting. Section 8 presents references cited in the report.

Supporting data are included in the appendices to the report. Appendix A presents tables listing hazardous and nonhazardous waste streams disposed in the landfill prior to 1986. Appendix B contains selected as-built drawings of the existing groundwater intercept system. Appendix C summarizes the Phase I RFI/RI field investigation. Appendix D presents cone penetration test profiles and interpretations. Appendix E presents borehole logs in LOGGER format. Appendix F contains well construction diagrams. Appendix G presents Phase I RFI/RI field data in electronic format. Appendix H presents drawdown recovery test data and analytical solutions in hard copy and electronic format. Appendix I contains input data and calculations for the water balance. Appendix J presents data-quality tables. Appendix K contains box plots for each analyte by media. Appendix L presents histograms for each analyte by media. Appendix M presents the results of statistical analyses. Appendix N presents OU 7 analytical data in electronic format. Appendix O presents time-series plots. Appendix P presents responses to agency comments on the draft final work plan technical memorandum.

1.3 Background

The Rocky Flats site is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1), and comprises approximately 6,550 acres of land in Sections 1 through 4 and 9 though 15 of Township 2 South, Range 70 West, 6th Principal Meridian.

Major buildings are located within the industrial area, which encompasses approximately 400 acres. The industrial area is surrounded by a buffer zone of approximately 6,150 acres.

Until January 1992, Rocky Flats was operated as a nuclear weapons research, development, and production plant. Nuclear weapon components were fabricated from plutonium, uranium, beryllium, and stainless steel. Parts made at the plant were shipped elsewhere for assembly. Support activities conducted at the plant included chemical recovery and purification of recyclable transuranic radionuclides and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (Rockwell International 1987a). Both radioactive and nonradioactive wastes were generated in the production process and were either stored or disposed on the site.

The Rocky Flats site is currently in transition from a defense production facility to a facility whose planned future missions include environmental restoration, waste management, maintaining production contingency, and eventual decontamination and decommissioning. The preliminary assessment performed under the DOE Environmental Restoration program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination (DOE 1986). Additional information regarding historical plant operations, production activities, past waste disposal practices at Rocky Flats, and previous investigations not directly related to OU 7 are provided in the OU 7 Phase I work plan (DOE 1991b).

This report addresses investigations at OU 7, which is located north of the plant complex on the western end of No Name Gulch (Figure 1-2). OU 7 encompasses approximately 44 acres (Figure 1-3). The Present Landfill and the Inactive Hazardous Waste Storage Area were assigned IHSS (formerly solid waste management unit [SWMU]) reference numbers by Rockwell International (1987a) and were grouped together and designated as OU 7. During 1991, the boundary of OU 7 was modified to include the East Landfill Pond and adjacent spray evaporation areas which were not included in OU 6. The locations of two of the spray fields in OU 6 (IHSSs 167.2 and 167.3) were changed based on historical research, including a review of files and photographs from the Rocky Flats site repository and employee interviews conducted for the historical release report, and now fall within the OU 7 boundary (DOE 1992a). The updated locations of IHSSs 167.2 and 167.3 directly overlie the area investigated during

the Phase I RFI/RI for OU 7, and discussions of results relevant to these IHSSs are included in this report.

Section 1.3.1 presents details of the IHSS locations and operations. Section 1.3.2 summarizes the regulatory histories of these IHSSs. Section 1.3.3 discusses physical features of the landfill and historical interim response actions for OU 7.

1.3.1 Description and Operational History of OU 7

The background and physical setting of the Present Landfill, Inactive Hazardous Waste Storage Area, and East Landfill Pond and adjacent spray evaporation areas composing OU 7 are discussed below. Also located within No Name Gulch are OU 6 IHSSs, including trenches A, B, and C (IHSSs 166.1, 166.2, and 166.3, respectively) and a spray evaporation area (IHSS 167.1). Trenches A and B received uranium- and/or plutonium-contaminated sludge from the sewage treatment plant (Building 995) from approximately 1964 to 1974. The materials placed in Trench C are not known, but it is probable that sewage sludge was placed within this trench. IHSS 167.1 was used for spray evaporation of pond water. More information regarding the operational history of these IHSSs is presented in the Phase I RFI/RI Work Plan for Operable Unit 6 - Walnut Creek Priority Drainage (OU 6 work plan) (DOE 1992b). These IHSSs will be further evaluated as part of the RFI/RI for OU 6. If the Baseline Risk Assessment for OU 6 indicates that remediation of these IHSSs is warranted, then the OU 6 IHSSs will be transferred to OU 7 and contaminated environmental media will be disposed in the Present Landfill (IHSS 114). Soils may be excavated and placed in the landfill using the Corrective Action Management Unit (CAMU) approach or, alternatively, they may be capped in place.

1.3.1.1 Present Landfill (IHSS 114)

Operation of the Present Landfill began on August 14, 1968, and is expected to continue until the opening of the new landfill. A portion of the natural drainage was filled with soils from an onsite borrow area to a thickness of up to 5 feet to construct a surface on which to start landfilling. Waste was then delivered to the landfill and spread across the work area. Disposal procedures at the landfill have not changed significantly since the landfill went into operation (DOE 1991b). The landfill was originally constructed to provide for disposal of nonradioactive

solid wastes. However, the criteria used historically to define nonradioactive material is not known.

In 1973, after tritium and strontium were detected in leachate draining from the landfill, Health Physics Operations initiated a radiation monitoring program to prevent further inadvertent disposal of radioactive material. Prior to compaction and burial at the landfill, the waste material is screened with a Bicron Analyst FIDLER, which is a field instrument for detecting low-energy radiation. Any radioactive items are returned to the building of origin for disposal (DOE 1992a). After radiation monitoring is completed, the waste layer is compacted and covered with 6 inches of soil from onsite stockpiles. Waste disposal operations continue in this manner until the waste layer is within 3 feet of a predetermined elevation. The lift is then completed with the addition of a 3-foot-thick layer of compacted soil. Based on visual observation (Rockwell International 1988a), some areas of the landfill surface may not have received a full 3-foot layer of compacted soil.

Other than monitoring for radioactivity, little testing was performed to characterize the landfilled wastes prior to 1986. In 1986, waste streams generated at the plant were characterized under the Waste Stream Identification and Characterization (WSIC) program (Rockwell International 1986a, 1986b, 1986c, 1986d, and 1987b). Beginning in 1989, waste streams generated at the plant were characterized under the Waste Stream Residue Identification and Characterization (WSRIC) program. More detailed characterization and analytical testing of Rocky Flats waste streams are currently being performed under the WSRIC program. Section 4 discusses further the composition of landfilled wastes.

1.3.1.2 Inactive Hazardous Waste Storage Area (IHSS 203)

The Inactive Hazardous Waste Storage Area is located at the southwest corner of the Present Landfill (Figure 1-3). This area was actively used between 1986 and 1987 as a hazardous waste storage area for both drummed liquids and solids (Rockwell International 1988b). Fifty-five-gallon drums containing liquids were stored in 14 cargo containers. One additional container was used to store spill-control items such as oil sorbent and sorbent pillows.

At maximum inventory, the hazardous waste area consisted of eight 20-foot-long cargo containers, each capable of holding 18 55-gallon drums, and six 40-foot-long cargo containers,

each capable of holding 40 55-gallon drums. Fifty-five-gallon drums were placed and conveyed within the cargo containers on rollers constructed of aluminum. Two conveyors extended along the full length of the cargo container. A 3-foot-wide aisle extended down the center of the cargo container to permit access and inspection. The rollers elevated the drums approximately 2 inches above the catch-basin floor (Rockwell International 1988b).

The cargo containers were modified to meet the requirements for secondary containment in accordance with 6 Colorado Code of Regulations (CCR) 1007-3 Section 264.175. Containers were fitted with signs, air vents, electrical grounding, and locks. A catch basin, constructed of 11-gauge steel with a welded steel rim and a minimum height of 6 inches, was placed within each cargo container to contain spills. The basins, as designed, were capable of containing at least 10 percent of the total volume of hazardous waste stored within the cargo containers. Drummed solids in 55-gallon containers were placed outside the cargo containers on the ground surface.

Total liquid storage capacity for the 14 cargo containers was 21,120 gallons. The maximum inventory recorded for all wastes, including solids, is not known. Because wastes were transferred between drums for consolidation, small spills may have occurred; however, no spills of reportable quantities occurred in this area during transfer operations (Rockwell International 1988b).

RCRA-listed wastes were stored in 12 of the 14 cargo containers and included solvents, coolants, machining wastes, cuttings, lubricating oils, organics, and acids. No information is available regarding the separation of waste types between the individual cargo containers. Two of the 20-foot-long cargo containers also were used to store polychlorinated biphenyl (PCB)-contaminated soil and debris, as well as PCB-contaminated oil from transformers taken out of service (Baker 1988).

During the first week of May 1987, all cargo containers were removed from the Inactive Hazardous Waste Storage Area. Hazardous materials are no longer stored at the site.

1.3.1.3 East Landfill Pond Spray Evaporation Areas

Spray evaporation of water from the East Landfill Pond along the north and south banks of the pond began in approximately May 1974 and continues as necessary. Spray evaporation is

conducted to prevent overflow of the pond and release of water downstream and to protect surface water and groundwater in the vicinity of the landfill (DOE 1992a).

Two discrete spray evaporation areas have been identified within OU 7. The Pond Area Spray Field (IHSS 167.2) and South Area Spray Field (IHSS 167.3) are located along the north and south banks of the East Landfill Pond immediately above the water line (DOE 1992a) and were investigated as part of the Phase I RFI/RI for OU 7. Dimensions of the spray fields are approximately 100 feet by 460 feet for IHSS 167.2 and 120 feet by 440 feet for IHSS 167.3.

1.3.2 Regulatory History of OU 7

Since the landfill opened in 1968, operations have continuously evolved in response to state and federal regulations. Prior to the IAG, both IHSS 114 and IHSS 203 were subject to RCRA regulations because of ongoing disposal and/or storage of hazardous wastes related to production operations. For this reason, these units were included in the November 1986 RCRA Part B permit application for Rocky Flats. With the signing of the IAG, IHSS 114 and IHSS 203 were incorporated into OU 7. The IAG integrates both RCRA and CHWA closure and corrective action obligations and CERCLA response obligations that apply to OU 7. Additional details of the regulatory history of IHSSs 114 and 203 are discussed below.

1.3.2.1 Present Landfill (IHSS 114)

The landfill was originally constructed for disposal of noncontaminated solid wastes. In October 1972, the policies concerning disposal of waste at the landfill were reviewed and judged to be in accordance with applicable state and federal regulations (Rockwell International 1988a).

DOE issued additional guidelines in February 1973 to control burial of solid and liquid wastes in the landfill. Detectable contaminant concentrations were established for specific radioactive materials, such as plutonium, in both solid and liquid phases. In the fall of 1973, Health Physics Operations began its program of monitoring the waste for radiation in response to the DOE guidelines.

In July 1977, DOE established guidelines and procedures for solid waste management, in accordance with 40 Code of Federal Regulations (CFR) 241 (Rockwell International 1988a). Guidelines for waste disposal were redefined to prevent disposal of waste material with

detectable radioactivity. Further guidelines were established to prohibit disposal of liquids, "special items," and "non-routine wastes" in the landfill, except by special permit. The Waste Management Section and the Hazardous Materials Committee of Rockwell International issued the permits. The solid waste management procedures were established in 1977 for both radiation monitoring and groundwater monitoring programs. Radiation monitoring included measurements at the point of waste origination and at the landfill. The groundwater monitoring program consisted of installing wells at the landfill site and sampling the wells once every five months. Water samples were analyzed for plutonium, gross alpha, conductivity, pH, and nitrate.

At the request of Rockwell International, CDPHE inspected the landfill in 1978 and 1979. CDPHE stated that the landfill appeared to comply with state and federal minimum standards and health department regulations (CDH 1979).

In 1986 and 1987, studies were conducted to identify waste streams generated at the plant (Rockwell International 1986a, 1986b, 1986c, and 1986d). These WSIC reports identified 338 waste streams being disposed in the landfill, including 241 waste streams identified as nonhazardous solid waste and 97 solid waste streams that contained hazardous waste or hazardous constituents. As of November 1986, the waste streams identified as hazardous in the 1986 studies were no longer disposed in the landfill. In 1987, recommendations that outlined how the waste streams identified at the plant should be disposed were made (Rockwell International 1987b). The report identified 144 waste streams that were recommended for continued landfill disposal.

Because records indicate that some hazardous waste was disposed at the landfill, it was designated as an interim status RCRA-regulated unit and included in the RCRA Part B permit application for the plant (Rockwell International 1987b). The landfill currently accepts only nonhazardous solid waste and therefore will not be permitted as an operating RCRA unit. In 1988, an alternate groundwater monitoring program was implemented at OU 7 in accordance with 6 CCR 1007-3 and 40 CFR 265.90 (d) for interim status RCRA units. OU 7 will remain under interim status until closure. A closure plan (Rockwell International 1988a) was prepared for OU 7 and submitted to CDPHE and EPA in July 1988. However, prior to approval, the closure plan was superseded by the IAG.

The presumptive remedy outlined in EPA guidance documents (EPA 1993a and 1993b) addresses containment of the landfill mass and control of leachate–groundwater and landfill gas. These activities will be implemented under the IM/IRA. Post-closure inspection, maintenance, and monitoring of the landfill will be performed in accordance with 6 CCR 1007-3 Part 264 (40 CFR Part 264).

1.3.2.2 Inactive Hazardous Waste Storage Area (IHSS 203)

IHSS 203 was used between 1986 and 1987 as a hazardous waste storage area. This IHSS was included in the November 1986 RCRA Part B permit application for Rocky Flats as an operating RCRA hazardous waste unit. In that application, it was referred to as Unit #1. Cargo containers used to store drums of hazardous waste at this location were designed to meet the requirements for secondary containment in accordance with 6 CCR 1007-3 Section 264.175.

Because IHSS 203 is located within the Present Landfill (IHSS 114), it will be contained along with the landfill mass for closure. Post-closure inspection, maintenance, and monitoring of the landfill will be performed in accordance with 6 CCR 1007-3 Part 264 (40 CFR Part 264). These activities will be implemented under the IM/IRA, in accordance with the IAG.

1.3.3 Landfill Structures and Historical Interim Response Actions

As previously mentioned, in May 1973 tritium and strontium were detected in leachate draining from the landfill. In response, an investigation was conducted to determine the location of the source. Monitoring of waste prior to burial was initiated to prevent further disposal of radioactive material, and interim response activities were undertaken to control the generation and migration of landfill leachate.

Historical interim response activities included construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill, a subsurface intercept system for diverting groundwater around the landfill, and a subsurface leachate collection system. Construction of the semi-permanent, engineered systems began in October 1974 and was completed in January 1975. These interim response action systems are discussed briefly below. Figure 1-4 shows the locations of the landfill structures.

1.3.3.1 Surface-Water Diversion System

The surface-water diversion ditch diverts surface runoff around the landfill (Figure 1-4). This system was designed to reduce the infiltration of surface water into the landfill, thereby reducing the volume of leachate draining from the landfill.

1.3.3.2 Ponds

Two ponds were constructed as part of the interim response action to control leachate generated by the landfill (Figures 1-3 and 1-4). These ponds were formed by constructing temporary berms across the drainage immediately downstream of the landfill. Both ponds covered approximately ½ acre. The West Landfill Pond (initially called Pond #1) impounded leachate generated by the landfill. The East Landfill Pond (initially called Pond #2) provided a back-up system for any overflow from the West Landfill Pond and was also used to collect intercepted groundwater, as needed. The leachate collection system originally drained only to the West Landfill Pond. Discharge of the intercepted groundwater could be directed (via a series of valves in the subsurface pipes) to either pond or to surface drainages downgradient of the ponds.

In 1974, a more permanent embankment was constructed for the East Landfill Pond in approximately the same location as the original berm. The new embankment was an engineered dam structure with a spillway, designed to retain the majority of the water in the channel. A low-permeability clay core keyed into bedrock was constructed within the embankment to reduce seepage. The remaining shell of the embankment was constructed of more permeable silty to clayey granular soils. The East Landfill Pond covers approximately two and one-half acres.

To prevent the two ponds from overfilling and discharging into No Name Gulch, excess pond water was originally pumped to the Solar Evaporation Ponds (DOE 1992a). From January of 1974 to September of 1975, pond water was diverted to a manhole northwest of Building 990 and discharged to Pond B-2 (DOE 1992a). Beginning in September of 1975, pond water was sprayed on the ground surface to enhance evaporation. Areas where spray evaporation operations historically occurred were designated as IHSSs and incorporated into OU 6 (Figure 1-3). Water that collected in the West Landfill Pond was sprayed on a 3.9-acre plot (designated

IHSS 167.1) located approximately 800 feet northeast of the West Landfill Pond. Two other spray fields (IHSSs 167.2 and 167.3) were located on the hillsides near the East Landfill Pond and were used for spray evaporation of water that collected in the East Landfill Pond. Water from the East Landfill Pond is still sprayed on the hillside south of the pond. After finalization of the OU 6 work plan (DOE 1992b) and implementation of OU 6 Phase I RFI/RI fieldwork, the correct locations of IHSSs 167.2 and 167.3 were identified based on a review of historical information (DOE 1992a) (Figure 1-3). Because the locations of these IHSSs now lie within the area investigated for OU 7, the two IHSSs are considered part of the OU 7 investigation and are addressed in this report. As discussed in Section 1.3.1, IHSSs 166.1, 166.2, 166.3, and 167.1 currently being evaluated under the OU 6 RFI/RI may be transferred to OU 7.

Between 1977 and 1981, landfill expansion covered the discharge points of the leachate collection system into the West Landfill Pond. The West Landfill Pond was covered in May of 1981 during further eastward expansion of the landfill. Apparently, the berm that created the West Landfill Pond was not removed, nor was the leachate collection system rerouted to drain into the East Landfill Pond. Presumably, leachate collected by the subsurface control system still drains to the area of the former West Landfill Pond. The East Landfill Pond now receives leachate draining from the face of the landfill.

1.3.3.3 Subsurface Drainage Control System

A subsurface drainage control system was installed around the perimeter of the landfill in 1974. The subsurface drainage system included both a leachate collection system and a groundwater intercept system, constructed outside the perimeter of the landfilled wastes (Figure 1-5). The leachate collection system collects leachate generated from the landfill waste and discharges to the West Landfill Pond. The groundwater intercept system was designed to intercept and divert groundwater flow around the landfill, thereby reducing the volume of leachate generated from the landfill waste.

The two-part system was constructed by excavating around the perimeter of the landfilled wastes to depths of 10 to 25 feet below ground surface. The excavation was 24-feet wide at the base. Selected as-built drawings of the intercept system are presented in Appendix B of this report. All as-built drawings of the intercept system are included in Appendix A of the OU 7 Phase I work plan (DOE 1991b).

The groundwater intercept portion of the system was installed on the outside of the excavation, away from the landfill waste (Figure 1-5). This system consisted of a 1-foot-thick sand and gravel filter blanket installed along the excavation face and covered by a 4.5-foot-thick clay barrier. The filter blanket was designed to intercept groundwater and drain to a 6-inch-diameter perforated pipe installed at the bottom of the excavation (and outside of the clay barrier). The intercepted groundwater could then be discharged to either pond or to surface drainage. The clay barrier was designed to prevent or reduce groundwater flow into the landfill. The as-built sections and profile sheets (sheets 2 and 3 of 12, Sanitary Landfill Renovations, Appendix B) indicate that the bottom of the system may be above the bedrock surface approximately halfway between wells B106089 and 6587 (on the south side of the intercept system) and approximately halfway between wells B106089 and 6387 (on the north side of the intercept system).

The leachate collection system was constructed immediately inside of, and in the same trench as, the groundwater intercept system. Although the design drawings specified a 6-inch-diameter perforated pipe for the leachate collection system, as-built drawings indicate that the leachate collection system consisted of a 5-foot-thick gravel backfill placed in the bottom of the trench on the landfill side. The collected leachate was directed into the West Landfill Pond, which was intended to retain the leachate without discharging to the East Landfill Pond (Rockwell International 1988a).

Between 1977 and 1981, the leachate collection and groundwater intercept system was buried beneath waste during landfill expansion. It has been speculated that lateral expansion of waste placement has resulted in wastes being located beyond the extent of the subsurface drains to the north and south (Rockwell International 1988a). Eastward expansion covered the points where the leachate collection system discharged into the West Landfill Pond.

1.3.3.4 Slurry Walls

In 1982, two soil-bentonite slurry walls were constructed to prevent groundwater migration into the expanded landfill area. These slurry walls were tied into the north and south arms of the groundwater intercept system (Figure 1-4).

Details of the connection in the design drawings indicate that the west end of each slurry wall intersects, but does not break, the groundwater intercept system. At these intersections the existing drain pipe was replaced with ductile iron pipe, which was joined with the existing drain pipe using mechanical compression joints. These sections of ductile iron pipe and the joints at each end were then encased with concrete poured against undisturbed bedrock at the bottom of the excavation. This concrete block interrupted the hydraulic continuity of the sand and gravel filter blanket located outside of the clay barrier, and the only hydraulic connection of the groundwater diversion drain across the slurry trench was through the new segment of pipe. As a result, there would be no outlet from the groundwater intercept system if these pipes were to be damaged or clogged. The slurry walls extend eastward approximately 700 feet from these points of intersection. Based on as-built drawings, the slurry walls vary in depth from 10 to 25 feet.

1.4 Previous Investigations at OU 7

A number of previous investigations have been conducted at the site for the purpose of evaluating physical characteristics and potential contamination. Previous investigation reports reviewed for this investigation include:

- Present Landfill Closure Plan, Rocky Flats Plant (Rockwell International 1988a)
- RCRA Annual Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant (EG&G 1994a)
- Phase II Geologic Characterization Data Acquisition Surface Geologic Mapping of the Rocky Flats Plant and Vicinity (EG&G 1992a)
- Surface Water and Sediment Geochemical Characterization Reports, Rocky Flats Plant (EG&G 1991a and 1994b)
- Background Geochemical Characterization Reports, Rocky Flats Plant (EG&G 1992b and 1993a)
- Closure Plan, Inactive Interim Status Facilities, Hazardous Waste Storage Area, SWMU #203, Rocky Flats Plant (Rockwell International 1988b)

- Present Landfill Hydrogeologic Characterization Report, Rocky Flats Plant (Rockwell International 1988c)

- Phase I RFI/RI Work Plan for Operable Unit 6 - Walnut Creek Priority Drainage (DOE 1992b)

- Geotechnical Engineering Report for Geotechnical Analysis of Earthen Dams A-3, B-1, B-3, and Landfill Dam (EG&G 1993b)

- Final Historical Release Report for the Rocky Flats Plant (DOE 1992a).

Results of other unpublished or not widely available studies conducted at the Present Landfill are discussed below.

1.4.1 Tritium Investigation

In May of 1973, tritium and strontium-89,90 were detected in leachate at a drainage seep from the landfill (Rockwell International 1987c). As a result, temporary berms were constructed across the drainage to halt the flow of leachate into No Name Gulch. Monitoring wells were installed directly in the landfilled waste or directly below the saturated waste materials, and leachate samples from wells were collected and analyzed to locate the source of the tritium and strontium (Woodward-Clevenger 1974). Elevated readings were followed by drilling more borings and wells until the general location of the source was identified (Rockwell International 1987c). The number of wells installed is referenced in previous reports and varies from 47 (Rockwell International 1987c) to 52 (DOE 1992a).

Of the samples of leachate from boreholes in the landfill analyzed for strontium-89,90, the concentration in only one sample appeared elevated (7 picocuries per liter [pCi/L]) (Woodward-Clevenger 1974). All other samples of leachate contained strontium-89,90 at concentrations of less than 1 pCi/L. The method detection limit for strontium-89,90 at the time of analysis was 0.1 pCi/L. Strontium-89,90 concentrations were analyzed in samples collected from the landfill ponds, drainages, and the groundwater intercept system and were generally found at or below background levels.

The concentrations of tritium detected in leachate during 1973 are shown in Figure 1-6. The highest measured concentration of tritium was 301,609 pCi/L. The depth of the tritium source, total activity, configuration, and source container, if any, were not determined. The tritium source is located in an area of the landfill used during 1970. Concentrations of tritium in leachate seeping from the landfill decreased from a high in 1973 to substantially lower concentrations in 1980 (Figure 1-7). Concentrations of tritium during 1980 were approximately equal to the CDH Water Quality Control Commission (WQCC) surface-water standard of 500 pCi/L promulgated in April 1991. The wells near the eastern end of the landfill exhibited decreasing tritium concentrations between 1973 and 1981. No information is available regarding abandonment of the wells installed for the tritium investigation.

Although the appropriate location was determined, the source of tririum was never removed. To control the migration of trituim, interim response actions, discussed in Section 1.3.3, were taken.

1.4.2 Geotechnical Investigations

A geotechnical engineering study for landfill remediation was performed in 1974 (Zeff, Cogorno and Sealy, Inc. 1974). Recommendations were made and plans were developed for a groundwater diversion and leachate collection system around the perimeter of the landfill (see Section 1.3.3).

Another geotechnical engineering study was performed to evaluate proposed landfill expansion (Lord 1977). The claystone bedrock beneath the landfill was judged adequate to serve as a subsurface hydraulic barrier, and the overburden soils were judged adequate for daily landfill cover (Rockwell International 1988a).

1.4.3 Soil-Gas Surveys

In 1986, Tracer Research conducted a sitewide soil-gas survey for chlorinated organic compounds. Samples were analyzed for chloroform; 1,1,1-trichloroethane (1,1,1-TCA); trichloroethene (TCE); tetrachloroethene (PCE); and 1,1-dichloroethene (1,1-DCE). Only one sampling site was located at the landfill. PCE was the only target analyte detected at this site.

Another soil-gas survey using the Petrex method was initiated in 1987 in the landfill area; however, no actual data were obtained because the sampling points were improperly located.

During 1987, a soil-gas survey was performed using portable gas chromatography methods to detect gases commonly generated by landfill wastes. Results were reported by Rockwell International (1988a) and are presented in Appendix B of the OU 7 Phase I work plan (DOE 1991b). Methane was detected at 2 of the 20 sampling locations at concentrations less than 0.4 parts per million (ppm). Other compounds were detected but not identified in the landfill soil gas. Hydrogen sulfide was not detected. The sampling methodology used during the investigation was not documented in the report.

Because of limited sampling and/or the lack of documentation of sampling methods, data from these investigations are of limited value.

1.4.4 Geophysical Investigations

Geophysical surveys using ground-penetrating radar and electromagnetics were conducted at OU 7 during early 1991. Ground-penetrating radar was used in an attempt to delineate the individual components of the groundwater intercept system and the slurry walls (EG&G 1991b). Although clays and buried conductive materials (landfilled debris) presented difficulties in locating the groundwater intercept system, the inferred slurry wall locations approximated the as-built drawings. The ground-penetrating radar data suggest that the intersection of the slurry wall with the groundwater intercept system on the north side is located further to the west than previously thought.

The electromagnetic geophysical survey was performed to determine its effectiveness in mapping subsurface total dissolved solids (TDS) plumes (EG&G 1991c). Suspected areas of high TDS content were delineated by the survey; however, these potential plumes could also be interpreted as lenses of conductive clay. The report concluded that additional characterization of the physical properties of alluvial and bedrock materials was required to delineate high TDS plumes from naturally occurring, conductive geologic material.

1.4.5 Phase I RFI/RI

A Phase I RFI/RI investigation was conducted at OU 7 in 1992 and 1993. The 12 specific objectives of this investigation as detailed in the OU 7 Phase I work plan (DOE 1991b) are listed below.

Characterize Site Physical Features:

- Determine representative site-specific background concentrations of analytes in groundwater and subsurface materials.
- Characterize the flow regime within and around OU 7 to evaluate the effects of the groundwater intercept system and slurry walls on leachate and groundwater movement.
- Characterize surface-water and groundwater interactions.
- Evaluate infiltration of precipitation through the existing soil cover material.

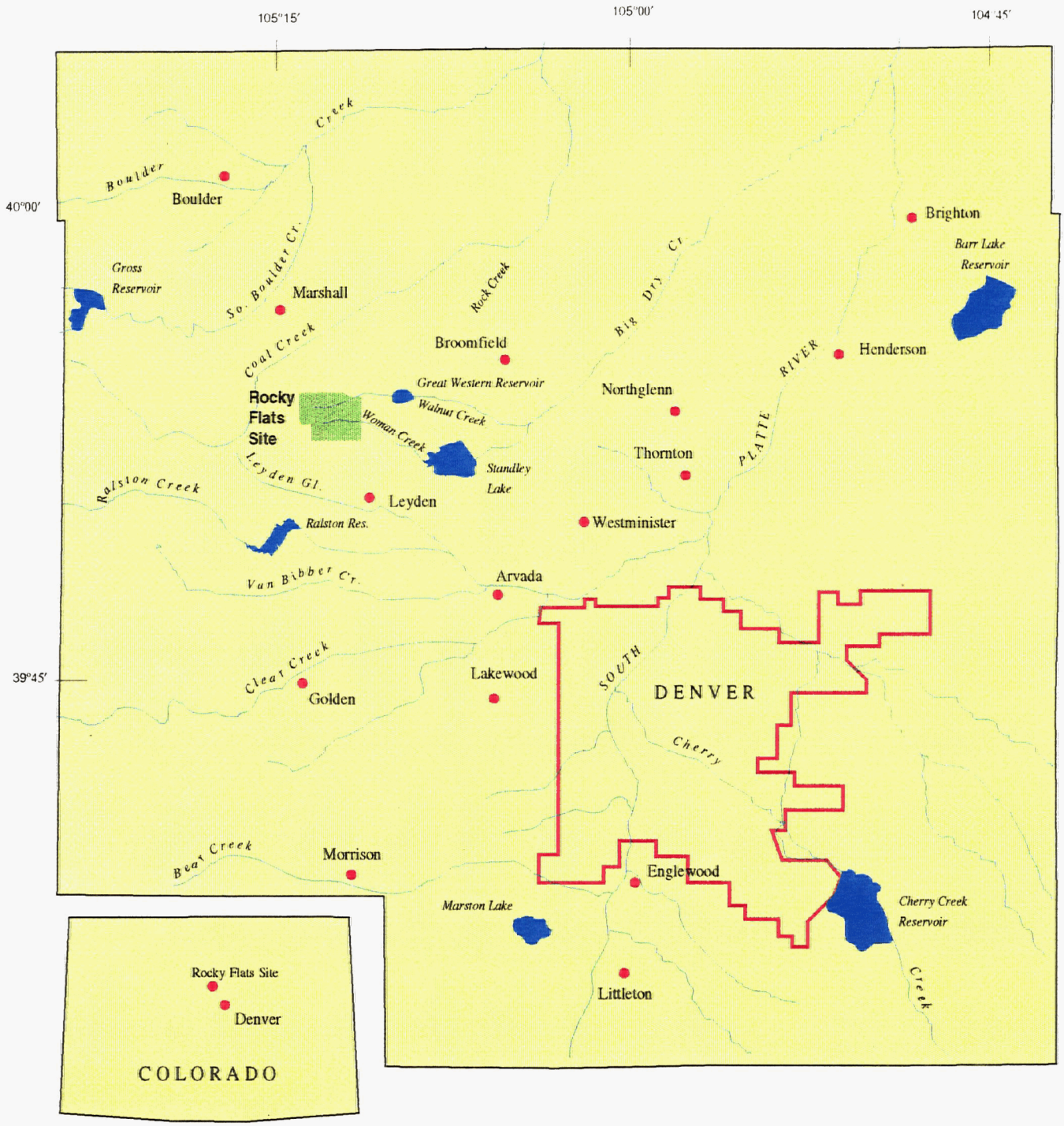
Define Contaminant Sources:

- Determine the presence or absence of soil contamination at IHSS 203.
- Determine the presence or absence of contamination in soils where spray evaporation occurred.
- Further characterize the waste streams disposed in the landfill, and evaluate the environmental fate and transport of the chemicals associated with the identified waste streams.
- Determine the area and volume of landfill material.
- Determine the volume and character of leachate.
- Determine the character and volumes (gas production) of landfill-generated gases.
- Characterize leachate-contaminated materials (including soils, bedrock, and former West Landfill Pond sediments) beneath the landfill.

- Characterize contamination in surface water and sediments in the East Landfill Pond.

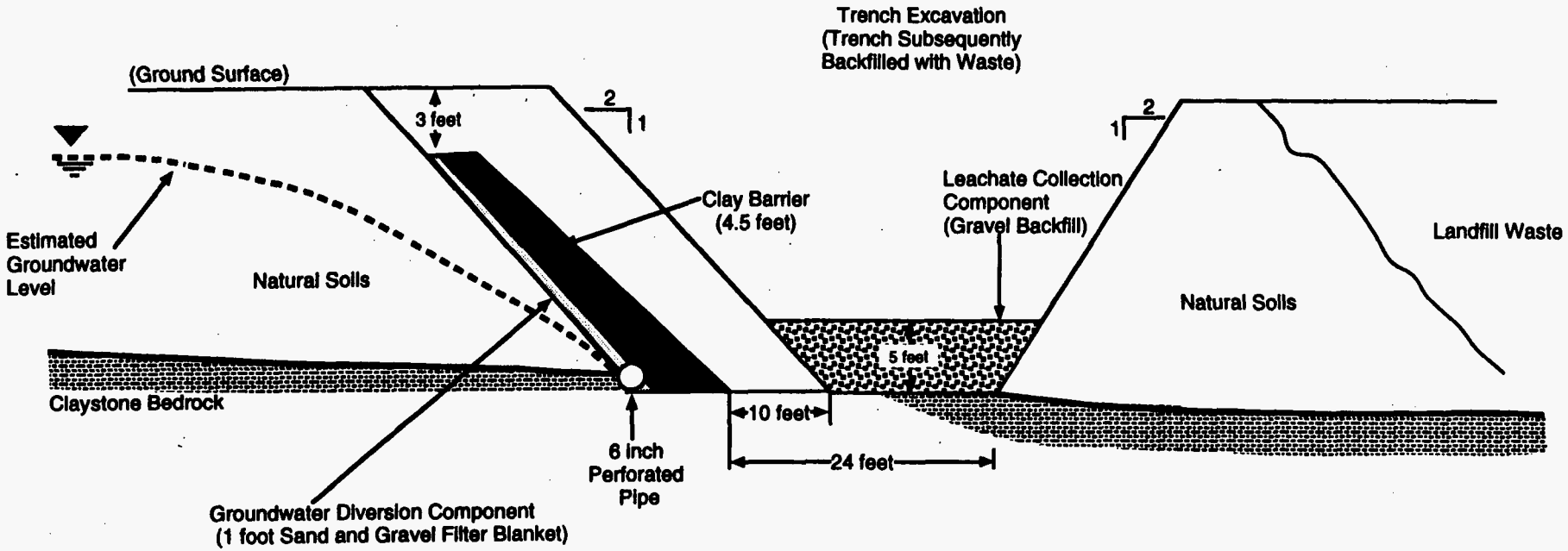
Existing data and the data generated by the Phase I RFI/RI are used in the following sections to characterize site physical features, define contaminant sources, and identify additional data needs. Appendix C summarizes the Phase I RFI/RI investigation in detail.

Section 1
Figures



U.S. DEPARTMENT OF ENERGY Rocky Flats Site, Golden, Colorado	
Location of Rocky Flats Site	
Revised Work Plan	Operable Unit No. 7
Date: April 1994	Figure 1-1

M\ES\RFP & Vicinity Map.ill\11-11-93



Approximate Scale: 1 inch = 20 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Design Section of Groundwater Intercept and Leachate Collection System

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-5

Source: Rockwell International 1988b

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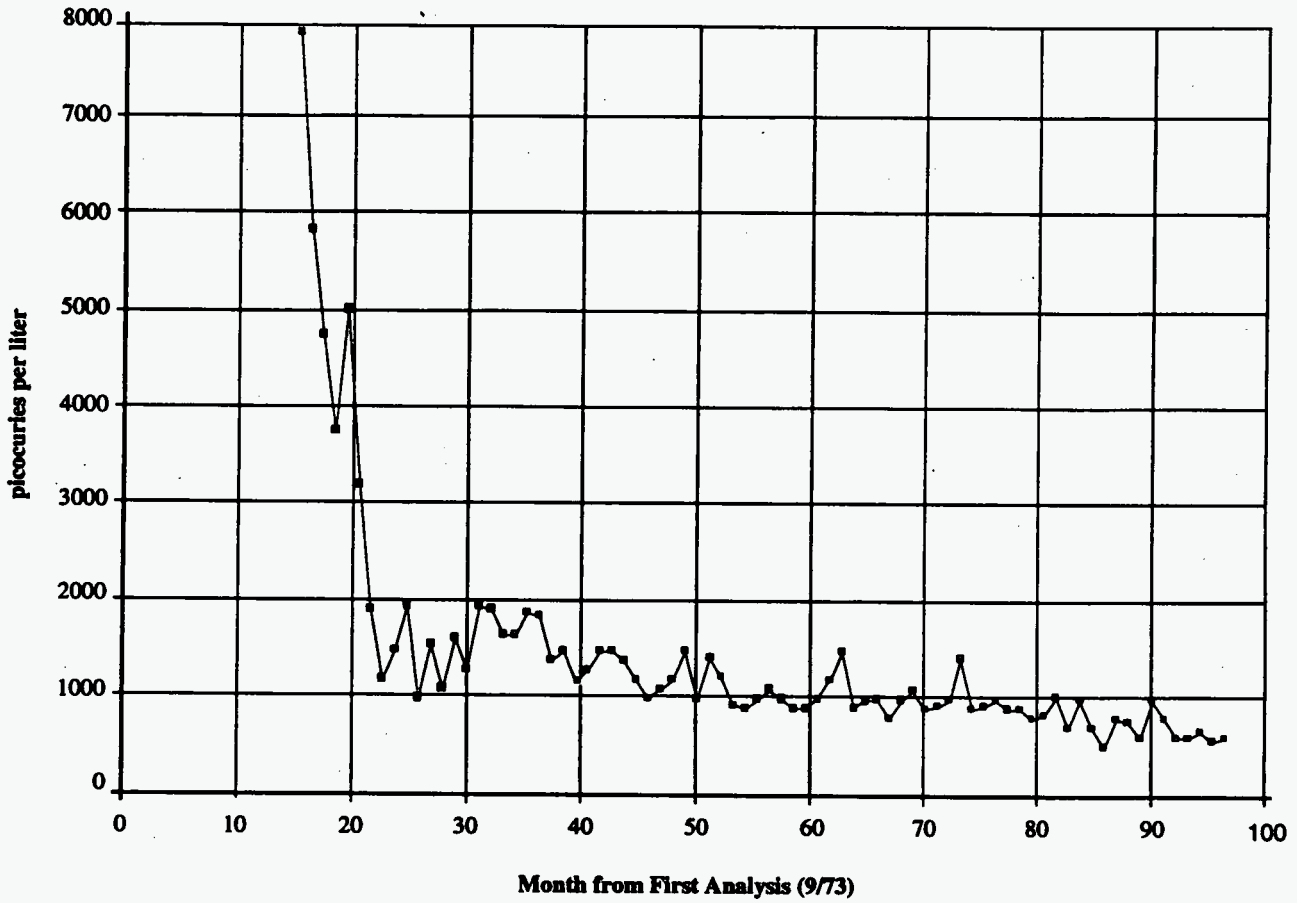

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Tritium in West Landfill Pond from 1973 to 1980

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-7

M\ES\Fig 1-5 Tritium Conc.mdw\7-26

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2. SITE CHARACTERIZATION

Section 2 fulfills the general objective of characterizing the physical and biological features of OU 7 and three of the four specific objectives of the Phase I RFI/RI site characterization as follows:

- Characterize the flow regime within and around OU 7 to evaluate the effects of the groundwater intercept system and slurry walls on leachate and groundwater movement.
- Evaluate infiltration of precipitation through the existing soil cover material.
- Characterize surface water–groundwater interactions.

The fourth specific objective, to determine representative site-specific background concentrations of analytes in groundwater and subsurface materials, is addressed in Section 4.

Sections 2.1 through 2.7 describe surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology.

2.1 Surface Features

OU 7 lies north of the industrial area on the western end of No Name Gulch. OU 7 includes the Present Landfill (IHSS 114), the Inactive Hazardous Waste Storage Area (IHSS 203), and the East Landfill Pond and adjacent spray evaporation areas (IHSSs 167.2 and 167.3). In addition, a surface-water diversion system, a groundwater intercept system, and a leachate collection system lie within OU 7 (Figure 2-1). The physical setting and surface features for each of the IHSSs and other areas that constitute OU 7 are described in the following sections.

2.1.1 Present Landfill (IHSS 114)

The Present Landfill (IHSS 114), is an operating landfill that covers an area of approximately 27 acres. The actively operating area of the landfill is surrounded by a 3-foot-high, chain-link fence. Access to the landfill is currently through the south gate, located in the center of the

south edge of the landfill. Two other gates have been used in the past, the west gate, east of IHSS 203, and the north gate, on the north side of the landfill. These gates remain locked except during the operating hours of the landfill when the south gate is open.

A surface-water diversion ditch is located just outside the landfill fence and follows the fence perimeter on its north and south sides (Figure 2-1). The ditch was designed to divert surface runoff around the landfill. On the north side of the landfill the ditch runs under a perimeter road through a small culvert and east into a small, natural drainage that eventually joins No Name Gulch below the East Landfill Pond. On the south side of the landfill, the ditch runs east above the East Landfill Pond and drops into the unnamed tributary to No Name Gulch below the East Landfill Pond. The ditch is 2- to 3-feet deep and 5-feet wide at the bottom and has a trapezoidal shape. The slopes and floor of the ditch are composed of sparsely vegetated native soil material. No waste disposal is known to have occurred outside of the surface-water diversion ditch.

A gravel road, located outside of the fence and the surface-water diversion ditch, follows the perimeter of the landfill on its north, south, and west sides. The road continues east, beyond the eastern limit of landfill operations, towards the East Landfill Pond. The Property Utilization and Disposal (PU&D) yard lies southwest of the landfill along the south side of this road (Figure 2-1). The PU&D yard is surrounded by an eight-foot chain link fence, and access is controlled through locked gates. This open storage area has been used by various groups at the Rocky Flats site for surplus storage since 1974. Currently the area is used by the carpentry, power, and trucking groups. Historically, such items as surplus roofing tar and motor oil have been stored in the area but no documentation was found indicating any releases of hazardous materials to the environment (DOE 1992a). A power substation is located east of this open storage area and south of the landfill. No documentation was found that detailed incidents of concern related to the power substation (DOE 1992a).

As discussed in Section 1.3.1.1, waste disposal procedures currently used at the landfill have not significantly changed since the landfill went into operation in 1968 (DOE 1991b). During the Phase I RFI/RI field investigation, active disposal operations took place in the western and central portions of the landfill. Heavy equipment used to move waste and fill was stored within the landfill. Temporary roads or access routes were routinely placed within the landfill for use

by trucks carrying waste. These temporary roads consisted of a 2- to 6-inch-thick, coarse gravel layer over clean fill.

During the Phase I RFI/RI field investigation, a large volume of clean fill material was stockpiled in a number of 10- to 20-foot-tall mounds along the south and west margins of the landfill. The stock piles of clean fill were used as the interim soil cover on waste material. Excluding the areas of stockpiled clean fill, the ground surface of the landfill was irregular and hummocky during the fall and winter of 1992. Standing water collected in low areas and within small depressions during precipitation or snowmelt events. Regrading of the landfill surface in the spring of 1993 eliminated the hummocky topography, and the ground surface slopes to the east at a 2 to 3 degree angle. The landfill was reseeded in the fall of 1993.

The location of the old landfill pond, also known as the West Landfill Pond or Pond #1, is no longer evident at the ground surface because of continuing eastward expansion of the landfill. The current eastern extent of landfill operations is marked by a steep face that descends approximately 50 feet to the edge of the East Landfill Pond. This face was advanced farther eastward and regraded in late spring 1993. The face is now covered with clean fill and has approximately a 40 percent slope. During the Phase I RFI/RI field investigation large pieces of asphalt were piled along the top of the east face of the landfill. When the landfill was advanced eastward in spring 1993 the asphalt was moved east and down the slope, then covered with clean fill.

In the northeast and southeast corners of the landfill old asbestos disposal areas are marked by several large warning signs. Asbestos had been buried in several pits within these posted areas. There is no surface expression of these disposal areas, and the ground surface appears undisturbed. The areal extents of these disposal areas cannot be delineated by an inspection of surface features.

Five gas vents are present within the operating landfill. These vents are constructed of polyvinyl chloride (PVC) and project above the ground surface approximately 5 feet. Each vent is protected from heavy equipment by four, 15-foot-high steel posts. Numerous monitoring wells are also present within the landfill. The construction and location of these wells are discussed in Appendix C.

2.1.2 *Inactive Hazardous Waste Storage Area (IHSS 203)*

The Inactive Hazardous Waste Storage Area (IHSS 203) is located at the southwest corner of the landfill and covers less than one-half acre (Figure 2-1). This area was actively used between 1986 and 1987 for the storage of drummed liquid and solid hazardous wastes (Rockwell International 1988b). The IHSS is unfenced and the boundaries, as shown on maps, are not marked by any distinctive surface features. No visible evidence for past usage of this area remains except for sparse remnants of an asphalt-paved surface just east of the IHSS and some red gravel fill within the IHSS. The ground surface is generally flat within IHSS 203. The IHSS is bounded along its western edge by the surface-water diversion ditch that runs adjacent to the IHSS 114 boundary (Figure 2-1).

A power line runs east-west just south of IHSS 203. At the southwest corner of the IHSS the power line joins a tall wooden pole (telephone pole). Power was available at this pole by a hook-up to the line during the Phase I RFI/RI field investigation. A small wooden guard house was also present at this location. There was no power available to this structure and the structure was removed in the spring of 1993.

2.1.3 *East Landfill Pond and Spray Evaporation Areas (IHSSs 167.2 and 167.3)*

The East Landfill Pond covers an area of approximately two and one-half acres and fills the center of the valley downgradient from the operating landfill. The pond receives landfill leachate and surface runoff from the landfill area and also collects groundwater flowing from the groundwater intercept system. Pond water is retained by an engineered embankment on the pond's east side that rises approximately 45 feet above the valley floor. The embankment slopes on the west side, facing the pond, are covered with well-graded, angular to subrounded, bouldery riprap. The embankment slopes on the east side are covered with herbaceous vegetation. A gravel road follows along the top of the pond embankment and crosses the valley occupied by the pond. Gravel-surfaced pullouts are present west of the road on both the south and north sides of the pond embankment. The gravel extends down into the water and is used as a boat ramp. A gravel road descends below the pond embankment on the north side of the pond and provides vehicle access to groundwater monitoring wells and surface-water discharge points in the valley bottom. The gravel pullouts and monitor well access road are not shown in Figure 2-1 but do appear in a recent photograph of the East Landfill Pond (Figure 2-2).

An emergency spillway is located on the south side of the pond embankment. The spillway is a trapezoidal, earth-cut spillway that is 6-feet deep and 10-feet wide at the bottom. A 6-foot by 8-foot concrete box culvert carries spillway discharge under the access and into the drainage below the embankment. There is a weir on the upstream side of the box culvert. Water from the East Landfill Pond can spill over into this structure when the pond surface elevation exceeds 5921 feet. The pond surface elevation was measured at 5919.5 feet above mean sea level in June 1993. The pond embankment has an elevation of 5926.3 feet.

The outlet works for the pond consist of a 10-inch iron pipe, equipped with an upstream butterfly valve. There is also a gate valve and concrete stilling basin located at the downstream toe of the landfill dam. There is a large area of riprap downstream of the stilling basin. The outlet works are currently non-operational because the East Landfill Pond is not a permitted discharge point (EG&G 1993b).

To prevent the pond from overfilling and spilling into the drainage, water is periodically sprayed onto the ground surface adjacent to the landfill to enhance evaporation. IHSSs 167.2 and 167.3 were used for spray evaporation of water from the pond and are located along its north and south banks. Recent spray evaporation from the pond continues in these areas as shown in Figure 2-2. A generator and pump are present on the south side of the pond adjacent to the road that follows the top of the pond embankment. The pump lifts water from the pond to plastic (PVC) pipes that lie on the south slope of the pond. The pipes extend west from the pump approximately 50 yards. Remnants of an earlier spray or water diversion system are present on the north and south slopes along the pond. Six-inch diameter, solid-walled pipes are present on the ground surface in these areas. Slotted metal pipe is also present on the north side of the pond. Excess pond water has also been pumped from the pond to holding ponds in the Walnut Creek drainage. Metal piping leading south from the East Landfill Pond toward the A-series ponds is present on the south slope of the pond and can be seen in Figure 2-2.

The ground on the north and south sides of the East Landfill Pond is sloped and covered with native herbaceous and shrubby vegetation. The slopes on either side of the pond are dissected by a generally north-south trending fence that marks the eastern extent of the fence line surrounding the landfill. The 3-foot-tall chain-link fence extends to the shoreline of the pond on both sides. On the east side of this fence the slopes appear undisturbed by landfill and

construction activities. On the north slope west of the fence, the ground surface was hummocky and showed evidence of recent slumping. Intermittent seepage may occur in an area on the north slope of the pond where plants indicative of wet conditions are present (cattails and small cottonwood trees). No seepage was observed in this area during the Phase I RFI/RI field investigation (November 1992 through April 1993). The slopes west of the fence line were recently regraded and reseeded. A temporary road constructed of coarse gravel leads from the southeast corner of the landfill to the monitoring wells and leachate seep at the western edge of the pond.

2.2 Meteorology and Climate

The area surrounding the Rocky Flats site has a continental, semiarid climate characteristic of the Southern Rocky Mountain region. Temperatures at the site exhibit large seasonal variations and, occasionally, dramatic short-term temperature changes. Summer high temperatures are typically in the mid-80°F range during the days with lows below 60°F at night. During the winter months temperatures are relatively mild, ranging from 40 to 45°F during the day and 15 to 25°F at night. Periods of extremely hot or cold weather are usually brief and do not occur every year. Temperature extremes recorded at the plant range from 102°F on July 12, 1971, to -26°F on January 12, 1963 (DOE 1980). Figure 2-3 summarizes average, monthly temperature ranges.

Mean annual precipitation at the Rocky Flats site, including rainfall and snowmelt, is nearly 16 inches. Approximately 40 percent of the annual precipitation falls during the months of April, May, and June. Summer thunderstorms (July and August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, occurring generally from October through May. Heaviest snowfall occurs in March. Snowfall provides approximately half of the total moisture for the year. The average relative humidity is 46 percent (DOE 1980). Figure 2-3 summarizes average, monthly precipitation totals.

The Rocky Flats site is noted for its strong, gusty winds, which frequently occur with thunderstorms and passage of weather fronts. The windstorm season extends from late November into April, and the height of the season occurs in January. The highest wind speeds occur during this season as westerly windstorms known as chinooks. Wind speeds typically

exceed 75 miles per hour, and gusts may exceed 100 miles per hour. However, northwesterly wind directions and wind speeds under 15 miles per hour are the predominant wind conditions at the Rocky Flats site. Moderately strong northerly or southerly winds are common in winter and summer, respectively, and easterly winds ("upslopes") may be associated with snowfall. The steep-sided canyons along the Front Range tend to channel the airflow during both upslope and downslope conditions (DOE 1980).

Meteorology at the site is strongly influenced by the diurnal cycle of mountain and valley breezes. Two dominant flow patterns exist, one during daytime conditions and one at night. During daytime hours, as the earth heats, air tends to flow toward the higher elevations (upslope). The general airflow pattern during upslope conditions for the Denver area is typically north to south, with flow moving up the South Platte River Valley and then entering the canyons into the Front Range. After sunset, the air against the mountain sides is cooled and begins to flow toward the lower elevations (downslope). During downslope conditions, air flows down the canyons of the Front Range onto the plains. This flow converges with the South Platte River Valley flow moving toward the north-northeast (Hodgin 1983, Hodgin 1984, and DOE 1986). A summary of 1992 wind direction and speed is illustrated in Figure 2-4 in the form of wind-rose diagrams. The diurnal pattern of wind directions is evident on these diagrams.

2.3 Soils

The surface soils at OU 7 are predominantly deep, well-drained loams, clay loams, and very cobbly sandy loams with slow permeability. Table 2-1 presents a brief description of soil types. Figure 2-5 shows the distribution of soil types in the vicinity of OU 7.

Soils around the East Landfill Pond consist of clay loams from the Denver-Kutch-Midway series. These soils are medium to very dark brown, fine, montmorillonitic, mesic Torrertic Argiustolls that formed in calcareous, clayey material derived from undifferentiated Arapahoe and Laramie Formation claystones. Soils on the pediment surrounding the landfill are from the Flatiron series. These soils are grayish brown to reddish or yellowish brown, clayey, montmorillonitic, mesic Aridic Paleustolls that formed in non-calcareous, cobbly, stony, gravely, and loamy material of the Rocky Flats Alluvium. Soils on the edge of the pediment are from the Nederland series. These soils are medium to dark brown, loamy, mixed, mesic Aridic Argiustolls that formed in cobbly, gravely, and loamy alluvium derived from mixed sources

(Rocky Flats Alluvium and undifferentiated Arapahoe and Laramie Formation claystones). Soils in the valley bottoms are from the Haverson series. These soils are fine, loamy, mixed, mesic Ustic Torrifluvents formed in stratified, loamy alluvium of mixed origin adjacent to intermittent streams (Price and Amen 1980).

Interim soil cover material currently stockpiled and used at the landfill was obtained from the Rocky Flats Alluvium at a location outside OU 7. Historical analytical data characterizing the daily soil cover and fill material underlying the interim soil cover were presented in the OU 7 work plan (DOE 1991b). These data are limited to borehole samples collected during drilling of groundwater monitoring wells B106089, B206189, and B206389. Interim soil cover material was described during surface-soil sampling activities at the landfill. These soils are reddish brown to dark brown, clayey sands and poorly graded, clayey gravels. The gravel component was 30 to 40 percent in the eastern (older) part of the landfill and greater than 50 percent in the active landfill area in March 1993. The landfill has since been regraded, and a new layer of soil cover material was placed on top. Because the soil cover material was recently placed on the landfill surface, vertical stratification into soil horizons has not yet taken place. Analytical data characterizing the interim soil cover material and soils around the East Landfill Pond are discussed in Section 4.3 and presented in Appendix N.

During the Phase I RFI/RI soil sampling program, general descriptions of soil texture and color were recorded at each sample location. Within the 0- to 2-inch soil horizon at IHSS 203, three general soil types were identified. A dark brown, very gravely loam covered the northern half of the sample grid. The south-central portion of the grid was composed of non-native red gravel fill, and two sample locations at the far western corner of the grid consisted of a very gravely, sandy clay loam. Within the 2- to 10-inch soil horizon the majority of the grid consisted of a dark brown, very gravely loam. Two sample locations in the northwestern portion of the grid consisted of a yellow-brown clay. Two sample locations in the southeastern portion of the grid consisted of non-native red gravel fill.

Soil in the 0- to 2-inch horizon within the spray evaporation areas on the northern and southern edges of the East Landfill Pond and the sample area east of the dam generally consisted of loam and clay loam with small isolated areas of gravely loam. Soils on the western edge and the northwestern corner of the sample grid contained more gravel and sand. Soil on the dam itself consisted of a gravely loam. At a soil depth of 2 to 10 inches the majority of the East

Landfill Pond sample area consisted of clay and clay loam. A small area in the north-central portion of the grid and the dam itself consisted of gravely clay.

2.4 Geology

The geology at OU 7 is a function of the regional tectonic setting and local depositional and erosional conditions. Geologic data used to characterize OU 7 were compiled from previous landfill investigations (Rockwell International 1988c, DOE 1991b); existing geologic characterization reports (EG&G 1991d, EG&G 1992a); U.S. Geological Survey publications (Spencer 1961, Van Horn 1972); Colorado School of Mines reports (Weimer 1976); and the borehole drilling, monitoring well installation, and cone penetration test (CPT) tasks of the Phase I RFI/RI field investigation. A description of the general geologic framework and specific descriptions of surficial and bedrock geologic units are presented in the following sections. Geologic interpretations of CPT profiles are included in Appendix D and geologic borehole logs are presented in Appendix E.

2.4.1 General Geologic Framework

The Rocky Flats site is located on a broad, eastward sloping plain just east of the Colorado Front Range. The surface cover is composed of a series of coalescing alluvial fans that were developed along the Front Range during the Pleistocene. The alluvial fans extend eastward approximately 5 miles from their origin near the mouth of Coal Creek Canyon. The industrial area and the Present Landfill are located near the eastern extent of the alluvial-fan deposits. The alluvial fans were deposited on a broad, gently sloping erosional surface, or pediment.

The pediment at the Rocky Flats site is underlain by more than 10,000 feet of gently dipping (less than 2 degrees) Pennsylvanian to Upper Cretaceous sedimentary rocks in the Denver Basin. West of the site these strata are abruptly upturned and form hogback ridges parallel to the Front Range uplift. The slope of the pediment at the Rocky Flats site (approximately 6 degrees) is steeper than the dip of the underlying sedimentary rocks (approximately 1 to 2 degrees). As a result, shallow Upper Cretaceous strata pinch out to the east against the erosion surface rather than plunging down into the subsurface toward the center of the Denver Basin.

Dissection of the gravel-capped pediment has occurred by headward erosion and planation along several eastward-flowing streams and their tributaries, including Rock Creek, Walnut Creek, and Woman Creek. Fluvial processes have formed moderately steep hill slopes adjacent to the stream drainages, with the steepest slopes formed along the tops of the incised drainages. The landfill at OU 7 is located in No Name Gulch at the western limit of headward erosion and pediment dissection.

Waste material has been placed on top of the bedrock and fills the valley to the top of the pediment at approximately 6000 feet. Waste material is confined laterally by the surface-water diversion ditch and by the bedrock slopes of the valley. Thickness of the artificial fill, which includes waste and interim soil cover material, ranges from approximately 5 to 45 feet. Artificial fill is thickest near the centerline of the valley and thinnest around the perimeter of the landfill, inside the surface-water diversion ditch.

Figure 2-6 presents a generalized stratigraphic section for the Rocky Flats site that shows the vertical sequence of surficial deposits and bedrock. Surficial and bedrock geologic units that influence groundwater flow include the Rocky Flats Alluvium and the underlying Arapahoe and Laramie Formations. Also important is the artificial fill material of the landfill, which is not shown on the figure. The Fox Hills Sandstone occurs at a depth of approximately 700 to 800 feet, which is too deep to be affected by the landfill. As such, it is not described.

Figure 2-7 shows the lateral distribution of surficial geologic material at OU 7. Eight cross-sections were constructed to illustrate the lateral and vertical relationships of surficial and bedrock units. The base of waste material, alluvium–weathered bedrock contact, weathered bedrock–unweathered bedrock contact, and potentiometric surfaces shown in the cross-sections were drawn using borehole, monitoring well, and CPT data and extrapolated in between data points. Tables 2-2 and 2-3 present the depths and elevations of the alluvium–weathered bedrock contact and weathered bedrock–unweathered bedrock contact from CPT profiles and boreholes and wells, respectively. The location and dimensions of the groundwater intercept system were obtained from as-built drawings. Figure 2-8 is an index map that shows where the eight cross-section lines are located. Figures 2-9 through 2-16 present geologic cross sections A-A' through H-H'. Horizontal and vertical scales of the cross sections are 1 inch equals 50 feet so there is no vertical exaggeration. Cross-sections A-A', B-B', C-C', D-D', and H-H' show the shape of the buried valley and the distribution of surficial materials along

north-south profiles from the western end of the landfill to the slope below the East Landfill Pond embankment. Cross sections E-E', F-F', and G-G' trend west-east along the centerline of the valley from the upgradient wells through the landfill and the East Landfill Pond to the downgradient wells below the embankment.

2.4.2 *Surficial Geology*

Surficial material consists of Quaternary alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, alluvial deposits of the valley-fill alluvium, and artificial fill (Figure 2-7). The Rocky Flats Alluvium caps the divides north and south of No Name Gulch. Colluvium covers the hillsides down to the drainage or to the East Landfill Pond. Valley-fill alluvium is present along the channel of No Name Gulch downstream of the East Landfill Pond. Artificial fill and disturbed surficial material is present within the boundaries of the landfill, at IHSS 203, and along the surface-water diversion ditch, Upper Church Ditch, and McKay Ditch. Several slumps or small landslides occur on the hillside south of the landfill and are depicted in Figure 2-7. An actively slumping area in the artificial fill material on the northeast side of the landfill is also shown. Seeps were observed along the slope in this area. This may not be the only area at OU 7 with unstable slopes. All surficial deposits are part of the upper hydrostratigraphic unit at the Rocky Flats site, which is discussed in more detail in Section 2.5.1.

2.4.2.1 Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at Rocky Flats (Scott 1965). The alluvium ranges from 0 to 100 feet in thickness. It is thickest west of the Rocky Flats site near the apex of the fans and thinnest just east of the Rocky Flats site near the depositional limit of the fans (EG&G 1992a). The Rocky Flats Alluvium consists of yellowish brown to reddish brown, poorly sorted, coarse bouldery gravel in a silt and clay matrix, with lenses of clay, silt, and sand, and varying amounts of caliche. Generally, the gravels are coarsest grained west of Rocky Flats and become finer grained toward the east. Pebbles, cobbles, and boulders are composed primarily of quartzite, but include lesser amounts of schist, gneiss, granite, pegmatite, sandstone, and siltstone (EG&G 1992a).

Thirteen wells (1086, 5887, 6087, 6687, 7087, 7187, 7287, 76792, 76992, 77392, 70093, 70393, and 70693) located around the perimeter of the landfill are completed in the Rocky Flats

Alluvium (Figure 2-7 and Table 2-4). Thickness of the alluvium is 25 to 30 feet in wells on the north, west, and south sides of the landfill west of the south gate (Figures 2-9, 2-10, 2-11, 2-12, and 2-13, Cross sections A-A', B-B', C-C', D-D', and E-E'), and 10 to 15 feet thick on the divides north and south of the East Landfill Pond east of the south gate (Figure 2-12, Cross section D-D'). The Rocky Flats Alluvium is composed of unconsolidated, yellowish brown to grayish orange, angular to subrounded, poorly sorted, coarse gravel in a clayey sand matrix, with interbeds or lenses of sand, silt, and clay. Pebbles and cobbles are composed of quartzite, granite, and gneiss. Maximum pebble size ranges from 1 to 3 inches in diameter. Caliche was described in drill cores from the ground surface down to the alluvium–bedrock contact at approximately 8 feet near the eastern limit of the Rocky Flats Alluvium on the divides north and south of the East Landfill Pond (wells 7187 and 7287). The caliche occurs in the matrix of gravel-rich zones and in pockets in clay-rich zones. These zones may be discharge points for alluvial groundwater along the hillside above the East Landfill Pond.

2.4.2.2 Colluvium

Quaternary colluvium covers the valley slopes between the pediment on which the Rocky Flats Alluvium is deposited and the No Name Gulch drainage or the East Landfill Pond (Figure 2-7). Colluvial materials have been deposited by slope wash and downward creep of alluvial material and bedrock. Three wells (0586, 0686, and 0786) are completed in the colluvial material, and several wells (0886, B206789, B206889, and B207289) were drilled through colluvium into the underlying bedrock. The colluvium is 1 to 5 feet thick on the slopes around the East Landfill Pond and below the dam (Figure 2-16, Cross-section H H'). The colluvium consists of unconsolidated, moderate to dark brown, structureless clay with some sand and a trace gravel. Soil development has occurred and roots are present down to depths of 3 feet.

2.4.2.3 Valley-Fill Alluvium

Quaternary valley-fill alluvium has been deposited in the No Name Gulch drainage downstream of the East Landfill Pond (Figure 2-7). The alluvium is derived from reworked alluvial material and bedrock. Two wells (4087 and 4287) are completed in valley-fill alluvium, and several wells (4187, B206989, B207089, and B207189) were drilled through valley-fill alluvium into the underlying bedrock (Figure 2-15, Cross section G-G'). The alluvium is 3- to 8-feet thick in the OU 7 area and becomes thicker downstream to the east (12 feet in well 0486). The alluvium

consists of unconsolidated, dusky brown, laminated to structureless clay with lenses of gravel. Gravels have a sandy- to clayey-silt matrix that is often iron stained.

2.4.2.4 Artificial Fill

Three types of artificial fill are present in the vicinity of the landfill: excavated gravels, construction materials, and landfill waste. The first type of artificial fill was derived from excavation of Upper Church Ditch and McKay Ditch and consists of stockpiles of gravel northwest of the landfill (Figure 2-7). This material is presumably disturbed Rocky Flats Alluvium.

The second type of artificial fill consists of materials used to construct the groundwater intercept system, the leachate collection system, and the embankment of the East Landfill Pond. Most of this material is below the ground surface and is not shown on the surficial geology map (Figure 2-7). Clay, coarse sand, and gravel were encountered during drilling of upgradient well B106089 (DOE 1991b). Disturbed claystone, sand, and gravel were encountered during drilling of well 71193 (Figure 2-10, Cross section B-B'). The occurrence of this material is inconsistent with bedding of native materials and has been interpreted as construction material for the groundwater intercept system. Material used to construct the East Landfill Pond embankment was encountered in test holes TH047292 and TH047492 (Figure 2-15, Cross section G-G'). The embankment consists of a clay core that is 40-feet thick surrounded by a clayey sand to gravel shell. Coarse, bouldery riprap covers the embankment slopes on the west side.

The third type of artificial fill consists of waste and daily soil cover material at the landfill. The fill is described in Phase I drill cores as a mixture of clay, sand, and gravel containing asphalt, concrete, insulated wire, wood, paper, plastic, rubber, metal, construction ribbon, surgical gloves, saranex suits, and other materials associated with landfilling activities.

Sixteen wells (6187, 6287, 6487, 6587, 6887, B106089, 71193, 71493, 71693, 71893, 72093, 72293, 72393, 72493, 00393, and 00493) located within the landfill are completed in the artificial fill. Five other wells (5987, 6387, 6787, B206189, and B206389) were originally completed in artificial fill but have since been replaced or abandoned. Waste material interlayered with daily soil cover was encountered in 32 CPTs (CPT00293 through CPT01593, CPT01993, CPT02093, and CPT02293 through CPT03793). Thickness of the artificial fill

ranges from approximately 4 feet at well 6287 to 35 feet at well 72093 and is up to 45 feet at CPT01393 near the centerline of the valley (Figure 2-14, Cross section F-F'). In some cases waste material is encountered throughout the borehole or CPT profile, and in other cases there is some clay, sand, and gravel fill material beneath the waste. The base of the waste material is delineated on each cross section.

2.4.3 Bedrock Geology

Bedrock unconformably underlies the surficial deposits and consists of claystones, siltstones, and sandstones of the Upper Cretaceous Arapahoe and Laramie Formations.

2.4.3.1 Arapahoe Formation

The Upper Cretaceous Arapahoe Formation, as defined in the Phase I geologic characterization report (EG&G 1991d), is approximately 150-feet thick beneath the middle portion of the Rocky Flats site. It contains at least five separate, discontinuous, but mappable sandstone units, designed as the No. 1 through No. 5 sandstones. More recent work, based on field mapping (EG&G 1992a), indicates that the Arapahoe Formation is less than 50-feet thick in the middle portion of the site. The basal Arapahoe sandstone, as defined in the Phase II geologic characterization surface geologic mapping report (EG&G 1992a), is stratigraphically equivalent to the uppermost, or No. 1, sandstone of the Phase I geologic characterization report. Attempts to resolve this controversy are in progress. Regardless of the thickness described for the Arapahoe Formation at the Rocky Flats site, the No. 1 sandstone is the uppermost sandstone unit of significant lateral extent, and it is of concern as a potential migration pathway.

The No. 1 sandstone is a yellowish-gray to dark yellowish-orange, fine-to medium-grained, locally conglomeratic, subangular to subrounded, moderately to poorly sorted, planar-laminated to trough cross-bedded sandstone, with an abundance of grains of well-rounded quartz sand. Conglomeratic sandstone lenses at the base of the unit contain pebbles of chert, ironstone, and rock fragments (EG&G 1992a, Van Horn 1972, and Weimer 1976).

2.4.3.2 Laramie Formation

The Upper Cretaceous Laramie Formation unconformably underlies the Arapahoe Formation and is approximately 600 to 800 feet thick. The Laramie Formation is informally subdivided into two members; the upper member is generally much finer grained than the lower member.

The upper member of the Laramie Formation is approximately 300 to 500 feet thick and consists primarily of olive-gray and yellowish-orange claystones. Four sandstone units (designated as the No. 2, No. 3, No. 4, and No. 5 sandstones) have been identified in the bedrock beneath the No. 1 sandstone and are in the Arapahoe Formation, as defined in the Phase I geologic characterization report or in the Laramie Formation, as defined in the Phase II geologic characterization report and shown in this report (Figure 2-6). Deep boreholes, drilled during the 1991–1992 sitewide geologic-characterization program and targeting these sandstones, encountered siltstone more often than sandstone. Where present the sandstones are olive gray, very fine-grained, subangular, well-sorted, platy-laminated to ripple-laminated, locally calcareous, silty, and clayey. Because they lie within claystones and they are not in hydraulic connection with either the No. 1 sandstone or the surficial deposits, the No. 2 through No. 5 sandstones are probably not significant migration pathways for potential contaminants to groundwater.

The lower member of the Laramie Formation is 300-feet thick and is composed of sandstones, claystones, and coal beds. The sandstones are yellowish gray, very fine- to medium-grained, subangular to subrounded, moderately sorted, thin- to thick-bedded, ripple-laminated to trough cross-bedded and contain abundant plant remains. These sandstone beds are more laterally extensive than sandstone beds in the upper Laramie Formation. Claystones present within the lower Laramie Formation are generally kaolinitic.

2.4.3.3 Undifferentiated Arapahoe and Laramie Formations

In general, the base of the Arapahoe Formation is marked by the presence of medium-grained to conglomeratic sandstones composed of well-rounded, frosted quartz sand grains with pebbles of chert, rock fragments, and ironstone. The lowermost 20 feet of the Arapahoe Formation is shown underlying the Rocky Flats Alluvium on the divides north and south of the unnamed tributary to No Name Gulch in the Phase II geologic characterization report (EG&G

1992a). However, sandstones exhibiting the distinctive characteristics of the basal Arapahoe Formation or No. 1 sandstone are not exposed at the surface nor in any of the drill cores from OU 7. The contact between the Arapahoe and Laramie Formations is difficult to interpret in the absence of the marker or No. 1 sandstone bed. Therefore, in this report, the Arapahoe and Laramie Formations are undifferentiated.

Figure 2-17 shows the topography of the bedrock surface, which has been scoured and shaped by various alluvial and fluvial processes. Features most apparent on the map are the west-trending channel of No Name Gulch, which extends from the present valley below the East Landfill Pond embankment under the pond and landfill to the upgradient wells near the west edge of the map area, and the two smaller northwest- and southwest-trending tributaries. Bedrock highs are evident between the main channel and the smaller tributaries. Weathering of bedrock is dependent on factors such as the abundance of fractures, presence of root zones, elevation relative to the water table, and proximity to drainages and appears most extensively along the drainages.

Weathering is evident in drill cores by color mottling and by the abundance of iron-oxide staining. Weathered and unweathered bedrock are discussed separately because weathered bedrock is considered part of the upper hydrostratigraphic unit (UHSU) at the Rocky Flats site, along with surficial materials. Unweathered bedrock comprises the lower hydrostratigraphic unit (LHSU). The upper and lower hydrostratigraphic units are discussed in more detail in Section 2.5.1.

Weathered Bedrock

Ten wells (B206289, B206589, B206689, B206789, B206889, B206989, B207089, B207289, 70193, and 70493) at OU 7 are completed in weathered bedrock. Thickness of weathered bedrock ranges from 0 feet at well 70893, which is located on the pediment along the southwest edge of the landfill, to 57 feet at CPT00793, which is located near the center of the channel beneath the landfill. Weathered bedrock is thickest in the valley bottom where surface water intermittently flowed down No Name Gulch before it was diverted around the landfill. The lateral and vertical distribution of weathered bedrock is shown in the geologic cross sections (Figures 2-9 through 2-16).

The weathered bedrock is composed primarily of gray to yellowish brown, mottled, structureless claystones and silty claystones containing a trace of carbonaceous material and occasional thin interbeds of siltstone and, less frequently, fine-grained sandstone. Vertical to subvertical fractures are occasionally observed in drill cores. Iron-oxide staining is common. In general, sandstone and siltstone interbeds encountered are less than 10-feet thick. Sandstones are composed of gray to yellowish brown, very fine- to fine-grained, subangular to subrounded, well sorted, friable, quartzose sand.

In the landfill closure plan (Rockwell International 1988a), subcropping sandstones directly underlying the unconsolidated surficial material were described at well locations 6487, 6587, 7087, and 7287 on the south side of the landfill and the East Landfill Pond. Plate 4-3 of the landfill closure plan shows the estimated areal extent of subcropping sandstones based on the thickness in wells 7087 and 7287 and a regional dip of 7 degrees east. A 7-degree dip was also used in proposing that the uppermost sandstone in well 4187 would subcrop underneath the East Landfill Pond. In the OU 7 Phase I work plan (DOE 1991b), subcropping sandstones were described at locations mentioned above and at well B206489. Shallow sandstones within 15 feet of the alluvial–bedrock contact were described in wells B206589 and B206789. Recent sitewide investigations were cited to explain the change in interpretation of regional dip from 7 degrees to 2 degrees east (EG&G 1992a).

Since the landfill closure plan and OU 7 Phase I work plan were completed, drill cores from 1986, 1987, and 1989 wells were relogged using grain-size analysis procedures in Geotechnical SOP GT.01 (EG&G 1992c) as part of the Phase I geologic characterization program (EG&G 1991d). Units that were originally described as sandstones are now described as siltstones and silty claystones. Because the original borehole logs were used for the landfill closure plan and the OU 7 Phase I work plan and the revised borehole logs were used for this report, the presence of interpreted subcropping sandstones has changed.

Based on the revised borehole logs, fine-grained silty sandstones subcrop beneath the alluvium only at well location B207089, which is downgradient of the East Landfill Pond. The subcropping sandstone at well B207089 is laminated, pale yellowish brown to dark yellowish orange, very fine- to fine-grained, moderately to well sorted, silty to clayey sandstone, interbedded with silty claystone and is less than 4-feet thick. This sandstone pinches out approximately 500 feet downstream and is not present at well 4287. Shallow sandstones

(present within 15 feet of the contact between alluvium and bedrock) were encountered in wells 6487 (24.5- to at least 28.0-feet deep — total depth not encountered), located within the landfill on the south side, and B206789 (8.0 to 8.3 feet), located on the southwest shore of the pond. Based on a 2-degree regional dip, these shallow sandstones will not subcrop in the OU 7 area.

Unweathered Bedrock

Six wells (0886, 0986, 4187, 70293, 70593, and 70893) at OU 7 are completed in unweathered bedrock. The lateral and vertical distribution of unweathered bedrock is shown in the geologic cross sections (Figures 2-9 through 2-16).

Unweathered bedrock is composed primarily of dark to very dark gray, laminated to structureless claystones and silty claystones with scattered fragments and stringers of carbonaceous material. Claystones contain occasional thin interbeds of siltstone and sandstone. Sandstones are composed of laminated to cross-laminated, gray to olive gray, very fine- to fine-grained, subangular to subrounded, well-sorted quartzose sands with a trace of mafic minerals and disseminated sulfides. Porosity ranges from 5 to 20 percent and averages approximately 10 percent. Calcite occasionally occurs as a pore-filling cement in thin sandstone beds.

2.4.4 Structural Features

The folded structure of bedrock strata immediately west of the Rocky Flats site results in steeply eastward-dipping exposures of the Laramie Formation and underlying units. These units receive recharge from precipitation along the exposed hogbacks northwest and southwest of the site. Other large-scale features that may significantly affect the direction and rate of groundwater flow are currently under investigation.

Small-scale structural features, such as joints and fractures, are present in bedrock units. Surfaces of joints and fractures are commonly coated with secondary oxide and hydroxide minerals in the weathered portion of bedrock units. Slickensides are also present on some fracture surfaces. The presence of such features increases secondary porosity and permeability and may facilitate groundwater transport through bedrock units by providing preferential flow paths in low-permeability claystones.

2.5 Hydrogeology

The hydrogeology at OU 7 is a function of the general geologic framework, recharge and discharge conditions, physical properties of the aquifer materials, hydrodynamic conditions, and landfill structures. Hydrogeologic data used to characterize OU 7 were compiled from previous landfill investigations (DOE 1991b); sitewide groundwater monitoring, assessment, and protection plans and reports (EG&G 1990a, EG&G 1990b, EG&G 1991e, EG&G 1993c, DOE 1992b, and DOE 1993a); and water-level measurement and hydraulic conductivity test activities of the Phase I RFI/RI field investigation.

Site characterization of the landfill began in 1986. Two well pairs, each consisting of an alluvial and a bedrock well, were installed to characterize the hydrogeology in the vicinity of the landfill (Rockwell International 1988a). One well pair was installed upgradient (0986 and 1086) and the other downgradient (0786 and 0886) of the landfill.

In 1987, 17 additional monitoring wells, 16 alluvial wells, and 1 bedrock well were installed to characterize the site and determine the effectiveness of the groundwater intercept system. Well 5887 was installed upgradient immediately west of the landfill. Eight wells (5987, 6087, 6187, 6287, 6387, 6487, 6587, and 6687) were installed across the groundwater intercept system on the west, north, and south sides. Five wells (6787, 6887, 7087, 7187, and 7287) were installed to evaluate the north and south slurry walls. Three wells (4087, 4187, and 4287), two alluvial and one bedrock, were installed downgradient of the East Landfill Pond embankment to monitor groundwater leaving the landfill. Well 4287 is located downstream of well 4087, just east of the OU 7 map coverage.

In 1989, 13 monitoring wells were installed. Well B106089 replaced well 5987, which was drilled into the clay seal of the groundwater intercept system. Six wells (B206189, B206289, B206589, B206689, B206789, and B207289) were drilled to locate and monitor potential subcropping sandstones around the East Landfill Pond. Two wells (B206389 and B206489) were installed to evaluate the effectiveness of the slurry walls. Two wells (B206889 and B206989) were installed to monitor groundwater in the vicinity of the discharge points for the groundwater intercept system, and two wells (B207089 and B207189) were installed to monitor bedrock sandstones encountered in wells 0886 and 4187.

In 1992 and 1993, 11 boreholes were drilled and 16 monitoring wells were installed as part of the Phase I RFI/RI field investigation for OU 7 (Appendix C). Thirty-six CPTs were also performed. Site characterization was performed using data from 1986 through 1993 wells and boreholes.

Descriptions of the groundwater flow system, drawdown recovery test-data analyses and results, groundwater flow directions and velocities, and the effectiveness of landfill structures are presented in the following sections. Descriptions of Phase I RFI/RI field activities including monitoring well installation, water-level measuring, well development, and drawdown recovery tests are presented in Appendix C. Water-level data are presented in Appendix G. Drawdown recovery test data are presented in Appendix H. Water balance data and calculations are presented in Appendix I.

2.5.1 *Groundwater Flow System*

The UHSU, which corresponds to the uppermost aquifer of the groundwater assessment plan (DOE 1993a), is unconfined and consists of saturated, unconsolidated surficial materials and weathered bedrock. As discussed in Sections 2.4.2 and 2.4.3, surficial materials include the Rocky Flats Alluvium, colluvium, valley-fill alluvium, and artificial fill. Weathered bedrock is composed of undifferentiated Arapahoe and Laramie Formation sandstones and claystones.

Sources of groundwater recharge to the UHSU include infiltration of precipitation, snowmelt, storm runoff, and seepage from ditches, drainages, and the East Landfill Pond. Discharge occurs through evaporation, evapotranspiration, and seepage where the water table intersects the ground surface or surface-water features such as streams, ditches, and ponds. The level of groundwater rises annually in response to spring and summer recharge and declines during the remainder of the year. Groundwater in the UHSU generally flows to the east, but localized flow near the landfill may be altered due to stresses induced by the groundwater intercept system. In the incised stream valley, groundwater flows toward the drainage or the East Landfill Pond, following the topography. Groundwater in No Name Gulch flows to the east in the valley-fill materials and intermittently discharges as subsurface flow across the eastern boundary of the Rocky Flats site.

The LHSU is generally confined and consists primarily of unweathered bedrock claystone with isolated sandstone units. Each sandstone bed in the LHSU could be considered a separate hydrostratigraphic unit.

Sources of groundwater recharge to the LHSU include infiltration of precipitation in outcrop areas, leakage from alluvial gravels of the UHSU in subcrop areas west of the landfill, and possibly seepage from weathered bedrock of the UHSU. Discharge may occur where sandstone units intersect incised stream valleys. Groundwater in the LHSU generally flows to the east, from recharge areas west of OU 7 toward discharge areas along incised stream valleys.

2.5.2 *Drawdown Recovery Test Data Analysis and Results*

Drawdown recovery test data were analyzed with AQTESOLV software (Geraghty and Miller 1991) using the Bouwer and Rice (1976) and Bouwer (1989) solution method for unconfined aquifers and the Cooper et al. (1967) solution method for confined aquifers. Well 70593, which is completed in a confined aquifer, was analyzed using both methods to compare and verify the results. Hydraulic conductivity estimates for well 70593 are within an order of magnitude for both methods. Hydraulic conductivities were calculated for surficial materials of the UHSU and for several sandstone and siltstone beds of the LHSU. Time-drawdown plots for each test, with best-fit lines used to estimate hydraulic conductivity, are presented in Appendix H. Appendix H also presents tables that compare parameter terminology for the Bouwer and Rice and Cooper et al. methods (Table H-1), list input parameters for each test (Table H-2), and list test-data file names (Table H-3). The test-data files are presented in digital format.

2.5.2.1 The Bouwer and Rice Method

The Bouwer and Rice method was developed specifically for the analysis of drawdown recovery tests and provides order of magnitude estimates of hydraulic conductivity (Bouwer and Rice 1976, Bouwer 1989). For the purpose of calculating hydraulic conductivity, the AQTESOLV program allows the user to choose among two curve matching techniques: (1) automated curve matching generated by iterative nonlinear least-squares numerical methods and (2) visual curve matching. The visual curve matching technique was the preferred method of analysis because it allows the user to neglect the data points representing pore drainage

from within the filter pack (initial steep curve on the time-drawdown plot) (Bouwer 1989). Data points representing radial flow through void spaces in the landfill were also neglected (initial steep curve on the time-drawdown plot). Type curves for the Bouwer and Rice method are presented in Appendix H (Figure H-1). The Bouwer and Rice equation, which was developed from the Thiem equation to solve for hydraulic conductivity (K), is as follows:

$$K = \frac{r_c^2 \ell n(R_e / r_w)}{2L_e} \frac{1}{t} \ell n (y_0 / y_t)$$

where:

K = hydraulic conductivity [L/T]
r_c = radius of casing or riser pipe where the head is rising (or falling) [L]
R_e = effective radial distance over which the head is dissipated [L]
r_w = horizontal distance to the undisturbed aquifer (borehole radius) [L]
L_e = length of open section (screen) [L]
t = time
y_o = head at time t_o (start of test) [L]
y_t = head at time t ($t>t_o$) [L]
[ ] = units in which terms are expressed; L = length, T = time

The parameters r_w, L_e, and r_c were determined from the well construction geometry (reported in Table 2-4 and shown in well construction diagrams presented in Appendix F). The radius of the well (r_w) was considered as the radius of the borehole reported on the well construction logs. L_e was considered to be the vertical length between the top and bottom of the slotted-screen section of the well for wells in which the screened section was fully saturated before the slug was introduced. For wells in which the depth to water was within the screened interval, L_e was calculated as the length of the saturated screen interval. In general, the parameter r_c was taken as the radius of the well casing when the static water level was above the screened section. However, when the water level was within the screened interval, an adjustment was made to the casing radius (r_c) value to compensate for the thickness and high porosity of the sand pack around the well screen. This adjustment was made because the sand pack normally drains at a quicker rate than the surrounding aquifer when the screened interval is not fully saturated.

2.5.2.2 The Cooper Method

The Cooper method (Cooper et al. 1967) mathematically defines the hydraulic properties of the surrounding saturated formation after a known volume of water is instantaneously injected or withdrawn from a well of finite diameter. Observed hydraulic head displacement versus time

plots are compared to a set of type curves for the determination of transmissivity (T) and storativity (S) (Appendix H, Figure H-2). Hydraulic conductivity was calculated from the transmissivity and storativity values. Visual curve matching was used and data points representing pore drainage from within the filter pack were neglected. The Cooper method is based on the following equation:

$$H/H_0 = \frac{8\alpha}{\pi^2} \int_0^\infty \frac{e^{-\beta u^2/\alpha}}{u\cdot\{[uJ_0(u) - 2\alpha J_1(u)]^2 + [uY_0 - 2\alpha Y_1(u)]^2\}}\, du$$

Laplace solution for response in well:

$$\bar{h} = \frac{T_w S H_0 K_0(rq)}{T q [r_w q K_0(r_w q) + 2\alpha K_1(r_w q)]}$$

$$q = (pS/T)^{1/2}$$

p = Laplace transform variable

where:

H = head in well at time t [L]
H_0 = initial head in well due to slug injection or withdrawal [L]
a = $r_w^2 S/r_c^2$ [dimensionless]
r_w = effective radius of well [L]
r_c = internal radius of well casing [L]
β = Tt/r_c^2
J_0 = Bessel function of first kind, zero order
J_1 = Bessel function of first kind, first order
Y_0 = Bessel function of second kind, zero order
Y_1 = Bessel function of second kind, first order
K_0 = modified Bessel function of second kind, zero order
K_1 = modified Bessel function of second kind, first order
[ ] = units in which terms are expressed; L = length

2.5.2.3 Drawdown Recovery Test Results

Table 2-5 presents the drawdown recovery test results from the Phase I RFI/RI. The drawdown recovery tests provide approximations of hydraulic conductivity; however, there are limitations associated with the tests. Water levels may not have stabilized before the tests were performed due to slow recharge rates in bedrock wells in the LHSU, such as wells 70593 and 70893. Estimated hydraulic conductivities are only representative of the material a few radial feet around the borehole because of the small radius of influence of the drawdown stress. Test

results obtained from partially penetrating wells may not be representative of the entire saturated thickness of the formation because of geologic heterogeneity.

Hydraulic conductivity estimates for surficial materials in the UHSU range from 4.05×10^{-4} to 2.99×10^{-5} centimeters per second (cm/sec) for the Rocky Flats Alluvium, 6.20×10^{-5} to 5.90×10^{-6} cm/sec for artificial fill without waste material, 1.35×10^{-4} to 9.62×10^{-6} cm/sec for artificial fill with waste material, and 1.29×10^{-6} to 1.48×10^{-7} cm/sec for weathered bedrock. The high hydraulic conductivities for artificial fill with waste material indicate the presence of void spaces within the landfill debris. The low hydraulic conductivities for weathered bedrock reflect its composition (clayey siltstone and claystone). Hydraulic conductivity estimates for unweathered bedrock in the lower hydrostratigraphic unit range from 4.73×10^{-7} cm/sec for fine-grained sandstones to 5.90×10^{-7} cm/sec for siltstones.

Table 2-6 compares hydraulic conductivity values calculated for the Phase I RFI/RI at OU 7 to hydraulic conductivity values obtained from previous investigations at the landfill and values in the literature. There are fewer significant Figures for the values in this table than in Table 2-5 because of the uncertainty of the methodologies used to analyze historical aquifer test data. Phase I RFI/RI hydraulic conductivity estimates for surficial materials and bedrock are within an order of magnitude of values obtained from previous investigations and values in the literature.

Figures 2-18, 2-19, and 2-20 present the areal distribution of hydraulic conductivity values for surficial materials, weathered bedrock, and unweathered bedrock, respectively, using data from the Phase I RFI/RI and previous investigations. The Figures also show whether values were obtained from drawdown recovery tests or slug tests. No distinct trends are apparent on any of the maps; however, the range of hydraulic conductivity values varies by an order of magnitude on each map. Hydraulic conductivity ranges from 10^{-3} to 10^{-6} cm/sec for surficial materials, 10^{-6} to 10^{-7} cm/sec for weathered bedrock, and 10^{-7} to 10^{-8} cm/sec for unweathered bedrock. The large range for surficial materials is a result of the high variability of constituent materials, which include clay, silt, sand, gravel, and waste material. Many geologic materials display an order of magnitude variability in saturated hydraulic conductivity (Jury 1985).

2.5.3 Groundwater Flow

Groundwater elevation data from 34 monitoring wells were used to construct potentiometric maps of saturated surficial materials for the months of December 1992, January 1993, February 1993, and March 1993 (Figures 2-21 through 2-24). Groundwater elevation data from 12 monitoring wells were used to construct potentiometric maps of weathered bedrock for the same four months (Figures 2-25 through 2-28). These maps show that the configuration of the potentiometric surfaces and hydraulic gradients changed little during that four-month period. Historical groundwater elevation data indicate that water levels are generally lower from December through March. Groundwater elevations are presented in Table 2-7 and well construction details are summarized in Table 2-4.

Groundwater elevations from several monitoring wells were below the reported elevation of the bottom of the well screen and/or the top of weathered bedrock (Table 2-8). The surficial materials or weathered bedrock at most of these monitoring well locations was assumed to be unsaturated for the purpose of constructing potentiometric maps. Surficial materials at well B206389 were not considered unsaturated because measured water levels were below the screened section but above the weathered bedrock contact.

The groundwater flow observations discussed in this section are based on the configuration of the potentiometric and isopach map surfaces presented in Figures 2-21 through 2-28 and Figures 2-29 and 2-30, respectively. Hydraulic gradients were determined by calculating the change in hydraulic head along the flowpath distance between two points. Three flow paths were chosen to account for the observed change in hydraulic gradient from the main landfill area to the East Landfill Pond drainage area. Well pair 5887/72293 was selected for measuring the flow path distance in the main landfill area; well pair B206389/0786 was selected for the flow path distance in the East Landfill Pond drainage area; and piezometer–well pair TH047492/4187 was selected for the flow path distance along the East Landfill Pond embankment. Hydraulic head differences were determined from the potentiometric surfaces (Figures 2-21 through 2-28).

The potentiometric maps show that surficial groundwater within the Present Landfill generally flows to the east along the buried drainage. The isopach maps confirm that areas of greatest saturated thickness occur along this buried drainage. The vertical hydraulic gradients between

surficial and weathered bedrock groundwater generally show a downward component of flow. This suggests that contaminated surficial leachate–groundwater may be affecting the groundwater quality in weathered bedrock.

2.5.3.1 Groundwater Flow in Surficial Materials

Based on the potentiometric maps, the U-shaped patterns of the equipotential lines indicate that groundwater flow inside the intercept system is directed toward the center of the landfill. However, the major component of flow is to the east (Figures 2-21 through 2-24). The mean hydraulic gradient computed from the monthly potentiometric maps is 0.030 (Table 2-9). Groundwater flow in the East Landfill Pond drainage and east of the pond embankment appears to be topographically controlled, with flow from the west, north, and south directed toward the East Landfill Pond or No Name Gulch. The mean hydraulic gradient is 0.128 for the East Landfill Pond drainage and 0.16 for the East Landfill Pond embankment.

The saturated thickness maps show three areas where surficial materials are unsaturated (Figures 2-29 and 2-30). One consistently unsaturated area is located on the ridge south of the East Landfill Pond; a second is located at the southwest end of the landfill at well 71693; and the third is located in No Name Gulch east of the East Landfill Pond embankment.

The saturated thickness of surficial materials is greatest near the center of the landfill in the vicinity of wells 72093 and 72293 (Figures 2-29 and 2-30). The concentric patterns of the isopach lines in this area suggest that recharge may be occurring by groundwater flow under or through the north groundwater intercept system. The geologic cross section presented in Figure 2-11 shows that this area is coincident with a depression in the weathered bedrock surface. Groundwater inflow may occur in this area where the groundwater intercept system is not keyed into bedrock.

2.5.3.2 Groundwater Flow in Weathered Bedrock

Similar to flow in surficial materials, groundwater in weathered bedrock generally flows to the east (Figures 2-25 through 2-28). The mean hydraulic gradient computed from potentiometric maps is 0.030 (Table 2-9). Groundwater flow in the East Landfill Pond drainage and east of the pond embankment is topographically controlled and flows from the west, north, and south toward the pond. The mean hydraulic gradient is 0.103 for the East Landfill Pond drainage and

0.254 along the East Landfill Pond embankment. Weathered bedrock on the ridge south of the pond was unsaturated from December 1992 through March 1993. Weathered bedrock beneath No Name Gulch was unsaturated in February and March 1993.

2.5.3.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients were calculated using groundwater elevations from four well pairs (Table 2-10). A well pair consists of two wells, one screened across surficial materials and the other screened across weathered bedrock. The vertical hydraulic gradients vary from December 1992 through March 1993 because of monthly changes in groundwater elevations. Vertical hydraulic gradients were calculated using methods in the 1992 annual RCRA groundwater monitoring report (EG&G 1993c). These calculations were based on the assumption that the measured hydraulic head values were obtained from homogeneous and isotropic groundwater flow systems. The method used to calculate vertical hydraulic gradients is explained in Table 2-10.

The vertical hydraulic gradients calculated range from 0.070 to 0.561 for well pair 6487/B206189, 0.388 to 0.599 for well pair 4087/B207089, and 0.098 to 1.103 for well pair 70393/70493. The vertical gradients generally indicate a downward component of flow. The vertical hydraulic gradient calculated for well pair 70093/70193 ranges from -0.057 to 0.024. The negative vertical gradient during January 1993 at this well pair indicates an upward component of flow.

Vertical hydraulic gradients were also calculated for well pair 72393/72093. Both of these monitoring wells are completed in artificial fill but are screened across separate intervals. Well 72393 is screened across the upper 7 feet of saturated material, and well 72093 is screened across the bottom 5 feet of saturated material. The calculated vertical hydraulic gradients range from 0.005 to 0.003 at this well pair (Table 2-10). The low vertical gradient indicates a relatively slow downward component of flow through artificial fill at this location.

2.5.3.4 Groundwater Flow Velocities

Groundwater flow velocities calculated for saturated surficial materials and weathered bedrock approximate advective transport rates for dissolved constituents. In the 1992 annual RCRA groundwater monitoring report (EG&G 1993c), an assumed effective porosity of 0.1 had been

used to calculate groundwater flow velocities within the Present Landfill area. However, estimated porosity values reported on the borehole logs are often greater than 0.1 for weathered bedrock (Appendix E). In addition, the effective porosity of surficial materials within the landfill may be slightly higher than 0.10 as a result of the presence of void spaces. Because of the uncertainty of the actual effective porosity values, an assumed range of effective porosity values (0.1 to 0.2) was used to calculate the groundwater flow velocities presented in Table 2-11.

Horizontal Groundwater Flow Velocities in Surficial Materials

Average linear groundwater flow velocities for surficial materials within the Present Landfill were calculated along three flow paths to account for the steeper gradients in the East Landfill Pond drainage area and the East Landfill Pond embankment (Table 2-11). Input parameters for the calculation include geometric mean hydraulic conductivity values, effective porosity (0.1 to 0.2), and mean hydraulic gradients for well pairs along the flow paths. Geometric mean hydraulic conductivity values for artificial fill (2.99×10^{-5} cm/sec) and colluvium (1.59×10^{-4} cm/sec) were estimated using drawdown recovery test data for wells 71193, 71493, 71893, 72093, 72293, and 72393 (Table 2-6). The geometric mean hydraulic conductivity value (1.59×10^{-4} cm/sec) for the Rocky Flats Alluvium, estimated using drawdown recovery test data for wells 70093, 70393, and 70693, was used for colluvium within the East Landfill Pond drainage area. A hydraulic conductivity value of 1.27×10^{-7} cm/sec, measured at piezometer TH047492 (EG&G 1993e), was used for the East Landfill Pond embankment. The average linear groundwater flow velocity in the landfill ranges from 9.28 feet per year (ft/yr) to 4.64 ft/yr (well pair 5887/72293). The average linear groundwater flow velocity in the colluvial material in the East Landfill Pond drainage area ranges from 210.57 ft/yr to 105.29 ft/yr (well pair B206389/0786). Average linear groundwater flow velocities through the East Landfill Pond embankment are greatly retarded as a result of the clay core and range from 0.21 ft/yr to 0.10 ft/yr (piezometer–well pair TH047492/4187).

Groundwater Flow Velocities in Weathered Bedrock

Average linear groundwater flow velocities for weathered bedrock were calculated along three flow paths (Table 2-11). Input parameters for the calculation include a geometric mean hydraulic conductivity value of 4.37×10^{-7} cm/sec estimated using drawdown recovery test data

for wells 70193 and 70493, assumed effective porosity values ranging from 0.1 to 0.2, and mean hydraulic gradients for well pairs along the flow paths. Average linear groundwater flow velocities range from 0.14 ft/yr to 0.07 ft/yr in the landfill area (well pair 5887/72293). Average linear groundwater flow velocities in the East Landfill Pond drainage range from 0.47 ft/yr to 0.23 ft/yr (well pair B206389/0786). Average linear groundwater flow velocities through the East Landfill Pond embankment range from 1.15 ft/yr to 0.57 ft/yr (piezometer–well pair TH047492/4187). In general, the groundwater flow velocities in weathered bedrock are one to three orders of magnitude lower than the groundwater flow velocities in surficial materials.

2.5.4 Effectiveness of Landfill Structures

The effectiveness of landfill structures can be evaluated using historical groundwater elevation data and TDS data.

2.5.4.1 Well Hydrograph Comparison

Well hydrographs were constructed for 25 monitoring wells completed in surficial materials to compare water levels upgradient and downgradient of the landfill structures. These wells are located along five north-south transects (AA-AA', BB-BB', CC-CC', DD-DD', and EE-EE') and one east-west transect (FF-FF') (Figure 2-31). The well hydrographs, presented in Figures 2-32 through 2-37, are used in conjunction with the potentiometric (Figures 2-21 through 2-28) and isopach (Figures 2-29 and 2-30) maps to assess the effectiveness of landfill structures.

Transect AA-AA': Evaluation of the North and South Sides of the Groundwater Intercept System

The well hydrograph presented in Figure 2-32 shows that water levels within the groundwater intercept system are lower than water levels upgradient or outside the system. Well 71693, located within the groundwater intercept system, was consistently dry while the saturated thickness on the upgradient side approaches 9 feet at well 71893 (Figure 2-32). The tightly spaced configuration of the isopach lines between wells 71893 and 71693 (Figures 2-29 and 2-30) indicate that groundwater is being drawn toward the groundwater intercept system in this area. The isopach lines upgradient of the north side of the groundwater intercept system (between wells 70093 and 71193) also indicate that groundwater is being drawn toward the intercept system. The hydrograph for well 71493 shows that water levels have remained

constant and suggests that the leachate collection system is working properly, assuming there is a line sink controlling head in the vicinity, or that well 71493 is actually situated outside of the intercept system near the perforated drain.

Transect BB-BB': Evaluation of the North Side of the Groundwater Intercept System

The well hydrograph presented in Figure 2-33 shows that the water levels within the intercept system are generally lower than the water levels outside of the system. Well 6287 is situated upgradient of the intercept system near the drain (refer to cross section C-C', Figure 2-11). If the drain was working properly, the induced drawdown would have a noticeable impact on the water levels at well 6287. However, the water levels at this monitoring well show seasonal fluctuations similar to those observed in wells 6087 and 6187, situated upgradient of the influence of the drain, which suggests that the perforated drain near this location is not working properly. The configuration of the isopach (Figures 2-29 and 2-30) and potentiometric (Figures 2-21 through 2-24) maps indicate a source of recharge to the center part of the landfill. The recharge may occur by groundwater flow under or through the north intercept system. The potential cause of failure in the groundwater intercept system is illustrated in geologic cross section C-C' (Figure 2-11) and shows that the intercept system is not keyed into bedrock, indicating that groundwater may be flowing underneath the system. Groundwater inflow may also be occurring through a breach in the clay barrier.

Transect CC-CC': Evaluation of the South Side of the Groundwater Intercept System

Figure 2-34 shows that water levels outside or upgradient of the intercept system are higher than water levels within the system. Seasonal water-level fluctuations in wells 6587 and 6687 (located outside of the intercept system) are similar in magnitude to fluctuations observed in well 6487 (located inside of the system). Apparently these wells are situated beyond the extent of the drawdown influence induced by the groundwater intercept system. The isopach maps (Figures 2-29 and 2-30) indicate that the groundwater intercept system is effectively diverting groundwater in this area. The difference in saturated thicknesses (Figure 2-29) between wells 6587 (8.03 feet) and 6487 (3.1 feet) confirm the effectiveness of the intercept system along transect CC-CC'.

Transect DD-DD': Evaluation of the North Slurry Wall

The well hydrograph presented in Figure 2-35 allows a comparison of the groundwater elevation data from a well pair (6787/6887) that straddles the north slurry wall. The hydrograph shows that water levels in these two wells are generally within two tenths of a foot of one another. The isopach maps (Figures 2-29 and 2-30) show that the saturated thicknesses at wells 6787 and 6887 are nearly identical (within a hundredth of a foot). Based on the well hydrograph and isopach maps, groundwater appears to be flowing over and/or through the slurry wall. However, based on supporting evidence from the 1991 ground-penetrating radar investigation (see Section 1.4.4), it is possible that the well pair was not properly positioned on either side of the slurry wall or that the slurry wall does not extend this far to the east. In either case, the north slurry wall is not effective in diverting groundwater away from the landfill.

Transect EE-EE': Evaluation of the South Slurry Wall

The well hydrograph used to evaluate the effectiveness of the south slurry wall is presented in Figure 2-36. Generally, water levels inside of the slurry wall are lower (2 to 6 feet at well B206389) than water levels measured outside of the slurry wall. The potentiometric (Figures 2-21 through 2-24) and isopach (Figures 2-29 and 2-30) maps indicate that groundwater flow is being diverted away from the landfill in this area. The isopach maps also show that saturated surficial materials are slightly thicker on the upgradient side of the south slurry wall, confirming the effectiveness of the system at this location.

Transect FF-FF': Evaluation of the West Side of the Groundwater Intercept System

The well hydrograph presented in Figure 2-37 shows seasonal water-level fluctuations of 3 to 5 feet in well B106089 compared to fluctuations of approximately 10 feet observed in wells located farther way from the intercept system. This suggests that drawdown induced by the drain is affecting seasonal water-level fluctuations at well B106089. Based on these observations it appears that the perforated drain (refer to cross section E-E', Figure 2-13) is working properly in this area. Water levels outside of the system are consistently lower in wells situated near the groundwater intercept system suggesting a downward gradient toward the drain. The potentiometric (Figures 2-21 through 2-24) and isopach (Figures 2-29 and 2-30) maps also indicate that groundwater is being drawn toward the intercept system. Figure 2-30

shows that the saturated surficial materials are thicker on the upgradient side of the intercept system (9.71 feet at well 0986), verifying that groundwater is being diverted around the landfill in this area.

Evaluation of the Leachate Collection System

As discussed in Section 1.3.3, the leachate collection system drains to the buried West Landfill Pond, located in the vicinity of wells 72293 and 72493. Geologic cross section D-D' (Figure 2-12) illustrates the location of these wells with respect to the bottom of the buried drainage and the West Landfill Pond. The saturated thickness of landfill material near wells 72293 and 72493 is approximately 10 feet (Figures 2-29 and 2-30), which indicates preferential flow of groundwater and leachate to this area of the landfill. However, it is unlikely that the recharge to this area has occurred as discharge from the buried leachate collection system. Instead the 10 feet of saturated thickness at this location is probably a reflection of preferential flow within the buried drainage, as suggested by the configuration of the potentiometric surface (Figures 2-21 through 2-24) and saturated thickness (Figures 2-29 and 2-30) maps. Therefore, the volume of discharge from the leachate collection system is probably minimal.

2.5.4.2 Groundwater Quality Comparison

The distribution of TDS was used to evaluate the effectiveness of landfill structures. Comparison of groundwater quality data, for the purpose of evaluating the effectiveness of the groundwater intercept system, is based on the null hypothesis that TDS concentrations in groundwater outside of the intercept system are statistically different than TDS concentrations in groundwater inside of the intercept system.

The confidence interval width about the mean was calculated using observations from each monitoring well location (Figure 2-38) to test the previously stated null hypothesis. The following equation (Sanders et al. 1983), based on the assumption that the observations are normally distributed and are independent of each other, was used to calculate the confidence interval (CI):

$$CI = \bar{X} \pm t_{\alpha/2}(s/\sqrt{n})$$

where:

$\overline{X}$ = mean
$t_{\alpha/2}$ = tabulated "t" value at a specified level of significance
s = standard deviation
n = number of observations
CI = confidence interval width about the mean

In practice, the normal distribution assumption may be validated by the Central Limit Theorem, which applies to sample populations where the number of observations approach 10, regardless of the underlying distribution (Sanders et al. 1983). Therefore, the normal distribution assumption is justified for the data sets used to calculate TDS confidence interval widths because the number of samples in each data set are either greater than or approach 10 observations (Table 2-12). In addition, quarterly and/or monthly samples were assumed independent for this analysis. The confidence interval widths were computed using a confidence level of 90 percent with a two-tailed level of significance $\alpha/2$. The "t" constant value is a function of degrees of freedom and probability of nonexceedance and was obtained from tabulated values presented by Sanders et al. (1983). Input parameters and computed confidence interval widths are summarized in Table 2-12. Confidence interval widths were not calculated for wells with a limited number of observations; instead the range and mean were used to compare TDS concentrations.

The spatial distribution of TDS concentrations in surficial groundwater within the Present Landfill area are presented in Figure 2-38. The map shows that TDS concentrations in general are significantly greater in the landfill within the groundwater intercept system. However, groundwater quality outside of the intercept system may be affected by upgradient contaminant sources or by waste material disposed beyond the perforated drain. A map showing the distribution of TDS concentrations in UHSU groundwater at OU 7 is presented in Section 4.

TDS concentrations in wells located along Transect AA-AA' (Figure 2-31) [wells 70093 (170 milligrams per liter [mg/L]), 71193 (170 mg/L to 280 mg/L), and 71493 (170 mg/L to 270 mg/L)] are similar. The similarity of TDS concentrations at these three wells suggests that the north groundwater intercept system is failing at this location. The TDS concentrations at these locations are also significantly lower than TDS concentrations observed in nearby wells 72393 (1300 mg/L) and 72093 (1200 mg/L) in the landfill indicating that waste material is probably not buried beyond the intercept system in this area.

TDS concentrations within the intercept system are significantly greater than concentrations outside of the intercept system for wells located along Transect BB-BB' (Figure 2-31). Groundwater quality does not appear to be affected by waste material outside the intercept system in this area. Groundwater flow under the north side of the groundwater intercept system may be diluting TDS concentrations in wells 6387 (Cl = 556 mg/L to 502 mg/L), 72393 (1300 mg/L), and 72093 (1200 mg/L) because the concentrations are much lower than elsewhere in the landfill (i.e., well 72293, 1700 mg/L).

In reference to the wells located along Transect CC-CC' (Figure 2-31), TDS concentrations in well 6487 (Cl = 380 mg/L to 298 mg/L), located within the intercept system, are significantly greater than TDS concentrations in well 6587 (Cl = 249 mg/L to 215 mg/L), located outside the system. This indicates that the south side of the groundwater intercept system is diverting groundwater around the landfill. Well hydrograph (Figure 2-34) and isopach maps (Figures 2-29 and 2-30) confirm this interpretation. However, elevated TDS concentrations in well 6687 (Cl = 441 mg/L to 242 mg/L) imply that waste material or an upgradient contaminant source may have an impact on groundwater quality in this area.

TDS concentrations in wells 6787 (Cl = 191 mg/L to 160 mg/L) and 6887 (Cl = 216 mg/L to 176 mg/L) located along Transect DD-DD' (Figure 2-31) are similar to TDS concentrations in upgradient wells 70093 (170 mg/L) and 70393 (190 mg/L). The TDS concentrations in wells 6787 and 6887 suggest that buried waste material does not extend this far to the north and that the well pair does not straddle the north slurry wall. As suggested by the results of the ground-penetrating radar investigation (see Section 1.4.4), the north slurry wall may actually be located farther to the south or may not extend this far to the east.

In reference to the wells located along Transect EE-EE' (Figure 2-31), the TDS concentrations in well B206389 (Cl = 726 mg/L to 619 mg/L), located downgradient of the south slurry wall, are significantly greater than the TDS concentrations in wells 7287 (Cl = 372 mg/L to 321 mg/L) and B206489 (405 mg/L to 359 mg/L), located upgradient of the south slurry wall. The distribution of TDS concentrations along the EE-EE' transect suggest that groundwater is diverted away from the south slurry wall, which is supported by the well hydrograph (Figure 2-36) and isopach maps (Figures 2-29 and 2-30). However, TDS concentrations in wells 7287 and B206489 are significantly higher than TDS concentrations in upgradient wells 70093 (170

mg/L) and 70393 (190 mg/L) suggesting that the groundwater quality in this area may be affected by contaminant sources in IHSSs 166.1, 166.2, and 166.3.

TDS concentrations in well B106089 (Cl = 406 mg/L to 301 mg/L), located close to the groundwater intercept system, are significantly greater than the TDS concentrations in wells 5887 (Cl = 182 mg/L to 154 mg/L), 1086 (Cl = 147 mg/L to 125 mg/L), and 70393 (190 mg/L), which are located farther away. The elevated TDS concentrations in well B106089 indicate that groundwater quality may be affected by contaminant sources in IHSS 203 or by waste material buried beyond the intercept system (Transect FF-FF' [Figure 2-31]).

2.5.4.3 Significance of Comparisons

The groundwater elevation data (potentiometric maps, isopach maps, and well hydrographs) indicate that the groundwater intercept system is functioning effectively except on the north side between Transects AA-AA' and BB-BB'. The isopach maps show that groundwater flow is occurring under and/or through the groundwater intercept system in this area. There is also compelling evidence based on the groundwater elevation data that the south slurry wall is effectively diverting groundwater around from the landfill. Based on supporting evidence from the 1991 ground-penetrating radar investigation (Section 1.4.4) and the TDS distribution map, it is apparent that the north slurry wall is not effective in diverting groundwater away from the landfill.

The TDS distribution map shows that maximum TDS concentrations in surficial materials occur within the groundwater intercept system, with the highest concentrations in the center of the landfill. Elevated TDS concentrations are observed in wells located beyond the limit of the groundwater intercept system and slurry walls along the western and southern perimeter of the landfill. The groundwater quality outside of the south slurry wall may be affected by contaminant sources in the PU&D yard and in IHSSs 166.1, 166.2, and 166.3. Waste material buried beyond the limit of the intercept system may be affecting groundwater quality along the western and southwestern perimeter of the landfill.

2.6 Surface-Water Hydrology

Surface-water hydrology at OU 7 is controlled by natural drainages, ditches, a surface-water diversion system, a subsurface drainage control system, a detention pond, a spray evaporation

system, and surface-water runoff. Hydrologic data used to characterize OU 7 were compiled from previous landfill investigations (DOE 1991b and EG&G 1991f), sitewide drainage and flood-control reports (EG&G 1992d and 1992e), precipitation data (Pamp 1993), and pond water elevation measurements, flow rate measurements, and pond sediment coring activities of the Phase I RFI/RI. Descriptions of the landfill structures and interim response actions are included in Section 1.3.3. Descriptions of natural surface-water features, surface-water runoff, infiltration through the existing soil cover material, and groundwater–surface water interactions are presented in the following sections. A water balance is calculated for the East Landfill Pond drainage basin and the Present Landfill area. The water balance models quantify the change in groundwater/leachate storage within the Present Landfill area and change in storage of the East Landfill Pond. Water balance data for the OU 7 watershed are presented in Appendix I.

2.6.1 Drainages and Ditches

The Rocky Flats site is drained by three intermittent streams and their tributaries: Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2). Flow is generally from west to east and occurs mainly after precipitation events or during spring snowmelt.

The Walnut Creek drainage basin occupies approximately 3,110 acres from the base of the foothills near the mouth of Coal Creek Canyon, through the Rocky Flats site, to Great Western Reservoir. Walnut Creek is comprised of three tributaries: No Name Gulch, North Walnut Creek, and South Walnut Creek. These tributaries drain the central and northeastern area of the Rocky Flats site, including the northernmost portion of the industrial area. The three tributaries converge in the northeast buffer zone west of Indiana Street. From this confluence, the Walnut Creek drainage extends approximately 1 mile east to Great Western Reservoir. Just east of the plant boundary, water from Walnut Creek is diverted around Great Western Reservoir to Big Dry Creek via the Broomfield Diversion Canal, which is an offsite canal operated by the city of Broomfield.

There are seven water supply ditches that occur in the Rocky Flats drainage system. Two ditches, McKay Ditch and Upper Church Ditch, are located just north of OU 7 in the Walnut Creek drainage basin (Figure 2-1). McKay Ditch conveys water from Coal Creek to Great Western Reservoir via Walnut Creek. Upper Church Ditch conveys water from Coal Creek

directly to Great Western Reservoir for storage purposes. These ditches have not diverted water since 1989 (Weatherbee 1993).

Surface-water flow to the landfill is controlled by a diversion ditch constructed around the north, west, and south perimeter of the landfill. The north and south branches of the ditch discharge into small natural drainages that flow to points downslope of the East Landfill Pond embankment in No Name Gulch. Standing water may be observed in sections of the ditch after a significant storm event or snowmelt.

2.6.2 *Landfill Seep*

Surface-water sampling station SW097 is located at the base of the east face of the landfill where leachate seeps from the landfill into the East Landfill Pond. During field activities for the Phase I RFI/RI field investigation at OU 7, leachate flow rates were estimated between 0.01 and 0.02 cubic feet per second (cfs). Table 2-13 shows historical flow rates measured at station SW097. These data are incomplete and not consistent with other discharge monitoring efforts. In August 1990, landfill leachate discharge was measured using a temporarily installed 8-inch Palmer-Bowlus flume. The flow rate was measured at 0.015 cfs (EG&G 1991f).

2.6.3 *Intercept System Discharge Points*

Surface-water sampling stations SW099 and SW100, located downslope in No Name Gulch, are discharge points. A series of valves control the discharge points of the groundwater intercept system. During the four-month Phase I field investigation at OU 7, intercepted groundwater was presumably discharged into the East Landfill Pond rather than No Name Gulch. No flows were observed at station SW100, the southern groundwater intercept discharge point. Flow was observed once, in March 1993, at station SW099, the northern groundwater intercept discharge point. Discharge was measured at a flow rate of 0.003 cfs. The water in the concrete weir may have originated from snowmelt or precipitation instead of being discharged from the groundwater intercept system.

2.6.4 *East Landfill Pond and Spray Evaporation System*

The East Landfill Pond and surrounding slopes are considered a subbasin within the OU 7 watershed and are referred to as the East Landfill Pond drainage basin. The pond is recharged

by groundwater, leachate, and surface-water runoff from the landfill and surrounding slopes. Surface-water sampling station SW098 is located in the central east section of the pond adjacent to the dam. Water surface elevations are recorded at this site during sampling events. Historical water surface elevations for station SW098 range from 5,919.0 to 5,920.5 feet.

Water loss from the pond consists of natural and controlled evaporation. The pond water volume fluctuates seasonally. On average, the volume occupies 2.5 surface area acres. An emergency spillway, located at the southeast corner of the pond (Figure 2-1), is at an elevation of approximately 5,921 feet. Pond water levels are controlled by spray evaporation to prevent overflow into the spillway draining to No Name Gulch. The spray evaporation system operates six months per year. Ideally, the spray evaporation system reduces East Landfill Pond water volumes to 75 percent capacity (5.65 million gallons). When water levels approach the spillway elevation and spray evaporation does not significantly reduce the pond volume, water is diverted to Pond A-1 or A-2. This emergency response to elevated water levels rarely occurs and was last known to have occurred in March 1992.

Sediment in the East Landfill Pond ranges from 0.5- to 0.8-feet thick and consists of clay, silt, and organic matter. The upper 0.2 to 0.5 feet consists of black silt and clay with very fine roots occurring in either thin mats or scattered throughout the core. No bedding or lamination were visible. The remaining 0.3 to 0.4 feet of core consists of very dark gray clay with some silt. Very fine roots were observed but they decreased with depth. Olive gray claystone was present at the bottom of core SED70193. The moisture content of the cores ranged from 40 to 50 percent.

2.6.5 *Surface-Water Runoff*

The relationship between precipitation and the resulting runoff in the OU 7 drainage basin was examined. Many factors affect this relationship, such as the topography, geology, soil types, and physical characteristics of the basin. The OU 7 drainage basin characteristics were delineated in the Rocky Flats drainage and flood control master plan (EG&G 1992d). The average slope of the basin is estimated at 0.037 feet per feet (ft/ft). Six percent of the drainage basin area is designated as impervious to infiltration. Impervious retention (the retention of rainfall in depressions such as road ways or parking lots that does not contribute to runoff or infiltration) is expressed as an equivalent depth of rainfall and is estimated at 0.10 inches.

Conversely, pervious retention (the retention of rainfall in depressions or on vegetation that does not contribute to runoff but can infiltrate) is assumed to be 0.5 inches (EG&G 1992d).

2.6.6 *Infiltration*

Infiltration is the process by which precipitation moves downward into the soil. Surface effects between the soil particles and the water exert tension that draws moisture downward into the soil through capillary passages. Factors influencing rates of infiltration include soil type, soil cover, slope, precipitation intensity, antecedent moisture content of the soil, and water quality. Infiltration rates are quantified using Horton's equation (EG&G 1992d) as follows:

$$F = Fo + (Fi - Fo)e^{-at}$$

where:

- F = infiltration rate (inches per hour)
- Fi = initial infiltration rate (inches per hour)
- Fo = final infiltration rate (inches per hour)
- a = decay coefficient
- t = time (seconds)

Site-specific coefficients and input parameters used to calculate the infiltration rate for the OU 7 drainage basin are Fi = 3.5 (inches per hour), Fo = 0.55 (inches per hour), and a = 0.0013 (EG&G 1992d). The infiltration rate is initially 3.5 inches per hour but decreases exponentially to 0.5 inches per hour in the first hour. The potential infiltration rate is highest at the beginning of a precipitation event. As infiltration continues, the wetted zone in the soil expands downward and the infiltration rate decreases in an exponential manner until the soil reaches field capacity. At field capacity the soil is holding all of the water that it can under the pull of gravity. Precipitation greater than the amount of water infiltrated results in surface-water runoff.

2.6.7 *Water Balance*

The Phase I RFI/RI water balance for the OU 7 watershed is confined to the drainage boundary of the Present Landfill within the surface-water diversion ditch and the East Landfill Pond drainage basin. Due to the presence of the groundwater and surface water diversion systems, the hydrologic flow regime and associated inflow and outflow components at OU 7 are complex. Therefore, the water balance for the OU 7 watershed was modeled as two separate systems:

the East Landfill Pond drainage basin and the Present Landfill area. The inflow and outflow components for the OU 7 watershed are illustrated schematically in Figure 2-39.

2.6.7.1 East Landfill Pond Drainage Basin

The purpose of the water balance for the East Landfill Pond drainage basin was to quantify the inflow and outflow components to the East Landfill Pond. The storage volume of the East Landfill Pond is calculated by adding the inflows and subtracting the outflows using the following equation:

$$\Delta \text{ East Landfill Pond Storage} = \text{Inflows} - \text{Outflows}$$

Inflows = precipitation + surface water inflow + groundwater base flow + surface runoff + discharge from the groundwater intercept system + runoff from spray evaporation

Outflows = downward seepage + pond evaporation + evapotranspiration

The inflow and outflow components for the East Landfill Pond drainage basin are quantified for a typical year in Table 2-14. Each of the components of the water balance on Table 2-14 is described below.

Column A, Month

All rows of the water balance table are entered monthly, starting with January and ending in December.

Column B, Precipitation

Precipitation is reported as average monthly rainfall. Precipitation data were obtained from the Rocky Flats meteorological station (Figure 2-3).

Column C, Pan Evaporation

Pan evaporation data were taken directly from meteorological station monthly pan evaporation data for the period October 1991 to September 1992 (Appendix I). Collection of pan evaporation data was discontinued after September 1992. The evaporation pan is assumed to

be the standard Weather Bureau Class A pan. The pan is screened and is estimated at 3 to 4 feet in diameter and 10 inches in depth. Pan evaporation data were used to calculate evaporation from the East Landfill Pond (Column L).

Column D, Surface Water Inflow

Surface water inflow originating from the landfill seep was determined from the historical flow measurements obtained from SW097 (Table 2-13). Due to the incomplete nature of the measured flow rates, seasonal cyclic fluctuations in flow rates cannot be adequately assessed. Therefore, a mean value of 0.087 million gallons was assumed as a constant flow rate for each month. This value was obtained by excluding observations believed to be erroneous flow measurements and the single measurement obtained from the Palmer-Bowlus flume. The Palmer-Bowlus flume measurement was an order of magnitude greater than the other measurements. This observation was not comparable to the other data as a result of the difference in measurement techniques.

Column E, Groundwater Base Flow

As stated earlier, it is assumed that groundwater within the surficial material of the landfill is isolated from the underlying unweathered bedrock. Although a deeper groundwater system within the bedrock exists, it is assumed that the gradient between these two groundwater systems is negligible in comparison to the gradient of flow to the East Landfill Pond. A constant base flow to the pond is assumed (see potentiometric maps, Figures 2-21 through 2-24). The magnitude of groundwater base flow is based on Darcy's Law, as follows:

$$Q = KIA$$

where:

- Q = groundwater flow
- K = hydraulic conductivity
- I = hydraulic gradient
- A = cross-sectional area of flow

As described in Section 2.5, the average hydraulic conductivity of landfill material is 2.99 x 10^{-5} cm/sec. The average hydraulic conductivity of the Rocky Flats Alluvium is 1.59 x 10^{-4} cm/sec. The surficial deposits surrounding most of the East Landfill Pond are assumed to have

the same average hydraulic conductivity as the alluvium (1.59×10^{-4} cm/sec). Based on data from December 1992 to March 1993, the groundwater hydraulic gradient within the vicinity of the East Landfill Pond is equal to an average of 0.128 ft/ft.

To calculate the rate of groundwater base flow to the East Landfill Pond, a cross-sectional area of flow must be estimated. Because surficial groundwater appears to be recharging the East Landfill Pond (see Section 2.6.8), the cross-sectional area of flow is defined by the saturated thickness at the pond shoreline. The saturated thickness of the surfical materials at the pond shoreline is less than 2.5 feet (Figures 2-29 and 2-30) and was, therefore, estimated as 1.25 feet along the perimeter of the pond. The cross-sectional area of flow is estimated by multiplying a saturated thickness of 1.25 feet by the perimeter of the pond shoreline (approximately 1,500 feet).

Column F, Surface Runoff

The OU 7 watershed is located in the drainage area of No Name Gulch and occupies approximately 37 acres. The watershed has been divided into four subareas (Figure 2-41), each having different runoff characteristics. Area I incorporates the Present Landfill and contains 22.3 acres. Area II is an engineered slope just below the landfill and above the East Landfill Pond. This subarea has light vegetation and occupies 2.5 acres. Area III consists of highly vegetated steep slopes on the north and south sides of the East Landfill Pond and contains 9.3 acres. Area IV is the East Landfill Pond, which covers 2.4 to 2.7 acres.

The monthly surface runoff is estimated using the runoff coefficient (C) of the Rational Method formula (Appendix I). The runoff volume for each subarea is estimated as a fraction of the total precipitation by multiplying the total rainfall volume by the subarea runoff coefficient. The magnitude of the runoff coefficient is dependent upon surface slope, permeability, vegetation, and roughness (Appendix I). The estimated areas and runoff coefficients of each subarea are as follows:

- Area I — 22.3 acres, flat, no vegetation C = 0.20
- Area II — 2.5 acres, steep, light vegetation C = 0.50

- Area III — 9.3 acres, steep, heavy vegetation C = 0.40
- Area IV — 2.5 acres, leachate pond surface C = 1.00

As shown above, a runoff coefficient of 1.00 is delineated for the leachate pond surface to simulate the direct storage of rainfall in the pond. Total monthly landfill runoff is estimated with the following formula.

$$\text{Runoff} = (\text{precip.})(\text{Area I})(0.2) + (\text{precip.})(\text{Area II})(0.5) + (\text{precip.})(\text{Area III})(0.4) + (\text{precip.})(\text{Area IV})$$

Column G, Discharge to Pond from the Groundwater Intercept System

The volume of water discharging to the East Landfill Pond via the groundwater intercept system was calculated for high and low flow periods using Darcy's Law and the Dupuit-Forchheimer assumptions (Appendix I). The Dupuit-Forchheimer assumptions include isotropic and homogeneous flow, steady state flow, horizontal flow, a hydrostatic pressure head distribution along all vertical planes, flow normal to the drain, and a horizontal, impermeable weathered bedrock surface (McWhorter and Sunada 1977).

The well hydrograph presented in Figure 2-37 indicates a sloping water table toward the perforated drain, verifying the Dupuit-Forchheimer assumptions. The near-constant head conditions observed in well B106089 confirm the proximity of that well to the perforated drain. The problem is simplified by assuming that the observed hydraulic head in well B106089 represents the hydraulic head in the filter pack that surrounds the perforated pipe. Based on this assumption, groundwater elevation data obtained from wells 5887 and B106089 were chosen to satisfy the h_x, h_l and L boundary conditions in the following equation:

$$Q = K/2L\,(h_x^2 - h_l^2)$$

where:

- Q = volumetric flow rate into drain [L^3/T]
- K = hydraulic conductivity [L/T]
- h_x = thickness of flow and head potential at a distance [L] from the drain {l}
- h_l = thickness of flow and head potential at the drain [L]
- L = distance between h_x and h_l ([L]

A hydraulic conductivity value of 2.99×10^{-5} cm/sec (8.46×10^{-2} ft/day) was used to solve for the volumetric flow rate (Q). The resulting flow rate across the seepage face at well B106089 is assumed to be intercepted by the drain and diverted to the East Landfill Pond. Calculations and relevant input parameters used to solve the equation are presented in Appendix I. The volumetric flow rate per unit area was multiplied by the length of the drain (1,748 feet) that is effectively intercepting groundwater. This value was obtained by subtracting the length of the north groundwater intercept system that is presumed to be failing (444 feet) from the total length of the drain (2,192 feet). Solving for Q in the equation yields a monthly volume of flow that is intercepted by the drain and diverted to the East Landfill Pond (Appendix I).

The volumetric flow rate into the drain per unit area ranges from 4.32×10^{-2} cubic feet per day per square feet ($ft^3/day/ft^2$) in December to 4.26×10^{-2} $ft^3/day/ft^2$ in March. The monthly volume of intercepted groundwater diverted to the East Landfill Pond ranges from 2,341 cubic feet (ft^3) in December to 2,308 ft^3 feet in March. The flow rates computed for December 1992 (low flow period) are unexpectedly higher than the computed flow rates for March 1993 (high flow period). However, the Dupuit-Forchheimer discharge equation is limited by many simplifying assumptions. Violation of the homogeneous and isotropic assumptions may have slightly overestimated the December 1992 flow rate and/or slightly underestimated the March 1993 flow rate. Despite these differences, the computed flow rates for December 1992 and March 1993 vary only slightly suggesting that the flow rate into the drain remains relatively constant. The monthly volume of intercepted groundwater for March 1993 was used in the water balance.

Column H, Downward Seepage from the East Landfill Pond

The volume of groundwater seeping from the East Landfill Pond down into weathered bedrock, vertical flow (Q), was estimated from Darcy's Law by multiplying the vertical Darcy flux (q_z) by the cross-sectional area (A), where $Q = q_zA$. Assumptions inherent in the estimate include homogeneous and isotropic flow conditions, steady one-dimensional flow, vertical flow normal to the weathered bedrock surface, and vertical flow through fully saturated units. The input parameters used to estimate vertical seepage are the same as the input parameters listed in Column FF.

Column I, East Landfill Pond Evaporation

Reservoir and pond evaporation are commonly estimated as a fraction of the pan evaporation rate. For Weather Bureau Class A pans, pond evaporation is typically calculated as approximately 70 percent of the pan evaporation rate (Linslay et al. 1975). Assuming this 70 percent reduction, the monthly pond evaporation volume is estimated by the following formula.

Pond evaporation = (-pan evap.)(0.7)(pond surface area)

As shown in Table 2-14, pond evaporation rates for December, January, and February are zero because the East Landfill Pond is typically covered with ice.

Column J, Total Volume of Spray Evaporation

Total spray evaporation represents the total volume of water sprayed on the grassy slopes around the pond for a given month. Because historical data on actual spray volumes are minimal, the estimated volume is based on typical operation procedures during the spray evaporation season (Andrews and Murray 1993).

The approximate spray evaporation pump rate is 700 gallons per minute. Spray evaporation is generally conducted from May to October. Spray evaporation does not take place on days when it is raining or there is significant cloud cover. For the purpose of the water balance, an average of 22 spray evaporation days per month was assumed. Spray evaporation pumps are generally turned on at 8:00 or 9:00 a.m. and turned off at 4:30 or 5:00 p.m. For the purposes of the water balances, an average of 7 hours of pump operation per day were assumed. Based on the operational parameters and assumptions, an average monthly total spray evaporation is estimated as follows:

Total flow = (700 gal/min)(60 min/hr)(7 hr/day)(22 day/month)
= 6,468,000 gal/month
= 6.47 MG/month

where:

gal/min	=	gallons per minute
min/hr	=	minutes per hour
hr/day	=	hours per day
gal/month	=	gallons per month
MG/month	=	million gallons per month

Column K, Runoff From Spray Evaporation

Approximately 90 percent of the total volume of water pumped through the spray evaporation system runs back into the leachate pond (Andrews and Murray 1993) and therefore spray evaporation runoff is estimated as 90 percent of the total spray volume.

Column L, Grass Area Evapotranspiration

As stated above, approximately 90 percent of the total volume of water pumped through the spray evaporation system runs back into the leachate pond. It is assumed that no infiltration occurs and the remaining 10 percent of the total volume pumped undergoes evapotranspiration.

Column M, East Landfill Pond Storage

The monthly pond storage is equal to the sum of the previous month storage, Column D (Surface Water Inflow), Column E (Groundwater Baseflow), Column F (Surface Runoff), Column G (Discharge to Landfill Pond from the Groundwater Intercept System), Column H (Downward Seepage from the East Landfill Pond), Column I (Landfill Pond Evaporation), and Column L (Grass Area Evapotranspiration). Based on historical data, a starting storage volume of 6.0 million gallons (MG) in January is assumed.

Column N, Pond Water Surface Elevation

The pond surface water elevation is estimated with the East Landfill Pond capacity chart (Appendix I). The curve was generated from a detailed survey of the pond.

2.6.7.2 Present Landfill Area

Water-balance calculations for the Present Landfill area, presented in the groundwater-surface water-collection study (EG&G 1991f), accounting for precipitation, evapotranspiration, and soil-

water storage resulted in zero recharge to the surficial groundwater system due to the high evapotranspiration rate. An alternative method accounting only for runoff assumed that 75 percent of the incident precipitation infiltrated through the soil cover to recharge the surficial groundwater. This method most likely overestimates recharge from precipitation because soil evaporation loss was neglected. In semiarid regions where the duration of storm events is low to moderate, the soil evaporation loss is a major component in the water-balance calculations.

Water balance calculations for the Present Landfill area were computed for the months of December 1992 and March 1993 (high and low flow regimes). The inflow and outflow boundaries of the Present Landfill area are presented in Figure 2-40. The change in groundwater storage of the Present Landfill area is computed by subtracting the sum of the inflows from the sum of the outflows using the following equation.

A change in Groundwater Storage = (Inflow - Outflow) Δ time

where:

Inflows = Infiltration/Recharge + Groundwater Inflow Under the North Groundwater Intercept System

Outflows = Downward Seepage From the Landfill + Groundwater Outflow Through the Eastern Boundary

The inflow and outflow components for the Present Landfill area are quantified for December 1992 and March 1993 in Table 2-15. Each of the components of the water balance on Table 2-15 is described below.

Column AA, Month

All rows of the water balance table are entered monthly, starting with December and ending in March.

Column BB, Precipitation

Precipitation is reported as average monthly rainfall. Precipitation data were obtained from the Rocky Flats meteorological station (Figure 2-3).

Column CC, Evaporation from the Landfill Surface

Evaporation of incident precipitation from the surface of the landfill was estimated at 70 percent of the total monthly precipitation (Brady 1974).

Column DD, Infiltration

Infiltration of precipitation into the surficial material covering the landfill surface was estimated at 10 percent of the total monthly precipitation, based on evaporation of 70 percent (see Column CC) and a runoff coefficient of 20 percent (see Column F, Table 2-14).

Column EE, Groundwater Inflow Under the Groundwater Intercept System

The monthly volume of groundwater inflow under the north groundwater intercept system into the landfill was estimated using the following equation based on Darcy's Law and the Dupuit-Forchheimer assumptions (McWhorter and Sunada 1977):

$$Q = Kh\,dh/dx$$

where:

Q = volumetric flow [L^3/T]
K = hydraulic conductivity [L/T]
h = thickness of flow and hydraulic head [L]
dh/dx = hydraulic gradient [dimensionless]

Assumptions used in the calculations include homogeneous and isotropic flow conditions, steady one-dimensional flow, the cross-sectional area of flow decreases along the flow path as the saturated thickness decreases, flow is normal to the intercept system, and inflow occurs through a 444-foot-long section where it is presumed that the intercept system is failing. The input parameters include a hydraulic conductivity value of 2.99×10^{-5} cm/sec (geometric mean value for artificial fill; Table 2-5), a hydraulic gradient of 0.01 obtained from well pair 6187/6287, and saturated thicknesses along the 444-foot-long stretch of the intercept system were determined from the isopach maps (Figures 2-29 and 2-30). The groundwater inflow calculations and relevant parameters are summarized in Appendix I.

Column FF, Downward Seepage from the Landfill

The volume of groundwater seeping from the landfill down into weathered bedrock, vertical flow (Q), was estimated from Darcy's Law by multiplying the vertical Darcy flux (q_z) by the cross sectional area (A), where $Q = q_zA$. Assumptions inherent in the estimate include homogeneous and isotropic flow conditions, steady one-dimensional flow, vertical flow normal to the weathered bedrock surface, and vertical flow through fully saturated units. The input parameters used to estimate vertical seepage include a hydraulic conductivity value of 4.37×10^{-7} cm/sec (geometric mean value for weathered bedrock groundwater, Table 2-5), a vertical hydraulic gradient of 0.098 (geometric mean value, Table 2-10) for the December 1992 flux calculations, a vertical hydraulic gradient value of 0.183 (geometric mean value, Table 2-10) for the March 1993 flux calculations, and a seepage area of 714,375 square feet (see Appendix I). The vertical hydraulic gradient value for the December flux calculations was obtained from February 1993 groundwater elevation data because it is assumed to be more representative of the actual flow conditions. The geometric mean value of 0.483 for December 1992 was obtained from only two observations and would greatly overestimate the volume flux. The well hydrographs (Figures 2-32 through 2-37) verify that surficial groundwater conditions in December 1992 are similar to conditions in February 1993.

Column GG, Groundwater Outflow Through the Eastern Boundary

The monthly volume of groundwater flowing laterally through the system was estimated from the Dupuit-Forchheimer equation (see Appendix I). The following assumptions were used to estimate the lateral outflow: the cross-sectional area of lateral flow decreases along the flow path as the saturated thickness decreases, isotropic and homogeneous flow conditions exist, steady one-dimensional flow exists, and lateral flow is normal to the eastern boundary of the landfill (Figure 2-40). The input parameters for lateral flow include a hydraulic conductivity value of 2.99×10^{-5} cm/sec and lateral hydraulic gradients of 0.129 for December 1992 and 0.128 for March 1993 (hydraulic gradients for the East Landfill Pond drainage area were used; Appendix I). The isopach maps (Figures 2-29 and 2-30) were used to determine the saturated thicknesses along the eastern boundary.

Column HH, Total Groundwater Inflow

The Total Groundwater Inflow is equal to the sum of Column DD (Infiltration Through Landfill Surface) and Column EE (Groundwater Inflow Under the Groundwater Intercept System).

Column II, Total Groundwater Outflow

The Total Groundwater Outflow is equal to the sum of Column FF (Downward Seepage From the Landfill into Weathered Bedrock) and Column GG (Groundwater Outflow Through the Eastern Boundary).

Column JJ, Mass Balance: Change in Storage

The Mass Balance: Change in Storage is equal to the sum of Column HH (Total Groundwater Inflow) and Column II (Total Groundwater Outflow). The mass balance results in Column JJ show that the groundwater/leachate system within the landfill decreases in storage during December and then increases significantly during March. This change in storage from high to low flow regimes is confirmed qualitatively by the seasonal water level fluctuations on the well hydrographs (Figures 2-32 through 2-37).

2.6.8 Groundwater–Surface-Water Interactions

As shown by the water balance presented in Table 2-14, the reduction or increase in leachate pond volume is primarily determined by the magnitude of monthly rainfall runoff, spray evaporation, surface water inflow, and direct pond evaporation. Ideally, the spray evaporation system is operated with the intent of reducing the pond volume to 75 percent capacity or 5.65 MG by the end of the spray season in October. As shown in the water balance, under normal rainfall and spray evaporation conditions, the pond volume can be reduced to 5.79 MG by the end of October. Although a reduction near 75 percent capacity is achieved, it is interesting to note that the peak surface-water elevation in May reached a level of approximately 5,921 feet, the approximate spill elevation.

The hydrographs presented in Figures 2-32 through 2-37 show seasonal water-level fluctuations at most of the monitoring well locations. These water-level fluctuations are compared to monthly precipitation data acquired from the Rocky Flats meteorological station

(Pamp 1993). The precipitation hydrographs presented in Figures 2-32 through 2-37 show that seasonal groundwater elevations roughly coincide with monthly precipitation although some lag is apparent. This suggests that surficial groundwater and/or leachate is recharged from precipitation that infiltrates through the soil cover. The infiltration rate through the soil cover varies from 3.5 inches/hour to 0.55 inches/hour.

The East Landfill Pond is the major surface-water feature within OU 7. The East Landfill Pond impounds groundwater and leachate generated by the landfill. The majority of the surface-water inflow to the East Landfill Pond occurs as runoff from spray evaporation and drainage from the seep located near the west end of the pond. Groundwater from the groundwater intercept system can be discharged into the pond at two outfall points located along the northern and southern shoreline. Pond water evaporates directly to the atmosphere or via spray irrigation onto the hillsides adjacent to the pond.

Water elevations in surficial groundwater and surface-water elevations at the East Landfill Pond have similar seasonal trends, which suggests that surficial groundwater and surface water in the pond are hydraulically connected. The water levels in well 0786, screened in surficial materials, are consistently greater than the East Landfill Pond water levels, suggesting that surficial groundwater is continuously recharging the pond. Water levels in weathered bedrock well (B206789) show extreme water-level fluctuations, possibly the result of quarterly sampling events. As a result, seasonal trends are not apparent and correlation of weathered bedrock groundwater with pond surface elevations is not possible. The hydrograph data are inconclusive regarding a hydraulic connection between the weathered bedrock and the pond. However, observed water levels in well B206789 are consistently lower than the pond water elevations indicating that the East Landfill Pond may be recharging the weathered bedrock near the shoreline. Estimated vertical hydraulic gradients between the East Landfill Pond and the weathered bedrock groundwater system are presented in Appendix I. Based on these vertical gradients and a hydraulic conductivity value of 4.37×10^{-7} cm/sec, and assuming homogeneous, isotropic, steady state, one-dimensional flow, the vertical Darcy flux (geometric mean) through the pond–weathered bedrock interface is 7.65×10^{-8} cm/sec.

The configuration of the potentiometric maps (Figures 2-21 through 2-24) suggest that water is seeping through the East Landfill Pond embankment. The equipotential lines of the surficial and weathered bedrock groundwater systems are tightly spaced along the embankment

indicating a steep gradient toward No Name Gulch. The volume of water seeping through the embankment is probably minimal as indicated by the isopach maps (Figures 2-29 and 2-30) which show a saturated thickness of less than 2.5 feet in this area. Based on the hydraulic conductivity value of 1.27×10^{-7} cm/sec measured at piezometer TH047292 (EG&G 1993b) and a mean hydraulic gradient of 0.16, the lateral Darcy flux through the embankment is 2.03×10^{-8} cm/sec, assuming homogeneous, isotropic, steady-state, one-dimensional flow conditions. Based on a Darcy flux of 2.03×10^{-8} cm/sec, an average saturated thickness of 2.5 feet, and a width of approximately 550 feet, the volume flux below the dam is estimated at 9.23×10^{-7} ft^3/sec. This corresponds to 0.000414 gallons per minute or 218 gallons per year. Only some fraction of the flux below the landfill dam can be attributed to leachate. Therefore, the weathered bedrock unit is not believed to represent a significant migration pathway of contamination down No Name Gulch.

Conclusions from the water-balance calculations include the following: (1) leachate–groundwater is primarily recharged by precipitation through the interim soil cover, (2) groundwater flow under the failed intercept system contributes less than 5 percent of the total inflow, and (3) leachate–groundwater outflow primarily occurs as downward seepage into weathered bedrock beneath the landfill.

Conclusions based on the water-elevation data include the following: (1) cyclic trends in groundwater elevations coincide with precipitation events; (2) surficial groundwater appears to be continuously recharging the East Landfill Pond; (3) downward seepage appears to be recharging the weathered bedrock beneath the East Landfill Pond; and (4) seepage through the East Landfill Pond embankment appears to be minimal, as indicated by the calculated Darcy flux of 2.03×10^{-8} cm/sec and saturated thickness of less then 2.5 feet below the embankment.

2.7 Ecology

The buffer zone surrounding the industrial area of the Rocky Flats site generally supports a wide variety of native plant communities and wildlife. However, the areas in and around OU 7 have been subject to extensive physical disturbance associated with the landfill operations and construction of the East Landfill Pond and groundwater intercept system.

2.7.1 *Vegetation*

The Rocky Flats site is located between Boulder and Golden, Colorado, in a transitional zone known as the Colorado Piedmont. The Colorado Piedmont is an area of dissected topography containing floristic features from the Great Plains prairie and the Rocky Mountain foothills. The present-day vegetation of Rocky Flats is dominated by mesic mixed grassland with integrated tall- and short-grass prairie community features. Grasses prevalent on upland sites are western wheatgrass, blue grama, sideoats grama, Canada bluegrass, Kentucky bluegrass, and prairie junegrass. Mesic sites support tall-grass and mixed-grass prairie species such as big bluestem, little bluestem, green needlegrass, and switchgrass. More xeric sites are dominated by short-grass species, including buffalograss, needle-and-thread, red three-awn, ring muhly, and mountain muhly. Dominant forbs were hairy gold-aster, Louisiana sage, western ragweed, broom snakeweed, and slimflower scurfpea. Riparian and wetland vegetation occupy the seeps and valley floors with rushes, bulrushes, sedges, cattails, willows, and cottonwoods. Weedy species such as cheatgrass, Japanese brome, diffuse knapweed, and klamath weed predominate on disturbed sites. Reclaimed sites are dominated by smooth brome, crested wheatgrass, and intermediate wheatgrass. Specific plant communities present in the OU7 study area are described in the following subsections (Figure 2-42).

2.7.1.1 Mesic Mixed Grassland

Mesic mixed grassland is the most prevalent native habitat type at OU 7. This diverse plant community occurs in a wide variety of topographies, including broad flat uplands, valley floors, and hillsides. Differences in slope, aspect, soil type, disturbance, and land use history are reflected in differences in dominance of the various grasses and forbs characterizing the mesic grassland. Species richness was sampled along 2 meter by 50 meter belt transects within the mesic mixed grassland. Of the one hundred and six species identified, 34 were graminoids, 63 forbs, 5 shrubs, and 4 cacti. Of the identified species within the OU 7 study area, 67.9 percent were native perennial species, suggesting a possible trend toward a native grassland climax community. Dominant grasses are western wheatgrass, Canada bluegrass, prairie junegrass, and big bluestem. Kentucky bluegrass, little bluestem, crested wheatgrass, sand dropseed, blue grama, and needle-and-thread were also present. The most dominant forbs were diffuse knapweed, Louisiana sage, and Canada thistle. Secondary forbs present included aster, slimflower scurfpea,

and klamath weed. Wild rose was the most commonly encountered shrub, and prickly pear the most common cactus encountered along transects within this habitat type.

2.7.1.2 Disturbed Community

A large portion of the industrial complex at the Rocky Flats site has been severely disturbed and currently supports primarily weedy species. The majority of disturbance at OU 7 is attributable to surficial soil disturbance by heavy equipment used in landfill activities.

A belt transect sampled within the disturbed community contained 27 plant species: 7 grasses, 1 sedge, and 19 forbs. Native species constituted 70.3 percent of the community, including all of the dominant grasses: big bluestem, blue grama, Canada bluegrass, and mountain muhly. Narrow-leaf sedge was also common. The dominant forb was diffuse knapweed, an introduced and aggressive weed that infests disturbed sites such as roadsides, waste areas, and dry, overgrazed rangelands. Other forbs present included Louisiana sage, hairy gold-ester, blazing star, western ragweed, klamath weed, and fringed sage. There were no shrubs present, although fringed sage is sometimes considered a subshrub, as it arises from a wood crown.

2.7.1.3 Bare Ground

A large section of OU 7 was bare ground due to continuous earthmoving at the landfill. Plants have little opportunity to germinate, grow, or establish in bare areas. Most of the original topsoil has either been lost through wind and water erosion or buried in the landfill.

2.7.1.4 Marshland

Tall and short marsh occur in the area around the East Landfill Pond. Tall marsh occurs at the pond margins and is comprised of a near monoculture of broad-leaved cattail, which probably impacts establishment and growth of other hydrophytic plants. The static water level in the pond probably promotes the persistence of the cattails. The short marsh type occurs in the sprayed areas north and south of the pond where intermittent spray operations cause more variable hydrologic conditions. The short marsh area is dominated by Baltic rush, which prefers mesic to hydric conditions but will tolerate drier conditions. Disturbed areas around the pond contain weedy species such as Canada thistle and western ragweed.

2.7.2 Wildlife

The Rocky Flats site supports a wide variety of wildlife; large and small mammals, birds, reptiles, amphibians, aquatic macroinvertebrates, and fish. This relatively rich animal community is, in part, due to the isolation of the site from the increasing human activity in the surrounding areas.

The most abundant large mammal is the mule deer; population estimates exceed 100 animals. White-tailed deer have also been infrequently observed. Large carnivores present at Rocky Flats are coyotes, red foxes, gray foxes, striped skunks, long-tailed weasels, badgers, bobcats, and raccoons. Eastern cottontails and white-tailed jack rabbits are also present. Black-tailed prairie dogs occur in flat, upland areas in the northeastern corner of the buffer zone. Some ponds support muskrats.

The Rocky Flats environmental impact statement (EIS) (DOE 1980) reported that eight species of small mammals were captured during a live-trapping program in 1975: harvest mice, deer mice, meadow voles, thirteen-lined ground squirrels, hispid pocket mice, silky pocket mice, pocket gopher, and house mouse. A more recent study has documented the occurrence of six additional species: Mexican woodrats, plains and western harvest mice, prairie voles, and both western and meadow jumping mice (DOE 1993c).

The varied habitats at the Rocky Flats site support many bird species. Common grassland birds include western meadowlarks, horned larks, vesper sparrows, grasshopper sparrows, western kingbirds, and eastern kingbirds. Riparian areas dominated by cottonwoods support black-billed magpies, northern orioles, yellow warblers, warbling vireos, American robins, indigo buntings, blue grosbeaks, and lesser and American goldfinches. MacGillivray's warblers, yellow-breasted chats, black-headed grosbeaks, green-tailed and rufous-sided towhees, and lazuli buntings occur in other wooded areas. Marshlands support song sparrows, common yellowthroats, red-winged blackbirds, common snipe, and sora rails. Common birds of prey occurring at the Rocky Flats site include American kestrels, northern harriers, red-tailed hawks, Swainson's hawks, great horned owls, and long-eared owls. Occasionally, golden eagles, prairie falcons, rough-legged hawks, and short-eared owls are observed. Bald eagles are noted visitors during the winter. Open water areas, including ponds and intermittent creeks, attract water birds such as mallards, gadwall, green-winged teal, blue-winged teal, pied-billed grebes, spotted sandpipers, killdeer, great blue

herons, black-crowned night-herons, and double-crested cormorants. Migrating sandhill cranes have also been observed at the site.

The Rocky Flats site supports several species of reptiles and amphibians. Snake species include the bullsnake, yellow-bellied racer, western terrestrial gartersnake, and prairie rattlesnake. Western painted turtles are also present. Amphibian species include plains leopard frogs, Woodhouse's toads, northern chorus frogs, and tiger salamanders.

Surface waters at Rocky Flats support a variety of aquatic macroinvertebrates, including snails and several orders of insects and crustaceans: Oligochaeta, Amphipoda, Decapoda, Hydracarina, Plecoptera, Ephemeroptera, Odonata, Trichoptera, Coleoptera, Diptera, Gastropoda, and Pelecypoda. Some ponds and creeks are inhabited by fathead minnows, common carp, white suckers, creek chubs, golden shiners, and green sunfish. Largemouth bass have been found in Ponds C-1, A-2, and Lindsay Pond. However, the East Landfill Pond supports no fish and only a depauperate benthic macroinvertebrate community.

Surveys for terrestrial arthropods, large mammals, birds, reptiles, and amphibians specifically on OU 7 were not performed due to its small area. No fish were collected during surveys conducted in the landfill pond.

2.7.3 *Sensitive Habitats and Endangered Species*

Several wetlands identified at the Rocky Flats site come under the protection of state and federal wetland laws. Wetlands at the Rocky Flats site were identified in conjunction with the National Wetlands Inventory (see FWS 1979) and field checked to verify their jurisdictional status by U.S. Army Corps of Engineers personnel. These wetlands consist of emergent, intermittently flooded stream channels and artificial, semipermanent ponds (wetland types PEMW and POWKF, respectively) (FWS 1979). At this time, the East Landfill Pond is classified as a RCRA management unit, although several wetland species grow in and around the pond.

Three federally listed endangered wildlife species potentially occur at Rocky Flats. These are the black-footed ferret, peregrine falcon, and bald eagle (ASI 1991). Black-footed ferrets require habitat in and around prairie dog colonies. Although several prairie dog colonies exist at the Rocky Flats site, there are none in the immediate vicinity of OU 7. Black-footed ferrets are not known to occur in the vicinity. Though bald eagles are seen during winter months, no roost areas

or nest sites have been located on the Rocky Flats site. Peregrine falcons may be periodic migrants in this area. In 1991, a peregrine falcon pair nested approximately 10 kilometers northwest of the Rocky Flats site. It is possible that the hunting territory of such nesting peregrines could include Rocky Flats, although suitable habitat occurs closer to the known nest area. Small size and lack of an appropriate prey base precludes OU 7 as an important habitat for these federally listed species.

Potential habitat for several Colorado "Category 2" wildlife species occurs at Rocky Flats site. Ferruginous hawks have been observed throughout the year and appear to be vagrants. This species may nest near the Rocky Flats site and use the site for hunting. Preble's meadow jumping mice were captured in small numbers along Woman Creek in 1991, and one individual was captured in reclaimed grassland within the OU 1 study area. As a result, an intense survey was conducted in 1992. The 1992 program resulted in live captures of 10 Preble's meadow jumping mice, including 2 along Woman Creek below Pond C-1. Animals were captured in hydrophytic shrublands dominated by sandbar willow and leadplant, with relatively lush understory grasses and forbs. Other Category 2 wildlife species potentially occurring, but not documented, at the Rocky Flats site include the white-faced ibis, mountain plover, long-billed curlew, and swift fox (ASI 1991). Again, the small size of OU 7, and inappropriate habitat, limits the value of OU 7 for these sensitive species.

ASI (1991) reported four plant species of special concern potentially present at the Rocky Flats site. These plants include one federally-listed threatened species, Ute lady's tresses; one Category 2 species, Colorado butterfly plant; and two species of concern in Colorado, forktip three-awn and toothcup. Ute lady's tresses has been reported near Clear Creek to the south of the Rocky Flats site and near South Boulder Creek to the north of the Rocky Flats site (ASI 1991), and suitable habitat does occur at the Rocky Flats site. Colorado butterfly plant has not been reported near the Rocky Flats site, but wetlands along the major creeks represent suitable habitat for this species. Neither species was found during surveys conducted 1992 (EG&G 1992f). Forktip three-awn was reported along Woman Creek in 1973 and was documented in the same area during intensive vegetation investigations of OU 5 in 1991. Toothcup has been reported in a temporary pool about 4 miles east of Boulder.

Section 2
Tables

Table 2-1
Description of Soil Types

Series[1]	Family	Phase	Minimum-Maximum Slope (%)	Infiltration Rate	Soil Type[1]
Denver-Kutch-Midway	Torrertic Argiustolls	clay loam	9-25	slow	31
Flatirons	Aridic Paleustolls	very cobbly sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	slow	60
Nederland	Aridic Argiustolls	very cobbly sandy loam	15-50	moderate	100
Gravel/Disturbed Ground/Interim Soil Cover	—	—	varies	moderate to rapid	111

[1] After Price and Amen 1980 (See Figure 2-5 for the distribution of soil types at OU 7).

Table 2-2
Depth to Bedrock at Cone Penetration Test Locations

CPT Location	Depth to KaKl(w) (feet bgs)	Elevation Top of KaKl(w) (feet)	Thickness of KaKl(w) (feet)	Depth to KaKl(u) (feet bgs)	Elevation Top of KaKl(u) (feet)
CPT00193	NDE	NDE	NDE	NDE	NDE
CPT00293	NDE	NDE	NDE	NDE	NDE
CPT00393	21.0	5971.5	23.0	44.0	5948.5
CPT00493	22.0	5968.6	18.0	40.0	5950.6
CPT00593	32.0	5958.3	13.0	45.0	5945.3
CPT00693	25.0	5964.9	11.0	36.0	5953.9
CPT00793	28.0	5957.7	57.0	85.0	5900.7
CPT00893	29.0	5956.6	39.0	68.0	5917.6
CPT00993	36.5	5950.1	8.5	45.0	5941.6
CPT01093	37.0	5951.9	10.0	47.0	5941.9
CPT01193	45.0	5936.9	9.0	54.0	5927.9
CPT01293	41.5	5940.0	7.5	49.0	5932.5
CPT01393	42.0	5934.8	15.0	57.0	5919.8
CPT01493	45.0	5929.6	12.0	57.0	5917.6
CPT01593	40.0	5933.4	18.0	58.0	5915.4
CPT01693	NP	NP	NP	NP	NP
CPT01793	NDE	NDE	NDE	NDE	NDE
CPT01893	14.0	5955.0	42.0	56.0	5913.0
CPT01993	12.0	5953.9	NDE	NDE	NDE
CPT02093	18.0	5945.1	21.0	39.0	5924.1
CPT02193	NP	NP	NP	NP	NP
CPT02293	42.0	5930.1	16.0	58.0	5914.1
CPT02393	32.0	5941.2	18.0	50.0	5923.2
CPT02493	NDE	NDE	NDE	NDE	NDE
CPT02593	15.0	5955.2	24.0	39.0	5931.2
CPT02693	26.0	5960.4	14.0	40.0	5946.4
CPT02793	24.0	5960.7	18.0	42.0	5942.7
CPT02893	38.5	5956.4	15.5	54.0	5940.9
CPT02993	24.0	5961.0	10.0	34.0	5951.0
CPT03093	NDE	NDE	NDE	NDE	NDE
CPT03193	NDE	NDE	NDE	NDE	NDE
CPT03293	25.0	5959.0	10.0	35.0	5949.0
CPT03393	NDE	NDE	NDE	NDE	NDE
CPT03493	23.0	5966.3	12.0	35.0	5954.3
CPT03593	NDE	NDE	NDE	NDE	NDE
CPT03693	28.0	5961.1	9.0	37.0	5952.1
CPT03793	25.0	5962.1	9.0	34.0	5953.1
CPT03893	NDE	NDE	NDE	NDE	NDE

Definitions:

bgs	below ground surface
CPT	cone penetration test
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
NDE	not deep enough
NP	not performed

Table 2-3
Depth to Bedrock at Borehole and Well Locations

Borehole or Well Location	Elevation of Ground Surface (feet)	Depth to Top of KaKl(w) (feet bgs)	Elevation of Top of KaKl(w) (feet)	Depth to Top of KaKl(u) (feet bgs)	Elevation of Top of KaKl(u) (feet)	Thickness of KaKl(w) (feet)
0586	5724.38	9.00	5715.38	NDE	NDE	ND
0686	5814.68	10.50	5804.18	NDE	NDE	ND
0786	5924.94	5.00	5919.94	NDE	NDE	ND
0886	5925.60	1.00	5924.60	15.60	5910.00	14.60
0986	5996.39	30.30	5966.09	NDE	NDE	ND
1086	5996.62	23.00	5973.62	NDE	NDE	ND
4087	5883.00	5.80	5877.20	NDE	NDE	ND
4187	5882.95	3.50	5879.45	25.45	5857.50	21.95
4287	5854.34	6.10	5848.24	NDE	NDE	ND
5887	5995.46	22.00	5973.46	NDE	NDE	ND
5987	5992.90	20.50	5972.40	NDE	NDE	ND
6087	5984.44	27.00	5957.44	NDE	NDE	ND
6187	5984.42	28.00	5956.42	NDE	NDE	ND
6287	5984.54	26.30	5958.24	NDE	NDE	ND
6387	5985.63	25.00	5960.63	NDE	NDE	ND
6487	5986.09	22.00	5964.09	NDE	NDE	ND
6587	5983.48	21.00	5962.48	NDE	NDE	ND
6687	5982.26	15.30	5966.96	NDE	NDE	ND
6787	5970.00	16.40	5953.60	NDE	NDE	ND
6887	5968.91	15.50	5953.41	NDE	NDE	ND
7087	5966.71	12.00	5954.71	NDE	NDE	ND
7187	5963.89	14.00	5949.89	NDE	NDE	ND
7287	5969.60	8.00	5961.60	NDE	NDE	ND
B106089	5993.30	22.50	5970.80	NDE	NDE	ND
B206189	5984.50	20.90	5963.60	NDE	NDE	ND
B206289	5977.59	15.00	5962.59	31.50	5964.09	16.50
B206389	5969.70	13.30	5956.40	31.50	5964.09	16.50
B206489	5969.14	7.30	5961.84	NDE	NDE	ND
B206589	5967.80	7.50	5960.30	36.80	5931.00	29.30
B206689	5959.31	3.70	5955.61	36.80	5931.00	29.30
B206789	5927.90	4.80	5923.10	36.80	5931.00	29.30
B206889	5917.09	3.00	5914.09	36.80	5931.00	29.30
B206989	5882.42	6.00	5876.42	36.80	5931.00	29.30
B207089	5883.07	6.00	5877.07	31.50	5851.57	25.50
B207189	5884.80	5.50	5879.30	30.42	5854.38	24.92
B207289	5948.27	0.20	5948.07	30.42	5854.38	24.92

Borehole or Well Location	Elevation of Ground Surface (feet)	Depth to Top of KaKI(w) (feet bgs)	Elevation of Top of KaKI(w) (feet)	Depth to Top of KaKI(u) (feet bgs)	Elevation of Top of KaKI(u) (feet)	Thickness of KaKI(w) (feet)
76792	ND	ND	ND	30.42	5854.38	24.92
76992	ND	ND	ND	30.42	5854.38	24.92
77392	ND	ND	ND	30.42	5854.38	24.92
70093	5990.90	22.30	5968.60	30.42	5854.38	24.92
70193	5990.30	19.50	5970.80	30.42	5854.38	24.92
70293	5990.70	21.50	5969.20	45.07	5945.63	23.57
70393	5997.90	22.80	5975.10	NDE	NDE	ND
70493	5998.00	21.30	5976.70	NDE	NDE	ND
70593	5998.00	22.00	5976.00	54.25	5943.75	32.25
70693	5991.20	28.50	5962.70	NDE	NDE	ND
70893	5991.20	26.30	5964.90	31.20	5960.00	4.90
70993	5884.40	7.20	5877.20	28.00	5856.40	20.80
71093	5908.40	8.40	5900.00	32.70	5875.70	24.30
71193	5989.30	20.20	5969.10	NDE	NDE	ND
71393	5989.90	21.80	5968.10	38.00	5951.90	16.20
71493	5990.40	24.00	5966.40	NDE	NDE	ND
71593	5988.30	27.00	5961.30	37.00	5951.30	10.00
71693	5988.30	26.50	5961.80	NDE	NDE	ND
71793	5987.27	25.60	5961.67	31.80	5955.47	6.20
71893	5987.70	26.00	5961.70	NDE	NDE	ND
71993	5986.20	36.40	5949.80	42.50	5943.70	6.10
72093	5986.00	35.40	5950.60	NDE	NDE	ND
72193	5973.16	39.60	5933.56	58.20	5914.96	18.60
72293	5973.70	32.70	NDE	NDE	NDE	ND
TH047292	5926.68	45.50	5881.18	NDE	NDE	ND
TH047492	5891.75	12.50	5879.25	NDE	NDE	ND
70993	5884.40	7.20	5877.20	26.27	5858.13	19.07
71093	5908.40	8.10	5900.30	33.40	5875.00	25.30
65792	5937.80	0.00	5937.80	NDE	NDE	ND
62792	5953.20	3.10	5950.10	NDE	NDE	ND
61992	5944.30	1.80	5942.50	NDE	NDE	ND
71593	5988.30	27.00	5961.30	NDE	NDE	ND
71793	5987.27	25.50	5961.77	NDE	NDE	ND
71393	5989.90	21.90	5968.00	NDE	NDE	ND
72393	5985.20	35.40	5949.80	NDE	NDE	ND
72493	5973.70	32.70	NDE	NDE	NDE	ND

Definitions:

bgs	below ground surface
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
ND	no data
NDE	not deep enough

Table 2-4
Well Construction Details

Location	Ground Surface Elevation (feet)	Top of Casing Elevation (feet)	Formation Completed	Well Casing and Screen Diameter (inches)	Depth to Top of Screen (feet bgs)	Depth to Bottom of Screen (feet bgs)	Depth to Bottom of Well (feet toc)	Bottom of Well Elevation (feet)
0586	5724.38	5726.37	Qc	2.00	4.40	9.76	12.34	5714.03
0686	5814.68	5816.72	Qc	2.00	3.28	8.88	11.47	5805.25
0786	5924.94	5926.54	Qc	2.00	3.00	5.74	7.70	5918.84
0886	5925.60	5926.90	KaKlss(u)	2.00	59.08	63.79	65.50	5861.40
0986	5996.39	5998.23	KaKlss(u)	2.00	122.57	135.35	144.22	5854.01
1086	5996.62	5998.19	Qrf	2.00	3.29	23.78	25.82	5972.37
4087	5883.00	5884.61	Qvf	2.00	3.50	6.46	8.70	5875.91
4187	5882.95	5884.49	KaKlss(u)	2.00	81.21	93.79	96.19	5788.30
4287	5854.34	5855.87	Qvf	2.00	3.00	6.36	7.68	5848.19
5887	5995.46	5996.77	Qrf	2.00	3.50	22.26	24.44	5972.33
5987	5992.90	5994.67	af		3.50	20.75	abandoned	
6087	5984.44	5985.96	Qrf	2.00	3.50	27.47	30.30	5955.66
6187	5984.42	5985.77	af	2.00	3.50	28.24	30.35	5955.42
6287	5984.54	5986.37	af	2.00	3.50	26.56	29.50	5956.87
6387	5985.63	5987.01	af		3.50	25.40	abandoned	
6487	5986.09	5987.34	af	2.00	13.00	23.33	26.11	5961.23
6587	5983.48	5984.99	af	2.00	10.70	23.96	25.67	5959.32
6687	5982.26	5983.67	Qrf	2.00	3.40	17.96	22.59	5961.08
6787	5970.00	5971.76	af		11.72	16.46	abandoned	5952.83
6887	5968.91	5970.32	af	2.00	11.15	15.75	17.02	5953.30
7087	5966.71	5968.38	Qrf	2.00	3.50	16.26	18.96	5949.42
7187	5963.89	5965.49	Qrf	2.00	3.50	13.51	16.25	5949.24
7287	5969.60	5971.25	Qrf	2.00	3.50	6.76	6.52	5964.73
B106089	5993.30	5995.35	af	4.00	3.70	22.40	26.46	5968.89
B206189	5984.50	5986.57	KaKl(w)	4.00	25.90	35.36	abandoned	5947.73
B206289	5977.59	5979.49	KaKl(w)	4.00	32.37	41.82	44.91	5934.58
B206389	5969.70	5971.56	af	4.00	4.00	9.50	abandoned	5954.85
B206489	5969.14	5971.46	KaKl(w)	4.00	3.25	10.00	13.31	5958.15
B206589	5967.80	5969.72	KaKl(w)	4.00	23.50	35.10	37.82	5931.90
B206689	5959.31	5961.20	KaKl(w)	4.00	8.70	18.17	21.56	5939.64
B206789	5927.90	5930.19	KaKl(w)	4.00	9.80	19.28	22.50	5907.69
B206889	5917.09	5919.15	KaKl(w)	4.00	8.00	17.45	20.20	5898.95
B206989	5882.42	5884.32	KaKl(w)	4.00	11.80	21.30	24.29	5860.03
B207089	5883.07	5884.95	KaKlss(w)	4.00	31.32	52.98	56.52	5828.43
B207189	5884.80	5886.72	KaKlss(u)		70.98	75.43	abandoned	5811.03
B207289	5948.27	5950.49	KaKl(w)	4.00	5.20	14.65	17.84	5932.65

Location	Ground Surface Elevation (feet)	Top of Casing Elevation (feet)	Formation Completed	Well Casing and Screen Diameter (inches)	Depth to Top of Screen (feet bgs)	Depth to Bottom of Screen (feet bgs)	Depth to Bottom of Well (feet toc)	Bottom of Well Elevation (feet)
76792	5943.50	5945.37	Qrf	4.00	ND	ND	10.30	5935.07
76992	5955.00	5957.99	Qrf	4.00	ND	ND	14.41	5943.58
77392	5962.50	5965.46	Qrf	4.00	ND	ND	12.05	5953.41
70093	5990.90	5992.91	Qrf	2.00	7.00	22.00	27.00	5965.91
70193	5990.30	5992.36	KaKl(w)	2.00	22.30	37.30	41.41	5950.95
70293	5990.70	5992.71	KaKlss(u)	2.00	52.10	67.10	70.80	5921.91
70393	5997.90	6000.01	Qrf	2.00	7.80	22.80	27.01	5973.00
70493	5998.00	5999.98	KaKl(w)	2.00	24.00	44.00	48.04	5951.94
70593	5998.00	5999.84	KaKlss(u)	2.00	121.00	136.00	140.07	5859.77
70693	5991.20	5992.71	Qrf	2.00	8.40	28.40	31.61	5961.10
70893	5991.20	5993.06	KaKlss(u)	2.00	51.00	66.00	70.02	5923.04
71193	5989.30	5991.11	af	2.00	18.00	20.00	24.01	5967.10
71493	5990.40	5992.43	af	2.00	18.80	22.80	27.03	5965.40
71693	5988.30	5990.22	af	2.00	16.30	26.30	30.20	5960.02
71893	5987.70	5989.67	af	2.00	10.70	25.70	30.33	5959.34
72093	5986.00	5988.32	af	2.00	30.40	35.40	39.31	5949.01
72293	5973.70	5975.94	af	2.00	27.60	32.60	37.32	5938.62
72393	5985.20	5987.52	af	2.00	12.00	22.00	25.86	5961.66
72493	5973.70	5975.88	af	2.00	17.90	27.90	32.01	5943.87

Definitions:

af	artificial fill
bgs	below ground surface
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone
ND	no data
Qc	colluvium
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium
RFEDS	Rocky Flats Environmental Database System
toc	top of casing

Table 2-5
Drawdown Recovery Test Data and Results

Well Location	Test Date	Geologic Unit	Lithology	Potentiometric Surface	Test Analysis Method	T (Cooper Only) (ft/day)	S (Cooper Only) (dimensionless)	Estimated K (cm/sec)
70093	04/06/93	Qrf	sandy gravel	Unconfined	Bouwer & Rice	NA	NA	4.05×10^{-4}
70193	04/12/93	KaKl(w)	clayey, siltstone	Unconfined	Bouwer & Rice	NA	NA	1.29×10^{-6}
70293	04/08/93	KaKlss(u)	sandstone, siltsone	Confined	Cooper et al.	0.012	0.0001	4.73×10^{-7}
70393	04/05/93	Qrf	gravelly sand	Unconfined	Bouwer & Rice	NA	NA	2.99×10^{-5}
70493	04/12/93	KaKl(w)	claystone	Unconfined	Bouwer & Rice	NA	NA	1.48×10^{-7}
70593	04/16/93	KaKlss(u)	siltstone	Confined	Bouwer & Rice	NA	NA	5.60×10^{-7}
70593	04/16/93	KaKlss(u)	siltstone	Confined	Cooper et al.	0.043	0.0001	5.92×10^{-7}
70693	04/05/93	Qrf	clayey sand	Unconfined	Bouwer & Rice	NA	NA	3.37×10^{-4}
70893	04/20/93	KaKlss(u)	siltstone	Unconfined	Bouwer & Rice	NA	NA	5.90×10^{-7}
71193	04/08/93	af	silty sand	Unconfined	Bouwer & Rice	NA	NA	5.90×10^{-6}
71493	04/06/93	af	trash, gravelly sand	Unconfined	Bouwer & Rice	NA	NA	9.62×10^{-6}
71693	NT-Dry	af	trash, silty sand	Unconfined	NT-Dry	NA	NA	NA
71893	04/06/93	af	sand clay	Unconfined	Bouwer & Rice	NA	NA	6.20×10^{-5}
72093	04/07/93	af	trash, silty clay	Unconfined	Bouwer & Rice	NA	NA	2.32×10^{-5}
72293	04/07/93	af	trash, sandy silt	Unconfined	Bouwer & Rice	NA	NA	6.48×10^{-5}
72393	04/07/93	af	trash, gravelly sand	Unconfined	Bouwer & Rice	NA	NA	1.35×10^{-4}
72493	NT-Dry	af	trash, clayey sand	Unconfined	NT-Dry	NA	NA	NA

Definitions:

af	artificial fill	Qrf	Rocky Flats Alluvium
ft	Feet	S	storage coefficient
K	hydraulic conductivity	T	transmissivity
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation		
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone or siltstone		
NA	not applicable	NT	not tested

Table 2-6
Hydraulic Conductivity Comparison

Saturated Material	K Values Obtained from the OU 7 Phase I RFI/RI (cm/sec)	K Values Obtained from Previous Investigations (cm/sec)	K Values from Freeze & Cherry (1979) (cm/sec)	K Values from Fetter (1980) (cm/sec)	K Geometric Mean OU 7 Phase I RFI/RI (cm/sec)
Rocky Flats Alluvium (Qrf)	3.37×10^{-4} - 2.99×10^{-5}	10^{-3} - 10^{-5} (d)	10^{-3} - 10^{-5} (silty sand)	10^{-4} - 10^{-6} (clayey sand)	1.59×10^{-4}
Weathered Bedrock KaKl(w)	1.29×10^{-6} - 1.48×10^{-7}	10^{-7} - 10^{-8}(b) 10^{-6} - 10^{-7} (d)	NA	NA	4.37×10^{-7}
Unweathered Bedrock KaKlss(u)	4.73×10^{-7} - 5.92×10^{-7}	10^{-6} - 10^{-8}(a) 10^{-7} - 10^{-8}(d)	10^{-4} - 10^{-8} (sandstone)	NA	5.41×10^{-7}
Disturbed Alluvium & Fill Material (af)	6.20×10^{-5} - 5.90×10^{-6}	NA 10^{-4} - 10^{-5}(d) 1.27×10^{-7} cm/sec (e)	NA	NA	1.91×10^{-5}
Landfill Debris (af)	1.35×10^{-4} - 2.32×10^{-5}	3.1×10^{-4} (c) 6.7×10^{-4} (d)	NA	NA	3.74×10^{-5}

Definitions:

af	artificial fill
cm/sec	centimeters per second
K	hydraulic conductivity
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
NA	not available
RFI/RI	RCRA facility investigation/remedial investigation

Sources:

(a) DOE 1991c
(b) EG&G 1991e
(c) EG&G 1990a
(d) DOE 1991b
(e) EG&G 1993b

Table 2-7
Groundwater Elevations and Saturated Thickness of Surficial Materials

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
0586	Qrf	5726.37	11.00	11.96	11.25	11.09	5715.37	5714.41	5715.12	5715.28	BTOB	BTOB	BTOB	BTOB
0686	Qrf	5816.72	11.16	dry	dry	dry	5805.56	dry	dry	dry	1.38	BTOB	BTOB	BTOB
0786	Qrf	5926.54	5.43	5.41	5.37	5.28	5921.11	5921.13	5921.17	5921.26	1.17	1.19	1.23	1.32
0886	KaKlss(u)	5926.90	41.81	34.24	57.90	49.62	5885.09	5892.66	5869.00	5877.28	NA	NA	NA	NA
0986	KaKlss(u)	5998.23	32.89	31.39	61.51	36.04	5965.34	5966.84	5936.72	5962.19	NA	NA	NA	NA
1086	Qrf	5998.19	13.90	14.43	14.57	13.91	5984.29	5983.76	5983.62	5984.28	10.67	10.14	10.00	10.66
4087	Qvf	5884.61	dry	dry	5.13	4.90	dry	dry	5879.48	5879.71	BTOB	BTOB	2.28	2.51
4187	KaKlss(u)	5884.49	46.40	38.47	34.48	70.13	5838.09	5846.02	5850.01	5814.36	NA	NA	NA	NA
4287	Qvf	5855.87	3.39	3.10	3.29	3.32	5852.48	5852.77	5852.58	5852.55	4.24	4.53	4.34	4.31
5887	Qrf	5996.77	13.60	14.15	14.29	13.67	5983.17	5982.62	5982.48	5983.10	9.71	9.16	9.02	9.64
5987	Qrf	5994.67	abandoned											
6087	Qrf	5985.96	13.28	13.66	13.55	13.18	5972.68	5972.30	5972.41	5972.78	15.24	14.86	14.96	15.34
6187	af/Qrf	5985.77	13.25	13.59	13.53	13.29	5972.52	5972.18	5972.24	5972.48	16.10	15.76	15.82	16.06
6287	af/Qrf	5986.37	14.50	14.75	14.74	14.58	5971.87	5971.62	5971.63	5971.79	13.63	13.38	13.39	13.55
6387	af/Qrf	5987.01	abandoned											
6487	af/Qrf	5987.34	20.15	20.62	21.02	21.13	5967.19	5966.72	5966.32	5966.21	3.10	2.63	2.23	2.12
6587	Qrf	5984.99	14.48	15.17	15.55	15.25	5970.51	5969.82	5969.44	5969.74	8.03	7.34	6.96	7.26
6687	Qrf	5983.67	13.20	13.85	14.22	13.96	5970.47	5969.82	5969.45	5969.71	3.51	2.86	2.49	2.75
6787	Qrf	5971.76	11.51	11.65	11.61	11.33	5960.25	5960.11	5960.15	5960.43	6.65	6.51	6.55	6.83
6887	Qrf	5970.32	10.24	10.39	10.33	10.07	5960.08	5959.93	5959.99	5960.25	6.67	6.52	6.58	6.84
7087	Qrf	5968.38	16.57	16.40	18.13	17.91	5951.81	5951.98	5950.25	5950.47	BTOB	BTOB	BTOB	BTOB
7187	Qrf	5965.49	7.58	7.57	7.40	7.13	5957.91	5957.92	5958.09	5958.36	8.02	8.03	8.20	8.47

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
7287	Qrf	5971.25	5.92	6.15	6.38	5.92	5965.33	5965.10	5964.87	5965.33	3.73	3.50	3.27	3.73
B106089	af/Qrf	5995.35	22.31	22.30	22.30	22.35	5973.04	5973.05	5973.05	5973.00	2.24	2.25	2.25	2.20
B206189	KaKl(w)	5986.57	27.27	23.48	21.91	21.34	5959.30	5963.09	5964.66	5965.23	NA	NA	NA	NA
B206289	KaKl(w)	5979.49	22.93	19.38	34.10	26.42	5956.56	5960.11	5945.39	5953.07	NA	NA	NA	NA
B206389	af/Qrf	5971.56	11.88	11.82	11.97	11.99	5959.68	5959.74	5959.59	5959.57	3.28	3.34	3.19	3.17
B206489	Qrf/KaKl(w)	5971.46	6.50	6.55	6.71	6.26	5964.96	5964.91	5964.75	5965.20	3.12	3.07	2.91	3.36
B206589	KaKlss(w)	5969.72	8.80	8.87	9.26	9.08	5960.92	5960.85	5960.46	5960.64	NA	NA	NA	NA
B206689	KaKl(w)	5961.20	18.38	17.56	20.60	19.74	5942.82	5943.64	5940.60	5941.46	NA	NA	NA	NA
B206789	KaKl(w)	5930.19	12.51	11.49	17.02	13.54	5917.68	5918.70	5913.17	5916.65	NA	NA	NA	NA
B206889	KaKl(w)	5919.15	18.55	18.08	19.44	19.03	5900.60	5901.07	5899.71	5900.12	NA	NA	NA	NA
B206989	KaKl(w)	5884.32	21.90	21.35	23.81	23.43	5862.42	5862.97	5860.51	5860.89	NA	NA	NA	NA
B207089	KaKlss(w)	5884.95	24.40	23.42	22.86	27.41	5860.55	5861.53	5862.09	5857.54	NA	NA	NA	NA
B207189	KaKlss(u)	5886.72	28.01	27.65	27.33	27.53	5858.71	5859.07	5859.39	5859.19	NA	NA	NA	NA
B207289	KaKl(w)	5950.49	dry	dry	dry	dry	dry	dry	dry	dry	NA	NA	NA	NA
76792	Qrf	5945.37	NA	NA	dry	dry	NA	NA	dry	dry	NA	NA	NA	BTOB
76992	Qrf	5957.99	NA	NA	dry	dry	NA	NA	dry	dry	NA	NA	NA	BTOB
77392	Qrf	5965.46	10.00	10.12	10.21	10.27	5955.46	5955.34	5955.25	5955.19	BTOB	BTOB	BTOB	BTOB
70093	Qrf	5992.91	NA	15.75	14.75	14.43	NA	5977.16	5978.16	5978.48	NA	NA	8.75	9.07
70193	KaKl(w)	5992.36	NA	14.41	14.43	14.21	NA	5977.95	5977.93	5978.15	NA	NA	NA	NA
70293	KaKlss(u)	5992.71	NA	21.85	18.94	51.00	NA	NA	5973.77	5941.71	NA	NA	NA	NA
70393	Qrf	6000.01	NA	NA	14.23	13.84	NA	NA	5985.78	5986.17	NA	NA	10.68	11.07
70493	KaKl(w)	5999.98	NA	NA	16.03	34.32	NA	NA	5983.95	5965.66	NA	NA	NA	NA
70593	KaKlss(u)	5999.84	NA	NA	45.26	102.96	NA	NA	5954.58	5896.88	NA	NA	NA	NA
70693	Qrf	5992.71	19.35	20.45	20.87	20.18	5973.36	5972.26	5971.84	5972.53	10.66	9.56	9.14	9.83
70893	KaKlss(u)	5993.06	NA	57.69	46.94	62.42	NA	5935.37	5946.12	5930.64	NA	NA	NA	NA
71193	Qrf/af	5991.11	NA	NA	16.47	16.74	NA	NA	5974.64	5974.37	NA	NA	5.54	5.27

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
71493	af	5992.43	NA	NA	22.58	22.29	NA	NA	5969.85	5970.14	NA	NA	3.45	3.74
71693	Qrf/af	5990.22	NA	NA	NA	dry	NA	NA	NA	dry	NA	NA	NA	BTOB
71893	af	5989.67	NA	NA	NA	19.31	NA	NA	NA	5970.36	NA	NA	NA	8.66
72093	af	5988.32	NA	NA	17.24	17.33	NA	NA	5971.08	5970.99	NA	NA	20.48	20.39
72293	af	5975.94	NA	NA	NA	32.53	NA	NA	NA	5943.41	NA	NA	NA	2.41
72393	af	5987.52	NA	NA	16.36	16.49	NA	NA	5971.16	5971.03	NA	NA	21.36	21.23
72493	af	5975.88	NA	NA	NA	dry	NA	NA	NA	dry	NA	NA	NA	BTOB

Definitions:

af	artificial fill
bgs	below ground surface
BTOB	below top of bedrock
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone
NA	not available
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium

Table 2-8
Wells with Measured Water Levels Below Screened Section and/or Below Top of Bedrock

Well Location[1]	Bottom of Well Screen Elevation	Top of Bedrock Elevation	December 1992 Water Level	January 1993 Water Level	February 1993 Water Level	March 1993 Water Level
4087	5876.54	5877.20	Dry	Dry	WABS	WABS
7087	5950.09	5954.71	5951.81	5951.98	5950.25	5950.47
77392	5956.56	5956.46	5955.46	5955.34	5955.25	5955.19
B206389	5960.20	5956.40	5959.68	5959.74	5959.59	5959.57
B206689	5941.14	NA	WABS	WABS	5940.60	WABS
B206989	5861.12	NA	WABS	WABS	5860.51	5860.89
B207289	5933.62	NA	Dry	Dry	Dry	Dry

[1] Wells completed in surficial materials - 4087, 7087, 77392, B206389. Wells completed in weathered bedrock - B206689, B206989, and B207289.

Definitions:

NA not applicable
WABS water level above bottom of screen

Table 2-9
Summary of Lateral Hydraulic Gradients[1]

Month	Surficial Materials			Weathered Bedrock		
	Main Landfill Area[2]	East Landfill Pond Drainage Area[3]	East Landfill Pond Embankment[4]	Main Landfill Area[2]	East Landfill Pond Drainage Area[3]	East Landfill Pond Embankment
December	0.031	0.129	0.160	0.031	0.100	0.241
January	0.031	0.129	0.160	0.030	0.100	0.267
February	0.031	0.128	0.160	0.033	0.113	0.267
March	0.029	0.128	0.160	0.026	0.100	0.241
Mean	0.030	0.128	0.160	0.030	0.103	0.254

[1] Hydraulic gradients are dimensionless parameters.

[2] Hydraulic gradients for the main landfill area were calculated using well pair 5887 and 72293.

[3] Hydraulic gradients for the East Landfill Pond drainage area were calculated using well pair 0786 and B206389.

[4] Hydraulic gradients for the East Landfill Pond embankment were calculated using piezometer/well pair TH047492/4187.

Note: Selected well pairs were used to calculate the flow path distance "dx". The change in head "dh" of the specified unit (i.e., surficial materials or weathered bedrock) was obtained from the appropriate potentiometric surface maps (Figures 2-21 through 2-28).

Table 2-10
Summary of Vertical Hydraulic Gradients[1]

Month	Well Pairs Used to Calculate Vertical Hydraulic Gradients				
	70093/70193	70393/70493	72393/72093	4087/B207089	6487/B206189
December	ND	ND	ND	0.415	0.561
January	-0.057	ND	ND	0.388	0.258
February	0.017	0.098	0.005	0.469	0.118
March	0.024	1.103	0.003	0.599	0.070

[1] The vertical hydraulic gradient was calculated as the quotient of the difference between elevations in water levels divided by the vertical distance between the screened intervals. Specifically, the divisor was the difference between the elevation at the center of the screened interval for the well completed in the surficial materials and the elevation of the screened interval completed in the weathered bedrock. Hydraulic head potentials and vertical distances between the screened intervals were based on the data presented in tables 2-4 and 2-7, respectively. Vertical hydraulic gradients are dimensionless parameters.

Definition:

ND no data

Table 2-11
Summary of Groundwater Flow Parameters and Rates

Geologic Material	Drainage Area	Geometric Mean Hydraulic Conductivity (cm/sec)	Mean Hydraulic Gradient[1]	Range of Effective Porosity	Range for Average Linear Groundwater Flow Velocity[2] (ft/yr)
af	Main Landfill	2.99×10^{-5}	0.030	0.1 - 0.2	9.28 - 4.64
Qc	East Landfill Pond Drainage Area	1.59×10^{-4}	0.128	0.1 - 0.2	210.57 - 105.29
KaKl(w)	Main Landfill	4.37×10^{-7}	0.030	0.1 - 0.2	0.14 - 0.07
KaKl(w)	East Landfill Pond Drainage Area	4.37×10^{-7}	0.103	0.1 - 0.2	0.47 - 0.23
af	East Landfill Pond Embankment	1.27×10^{-7}[3]	0.160	0.1 - 0.2	0.21 - 0.10
KaKl(w)	East Landfill Pond Embankment	4.37×10^{-7}	0.254	0.1 - 0.2	1.15 - 0.57

[1] Hydraulic gradient values based on data presented in Table 2-6.

$$dh/dx = \frac{H_1 - H_2}{X_1 - X_2} = \text{Hydraulic Gradient, which is a dimensionless parameter.}$$

[2] The average linear groundwater flow velocity is calculated as follows:

$$q = K \frac{dh}{dx}$$

$$\upsilon = \frac{q}{n} = \frac{K}{n} \frac{dh}{dl}$$

where:

- υ average linear groundwater flow velocity
- q Darcy flux (discharge per unit area)
- n effective porosity
- K hydraulic conductivity

[3] Hydraulic conductivity (K) value based on one observation (EG&G 1993b).

Definitions:

- af artificial fill
- cm/sec centimeters per second
- ft/yr feet per year
- KaKl(w) weathered undifferentiated Arapahoe and Laramie Formation
- Qc colluvium

Table 2-12
Computed Confidence Interval Widths for Total Dissolved Solids

Well Location	CV	s	n	α/2	t	Mean (mg/L)	CI (mg/L)
70093	NA	NA	1	NA	NA	170[1]	NA
71193	NA	NA	2	NA	NA	218	170-280[2]
71493	NA	NA	2	NA	NA	214	170-270[2]
71693	ND	ND	ND	ND	ND	ND	ND
71893	NA	NA	1	NA	NA	280[1]	NA
6087	0.424	109	18	0.05	1.74	257	301-212
6187	0.158	23	18	0.05	1.74	147	156-137
6287	0.208	36	13	0.05	1.78	174	192-157
6387	0.094	50	11	0.05	1.81	529	556-502
72393	NA	NA	1	NA	NA	1300[1]	NA
72093	NA	NA	1	NA	NA	1200[1]	NA
6487	0.255	86	14	0.05	1.77	339	380-298
6587	0.14	32	12	0.05	1.80	232	249-215
6687	0.667	228	16	0.05	1.75	342	441-242
6787	0.143	25	9	0.05	1.86	176	191-160
6887	0.248	49	18	0.05	1.74	196	216-176
72293	NA	NA	1	NA	NA	1700	NA
72493	ND	ND	ND	ND	ND	ND	ND
B206389	0.118	79	8	0.05	1.90	673	726-619
7287	0.148	51	13	0.05	1.78	346	372-321
B206489	0.121	46	13	0.05	1.78	382	405-359
70393	NA	NA	1	NA	NA	190[1]	NA
1086	0.195	26	17	0.05	1.75	136	147-125
5887	0.197	33	17	0.05	1.75	168	182-154
5987	ND	ND	ND	ND	ND	ND	ND
B106089	1.86	85	9	0.05	1.86	353	406-301

[1] Mean not computed; single observation reported.
[2] CI not computed; range of values reported.

Definitions:

α	level of significance	s	standard deviation
CI	confidence interval width	t	tabulates "t" value (Sanders et al. 1983)
CV	coefficient of variation		
mg/L	milligrams per liter		
n	number of observations		
NA	not applicable		
ND	no data		

Table 2-13
Landfill Leachate Flow Rates (SW097)

Date of Measurement	Flow Rate (gpm)	Flow Rate (cfs)
06/16/88	2.2	0.005
04/06/89	26.9[1]	0.06[1]
05/19/89	0.0	0.0
06/20/89	0.0	0.0
07/07/89	3.6	0.008
08/02/89	4.0	0.009
09/06/89	2.2	0.005
10/09/89	24.7[1]	0.05[1]
11/07/89	1.8	0.004
12/05/89	1.8	0.004
08/29/90	6.7	0.015[2]

[1] Believed to be an erroneous flow measurement.

[2] Measured using a Palmer-Bowlus flume.

Definitions:

cfs cubic feet per second
gpm gallons per minute

Source:

EG&G 1991f

Table 2-14
Water Balance for the East Landfill Pond Drainage Basin

Month	Average Precipitation (inches)	Pan Evaporation (inches)	Surface Water Inflow to ELP (MG)	GW Baseflow to ELP (MG)	Surface Runoff (MG)	Discharge to ELP from GWIS (MG)	Downward Seepage from ELP into Weathered Bedrock (MG)	ELP Evaporation (MG)	Volume of Spray Evaporation (MG)	Runoff from Spray Evaporation (MG)	Grass Area Evapotranspiration (MG)	ELP Storage	ELP Water Surface Elevation (feet)
A	B	C	D	E	F	G	H	I	J	K	L	M	N
Jan	0.46	-1.24	0.087	0.025	0.15	0.0173	-0.005	0.00	0.00	0.00	0.00	6.27	5919.5
Feb	0.48	-2.68	0.087	0.025	0.16	0.0173	-0.005	0.00	0.00	0.00	0.00	6.56	5919.8
Mar	1.22	-3.05	0.087	0.025	0.40	0.0173	-0.005	-0.15	0.00	0.00	0.00	6.93	5920.3
Apr	1.73	-4.48	0.087	0.025	0.56	0.0173	-0.005	-0.22	0.00	0.00	0.00	7.40	5920.8
May	2.74	-5.85	0.087	0.025	0.89	0.0173	-0.005	-0.29	6.47	5.82	-0.65	7.47	5920.9
Jun	1.85	-5.80	0.087	0.025	0.60	0.0173	-0.005	-0.29	6.47	5.82	-0.65	7.26	5920.6
Jul	1.49	-6.40	0.087	0.025	0.49	0.0173	-0.005	-0.32	6.47	5.82	-0.65	6.90	5920.4
Aug	1.52	-5.95	0.087	0.025	0.50	0.0173	-0.005	-0.29	6.47	5.82	-0.65	6.58	5919.6
Sep	1.49	-6.76	0.087	0.025	0.49	0.0173	-0.005	-0.33	6.47	5.82	-0.65	6.22	5919.4
Oct	0.92	-4.06	0.087	0.025	0.30	0.0173	-0.005	-0.20	6.47	5.82	-0.65	5.79	5918.9
Nov	0.79	-1.44	0.087	0.025	0.26	0.0173	-0.005	-0.07	0.00	0.00	0.00	6.11	5919.2
Dec	0.64	-1.24	0.087	0.025	0.21	0.0173	-0.005	0.00	0.00	0.00	0.00	6.44	5919.7

Assumed Starting Landfill Pond Storage Volume, Jan. 1, 1993 = 6.00 million gallons (MG)
Landfill Pond Spillway Elevation = 5921 feet

Definition:

ELP	East Landfill Pond
GW	groundwater
MG	million gallons
GWIS	Groundwater Intercept System

Column:

A	Month
B	Average Precipitation = average rainfall at the Rocky Flats meteorological station
C	Pan Evaporation = historical 1991 & 1992 data from the Rocky Flats meteorological station
D	Surface water inflow to the East Landfill Pond from landfill seep (SW097), mean flow rate computed from Table 2-13, assumed constant
E	Groundwater Base Flow to Landfill Pond, see Section 2.6.7 for description
F	Surface Runoff = (precip.)(Area I)(Runoff Coeff.) + ... + (precip.)(Area III)(Runoff Coeff.), see Section 2.6.7 for description
G	Discharge to Landfill Pond from Groundwater Intercept System, estimated with actual well pair data and assumed constant
H	Downward Seepage from Landfill Pond into Weathered Bedrock, estimated with actual well pair data and assumed constant
I	Landfill Pond Evaporation = (0.70)(Pan Evap.)(water surface area), see Section 2.6.7 for description
J	Volume of Spray Evaporation, based on 700 gallons per minute flow rate, 7 hours per day, 22 days per month, from May to October
K	Runoff from Spray Evaporation, 10% efficiency, 90% of spray runs off back to leachate pond
L	Grass Area Evapotranspiration, 10% of total spray volume
M	Landfill Pond Storage = volume of previous month + D + E + F + G + H + I + L
N	Pond Water Surface Elevation (see Appendix I)

Table 2-15
Water Balance for the Present Landfill Area

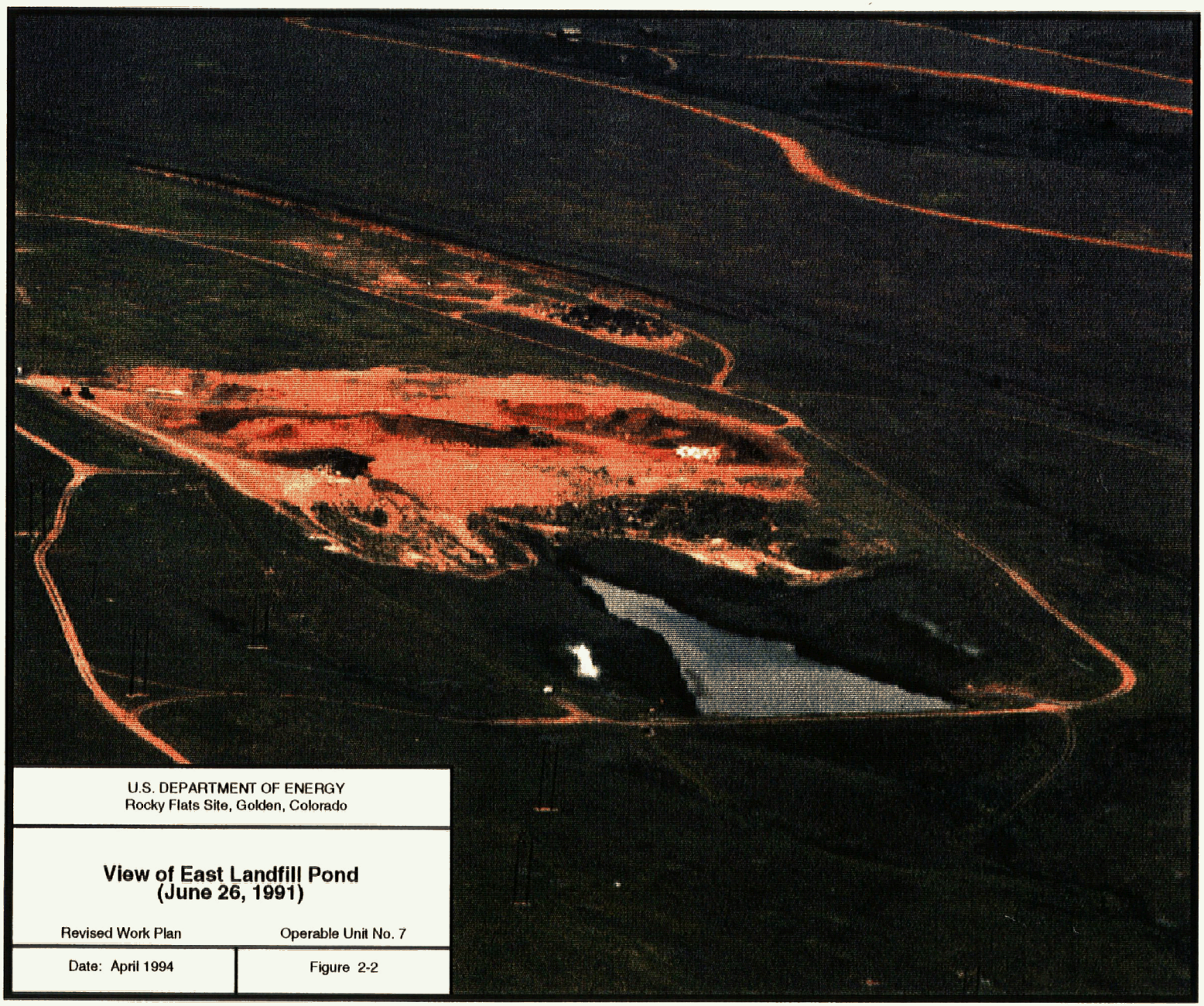
Month AA	Average Precipitation (inches) BB	Evaporation from Landfill Surface (MG) CC	Infiltration Through Landfill Surface (MG) DD	GW Inflow Under the GWIS (MG) EE	Downward Seepage from the Landfill (MG) FF	GW Outflow (MG) GG	Total GW Inflow (MG) HH	Total GW Outflow (MG) II	Mass Balance Change in Storage (MG) JJ
Jan	0.46	-0.205	0.019	0.0009	-0.020	-0.0089	0.0199	-0.0289	-0.009
Mar	1.22	-0.541	0.068	0.0010	-0.038	-0.0096	0.069	-0.0476	0.0214

Definition:

GW groundwater
MG million gallons
GWIS groundwater intercept system

Column:

AA Month
BB Average Precipitation = Average rainfall at the Rocky Flats meteorological station
CC Evaporation from Landfill Surface estimated at 70% of precipitation
DD Infiltration through Landfill Surface, estimated at 10% of precipitation
EE Groundwater Inflow Under North Groundwater (GW) Intercept System, assumed constant (see Appendix I)
FF Downward Seepage from Landfill into Weathered Bedrock (see Appendix I)
GG Groundwater Outflow, lateral groundwater flow through the eastern boundary (see Appendix I)
HH Total Groundwater (GW) Inflow, HH = DD + EE (see Appendix I)
II Total Groundwater (GW) Outflow, II = FF + GG (see Appendix I)
JJ Mass Balance: Change in Storage, JJ = HH + II (see Appendix I)



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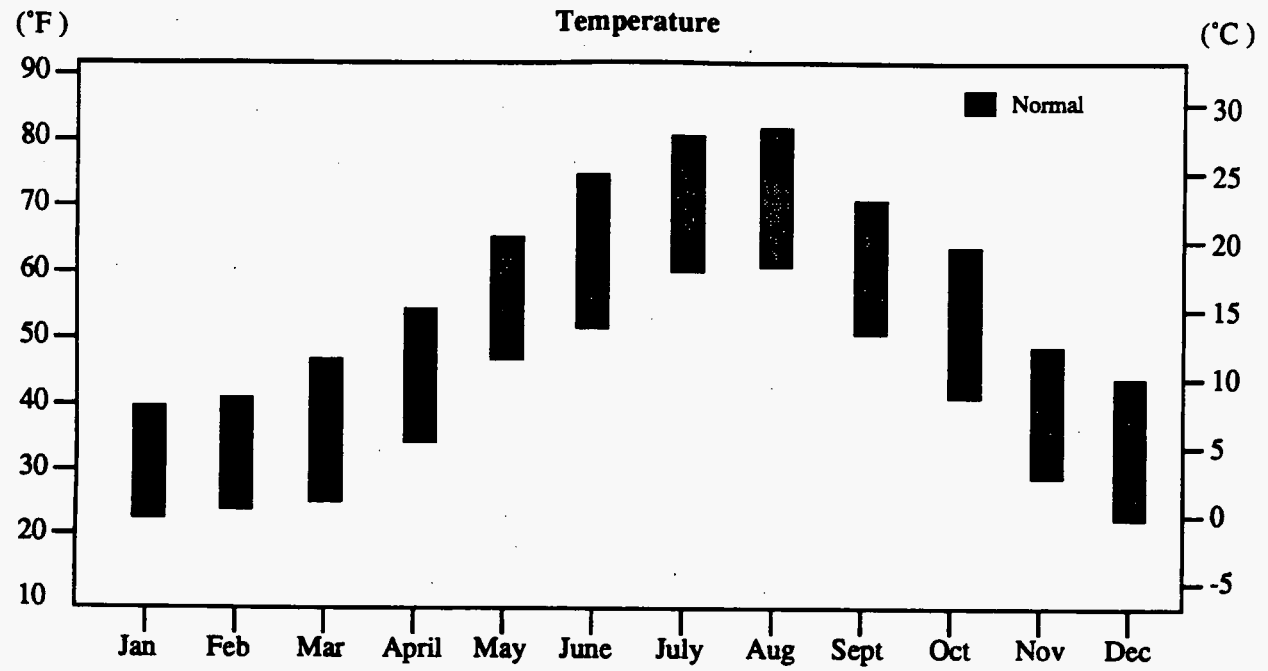
Rocky Flats Site, Golden, Colorado

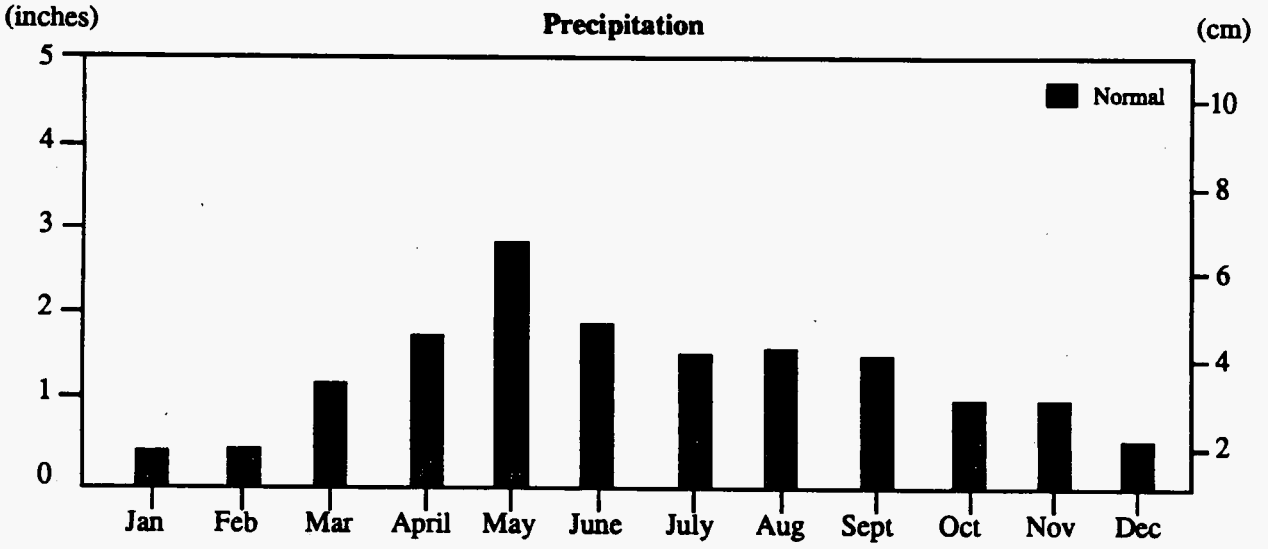
View of East Landfill Pond (June 26, 1991)

Revised Work Plan	Operable Unit No. 7
Date: April 1994	Figure 2-2

MEEC\EAST LANDFILL POND.MDW\4-6-94



Rocky Flats Plant Average Monthly Temperature Ranges



Rocky Flats Plant Average Monthly Precipitation

Note: Averages based on 25 years of temperature and precipitation data

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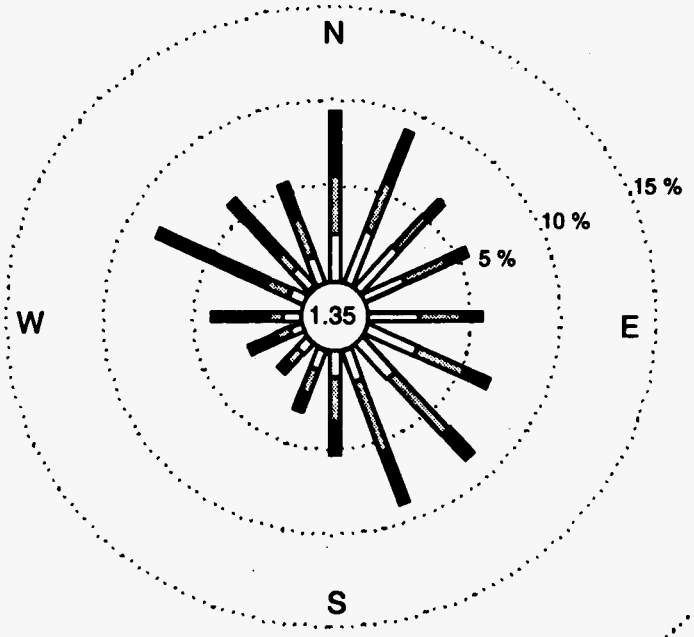
Rocky Flats Site, Golden, Colorado

Average Monthly Temperature Range and Precipitation

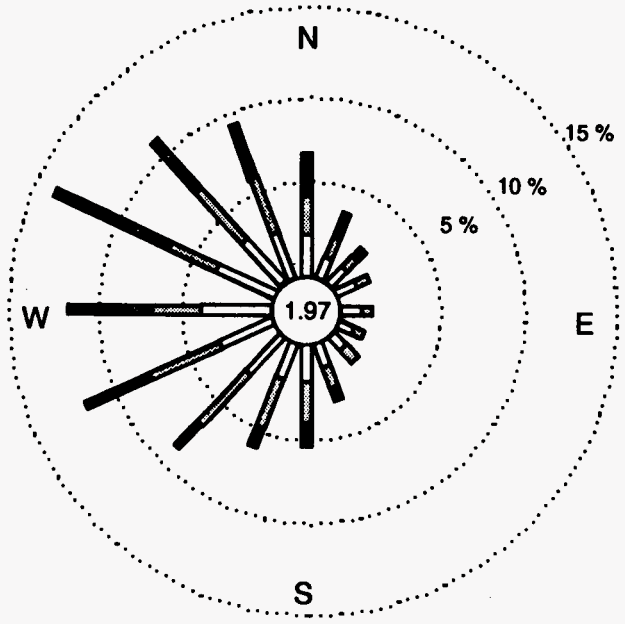
Revised Work Plan | Operable Unit No. 7

Date: May 1994 | Figure 2 - 3

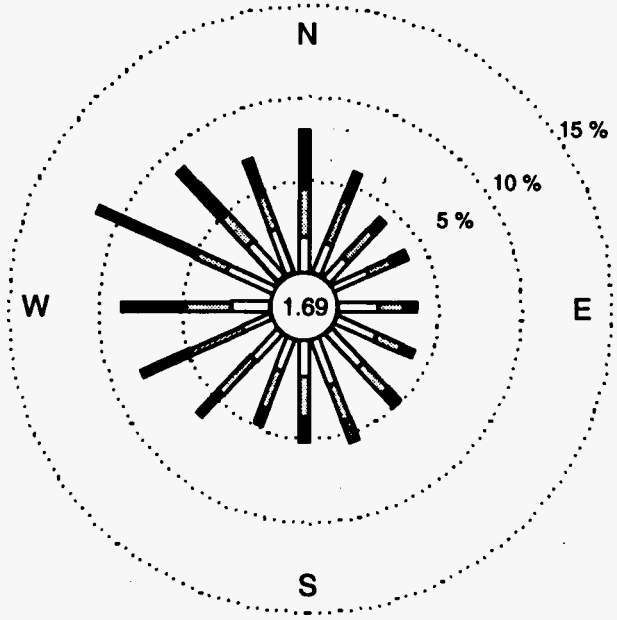
m\ee\precip graph.mdw/5-19-94



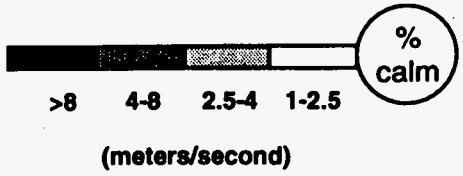
1992 Day



1992 Night



1992 Total



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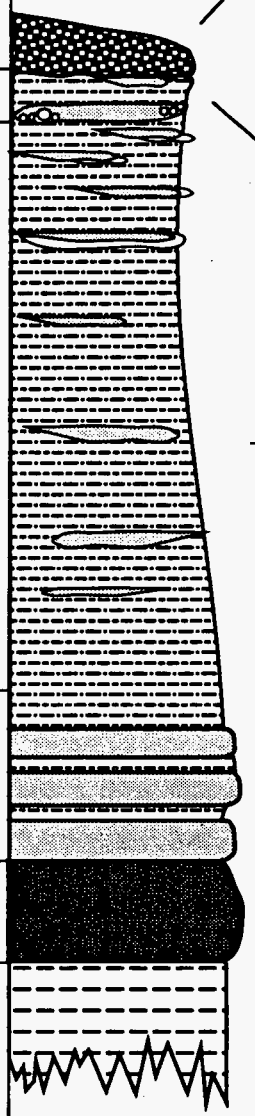
1992 Wind-Rose Diagrams for the Rocky Flats Site

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-4

M\ES\wind rose.mdw\4-5-94

Age	Formation	Thickness (feet)
Quaternary	Rocky Flats Alluvium/ Colluvium	0-100
Cretaceous	Arapahoe Formation	0-50
	Laramie Formation	600-800
		upper interval: 300-500
		lower interval: 300
	Fox Hills Sandstone	90-140
	Pierre Shale and older units	



Clayey Sandy Gravels – reddish brown to yellowish brown matrix, grayish-orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels, coarse sands and gravelly clays: varying amounts of caliche

Claystones, Silty Claystones, and Sandstones – light to medium olive-gray with some dark olive-black claystone, silty claystone, and fine-grained sandstone, weathers yellowish orange to yellowish brown; a mappable, light to olive gray, medium- to coarse-grained, frosted sandstone to conglomeratic sandstone occurs locally at the base (Arapahoe marker bed)

Claystones, Silty Claystones, Clayey Sandstones, and Sandstones – kaolinitic, light to medium gray claystone and silty claystone and some dark gray to black carbonaceous claystone, thin (2') coal beds and thin discontinuous, very fine to medium-grained, moderately sorted sandstone intervals

Sandstones, Claystones, and Coals – light to medium gray, fine- to coarse-grained, moderately to well sorted, silty, immature quartzose sandstone with numerous claystones, and subbituminous coal beds and seams that range from 2' to 8' thick

Sandstones – grayish orange to light gray, calcareous, fine-grained, subrounded glauconitic, friable sandstone

Reference: Phase II Geologic Characterization Surface Geologic Mapping Report, March 1992

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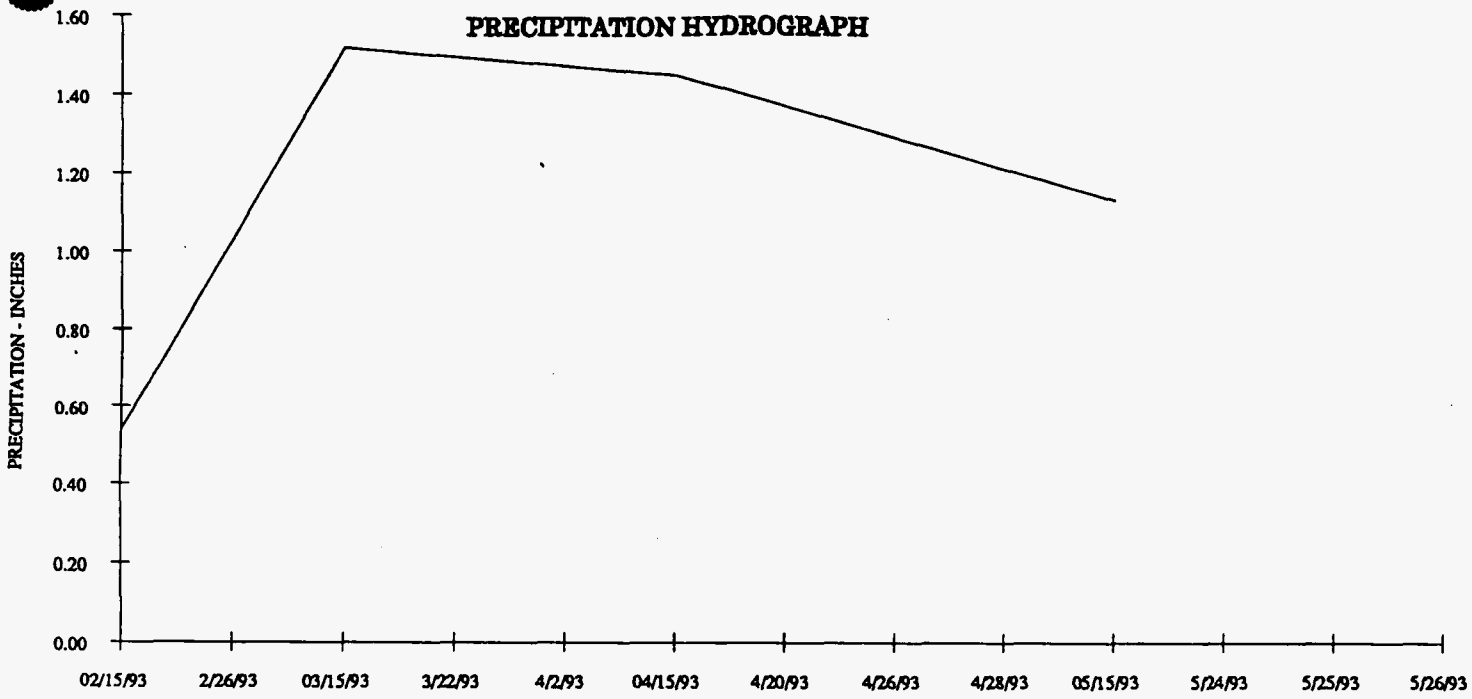
Rocky Flats Site, Golden, Colorado

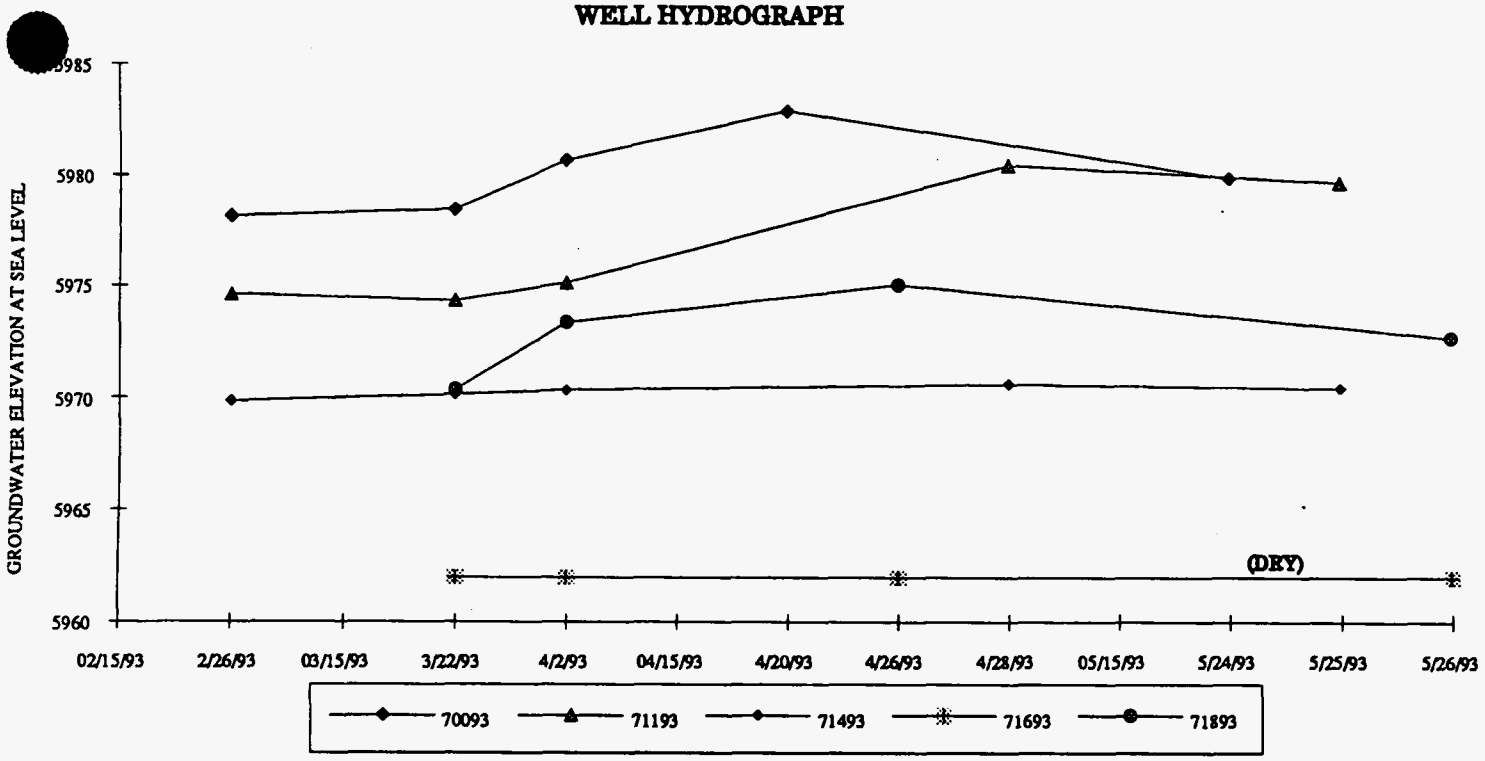
Generalized Stratigraphic Section for the Rocky Flats Site

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-6

TRANSECT AA-AA'





TRANSECT AA-AA'
Wells 70093, 71193, and 71893 are located outside the groundwater intercept system.
Well 71693 is located inside the groundwater intercept system.

U.S. DEPARTMENT OF ENERGY
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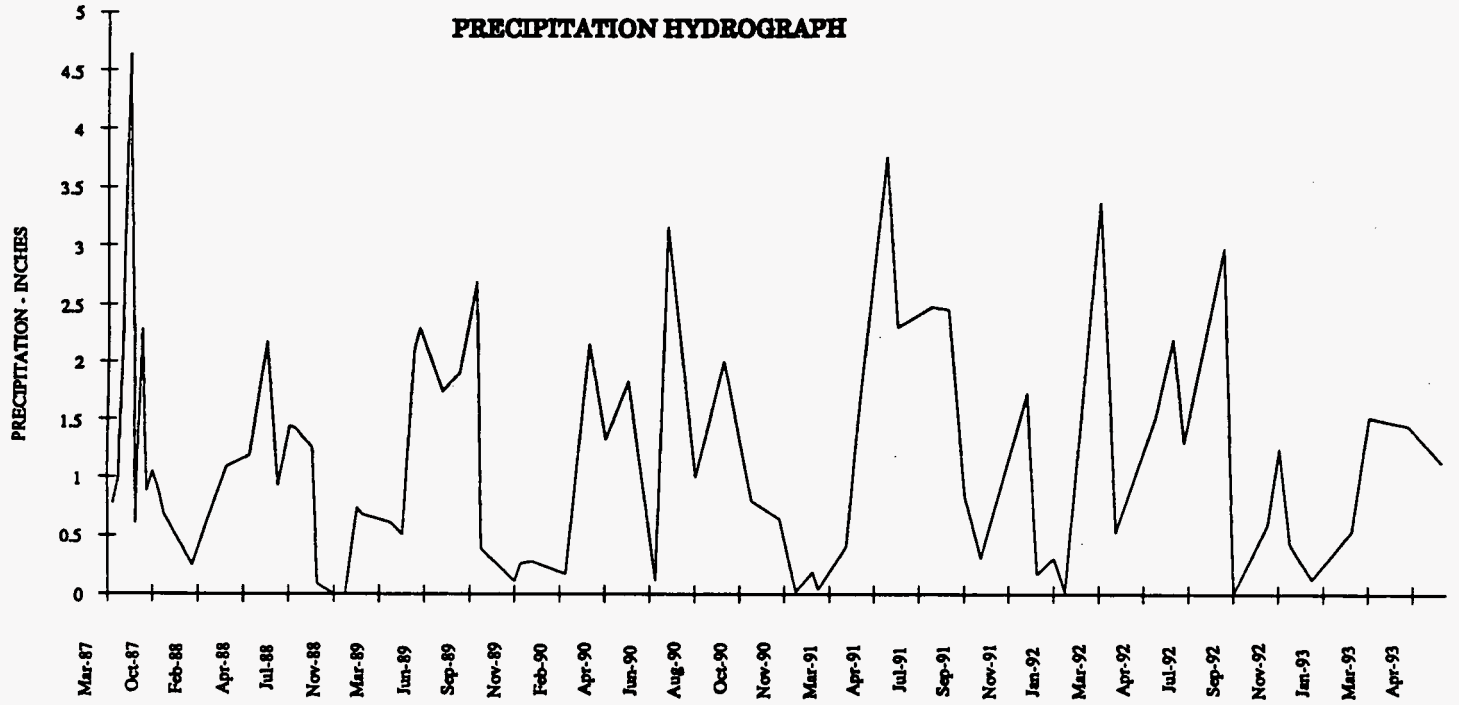
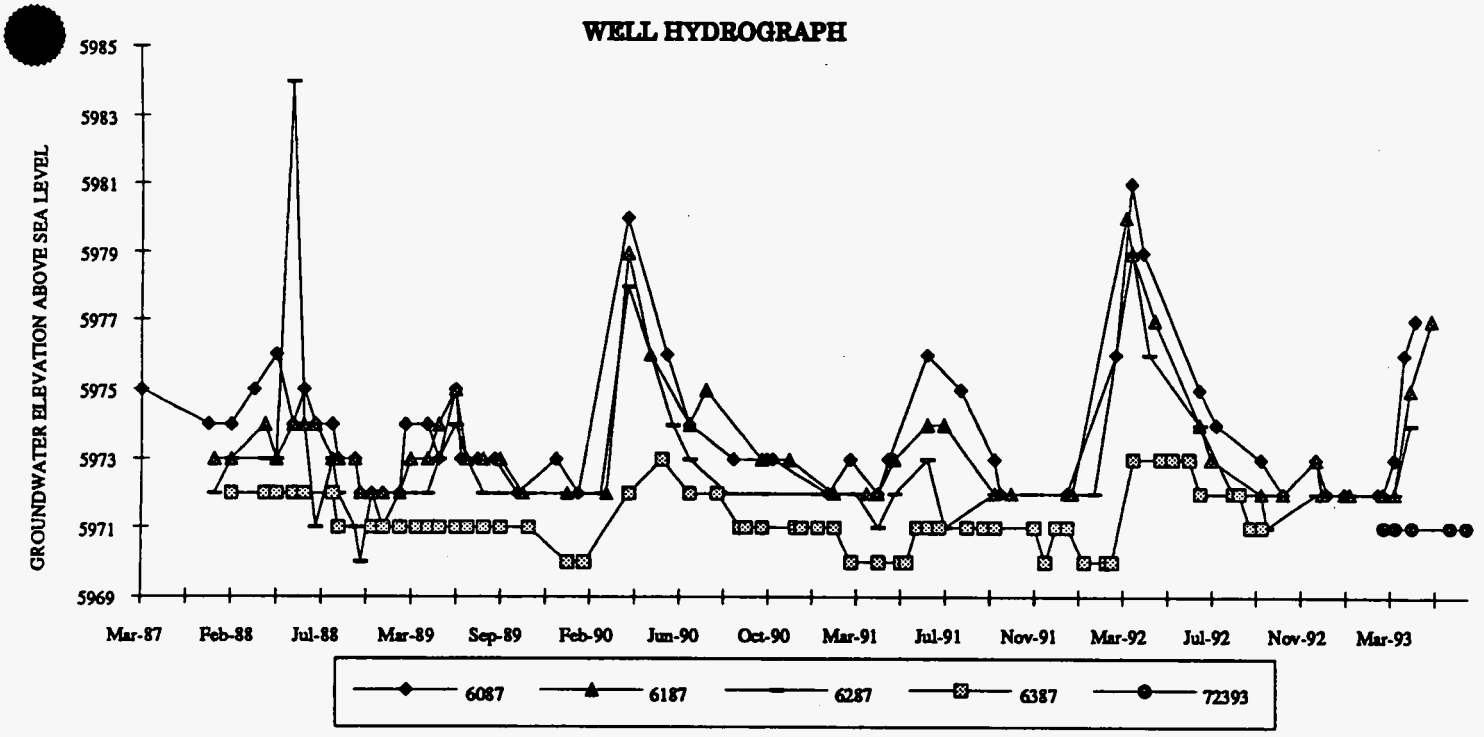
Hydrograph AA-AA'

Revised Work Plan Operable Unit No. 7

TRANSECT BB-BB'

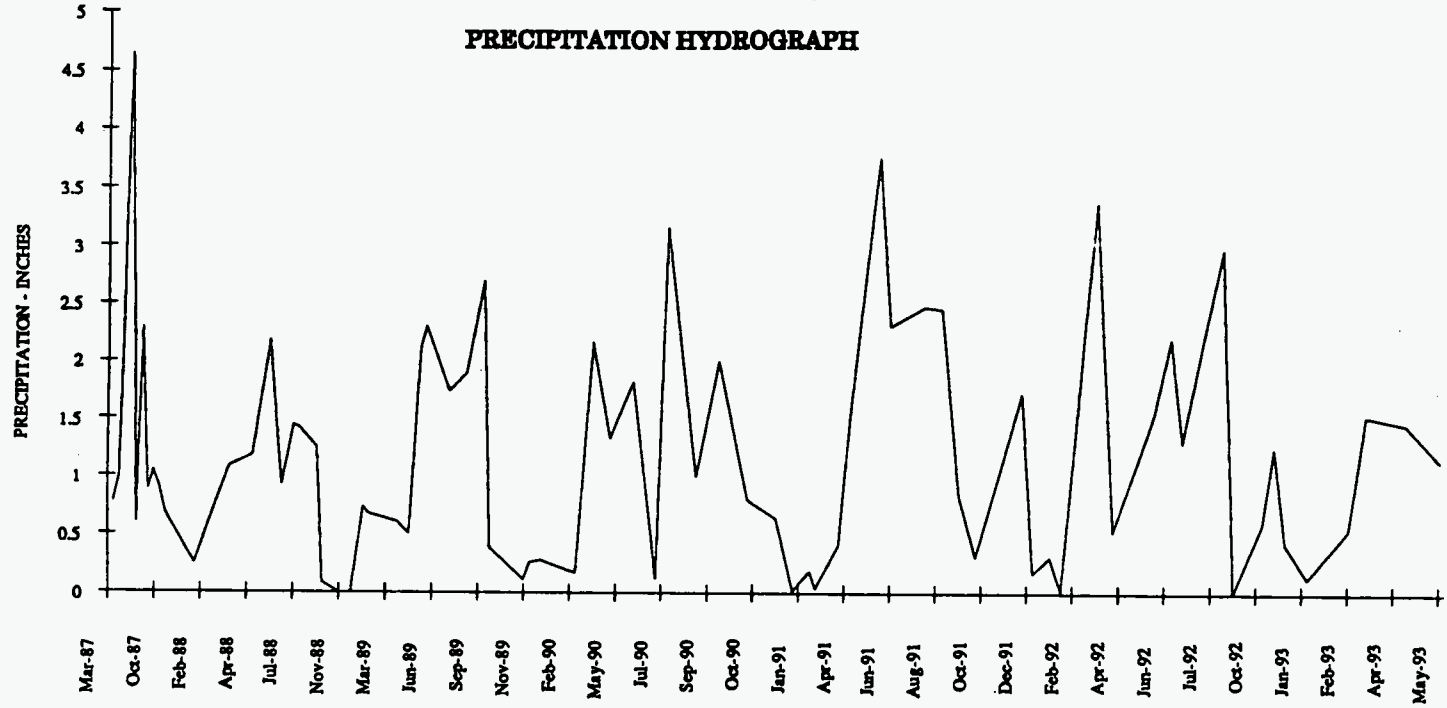


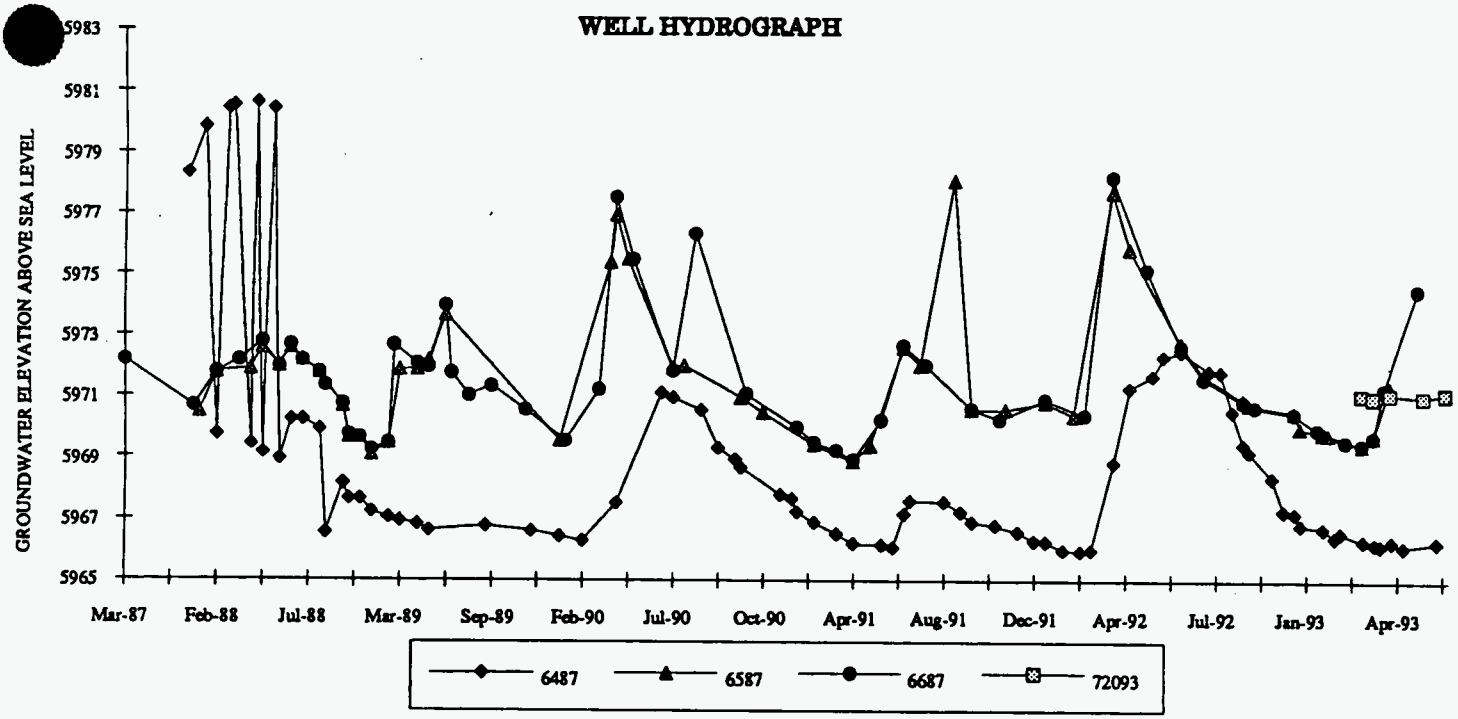


TRANSECT BB-BB'
Wells 6087, 6187, and 6287 are located outside the groundwater intercept system.
Wells 6387 and 72393 are located inside the groundwater intercept system.

U.S. DEPARTMENT OF ENERGY Rocky Flats Site, Golden, Colorado	
Hydrograph BB-BB'	
Revised Work Plan	Operable Unit No. 7

TRANSECT CC-CC'





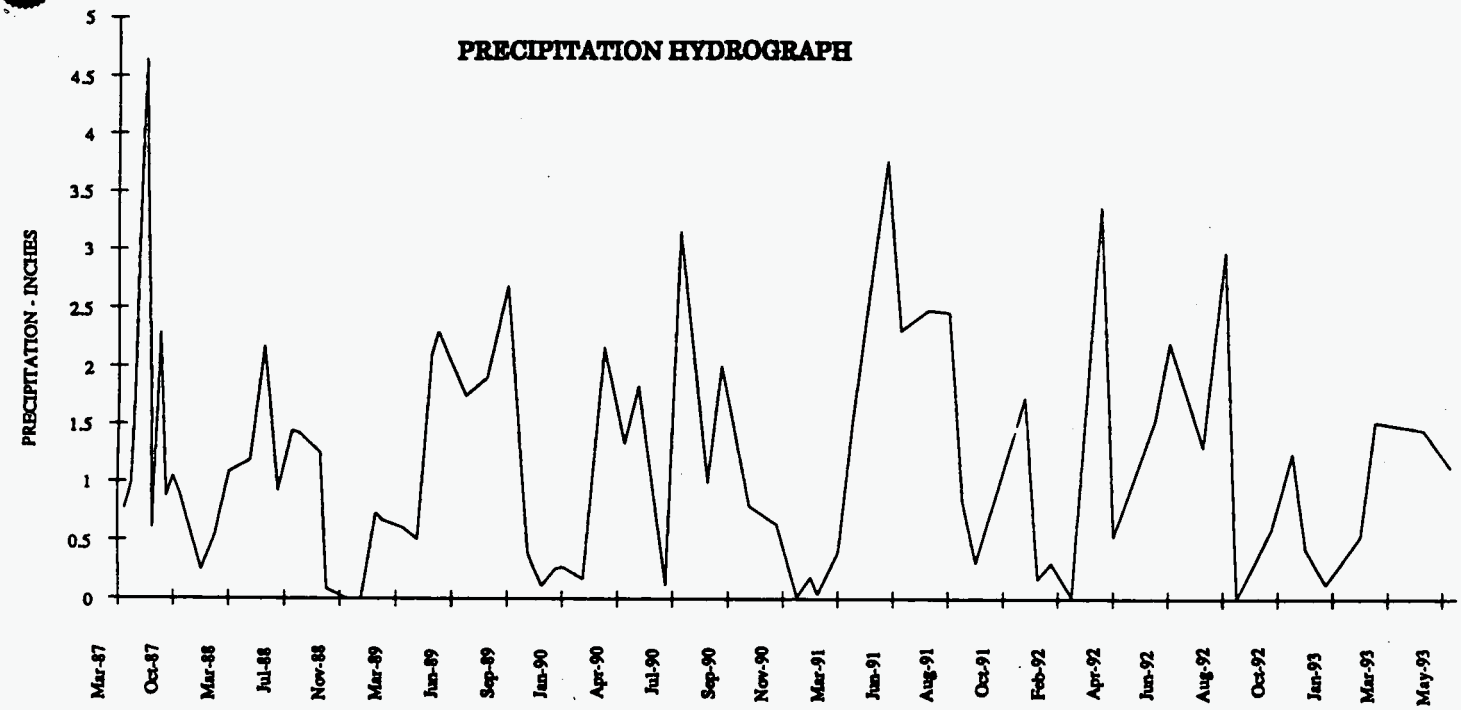
TRANSECT CC-CC'
Wells 72093 and 6487 are located inside the groundwater intercept system.
Wells 6587 and 6687 are located outside the groundwater intercept system.

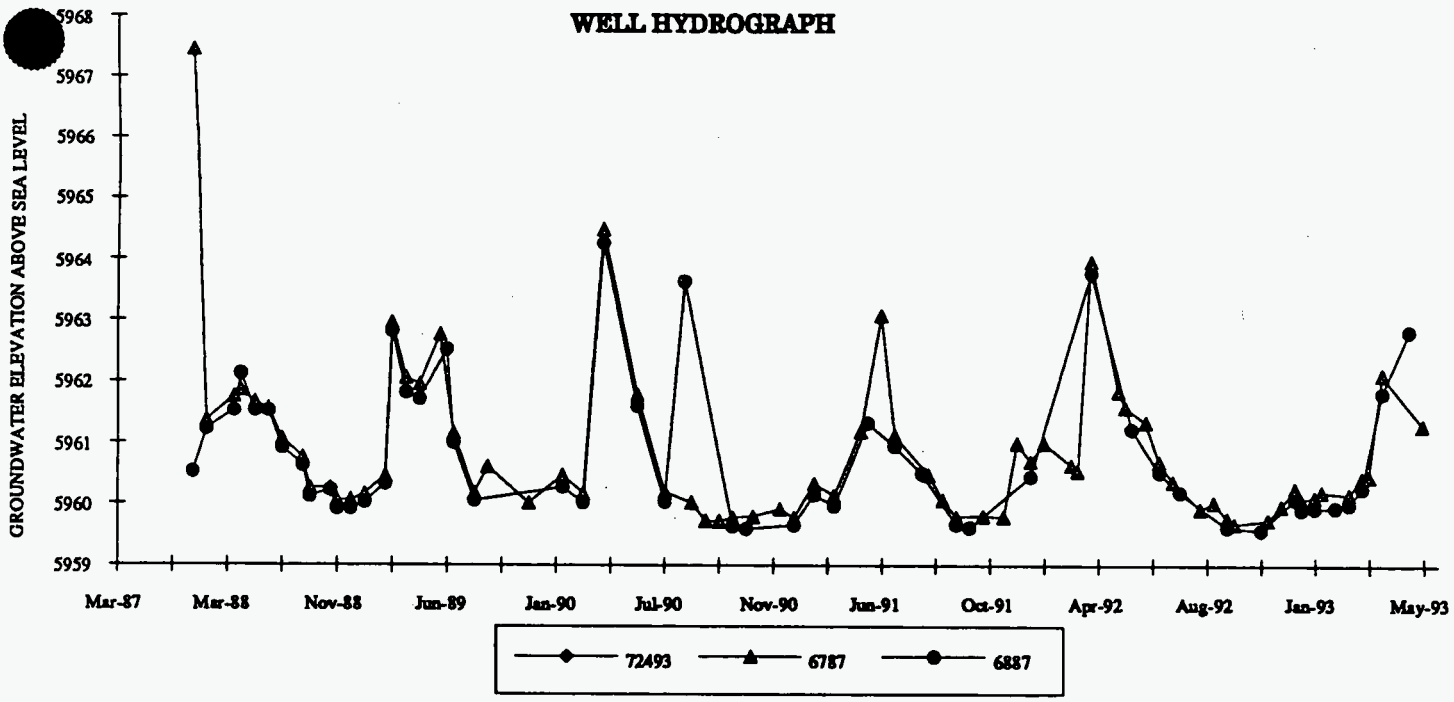
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydrograph CC-CC'

Revised Work Plan Operable Unit No. 7

TRANSECT DD-DD'





TRANSECT DD-DD'
Wells 6787 is located outside the north slurry wall.
Well 6887 is located inside the north slurry wall.

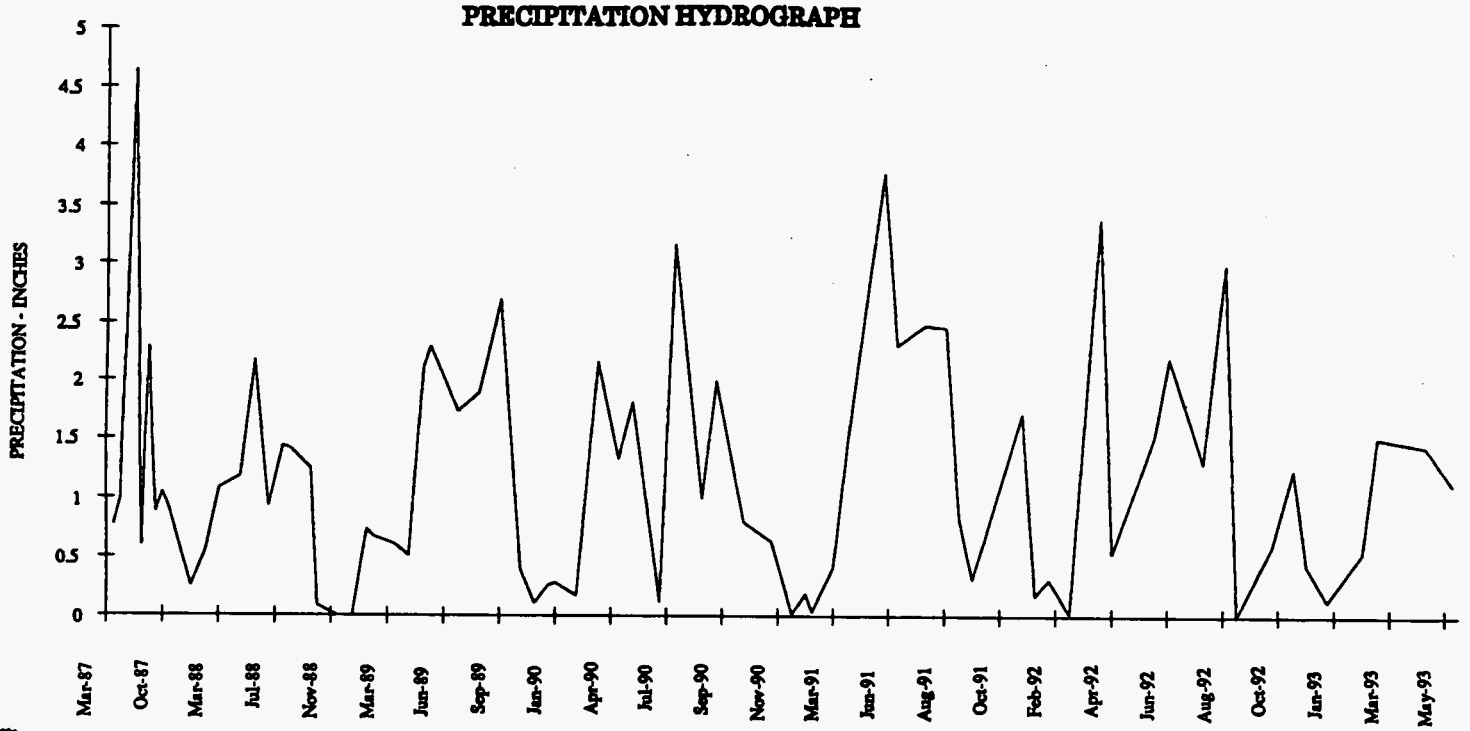
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydrograph DD-DD'

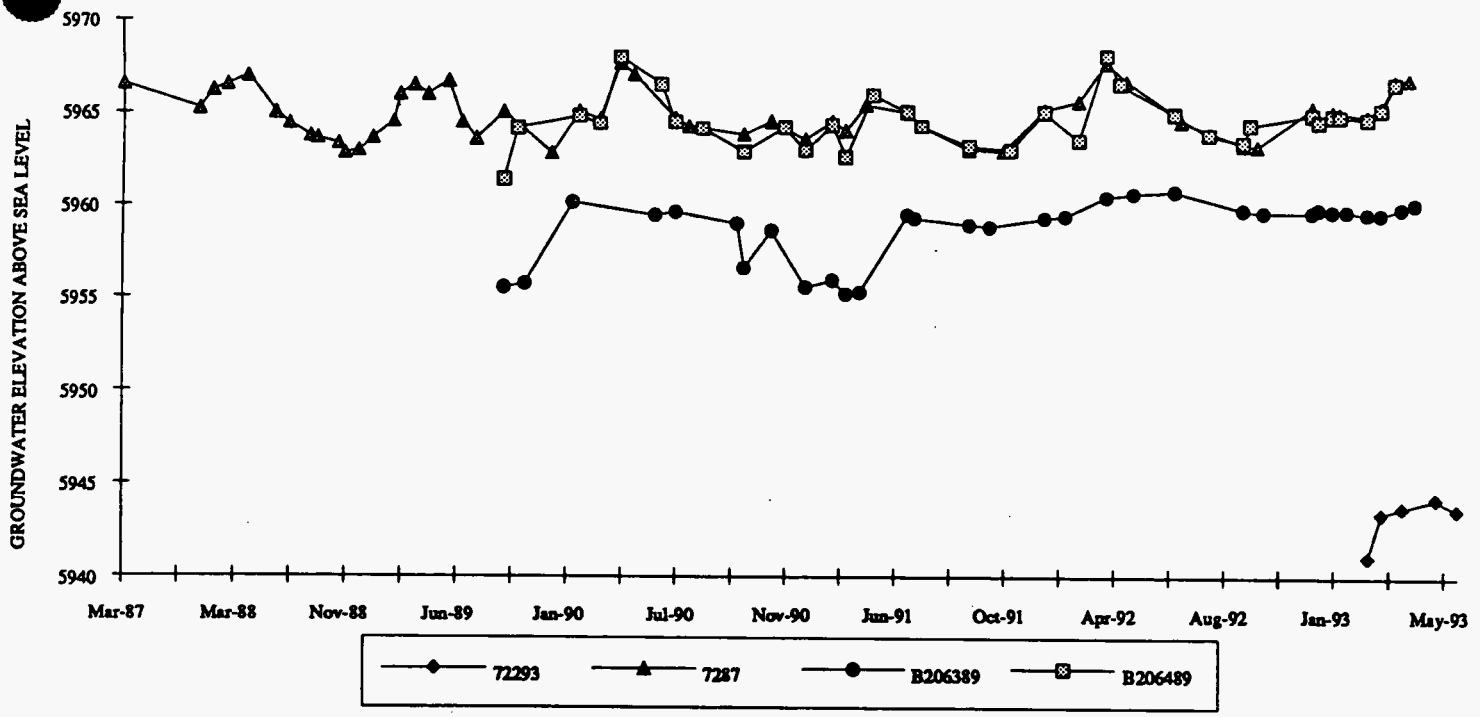
Revised Work Plan Operable Unit No. 7

TRANSECT EE-EE'

PRECIPITATION HYDROGRAPH



WELL HYDROGRAPH



TRANSECT EE-EE'
Wells 7287 and B206489 are located outside the south slurry wall.
Wells 72293 and B206389 are located inside the north slurry wall.

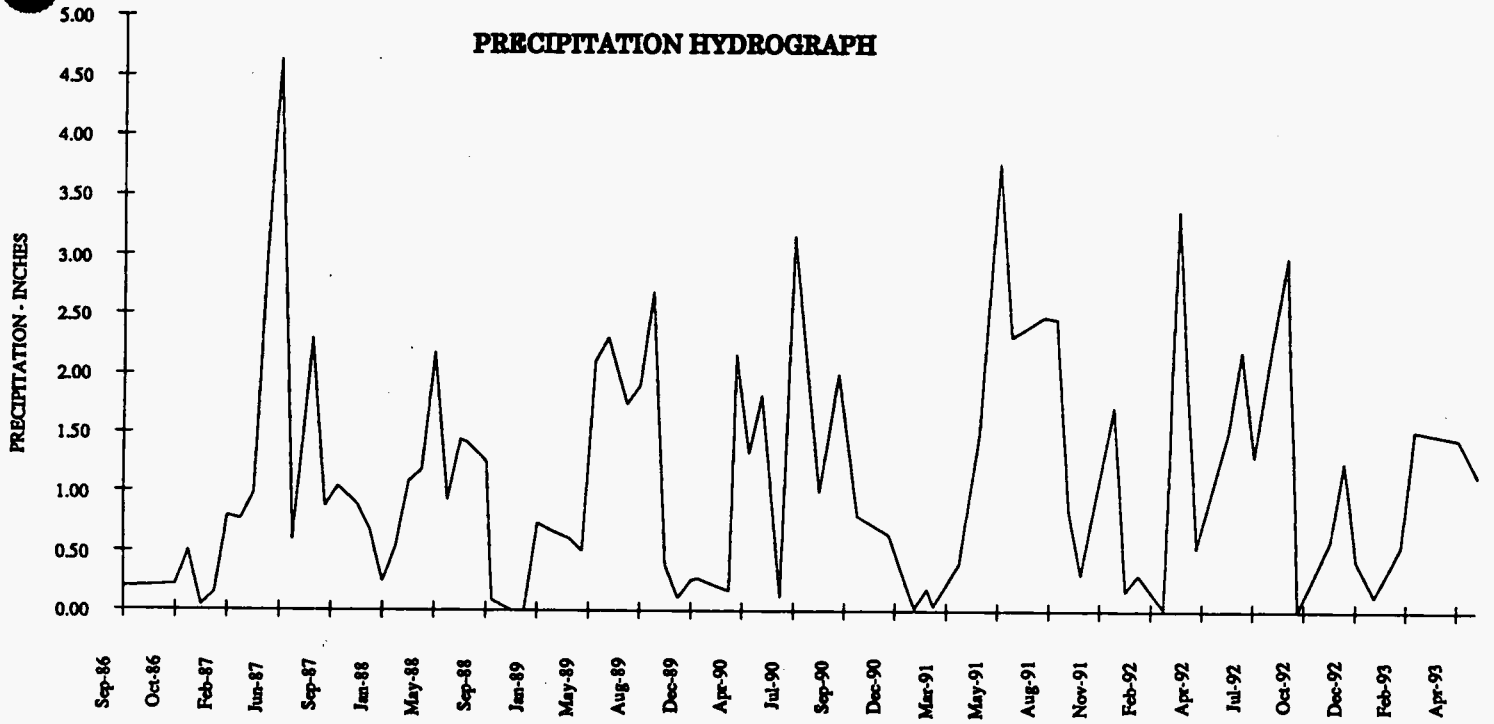
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydrograph EE-EE'

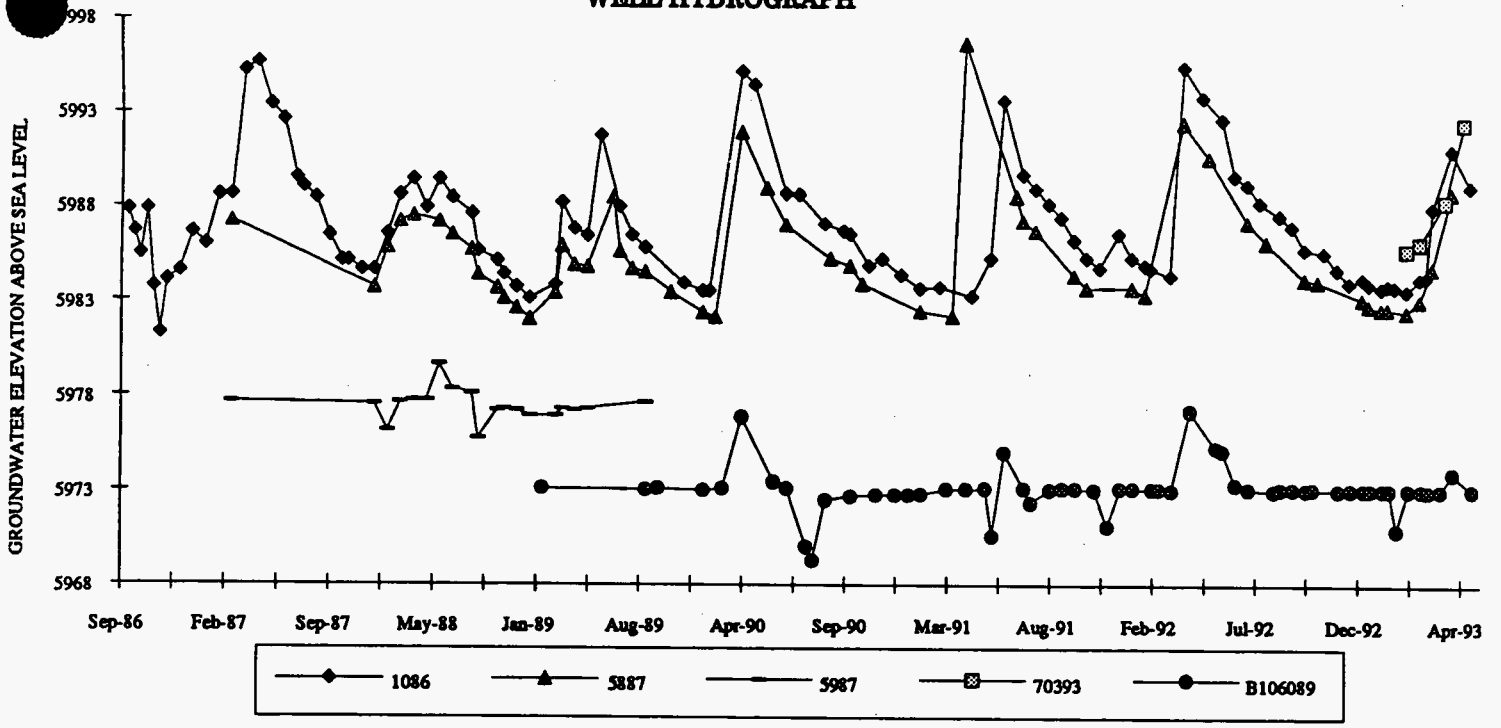
Revised Work Plan Operable Unit No. 7

TRANSECT FF-FF'

PRECIPITATION HYDROGRAPH



WELL HYDROGRAPH



TRANSECT FF-FF'

Wells 70393, 1086, 5887, 5987, and B106089 are located outside the groundwater intercept system.

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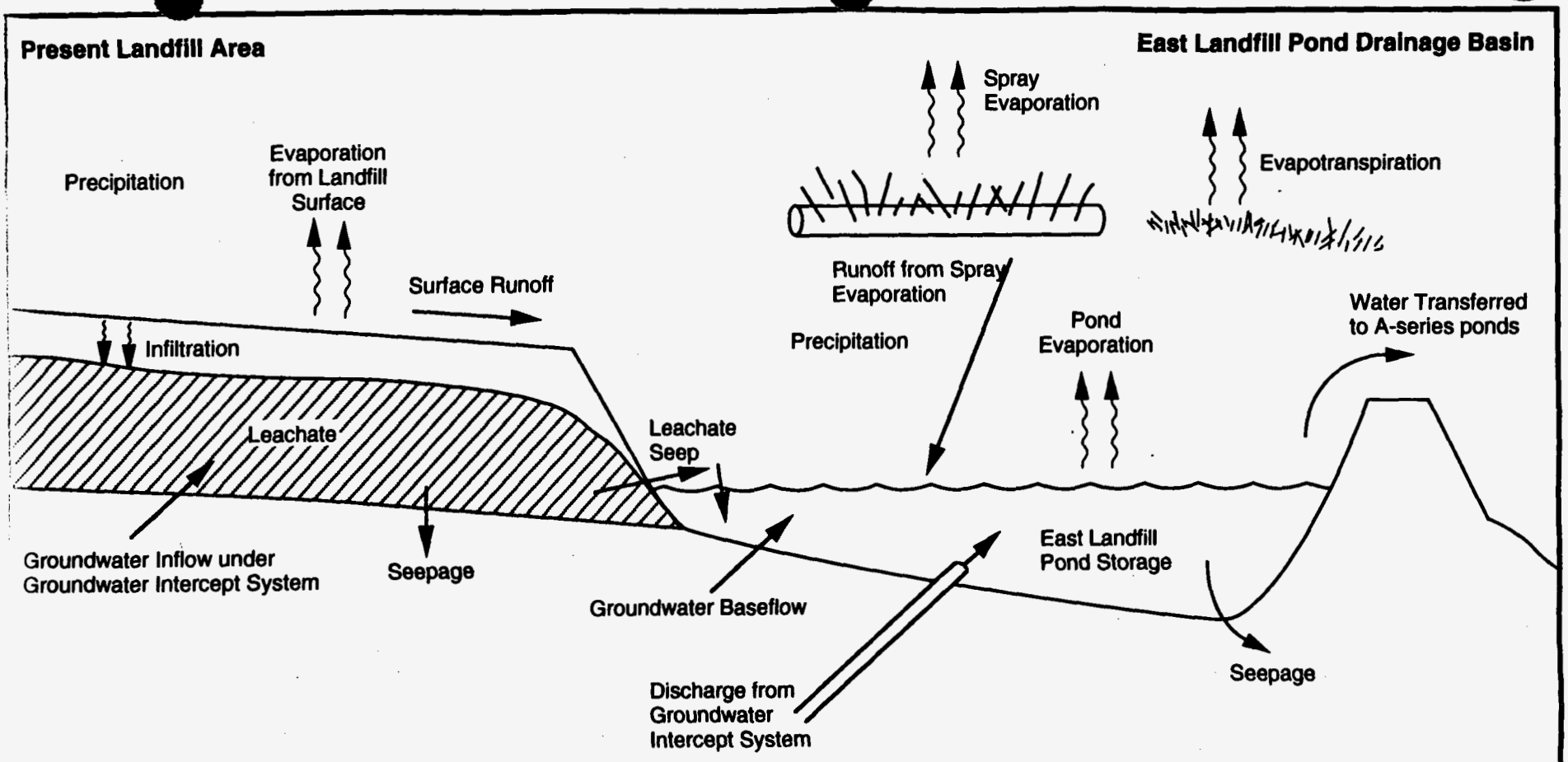
Rocky Flats Site, Golden, Colorado

Hydrograph FF-FF'

Revised Work Plan Operable Unit No. 7



U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Water Balance Inflows and Outflows for the OU7 Watershed

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2 - 39

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ENVIRONMENTAL MANAGEMENT
Technical Memorandum
12-16-94

Category

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INFORMATION ONLY

Title:
Section 3

Name

10/5/94
Date

3. DATA QUALITY AND USABILITY

The data quality objectives and their measurement criteria for the OU 7 Phase I RFI/RI were specified in the OU 7 Phase I work plan (DOE 1991b) to ensure that sample-collection and analytical methods used provided data of appropriate quality to characterize the site and describe the nature and extent of contamination.

The primary quality-assurance objective for analytical data is to ensure that the data generated are of documented quality and are defensible for the intended data uses. In order to meet this objective, appropriate steps were taken to ensure that the OU 7 data are (1) of known quantitative significance in terms of precision and accuracy at levels appropriate for the intended data use, (2) representative of actual physical and chemical conditions, (3) comparable to previous data, and (4) complete to the extent that conclusions can be made and supported. Quality of OU 7 data is discussed in Section 3.1.

Data usability describes what data can be used, how and why it is used, and when and where it can be used. Different types of data and data from various sources may vary in quality and, thus, in their usability. Absolute criteria regarding whether data can be used or not do not exist for all circumstances. Data usability for the OU 7 Phase I RFI/RI is determined by the data-quality needs and documentation of the field sampling, laboratory, and QA/QC protocols. Usability of OU 7 data is discussed in Section 3.2.

3.1 Data Quality

The OU 7 Phase I RFI/RI field activities were conducted in accordance with the OU 7 Phase I work plan (DOE 1991b), the OU 7 quality assurance addendum (QAA) which is included in the work plan, the sitewide quality assurance project plan (QAPjP) (EG&G 1990c; 1991h), and standard operating procedures (SOPs) (EG&G 1992c).

3.1.1 Field Quality-Control Sampling

Field QC samples provide information to assess sampling and analysis precision and to identify potential biases in analytical data resulting from cross contamination during sampling or contamination during sample transport and storage. At OU 7, QC samples were collected concurrently with real samples. Table 3-1 presents the required frequency of QC sample collection and Table 3-2 summarizes the actual QC samples collected during each OU 7 Phase I RFI/RI sampling activity.

The field QC samples collected during the OU 7 Phase I RFI/RI include field duplicates, equipment rinsate blanks (equipment rinses), trip blanks, and field preservation blanks (field blanks). Among the various types of QC samples, field duplicates provide additional sample volume for a duplicate laboratory analysis. These results, when compared to analytical results for the real samples, assess the precision of both the field sampling methods and analytical procedures.

Duplicate samples are collected at the same time as the real samples, using the same procedures and the same types of containers. They are also preserved in the same manner and submitted for the identical suite of analyses as required for the real samples.

Equipment rinses are collected upon completing decontamination procedures to evaluate whether or not decontamination activities are adequate to prevent cross contamination. Equipment rinses are obtained by pouring distilled water on decontaminated sample-collection equipment. The rinsate is collected and submitted for the same analyses as the real samples. For soil-gas samples, equipment blanks may also be collected by drawing ambient air through sampling equipment to evaluate decontamination procedures.

Trip blanks and field blanks are collected for water samples to provide information on the potential for contamination during sample collection and transport. Trip blanks and field blanks are not collected for solid media samples; therefore, contamination by ambient conditions during sample storage and shipping cannot be evaluated for the surface soil, subsurface geologic material, or sediment samples.

Trip blanks consisting of distilled water are prepared either by the laboratory or the sampling team and accompany each shipment of water samples for volatile organic compound (VOC) analysis.

Analysis of these blanks indicates possible contamination by VOCs or any problems associated with sample shipment, handling, or storage.

Field blanks of distilled water, preserved according to the applicable preservation requirements, are prepared by the sampling team and are used to provide an indication of any contamination introduced during field sampling preparation. Field blanks are only applicable to samples requiring chemical preservation.

3.1.2 Laboratory Qualifiers and Validation Codes

Two types of data qualifiers are used to describe data: laboratory qualifiers and validation codes. Validation codes are more important than laboratory qualifiers because they are determined as an independent quality check and are applied to the data after the laboratory qualifiers are applied.

3.1.2.1 Laboratory Qualifiers

Environmental samples were analyzed using EPA and other well-established analytical methods identified in General Radiochemistry and Routine Analytical Services Protocol (GRRASP) (EG&G 1991g). All laboratory analyses for target analyte list (TAL) metals and target compound list (TCL) organic compounds were performed using EPA Contract Laboratory Program (CLP) procedures. Methods for non-CLP analytes, including major ions and radionuclides, were based on EPA methods specified in the GRRASP.

Laboratory qualifiers are defined in Table 3-3. The table also specifies whether or not data with a particular qualifier should be included in the data analysis, whether or not the data are detected, and what value should be used for statistical analysis.

3.1.2.2 Validation Codes

EPA CLP methods and protocols were used in the validation process for these data. Because EPA guidelines for validating non-CLP analytes are not currently available, non-CLP data were validated by an independent subcontractor in accordance with guidelines developed by the Rocky Flats Environmental Management Department (EMD). These non-CLP guidelines are based on EPA validation protocol and are modified for non-CLP analytical methods. Data were validated at EPA Level IV or the equivalent for non-CLP analyses.

Laboratory QA/QC results, including laboratory control-sample analyses, are not available from the Rocky Flats Environmental Database System (RFEDS). However, this information is reported to the data validation subcontractor and is reviewed to evaluate the precision and accuracy of laboratory analyses. After reviewing laboratory QC results, the data validation subcontractor may qualify data as necessary.

Validated data are qualified as either (1) V = valid and usable without qualification, (2) A = acceptable for use with qualification(s), or (3) R = rejected and thus unacceptable for use. Valid data meet the following objective standards, where applicable:

- Analytical methods were followed (primary validation criteria)
- Acceptance criteria were achieved
- Sufficient numbers and types of QC samples were analyzed
- QC limits were achieved (primary validation criteria)
- Compounds and analytes were correctly identified (primary validation criteria)
- Equipment and instrumentation calibration criteria were achieved (primary validation criteria)
- Sample holding times were met

Data that are acceptable with qualifications meet most, but not all, of the above-listed standards. At a minimum, all of the primary validation criteria are achieved within acceptable limits. Rejected data fail to meet primary validation criteria. Data that were rejected were not used in any of the statistical calculations or in the data-quality assessment for OU 7. Data qualified as V or A are considered of equal utility, and both are used in computing statistics and evaluating data quality. Table 3-4 presents the validation codes.

Table 3-5 presents a summary of the data validation status for OU 7 as of December 1, 1993. Approximately 87 percent of all results have been validated. The percentage validated based on the total number of results varies by medium and analyte group. The percentage of data validated by medium varies from 73 percent for groundwater to 100 percent for biota and soil gas. The percentage of data validated by analyte group varies from 42 percent for dissolved radionuclides

to 96 percent for total metals. Section 3.1.8 presents a detailed evaluation of the completeness of the data, including percentage validated and percentage rejected.

3.1.3 Data Management

Data used for this report were extracted on December 1, 1993, from RFEDS, which is an electronic database that contains all data collected at the site. In addition to analytical data for environmental samples, the RFEDS database includes information such as field measurements, QC samples, and analytical results for sample dilutions. RFEDS contains all validated and unvalidated results. Prior to determining data quality and usability, the entire database was reformatted and made internally consistent using the following five steps:

1. Records reported with undefined units, laboratory qualifiers, or validation codes; blank results or unit fields; and non-radionuclide results equal to zero were researched. If a resolution was not possible, these records were labeled as unusable.

2. Tentatively identified compound (TIC) records were labeled based on a result type of TIC or laboratory qualifier of "A" or "N."

3. Unvalidated result values, detection limits, and units were replaced with validated result values, detection limits, and units if validated data were included with the record.

4. Result values were converted to consistent units of measurement for each group of analytes as follows:

   metals—milligrams per kilogram (mg/kg) and micrograms per liter (µg/L)

   organic compounds—micrograms per kilogram (µg/kg) and micrograms per liter(µg/L)

   radionuclides—picocuries per gram (pCi/g) and picocuries per liter (pCi/L)

   water-quality parameters—milligrams per kilogram (mg/kg) and micrograms per liter (µg/L)

5. Duplicate records were identified and researched to determine which record to use based on the result type (for example, TRG [target], DIL [dilution], REP [replicate], REX [re-extraction]), laboratory qualifier, and validation code. The record not to be used was labeled. For example, with an E-qualified organic compound TRG record and DIL record pair, retain the DIL record and label the TRG record as unusable.

An internally consistent database of supportable data, standardized units of measure, and unique records for each analyte for each sample was developed using these cleanup steps. Detect and nondetect criteria, summaries of the quantity, validation status, and usability status of the records were compiled from this database.

Five additional steps were performed to produce the final "working" database:

1. Records were labeled with usability categories based on the laboratory qualifiers and validation codes as presented in Table 3-6.

2. TIC records were removed.

3. Records labeled as unusable or rejected were removed.

4. Results that indicate detection of an analyte (hits) and results that indicate non-detections were labeled based on the combination of laboratory qualifier and validation code as specified in tables 3-3 and 3-4, respectively.

5. Two separate files, the "working" database (real sample results) and the QC database (QC sample results), were created as follows:

    a. Records of real and duplicate sample pairs were identified and copied to the QC database; duplicate sample records were removed from the working database.

    b. Records for field blanks, trip blanks, equipment rinses, and matrix spikes were moved from the working database to the QC database.

Data from the working database are used to perform statistical comparisons of site data to background data and to evaluate the nature and extent of contamination. Data from the QC database are used to describe the quality of data collected for the Phase I RFI/RI in terms of the data-quality indicators described below.

3.1.4 *Data-Quality Indicators*

Data quality is assessed in terms of precision, accuracy, representativeness, comparability, and completeness, also known as the five precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters. PARCC parameters apply to both laboratory and field data.

Precision is a measure of the reproducibility of analytical results. Accuracy is a measure of how closely an analytical result corresponds to the actual concentration in a sample. Representativeness is a qualitative measure of how well data meet the project goal of representing true background concentrations. Completeness is a measure of the amount of valid data derived from the sampling program. Comparability expresses the extent to which data collected over a period of years and analyzed by different methods can be considered to be equivalent.

Sections 3.1.5 through 3.1.9 briefly describe each PARCC parameter, summarize the QC data available to assess the parameter, present the results of the data-quality evaluation for each analyte group for each media sampled, and evaluate the overall quality of the environmental data over the sampling period for each analyte group in each medium sampled. Table 3-7 presents a summary of the PARCC parameter QC criteria for each analyte group for each media for the sampling period.

3.1.5 *Precision*

Precision is a quantitative measure of variability that is evaluated by comparing analytical results for real samples to analytical results for corresponding duplicate samples. Evaluating precision among duplicate samples provides information not only on reproducibility of sampling methods but also on reproducibility of analytical methods.

Quantitative estimates of precision are made by calculating the relative percent difference (RPD) as defined by the following equation:

$$RPD = (R - D) / ([R + D]/2) \times 100$$

where:

R = concentration of analyte in real sample

D = concentration of analyte in duplicate sample

Data that were rejected during data validation were eliminated from the data set prior to any data-quality assessment calculations. Data that were qualified as usable (V, A, or J) or that did not have a data validation code were used in the precision calculations. Data that were qualified with a U, indicating nondetect results, were also used in the precision calculations. When both real and duplicate results for a sample pair were nondetects, the RPD was calculated to be zero percent. Although poor reproducibility is inherent in results at levels near the detection limits, the occurrence of nondetect results in both the real and duplicate sample indicates good precision. For those sample pairs where a detectable result is reported for one sample and a nondetect result (U qualifier) is reported for the other sample, RPDs were calculated by substituting the detection limits for the nondetect result. In these cases, the true precision of the analysis cannot be calculated because the value reported for a non-detect is inherently imprecise. Therefore, the RPD values calculated for these sample pairs are only relative estimates of the precision.

QC criteria for RPD are specified in the QAPjP (EG&G 1990c), the GRRASP (EG&G 1991g), and the QAA to the OU 7 Phase I work plan (DOE 1991b). Acceptable RPDs are less than 20 percent for all analytes in water (surface water and groundwater) and less than 35 percent for all analytes in soil (surface soils, subsurface geologic materials, and sediments).

Where data are sufficient, summary statistics for RPDs were calculated by analyte group for each media sampled. The statistics include the number of duplicates for which the RPD could be calculated, the number of duplicates for which RPDs exceed the QC criterion (that is, 20 or 35 percent), the arithmetic average, the standard deviation, and the coefficient of variation and are presented in Appendix J. In most cases, the number of duplicates exceeding the QC criterion and the average RPD calculated is indicative of the overall precision of the data. However, when the number of samples is small or when the coefficient of variation exceeds 100 percent, the average may not be a good measure of the central tendency of the data, and it is important to examine the other parameters as well.

For some analytes, RPD values calculated for individual sample pairs commonly exceed the acceptable limits for precision. For analytes that do not meet precision goals in more than 50 percent of the sample pairs, or where the average RPD exceeds the acceptable RPD value, all of the results reported for that analyte are qualified as estimated results. The assessment of precision by analyte group for the media sampled are discussed below. The RPD values and final qualifications of results are tabulated in Appendix J, Tables J-1 through J-7.

3.1.5.1 Soil-Gas Assessment

Ten soil-gas duplicate sample pairs were collected during the OU 7 Phase I RFI/RI and analyzed for VOCs (Table 3-2). Duplicate sampling at IHSS 203 did not meet the QC sample collection frequency required by the QAPjP (EG&G 1991h). Because the soil-gas results are based on Level II screening activities, the results were not formally validated. As presented in Table J-1 (Appendix J), there are no data validation codes nor laboratory qualifiers associated with these results.

Approximately 20 percent of the VOC results for soil gas duplicate sample pairs were reported as nondetects (RPD is zero percent), including all benzene results. RPDs calculated for the remainder of the VOCs range from 0 to 197 percent. Based on the number of sample pair RPDs exceeding 20 percent and the average RPD, precision for VOCs in soil gas is fair. Results for the following analytes have been qualified as estimated values based on the results of the precision analysis: 2-butanone, 1,2-dichloroethene (1,2-DCE), acetone, hydrogen sulfide, methane, methylene chloride, toluene, TCE, para and meta xylene, ortho xylene, 1,1,1 TCA, and dichloromethane (see Table J-1).

3.1.5.2 Landfill Leachate–Groundwater Assessment

Two duplicate sample pairs of leachate–groundwater were collected within the landfill using the Bengt-Arne Torstensson (BAT®) system during the OU 7 Phase I RFI/RI. Duplicate sampling did not meet the QC sample collection frequently required by the QAPjP (EG&G 1991h). These samples were collected as part of the Level II field screening activities, and therefore, the results have not been formally validated.

Table J-2 (Appendix J) presents the RPDs for real and duplicate sample pairs. Approximately 20 percent of the VOC results were nondetects (RPD is zero percent). RPDs calculated for the

remainder of the analytes ranged from 5 to 172 percent. Based on the number of duplicate sample pairs with RPDs exceeding 20 percent and average RPD, overall precision for VOCs in landfill leachate–groundwater is fair. Results for the following analytes have been qualified as estimated values based on the precision analysis: 2-butanone, 1,2-DCE, methane, methylene chloride, toluene, TCE, and para, meta xylene (see Table J-2).

3.1.5.3 Surface-Soils Assessment

Twenty-nine duplicate surface-soil samples were collected during the OU 7 Phase I RFI/RI (Table 3-2). Duplicate sampling (0 to 10 inches) in the area around the East Landfill Pond did not meet the QC sample collection frequency required by the QAPjP (EG&G 1991h). Precision of surface-soil sample analytical results for metals, radionuclides, semivolatile organic compounds (SVOCs), PCBs, anions, and soil-sampling parameters was assessed. Table J-3 (Appendix J) presents the RPDs for all real and duplicate sample pairs.

Metals

Approximately 23 percent of the metal results from surface-soil duplicate sample pairs were reported as U-qualified by the laboratory. All results for cesium were reported as nondetects (RPD is zero percent). Metals for which most of the results were reported as nondetects include antimony, cadmium, mercury, molybdenum, selenium, silver, thallium, and tin. Of these, approximately 12 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, vanadium, and zinc, have fewer than one-half of the results reported as nondetects.

RPDs calculated for metals in surface soils are presented in Table J-3. Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision for metals is very good. Some RPDs exceed the target value of 35 percent for individual surface-soil sample pairs; however, the majority of the RPDs and all average RPDs do not exceed the QC criterion. All RPDs calculated for aluminum, iron, magnesium, potassium, strontium, and vanadium are below 35 percent. Based on the precision analysis, results for all metals met the QC requirement for precision (see Table J-3). It should be noted that it is difficult to reproduce

metal concentrations between duplicate soil samples because of the heterogeneous nature of the matrix. Resultant RPDs may reflect poor sampling precision due to the soil matrix, rather than poor laboratory precision.

Radionuclides

Two percent of the radionuclide results for surface-soil duplicate sample pairs were reported as nondetects. Approximately 30 percent of the radionuclide results were reported by the laboratory with a J- or an X-qualifier, indicating estimated or calculated concentrations, respectively. RPDs calculated for radionuclides in surface soils are presented in Table J-3. Overall precision is fair for the majority of radionuclides. None of the RPDs calculated for individual sample pairs exceed 35 percent for gross beta. At least one-half of all RPDs for individual surface-soil sample pairs exceed the QC criterion of 35 percent for americium-241, cesium-134, tritium, and uranium-235. Reproducibility of radionuclide concentrations among field duplicates can be difficult to achieve due to analytical limitations. Many of the concentrations detected in surface soils were at levels very near the minimum detectable activity; several results were reported as negative values.

Results for the following analytes have been qualified as estimated values based on the results of the precision analysis: americium-241, cesium-134, cesium-137, plutonium-239, 240, strontium-89,90, tritium, and uranium-235 (see Table J-3).

SVOCs

Approximately 87 percent of the SVOC results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent). Of the remaining 13 percent, several analytes have a result for one sample of the pair and a nondetect for the other sample. RPDs calculated for SVOCs are presented in Table J-3. Based on the number of sample pairs exceeding the QC criterion for precision and average RPD, overall precision is very good for SVOCs in surface soils.

Results for the following analytes have been qualified as estimated values based on the results of the precision analysis: acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, phenanthrene, and pyrene (see Table J-3).

PCBs

Approximately 92 percent of the PCB results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent). The U-qualified results include Aroclor-1016, -1221, -1232, -1242, and -1248 for all surface soil duplicate samples. The only PCBs with RPDs in excess of 35 percent are Aroclor-1254 and Aroclor-1260 (Table J-3). In both cases, a result was reported for one sample of the pair and a nondetect was reported for the other sample. Based on the number of sample pairs where the RPD exceeds QC criterion and the average RPD, overall precision for PCBs in surface soils is excellent. Based on the results of the precision analysis, all PCB results met the QC requirement for precision (see Table J-3).

Anions and Soil-Sampling Parameters

Approximately 16 percent of the anions and soil-sampling parameter results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent). Table J-3 presents RPDs calculated for anions and soil-sampling parameters. RPDs are below 35 percent indicating that overall precision is very good for the analytes percent solids, nitrate/nitrite (historical code), and pH. RPDs for individual soil samples exceeded 35 percent for alkalinity as C_aCo_3, nitrate/nitrite, and total organic carbon. Based on the results of the precision analysis, results for the following analytes have been qualified as estimated values: alkalinity as C_aCO_3 and total organic carbon.

3.1.5.4 Subsurface Geologic Materials Assessment

Sixteen duplicate subsurface geologic material samples were collected during the OU 7 Phase I RFI/RI. Precision of subsurface geologic material sample analytical results for metals, radionuclides, SVOCs, pesticides, PCBs, major ions, and inorganic parameters was assessed. Duplicate samples of subsurface geologic materials were not collected for VOC analysis because of the *in situ* nature of sampling for VOCs. Table J-4 (Appendix J) presents the RPDs for all real and duplicate sample pairs.

Metals

Approximately one-half of all metal results for subsurface geologic material duplicate sample pairs were reported with a U qualifier by the laboratory. Metals for which all results were reported as

nondetects include cadmium and cesium (RPD is zero percent). Metals for which most of the results were reported as nondetects (RPD is zero) include antimony, mercury, molybdenum, selenium, silver, thallium, and tin. Of these, approximately 20 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, vanadium, and zinc, have results reported.

RPDs calculated for metals in subsurface geologic materials are presented in Table J-4. RPDs for individual soil samples exceed 35 percent for all metals except magnesium and sodium; however, average RPDs do not exceed the QC criterion for many metals. Based on the number of sample pair RPDs exceeding the QC criterion for precision and the average RPD, overall precision is very good. Results for the following metals have been qualified as estimated values based on the results of the precision analysis: cobalt, iron, and manganese (see Table J-4). It is difficult to reproduce metal concentrations between duplicate soil samples because of the heterogeneous nature of the matrix. The RPDs calculated may reflect poor sampling precision due to the soil matrix rather than poor laboratory precision.

Radionuclides

Approximately 30 percent of the radionuclide results for subsurface geologic material duplicate sample pairs were reported by the laboratory with a J qualifier to indicate estimated values. Approximately 5 percent of all radionuclide results were reported with a U qualifier (RPD is zero percent), including all results for cesium-134 and approximately 29 percent of the results for cesium-137. RPDs calculated for radionuclides in subsurface geologic materials are presented in Table J-4. Based on the number of sample pair RPDs exceeding 35 percent and the average RPDs, overall precision is fair for the majority of radionuclides. RPDs significantly exceed 35 percent for americium-124, cesium-137, plutonium-239,240, strontium-89,90, and tritium. RPDs are below the precision limit for gross beta. It is difficult to reproduce radionuclide concentrations because of equipment limitations.

Results for the following radionuclides have been qualified as estimated results based on the precision analysis: americium-241, cesium-137, plutonium-239,240, strontium-89,90, and tritium (see Table J-4).

SVOCs

Over 99 percent of the SVOC results for subsurface geologic material duplicate sample pairs were reported with a U qualifier by the laboratory. Results for benzo(b)fluoranthene and di-n-butyl phthalate were reported with a J qualifier. The RPD calculated for benzo(b)fluoranthene is 10 percent. The RPD calculated for di-n-butyl phthalate is 14 percent. These percentages indicate excellent precision for those SVOCs. Based on the precision analysis, all SVOCs met the QC requirement for precision (based Table J-4).

Pesticides and PCBs

All pesticide and PCB results for subsurface geologic material duplicate sample pairs were reported as U-qualified by the laboratory (RPDs are zero percent). Based on these results, all analytes met the QC requirement for precision (see Table J-4).

Major Ions and Inorganic Parameters

Approximately 60 percent of the major ions and inorganic parameter results for subsurface geologic material duplicate sample pairs were reported by the laboratory with a U or UX qualifier (RPD is zero percent), including all nitrite and sulfide data. RPDs were calculated for nitrate, nitrate/nitrite, total organic carbon, pH, and percent solids. Based on the number of sample pair RPDs exceeding the QC criterion for precision and the average RPD, overall precision is excellent for these parameters. All major ions and inorganic parameter results met the QC requirement for precision (see Table J-4).

3.1.5.5 Sediments Assessment

One sediment duplicate sample pair was collected during the OU 7 Phase I RFI/RI. Precision of sediment sample analytical results for metals, radionuclides, VOCs, SVOCs, major ions, and inorganic parameters was assessed. Table J-5 (Appendix J) presents all RPDs for this sample pair.

Metals

Approximately 18 percent of the metal results for the sediment duplicate sample pair were reported as U-qualified by the laboratory. Metals for which both results were reported as

nondetect (RPD is zero percent) include cesium, mercury, molybdenum, and thallium. Metals for which only one of the results was a nondetect include cadmium and tin. For the remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, selenium, silicon, silver, sodium, strontium, vanadium, and zinc, both the real and duplicate sample have results reported. RPDs calculated for sediment are presented in Table J-5. RPDs exceeded 35 percent for only lithium and silver. RPDs for these metals are 37 percent and 39 percent, respectively. Based on the number of sample pair RPDs exceeding the QC criterion for precision, overall precision is excellent for the majority of metals. Results for lithium and silver have been qualified as estimated results based on the precision analysis (see Table J-5).

Radionuclides

Approximately 22 percent of the radionuclide results for the sediment duplicate sample pair were reported by the laboratory with either a J or an X qualifier. Approximately 56 percent of the duplicate analyses have RPDs in excess of the QC criterion for precision. RPDs exceed 35 percent for cesium-137, gross alpha, plutonium-239,240, strontium-89,90, and uranium-235 and range from 37 to 117 percent. Results for those radionuclides have been qualified as estimated values based on the precision analysis (Table J-5). Based on these percentages, overall precision is fair for radionuclides in sediments.

VOCs

Approximately 94 percent of the VOC results for the sediment duplicate sample pair were reported as U-qualified by the laboratory. All results for 31 of the 33 VOCs analyzed were reported as nondetects (RPD is zero percent). As presented in Table J-5, the RPD calculated for acetone is 114 percent. The RPD calculated for toluene is 23 percent. Based on the QC criterion of 35 percent, precision for acetone (a common laboratory contaminant) is poor whereas precision for toluene in sediments is very good. Results for acetone have been qualified as estimated values based on the precision analysis (see Table J-5).

SVOCs

Approximately 95 percent of the SVOC results for the sediment duplicate sample pair were reported by the laboratory with a U qualifier. For bis(2-chloroisopropyl)ether, fluoranthene,

phenanthrene, and pyrene, one result was reported as a nondetect and the other as a detect. Estimated values, reported by the laboratory with a J qualifier, were reported for benzoic acid. The RPD calculated for benzoic acid is 133 percent (Table J-5) indicating that precision for this analyte is very poor. Based on the precision analysis, results for benzoic acid, bis (2-chloroisopropyl) ether, fluoranthene, phenanthrene, and pyrene have been qualified as estimated results (see Table J-5).

Major Ions and Inorganic Parameters

Sixty percent of the major ions and inorganic parameter results (including nitrate, nitrate/nitrite, and total organic carbon) for the sediment duplicate sample pair were reported by the laboratory with either a U or an X qualifier, indicating nondetect or calculated results, respectively. All RPDs were below 35 percent and ranged from 0 to 7 percent. These values indicate that precision is excellent for these parameters. All analytes met the QC requirement for precision (Table J-5).

3.1.5.6 Surface-Water Assessment

Two duplicate surface-water samples were collected from the East Landfill Pond at location SW098. Precision of surface-water sample analytical results for dissolved metals, total metals, dissolved radionuclides, total radionuclides, VOCs, SVOCs, pesticides, PCBs, anions, cyanide, and water-quality parameters was assessed. Table J-6 presents the RPDs for all real and duplicate samples pairs.

Dissolved Metals

Over 50 percent of the dissolved metal results were reported as U-qualified by the laboratory. Metals for which all results were reported as nondetects (RPD is zero percent) include aluminum, beryllium, cesium, chromium, cobalt, mercury, selenium, silver, thallium, tin, and vanadium. Metals for which most of the results were reported as nondetects include antimony, cadmium, copper, molybdenum, and nickel. Of these, approximately 60 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining dissolved metals, including arsenic, barium, calcium, iron, lead, lithium, magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than one-half of the results reported as nondetects.

RPDs calculated for dissolved metals in surface water are included in Table J-6. Based on the number of samples pairs exceeding the QC criterion for precision and the average RPD, overall precision is very good. Individual RPDs exceed 20 percent only for iron and zinc. The following dissolved metal results have been qualified as estimated values based on the precision analysis: antimony, iron, nickel, and zinc (see Table J-6).

Total Metals

Approximately 56 percent of the total metal results for surface-water duplicate sample pairs were reported as U-qualified results by the laboratory. Metals for which all results were reported as nondetects (RPD is zero percent) include antimony, arsenic, beryllium, cadmium, cesium, cobalt, lead, mercury, selenium, silver, thallium, and vanadium. Metals for which at least one-half of all results were reported as nondetects include aluminum, chromium, copper, molybdenum, nickel, and tin. Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining total metals, including barium, calcium, iron, lithium, magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than half of the results reported as nondetects.

RPDs calculated for total metals in surface water are presented in Table J-6. Based on the overall number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is excellent for total metals in surface water. Individual RPDs exceed 20 percent only for iron and zinc. Based on the precision analysis results, only iron, nickel, and zinc results have been qualified as estimated values (see Table J-6).

Dissolved Radionuclides

Approximately 12 percent of the dissolved radionuclide results for surface-water duplicate sample pairs were reported as U-qualified or UE-qualified (detection limit reported as result) by the laboratory. In addition, many results are qualified with a J. All of the RPDs calculated for americium-241, cesium-137, gross alpha, plutonium-239,240, and uranium-235 exceed 20 percent. RPDs for these analytes range from 26 to 447 percent. One-half of the RPDs calculated for gross beta, uranium-233,234, and uranium-238 exceed 20 percent (Table J-6). The values for much of the radionuclide activity observed were at levels indistinguishable from the minimum detectable activity and in many cases were negative. Reproducibility is difficult to achieve under

these circumstances because of analytical limitations, and this does not necessarily indicate poor field precision.

Results for the following dissolved radionuclides have been qualified as estimated values based on the precision analysis: americium-241, cesium-137, gross alpha, plutonium-239,240, uranium-233,244, uranium-235, and uranium-238 (see Table J-6).

Total Radionuclides

Approximately 11 percent of the total radionuclide results for surface-water duplicate sample pairs were reported by the laboratory with a U or UC qualifier. Many of the results are J-qualified. All but one RPD calculated for total radionuclides exceeds 20 percent (Table J-6). The majority of activity observed was at levels indistinguishable from minimum detectable activity. In several cases, the radionuclide results are negative. Reproducibility can be difficult to achieve due to analytical limitations, and this may not necessarily indicate poor precision. Based on the precision analysis, all results for total radionuclides, with the exception of radium-226 and total radiocesium have been qualified as estimated values (see Table J-6).

VOCs

All VOC results for surface-water duplicate sample pairs are U-qualified by the laboratory indicating that there were no VOCs detected. Consequently, RPDs calculated for these analytes are zero percent (Table J-6). The occurrence of nondetect results in both real and duplicate samples indicates excellent precision for VOCs in surface water. All VOC results have met the QC requirement for precision (see Table J-6).

SVOCs

Approximately 99 percent of the SVOC results for surface-water duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent). The only SVOCs detected in duplicate samples are bis(2-ethylhexyl)phthalate and di-n-butyl phthalate. Estimated analytical results were reported for bis(2-ethylhexyl)phthalate; the RPD is 120 percent (Table J-6). An estimated result and a nondetect result were reported for di-n-butyl phthalate; the RPD is 164 percent. Results for these two analytes have been qualified as estimated values based on the

precision analysis (see Table J-6). Based on consistent nondetect results in real and duplicate samples, overall precision for SVOCs in surface water is excellent.

Pesticides and PCBs

As presented in Table J-6, all pesticide and PCB results for surface-water duplicate sample pairs are nondetects (RPD is zero percent). All pesticide and PCB results have met the QC requirement for precision (see Table J-6).

Anions, Cyanide, and Water-Quality Parameters

Approximately 36 percent of the anion, cyanide, and water-quality parameter results for surface-water duplicate sample pairs are U-qualified by the laboratory, including all results for carbonate, cyanide, sulfide, and total suspended solids (TSS). The only analytes that exceed the QC criterion for precision are nitrate and TDS. RPDs for these analytes are 123 percent and 21 percent, respectively. Based on the number of sample pairs exceeding the QC criterion and the average RPD, overall precision is very good for the majority of analytes. The only analyte with results that have been qualified as estimated values based on the precision analysis is nitrate (see Table J-6).

3.1.5.7 Groundwater Assessment

Three duplicate groundwater samples were collected during the OU 7 Phase I RFI/RI (Table 3-2). Duplicate sampling did not meet the QC sample collection frequency required by the QAPjP (EG&G 1991h). Precision of groundwater-sample analytical results for dissolved metals, total metals, dissolved radionuclides, total radionuclides, VOCs, SVOCs, anions, cyanide, and water-quality parameters was assessed. Table J-7 in Appendix J presents the RPDs for all real and duplicate sample pairs.

Dissolved Metals

More than 60 percent of the dissolved metal results for groundwater duplicate sample pairs were reported by the laboratory with a U qualifier (analyte not detected at the quantitation limit) or a UN qualifier (sample result below detection limit). Metals for which all results were reported as nondetects (RPD is zero percent) include antimony, arsenic, beryllium, cadmium, cesium,

chromium, mercury, molybdenum, nickel, selenium, silver, thallium, tin, and vanadium. Metals for which most of the results were reported as nondetects include aluminum, cobalt, copper, and lead. Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining dissolved metals, including barium, calcium, iron, lithium, magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than half of the results reported as nondetects.

RPDs calculated for dissolved metals in groundwater are presented in Table J-7 (Appendix J). Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is very good for the majority of these analytes. Individual RPDs exceed 20 percent for iron, manganese, potassium, and zinc. RPDs for these metals range from 27 to 170 percent. Based on the results of the precision analysis, results for the following dissolved metals have been qualified as estimated values: aluminum, copper, iron, lead, manganese, and potassium (see Table J-7).

Total Metals

Approximately 30 percent of the total metal results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory. Metals for which all results were reported as nondetects (RPD is zero percent) include cesium, mercury, molybdenum, selenium, silver, and thallium. Metals for which at least one-half of all results were reported as nondetects include antimony, cadmium, and selenium. Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample. The remaining total metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, tin, vanadium, and zinc, have fewer than 50 percent of the results reported as nondetects.

RPDs calculated for total metals in groundwater are presented in Table J-7. Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is poor for the majority of these analytes. Approximately 60 percent of the RPDs exceed the QC criterion. RPDs for aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, tin, vanadium, and zinc exceed 20 percent. RPDs for these metals range from 22 to 110 percent. RPDs are below 20 percent for calcium, sodium, and strontium only. Based on the precision analysis, results for the following

analytes have been qualified as estimated values: aluminum, antimony, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, tin, vanadium, and zinc (see Table J-7).

Dissolved Radionuclides

Approximately 40 percent of the dissolved radionuclide results for groundwater duplicate sample pairs were reported by the laboratory with a J qualifier to indicate estimated values. None of the results were reported as nondetects.

The RPDs calculated for dissolved radionuclides including americium-241, cesium-134, cesium-137, gross alpha, gross beta, plutonium-239,240, strontium-89,90, uranium-233,234, uranium-235, and uranium-238 are presented in Table J-7. Many of the RPDs calculated exceed 20 percent; however, many activities observed were at levels indistinguishable from the minimum detectable activity and in many cases are negative values. Reproducibility under these circumstances is difficult to achieve because of analytical limitations, and this does not necessarily reflect poor field precision. All RPDs for americium-241, cesium-134, cesium-137, plutonium-239-240, strontium-89,90, uranium-233,234, uranium-235, and uranium-238 exceed 20 percent and range from approximately 64 percent to 1,089 percent. One-half of the RPDs calculated for both gross alpha and gross beta exceed 20 percent. Based on the results of the precision analysis, all dissolved radionuclide results have been qualified as estimated values (see Table J-7).

Total Radionuclides

One-half of the total radionuclide results for groundwater duplicate sample pairs were reported as J-qualified results by the laboratory. Approximately 85 percent of the RPDs calculated exceed the QC criterion of 20 percent and include all values for americium-241 and plutonium-239,240 and the majority of values for tritium. These elevated RPDs, which range from approximately 51 to 250 percent (Table J-7) reflect the difficulty of obtaining consistent reproducibility with radionuclide results because of analytical limitations. Therefore, the high RPDs do not necessarily represent poor field precision. Based on the results of the precision analysis, all total radionuclide results have been qualified as estimated values (see Table J-7).

VOCs

Approximately 96 percent of the VOC results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory. All results for 31 of 34 VOCs analyzed are reported as nondetects. For 1,1,1-TCA, the majority of individual results are nondetects; however, for one sample pair the result for one member was reported as nondetect whereas a detectable result was reported for the other member. Those analytes for which the laboratory reported detectable results for each sample in a pair include 1,2-DCE and TCE. RPDs for VOCs in groundwater are presented in Table J-7. The RPD calculated for 1,2-DCE is 18 percent. The RPD calculated for TCE ranges from 0 to 75 percent. These percentages indicate very good precision for 1,2-DCE and fair precision for TCE. Based on the results of the precision analysis, only the results for TCE have been qualified as estimated values (see Table J-7).

SVOCs

Approximately 99 percent of the SVOC results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent). These results include analysis for 63 of 65 SVOCs. For di-n-butyl phthalate, one result was reported as an estimated value although the other five results were reported by the laboratory with a U qualifier. Similarly, the laboratory results for diethyl phthalate included an estimated value and a nondetect value. Based on results of the precision analysis, results for these two analytes have been qualified as estimated values (see Table J-7).

Anions, Cyanide, and Water-Quality Parameters

More than 30 percent of the anion, cyanide, and water-quality parameter results for groundwater duplicate sample pairs were reported as U-qualified by the laboratory. The only analyte for which all results are reported as nondetects is carbonate (RPD is zero percent). For cyanide, fluoride, and sulfide, the majority of individual results are nondetects (RPD is zero percent). However, for approximately 5 percent of the cyanide, fluoride, and sulfide results, one result is reported as a nondetect and the other as a detect.

RPDs calculated for bicarbonate as $CaCO_3$, chloride, nitrate, nitrate/nitrite, nitrite, sulfate, TDS, and TSS in groundwater are presented in Table J-7. Based on the number of sample pairs exceeding the QC criterion and the average RPD, overall precision is good for the majority of

these analytes. Individual RPDs exceed 20 percent only for bicarbonate as $CaCO_3$, nitrate/nitrite, TDS, and TSS. RPDs for these analytes range from 23 to 103 percent. Results for the following analytes have been qualified as estimated values based on the results of the precision analysis: nitrate/nitrite, TDS, and TSS (see Table J-7).

3.1.6 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value. Analytical accuracy is determined by laboratory analyses of materials with known analyte concentrations such as laboratory standards, laboratory control samples, and matrix spike samples. This measure is expressed as bias and is determined by calculating percent recovery from spiked samples. Percent recovery (%R) is defined as:

$$\%R = (SSR - SR) / SA \times 100$$

where:

SSR = spiked sample result

SR = sample result

SA = spike added

Percent recovery is reported in the data set and is presented for each analyte group in each medium sampled. The QC criterion for percent recovery, specified in the QAA for OU 7 (DOE 1991b) and the GRRASP (EG&G 1991g), is 80 percent to 120 percent for all analytes in all media.

Spike data in the OU 7 data set consist of matrix spike (MS) and matrix spike duplicate (MSD) data for groundwater. As consistent with the requirements of the OU 7 QAA and Rocky Flats SOPs, the only medium for which spikes were collected and analyzed is groundwater. Total and dissolved metals were used as the spike analytes. No information on spike concentrations is available, thus possible correlations between accuracy and concentration cannot be evaluated.

Where sufficient data are available, summary statistics for accuracy are calculated. Because %R can be either positive or negative, summary statistics are reported in terms of the absolute value of the percent bias (%Bias) to better express variations around 100-percent recovery (%Bias =

100 - %R). In terms of %Bias, the QC criterion is 20 percent. Data presented in the OU 7 summary tables (Appendix J) for accuracy include %R, %Bias, number of %Rs reported, number of %Biases exceeding 20 percent, and data qualifiers provided by RFEDS.

For all other media sampled, accuracy is evaluated by the data validation subcontractor based on QC information supplied by the analytical laboratory. Analytical accuracy is reported by the laboratory and is based on analysis of internal standards or laboratory spikes. The laboratory qualifiers and validation codes associated with each result are used to classify the usability of results, and these qualifiers are based in part on the reported accuracy of analyses. Therefore, the accuracy of laboratory analyses of media other than water has not been described quantitatively for the OU 7 data set.

3.1.6.1 Groundwater Assessment

One MS and one MSD groundwater sample were collected and analyzed during the OU 7 Phase I RFI/RI. Table J-8 in Appendix J presents the %Bias results for the groundwater spike samples collected.

Dissolved Metals

For the MS sample, all dissolved metals, with the exception of cesium and selenium, meet the QC criterion for accuracy of 20 percent. These metals measure %Biases of 517 percent (reported by the laboratory with a U qualifier) and 26 percent, respectively. The MSD was analyzed for two dissolved metals, cesium and silicon. Only silicon has a %Bias that exceeds the QC criterion of 20 percent. The %Bias for silicon is 44 percent.

Total Metals

Table J-8 presents %R and %Bias for total metals. All MS and MSD results, with the exception of those for aluminum, arsenic, cesium, iron, and silicon, are below the QC criterion for accuracy of 80 percent to 120 percent for %R and 20 percent for %Bias. These five metals measure %Biases ranging from 34 to 517 percent. Based on the MS and MSD data, total metals generally meet the %Bias criterion for accuracy.

3.1.7 *Representativeness*

Representativeness is a qualitative parameter that expresses the degree to which sample data accurately and precisely represent the characteristics of a particular site or condition. Representativeness is evaluated through the careful development and review of the sampling and analysis strategy. The representativeness of OU 7 samples is determined by evaluating whether or not the samples collected are truly representative of the concentrations in the field, or if they have been affected by the introduction of contamination during collection and handling. Adherence to the field sampling plan for OU 7 ensured that samples collected from environmental media are representative. Possible contamination in the laboratory is addressed during data validation.

Possible contamination of the environmental samples during sample collection and transport is evaluated by examining analytical results for field blanks, equipment rinses, and trip blanks. Field blanks were prepared in the field using distilled water. These blanks accompany environmental water samples (groundwater and surface water) through collection, preparation, shipping, and analytical procedures. Analytical results of the field blanks can identify contamination that may have been introduced during any of these steps. The only field blanks collected during the OU 7 Phase I RFI/RI are surface water samples.

Equipment rinses are used to evaluate the effectiveness of the decontamination process and potential for cross-contamination between samples. Equipment rinses are prepared in the field using distilled water that has been used to clean decontaminated sampling equipment. Equipment rinses are handled in the same manner as environmental samples. tables J-9 through J-15 summarize the analytes detected in all field QC samples collected during the OU 7 Phase I RFI/RI. Results are presented as the "frequency of hits", i.e., the number of detectable results per total number of QC blanks analyzed.

Trip blanks are used to assess the possibility that environmental water samples become contaminated during storage and transportation. Only one trip blank was analyzed during OU 7 Phase I RFI/RI sampling activities; this blank was collected in conjunction with surface-water sampling. The trip blank was prepared in the sample preparation area of the OU 7 field trailer and accompanied the sample containers to the field and then to the laboratory for analysis.

3.1.7.1 Soil-Gas Assessment

Four equipment rinses were collected in conjunction with soil-gas sampling at IHSS 114. Seven equipment blanks were collected during soil-gas sampling at IHSS 203. Table J-9 presents the equipment rinse and equipment blank results.

Results for the equipment rinses collected at IHSS 114 indicate that residual concentrations of several VOCs present may have affected the representativeness of the soil-gas screening samples. Several VOCs were also detected in the equipment blanks collected at IHSS 203. However, based on the frequency of detection and the concentrations detected, their presence does not appear to have affected the representativeness of soil-gas samples collected at IHSS 203. Similarly, the frequency of detection and the concentration of analytes detected in these equipment blanks may have affected the representativeness of soil-gas samples collected at IHSS 203.

3.1.7.2 Landfill Leachate–Groundwater Assessment

Two equipment rinses were collected at the landfill in conjunction with leachate–groundwater sampling using the BAT® system. Table J-10 presents the results for these QC samples. Several VOCs were detected in these samples indicating that their presence may have affected the representativeness of the leachate–groundwater screening samples.

3.1.7.3 Surface-Soils Assessment

Thirteen equipment rinses were collected in conjunction with surface-soil sampling. Table J-11 summarizes the analytical results.

Metals

Metals detected include aluminum, arsenic, barium, beryllium, calcium, copper, iron, magnesium, manganese, potassium, selenium, silicon, sodium, and zinc. With the exception of arsenic, beryllium, selenium, and zinc, these metals are probable components of the distilled water used to rinse sampling equipment. There is no known analytical data available to describe the distilled water used to prepare the equipment rinses and field blanks. These metals were detected

relatively infrequently and at concentrations that should not affect the representativeness of the surface-soil samples.

Radionuclides

Equipment rinses were also analyzed for radionuclides. Because of the nature of reporting requirements, all radionuclide results are reported as hits.

VOCs

One of the 13 equipment rinses collected in conjunction with surface-soil sampling was analyzed for VOCs. As presented in Table J-11, VOCs were not detected in this sample indicating that decontamination procedures were adequate to prevent cross contamination of samples.

SVOCs

The equipment rinse analyzed for VOCs was also analyzed for SVOCs. The only SVOC detected was bis(2-ethylhexyl)phthalate at a concentration that should not affect the representativeness of the surface-soil samples.

PCBs

Five of the 13 equipment rinses collected during surface-soil sampling activities were analyzed for PCBs, specifically Aroclor compounds. Because no PCBs were detected, surface-soil samples collected and analyzed for PCBs are representative of site conditions and were not affected by cross contamination.

Major Ions and Inorganic Parameters

Ten of the 13 equipment rinses collected were analyzed for nitrate/nitrite, and all of the rinsate samples were analyzed for total organic carbon (TOC). Nitrate/nitrite and TOC were detected in at least one sample. Their presence does not occur with the frequency or the concentration levels that should affect the representativeness of the surface-soil samples.

3.1.7.4 Subsurface Geologic Materials Assessment

Ten equipment rinses were collected during subsurface geologic material sampling at OU 7. Table J-12 presents the analytical results.

Metals

Metals detected in equipment rinses include aluminum, antimony, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, potassium, selenium, silicon, silver, sodium, tin, and zinc. With the possible exception of beryllium, cadmium, copper, selenium, silver, and zinc, these metals are major-ion constituents of natural waters and may have originated from the distilled water used to rinse sampling equipment. These metals were detected at frequencies and concentrations low enough so that their presence should not affect the representativeness of subsurface geologic material samples.

Radionuclides

Nine of the 10 equipment rinses collected during subsurface geologic material sampling were analyzed for radionuclides. Due to the nature of reporting requirements, all radionuclide results are reported as hits (Table J-12).

VOCs

All ten of the equipment rinses were analyzed for VOCs. The only VOCs detected were acetone and methylene chloride, both of which are common laboratory contaminants. Based on these data, it appears that decontamination procedures were adequate to prevent cross contamination and that analytical results for VOCs in subsurface geologic material samples are representative of actual site concentrations.

SVOCs

All equipment rinses were also analyzed for SVOCs. SVOCs were not detected in any of the equipment rinse samples indicating that decontamination procedures were adequate to prevent cross contamination of samples collected during subsurface geologic material sampling.

Pesticides and PCBs

Neither pesticides nor PCBs were detected in any of the 10 equipment rinses indicating that any pesticides or PCBs detected in the subsurface geologic material samples are representative of site concentrations and not the result of inadequate decontamination procedures.

Major Ions and Inorganic Parameters

The only major ions detected in any of the 10 equipment rinses are nitrate and nitrate/nitrite; both analytes were detected in one rinse sample only. Their presence in equipment rinses does not occur with the frequency that could adversely affect the representativeness of the subsurface geologic material samples.

3.1.7.5 Sediments Assessment

One equipment rinse was collected in conjunction with sediment sampling during the OU 7 Phase I RFI/RI. Table J-13 presents the analytical results.

Metals

The only metals detected were arsenic, cadmium, iron, silicon, sodium, and zinc. With the possible exception of arsenic, cadmium, and zinc, the most likely source for these metals is the distilled water used to rinse sampling equipment. The concentrations of arsenic, cadmium, and zinc detected are low and should not affect the representativeness of the sediment samples.

Radionuclides

Equipment rinses were also analyzed for radionuclides. Because of the nature of reporting requirements, all radionuclide results are reported as hits.

VOCs

The only VOC detected in the equipment rinse was acetone, which is a common laboratory contaminant. These data indicate that decontamination procedures conducted during OU 7 sediment sampling were adequate to prevent cross contamination of samples.

SVOCs

SVOCs were not detected in the equipment rinse indicating that decontamination activities were adequate. Therefore, concentrations of SVOCs detected in sediment samples should be representative of environmental concentrations.

Major Ions and Inorganic Parameters

The only inorganic parameter detected in the equipment rinse collected during sediment sampling was TOC. Based on these data, it does not appear that cross contamination occurred during sediment sampling.

3.1.7.6 Surface-Water Assessment

Three equipment rinses were collected and analyzed for metals during surface-water sampling at OU 7. One field blank was also collected. Table J-14 presents the analytical data.

Metals

Aluminum, antimony, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, manganese, silicon, sodium, tin, and zinc were detected in at least one of the three equipment rinses collected. The most likely source for the metals, with the possible exception of beryllium, cadmium, and zinc, is the distilled water used to rinse sampling equipment. Based on the concentrations detected, it does not appear that the presence of these metals affects the representativeness of the surface-water samples.

The only metals detected in the field blank were beryllium, calcium, iron, lead, molybdenum, silicon, sodium, and zinc. All metals, with the possible exception of beryllium, lead, and zinc, most likely were present in the distilled water used to rinse sampling equipment. The levels of these metals detected do not appear to affect the representativeness of surface-water samples.

Radionuclides

The equipment rinses and field blank were also analyzed for radionuclides. Because of the nature of reporting requirements, all radionuclide data are reported as hits.

VOCs

All of the equipment rinses were analyzed for VOCs. The only VOCs detected, at relatively low levels, were acetone and methylene chloride, both of which are common laboratory contaminants. Based on these data, it appears that decontamination procedures were adequate to prevent cross contamination.

In addition, a trip blank was prepared and accompanied surface-water samples to the laboratory. There were no VOCs detected in this blank, indicating that surface-water samples were not subject to introduced contamination during storage or transportation to the laboratory. Based on these data, surface-water samples collected are representative of actual environmental conditions.

SVOCs

The only SVOC detected in any of the equipment rinses associated with surface-water sampling was bis(2-ethylhexyl)phthalate, which was detected at a low concentration in one of the three rinses. The presence of this compound does not occur with the frequency or the concentration level that should affect the representativeness of the surface-water samples.

Pesticides and PCBs

All of the equipment rinses were analyzed for pesticides and PCBs. As presented in Table J-14, no pesticides nor PCBs were detected in the equipment rinses collected after the field sampling equipment was decontaminated. Therefore, it appears that decontamination procedures during surface-water sampling were adequate to prevent cross contamination and that samples collected are representative of site conditions.

Anions, Cyanide, and Water-Quality Parameters

All equipment rinses were analyzed for anions, cyanide, and water-quality parameters. Sulfate and TDS were the only analytes/parameters detected in the three equipment rinses. The most likely source for these analytes/parameters is the distilled water used to rinse sampling equipment. These data indicate that surface-water samples collected are representative of site conditions.

The field blank collected during surface-water sampling was analyzed for nitrate/nitrate, which was not detected.

3.1.7.7 Groundwater Assessment

Two equipment rinses were collected and analyzed in conjunction with groundwater sampling during the OU 7 Phase I RFI/RI. Table J-15 presents the analytical results for these equipment rinses, including the frequency of "hits" with detectable concentrations reported.

Metals

The metals detected in at least one of the two equipment rinses include aluminum, arsenic, calcium, copper, iron, lead, manganese, potassium, silicon, sodium, strontium, and zinc. The most likely source for these metals, with the exception of arsenic, lead, and zinc, is the distilled water used to collect the equipment rinses. The presence of the metals detected does not occur with the frequency or at the concentration levels that should affect the representativeness of the groundwater samples.

Radionuclides

Because of the nature of reporting requirements, all radionuclide results are reported as hits in the equipment rinses. Table J-15 presents the data, including the minimum, maximum, and mean results.

VOCs

There were no VOCs detected in the equipment rinses, indicating that decontamination procedures conducted during groundwater sampling were adequate to prevent cross contamination. Based on the VOC data, groundwater samples collected and analyzed during the OU 7 Phase I RFI/RI appear to be representative of site conditions.

SVOCs

SVOCs were not detected in either of the two equipment rinses. Based on the data, it appears that decontamination of the groundwater sampling equipment was adequate to prevent cross contamination.

Anions, Cyanide, and Water-Quality Parameters

As presented in Table J-15, the only analytes/parameters detected in one of two equipment rinses were sulfide, TDS, and TSS. No analytes were detected in the other equipment rinse. TDS is a common constituent of natural waters and may originate from the distilled water used to rinse sampling equipment. Sulfide and TSS were detected in one of the two equipment rinses. Their occurrence may indicate that decontamination procedures associated with these rinses may not have been adequate to prevent cross contamination.

3.1.8 Completeness

Completeness is a measure of the amount of usable data resulting from a data collection activity. The target completeness objective for the OU 7 Phase I RFI/RI field and analytical data is 100 percent with a minimum acceptable limit of 90 percent (DOE 1991b). The completeness of field activities is defined by the actual number of samples or measurements collected relative to the number of samples or measurements specified in the work plan. Analytical data completeness is defined as the percentage of measurements made that are judged to be valid.

The completeness of field activities is described in Appendix C of this report. Completeness for the OU 7 Phase I RFI/RI is evaluated by comparing the planned to the actual number of samples collected and analyzed. Table C-2 (Appendix C) presents this comparison. It is difficult to quantify completeness in strict accordance with the guidelines noted above. In general, the number of samples collected and types of analyses performed at each sampling location matched those specified in the work plan. Samples not collected were due to extenuating circumstances related to field conditions (that is, location inaccessible to the rig, dry wells). Additional samples were collected beyond those specified in the work plan (that is, methane survey at the Present Landfill) to further characterize the site and determine the nature and extent of contamination.

Based on the information presented in Table C-2, the OU 7 Phase I RFI/RI data are approximately 95 percent complete. Specific field activities for which completeness did not meet the target of 90 percent include soil-gas and landfill leachate–groundwater sampling using the BAT® system (IHSS 114 area), subsurface geologic material sampling in boreholes, groundwater sampling, surface-water sampling and flow-rate measuring at the groundwater intercept system discharge points, and radiation field screening using a Geiger-Mueller detector. Specific field activities for

which completeness exceeded 100 percent because additional samples were collected include the screening-level methane survey; well tests; soil-gas sampling (IHSS 203 area), surface-soil sampling, and surveying at IHSS 203; and surface-soil sampling and surveying around the East Landfill Pond.

Analytical results should be validated to be considered in an assessment of completeness. Table 3-5 presents a summary of the data validation results as of December 1, 1993 (date of most recent RFEDS extraction), including the percent validated and percent rejected. The percent results validated was calculated using the total number of results. Similarly, the percent results rejected was also calculated as a function of the total number of results. A percentage rejected of more than approximately 10 percent is used as an indicator of poor completeness. The percentage validated varies by medium and by analyte group. Percentage validated by medium ranges from 73 percent (groundwater) to 100 percent (biota) of the total number of results, approximately 2 percent have been rejected.

With the exception of VOCs, all analyte groups for surficial soils had less than 8 percent of their data rejected. Approximately 37 percent of the VOC results were rejected. Overall, the number of results rejected for surface soils is 2 percent indicating excellent completeness. As presented in Table 3-5, completeness for subsurface geologic materials and sediments is also excellent; the total results rejected are 2 percent and 4 percent, respectively.

For groundwater, the percentage of results rejected for each analyte group was less than 3 percent. The total percentage rejected is 2 percent indicating excellent completeness. Similarly, the total percentage of results rejected for surface water is 7 percent. With the exception of SVOCs, which had 18 percent of its total results rejected, all analyte groups for surface water had less than 5 percent of their results rejected. These data indicate that completeness for surface-water analytical results is very good.

3.1.9 Comparability

Comparability expresses the confidence with which data are considered comparable. Because data are collected over a period of months or years and analyzed by different analytical laboratories or methods, comparability of different data sets is critical to data analysis. Comparability is a qualitative parameter that is ensured by implementation of an approved

sampling and analysis plan, standardized analytical protocols, and standard operation procedures for field investigations.

In order to achieve comparability, work has been performed at OU 7 in accordance with an approved work plan (DOE 1991b), standard analytical protocols outlined in the GRRASP (EG&G 1991g), and approved SOPs for data collection (EG&G 1992c). OU 7 Phase I RFI/RI data are reported in uniform units: µg/L, µg/kg, milligrams per liter (mg/L), mg/kg, pCi/L, pCi/g.

Prior data collection activities employed variable sample collection and laboratory analytical methods. As a result, historical data may not always be comparable to data obtained during the OU 7 Phase I RFI/RI.

3.1.10 Summary of Data Quality by Media

Data quality by sample media for soil gas, landfill leachate–groundwater, surface soils, subsurface geologic materials, sediments, surface water, and groundwater is summarized below.

3.1.10.1 Soil Gas

Precision for soil-gas data is fair. The majority of RPDs calculated for several individual VOCs exceeded the QC criterion of 20 percent, including 2-butanone, 1,2-DCE, acetone, toluene, TCE, 1,1,1-TCA, and xylenes. Based on the precision analysis, results for the following analytes have been qualified as estimated values: 2-butanone, 1,2-DCE, acetone, hydrogen sulfide, methane, methylene chloride, toluene, TCE, xylenes, 1,1,1-TCA, and dichloromethane.

Accuracy was not determined for soil gas sampling.

Results for equipment rinses and blanks indicate that residual concentrations of several VOCs may have affected the representativeness of soil-gas screening results. Almost all of the VOCs analyzed for were detected in at least one of the equipment rinses or equipment blanks; however, the concentrations detected are generally low. For the purpose of Level II screening data, the results of the soil-gas samples do provide a qualitative assessment of the location and relative concentrations of any "hotspots."

Completeness of the soil-gas sampling activities was 84 percent. This value is below the minimum acceptable limit of 90 percent.

Comparability of the soil-gas data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c).

3.1.10.2 Landfill Leachate–Groundwater

Precision for landfill leachate–groundwater data is poor. VOCs with at least half of the RPDs exceeding the QC criterion of 20 percent include 2-butanone, 1,2-DCE, hydrogen sulfide, methane, methylene chloride, toluene, TCE, and xylenes. Results for the following analytes have been qualified as estimated values based on the results of the precision analysis: 2-butanone, 1,2-DCE, methane, methylene chloride, toluene, TCE, and para, meta xylene.

Accuracy was not determined for landfill leachate–groundwater samples.

Representativeness is good. Several VOCs, including 1,2-DCE, acetone, methane, 2-butanone, methylene chloride, and TCE, were detected in the field QC samples; however, the concentrations detected were generally low. These samples were used as a screening tool, and their qualitative results were backed up with Level III and IV data (that is, groundwater samples collected from monitoring wells).

Completeness of the leachate–groundwater sampling activities was 40 percent. Although this level of completeness did not meet DQO objectives, data obtained were supplemented with data from groundwater monitoring wells to achieve overall objectives.

Comparability of the data has been established using an approved sampling and analysis plan, standard analytical protocols, and an SOP currently in preparation (EG&G in progress).

3.1.10.3 Surface Soils

Precision for most analytes for surface soils is good, even though it can be difficult to achieve reproducibility in soil samples because of the heterogeneity of the matrix. Precision for radionuclides in surface soils, including americium-241, cesium-134, strontium-89,90, tritium, and uranium-235 was poor, particularly at levels near the minimum detectable activity. Based on the result of the precision analysis, results for several radionuclides (americium-241, cesium-134, cesium-137, plutonium-239,240, strontium 89,90, tritium, and uranium-235), SVOCs (acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene,

bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, phenanthrene, and pyrene), and anions and soil-sampling parameters (alkalinity as C_aCO_3 and total organic carbon) have been qualified as estimated values. All metals and PCB data met the QC requirement for precision.

Accuracy was not determined for surface-soil sampling.

Representativeness is good. Although several metals were detected in the equipment rinses collected during surface-soil sampling, the majority are major ions commonly found in water and most likely originated in the distilled water used to rinse sampling equipment. Arsenic, beryllium, selenium, and zinc, which were most likely not present in the distilled water, were detected relatively infrequently and at low concentrations.

Completeness of surface-soil sampling activities at IHSS 203 and the areas around the East Landfill Pond exceeded 100 percent because additional samples were collected at each area. Additional soil sampling at IHSS 114 also exceeded the DQOs for completeness. Of the total results available as of December 1, 1993, approximately 88 percent have been validated and 2 percent rejected.

Comparability of Phase I RFI/RI surface-soil data from IHSS 114 is not comparable to surface-soil data from IHSS 203 and the East Landfill Pond because the sampling methods were different.

3.1.10.4 Subsurface Geologic Materials

Precision for most analytes in subsurface geologic material samples is generally very good, with the exception of manganese, nickel, and the majority of radionuclides. Reproducibility associated with these metals is poor as indicated by the number of RPDs exceeding the QC criterion of 35 percent. Similarly, reproducibility among the radionuclides is generally poor with the exception of gross alpha, gross beta, radium-226, radium-228, uranium-233,234, uranium-235, uranium-238, particularly at levels near the minimum detectable activity. Based on the results of the precision analysis, results for several metals (cobalt, iron, and manganese) and radionuclides (americium-241, cesium-137, plutonium-239,240, strontium-89,90, and tritium) have been qualified as estimated values. All SVOC, pesticides, PCBs, major ions, and inorganic parameters data met the QC requirement for precision.

Accuracy was not determined for subsurface geologic material sampling.

Representativeness is good. Several metals were detected in the field QC samples; however, most analytes, with the exception of beryllium, cadmium, copper, selenium, silver, and zinc, probably originated in the distilled water used to rinse sampling equipment. These metals occurred infrequently and at low concentrations.

Completeness of subsurface geologic material sampling was 100 percent for upgradient boreholes, 95 percent for downgradient boreholes, and 56 percent for landfill boreholes (48 percent complete in artificial fill and 95 percent complete in bedrock). The average completeness for subsurface geologic material sampling was 84 percent. Of the total results available as of December 1, 1993, approximately 96 percent have been validated and 2 percent rejected indicating that analytical completeness is very high.

Comparability of Phase I RFI/RI subsurface geologic material data to historical subsurface geologic material data has been ensured by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c).

3.1.10.5 Sediments

Precision is generally very good for all analytes, with the exception of lithium, silver, cesium-137, gross alpha, plutonium-239,240, strontium-89,90, uranium-235, acetone, and benzoic acid. RPDs for these analytes exceed the QC criterion of 35 percent for solid media. Results for several analytes have been qualified as estimated values based on the results of the precision analysis, including lithium, silver, cesium-137, gross alpha, plutonium-239,240, strontium-89,90, uranium-235, acetone, benzoic acid, bis(2-chloroisopropyl) ether, fluoranthene, phenanthene, and pyrene. Results for all major ions and inorganic parameters met the QC requirement for precision.

Accuracy was not determined for sediment sampling.

Representativeness is good. Although acetone and several metals were detected in the equipment rinse collected in conjunction with sediment sampling, the majority of these analytes most likely were present in the distilled water used to prepare the rinsate sample. Arsenic, cadmium, zinc, and acetone, which probably did not originate in the distilled water, were detected infrequently and at low concentrations.

Completeness of sediment sampling is 100 percent indicating that supported conclusions can be made based on these data. Analytical completeness is very high. Of the total results in RFEDS as of December 1, 1993, approximately 98 percent have been validated and 4 percent rejected.

Comparability of sediment data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c).

3.1.10.6 Surface Water

Precision of field sampling methods and laboratory analysis of surface water is very good, with the exception of iron, zinc, and radionuclides (except for strontium-89,90), which exceeded the QC criterion of 20 percent. In general, reproducibility of radionuclide data is difficult to achieve, particularly at levels near the minimum detectable activity. Results for the following analytes have been qualified as estimated values based on the precision analysis: dissolved metals (antimony, iron, nickel, and zinc), total metals (iron, nickel, and zinc), dissolved radionuclides (americium-241, cesium-137, gross alpha, plutonium-239,240, uranium-233, 234, uranium-235, and uranium-238), all total radionuclides except radium-226 and total radiocesium, SVOCs (bis(2-ethylhexyl)phthalate and di-n-butylphthalate), and nitrate. All VOC, pesticide, and PCB results met the QC requirement for precision.

Accuracy was not evaluated for surface-water samples.

Representativeness is good based on the results of the field QC sample analysis. However, several analytes were detected in the blank samples, including beryllium, cadmium, lead, zinc, acetone, methylene chloride, and bis(2-ethylhexyl)phthalate. These analytes were detected infrequently and at low concentrations.

Completeness of surface-water sampling activities is 100 percent for two sampling locations (the leachate seep and surface water from the East Landfill Pond). Completeness is only 12 percent for the other two sampling locations (groundwater intercept system discharge points) as a result of field conditions. The lack of data from these locations will not affect DQOs because groundwater apparently discharges to the East Landfill Pond, not to the discharge points. Of the total results available as of December 1, 1993, approximately 89 percent of the results have been validated. Approximately 7 percent have been rejected.

Comparability of the surface-water data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c).

3.1.10.7 Groundwater

Precision of field sampling methods and laboratory analysis is generally very good. Based on the number of RPDs that exceed the QC criterion of 20 percent for groundwater, however, several metals (aluminum, barium, chromium, cobalt, copper, iron, lithium, magnesium, manganese, nickel, potassium, silicon, vanadium, and zinc), nitrate/nitrite, TDS, and TSS exhibit poor precision. In addition, radionuclides generally exhibit poor precision, particularly at levels near the minimum detectable activity. Based on results of the precision analysis, results for the following analytes have been qualified as estimated values: dissolved metals (aluminum, copper, iron, lead, manganese, and potassium), total metals (aluminum, antimony, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, tin, vanadium, and zinc), all dissolved and total radionuclides, TCE, di-n-butyl phthalate, diethyl phthalate, nitrate/nitrite, TDS, and TSS.

Accuracy goals were met using analytical results for the MS and MSD samples, with the exception of dissolved selenium and silicon and total aluminum, arsenic, and silicon. Recovery of these metals in the QC spikes exceeded the QC criterion. Several metals (arsenic, chromium, lead, and zinc) were detected in the equipment rinses and were most likely not present in the distilled water used to rinse sampling equipment. However, these metals were detected infrequently and at low concentrations.

Representativeness is good based on the results of the field QC sample analysis. Although several metals were detected in the equipment rinses, with the exception of arsenic, lead, and zinc, these metals most likely originated in the distilled water used to prepare the rinses. Arsenic, lead, and zinc were detected infrequently and at low concentrations indicating that their presence should not affect the representativeness of the groundwater samples.

Completeness of groundwater sampling activities is 78 percent for the 16 wells installed during the OU 7 Phase I RFI/RI. These data indicate that for the wells sampled completeness DQOs have been met and defensible conclusions can be made regarding the nature and extent of

groundwater contamination. An evaluation of the analytical completeness reveals that, as of December 1, 1993, approximately 73 percent of the total results have been validated and 2 percent have been rejected.

Comparability of groundwater data has been established by the use of an approved work plan (DOE 1991b), standard analytical methods (EG&G 1991g), and approved SOPs (EG&G 1992c). Data were reported in uniform units.

3.2 Data Usability

The usability of data was evaluated for each media sampled using the laboratory qualifier, the validation code, and the results of the data-quality analysis. The usability of individual records was defined by the laboratory and validation codes. The usability of larger groups of data, such as all records for a specific analyte, was determined by the data-quality indicators.

Four usability categories have been defined for data collected during the OU 7 Phase I RFI/RI based on laboratory qualifiers and validation codes. Table 3-6 lists these categories and the qualifiers and codes associated with each one. Fully usable data include validated records that are not qualified by the laboratory as estimated values. Estimated results are those data considered acceptable by the validation code but reported by the laboratory as estimated values based on a variety of QA/QC criteria. Unusable data include rejected results and unvalidated records with undefined laboratory qualifiers or qualifiers indicating poor analytical results (such as "E"-qualified organic compound results). The fourth category includes unvalidated records that may or may not be qualified by the laboratory. The status of these records remains undetermined at this time, but they have been considered usable as estimated values similar to the estimated-results category.

The percentages of the records for each medium that falls within each category are provided in Table 3-8. In general, the majority of data from all media types are fully usable. The percentage of rejected or unusable data for each medium ranges from 0 percent for biota samples to 6 percent for surface-water samples. Data in this category were removed from the working database.

Data usability has been assessed for two distinct data sets: (1) historical data collected prior to the Phase I RFI/RI and (2) data collected during the OU 7 Phase I RFI/RI.

3.2.1 *Historical Data*

Historical data collected prior to first-quarter 1990 are considered not usable for two reasons. Prior to 1989, there was no EPA CLP in effect at Rocky Flats, and prior to 1990, there were no documented SOPs for sample collection. Some samples were analyzed by laboratories that did not provide adequate QA/QC documentation to conduct data validation. Many results obtained prior to 1990 are unvalidated and will necessarily remain so. Because there is no way to verify the results of analyses prior to 1990, these data should not be used in the human health risk assessment or the evaluation of remedial alternatives. These data have only limited use for site characterization. For example, they may be used to evaluate general temporal trends, but they should not be used to describe the nature and extent of contamination.

The quality of historical data collected from 1990 through 1992 was not evaluated. These data are considered fully usable if they fall into one of the three usable categories defined by laboratory qualifiers and validation codes (refer to Table 3-6).

3.2.2 *Phase I RFI/RI Data*

Data collected during the Phase I RFI/RI have undergone rigorous review and data-quality evaluation. Specific results of the data-quality analysis are summarized in Section 3.1.10. Results indicate that, with the exception of soil-gas samples and landfill leachate–groundwater samples collected using the BAT® system, data quality is generally good. Therefore, data are usable for the intended purposes of characterizing site physical features and identifying contaminant sources.

As of December 1993, approximately 87 percent of the records in the OU 7 Phase I RFI/RI data set have been reviewed and evaluated in accordance with EPA procedures for documentation and validation of Level IV data (Level V data for radiological analyses). The valid data are considered usable for site characterization, human health and environmental risk assessments, remedial alternative evaluation, engineering design and remedial actions, and potentially responsible party determination (EPA 1987).

Unvalidated data may not be as usable as the validated Level IV and Level V data. According to EPA guidance (EPA 1992), unvalidated data may be used in risk assessments only qualitatively to identify analytes during preparation of a sampling and analysis plan. The data used for a baseline

risk assessment must also meet criteria for the PARCC parameters. As presented in Section 3.1, data quality has been assessed for all Level IV and Level V data. For analytes that do not meet precision goals in more than 50 percent of the sample pairs, or where the average RPD exceeds the acceptable RPD value, all of the results reported for that analyte should be qualified as estimated results for the risk assessment.

Data quality for the soil-gas samples and landfill leachate–groundwater samples collected using the BAT® system is fair. Precision and representativeness for these samples, which were collected during screening activities, is generally poor. These samples were analyzed on site using a portable field gas chromatogram (GC); results are EPA Level II screening data. Data of this level is typically subject to a wide range in data quality. Level II data provide qualitative information on the presence of elevated compounds (that is, hotspots) and on relative concentrations to aid in characterizing the site.

Table 3-8 provides a summary of specific data usability for each media sampled. Fully usable data, including valid and estimated data, range from 69 percent (groundwater) to 100 percent (biota) of the total results. These percentages indicate that the majority of data meet the data usability needs for addressing the Phase I RFI/RI objectives of characterizing the site and evaluating contaminant sources.

Surface-soil results indicate that 85 percent of the total number are fully usable, 3 percent are rejected, and 13 percent are unvalidated. Subsurface-soil results indicate that 89 percent of the total number are fully usable, 3 percent are rejected, and 8 percent are unvalidated. Sediment results reflect that 90 percent of the total number are fully usable, 3 percent are rejected, and 7 percent are unvalidated. Surface-water results indicate that 85 percent of the total number are fully usable, 6 percent are rejected, and 9 percent are unvalidated. Groundwater results indicate that 69 percent of the total number are fully usable, 4 percent are rejected, and 28 percent are unvalidated. Many of these unvalidated results were collected during the third and fourth quarters of 1993 and have not yet gone through data validation.

Several specific deficiencies were identified during the data-quality assessment:

- The frequency of metals detected in equipment rinses is relatively high. The most frequently detected metals include calcium, iron, potassium, magnesium, silicon, sodium, and zinc.

Commercial-grade distilled water was used to prepare these rinsates and is a likely source of several metals. For this reason, analyses of these frequently detected metals in equipment rinses may not be useful in identifying field contamination of real samples. The concentrations of most metals detected are lower than the EPA contract-required detection limit (CRDL), indicating that the presence of these analytes in equipment rinses should not affect the representativeness, and thus usability, of the environmental samples collected.

- For radionuclide analyses, RPDs were extremely variable and typically high. Elevated RPDs are associated with low radionuclide activities that are not within the range required to obtain reproducible results. Because of the poor laboratory precision associated with measuring these activities, analyses of duplicate samples for radionuclides does not provide a measure of sampling precision.

- VOC analyses of equipment rinses indicate that acetone was typically present in the rinsates. This compound may originate from the commercial-grade distilled water used to rinse the sampling equipment, and it has also been identified as a common laboratory contaminant (EPA 1988a). In accordance with procedures specified in EPA functional guidelines (EPA 1988a, EPA 1988b, and EPA 1992a), results for analytes detected in blanks may require results from associated real samples to be restated as undetected. This assessment should be performed during data validation. Until the results of such an assessment are available, the presence of acetone in a field sample should be considered as potentially resulting from laboratory contamination. Results for this compound should be qualified in RFEDS and further evaluated. At present, these results are considered usable as screening-level data.

Section 3
Tables

Table 3-1
Required Field QC Sample-Collection Frequency

QC Sample	Frequency
Field Duplicate	1 per 10 real samples or 1 per sampling event[1]
Field Blank[2]	1 per shipping container (or a minimum of 1 per 20 real water samples)
Trip Blank[3]	1 per 20 real water samples
Equipment Rinse	1 per 20 real samples or 1 per day[4]
Triplicate Sample (benthic samples)[5]	For each sampling site

[1] Whichever is more frequent.
[2] For samples to be analyzed for inorganic compounds.
[3] For samples to be analyzed for volatile organic compounds only. Trip blanks shall not be used for radiochemistry samples because these samples are less likely to be contaminated through the introduction of radionuclides from direct exposure to air than by the introduction of volatile organic compounds.
[4] Whichever is more frequent for each specific sample matrix being collected when non-dedicated equipment is being used.
[5] For samples collected for tissue analysis.

Definitions:

QC quality control

Source: EG&G 1990c, DOE 1991b

Table 3-2
Field QC Sample-Collection Summary

QC Sample Type	Sample Type											
	IHSS 203 Soil Gas	IHSS 114 Soil Gas	IHSS 114 BAT Liquid	IHSS 203 Soil (0–2 inches)	IHSS 203 Soil (0–10 inches)	IHSS 114 Soil	East Landfill Pond Soil (0–2 inches)	East Landfill Pond Soil (0–10 inches)	Borehole Samples	Groundwater Samples	Surface-Water Samples	Sediment Samples
Real	48	67	26	31	17	22	139	67	125	69	9	3
Field Duplicate	*2*	*8*	*2*	*4*	*2*	*2*	*14*	*6*	16	*5*	*2*	*1*
Equipment Rinse[1]	7	4	2	3	1	1	8	3	10	3	2	1
Trip Blank	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	*1*	2	NR-WP
Field Blank	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	*1*	1	NR-WP
Replicate	NR-WP	19	4	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	2	1	NR-WP
Matrix Spike	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	NR-WP	2	NR-WP	NR-WP

[1] Equipment blank for soil-gas samples collected at IHSS 203.
Values in italics do not meet required QC-sample collection frequency as defined by the QAPjP (EG&G 1991h).

Definitions:

IHSS individual hazardous substance site
NR-WP not required-work plan; not required in accordance with the OU 7 Phase I work plan (DOE 1991b)
QC quality control

Table 3-3
Definition of Laboratory Qualifiers

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")	Value for Statistical Analysis
+	Inorganics: correlation coefficient for the matrix spike analysis is less than 0.995 (estimated value)	yes	yes	result
*	Inorganics: duplicate analysis is not within control limits (estimated value)	yes	yes	result
	Organics: outside contract-required QC limits	yes	yes	result
A	Organics: identifies TIC as a suspected aldol condensation product	yes, remove to TIC table	no	not included
B	Inorganics: reported value is less than CRDL but greater than IDL	yes	yes	result
	Organics: warns that analyte also detected in blank	yes	yes	result
	Note: for common laboratory contaminants[1] include as hit if blank result is greater than 10 times detection limit; for all other organics include as hit if blank result is greater than 5 times detection limit	yes	yes	result
	Radionuclides: constituent also detected in associated blank whose concentration was greater than CRDL and/or minimum detectable activity (estimated value)			
C	Organics: pesticide result confirmed by GC/MS	yes	yes	result
	Radionuclides: presence of high TDS in sample increased minimum detectable activity	yes	yes	result
D	Organics: identified in an analysis at a secondary dilution	yes	yes	result
E	Inorganics: value is an estimate due to interference (estimated value)	yes	yes	result
	Organics: compound exceeded calibration range of instrument, sample must be re-analyzed	no	no	not included
F	Organics: compound off scale (estimated value)	yes	yes	result
	Radionuclides: for alpha spectrometry - FWHM exceeded acceptable limits (estimated value)	yes	yes	result
G	Inorganics: native analyte is greater than 4 times spike added	yes	yes	result
	TOC: dilution result exceeded range of instrument, estimated result	yes	yes	result
H	Radionuclides: sample analysis performed outside of method-specified maximum holding time	yes	yes	result
I	Organics: interference with target peak (estimated value)	yes	yes	result
J	Inorganics: value greater than IDL but control sample analysis not within control limits (estimated value)	yes	yes	result
	Organics: MS data indicate presence of compound but below detection limit (estimated value)	yes	yes	result

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")	Value for Statistical Analysis
JB	Organics: result below detection limit and analyte detected in laboratory blank	yes	no	½ detection limit
K	Result is less than MDL (CRDL) but greater than IDL	yes	yes	result
L	Undefined	no	no	not included
M	Inorganics: duplication injection precision not met (estimated value)	yes	yes	result
N	Inorganics: spiked sample recovery is not within control limits (estimated value) Organics: compound presumed present (TIC)	yes yes, remove to TIC table	yes no	result not included
R	Validation code for rejected data entered in lab qualifier field/unusable data	no	no	not included
S	Inorganics: the reported value determined by the method of standard additions	yes	yes	result
T	Compound found in TCLP extract blank and sample	yes	yes	result
U	Organics and inorganics: analyte analyzed but not detected at the quantitation limit	yes	no	½ detection limit
UC	Organics: pesticide result confirmed but below detection limit	yes	no	½ detection limit
UE	Radionuclides: detection limit reported as result (?)	no	no	not included
UJ	Organics: analyzed but not above the detection limit (estimated value)	yes	no	½ detection limit
UN	Inorganics: spiked sample recovery not within control limits and sample result below detection limit Organics: compound presumed present but below detection limit	yes yes, remove to TIC table	no no	½ detection limit not included
UW	Inorganics: post-digestion spike for GFAA analysis is out of control limits and sample result is below detection limit	yes	no	½ detection limit
UX		yes	no	½ detection limit
V	Validation code for valid data entered into laboratory qualifier field	yes	yes	result
W	Inorganics: post-digestion spike for GFAA analysis is out of control limits while sample absorbance is less than 50% of spike absorbance	yes	yes	result
X^2	Inorganics (pre-1992): detection limit greater than normal, sample matrix interference Organics (pre-1992): laboratory software flag (combines more than one qualifier) - not defined Other (OU 7 RFI/RI samples): result by calculation defined in GRRASP	yes no (unless accompanied by a validated result) yes	yes no yes	result not included result

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")	Value for Statistical Analysis
Y	Organics: indistinguishable isomer in TIC	yes, remove to TIC table	no	not included
	Radionuclides: chemical yield exceeded acceptable limits (estimated value)	yes	yes	result
Z	Organics: "quest identification, matrix interference of column"	no	no	not included

[1] common laboratory contaminants: 2-butanone, acetone, common phthalate esters, methylene chloride, toluene.

[2] Note on use of X qualifiers: X is defined in the GRRASP as a result determined by calculation not by direct laboratory analysis. Therefore, for samples analyzed during the period that GRRASP has been in effect (since January 1992) the results qualified by an X will be treated as estimated values (similar to J). For historic data, when GRRASP was not used by laboratories, an X qualifier has two definitions. For organics, the X is a flag entered manually by the laboratory, but is not defined in RFEDS. Therefore, organic results qualified by X are not considered usable data, unless a validated result is given. For inorganics, an X qualifier indicates that the detection limit for the analyte is higher than normal due to matrix interference. An inorganic qualified with an X will be treated like a J result. The X qualifier is sometimes also used with other qualifiers (for example, UX, XJ). In these cases the meaning of X depends on the analyte and the date of the analysis.

Definitions:

CRDL	contract-required detection limit
FWHM	full width at half maximum (the width of the distribution at a level that is just half the maximum ordinate of the peak)
GC/MS	gas chromatography/mass spectrometry
GFAA	graphic furnace atomic adsorption
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
IDL	instrument detection limit
MDL	method detection limit
MS	matrix spike
OU	operable unit
QC	quality control
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA facility investigation/remedial investigation
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TIC	tentatively identified compound
TOC	total organic carbon

Table 3-4
Definition of Validation Codes

Code	Definition	Include in Data Analysis
A	Acceptable result	yes
B	Laboratory qualifier	no
C	Laboratory qualifier	no
J	Estimated result	yes
JA	Acceptable result (for estimated value)	yes
N	Laboratory qualifier	no
P	Undefined	no
R	Rejected result	no
S	Laboratory qualifier	no
V	Valid result	yes
Y	Analytical results in validation process	yes
Z	Validation not required or performed	no

Table 3-5
Data Validation Summary (as of December 1, 1993)

Medium/Analyte Group	Total Number of Results	Number of Validated Results	Number of Rejected Results	% Results[1] Validated	% Results[2] Rejected
Subsurface Geologic Materials					
Metals, Total	3315	3315	40	100	1
Pesticides and Polychlorinated Biphenyls	1247	1163	36	93	3
Radionuclides, Total	1231	894	93	73	8
Semivolatile Organic Compounds	7462	7397	26	99	<1
Volatile Organic Compounds	3597	3464	148	96	4
Water-Quality Parameters	592	568	87	96	15
TOTAL	17444	16801	430	96	2
Biota					
Metals, Total	252	252	0	100	0
Radionuclides, Total	81	81	0	100	0
TOTAL	333	333	0	100	0
Groundwater					
Metals, Dissolved	1815	1351	17	74	1
Metals, Total	1758	1294	23	74	1
Pesticides and Polychlorinated Biphenyls	61	3	0	5	0
Radionuclides, Dissolved	601	220	0	37	0
Radionuclides, Total	236	39	1	17	<1
Semivolatile Organic Compounds	4859	4202	78	86	2
Volatile Organic Compounds	2654	1566	72	59	3
Water-Quality Parameters	675	506	5	75	1
TOTAL	12659	9181	196	73	2
Sediment					
Metals, Total	77	77	2	100	3
Pesticides and Polychlorinated Biphenyls	32	32	0	100	0
Radionuclides, Total	33	30	0	91	0
Semivolatile Organic Compounds	254	247	12	97	5
Volatile Organic Compounds	121	121	5	100	4
Water-Quality Parameters	15	14	0	93	0
TOTAL	532	521	19	98	4
Soil Gas					
Volatile Organic Compounds	187	187	0	100	0
TOTAL	187	187	0	100	0

Medium/Analyte Group	Total Number of Results	Number of Validated Results	Number of Rejected Results	% Results[1] Validated	% Results[2] Rejected
Surface Soils					
Metals, Total	7321	7233	35	99	<1
Pesticides and Polychlorinated Biphenyls	545	435	0	80	0
Radionuclides, Total	3483	2495	255	72	7
Semivolatile Organic Compounds	1555	1435	17	92	1
Volatile Organic Compounds	54	54	20	100	37
Water-Quality Parameters	887	590	0	67	0
TOTAL	13845	12242	327	88	2
Surface Water					
Metals, Dissolved	238	238	1	100	<1
Metals, Total	237	237	4	100	2
Pesticides and Polychlorinated Biphenyls	81	54	0	67	0
Radionuclides, Dissolved	99	71	4	72	4
Radionuclides, Total	97	81	0	84	0
Semivolatile Organic Compounds	726	589	131	81	18
Volatile Organic Compounds	392	392	3	100	1
Water-Quality Parameters	78	78	1	100	1
TOTAL	1948	1740	144	89	7

[1] (number of validated results/total number of results) *100

[2] (number of rejected results/total number of results) *100

Table 3-6
Usability Categories

Category	Definition	Validation Codes	Laboratory Qualifiers
VALID	Fully usable	A, V	blank, U
ESTIMATE	Usable as estimated result	A, J, V, JA[1]	+, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, UJ, UN, UW, UX, W, X, Y, Z
REJECT	Not valid	B, C, N, P, R, S, Z	E (organics), L, R, UE (radionuclides)
BLNK/Y VAL	Acceptable or estimated result, no validation code	Y, blank	blank, +, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, U, UJ, UN, UW, UX, W, X, Y, Z

[1] If the validation code is J or JA, then U and blank lab qualifiers are considered to be estimates.

Table 3-7
PARCC Parameter QC Criteria by Media Sampled

Medium	PARCC Parameters				
	Precision	Accuracy	Representativeness	Completeness	Comparability
Groundwater	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Surface Water	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 Percent	Qualitative
Surface Soils	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Subsurface Geologic Materials	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Sediments	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Soil Gas	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Leachate–Groundwater Collected Using BAT® System	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative

Definitions:

PARCC	precision, accuracy, representativeness, completeness, and comparability; used to assess data quality
QC	quality control
RPD	relative percent difference
% Bias	percent bias; equal to 100-percent recovery

Table 3-8
Data Usability by Media Sampled

Medium	Total Results	Valid Results—Fully Usable		Estimated Results—Fully Usable		Rejected or Unusable Results		Unvalidated Results—Usability Not Determined	
		Number of Results	Percent of Total Results	Number of Results	Percent of Total Results	Number of Results	Percent of Total Results	Number of Results	Percent of Total Results
Subsurface Geologic Materials	21,656	16,458	76%	2,889	13%	652	3%	1,657	8%
Biota	333	256	77%	77	23%	0	0%	0	0%
Groundwater	13,971	8,035	58%	1,497	11%	490	4%	3,949	28%
Sediment	859	558	65%	216	25%	29	3%	56	7%
Surface Soils	15,992	10,040	63%	3,455	22%	497	3%	2,000	13%
Surface Water	3,073	2,052	67%	550	18%	184	6%	287	9%

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4. NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination related to sources within OU 7 were evaluated by analysis of chemical data from environmental media collected during the Phase I RFI/RI and during sitewide surface water and groundwater monitoring programs. This evaluation was based on the following information: descriptive summary statistics for each analyte from each media type, graphical presentations of concentration data for each analyte from each media type, analyte-distribution maps for selected media (landfill gas, surface soils, and groundwater), comparisons of chemical data from OU 7 to chemical data from background media to identify PCOCs, and qualitative analysis of chemical data to evaluate the spatial and temporal variations in contaminant concentrations. This evaluation will be used for remedial investigation and design of remedial actions.

The statistical data-analysis methods are described in Section 4.1. The summary statistics for each media type are included in Appendix M, graphical presentations of chemical concentration data are included in Appendices K and L, and the results of statistical comparison tests are provided in Appendix M. A detailed description of contaminant sources is provided in Section 4.2. Sections 4.3 through 4.8 describe the nature and extent of contamination to environmental media in the vicinity of the landfill.

4.1 Methodology for Background Comparison and PCOC Identification

Data from OU 7 samples were compared to data from background samples for each media type sampled during the Phase I RFI/RI. Data from the background geochemical characterization report (EG&G 1993a) were used for background samples of sediment, geologic media, groundwater, seep water, and surface water. The characteristics of background soils were described from samples collected in the Rock Creek drainage (DOE 1993c). These background data sets were subject to the cleanup steps presented in Section 3.1.3. The data from each media type were aggregated in comparable subsets for comparison to background data to meet specific investigation objectives and to identify PCOCs. The

rationale for the data aggregation schemes used is presented in Section 4.1.1. The procedures used for statistical analysis and comparisons are described in Section 4.1.2.

Qualitative comparisons of site data to background data were made for each media type sampled at OU 7. Histograms and box-and-whisker plots (box plots) for each analyte from each media type were generated for both site and background data. The graphic presentations of the data were used to evaluate the magnitude, variability, and distribution of concentrations for each analyte. Box plots are presented in Appendix K. Histograms are presented in Appendix L.

Chemical concentration data from various media sampled at OU 7 were statistically evaluated to identify analytes present at concentrations elevated relative to concentrations in the same media from background locations. Analytes with elevated concentrations in media from OU 7 were considered PCOCs as defined in EG&G (1994b). PCOCs were identified by comparison to background data using the statistical and qualitative methods outlined in Statistical Comparisons of Site-to-Background Data in Support of RFI/RI Investigations (EG&G 1994b). The site-to-background comparison methods were used to identify inorganic analytes and radionuclide PCOCs. Organic compounds were considered PCOCs if detected in samples from OU 7.

4.1.1 Data Aggregation for Background Comparisons at OU 7

Chemical concentration data from various environmental media sampled at OU 7 were evaluated with the following two distinct objectives: to identify PCOCs and to describe the nature and extent of contamination. Prior to comparison of chemical concentration data from OU 7 to background values, data were aggregated by media. Data aggregation was based on the statistical assumption that all samples within a data set were independent but comparable (collected and analyzed using the same methods), and represented by a single population characterized by a fixed mean and variance.

The media types at OU 7 include surface soil, surface water, seeps, pond sediments, geologic materials, and groundwater (Table 4-1). Within each media, samples were further subdivided by depth, sampling method, sample location, hydrostratigraphic unit, geologic unit, and location relative to contaminant sources, as needed, for comparability with background data. Table 4-1 presents the primary groups of data by media, defines the appropriate subdivisions of those

groups, and describes the aggregation scheme that will be used to perform the statistical comparisons to background data. The rationale for the aggregation approach used for each media is discussed below.

Surface soil data from OU 7 are comprised of samples collected from three areas: the East Landfill Pond area, the Inactive Hazardous Waste Storage Area (IHSS 203), and the Present Landfill (IHSS 114). Surface soil samples from the 0- to 2-inch depth interval at the East Landfill Pond and IHSS 203 were collected using the grab method. Surface soil samples from the 0- to 10-inch depth interval at these locations were collected using the hand auger method. Surface soil samples from IHSS 114 were collected using a different sampling method—the Rocky Flats method for composite samples. As a result, the samples collected from IHSS 114 cannot be directly compared to samples from the East Landfill Pond or IHSS 203, and the three areas were evaluated individually during statistical testing. Similarly, soil samples collected from the two different depth intervals at the East Landfill Pond and IHSS 203 are not considered directly comparable. Soils from the 0- to 2-inch depth interval may have different origins and contaminant transport pathways than soils from the 0- to 10-inch depth interval. As a result, the soils from the East Landfill Pond and IHSS 203 have been further subdivided by depth. The result is five subsets of surface soils as shown in Table 4-1. Statistical comparisons with background data were performed separately for each of the subsets. Surface soil data will be used for the risk assessment after final closure.

Borehole samples were collected from subsurface geologic materials upgradient, within, and downgradient of the Present Landfill. The two downgradient locations (70993 and 71093) were grouped separately because they have separate sources of potential contamination; borehole 70993 was drilled downgradient of the north intercept system discharge point, and borehole 71093 was drilled downgradient of the south intercept system discharge point. As a result, subsurface geologic materials were initially grouped into three subsets of data: upgradient (70493 and 70593), downgradient (70993), and downgradient (71093). Data in these subsets were further subdivided by geologic unit as follows: Rocky Flats Alluvium, colluvium, and weathered Arapahoe and Laramie Formation. Data in these subsets were compared against sitewide borehole data for each geologic unit.

Sediment was collected from three locations at the East Landfill Pond. The sediment samples were collected using a coring device, and multiple cores were collected at each location and

composited for analysis. The sediment thickness ranged from 6 to 10 inches. Sources of sediment to the pond include original stream sediments in the drainage, surface runoff, eolian material, and sediments associated with flow from the seep. Sediment from all three pond locations was grouped together and compared to stream sediments from background locations.

Surface water samples were collected from three locations: the East Landfill Pond (SW098) and the two discharge points for the groundwater-intercept system (SW099 and SW100). Sources of water to the East Landfill Pond are precipitation, surface runoff, groundwater base flow, and—to a lesser extent—leachate from the landfill. The sources of water to the intercept system are groundwater entering the system around the perimeter of the landfill and, potentially, leachate generated outside the intercept system. Thus, the surface water locations constitute two distinct groups: the East Landfill Pond water and water from intercept system discharge points (Table 4-1). Water from the two intercept system discharge points was compared separately to background data to determine if different analytes were elevated above background concentrations at the two discharge points. These data were used to investigate the impact to water quality of a potential breach in the groundwater intercept system along the northern perimeter of the landfill (Section 2.5).

Seep water was collected from one location—a seep at the bottom of the east face of the landfill (SW097). The source of the seep water is leachate from the landfill. Seep water data from this location were compared to natural seep water data from background locations.

Groundwater samples were collected from wells screened in the UHSU and LHSU. Because these units comprise separate flow systems, the data were divided by hydrostratigraphic unit. The UHSU comprises Rocky Flats Alluvium, colluvium, valley-fill alluvium, artificial fill, weathered bedrock, and bedrock sandstones in direct hydraulic connection with other units in the UHSU (subcropping sandstones). The LHSU is composed of unweathered bedrock. Wells that screen the UHSU have been further subdivided into three areas: upgradient, within the landfill, and downgradient. Groundwater samples from these areas constitute three distinct populations. Wells that screen the LHSU have been further subdivided into two areas: upgradient and downgradient of the landfill. No LHSU wells exist within the landfill. Groundwater samples from these areas constitute two distinct populations. PCOCs in the UHSU were identified by comparing all UHSU data to sitewide background UHSU data. PCOCs in the LHSU were identified by comparing data from LHSU wells downgradient of the landfill to sitewide background LHSU data.

The LHSU and UHSU wells upgradient of the landfill were compared to background data to evaluate the nature and extent of contamination. The nature and extent of contamination in the UHSU were also evaluated by comparing UHSU wells within the landfill to background UHSU data. Background comparisons for groundwater are summarized in Table 4-1.

4.1.2 *Statistical Analysis Procedures for PCOC Identification*

The flow chart presented in Figure 4-1 illustrates the process for identifying PCOCs. The statistical methodology for site-to-background comparisons for inorganic analytes and radionuclides followed the procedures outlined in Statistical Comparisons of Site-to-Background Data in Support of RFI/RI Investigations (EG&G 1994b). The PCOC identification process consisted of the following steps: (1) a hot-measurement test, (2) the Gehan test, (3) the Quantile test, (4) the Slippage test, (5) the t-test, and (6) professional judgment. Analytes having concentrations elevated relative to background concentrations, as indicated by the hot-measurement test or any one of the inferential statistical tests (Gehan, Quantile, Slippage, and t-test), are considered PCOCs. The five comparison tests are described below.

Chemical data from OU 7 were evaluated using a hot-measurement test, which compares each measurement with an upper tolerance limit (UTL) value for the corresponding analyte in the background data. The hot-measurement test is useful as a screening tool to ensure that unusually large measurements are adequately evaluated regardless of the output of the more formal inferential statistical tests. The UTL concentration used during comparison of site to background data was the $UTL_{99/99}$ value in accordance with Rocky Flats guidance on statistical comparisons (EG&G 1994b). This UTL represents a value for which there is 99-percent confidence that the UTL is equal to or greater than the true 99th percentile of the background population. The UTL values for background data are reported in the background geochemical characterization report (EG&G 1993a).

Statistical inference tests (Gehan, Quantile, Slippage, and t-tests) were used to compare the means and medians of the OU 7 and background populations. The null (H_o) and alternative (H_a) hypotheses used during the statistical analyses are as follows (Gilbert 1993):

H_o: Chemical concentrations within OU 7 are not significantly greater than those in the background area.

H_a: Chemical concentrations within OU 7 are significantly greater than those in the background area.

The nonparametric Gehan test (Palachek et al. 1993, Gehan 1965) can be used to evaluate data sets with multiple detection limits and nondetects and can be used regardless of the distribution of the data. The Gehan test is a generalization of the more common non-parametric ANOVA Wilcoxon Rank Sum test. The Gehan test was performed for all analytes. The parametric ANOVA t-test was used only when background and site data contained less than 20 percent nondetects and normality assumptions based on the Shapiro-Wilk test were satisfied.

Other nonparametric tests used to compare background and site data included the Quantile and Slippage tests. The Slippage test consists of counting the number of OU measurements that exceed the maximum background measurement. If the number of measurements exceeding the maximum background measurement was greater than a critical value obtained from tables in Rosenbaum (1954), then the analyte was considered a PCOC.

The Quantile test is similar to the Slippage test and was performed by listing the combined background and OU measurements from smallest to largest. The test counts the number of measurements from the OU that are among the largest measurements of the combined data sets. If the number of measurements is greater than a critical value, the analyte was considered a PCOC. The largest measurement and critical values were determined from tables in Gilbert and Simpson (1992).

The inferential statistical tests (Gehan, Slippage, Quantile, and t-test) compare background and OU 7-wide concentration distributions. The hot-measurement test compares each measurement to a corresponding $UTL_{95/95}$ value. The difference in the two methods is that the inferential tests compare differences between population distributions and the hot-measurement test compares individual measurements to a single value. The hot-measurement test is not considered a formal statistical test because false positive and power requirements are not explicitly stated.

The final identification of PCOCs was subject to professional review of the test results and graphic presentation of the data. The professional judgment of the analyst is required to consider other factors such as the spatial and temporal distribution of analytes; historic information regarding past

operations at the site; inter-element correlations; mass balance calculations; and knowledge of the hydrology, geochemistry, and geology of the site.

4.2 Sources

The primary sources of contamination at OU 7 are landfilled wastes and associated leachate and gas within the Present Landfill. Potential secondary sources of contamination at IHSS 114 include (1) soils and other geologic material beneath the landfill that may have been contaminated by leachate, (2) leachate seeping from the landfill, (3) surface water in the East Landfill Pond, (4) sediments in the East Landfill Pond, and (5) potentially contaminated surface soils in the spray evaporation areas. At IHSS 203, the primary source of contamination, if any, is surface soil affected by past spills or chemical releases.

Primary sources at OU 7 are discussed below. Section 4.2.1 describes the characteristics of the landfill solids. Section 4.2.2 discusses gases detected within the landfill during the OU 7 Phase I RFI/RI methane survey and soil-gas sampling. Section 4.2.3 presents data describing leachate within the landfill and its role as a source.

Potential secondary sources are discussed in Sections 4.3 through 4.7. These sections present the nature and extent of contamination in surface soils and vadose zone, subsurface geologic materials, sediments, surface water, and groundwater, respectively, originating from sources at IHSSs 114 and 203.

4.2.1 Landfill Solids

Characteristics of the landfill solids are based on historical information characterizing waste disposal and information obtained during the OU 7 Phase I RFI/RI. Physical and chemical factors affecting the degradation of landfill wastes are also presented based on information from similar solid waste (municipal) landfills.

4.2.1.1 Waste Volume

The volume of landfill solids has been estimated using historical and future waste disposal rates and information obtained during the OU 7 Phase I RFI/RI characterizing the areal and vertical extent of landfill material.

From 1968 to 1978, the landfill received approximately 20 cubic yards (cy) of compacted waste per day. By 1974, the surface area covered by the landfill had expanded to approximately 300,000 square feet. The volume occupied by the landfill was estimated by areal photographs to be approximately 95,000 cy (Table 4-2). The volume of cover material included in this total was estimated at 30,000 cy. The remaining 65,000 cy consisted of compacted waste intermixed with the daily cover material placed during disposal. Estimates made in 1986 indicate that approximately 160,000 cy of material had been placed between 1974 and 1986, for a total landfill volume of 225,000 cy. The volume included solid wastes, wastes with hazardous constituents, and soil cover material. Estimates made in 1988 indicate that approximately 330,000 cy of material had been deposited in the landfill since it began operation in 1986 (Rockwell International 1988a). No volume estimates have been published since 1988.

Assuming that the yearly volume of waste and fill entering the landfill remained the same from 1988 to 1991, the estimated total volume of waste and fill in 1991 is approximately 442,000 cy. On November 1, 1992, EG&G Waste Operations began monitoring the volume of waste entering the landfill. The average monthly volume of waste deposited in the landfill for a six-month period from November 1992 to April 1993 was 1,000 cy per month or 12,000 cy per year. Waste Operations currently estimates the average amount of cover material to be 30 percent of the total material deposited into the landfill (McMillan 1993). The anticipated date of closure of the landfill is 1997. Based on the present yearly disposal rate (approximately 16,000 cy of waste and fill), the total volume of landfill material at the time of closure is estimated to be 539,000 cy (tables 4-2 and 4-3).

The areal extent of the waste disposal area and the elevation of the base of the landfill is illustrated in Figure 4-2. Landfill wastes have been placed on top of and outside the groundwater intercept system, particularly along the northern portion. The extent of landfilled waste was evaluated by reviewing borehole and CPT logs for the presence of waste. Landfill waste was encountered at locations SS714893 (wood pieces) and SS716093 (plastic sheeting fragments) during the soil-gas survey at IHSS 203. As illustrated in Figure 4-2, waste material does not extend beyond the surface-water diversion ditch.

Geologic cross-sections (Figures 2-9 through 2-16) present the vertical thickness and the lateral extent of the waste. The waste is generally thinnest along the boundaries and thickest along the east-west axis, particularly in the easternmost section of the landfill along the steep face west of

the East Landfill Pond. The thickness of waste material ranges from less than 1 foot to approximately 40 feet.

Based on the areal and vertical extent of waste and soil cover, the total volume of material is estimated to be 415,000 cy. This value was calculated by comparing the elevations of the base of the landfill and ground surface (Figure 4-3). Assuming that approximately 30 percent of the total material deposited in the landfill is soil cover, the volume of waste in the landfill is approximately 291,000 cy.

4.2.1.2 Waste Composition

As discussed in Section 1.3.1, the landfill was designed for disposal of nonradioactive solid waste. In 1986 and 1987, waste streams were characterized under the WSIC program. Limited analytical testing, including the extraction procedure toxicity test, was performed as part of the WSIC program. Approximately 1,500 waste streams were identified, 338 of which were being sent to the landfill for disposal. This included 241 waste streams identified as nonhazardous and 97 solid waste streams that contained hazardous waste or hazardous waste constituents. Appendix A presents tables of the nonhazardous and hazardous waste streams identified during the WSIC program.

The nonhazardous waste streams disposed in the landfill include office trash, paper, rags, demolition materials, empty cans and containers, used filters, various electrical components, dried sanitary sewage sludge (disposed in the 1970s), solid sump sludge, and other miscellaneous sludges. These sludges were classified as nonhazardous, although radioactively contaminated sludge from the sanitary wastewater treatment plant (Building 995) was also, reportedly, routinely disposed in the landfill from August 1968 through May 1970. These sludges may instead have been disposed in trenches A, B, and C south of the landfill (which were investigated as part of the OU 6 RFI/RI).

Four general categories of hazardous waste streams were identified by the WSIC program as discussed in Section 1.3.1. These categories include (1) containers partially filled with paint, solvents, degreasing agents, and foam polymers, (2) wipes and rags contaminated with these materials, (3) paint and oil filters, and (4) metal cuttings and shavings, including mineral and

asbestos dust and miscellaneous metal chips coated with hydraulic oil and carbon tetrachloride. In the fall of 1986, wastes with hazardous constituents were no longer placed in the landfill.

Dried sanitary sewage sludge (placed during the 1970s), solid sump sludge, and other miscellaneous sludges were also disposed in the landfill. These sludges were classified as nonhazardous based on an evaluation of the processes that generated the waste sludge and on the likelihood that RCRA-listed wastes were generated or that the sludge might be a characteristic waste under RCRA. However, radioactively contaminated sludge from the sanitary wastewater treatment plant was reportedly routinely disposed at the landfill from 1968 through 1970 (DOE 1992a). The contaminated sludge contained uranium and plutonium, which had entered the sanitary sewage system with laundry water. Approximately 2,200 pounds of sludge containing an estimated total of 8 milligrams of plutonium, as well as an undetermined amount of depleted uranium, were buried in the landfill. This practice ceased in May 1970 when offsite shipment of sludge as a low-level waste began (DOE 1992a).

The landfill was also the site of asbestos and PCB disposal (DOE 1992a). In 1985, asbestos generated onsite was reportedly disposed in a designated 10-foot-deep pit (DOE 1992a). The asbestos-containing material was placed in heavy plastic bags, disposed in the pit, and covered with soil when the pit became full. Warning signs were placed near the pit. By December 1988, asbestos was disposed in several pits in specified areas near the center of the landfill. According to landfill records, disposal of asbestos continued until at least April 1990 (DOE 1992a). During the OU 7 Phase I RFI/RI, soil samples were collected at the estimated locations of these pits and analyzed for asbestos as described in Appendix C. A trace (less than one percent) of chrysotile asbestos was detected in surface soil samples from only two locations at IHSS 114. In addition, materials containing small quantities of PCBs were routinely disposed in the landfill (DOE 1992a). It is unknown when the disposal of PCBs in the landfill ceased. Soil samples collected from IHSS 203 and analyzed for PCBs are described in Section 4.3.

Incidents of non-routine disposal of nonradioactive hazardous wastes have occurred, including the disposal of a mercaptan (odor additive to natural gas) tank and disposal and subsequent puncturing of a bag containing tear gas powder (DOE 1992a). Contaminated materials associated with cleanup of a 700-gallon fuel oil spill in January 1971 were also reportedly disposed in the landfill.

As of 1989, waste streams at the Rocky Flats site have been characterized under the WSRIC program, which includes more detailed characterization and analytical testing of the waste streams. Under the WSRIC program, only nonhazardous solid waste is currently being placed in the landfill, including office trash, paper, rags, personal protective equipment, demolition materials, scrap metal, empty drums, cans and containers, used filters, and various electrical components. Table 4-4 summarizes the waste streams, as characterized by WSRIC, that are currently being disposed.

4.2.1.3 Factors Affecting Waste Degradation

There are several factors affecting the degradation of landfill waste and its impact as a potential source of contamination. These factors include age of waste, porosity, degree of settling and compaction, moisture content, and amount of organic material. The age of the waste varies across the site. In general, the oldest waste is located near the western portion of the landfill and younger wastes are located near the eastern portion as a result of expansion eastward. However, during the OU 7 Phase I RFI/RI, waste was being placed near the central portion of the landfill on top of relatively older waste.

Typically, porosity associated with landfill waste is estimated to be high (in the range of 30 percent) due to the heterogeneous nature of the material and the uneven distribution and packing common in landfilled waste (EPA 1991a). As the landfill waste undergoes natural settling over time, the porosity usually decreases as the material becomes compacted.

Waste material encountered during the OU 7 Phase I RFI/RI was commonly moist. However, perched zones within the landfill were not observed. The moisture content commonly associated with waste at the time of placement is approximately 25 percent. Moisture content is one of many factors affecting waste decomposition and gas production rates. High moisture contents (i.e., in the range of 60 to 80 percent) favor maximum methane production rates (Emcon Associates 1982).

Wastes disposed in the Rocky Flats landfill include primarily waste generated by maintenance operations, construction debris, nonhazardous industrial wastes, and sludges. Municipal landfills commonly contain a heterogeneous mixture of materials primarily composed of household refuse such as yard and food wastes and paper, and commercial waste such as plastics, inert mineral

waste, glass, and metals (EPA 1991a). Consequently, the amount of biodegradable organic material in the landfill is probably smaller than the amount typically found in municipal solid waste landfills. Waste composition directly affects both the rate of landfill gas generation and total yield. The lower the percentage of biodegradable materials, the lower the gas generation rate and total yield. For moderately decomposable wastes in a typical landfill, the gas generation rate peaks within six years after initial waste placement and declines steadily afterwards (EPA 1991a).

4.2.2 Landfill Gases

Landfill gases are generated by microbial degradation of organic waste. The composition, quantity, and generation rates of the gases depend on factors such as waste quantity and composition, waste placement characteristics, landfill thickness, moisture content, and amount of oxygen present. Carbon dioxide is the principal gas generated during early stages of a landfill, as the waste undergoes aerobic microbial degradation. As oxygen is depleted, anaerobic microbial degradation produces methane and carbon dioxide. The composition of landfill gas produced under anaerobic conditions is typically 50 to 70 percent methane and 30 to 50 percent carbon dioxide. In addition to the methane and carbon dioxide generated by waste degradation, trace concentrations of hydrogen sulfide, ammonia, and other VOCs may be present in landfill gases (EPA 1991a) depending on the types of wastes present.

The composition and distribution of landfill-generated gases were evaluated on the basis of data obtained during the methane survey. Details of the methane survey are discussed in Appendix C. Measurements were made using field instruments that provide screening level data (i.e., EPA Level II) on total combustible gases, methane, non-methane organic compounds (NMOCs), and carbon dioxide. Concentrations of NMOCs were determined by subtracting methane concentrations from the concentrations of total combustible gases. As a result, concentrations of NMOCs may include minor amounts of inorganic gases such as hydrogen sulfide. Table 4-5 presents results of the methane survey. Eight cross sections were constructed to illustrate the nature and extent of gases at the landfill during the OU 7 Phase I RFI/RI. Figure 4-4 presents the cross-section location map. Figures 4-5 through 4-12 present the cross sections. The composition of landfill gas at OU 7 is typically 45 to 70 percent methane and 20 to 40 percent carbon dioxide indicating anaerobic conditions. Concentrations of methane and carbon dioxide are highest in the eastern portion of the landfill where wastes are thickest and youngest (Figures 4-5 and 4-6). In general, landfill-generated gases appear to be contained within the existing

intercept system as shown in Figures 4-13 and 4-14. Concentrations of methane and carbon dioxide are low, as expected, in the vicinity of the gas-venting wells such as 44492 and 44692 (Figures 4-13 and 4-14).

In situ soil-gas sampling was performed to characterize VOCs in the unsaturated zone of the landfill. Details of the soil-gas sampling are discussed in Appendix C. Halogenated VOCs detected at the landfill include 1,2-DCE, 1,1,1-TCA, TCE, and methylene chloride. Non-halogenated VOCs detected include acetone, 2-butanone, toluene, xylenes, and hydrogen sulfide. No distinct spatial patterns in VOC concentrations were observed probably as a result of the extreme heterogeneity of the materials disposed in the landfill. Table 4-6 presents the results of the soil-gas sampling at IHSS 114.

The volume of landfill gas present within IHSS 114 was determined by calculating the volume of void space in unsaturated material within the landfill mass assuming an estimated porosity of 30 percent (EPA 1991a). The volume of material comprising the unsaturated zone is approximately 320,171 cy based on the areal extent of the landfill and an estimated average unsaturated zone thickness of approximately 11 feet. The volume of landfill gas occupying the pore space of unsaturated material is approximately 96,051 cy. However, the estimated volume is expected to vary temporally as a result of fluctuations in the potentiometric surface in response to precipitation events.

Gas flow through landfill waste and soils occurs in response to pressure gradients (i.e., advective flow), concentration gradients (i.e., diffusive flow), compaction and settling of wastes, barometric pressure changes, and displacement due to potentiometric surface fluctuations. Advection of landfill gas is typically the predominant transport mechanism (EPA 1991a). Off-gassing pressures up to 0.44 pounds per square inch were measured during the OU 7 Phase I RFI/RI. Gas pressures exceeding approximately 0.05 pounds per square inch indicate an advective, pressure driven system (Emcon Associates 1982).

Soil gas samples were also collected at IHSS 203 during the OU 7 RFI/RI investigation. These samples were collected at approximately 5 feet below ground surface and analyzed for VOCs. Appendix C discusses soil gas sampling at IHSS 203. Table 4-7 summarizes the analytical results. Individual analyte concentrations varied significantly within the sampling area and distinct sources were not identified that could be confidently interpreted as contamination associated with

spills or releases during waste storage activities at IHSS 203. Total soil-gas concentration contours for NMOCs are shown in Figure 4-15. Measured concentrations were highest in the northeast section of the sampling area. Because landfill wastes underlie IHSS 203, VOCs in soil gas in this area are probably associated with the landfill.

4.2.3 Leachate

Leachate from landfills is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through waste (EPA 1991a). This section discusses the volume and composition of leachate at IHSS 114. Volume estimates are based on all relevant OU 7 Phase I RFI/RI data. The composition of leachate discussed in this section is based on the field screening data (EPA Level II) obtained from the samples collected using the BAT® system. Chemical data (EPA Levels IV and V) characterizing landfill leachate are discussed in Section 4.7 along with comparable chemical data for groundwater at OU 7.

Figure 4-16 presents an isopach map of saturated landfill waste. The volume of leachate within the landfill debris is approximately 5,756,000 gallons assuming that the porosity of the saturated material is 30 percent. However, the volume of leachate is expected to vary as the potentiometric surface fluctuates in response to infiltration of precipitation through the interim soil cover.

As discussed in Appendix C, leachate screening samples were collected during the OU 7 Phase I RFI/RI at specific depths within saturated landfill material using the BAT® system. Headspaces of these samples were analyzed for methane, methylene chloride, acetone, 2-butanone, 1,2-DCE, 1,1,1-TCA, TCE, xylene (para, meta, and ortho isomers), toluene, and hydrogen sulfide. Equilibrium concentrations of these analytes in the liquid phase (i.e., leachate), presented in Table 4-8, were calculated using Henry's Law constants and the measured headspace concentrations.

Concentrations of volatile compounds within leachate vary significantly throughout the landfill. Due to dry conditions and refusal of the BAT® system during sampling, insufficient data were obtained to fully evaluate vertical chemical gradients within the leachate. However, at locations where multiple samples were obtained, no consistent trends in chemical gradients were observed. In general, analyte concentrations in samples collected using the BAT® system exceed the concentration of analytes in samples collected from monitoring wells by approximately three orders of magnitude. This difference is probably a result of the sampling methodology. The BAT®

system obtains a sample *in situ* from a small discrete interval. The BAT® sample is never exposed to air, and thus, no loss of volatile compounds can occur due to vaporization. In contrast, leachate is sampled from monitoring wells using a bailer that allows contact with air to occur prior to containerization of the sample.

Methane concentrations in leachate ranged from 0.003 to 31.4 mg/L (Table 4-8) and typically approached the solubility limit of 35 mg/L at 17°C (Merck Index 1989). Concentrations at OU 7 were also consistent with methane concentrations of 25 mg/L observed at other landfills (Beadecker and Back 1979).

The following sections describe the environmental media in the vicinity of the landfill and the nature and extent of contamination that have resulted from proximity to contaminant sources within OU 7.

4.3 Surface Soils and Vadose Zone

This section describes the nature and extent of contamination in surface soils at OU 7 and identifies the PCOCs for soils using data collected during the Phase I RFI/RI. Analytical results for surface soil samples collected during the Phase I RFI/RI were used in this analysis. Sample collection methods, sampling locations, and analytical suites are described in Appendix C. Surface soil data were aggregated by area (East Landfill Pond, IHSS 203, and IHSS 114) and depth (0 to 2 inches and 0 to 10 inches) as described in Section 4.1.1. Surface soil data from the 0- to 2-inch horizon within each subset were independently compared to background soil data from Rock Creek (DOE 1993c). Similarly, the 0- to 10-inch surface soil data from IHSS 203 and the East Landfill Pond area were independently compared to background soil data. Inferential statistical analyses discussed in Section 4.1.2 were used to determine which analytes in OU 7 surface soils were detected at concentrations that exceeded background. Spatial trends in analyte concentration and samples exceeding the $UTL_{95/95}$ concentration are also described. Box plots and histograms were generated for all analytes with at least 50 percent detects. Box plots are presented in Appendix K. Histograms are presented in Appendix L. Summary statistics and statistical test results for inferential analyses and for the hot-measurement test for OU 7 surface soils are presented in Appendix M.

4.3.1 *Inactive Hazardous Waste Storage Area (IHSS 203)*

Surface soil samples collected at IHSS 203 were analyzed for PCBs, metals, and radionuclides; samples were not analyzed for VOCs or SVOCs. PCOCs identified in surface soil at IHSS 203 include PCBs, metals, and radionuclides (Table 4-9). Calcium and copper concentrations were elevated in both the 0- to 2-inch and the 0- to 10-inch soil horizons. The distribution of calcium in surface soils is shown in Figure 4-17. The distribution of copper in surface soils is shown in Figure 4-18. The highest copper concentrations were associated with a dark brown, very gravelly loam covering the northern portion of the IHSS 203 sample grid (Figure 4-18). Radium-226 activities in the 0- to 2-inch horizon at IHSS 203 were elevated relative to background activities. However, a relationship between soil location and radium-226 activity could not be discerned from the available data.

Results of a hot-measurement test, performed to identify soil samples with analyte concentrations exceeding background $UTL_{95/95}$ concentrations, are presented in Table 4-10. The following metals were detected at concentrations that exceeded the $UTL_{95/95}$ concentration at one or more locations: calcium, copper, sodium, cobalt, and vanadium. Only calcium concentrations displayed a spatial correlation (Figure 4-17). Samples exceeding the $UTL_{95/95}$ define an area of high calcium concentration along the northeast portion of the sample grid.

Activity of uranium-235 and americium-241 exceeded the $UTL_{95/95}$ value in a few samples. The soil sample exceeding the $UTL_{95/95}$ for uranium-235 was collected along the eastern edge of the IHSS 203 sample grid, whereas the four soil samples exceeding the $UTL_{95/95}$ for americium-241 were located along the southwestern boundary of the sample grid (Figure 4-19). The uranium-235 activity was 1.4 times the maximum background activity. The americium-241 activities ranged from 1.5 to 8.5 times the maximum reported background activities.

Two PCBs, aroclor-1254 and aroclor-1260, were detected in 14 of 67 and 13 of 67 soil samples, respectively. All but one of the results for the analysis of PCBs in soil from IHSS 203 were J qualified, denoting estimated PCB concentrations below the detection limit of 230 µg/kg. Surface soil samples with detectable PCB concentrations are not spatially correlated, and of the 27 PCB detections, only three were in samples collected from the 0- to 10-inch horizon. These results indicate that PCBs are probably present at low concentrations throughout IHSS 203 surface soils but are not present at depth.

4.3.2 Present Landfill (IHSS 114)

Surface soil samples collected at IHSS 114 were analyzed for SVOCs, metals, and radionuclides; samples were not analyzed for VOCs. Surface soil at IHSS 114 consists of interim soil cover material, not native soil. Calcium was the only analyte identified by the inferential statistical tests as having elevated concentrations relative to background (Table 4-11). In addition, soils from an area in the northeast corner of the sample grid contained calcium concentrations that exceeded the $UTL_{95/95}$ concentration (Figure 4-20).

Two surface soil samples at IHSS 114 contained copper concentrations exceeding the $UTL_{95/95}$ value. These two concentrations were 2.0 and 3.7 times the maximum background copper concentration and were not spatially correlated. Gross beta and strontium-89,90 activities exceeded the $UTL_{95/95}$ value in one sample each. The gross beta and strontium-89,90 activities were 1.3 and 2.9 times the maximum background activity and occurred at two separate locations near the center of the IHSS 114 sample grid. All $UTL_{95/95}$ exceedances in IHSS 114 soil samples are listed in Table 4-12.

Twenty-one SVOCs were detected in surface soil samples from IHSS 114 (Table 4-11). Eight of those SVOCs were detected in more than 50 percent of the samples. These data indicate that surface soils at IHSS 114 contain low levels of some SVOCs. These contaminants may be associated with the interim soil cover material itself, or they may be introduced to the soil by leaks or emissions from construction equipment and vehicles used within IHSS 114.

4.3.3 East Landfill Pond Area

Surface soil samples collected adjacent to the East Landfill Pond were analyzed for metals and radionuclides; samples were not analyzed for VOCs or SVOCs. Statistical tests identified only three PCOCs in soil from the East Landfill Pond area: calcium, strontium, and radium-226 (Table 4-13). Calcium concentrations in both the 0- to 2-inch and the 0- to 10-inch surface soil horizons were elevated relative to sitewide background concentrations. Strontium concentrations and radium-226 activities were elevated relative to background only in the 0- to 2-inch soil horizon.

The hot-measurement test resulted in a list of 12 analytes present at concentrations in soil that exceeded the $UTL_{95/95}$ values for background (Table 4-14). Concentrations of the following metals exceeded their respective $UTL_{95/95}$ concentration: arsenic, barium, calcium, lead, magnesium,

selenium, sodium, vanadium, and zinc. Higher concentrations (exceedances) of these metals were not spatially correlated except for calcium. Calcium concentrations in soil exceeded the $UTL_{95/95}$ concentration in both the 0- to 2-inch and the 0- to 10-inch horizons in the area covered by the northwest corner of the sampling grid. This area of elevated calcium concentrations is in the vicinity of a seep and may be associated with a leak in the northern portion of the groundwater intercept system. The calcium enrichment at this location could be the result of evaporation of seep water (Figure 4-21). However, high concentrations of other major ions, such as magnesium and sodium, that would also be present in seep water and be concentrated in these soils were not present.

Ten surface soil samples from the 0- to 2-inch horizon had nitrate/nitrite concentrations that exceeded the $UTL_{95/95}$ (Figure 4-23). Two of these samples were collected from the spray area in IHSS 167.3 on the southern edge of the pond. Four of the samples were collected from the slope east of the pond embankment. Concentration isopleth maps display areas where the concentrations of lead, vanadium, and selenium are greater than the $UTL_{95/95}$ (Figures 4-22, 4-24, and 4-25).

Four surface soil samples at the East Landfill Pond had americium-241 activities that exceeded the $UTL_{95/95}$. These samples were collected along the southern edge of the pond and along the southern surface water diversion ditch below the dam (Figure 4-26). The activities ranged from 1.5 to 26.6 times the maximum background activity. All but one of the samples with an americium-241 activity greater than the $UTL_{95/95}$ value were from the 0- to 2-inch horizon. The sample from the 0- to 10-inch horizon was collected downslope of the point of discharge from the southern groundwater intercept system. This was the only sample from the 0- to 10-inch soil horizon with a radionuclide activity that exceeded the $UTL_{95/95}$.

Radium-226 activities exceeded the $UTL_{95/95}$ at six soil sample locations in the 0- to 2-inch soil horizon (Figure 4-27). Three of the samples were located in the center of the spray evaporation area along the northern edge of the pond. The other three samples were located along the slope immediately east of the landfill pond dam. The maximum radium-226 activity was 1.6 times the maximum background value.

4.4 Subsurface Geologic Materials

This section describes the nature and extent of contamination in subsurface geologic materials at OU 7 and presents the PCOCs identified by site-to-background comparisons. Drilling methods, borehole locations, sample collection methods, and analytical suites are described in Appendix C. Borehole logs are presented in Appendix E. Data from subsurface geologic materials were aggregated by location (upgradient and downgradient) and by geologic unit as described in Section 4.1.1 to make comparisons with the background data. Inferential statistical analyses described in Section 4.1.2 were used to determine which analytes were detected in subsurface geologic materials at concentrations that exceeded background concentrations.

Chemical data for subsurface geologic materials obtained during the Phase I RFI/RI at OU 7 were used in this analysis. Statistical comparisons were made using data from borehole samples collected both upgradient and downgradient of the Present Landfill. The two upgradient boreholes, 70493 and 70593, are immediately adjacent to one another and located approximately 200 feet upgradient of IHSS 203. Downgradient borehole 70993 is located approximately 50 feet directly downslope of the north groundwater intercept system discharge point, and downgradient borehole 71093 is located approximately 50 feet downslope of the south groundwater intercept system discharge point.

Statistical test results for subsurface geologic materials are presented in Appendix M. Box plots and histograms were generated for all analytes having greater than 50 percent detectable concentrations and are presented in Appendices K and L, respectively. The PCOCs for subsurface geologic materials from OU 7 are presented in tables 4-15 and 4-16.

4.4.1 Surficial Geologic Deposits

Surficial geologic deposits at the borehole locations upgradient of OU 7 consist entirely of Rocky Flats Alluvium, whereas surficial deposits at the boreholes downgradient of OU 7 consist of colluvium. Statistical analysis of chemical data for surficial deposits upgradient of OU 7 did not identify any metals with elevated concentrations relative to sitewide background. However, seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-238) have elevated activities in upgradient borehole samples relative to activities in

background surficial deposits. In addition, cesium-137 and radium-228 activities and lead and chromium concentrations exceed background $UTL_{95/95}$ values.

At downgradient borehole 70993, aluminum and manganese concentrations and cesium-137 and uranium-238 activities are higher in the surficial geologic deposits than in deposits from background locations. However, no analyte concentrations or activities exceeded the $UTL_{95/95}$ in samples from this borehole. At downgradient borehole 71093, surficial deposits contained elevated concentrations of aluminum, barium, lead, strontium, and zinc relative to background data. Cesium-137 activities and barium and nitrate/nitrite concentrations exceeded the $UTL_{95/95}$ values in surficial material at borehole 71093.

Toluene was detected in 100 percent of surficial deposit samples collected from both the upgradient and downgradient boreholes. No other organic parameters were consistently identified at concentrations above the detection limit in borehole samples from these locations. At borehole 70993, ten organic compounds other than toluene were detected. These detections were not co-located, and eight of the ten results were J qualified indicating that the results are estimated concentrations below the detection limit. A list of VOCs and SVOCs detected in geologic materials at OU 7 is presented in Table 4-15.

4.4.2 Bedrock Geologic Materials

Bedrock geologic materials consist of weathered Arapahoe and Laramie Formation claystone. Statistical tests indicated that barium, calcium, lead, and strontium concentrations and radium-226 activities were elevated relative to background concentrations or activities in bedrock material upgradient of OU 7. Concentrations of strontium in the upgradient bedrock material exceeded the $UTL_{95/95}$ value in all sample intervals. Calcium and zinc concentrations in upgradient bedrock material exceeded the $UTL_{95/95}$ value once and twice, respectively.

Bedrock geologic materials from downgradient borehole 70993 have elevated calcium, cobalt, copper, lead, nickel, selenium, sodium, strontium, and zinc concentrations and radium-226 activities relative to background bedrock materials. At downgradient borehole 71093, bedrock materials have elevated barium, calcium, cobalt, lead, manganese, nickel, selenium, sodium, strontium, and zinc concentrations and radium-226 and strontium-89,90 activities relative to background bedrock materials.

Other analytes that exceeded the $UTL_{95/95}$ values in bedrock materials from downgradient boreholes included arsenic, barium, calcium, cobalt, lead, manganese, and zinc. These values that exceeded UTL concentrations did not occur consistently in the same samples or in samples from the same depth interval.

4.5 Sediments

This section discusses the nature and extent of contamination in East Landfill Pond sediments. The statistical methodology described in Section 4.1.2 was used to identify PCOCs by determining which inorganic analytes, metals, and radionuclides are present at higher concentrations in pond sediments than in sediments from background locations. Organic compounds detected in pond sediment samples were also identified as PCOCs. The following description of the pond sediments is based on data from samples collected and analyzed during the OU 7 Phase I RFI/RI.

Samples of pond sediment were collected from three locations at the East Landfill Pond (Figure C-3 [Appendix C]). Sampling locations were chosen to assess the impact of nearby point sources of contamination (leachate seep, north groundwater intercept outfall, and south groundwater intercept system outfall). Sample location SED70093 is located near the landfill leachate seep; SED70193 is located near the south groundwater intercept system discharge outfall point; and SED70293 is located approximately 100 feet northeast of the north groundwater intercept system discharge outfall, near the pond embankment. The pond also receives runoff containing sediment from adjacent slopes. Sediment derived from slope runoff may be a large component of the sediment now present along the edges of the pond. Sediment samples collected from stations SED70193 and SED70293 were analyzed for VOCs, SVOCs, radionuclides, metals, and inorganics. Sediment samples collected from SED70093 were analyzed for Appendix IX VOCs and SVOCs, radionuclides, metals, and inorganics. Sampling and analytical methods are described in Appendix C.

Only three VOCs were detected in pond sediment samples (Table 4-17): toluene was detected at all three locations, acetone was detected at SED70193 and SED70293, and 2-butanone was detected at SED70093. The following SVOCs were detected in the pond sediments: acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, benzoic acid, bis(2-chloroisopropyl)ether, and bis(2-

ethylhexyl)phthalate. With the exception of fluoranthene, the reported concentrations of all of these compounds were qualified with a J to indicate that these are estimated concentrations below the detection limit. Table 4-17 lists the SVOCs detected in the pond sediment samples.

The greatest number of SVOCs was detected in sediment from SED70093, the location closest to the leachate seep. In the sediment sample from SED70293, located near the north groundwater intercept system discharge point, five SVOCs were detected. Benzoic acid was the only compound detected in sediment from all three locations and the only organic compound detected at SED70193, located near the south groundwater intercept system discharge point. Landfill leachate discharges to the pond along its western edge and is the most likely source of SVOCs to sediments in the pond. SVOCs occur in leachate seep water (Section 4.6) and in leachate within the landfill (Section 4.7).

Statistical tests indicated that concentrations of the following metals and inorganic compounds were elevated in pond sediments relative to background concentrations: aluminum, arsenic, barium, beryllium, calcium, chromium, copper, iron, lead, magnesium, nickel, potassium, selenium, strontium, vanadium, and zinc. However, none of these analytes were present at concentrations that exceed background $UTL_{95/95}$ values.

Cesium-137 was the only radionuclide with elevated activities in sediments relative to background activities. None of the radionuclide activities measured from pond sediments exceeded $UTL_{95/95}$ values. The sample collected from SED70093, closest to the leachate seep, had the highest cesium-137 activity and the highest activities of americium-241, plutonium-239,240, gross beta, strontium-89,90, uranium-233,234, and uranium-238.

The results of the statistical analyses are presented in Appendix M, and the PCOCs for metal and inorganic parameters, based on results of the inferential statistical tests, are listed in Table 4-18.

These results suggest that the leachate seep may be a source of radionuclides, VOCs, and SVOCs to sediments in the pond. Some of the PCOCs identified for the pond sediments were not identified as PCOCs in water from the leachate seep or from the pond (cesium-137, beryllium, chromium, copper, lead, selenium, and vanadium). The sample from SED70193 had the highest concentrations of the three sediment samples for all of these analytes except cesium-137. The

SED70193 is located closest to the edge of the pond. These results suggest that sediments transported to the pond via runoff may be the source of some metals.

4.6 Surface Water

This section discusses the extent and magnitude of surface water contamination at OU 7 and identifies PCOCs in surface water based on comparisons of surface water data from the site to background surface water data. The statistical analysis procedures described in Section 4.1.2 were used to identify PCOCs. Statistical comparisons of site to background data were based on the data aggregation scheme shown in Table 4-1. Chemical data from leachate seep water (SW097) were statistically compared to sitewide background seep data. Chemical data from the East Landfill Pond (SW098) and the two groundwater intercept system discharge points (SW099 and SW100) were each independently compared to sitewide background surface water data for PCOC identification. All chemical data were also compared to the $UTL_{95/95}$ concentration for each analyte. Any analyte exceeding the $UTL_{95/95}$ concentration was also identified as a PCOC. The results of all statistical tests for OU 7 surface water are presented in Appendix M.

Surface water data used for the statistical evaluations included data collected quarterly from 1990 through 1993 and data obtained during the Phase I RFI/RI at OU 7. Data collected since 1990 were considered fully usable because they represent the first full year of data collection following the implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific standard operating procedures (SOPs) (EG&G 1991g). Analytes measured in surface water are presented in Appendix C.

4.6.1 Leachate Seep (SW097)

Statistical analysis of surface water data from the leachate seep (SW097) identified 12 total and 11 dissolved metals as PCOCs. Three total and three dissolved radionuclides and nitrite were also identified as PCOCs. Radionuclides identified as PCOCs based on the results of the inferential statistical tests included total and dissolved gross beta and strontium-89,90 and total tritium. In addition, the uranium-235 activity of one sample exceeded the $UTL_{95/95}$ value.

Nineteen VOCs were detected in the seep water at SW097. Benzene, toluene, ethylbenzene, and xylenes (BTEX) were frequently detected in SW097 surface water with detection frequencies ranging from 58 percent to 100 percent. Ethylbenzene, toluene, and total xylenes were the most

commonly detected BTEX compounds. The most common chlorinated hydrocarbons detected in the seep water were 1,1-dichloroethane (1,1-DCA) (90 percent), chloroethene (79 percent), TCA (58 percent), and 1,2-DCE (53 percent). Detection frequencies for SVOCs in leachate seep water ranged from 25 to 100 percent. These data indicate that seep water emanating from the front of the landfill has been contaminated by VOCs and SVOCs. Chemical data for groundwater within the landfill displayed similar analytes at elevated concentrations (BTEX, SVOCs, nitrite, and tritium) as seep water (Section 4.7). The PCOC list for seep water is given in Table 4-19.

4.6.2 *East Landfill Pond (SW098)*

The inferential statistical tests identified 11 total and 14 dissolved metals as PCOCs at station SW098 (East Landfill Pond). Seven total and four dissolved radionuclides were elevated relative to background surface water data. Total and dissolved strontium-89,90 and tritium activities were elevated in pond water relative to background, as in seep water. Uranium-235, uranium-238, americium-241, gross alpha, and gross beta activities were also elevated in pond water relative to the background data. In addition, the activity of americium-241, uranium-235, and uranium-238 from SW098 exceeded the $UTL_{95/95}$ values.

Two VOCs were detected in East Landfill Pond waters. Acetone and vinyl acetate were each detected in one of twenty and in one of nineteen samples, respectively. Two SVOCs were each detected in one of seven samples. These infrequent and non-repeatable occurrences of VOCs and SVOCs indicate that the quality of water in the East Landfill Pond is not adversely affected by organic compounds. Although data from the leachate seep indicate that VOCs and SVOCs may be introduced to the pond, volatilization, photolysis, and other degradation processes may effectively remove VOCs from the pond water. Table 4-20 lists PCOCs identified at surface water station SW098.

4.6.3 *Northern Groundwater-Intercept System Discharge Point (SW099)*

Statistical analysis of chemical data from samples collected at station SW099 identified eight total and eight dissolved metals and four total and two dissolved radionuclides as PCOCs. Total uranium-235, uranium-238, gross alpha, and americium-241 activities and dissolved strontium-89,90 and uranium-238 activities were elevated relative to background. This list of radionuclides is

similar to the list generated for water from the East Landfill Pond except that it does not include tritium.

Three dissolved metals (calcium, lead, and sodium) were present at concentrations exceeding the $UTL_{99/99}$ value. The remaining five dissolved metals were barium, cadmium, lithium, magnesium, and strontium.

The PCOC list for SW099 (northern groundwater-intercept discharge point) is given in Table 4-21 and includes four VOCs and one SVOC. Table 4-21 also shows that VOCs and SVOCs were infrequently detected in discharge from the north groundwater intercept system. The low frequency of detection and relatively low repeatability of these data indicate the VOC and SVOC contamination is not significant in surface water at SW099.

4.6.4 Southern Groundwater-Intercept Discharge System Point (SW100)

The inferential statistical tests identified eight total and eleven dissolved metals as PCOCs at surface water station SW100. Three total and three dissolved radionuclides were also identified as PCOCs based upon the results of the inferential statistical tests . Radionuclides identified as PCOCs include total and dissolved americium-241 and gross beta, total tritium, and dissolved uranium-238.

Six VOCs were detected at SW100. Three BTEX compounds (ethylbenzene, toluene, and total xylenes) and three chlorinated hydrocarbons (1,1-DCA, chloroethane, methylene chloride) were each detected once in the seven sample data set. No SVOCs were detected in water from station SW100. The infrequent detection of VOCs and absence of SVOCs at SW100 indicate that organic contamination at SW100 is not significant. However, because volatilization or degradation (i.e., photolysis) processes may effectively remove VOCs from water at SW100, the presence or absence of VOCs in water within the southern groundwater intercept system has not been determined. Table 4-22 presents PCOCs identified at surface water station SW100.

4.7 Groundwater

This section discusses the nature and extent of groundwater contamination at OU 7 and identifies PCOCs based on site-to-background comparisons of chemical data. The statistical analysis procedure described in Section 4.1.2 was used to identify PCOCs by determining which metals,

radionuclides, and water-quality parameters are present at higher concentrations in groundwater at OU 7 than in groundwater from background locations. Statistical analysis and PCOC identification were performed separately for wells screened in the UHSU and LHSU. In addition, spatial trends in analyte concentration and individual samples exceeding the background $UTL_{99/99}$ concentration were identified within each hydrostratigraphic unit.

Data from all wells included in the OU 7 monitoring network were used to describe the extent and magnitude of groundwater contamination at OU 7. The groundwater monitoring network at OU 7 includes 40 wells screened in the UHSU and 7 wells screened in the LHSU. Well construction diagrams are presented in Appendix F, and historical analytical data from monitoring wells are included in Appendix N.

Groundwater chemical data collected from 1990 through 1993 were used to describe groundwater contamination at OU 7. Included in this data set are data collected during the Phase I RFI/RI and data obtained since 1990 as part of the quarterly groundwater monitoring program at OU 7. Data collected since 1990 were considered fully usable because they represent the first full year of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific SOPs (EG&G 1992c).

Comparisons of site-to-background data were made to identify PCOCs in groundwater based on the data aggregation scheme shown in Table 4-1. Background values for groundwater chemical data were obtained from the Background Geochemical Characterization Report (EG&G 1993a). Data from all wells in the UHSU and LHSU at OU 7 were compared to their respective sitewide background hydrostratigraphic unit (HSU) data. The PCOCs in the UHSU were identified using all UHSU data. PCOCs in the LHSU were identified using downgradient LHSU wells.

To assist in describing contaminants present in leachate (water in contact with landfilled wastes), data from wells screened within the landfill were also compared to sitewide background data from UHSU groundwater. Data from upgradient LHSU wells were also separately compared to LHSU background data to assist in evaluating the nature and extent of LHSU groundwater contamination.

Groundwater-quality data from monitoring wells located upgradient of the landfill were compared to groundwater-quality data from monitoring wells located downgradient of the landfill to assess

potential contaminant releases to the UHSU. The comparisons between upgradient and downgradient groundwater quality were made using the statistical methodology from the RCRA groundwater monitoring report (EG&G 1994a).

Time-series plots showing analyte concentrations versus time were prepared for selected analytes in downgradient wells. These plots are included in Appendix O. Analytes were selected primarily on the basis of their association with historical waste-management practices and the number of quantified, or detectable, results.

4.7.1 *PCOCs for Metals, Radionuclides, and Water-Quality Parameters*

Statistical comparison of UHSU and LHSU groundwater concentration data for metals, radionuclides, and water-quality parameters to sitewide background data determined that the concentrations of the analytes shown in tables 4-23 and 4-24 were elevated in groundwater relative to background concentrations. The results of statistical tests for the data aggregations shown in Table 4-1 are given in Appendix M.

Using total analyte concentrations, 28 analytes were identified as PCOCs in the UHSU groundwater compared to 15 analytes in LHSU groundwater. The PCOC list developed using total analyte concentrations for the UHSU consisted of 24 metals and 3 radionuclides compared to 14 metals for the LHSU. Nitrate/nitrite was also identified as a PCOC in UHSU groundwater.

Using dissolved concentrations, 16 analytes were identified as PCOCs in the UHSU groundwater compared to 23 analytes in the LHSU groundwater. The dissolved concentration PCOC list for the UHSU consisted of 13 metals and 3 radionuclides compared to 20 metals and three radionuclides for the LHSU.

4.7.2 *Analysis of Organic Compound Distribution in Groundwater*

Contamination of UHSU and LHSU groundwater by organic compounds was evaluated by determining which organic analytes have been detected in groundwater from OU 7, determining detection frequencies for these analytes, analyzing spatial trends in average "total" VOC concentrations, and attempting to correlate total VOC concentrations with concentrations of other parameters indicative of landfill-generated contamination. This approach was necessary because

individual VOCs were detected infrequently at any one location and their spatial distribution could not be evaluated.

Total VOC concentrations were estimated by summing the concentrations of the most frequently detected volatile organic parameters at OU 7. In the UHSU, volatile organic parameters detected at least 5 percent of the time were used to estimate the total VOC concentration. In the LHSU, all detected VOCs were used to calculate total VOC concentrations. Total VOC concentrations were calculated quarterly from 1990 to 1993 for each well, and these data were used to calculate an average total-VOC concentration. Average total-VOC concentrations represent the average concentration using sampling periods during which VOCs were detected at a well. These data were used to analyze the spatial distribution of VOC concentrations within groundwater and should not be interpreted as unbiased estimates of the true average concentration at each well. Average total-VOC concentrations were used to minimize variable data availability caused by water-level fluctuations and dry wells, sampling techniques, data rejection during the validation process, and variable sample recovery throughout the monitoring network for any given monitoring event. These data provide a conservative estimate of the spatial extent and relative levels of VOC contamination within groundwater. The data do not provide an unbiased estimate of true average total-VOC concentrations for the period of analysis. However, given the intrinsic and extrinsic factors affecting VOC concentrations during any given sampling event, average total-VOC concentrations provide a useful estimate of VOC concentrations within groundwater for the purpose of examining the spatial extent of contamination.

Total-VOC concentrations were subdivided into average chlorinated hydrocarbon and average BTEX concentrations. These data were mapped separately in the UHSU. Average total concentrations of SVOCs detected in more than 5 percent of samples were also mapped. The spatial correlation of total VOC and landfill indicator-parameter concentrations was also investigated. Table 4-25 displays the frequency of detections of all organic parameters for both the UHSU and LHSU at OU 7. The organic parameters listed in Table 4-25 represent the PCOCs for organic compounds in groundwater at OU 7. The statistics used to generate all total VOC maps are given in Appendix M.

4.7.3 Nature and Extent of UHSU Groundwater Contamination

Tables 4-23 and 4-25 list PCOCs for UHSU groundwater at OU 7. Groundwater concentration data from all UHSU wells and from UHSU wells screened within the landfill were compared to sitewide background UHSU data. Two PCOC lists were developed from these analyses. Comparison of chemical data (total concentrations) from UHSU wells within the landfill to sitewide background UHSU data resulted in 23 metals and 3 radionuclides being identified as PCOCs compared to 24 metals and 1 radionuclide identified comparing all UHSU wells within OU 7 to sitewide background data. Table 4-26 presents the results of UHSU statistical comparisons.

Dissolved metals that were identified as PCOCs using downgradient data, but were not elevated in the upgradient data set, include calcium, chromium, lithium, magnesium, potassium, selenium, sodium, tin, and vanadium. The greater number of dissolved metals identified as PCOCs in downgradient groundwater may be the result of increased contact between downgradient groundwater and landfill materials or other sources of contamination.

Some notable differences exist between the analytes identified as PCOCs using only data from landfill wells compared to using all OU 7 UHSU data. Nitrate/nitrate is identified as a PCOC using all OU 7 UHSU data but not when using data from landfill wells alone. This may indicate a source of nitrate/nitrite outside the landfill or may be the result of a more limited set of nitrate/nitrite data from wells within the landfill. However, nitrite is elevated for background concentrations within the landfill, and the Gehan test (0.07) indicated that nitrite may also be elevated sitewide for background data. Elevated nitrite in landfill leachate relative to other UHSU groundwater may be indicative of more reducing conditions within the landfill.

Other analytes not identified as PCOCs in landfill leachate that were identified as PCOCs using all OU 7 UHSU data include total antimony and selenium; total strontium-89,90; and dissolved copper and strontium. Total americium-241 and radium-226 activities were elevated with respect to background using all OU 7 UHSU data and data from the landfill wells alone. Tritium activities were elevated with respect to background activities in landfill leachate but not in all OU 7 UHSU groundwater. This finding is consistent with the documented disposal of tritium-contaminated waste in the landfill (Rockwell International 1987c).

Groundwater concentration data from UHSU wells downgradient of the landfill were also compared to sitewide background UHSU data. This comparison resulted in nine metals and two radionuclides (total concentrations) being identified as PCOCs compared to 24 metals and 3 radionuclides using all OU 7 UHSU data. Dissolved concentrations of 12 metals and 5 radionuclides were identified as PCOCs using downgradient UHSU data compared to 13 metals and 2 radionuclides using all OU 7 UHSU data.

Different analytes appear on the downgradient PCOC list than on the PCOC list generated using all OU 7 UHSU data. Uranium-235 and uranium-238 (both total and dissolved) are identified as PCOCs in downgradient UHSU groundwater. These radionuclides were not identified as PCOCs when all OU 7 USHU data or data from UHSU wells located within the landfill were compared to sitewide background data. Dissolved gross alpha and dissolved gross beta were also identified as PCOCs in downgradient UHSU groundwater. Dissolved gross beta was also identified as a PCOC using both OU 7-wide data and data from landfill wells. Dissolved gross alpha was not identified as a PCOC in either of the other comparisons. These data may indicate that a source of uranium-235 and uranium-238 exists outside of the landfill or that these analytes are elevated at downgradient wells as the result of discharges from the groundwater intercept system.

Groundwater-quality data from monitoring wells located upgradient of the landfill were compared to groundwater-quality data from monitoring wells located downgradient of the landfill to assess potential contaminant releases to the UHSU. Seven wells (1086, 5887, 70093, 70193, 70393, 70493, and 70693) monitor upgradient groundwater-quality data in the UHSU immediately upgradient of the landfill. Of these wells, five are completed in surficial materials (1086, 5887, 70093, 70393, and 70693), and two (70193 and 70493) are completed in weathered bedrock. Three wells located east of the East Landfill Pond embankment monitor downgradient groundwater quality in the UHSU. Of these wells, two are completed in weathered bedrock (B206989 and B207089) and one (4087) is completed in surficial materials. However, because the East Landfill Pond dam depresses the potentiometric surface to the east, well 4087 is frequently dry. Statistical comparisons were made using 1993 groundwater-quality data from all UHSU wells and from the UHSU completed in weathered bedrock. Groundwater-quality data from downgradient wells completed in surficial materials were not sufficient in number to conduct statistical tests.

For analytes with greater than 50-percent quantifiable results, ANOVA testing indicated statistically significant differences at the 5-percent significance level in upgradient versus downgradient groundwater quality in the UHSU for dissolved metals (calcium, lithium, magnesium, potassium, sodium, and strontium) and inorganic parameters (chloride and sulfate). In weathered bedrock wells, ANOVA testing demonstrated statistically significant differences at the 5-percent significance level in upgradient versus downgradient groundwater quality for dissolved metals (calcium, lithium, magnesium, potassium, sodium, and strontium) and inorganic parameters (chloride and sulfate). Concentrations of radionuclides were not statistically different (at the 5-percent significance level) in upgradient versus downgradient groundwater from the entire UHSU or from weathered bedrock. These results indicate that concentrations of some dissolved metals (calcium, lithium, magnesium, potassium, sodium, and strontium) and inorganic parameters (chloride and sulfate) are higher in groundwater downgradient of the landfill. Only one detection of a VOC (methylene chloride) occurred in UHSU groundwater downgradient of the landfill.

Time-series plots compiled for plutonium-239, 240; methylene chloride; chloride; TDS; and sulfate show no trends in the concentrations of these parameters through time (1990-1993) in UHSU groundwater downgradient of the landfill. The time-series plot for calcium at well B206789, completed in weathered bedrock, shows a trend toward increasing calcium concentrations through time. Time-series plots are presented in Appendix O.

4.7.3.1 Isoconcentration Maps

Isoconcentration maps generated using average concentrations were used to analyze the nature and extent of groundwater contamination in the UHSU at OU 7 and to investigate possible contaminant sources and transport pathways. Average concentrations were determined from quarterly groundwater monitoring data collected from 1990 through 1993. Quarterly data were averaged to minimize the influence of seasonality and natural variability in intra-well concentrations. Analytes were selected for mapping based on their frequency of occurrence, contaminant transport characteristics, and association with specific waste types. Average concentration contour maps for the UHSU were constructed for inorganic indicator parameters (TDS and nitrate/nitrite); organic parameters (total VOCs, total chlorinated hydrocarbons, BTEX, and total SVOCs); and radionuclides (dissolved and total uranium-235 and uranium-238, dissolved radium-226, and total americium-241).

Indicator Parameters

The highest average TDS concentrations occurred in leachate and in groundwater downgradient of the landfill (Figure 4-28). The highest average TDS concentration in landfill leachate (2,211 mg/L) was from well 72293 within the central portion of the landfill. The highest average TDS concentration in UHSU groundwater (5,100 mg/L) occurred at downgradient well B206989 located near the discharge of the northern groundwater intercept system. Other wells downgradient of the landfill located near the groundwater intercept system discharge points (B206889, B207089, and 4087) also had average TDS concentrations greater than 1,000 mg/L. Discharges from the groundwater intercept system may introduce water with a high TDS content from the landfill to the UHSU groundwater in the vicinity of the outfall points.

Average concentrations of nitrate/nitrite were mapped within the UHSU (Figure 4-29). The highest concentrations of nitrate/nitrite were present in groundwater downgradient of the landfill near the groundwater intercept system discharge points. Average nitrate/nitrite concentrations of 160 and 51 mg/L were in groundwater from wells B206889 and B206989, respectively. These concentrations are much higher than the average nitrate/nitrite concentrations in water from within the landfill, which were generally less than 1.0 mg/L. However, nitrate/nitrite data was not available for all wells within the landfill. Nitrate/nitrite concentrations in the range of 1 to 5 mg/L (slightly higher than mean background concentrations) occur in groundwater along the northern, western, and southern perimeter of the landfill. Although these concentrations are higher than those within the landfill, an upgradient source of nitrate/nitrite has not been identified.

Total Organic Compounds

Total concentrations of organic compounds frequently detected in UHSU groundwater were mapped to determine their spatial distribution in groundwater and to identify possible sources of these compounds. The parameters included in total VOCs, chlorinated hydrocarbons, BTEX, and SVOCs are listed in Table 4-25.

The highest average total VOC concentration and highest average TDS concentration occur in the east-central portion of the landfill in leachate from well 72293 (730 µg/L) (Figure 4-30). Water from this portion of the landfill probably has the longest residence time within the landfill and, therefore, may have the highest contaminant concentrations.

Elevated total VOC concentrations in wells located upgradient south and southwest of the landfill indicate that source(s) of VOC contamination is also present outside of the landfill. Upgradient groundwater from well 70393 had an average total VOC concentration of 71 µg/L. These VOCs may be associated with past activities at the PU&D yard as discussed in Section 2.1. Groundwater from wells located within IHSS 166.1, which is southeast of the landfill, had average total VOC concentrations of 36 and 76 µg/L, respectively.

Groundwater downgradient of the landfill and below the discharge points of the groundwater intercept system contains relatively low concentrations of total VOCs compared to water from within the landfill. None of the organic compounds detected at B206889 (methylene chloride, acetone, benzene, ethylbenzene, toluene, or total xylenes) was detected in subsequent analyses. Isolated detections of VOCs have occurred at well 7187 located northeast of the landfill.

Maps of average total chlorinated hydrocarbon and total BTEX concentrations were constructed to identify patterns in the types of VOC contamination occurring at the site. The total chlorinated hydrocarbon map (Figure 4-31) indicates that the highest concentration of chlorinated hydrocarbons occurred in groundwater upgradient of the landfill at well 70693 (416 µg/L). VOC contamination at this upgradient well was composed entirely of chlorinated hydrocarbons. Upgradient well 70393 had an average (detected) chlorinated hydrocarbon concentration of 72 µg/L. Concentrations of chlorinated hydrocarbons were much higher in groundwater upgradient of the landfill than in leachate from the central portion of the landfill, with the exception of well B206389 (average concentration of 278 µg/L). Well B206389 is located downgradient from IHSS 166.1. Chlorinated hydrocarbon concentrations in groundwater from within IHSS 166.1 (wells B206489 and 7287) were also elevated (32 and 68 µg/L, respectively).

In contrast, average BTEX concentrations were highest in leachate collected from the landfill (Figure 4-32). The BTEX compounds were not detected in upgradient groundwater from wells 70393 and 70693 (where the highest total chlorinated hydrocarbon concentrations were found). The highest average BTEX concentrations occurred in water from wells 72293 and 72393 (423 and 345 µg/L, respectively) within the central portion of the landfill. Wells B206489 and 7287 within IHSS 166.1 had average BTEX concentrations of 8 and 56 µg/L, respectively. Thus, different types of VOC contamination are present within the landfill and upgradient (southwest) of the landfill, suggesting that a distinct source of VOC contamination is present upgradient of the landfill.

Average total SVOC concentrations were highest in leachate from the east-central portion of the landfill at wells 72293 and 72393 (710 and 717 µg/L, respectively) (Figure 4-33). Isolated detections of SVOCs occurred at wells 70693 and 71693 (21 and 25 µg/L, respectively). These data indicate that SVOC contamination is largely contained within the central portion of the landfill.

In summary, the organic parameter maps indicate that the landfill is not the sole source of contamination to groundwater in the vicinity of OU 7. A VOC plume characterized by relatively high BTEX and low chlorinated hydrocarbon concentrations exists within the landfill. The VOC concentrations within the landfill increase in the downgradient direction. A second, chemically distinct VOC plume exists southwest and upgradient of the landfill. This plume is composed entirely of chlorinated hydrocarbons and may be associated with activities at the PU&D yard. A third plume within and downgradient of IHSS 166.1 is characterized by a mixture of BTEX and chlorinated hydrocarbon compounds. Other regions of isolated VOC contamination occur at IHSS 203 (BTEX compounds), downgradient at the groundwater intercept system discharge points (BTEX and chlorinated hydrocarbons), and northeast of the landfill at well 7187 (chlorinated hydrocarbons). Leachate collected from the northern portion of the landfill had the lowest concentrations of VOCs and SVOCs. Also, groundwater near the discharge of the northern groundwater intercept system had lower concentrations of VOCs than groundwater near the southern groundwater intercept system discharge.

Radionuclides

Maps of average dissolved and total uranium-235 activity (Figures 4-34 and 4-35) indicate that dissolved and total activities of uranium-235 were highest in groundwater from wells B206589 (located upgradient and south of the landfill) and B206889 (located downgradient of the landfill near the southern groundwater intercept discharge). Both dissolved and total activities of uranium-235 were relatively low in water from within the landfill with total activities less than 0.5 pCi/L. Average total and dissolved uranium-238 (Figures 4-36 and 4-37) followed the same general distribution pattern in groundwater as uranium-235. The highest activities of uranium-238 occurred in groundwater from wells B206589 and B206889 and indicate that a source(s) of uranium-235 and uranium-238 may be present outside and south of the landfill. Uranium-235 and uranium-238 activities were also relatively high at wells located near the north groundwater intercept system discharge, and at well 0786 located near the East Landfill Pond.

The map of average dissolved radium-226 activity indicated that the highest activities occur within the southern and central portions of the landfill at wells B206389, 6987, 72093, 72293, and 72393 (Figure 4-38). Both total and dissolved radium-226 were identified as PCOCs. The highest americium-241 levels also occur within the landfill at wells 72093, 72393, and abandoned well 6387 (Figure 4-39).

Dissolved Oxygen and pH Maps

The average pH and dissolved oxygen content (field measurements) of groundwater were mapped to identify their spatial relationship to other contaminants (Figures 4-40 and 4-41). Groundwater within the landfill (leachate) generally has pH values ranging from 6.5 to 7.5. The lowest pH values occur in the northern portion of the landfill. Dissolved oxygen contents were lowest in leachate from the central and southern portion of the landfill. The lowest dissolved oxygen concentration (1.63 mg/L) occurred at well 72293 in the east-central portion of the landfill. These data indicate that landfill leachate is generally neutral and mildly oxidizing. Because dissolved oxygen was measured in samples exposed to air, the dissolved oxygen contents reported may not be representative of redox conditions within the landfill.

4.7.3.2 Exceedances of the $UTL_{95/95}$ Concentration

All inorganic and radionuclide data from UHSU wells at OU 7 were compared to background $UTL_{95/95}$ values. The list of values that exceed the $UTL_{95/95}$ concentration, by well, are given in Appendix M.

Additional analytes identified as PCOCs using the comparison to the $UTL_{95/95}$ concentration include dissolved aluminum, antimony, cadmium, chromium, lithium, molybdenum, and selenium. Comparison of total concentrations to the $UTL_{95/95}$ concentration resulted in cadmium, cyanide, molybdenum, tin, and cesium-137 being identified as additional PCOCs. Table 4-23 lists all analytes exceeding the $UTL_{95/95}$ concentration and the range of values that exceed the UTL.

4.7.4 Nature and Extent of LHSU Groundwater Contamination

Data from wells downgradient of the landfill were used to develop the PCOC list for LHSU groundwater. Data from LHSU wells upgradient of the landfill were then separately compared to

sitewide LHSU background data to determine if LHSU groundwater upgradient of the landfill contains analytes at concentrations elevated with respect to background concentrations.

Statistical comparison of upgradient LHSU groundwater data to sitewide background resulted in identification of 22 analytes with elevated concentrations relative to background: 6 dissolved metals and 1 dissolved radionuclide and 14 total metals and 1 total radionuclide. Using downgradient LHSU data, 20 dissolved metals and 3 dissolved radionuclides and 8 total metals were identified as elevated relative to background. Table 4-27 presents the results of the LHSU statistical comparisons. These analytes are all PCOCs in LHSU groundwater as summarized on Table 4-24.

Dissolved metals that were identified as PCOCs using downgradient data, but were not elevated in the upgradient data set, include aluminum, beryllium, cadmium, chromium, cobalt, copper, lithium, potassium, selenium, silver, sodium, strontium, thallium, and tin. The greater number of dissolved metals identified as PCOCs in downgradient groundwater may be the result of increased contact between downgradient groundwater and landfill materials or other sources of contaminants.

Dissolved radionuclides identified as PCOCs comparing downgradient data to sitewide background included gross alpha, gross beta, and uranium-238. Comparison of upgradient dissolved radionuclide data to background data indicated that uranium-235 was elevated for background activities. Using total activities, cesium-137 was found to be elevated with respect to background in upgradient groundwater.

4.7.4.1 Isoconcentration Maps

Maps of average analyte concentrations were used to analyze the nature and extent of LHSU contamination and to investigate possible contaminant sources and transport pathways. Isoconcentration contour maps for the LHSU were constructed for average TDS, average total VOCs, and average dissolved uranium-238 activity. Due to the limited spatial extent of LHSU chemical data, particularly underlying the landfill, only general conclusions could be reached regarding the extent of LHSU contamination.

Inorganic Indicator Parameters

The highest average TDS concentrations were present in groundwater downgradient of the landfill (Figure 4-42). Average TDS concentrations at wells 4187 and B207189 were 1,885 and 1,688 mg/L, respectively. These concentrations exceed the mean and maximum reported background TDS concentrations of 406 and 1,430 mg/L, respectively. These data may indicate that LHSU groundwater downgradient of the landfill may have been adversely affected by discharges from the groundwater intercept system.

Total Organic Compounds

Average total concentrations of organic compounds frequently detected in LHSU groundwater were mapped to determine the spatial distribution of these compounds and to identify possible source areas of VOC contamination to LHSU groundwater (Figure 4-43). The parameters included in total concentrations of VOCs are listed in Table 4-24.

The average total VOC concentration map indicates that VOCs have been detected in five of eight LHSU groundwater wells. However, detections of VOCs are infrequent and generally not repeated at single wells. As discussed below, these detections probably do not indicate contamination of groundwater in the LHSU.

At downgradient well B207189, methylene chloride was detected once in 1991 at a concentration of 8 µg/L. Methylene chloride was detected in samples collected from this well on two other occasions, but on those occasions, it was also reported in the laboratory blanks. Because there have been no additional detections of methylene chloride in LHSU well B207189, the 1991 detection is questionable. Acetone has been detected twice at B207189. In one instance, acetone was also detected in the laboratory blank; on the other occasion it was reported below the detection limit as a suspected aldol condensation product. These data do not provide sufficient evidence of VOC contamination at downgradient well B207189.

Eight of the nine VOC detections reported in downgradient well 4187 were detected in the laboratory blank, suspected as an aldol condensation product, or estimated at a concentration less than the detection limit. Methylene chloride, detected during one sampling event, was the only valid VOC detected from 1990 to 1993. Methylene chloride was detected on four other occasions but was present in the laboratory blank, suspected as an aldol condensation product, or both on

these occasions. Because there have been no subsequent VOC detections, the methylene chloride detection in LHSU well 4187 was not considered to indicate contamination.

In upgradient well 70893, only acetone was detected during one 1993 sampling event. However, the laboratory reported this analyte as a suspected aldol condensation product. Therefore, this detection does not represent actual groundwater contamination in well 70893. The lack of verification of acetone in subsequent samples also indicates that VOC contamination is not present at well 70893.

In well 0886, located near the East Landfill Pond, nine of the ten VOC detections were either also detected in the laboratory blank, reported as an estimated concentration below the detection limit, or suspected as an aldol condensation product. Methylene chloride was detected at 16 µg/L once in 1992. However, this detection was not verified in subsequent sampling events. This one sample does not provide evidence of VOC contamination at well 0886. In upgradient well 0986, acetone and methylene chloride were detected at 24 and 9 µg/L, respectively, in one sampling event in 1992. However, these detections were not verified in subsequent sampling events.

Radionuclides

The highest average dissolved uranium-238 activities occurred in groundwater from upgradient wells 70293 and 70593 (3.2 and 2.1 pCi/L) (Figure 4-44). The average dissolved uranium-238 activity in downgradient groundwater from well 4187 was 1.1 piC/L. These values are within the range of background values (up to 11.00 pCi/L) for dissolved uranium-238 in groundwater from weathered claystone (EG&G 1993d).

4.7.4.2 Exceedances of $UTL_{95/95}$ Concentration

Inorganic and radionuclide data from LHSU wells at OU 7 were compared to the $UTL_{95/95}$ concentration for each analyte. The list of values that exceed the $UTL_{95/95}$ concentration, by well, are given in Appendix M.

Additional analytes identified as PCOCs using the comparison to the $UTL_{95/95}$ concentration include dissolved antimony, arsenic, iron, lead, mercury, strontium-89,90, vanadium, and uranium-235 and total aluminum, americium-241, arsenic, cesium-137, copper, iron, lead, lithium, manganese,

nitrate/nitrite, potassium, silicon, silver, tin, uranium-235, and zinc. Table 4-24 lists all analytes exceeding the $UTL_{95/95}$ concentration and the range of sample concentrations.

4.8 Contaminant Distribution Summary

A comprehensive list of PCOCs for all media is presented in Table 4-28.

4.8.1 Surface Soils

Statistical evaluation of surface soils at IHSS 203 and IHSS 114 revealed that calcium, copper, and radium-226 (IHSS 203 only) occurred at elevated concentrations or activities relative to background. Two PCBs were detected at low concentrations in approximately 20 percent of the soil samples from IHSS 203. At IHSS 203, americium-241 and uranium-235 activities exceeded the $UTL_{95/95}$ and at IHSS 114 strontium-89,90 and gross beta exceeded the $UTL_{95/95}$ in some soil samples.

Three PCOCs (calcium, strontium, and radium-226) were identified in soils from the East Landfill Pond area based on results of the inferential statistical tests. Nine metals, two radionuclides, and nitrate/nitrite were also identified as PCOCs based on $UTL_{95/95}$ comparisons. These exceedances were generally in the range of 2 to 3 times the maximum background concentration. The americium-241 activity of one sample was 27 times higher than the maximum background activity. Radionuclides exceeded background activities only in the 0- to 2-inch soil samples.

4.8.2 Subsurface Geologic Materials

Seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-238) were identified as PCOCs in surficial deposits upgradient of OU 7. However, only radium-226 was identified as a PCOC in upgradient bedrock material, indicating that significant downward transport of these radionuclides has not occurred. At downgradient borehole 70993 (located near the north groundwater intercept system discharge outfall), cesium-137 and uranium-238 were identified as PCOCs in surficial deposits. Uranium-238 was also identified as a PCOC in north groundwater intercept system discharge water (Section 4.6). These data suggest that the north groundwater intercept system discharge water may be a source of uranium-238 to geologic materials downgradient of the landfill. However, the ultimate source of uranium-238 may be located upgradient of the landfill, as indicated by the upgradient borehole

data. Five VOCs and six SVOCs were also detected in geologic materials and identified as PCOCs.

4.8.3 *Sediments*

Statistical comparisons of East Landfill Pond sediments to background stream sediments identified metal, radionuclide, and inorganic analytes present at concentrations elevated with respect to background concentrations. Two VOCs and 15 SVOCs were detected in the East Landfill Pond sediments and are considered PCOCs.

Fifteen SVOCs were detected in East Landfill Pond sediment at SED70093 near the leachate seep. Fourteen of the detected concentration values were qualified as estimated concentrations below the detection limit. However, the occurrence of these in sediments close to a potential source of SVOCs indicates that SVOC contamination of East Landfill Pond sediments has probably occurred.

Cesium-137 was the only radionuclide found at activity levels higher than background activities. No single sediment sample had measured radionuclide activities higher than the $UTL_{95/95}$ value. The highest radionuclide activities were present in the sample collected from the west end of pond, closest to the leachate seep. These data indicate that radionuclide contamination in East Landfill Pond sediments is not extensive.

4.8.4 *Surface Water*

Surface waters at OU 7 are not contaminated by VOCs and SVOCs, except at the leachate seep. BTEX, chlorinated hydrocarbons, and SVOCs were consistently detected only in water samples from the leachate seep.

Tritium activities were elevated relative to background activities in the leachate seep, the East Landfill Pond, and the southern groundwater intercept discharge. Americium-241 was elevated above background in the East Landfill Pond, southern groundwater intercept discharge, and the northern groundwater intercept discharge. Uranium -235 and uranium-238 were both elevated relative to background at the pond and the northern discharge point, whereas only uranium-238 was elevated above background at the southern discharge point. As may be expected, water in the East Landfill Pond reflects the quality of the water from the leachate seep and from the

groundwater intercept system except that seep water contains VOCs and SVOCs more frequently.

4.8.5 Groundwater

Groundwater in the UHSU at OU 7 contains higher-than-background concentrations of metals, radionuclides, organic parameters, and nitrates. Sources of radionuclide and chlorinated hydrocarbon contamination to UHSU groundwater may be located upgradient of the landfill and within IHSS 166.1 (within OU 6). The landfill appears to be the main source of metals and BTEX compounds to UHSU groundwater. Additional data are necessary to characterize the downgradient extent of UHSU groundwater contamination, especially in No Name Gulch.

Statistical comparisons of upgradient versus downgradient UHSU groundwater indicate statistically significant increases in downgradient concentrations of calcium, chloride, lithium, magnesium, potassium, sodium, strontium, and sulfate. None of the radionuclides or VOCs show a statistically significant difference in upgradient versus downgradient concentrations (EG&G 1994a).

Radionuclide activities and concentrations of VOCs, metals, and inorganic parameters were notably highest within the landfill and in the area adjacent to IHSSs located southeast of the landfill relative to other areas in the vicinity of the Present Landfill. Concentrations of VOCs and radionuclides were higher in the central portion of the landfill than in other areas within the landfill. VOCs were detected infrequently in groundwater from UHSU bedrock beneath and downgradient of the landfill, but radionuclides were present at activities higher than background in UHSU-bedrock groundwater.

PCOCs were identified in groundwater from the LHSU. However, in LHSU groundwater collected downgradient of the landfill, radionuclide and VOC concentrations were not significantly higher than in LHSU groundwater from background wells.

Section 4
Tables

Table 4-1
Data Aggregation at OU 7 to Support Site Characterization, Risk Assessment, and Remedial Design

Media	OU 7 Data Set	Background Data Set	Objective
Surface Soil	IHSS 203 (0 to 2 inches)	OU 1 and OU 2 background data	nature and extent, remedial investigation and design, potential contaminant of concern
	IHSS 203 (0 to 10 inches)	OU 1 and OU 2 background data	nature and extent, remedial investigation and design, potential contaminant of concern
	IHSS 114 (0 to 2 inches)	OU 1 and OU 2 background data	potential contaminant of concern
	East Landfill Pond (0 to 2 inches)	OU 1 and OU 2 background data	nature and extent, potential contaminant of concern
	East Landfill Pond (0 to 10 inches)	OU 1 and OU 2 background data	nature and extent, potential contaminant of concern
Subsurface Geologic Materials (i.e., borehole samples)	Samples downgradient of landfill, 70993, by geologic unit	Sitewide borehole data for each geologic unit	nature and extent, potential contaminant of concern
	Samples downgradient of landfill, 71093, by geologic unit	Sitewide borehole data for each geologic unit	nature and extent, potential contaminant of concern
	Combined upgradient boreholes, 70493 and 70593, by geologic unit	Sitewide borehole data for each geologic unit	nature and extent, evaluation of upgradient contamination impacting OU 7
Pond Sediments	East Landfill Pond sediments (SED70093, SED70193, and SED70293)	Sitewide background data for stream sediments	potential contaminant of concern
Surface Water	(SW098) East Landfill Pond	Sitewide background data for surface water	nature and extent, fate and transport, remedial investigation and design, potential contaminant of concern
	(SW099) North intercept system discharge	Sitewide surface water data	nature and extent, remedial investigation and design, potential contaminant of concern
	(SW100) South intercept system discharge	Sitewide surface water data	nature and extent, remedial investigation and design, potential contaminant of concern
Leachate Seep	SW097 leachate seep	Sitewide background data for seep waters/regional information	nature and extent, remedial investigation and design, potential contaminant of concern

Media	OU 7 Data Set	Background Data Set	Objective
Groundwater	All wells in UHSU	Sitewide background data for UHSU	OU-wide potential contaminant of concern identification
	Landfill wells in UHSU	Sitewide background data for UHSU	nature and extent
	Downgradient wells in UHSU	Sitewide background data for UHSU	nature and extent, fate and transport, remedial investigation and design
	Downgradient wells in LHSU	Sitewide background data for LHSU	nature and extent, fate and transport, potential contaminant of concern, remedial investigation and design
	Upgradient wells in LHSU	Sitewide background data for LHSU	nature and extent

Definitions:

IHSS	individual hazardous substance site
LHSU	lower hydrostratigraphic unit
OU	operable unit
UHSU	upper hydrostratigraphic unit

Table 4-2
Volume Estimates of Previous Landfill Operations

Year	Volume of Compacted Trash (cubic yards)	Volume of Compacted Trash & Fill[1] (cubic yards)	Cumulative Compacted Trash & Fill to Date (cubic yards)	Estimated Volume of Trash & Fill by Photo (cubic yards)	Weight of Trash & Fill[2] (pounds)	Weight of Trash & Fill (kilograms)
1968	10,178	13,571	13,571		13,571,000	6,155,806
1969	10,178	13,571	27,142		13,571,000	6,155,806
1970	10,178	13,571	40,713		13,571,000	6,155,806
1971	10,178	13,571	54,284		13,571,000	6,155,806
1972	10,178	13,571	67,855		13,571,000	6,155,806
1973	10,178	13,571	81,426		13,571,000	6,155,806
1974	10,178	13,571	94,997	95,000	13,571,000	6,155,806
1975	10,000	13,333	108,330		13,333,000	6,047,849
1976	10,000	13,333	121,663		13,333,000	6,047,849
1977	10,000	13,333	134,996		13,333,000	6,047,849
1978	10,000	13,333	148,329		13,333,000	6,047,849
1979	10,000	13,333	161,662		13,333,000	6,047,849
1980	10,000	13,333	174,995		13,333,000	6,047,849
1981	10,000	13,333	188,328		13,333,000	6,047,849
1982	10,000	13,333	201,661		13,333,000	6,047,849
1983	10,000	13,333	214,994		13,333,000	6,047,849
1984	10,000	13,333	228,327		13,333,000	6,047,849
1985	10,000	13,333	241,660		13,333,000	6,047,849
1986	10,000	13,333	254,993	255,000	13,333,000	6,047,849
1987	28,125	37,500	292,493		37,500,000	17,010,000
1988	28,125	37,500	329,993	330,000	37,500,000	17,010,000
1989	28,031	37,375	367,368		37,375,000	16,953,300
1990	28,125	37,500	404,868		37,500,000	17,010,000
1991	28,125	37,500	442,368		37,500,000	17,010,000
1992	11,964	15,952	458,320		15,952,000	7,235,827
1993	11,964	15,952	474,272		15,952,000	7,235,827
TOTAL	355,705	474,272			474,272,000	215,129,779

[1] Based on a trash to fill ratio of 3 to 1

[2] Based on a compacted trash density of 1000 pounds per cubic yard (Brunner and Keller 1972)

Table 4-3
Volume Estimates of Future Landfill Operations

Year	Volume of Compacted Trash (cubic yards)	Volume of Compacted Trash & Fill[1] (cubic yards)	Cumulative Compacted Trash & Fill to Date (cubic yards)	Weight of Trash & Fill[2] (pounds)	Weight of Trash & Fill (10^6 Kilograms)
1994	11,964	15,952	490,224	15,952,0	7,235,827
1995	11,964	15,952	506,176	15,952,0	7,235,827
1996	11,964	15,952	522,128	15,952,0	7,235,827
1997	11,964	15,952	538,080	15,952,0	7,235,827
TOTAL	47,856	63,808			28,943,308

[1] Based on a trash to fill ratio of 3 to 1

[2] Based on a compacted trash density of 1000 pounds per cubic yard (Brunner and Keller 1972)

Table 4-4
Waste Streams Disposed in the Landfill from 1989 to Present (WSRIC)[1]

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
025/026	025/026-1-4	Scrap or Reject Drums	Empty Containers	Nonhazardous	insufficient data
111	111-1-4	Empty Containers	Empty Containers	Nonhazardous	100/year
111	111-1-5	Empty Ink Cans	Empty Containers	Nonhazardous	120/year
111	111-1-6	Empty Solvent Containers	Empty Containers	Nonhazardous	12/year
111	111-1-12	Aerosol Cans	Empty Containers	Nonhazardous	16/year
111	111-1-13	Machine Cleaning Waste	Solid	Nonhazardous	insufficient data
112	112-1-1[3]	Wire	Metal	Nonhazardous	insufficient data
112	112-1-2	Dry Combustibles	Solid	Nonhazardous	< 10 gal/year
119	119-1-3	Waste Parts	Solid	Nonhazardous	insufficient data
119	119-1-4	Empty Containers	Empty Containers	Nonhazardous	insufficient data
119	119-1-8	Empty Aerosol Containers	Empty Containers	Nonhazardous	insufficient data
123	123-16-4	Alkaline Batteries	Solid	Nonhazardous	insufficient data
124	124-1-5	Rubber Gloves	Solid	Nonhazardous	1 pair/mo
125	125-1-3	Kimwipes® Cont. with Presolve/Ethanol	Solid	Nonhazardous	10 gal/year
125	125-1-4	Wipes & Rags w/Oil and/or Ethanol	Solid	Nonhazardous	60 gal/year
125	125-2-5	Used Cotton Gloves	Solid	Nonhazardous	< 1 gal/year
125	125-3-7	Broken Glass	Solid	Nonhazardous	insufficient data
125	125-3-9	Uncontaminated Kimwipes®	Solid	Nonhazardous	< 10 gal/year
125	125-6-2	Uncontaminated Kimwipes®	Solid	Nonhazardous	260 gal/year
130	130-6-2	Dry Combustibles	Solid	Nonhazardous	insufficient data
218	218-1-1	Dry Combustibles	Solid	Nonhazardous	10 rags/year
333	333-3-2[4]	Empty Paint Cans	Empty Containers	Nonhazardous	100 cans/year
333	333-3-4[4]	Spent Paint Booth Filters	Solid	Unknown	1900 panels/year
334	334-1-9	Greasy Kimwipes®	Solid	Nonhazardous	variable
334	334-1-11	Contact Cleaner Containers	Empty Containers	Nonhazardous	24 cans/year
334	334-1-12	Used Light Bulbs	Solid	Nonhazardous	variable
334	334-2-2[3]	Metal Cuttings	Metal	Nonhazardous	variable
334	334-2-7	Rags and Kimwipes®	Solid	Nonhazardous	550 gal/year
334	334-3-3	Rags and Kimwipes®	Solid	Nonhazardous	insufficient data
334	334-4-5	Wood Scraps and Sawdust	Solid	Nonhazardous	24 cu yds/year
334	334-4-6	Plastic Shavings and Scraps	Solid	Nonhazardous	60 gal/year
334	334-4-9	Glass Scrap	Solid	Nonhazardous	1 cu yd/year
334	334-4-10	Kimwipes® and Rags	Solid	Nonhazardous	6 gal/year
334	334-5-7	Freon Cans	Solid	Nonhazardous	60 cans/year
334	334-5-10	Waste Glue Cans	Solid	Nonhazardous	24 cans/year
334	334-5-13	Rags and Brushes	Solid	Nonhazardous	insufficient data
334	334-5-14	Rags and Kimwipes®	Solid	Nonhazardous	insufficient data
371	371-9-4	Used Kimwipes®	Solid	Nonhazardous	12 cases/year

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
371	371-12-2[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
371	371-13-2[4]	Paint Rags, Brushes, and Rollers	Solid	Nonhazardous	variable
371	371-13-4[4]	Empty Paint Cans	Empty Containers	Nonhazardous	variable
371	371-15-1	Expired Leaded Glovebox Gloves	Solid	Nonhazardous	insufficient data
439	439-2-1[3]	Metal Chips	Metal	Nonhazardous	1/2 ton/mo
439	439-3-4	Kimwipes® with Coolant Sludge	Solid	Nonhazardous	insufficient data
442	442-1-2	Used Kimwipes® and Rags	Solid	Nonhazardous	15 gal/year
442	442-1-4	Rejected Respirator Cartridges	Solid	Nonhazardous	900 cartridges/year
442	442-1-7	Defective HEPA Filters	Solid	Nonhazardous	500 filters/year
443	443-1-13	Contaminated Rags/Wipes	Solid	Nonhazardous	55 gal every 2 years
444	444-4-7	Silica	Solid	Nonhazardous	250 lbs/year
444	444-4-14	Air Filters	Solid	Nonhazardous	8 filters/year
444	444-9-2[3]	Metal Scraps	Metal	Nonhazardous	50 dumpsters/year
444	444-9-7[3]	Metal Chips w/Used Cutting Oil	Metal	Nonhazardous	insufficient data
444	444-22-1	Shredded Papers	Solid	Nonhazardous	15 lbs/year
444	444-22-4	Wipes with Oil Residue	Solid	Nonhazardous	5 gal/year
444	444-25-8	Sanitary Solid Waste	Solid	Nonhazardous	insufficient data
444	444-26-4	Furnace Filter Pads	Solid	Nonhazardous	800 gal/year
444	444-29-16	Light Metal	Metal	Nonhazardous	insufficient data
444	444-29-26	Dry Combustibles	Solid	Nonhazardous	insufficient data
444	444-31-6	Non-RCA Plenum Prefilters	Solid	Nonhazardous	variable
445	445-1-1[3]	Metal Fines	Metal	Nonhazardous	100 lbs/wk
445	445-1-2[3]	Scrap Material	Metal	Nonhazardous	100 lbs/wk
445	445-1-3	Combustible Waste	Solid	Nonhazardous	25 lbs/wk
447	447-8-5	Furnace Filters (uncontaminated)	Solid	Nonhazardous	insufficient data
448	448-1-5	Reject Metal Drums	Empty Containers	Nonhazardous	variable
449	449-1-4	Empty Containers	Empty Containers	Nonhazardous	660 lbs/year
449	449-1-8[4]	Rollers, Tape Brushes, Paper Containers	Solid	Nonhazardous	100 lbs/year
454	454-1-3	Sump Sludge	Solid	Nonhazardous	200 lbs/year
460	460-6-2	Wipes	Solid	Nonhazardous	insufficient data
460	460-6-9[3]	Grinding Wheels	Metal	Nonhazardous	insufficient data
460	460-13-14	Used Coolant Filters	Solid	Nonhazardous	variable
460	46-13-15	Used Exhaust Filters	Solid	Nonhazardous	variable
460	460-21-15	Used Compressor Filters	Solid	Nonhazardous	insufficient data
460	460-21-25	Ful-Flo Filters	Solid	Nonhazardous	10 filters/year
460	460-21-26	Used Cuno Filters	Solid	Nonhazardous	100 filters/year
460	460-29-6	Sanitary Trash/Discarded Containers	Solid	Nonhazardous	insufficient data
460	460-31-22	Fluorescent Ballast	Metal	Nonhazardous	Insufficient data
460	460-32-2	Combustibles	Solid	Nonhazardous	insufficient data

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
460	460-32-3	Scrap PVC Pipe	Solid	Nonhazardous	insufficient data
460	460-32-9	Rags and Wipes	Solid	Nonhazardous	insufficient data
460	460-33-3	Construction Scrap	Solid	Nonhazardous	insufficient data
460	460-34-1[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
460	460-34-2	Scrap Neoprene Rubber	Solid	Nonhazardous	insufficient data
460	460-34-3	Scrap Fiberglass	Solid	Nonhazardous	insufficient data
462	462-1-4	Sludge	Solid	Nonhazardous	30 gal/year, varies
549	549-1-10[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
551	551-3-10	Uncontaminated Solids	Solid	Nonhazardous	insufficient data
551	551-3-14[3]	Scrap Stainless Steel	Metal	Nonhazardous	insufficient data
553	553-1-2[3]	Scrap Metal	Metal	Nonhazardous	< 50 gal/year
553	553-2-4[3]	Copper Wire Waste	Metal	Nonhazardous	< 1 gal/year
553	553-3-2[3]	Scrap Metal	Metal	Nonhazardous	400 gal/year
559	559-26-10	Roll-a-Mat Filters	Solid	Nonhazardous	insufficient data
563	563-1-2	Sump Sludge	Solid	Nonhazardous	insufficient data
563	563-1-4	Dry Combustibles	Solid	Nonhazardous	insufficient data
563	563-1-8	Wet Combustibles	Solid	Nonhazardous	insufficient data
566	566-1-14	Sanitary Waste	Solid	Nonhazardous	insufficient data
662	662-2-3	Used Kimwipes® (with Oil)	Solid	Nonhazardous	variable
662	662-2-5	Used Rags (with Oil)	Solid	Nonhazardous	variable
662	662-2-7	Used Syringes	Solid	Nonhazardous	36/year
662	662-2-9	Used Pipettes	Solid	Nonhazardous	36/year
662	662-2-11	Used Sample Bottles	Empty Containers	Nonhazardous	36 bottles/year
662	662-3-2	Oil-Soaked Rags	Solid	Nonhazardous	insufficient data
662	662-3-3	Oil-Soaked Floor Dri	Solid	Nonhazardous	insufficient data
662	662-6-8	Plastic	Solid	Nonhazardous	variable
662	662-7-1	Sanitary Waste	Solid	Nonhazardous	variable
662	662-7-2	Dry Combustible	Solid	Nonhazardous	variable
662	662-7-3	Plastic	Solid	Nonhazardous	variable
662	662-7-4	Glass	Solid	Nonhazardous	variable
662	662-7-5	Light Metal	Metal	Nonhazardous	variable
663	663-1-3	Miscellaneous Scrap	Solid	Nonhazardous	insufficient data
663	663-1-4	Drywall Scraps	Solid	Nonhazardous	insufficient data
663	663-1-5	Kimwipes®	Solid	Nonhazardous	insufficient data
663	663-1-8	Scrap Lumber	Solid	Nonhazardous	insufficient data
663	663-1-9	Plastics	Solid	Nonhazardous	insufficient data
663	663-1-11	General Trash and Scrap Lumber	Solid	Nonhazardous	insufficient data
663	663-1-12	Empty Adhesive Cans	Empty Containers	Nonhazardous	insufficient data
664	664-1-3[4]	Empty Containers	Empty Containers	Nonhazardous	8-9 gal/year
664	664-1-10	Empty Non-Spray Paint Containers	Empty Containers	Nonhazardous	100 gal/year
664	664-1-12	Incandescent Bulbs & Non-PCB Ballast	Solid	Nonhazardous	30 bulbs/year

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
701	701-2-4	Empty Bags	Solid	Nonhazardous	780 bags/year
701	701-2-5	HEPA Filters	Solid	Nonhazardous	variable
701	701-4-3[3]	Metals	Metal	Nonhazardous	insufficient data
701	701-5-5[3]	Metals	Metal	Nonhazardous	insufficient data
702	702-1-7	Kimwipes®	Solid	Nonhazardous	insufficient data
703	703-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
707	707-29-3	Bag Filters	Solid	Nonhazardous	insufficient data
707	707-29-6	Roll-a-mat Filters	Solid	Nonhazardous	a roll/year
708	708-1-1	Used HEPA Filters	Solid	Nonhazardous	2 every 20 years
708	708-2-2	Brine Leakage	Solid	Nonhazardous	105 gal/year
708	708-3-10	Kimwipes® Contaminated with Oil	Solid	Nonhazardous	insufficient data
712	712-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
713	713-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
715	715-1-3	Kimwipes® and Rags	Solid	Nonhazardous	10 gal/year
715	715-1-15	Oil Dri	Solid	Nonhazardous	insufficient data
727	727-1-7	Contaminated Wipes	Solid	Nonhazardous	< 1 gal/year
750	750-1-2	Rags/Kimwipes®	Solid	Nonhazardous	15 lbs/year
771	771-22-4	Chemical Containers	Empty Containers	Nonhazardous	insufficient data
771	771-30-7	Dry Cell Batteries	Solid	Nonhazardous	insufficient data
774	774-2-11	Nonline Dry Combustibles	Solid	Nonhazardous	1560 bags/year
774	774-3-11	Dry Combustibles	Solid	Nonhazardous	1560 bags/year
774	774-5-8	Sanitary Trash	Solid	Nonhazardous	100 drums/year
776	776-7-9	Alkaline Batteries	Solid	Nonhazardous	insufficient data
776	776-8-2	Wood and Plastic Chips	Solid	Nonhazardous	4000 lbs/year
778	778-3-2[4]	Empty Paint Cans	Empty Containers	Nonhazardous	variable
778	778-3-5	General Waste	Solid	Nonhazardous	7500 gal/year
778	778-3-8[4]	Dry Brushes and Rollers	Solid	Nonhazardous	variable
778	778-4-1[3]	Metal Waste	Metal	Nonhazardous	60 gal/year
779	779-35-1	Dry Combustibles	Solid	Nonhazardous	insufficient data
779	779-35-2	Wet Combustibles	Solid	Nonhazardous	insufficient data
779	779-35-3	Light Metal	Metal	Nonhazardous	insufficient data
779	779-35-5	Plastic	Solid	Nonhazardous	insufficient data
782	782-1-5	Used Furnace Filters	Solid	Nonhazardous	insufficient data
783	783-1-4	Kimwipes® with Lubrication Grease	Solid	Nonhazardous	10-12 wipes/year
783	783-1-5	Dry Kimwipes®	Solid	Nonhazardous	insufficient data
790	790-1-1	Dry Combustibles	Solid	Nonhazardous	10 gal/wk
865	865-9-5	Roughing Filters	Solid	Nonhazardous	64 filters/wk
865	865-9-11	Wipes and Rags	Solid	Nonhazardous	insufficient data
865	865-9-14	Air Filters	Solid	Nonhazardous	insufficient data
865	865-11-3	Sanitary Combustible Waste	Solid	Nonhazardous	insufficient data
881	881-49-1	Waste Scrap Paper	Solid	Nonhazardous	400 cu ft/year

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
883	883-11-6	Wipes and Rags	Solid	Nonhazardous	variable
883	883-11-14	Prefilters-Air Comp./Intake/HVAC	Solid	Nonhazardous	variable
903A	903A-1-9	Combustibles	Solid	Nonhazardous	insufficient data
910	910-4-1	Sanitary Waste	Solid	Nonhazardous	insufficient data
910	910-4-3	Glass	Solid	Nonhazardous	insufficient data
910	910-4-6	Dry Combustibles	Solid	Nonhazardous	insufficient data
910	910-4-8	Light Metal	Metal	Nonhazardous	insufficient data
910	910-4-11	Plastic	Solid	Nonhazardous	insufficient data
965	965-1-4	Floor Sweepings	Solid	Nonhazardous	insufficient data
980	980-2-8	Used Drop Cloths & Plastic Sheeting	Solid	Nonhazardous	insufficient data
989	989-1-10	Used Kimwipes®	Solid	Nonhazardous	< 1 lb/year
991	991-1-11[3]	Uncontaminated Scrap Metal	Metal	Nonhazardous	variable
991	991-3-9	Mounting Compound	Solid	Nonhazardous	insufficient data
991	991-5-2	Furnace Filters	Solid	Nonhazardous	30 filters/year
991	991-6-2	Glass	Solid	Nonhazardous	variable
991	991-6-4	Wood	Solid	Nonhazardous	variable
991	991-6-8	Wire and Switches	Metal	Nonhazardous	variable
991	991-6-12	Belts	Solid	Nonhazardous	variable
991	991-6-17	Combustibles	Solid	Unknown	variable
991	991-6-22	Insulation	Solid	Nonhazardous	insufficient data
T707S	T707S-1-7	Floor Dri	Solid	Nonhazardous	variable
T900D	T900D-1-4	Empty Chemical Bags	Solid	Nonhazardous	23 bags/mo
T900D	T900D-1-5	Personal Protective Equipment	Solid	Nonhazardous	2 bags/mo
T900D	T900D-1-12	Air Filters	Solid	Nonhazardous	1 filter/mo

[1] This information is obtained from the Waste Stream Residue Identification and Characterization (WSRIC) Program, which was developed in 1989. Therefore, this list of nonhazardous waste streams disposed in the Rocky Flats landfill covers the period from 1989 to the present.

[2] The process numbers, which were assigned by the WSRIC Program, include the building number, the process number, and the output number.

[3] According to the WSRIC program, these wastes are either placed in a metal dumpster and taken to the Property Utilization and Disposal (PU&D) yard as scrap or placed in the landfill.

[4] As of June 1993, these wastes are no longer being sent to the landfill.

Definitions:

cu ft cubic feet
cu yd cubic yard
gal gallon
lb pound
mo month
wk week

Table 4-5
Results of Methane Survey

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in. Hg)	Total Organic Gases(ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
MET00293	3.28	<.10	0	330	75	255	NP-EQUIP
MET00393	3.28	<.10	0	510	210	300	NP-EQUIP
	8.20	<.10	0	5,000	375	4,625	NP-EQUIP
	13.12	<.10	0	≥67,600[4]	≥0	67,600	54,000
	16.73	<.10	0	95,000	1,260	93,740	NP-EQUIP
MET00493	3.28	<.10	2	1,900	65	1,835	NP-EQUIP
	8.20	<.10	8	120,000	23,000	97,000	72,000
	13.12	<.10	11.5	100,000	24,000	76,000	70,000
	18.04	<.10	13	1,200	50	1,150	NP-EQUIP
	22.96	<.10	13.5	140	26	114	NP-EQUIP
MET00593	3.28	<.10	2	700	90	610	NP-EQUIP
	8.2	<.10	5	150,000	31,000	119,000	6,800
	13.12	<.10	0	270,000	57,000	213,000	111,000
	18.04	<.10	12	640	18	622	NP-EQUIP
	22.96	<.10	12.5	6,000	2,000	4,000	6,000
MET00693	3.28	<.10	10	200,000	41,000	159,000	113,000
	8.20	<.10	12	360,000	58,000	302,000	166,000
	13.12	<.10	11.5	380,000	74,000	306,000	149,000
	18.04	<.10	12	330,000	48,000	282,000	164,000
	22.96	<.10	14	340	6	334	NP-EQUIP
MET00793	3.28	<.10	12	270,000	45,000	225,000	102,000
	8.20	<.10	12	70,000	29,000	41,000	34,000
	13.12	<.10	12	390,000	73,000	317,000	156,000
	18.04	<.10	13	≥17,000[5]	≥0	17,000	16,000
	22.14	<.10	13.5	9,600	220	9,380	NP-EQUIP
MET00893	3.28	<.10	12.5	65,000	27,000	38,000	16,000
	8.20	<.10	0	3,700	49	3,651	5,000
	13.12	<.10	13	180,000	37,000	143,000	60,000
	18.04	.25/<.10/<.10/<.10/<.10	13.5	100,000	26,000	74,000	37,000
	22.96	<.10	13	68	6	62	NP-EQUIP
MET00993	3.28	.21/.21/.21/.21/.21	3	360,000	85,000	275,000	191,000
	8.20	<.10	2	≥25,000[5]	≥0	25,000	22,000
	13.12	.20/.20/.20/.20/.20	3	140,000	41,000	99,000	64,000
	18.04	<.10	12	260,000	59,000	201,000	108,000
MET01093	3.28	<.10	0	520,000	81,000	439,000	218,000
	8.20	<.10	0	380,000	35,000	345,000	219,000
	13.12	<.10	13.5	65,000	27,000	38,000	29,000
	18.04	<.10	13	200,000	33,000	167,000	88,000
	22.96	<.10	13.5	120,000	24,000	96,000	65,000
	27.88	<.10	11.5	110	0	110	NP-EQUIP

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in. Hg)	Total Organic Gases(ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET01193	3.28	<.10	0	560,000	70,000	490,000	173,000
	8.20	<.10	13	180,000	41,000	139,000	54,000
	13.12	<.10	0	570,000	101,000	469,000	160,000
	18.04	.30/.31/.31/.32/.32	12.5	200,000	46,000	154,000	55,000
MET01293	3.28	<.10	14.5	54	2	52	NP-EQUIP
	8.20	<.10	14.5	100	0	100	NP-EQUIP
	13.12	<.10	10	400,000	32,000	368,000	155,000
	18.04	<.10	14.5	50	0	50	NP-EQUIP
MET01393	3.28	<.10	3	510,000	74,000	436,000	173,000
	8.20	<.10	8	480,000	54,000	426,000	181,000
	13.12	<.10	5	520,000	72,000	448,000	188,000
	18.04	<.10/<.10/.20/.20/.20	14.5	880	12	868	NP-EQUIP
	22.96	<.10	6.5	470,000	75,000	395,000	189,000
	27.88	.19/.19/.19/.19/.19	13.5	570	58	512	NP-EQUIP
	32.80	<.10	13	52	0	52	NP-EQUIP
	37.72	<.10	13	540	22	518	NP-EQUIP
MET01493	3.28	<.10	14	22	0	22	NP-EQUIP
	8.20	.20/.20/.20/.20/.20	6	520,000	118,000	402,000	133,000
	13.12	.19/.19/.19/.19/.19	5	480,000	107,000	373,000	160,000
	18.04	<.10	5	540,000	118,000	422,000	161,000
	22.96	<.10/.20/.20/.20/.19	7.5	440,000	49,000	391,000	168,000
	27.88	.20/.20/.20/.20/.20	6	510,000	108,000	402,000	175,000
	32.80	.19/.20/.20/.20/.20	7.25	450,000	75,000	375,000	190,000
	37.72	.23/.23/.23/.23/.23	6	470,000	102,000	368,000	170,000
	42.64	.24/.24/.24/.24/.24	13.5	200,000	43,000	157,000	62,000
MET01593	3.28	<.10	0	370	4	366	NP-EQUIP
	8.20	<.10	0	640,000	147,000	493,000	114,000
	13.12	<.10	0	520,000	48,000	472,000	114,000
	18.04	<.10	2	430,000	30,000	400,000	202,000
	22.96	<.10	1	470,000	45,000	425,000	213,000
	27.88	<.10	2.75	470,000	82,000	388,000	199,000
	32.80	.31/.35/.31/.28/.25	12.5	310,000	79,000	231,000	59,000
MET01693	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
MET01793	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
MET01893	3.28	.22/.22/.22/.22/.22	0	140	24	116	NP-EQUIP
	8.20	<.10	12.75	250	98	152	NP-EQUIP
	13.12	<.10	12.50	140	0	140	NP-EQUIP
MET01993	3.28	<.10	11.75	140,000	35,000	105,000	52,000
	8.20	<.10	7.5	105	3	102	NP-EQUIP
	13.10	<.10	12.0	38	0	38	NP-EQUIP
MET02093	3.28	<.10	10.0	92	0	92	NP-EQUIP
	8.20	.25/.25/.25/.25/.25	7.0	470,000	112,000	358,000	86,000
	13.10	.19/.19/.19/.19/.19	0	570,000	152,000	418,000	103,000
	18.04	.19/.19/.19/.19/.19	0	600,000	122,000	478,000	78,000

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in. Hg)	Total Organic Gases(ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
	22.96	.19/.19/.19/.19/.19	8	100	0	100	NP-EQUIP
	27.88	<.10	5.5	590,000	85,000	505,000	132,000
	32.80	<.10	11	120	26	94	NP-EQUIP
MET02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
MET02293	3.28	<.10	1	360,000	40,000	320,000	135,000
	8.20	<.10	0	480,000	95,000	385,000	165,000
	13.12	<.10	0	370,000	15,000	355,000	169,000
	18.04	.37/.44/.44/.44/.44	12	230,000	7,000	223,000	125,000
	22.96	<.10	5	430,000	74,000	356,000	149,000
	27.88	<.10	4.5	470,000	114,000	356,000	145,000
	32.80	<.10	6	440,000	69,000	371,000	160,000
	37.72	<.10	6.5	490,000	95,000	395,000	128,000
	41.00	<.10	6	410,000	10,000	400,000	156,000
	42.64	<.10	12.5	230,000	61,000	169,000	75,000
MET02393	3.28	<.10	5	2,300	46	2,254	4,000
	8.20	<.10	2.5	390,000	43,000	347,000	106,000
	13.12	<.10	14	130,000	23,000	107,000	44,000
	18.04	<.10	13	340,000	54,000	286,000	111,000
	22.96	<.10	12.5	360,000	84,000	276,000	108,000
	27.88	<.10	13.75	230,000	2,000	228,000	94,000
MET02493	3.28	<.10	4	280	2	278	NP-EQUIP
	8.20	<.10	3.5	430,000	76,000	354,000	162,000
	13.12	<.10	6	480,000	67,000	413,000	171,000
	17.71	–	14.5	1,400	80	1,320	NP-EQUIP
MET02593	3.28	<.10	14.5	2	0	2	NP-EQUIP
	8.20	<.10	1	140,000	1,000	139,000	76,000
	13.12	<.10	13.75	38	4	34	NP-EQUIP
MET02693	3.28	<.10	13	≥18,000[5]	≥0	18,000	23,000
	8.20	<.10	12	≥9,000[5]	≥0	9,000	12,000
	13.12	<.10	12	130,000	26,000	104,000	52,000
	18.04	<.10	12	180,000	62,000	118,000	57,000
	22.96	<.10	13	1,800	12	1,788	4,000
MET02793	3.28	<.10	14	48	0	48	NP-EQUIP
	5.90	<.10	0	26	2	24	NP-EQUIP
MET02893	3.28	<.10	0	160,000	27,000	133,000	147,000
	8.20	<.10	0	≥15,000[5]	≥0	15,000	25,000
	13.12	<.10	13.75	1,100	12	1,088	2,000
	18.04	<.10	11	430,000	98,000	332,000	135,000
	22.96	<.10	13.75	740	6	734	2,000
	27.88	<.10	13.5	580	8	572	2,000
	32.80	<.10	14	350	2	348	NP-EQUIP
MET02993	3.28	<.10	13	290	28	262	NP-EQUIP
	8.20	<.10	13	4,200	80	4,180	2,000
	13.12	<.10	12	320,000	66,000	254,000	90,000

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in. Hg)	Total Organic Gases(ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
	18.04	<.10	14	68	2	66	NP-EQUIP
	22.96	<.10	14.5	38	0	38	NP-EQUIP
MET03093	3.28	<.10	0	820	76	744	NP-EQUIP
	8.20	<.10	7.5	170,000	56,000	114,000	88,000
	13.12	<.10	12	170,000	40,000	130,000	85,000
	18.04	<.10	11.5	150,000	45,000	105,000	73,000
	22.96	<.10	12.5	1,900	83	1,817	NP-EQUIP
	27.88	<.10	11.5	4,000	120	3,880	NP-EQUIP
	32.80	<.10	12	5,600	60	5,540	NP-EQUIP
MET03193	3.28	<.10	1	1,000	46	954	NP-EQUIP
	8.20	<.10	12.5	900	64	836	NP-EQUIP
	13.12	<.10	8	520,000	77,000	443,000	175,000
	18.04	<.10	12.5	160,000	41,000	119,000	51,000
	22.96	<.10	9	390,000	67,000	323,000	219,000
MET03293	3.28	<.10	0.25	1,200	8	1,192	NP-EQUIP
	8.20	<.10	0	5,200	120	5,080	NP-EQUIP
	13.12	<.10	11	≥14,000[5]	≥0	14,000	10,000
	18.04	<.10	12	350	12	338	NP-EQUIP
MET03393	3.28	<.10/<.10/<.10/.21/.20	0	5,600	205	5,395	NP-EQUIP
MET03493	3.28	<.10	8	167,390	390	167,000	77,000
	8.20	<.10	5	380,000	84,000	296,000	173,000
	13.12	<.10	5	291,000	64,000	227,000	136,000
	18.04	<.10	9	194,000	60,000	134,000	110,000
MET03593	3.28	<.10	13.5	55	0	55	NP-EQUIP
	8.20	<.10	1	10,000	0	10,000	10,000
	13.12	<.10	11	250,000	48,000	202,000	150,000
	18.04	<.10	13	120	4	116	NP-EQUIP
	22.47	<.10	13.5	92	3	89	NP-EQUIP
MET03693	3.28	<.10	0	18	0	18	NP-EQUIP
	8.20	<.10	5.5	430,000	70,000	360,000	146,000
	13.12	<.10	6	470,000	51,000	419,000	181,000
	18.04	<.10	6.25	480,000	61,000	419,000	178,000
	22.96	<.10	14.5	760	12	748	NP-EQUIP
MET03793	3.28	<.10	14	5	0	5	NP-EQUIP
	8.20	<.10	7	320,000	48,000	272,000	146,000
	13.12	<.10	14.5	52	0	52	NP-EQUIP
	18.04	<.10	14.5	110	0	110	NP-EQUIP
	22.96	<.10	13.5	52	0	52	NP-EQUIP
MET03893	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each methane survey location is within approximately 10 feet of the corresponding cone penetration test (CPT) location. For example, MET02093 is within approximately 10 feet of CPT02093. CPT locations are presented in Figure C-1 (Appendix C).

[2] Prior to collecting a gas sample at a given depth, off-gas pressures were measured and recorded for 5 one-minute intervals. When a detectable off-gas pressure was measured for any of the five one-minute intervals, all five measurements are presented.

[3] A vacuum pump was used to collect gas samples. Prior to collecting a sample, the vacuum created was measured and recorded.

[4] Exact concentration of total gas not available due to low batteries in the Digiflam analyzer.

[5] Concentration of total gas was between detection limits of the Digiflam analyzer and the GasTech Tank-Techtor. The Digiflam analyzer was used to detect concentrations above approximately 10,000 ppm, while the GasTech Tank-Techtor was used to measure concentrations below approximately 10,000 ppm.

Definitions:

in. Hg	inches of mercury
NMOCs	non-methane organic compounds
NP-ACC	not performed-access; methane survey not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond.
NP-DUP	not performed-duplication of effort; methane survey not performed at this site because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond and landfill gas measurements were obtained at these locations.
NP-EQUIP	not performed-equipment; instruments used were not capable of detecting low concentrations (i.e., <2,000 ppm) of carbon dioxide.
NP-REF	not performed-refusal; methane survey was not performed at this location due to shallow refusals encountered at this site during the CPT investigation.
ppm	parts per million
psi	pounds per square inch
--	due to equipment malfunction, off-gas pressure not measured

Table 4-6
Results of Soil-Gas Sampling at IHSS 114

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
SGS00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
SGS00293	4.92	Qrf	6.6	<0.005	7.308	<0.005	1.940	<0.005	<0.005	0.013	0.013	0.018	1.113
	8.20	Qrf	5.4	<0.005	5.509	0.081	11.387	<0.005	0.005	0.009	0.010	0.015	0.519
SGS00393	4.92	af	3,478.2	<0.005	2.367	0.147	9.337	<0.005	0.007	0.062	0.013	0.005	1.113
	14.76	af	41,727.2	472.302	17.643	3.558	46.857	<0.005	0.024	2.768	0.032	0.035	<0.005
SGS00493	4.92	af	20,814.9	<0.005	0.413	0.810	12.298	<0.005	<0.005	0.034	0.017	0.415	<0.005
	14.17	af	32,835.8	146.250	<0.005	0.505	11.501	<0.005	0.041	0.017	0.008	0.054	<0.005
	18.04	af	49,598.2	625.720	0.260	0.532	80.562	<0.005	0.011	0.023	0.030	0.015	<0.005
SGS00593	4.92	af	4,512.9	<0.005	3.287	0.074	9.678	<0.005	<0.005	0.013	0.013	<0.005	<0.005
	18.24	Qrf	66,267.8	1,138.456	0.424	0.330	129.070	24.260	0.030	0.016	0.015	<0.005	<0.005
SGS00693	4.92	af	72,199.2	1,708.544	13.333	7.851	57.560	<0.005	0.282	0.252	0.632	0.543	78.783
	13.94	af	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
SGS00793	4.92	af	3,265.0	<0.005	1.390	<0.005	<0.005	<0.005	0.006	0.005	<0.005	0.010	<0.005
	10.66	af	20,201.5	<0.005	1.085	0.108	16.283	<0.005	0.005	0.058	0.009	0.015	<0.005
SGS00893	4.92	af	27,679.4	6.309	3.600	0.355	4.099	<0.005	<0.005	0.009	0.016	0.011	0.223
	10.66	af	56,588.4	459.971	4.279	0.732	92.119	<0.005	0.180	0.252	0.891	0.753	<0.005
SGS00993	4.92	af	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
	7.87	af	83,348.1	228.265	14.282	1.000	74.640	<0.005	0.207	0.315	0.957	0.771	<0.005
	10.66	af	4,239.7	<0.005	4.062	0.561	6.950	<0.005	<0.005	0.007	0.020	0.008	<0.005
SGS01093	4.92	af	79,982.3	3,108.529	24.021	5.020	165.394	<0.005	1.288	2.196	3.887	3.277	<0.005
	13.12	af	69,081.4	2,292.397	19.855	7.436	275.107	<0.005	1.110	2.037	3.697	3.211	<0.005
SGS01193	4.92	af	74,848.2	1,975.750	4.490	0.699	67.638	<0.005	0.017	0.119	0.015	0.017	4.525
	9.84	af	84,390.3	1,834.721	13.157	7.454	131.404	148.340	0.054	1.261	0.109	0.127	<0.005
SGS01293	4.92	af	31,209.7	<0.005	5.612	0.763	13.664	<0.005	0.920	1.543	3.373	2.802	0.371
	9.84	af	48,916.8	676.191	6.170	2.389	29.037	<0.005	0.662	1.135	1.805	1.335	<0.005

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
	15.58	af	23,785.1	40.721	5.173	0.518	24.994	<0.005	0.740	1.166	2.180	1.667	0.223
SGS01393	4.92	af	47,712.6	759.639	6.357	1.679	44.295	<0.005	0.874	1.636	4.740	4.404	<0.005
	19.02	af	84,514.5	1,759.302	80.010	21.866	145.296	<0.005	0.641	2.928	2.819	2.430	<0.005
	23.78	af	75,164.8	1,652.625	32.656	26.007	115.064	<0.005	0.504	3.824	2.284	1.899	<0.005
SGS01493	4.92	af	57,335.5	798.352	8.455	0.432	78.455	<0.005	0.090	0.046	0.016	0.010	<0.005
	36.08	af	27,609.7	88.897	0.857	0.271	12.753	<0.005	<0.005	0.006	0.007	<0.005	0.148
SGS01593	4.92	af	56,003.9	322.610	6.884	1.784	79.253	<0.005	0.240	0.948	1.253	0.945	<0.005
	27.88	af	107,694.4	1,497.485	27.359	4.326	59.098	<0.005	0.297	0.805	1.016	0.744	<0.005
SGS01693	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
SGS01793	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
SGS01893	4.92	af	10,612.1	145.677	4.662	1.299	6.604	<0.005	0.185	0.346	1.064	0.801	0.223
	7.38	af	143.5	<0.005	2.212	0.389	17.080	<0.005	0.270	0.437	1.159	0.832	0.297
SGS01993	4.92	af	27,654.5	<0.005	22.170	<0.005	6.035	<0.005	0.008	0.103	<0.005	0.010	0.074
	8.20	Qrf	292.5	<0.005	2.350	0.189	20.382	<0.005	0.073	0.095	0.133	0.115	<0.005
SGS02093	4.92	af	73,272.7	730.103	7.049	4.002	43.384	<0.005	0.074	0.099	0.094	0.088	<0.005
	27.88	KaKl(w)	67,085.1	751.897	18.160	0.449	679.966	<0.005	0.131	0.005	5.234	<0.005	<0.005
	32.80	KaKl(w)	61.1	<0.005	7.623	<0.005	<0.005	<0.005	0.005	0.126	<0.005	4.830	0.816
SGS02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
SGS02293	4.92	af	63,551.1	1,027.191	9.525	3.289	34.047	<0.005	0.258	1.041	1.035	0.768	<0.005
	35.26	af	79,584.3	1,924.765	12.155	0.420	43.042	72.890	0.221	0.377	0.962	0.702	<0.005
SGS02393	4.92	af	1,680.2	<0.005	0.491	0.526	27.556	<0.005	<0.005	0.012	0.081	<0.005	0.519
	18.04	af	42,172.3	405.485	4.868	1.547	30.573	<0.005	0.021	0.260	0.011	0.006	<0.005
SGS02493	4.92	af	54,907.9	802.368	17.529	4.557	38.317	<0.005	0.217	0.346	0.759	0.530	<0.005
	10.66	af	67,023.9	3,437.735	18.718	<0.005	43.669	338.700	0.209	0.502	0.910	0.689	<0.005
SGS02593	4.92	af	12,227.5	<0.005	5.013	0.347	10.362	<0.005	0.156	0.245	0.728	0.525	0.742
	8.20	af	61,411.3	580.412	7.742	<0.005	24.254	66.860	0.243	0.250	0.005	0.558	<0.005
SGS02693	4.10	af	24.4	65.382	0.997	0.052	6.43	2.320	<0.005	0.010	0.006	0.006	0.223
SGS02793	4.92	af	946.1	<0.005	4.098	0.168	58.187	<0.005	0.134	0.317	0.673	0.480	0.890
SGS02893	4.92	af	52,083.5	749.024	10.879	<0.005	67.866	1,303.950	0.181	0.030	0.060	1.103	<0.005

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
	22.14	af	69,280.6	3,431.713	23.442	2.947	164.198	<0.005	0.232	0.338	0.919	0.290	<0.005
SGS02993	4.92	af	7,931.1	52.765	2.853	0.247	14.063	<0.005	0.048	0.067	0.207	0.155	0.074
	9.84	af	38,382.7	247.191	5.633	0.347	126.280	<0.005	0.038	0.071	0.203	0.177	0.148
SGS03093	4.92	af	40.6	<0.005	0.703	<0.005	14.404	<0.005	0.005	0.013	0.011	<0.005	<0.005
	16.40	af	57,490.5	575.824	0.672	5.809	59.382	<0.005	0.008	0.011	0.011	0.016	0.668
SGS03193	4.92	af	9,314.8	<0.005	2.440	<0.005	34.331	<0.005	0.151	0.183	0.581	0.461	0.074
	13.12	af	83,035.6	1,355.250	15.514	5.933	190.960	96.690	0.107	0.686	0.282	0.229	<0.005
SGS03293	4.92	af	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
	9.84	af	56,183.0	196.150	0.750	1.262	44.983	<0.005	0.230	0.290	0.778	0.636	0.074
SGS03393	4.26	af	46,726.0	452.515	0.171	0.142	36.096	< 0.005	0.007	0.015	0.007	<0.005	<0.005
	5.12	af	56,181.5	404.338	0.206	0.211	6.377	<0.005	0.006	0.049	0.007	0.034	<0.005
SGS03493	4.92	af	45,191.5	157.950	1.143	0.168	24.482	<0.005	0.010	0.012	0.012	0.010	<0.005
	18.04	af	47,422.4	308.530	1.674	0.129	21.407	<0.005	0.006	0.009	0.007	0.016	0.816
SGS03593	4.92	af	53,933.0	1,007.118	6.429	0.312	58.415	<0.005	0.030	0.008	0.012	0.017	<0.005
SGS03693	4.92	af	69,528.6	1,468.465	9.096	3.405	98.724	<0.005	0.069	1.243	0.055	0.053	<0.005
	18.86	af	8,053.3	<0.005	2.532	0.242	8.597	<0.005	<0.005	0.081	0.021	0.005	<0.005
SGS03793	4.92	af	12,822.1	<0.005	5.220	0.250	10.818	<0.005	<0.005	0.007	0.014	0.010	<00.005
	18.86	af	10,665.7	26.096	4.840	0.170	9.110	<0.005	<0.005	0.023	0.014	0.020	0.074
SGS03893	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each soil gas sampling location is within approximately ten feet of the corresponding cone penetration test (CPT) location. For example, SGS02093 is within approximately ten feet of CPT02093. CPT locations are presented in Figure C-1 (Appendix C).

[2] The stratigraphic units from which soil gas samples were collected are as follows:

af artificial fill

Qrf Rocky Flats Alluvium

KaKl(w) weathered undifferentiated Arapahoe and Laramie Formation

[3] Volatile organic compounds were analyzed onsite using a field gas chromatogram (GC) equipped with a photoionization detector (PID) and a flame ionization detector(FID).

Definitions:

DCE	dichloroethene
IHSS	individual hazardous substance site
ND-GC	no data-gas chromatogram; soil gas samples were not analyzed due to GC malfunction.
NP-ACC	not performed - access; soil gas sampling was not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond.
NP-DUP	not performed - duplication of effort; soil gas sampling was not performed at this location because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond and soil gas samples were collected from these locations.
NP-REF	not performed - refusal; soil gas sampling was not performed at this location due to shallow refusals encountered at this site during the CPT investigation.
TCA	trichloroethane
TCE	trichloroethene

Table 4-7
Results of Soil-Gas Sampling at IHSS 203

		Volatile Organic Compounds (micrograms per liter)[2]								
Sampling Location	Depth (feet)	Acetone	2-Butanone	1,2-DCE	Dichloromethane	1,1,1- TCA	TCE	Benzene	Toluene	Xylenes
SS712593	4.4	ND	0.4	ND	ND	0.08	0.62	ND	ND	ND
SS712693	4.4	0.9	ND	ND	ND	0.5	3	ND	ND	ND
SS712793	4.7	1	ND	ND	ND	0.07	2	ND	ND	ND
SS712893	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
SS712993	4.0	ND	ND	ND	ND	0.02	0.8	ND	ND	ND
SS713093	3.1	1	0.2	ND	ND	0.6	3	ND	ND	ND
SS713193	5.0	0.8	0.7	ND	ND	3	0.4	ND	ND	ND
SS713293	5.0	0.6	ND	ND	0.3	3	0.3	ND	ND	ND
SS713393	5.2	1	0.2	ND	ND	0.4	3	ND	ND	ND
SS713493	4.6	0.2	ND	ND	ND	3	2	ND	ND	ND
SS713593	5.3	0.1	ND	0.3	0.1	2	2	ND	ND	ND
SS713693	5.0	1.3	ND	ND	0.3	4	4	0.4	ND	1
SS713793	5.2	0.3	0.2	0.5	0.01	0.95	0.02	ND	ND	ND
SS713893	5.1	0.3	0.1	ND	0.01	0.93	0.09	ND	ND	ND
SS713993	5.2	0.8	0.1	1	2	0.01	0.08	0.2	1	ND
SS714093	5.2	0.4	ND	3	0.02	0.01	0.3	ND	1	ND
SS714193	5.1	ND	ND	1	0.04	ND	0.04	ND	ND	ND
SS714293	5.2	2	ND	22	0.8	0.03	0.04	1	2	5
SS714393	5.0	1	ND	3	0.3	2	1	ND	ND	ND
SS714493	5.0	0.9	0.4	3	0.03	2	2	0.3	ND	ND
SS714593	3.1	ND	ND	0.1	ND	0.2	0.1	ND	ND	ND
SS714693	5.0	2	0.5	3	0.4	0.3	1	ND	ND	ND
SS714793	5.0	0.5	0.2	9	0.3	0.06	2	0.2	6	12
SS714893	5.1	2	0.5	20	0.1	0.09	0.4	0.4	11	18
SS714993	5.1	3	0.9	25	0.47	0.5	2	0.6	3	8
SS715093	5.0	2	0.7	20	0.07	0.05	0.4	0.6	1	8

		Volatile Organic Compounds (micrograms per liter)[2]								
Sampling Location	Depth (feet)	Acetone	2-Butanone	1,2-DCE	Dichloromethane	1,1,1- TCA	TCE	Benzene	Toluene	Xylenes
SS715193	5.2	0.3	ND	2	0.07	0.03	0.6	ND	ND	ND
SS715293	5.2	ND	ND	ND	3	0.05	0.22	ND	ND	ND
SS715393	5.4	ND	ND	ND	0.8	0.08	0.6	ND	ND	ND
SS715493	5.2	0.5	ND	2	0.3	0.12	3	ND	ND	6
SS715593	5.4	4	1	29	0.2	0.05	1	2	3	23
SS715693	5.0	2	ND	17	0.09	0.4	3	0.7	2	3
SS715793	4.9	2	1	17	0.6	0.2	3	1	31	87
SS715893	4.9	0.7	1	8	2	0.07	1	2	27	79
SS715993	5.3	0.7	1	9	0.1	0.4	2	2	2	12
SS716093	4.7	3	6	ND	ND	0.2	3	ND	ND	3
SS716193	4.9	2	4	0.7	ND	ND	1	0.2	1	4
SS716293	5.1	1	2	15	0.14	0.08	1	1	9	12
SS716393	4.8	1	2	18	0.12	0.32	4	0.6	0.6	1
SS716493	5.0	2	ND	1	ND	0.07	3	ND	0.7	2
SS716593	5.0	ND	ND	ND	ND	0.2	1	ND	ND	0.4
SS716693	5.0	0.8	ND	1	2	0.14	1	ND	9	4
SS716793	5.1	ND	ND	ND	ND	ND	0.3	ND	ND	ND
SS716893	4.8	1	ND	0.7	0.2	1	1	ND	0.5	1
SS716993	5.1	0.4	ND	ND	ND	ND	0.5	ND	ND	1
SS717093	5.0	0.9	0.8	ND	6	0.3	0.8	ND	ND	0.7
SS717193	5.1	3	ND	ND	ND	1	ND	ND	ND	1
SS717293	5.2	1	ND	6	0.06	ND	0.5	0.5	0.9	5
SS717393	5.0	0.9	ND	10	0.08	0.5	4	0.4	0.5	6

[1] Figure C-4 (Appendix C) presents the soil gas sampling locations at IHSS 203.

[2] Volatile organic compounds analyzed using an onsite field gas chromatogram (GC) equipped with a photoionization detector (PID) and an electron capture detector (ECD).

Definitions:

DCE	dichloroethene
IHSS	individual hazardous substance site
ND	no data
TCA	trichloroethane
TCE	trichloroethene

Table 4-8
Results of Leachate–Groundwater Sampling

Sampling Location[1]	Depth Interval[2] (feet)	Volatile Organic Compounds[4] (milligrams per liter)[3]										
		Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
BAT00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
BAT00293	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT00393	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00493	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00593	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00693	18.99-19.35	16.319	0.463	0.045	0.150	4.124	<0.005	0.013	0.025	0.022	0.028	<0.005
BAT00793	16.86-17.22	30.821	0.564	1.128	0.268	4.698	<0.005	<0.005	<0.005	0.020	0.033	<0.005
	20.30-20.66	31.431	1.187	1.235	0.201	0.165	<0.005	<0.005	<0.005	0.012	0.043	<0.005
BAT00893	17.68-18.04	26.804	0.488	7.188	0.328	10.894	<0.005	0.009	0.019	0.074	0.110	<0.005
	20.14-20.50	25.227	0.361	5.889	0.194	8.522	<0.005	0.012	0.016	0.025	0.042	<0.005
	25.06-25.42	24.380	<0.005	20.340	0.370	4.009	<0.005	<0.005	0.024	0.040	0.118	<0.005
BAT00993	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT01093	21.78-22.14	15.817	2.018	5.958	0.982	9.700	<0.005	0.018	0.055	0.203	0.138	<0.005
	27.52-28.70	17.784	11.452	7.701	9.909	21.396	<0.005	0.028	0.180	0.100	0.112	97.774
	33.26-33.62	31.333	21.601	14.671	6.306	38.564	<0.005	0.064	0.122	0.049	0.066	27.745
BAT01193	14.73-15.09	16.488	2.490	0.620	0.420	4.853	<0.005	0.013	0.325	0.030	0.040	<0.005
	27.68-28.37	18.616	1.647	0.619	1.269	3.630	<0.005	0.028	0.087	0.196	0.042	<0.005
	37.03-37.39	15.928	0.329	1.418	0.316	4.020	<0.005	0.011	0.062	0.032	0.029	<0.005
BAT01293	10.30-10.66	8.728	0.240	1.940	0.320	0.275	<0.005	0.039	0.130	0.080	0.095	<0.005
BAT01393	32.44-32.80	12.453	5.270	<0.005	0.219	4.399	<0.005	0.021	0.042	0.168	0.149	<0.005
	34.90-35.26	18.055	0.494	0.335	0.194	3.383	<0.005	<0.005	0.011	0.005	<0.005	<0.005
BAT01493	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT01593	35.72-36.08	19.489	0.184	3.352	0.281	2.777	<0.005	<0.005	0.029	0.007	0.007	<0.005
BAT01693	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
BAT01793	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
BAT01893	9.48-9.84	0.488	0.079	0.320	0.029	0.214	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BAT01993	22.83-23.19	ND-GC	ND-GC	ND-Gc	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC

Sampling Location[1]	Depth Interval[2] (feet)	Volatile Organic Compounds[4] (milligrams per liter)[3]										
		Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
BAT02093	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
BAT02293	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT02393	29.00-23.19	16.090	0.003	1.423	0.976	1.223	< 0.005	0.008	0.254	0.006	0.006	< 0.005
BAT02493	15.22-15.58	20.949	1.849	0.556	0.376	0.214	< 0.005	< 0.005	0.051	< 0.005	< 0.005	< 0.005
BAT02593	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT02693	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT02793	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT02893	26.04-26.40	22.346	1.631	1.316	0.186	5.755	0.080	< 0.005	0.005	0.037	0.073	< 0.005
BAT02993	19.32-19.68	9.878	0.369	0.569	0.159	7.087	< 0.005	0.006	0.017	0.018	0.013	< 0.005
	21.78-22.14	16.787	0.327	0.476	0.090	6.950	< 0.005	< 0.005	0.010	0.010	0.009	< 0.005
BAT03093	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT03193	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT03293	16.04-16.40	22.919	1.842	1.573	0.359	0.262	< 0.005	0.037	< 0.005	< 0.005	0.030	< 0.005
	18.50-18.96	13.714	0.407	3.249	0.354	0.686	< 0.005	0.048	< 0.005	< 0.005	0.005	< 0.005
BAT03393	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03493	20.14-20.50	0.072	0.159	0.331	0.169	0.209	< 0.005	0.026	0.041	0.039	0.044	1.039
BAT03593	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03693	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03793	23.09-23.45	0.728	0.198	0.958	0.098	< 0.005	< 0.005	0.119	< 0.005	0.005	0.293	< 0.005
BAT03893	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each leachate–groundwater sampling location is within approximately ten feet of the corresponding cone penetration test (CPT) location. For example, BAT02093 is within approximately ten feet of CPT02093. CPT locations are presented in Figure C-1 (Appendix C).

[2] In general, the depth interval sampled was 11 centimeters (0.36 foot), which is the length of the filter screen used in the BAT® Enviroprobe. Due to insufficient volume, two 11-centimeter sample intervals were sometimes combined for the purpose of collecting a sufficient sample volume.

[3] Volatile organic compounds were analyzed onsite using a field gas chromatogram (GC) equipped with a photoionization detector (PID) and a flame ionization detector (FID).

Definitions:

DCE	dichloroethene
ND-GC	no data-gas chromatogram; leachate–groundwater samples were not analyzed due to GC malfunction.
NP-ACC	not performed - access; leachate–groundwater sampling was not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond.
NP-DRY	not performed - dry; leachate–groundwater sampling was not performed at this location because nearby groundwater monitoring wells (71193 and 71693) installed during recent OU 7 field activities were dry or nearly dry.
NP-DUP	not performed - duplication of effort; leachate–groundwater sampling was not performed at this site because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond, and leachate–groundwater samples were collected from one of these locations.
NP-REF	not performed - refusal; leachate–groundwater sampling was not performed at this location due to shallow refusals encountered at this site during the CPT investigation.
NS-DRY	not sampled - dry; leachate–groundwater samples were not collected at this location because leachate–groundwater was not encountered during BAT® sampling or because the water table surface was interpreted as being below the top of bedrock.
NS-REF	not sampled - refusal; leachate–groundwater samples were not collected at this location due to shallow refusal encountered during BAT® sampling.
TCA	trichloroethane
TCE	trichloroethene

Table 4-9
PCOCs in Surface Soils at IHSS 203

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Calcium	X	X	49/49	10,064	439 - 87,000
Cobalt		X	49/49	6	1.1 - 27.1
Copper	X	X	49/49	16	5.7 - 34.9
Vanadium		X	49/49	27	8.4 - 66.2
Radionuclides					
Americium-241		X	49/49	0.03	0.00363 - 0.3427
Radium-226	X		28/28	1.0	0.665 - 1.41
Uranium-235		X	49/49	0.039	-0.0149 - 0.199
Polychlorinated Biphenyls					
Aroclor-1254	NA	NA	12/49	40	9.9 - 100
Aroclor-1260	NA	NA	12/49	43	11 - 160
0 to 10 inches					
Metals					
Calcium	X	X	16/16	9,437	972 - 22,300
Copper	X	X	16/16	18	9 - 41.6
Sodium		X	16/16	403	37.8 - 3,000
Polychlorinated Biphenyls					
Aroclor-1254	NA	NA	2/16	46	46 - 95
Aroclor-1260	NA	NA	1/16	44	20 - 100

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations report in picocuries per gram. Polychlorinated biphenyl concentrations reported in micrograms per kilogram.

Definitions:

IHSS	individual hazardous substance site
NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-10
IHSS 203 Surface-Soil Samples Exceeding the Background $UTL_{95/95}$ Concentrations

Analyte	Sample Location	Sample Interval (inches)	Result[1]	Background $UTL_{95/95}$ Concentration[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals						
Calcium	SS716393	0 to 2	16,800	16,659	1.2	see Figure 4-17
Calcium	SS716293	0 to 2	17,100	16,659	1.3	see Figure 4-17
Calcium	SS717393	0 to 2	17,700	16,659	1.3	see Figure 4-17
Calcium	SS717093	0 to 2	18,900	16,659	1.4	see Figure 4-17
Calcium	SS716593	0 to 2	19,900	16,659	1.5	see Figure 4-17
Calcium	SS716993	0 to 2	20,400	16,659	1.5	see Figure 4-17
Calcium	SS716493	0 to 2	24,200	16,659	1.8	see Figure 4-17
Calcium	SS714293	0 to 2	87,000	16,659	6.4	see Figure 4-17
Calcium	SS716793	0 to 10	17,100	16,659	1.3	Distribution correlates with soil type
Calcium	SS717193	0 to 10	17,100	16,659	1.3	Distribution correlates with soil type
Calcium	SS715793	0 to 10	20,900	16,659	1.5	Distribution correlates with soil type
Calcium	SS716993	0 to 10	22,300	16,659	1.6	Distribution correlates with soil type
Cobalt	SS712893	0 to 2	27.1	24	1.1	No spatial correlation
Copper	SS716693	0 to 2	34.9	30	1.6	No spatial correlation
Copper	SS715393	0 to 10	41.6	30	1.9	No spatial correlation
Sodium	SS715393	0 to 10	1,280	1,052	5.1	No spatial correlation
Sodium	SS716793	0 to 10	3,000	1,052	12.0	No spatial correlation
Vanadium	SS714293	0 to 2	66.2	60	1.4	No spatial correlation
Radionuclides						
Americium-241	SS712693	0 to 2	.0623	.058	1.5	see Figure 4-19
Americium-241	SS713093	0 to 2	.08495	.058	2.1	see Figure 4-19
Americium-241	SS712993	0 to 2	.2104	.058	5.2	see Figure 4-19
Americium-241	SS712893	0 to 2	.3427	.058	8.5	see Figure 4-19
Uranium-235	SS715893	0 to 2	.199	.187	1.4	No spatial correlation

[1] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations reported in picocuries per gram.

Definitions:

IHSS	individual hazardous substance site
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level

Table 4-11
PCOCs in Surface Soils at IHSS 114

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Calcium	X	X	22/22	13,351	4,910 - 27,800
Copper		X	22/22	17	8.6 - 81.5
Radionuclides					
Gross Beta		X	22/22	30	23.82 - 53.5
Strontium-89,90		X	16/16	0.26	0.054 - 2.87
Semivolatile Organic Compounds					
2-Methylnaphthalene	NA	NA	1/22	183	200 - 390
Acenaphthene	NA	NA	9/22	186	46 - 800
Acenaphthylene	NA	NA	1/22	176	38 - 390
Anthracene	NA	NA	11/22	190	46 - 650
Benzo(k)fluoranthene	NA	NA	13/22	185	44 - 590
Benzo(ghi)perylene	NA	NA	8/22	190	99 - 450
Benzo(a)pyrene	NA	NA	13/22	282	59 - 1,000
Benzo(b)fluoranthene	NA	NA	16/22	362	64 - 1,400
Benzo(a)anthracene	NA	NA	16/22	294	84 - 1,100
Benzoic Acid	NA	NA	1/15	867	110 - 1,900
Bis(2-ethylhexyl)phthalate	NA	NA	7/22	155	36 - 390
Butylnenzylphthalate	NA	NA	1/22	191	350 - 390
Di-n-Butyl Phthalate	NA	NA	6/22	147	40 - 390
Di-n-Octyl Phthalate	NA	NA	2/22	170	40 - 390
Dibenzo(a,h)anthracene	NA	NA	4/22	165	61 - 390
Dibenzofuran	NA	NA	3/22	177	45 - 390
Fluoranthene	NA	NA	20/22	599	42 - 2,800
Fluorene	NA	NA	9/22	174	37 - 680
Naphthalene	NA	NA	3/22	194	42 - 690
Phenanthrene	NA	NA	19/22	528	64 - 3,500
Pyrene	NA	NA	20/22	597	41 - 2,600

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to a background $UTL_{95/95}$ concentration. The $UTL_{95/95}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations report in picocuries per gram. Semivolatile organic compound concentrations reported in micrograms per kilogram.

Definitions:

IHSS	individual hazardous substance site	PCOCs	potential contaminants of concern
NA	not applicable	X	denotes that analyte was identifed as a PCOC using the test(s) as noted

Table 4-12
IHSS 114 Surface-Soil Samples Exceeding the Background $UTL_{95/99}$ Concentrations

Analyte	Sample Location	Sample Interval (Inches)	Result[1]	Background $UTL_{95/99}$ Concentration[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals						
Calcium	SS718093	0 to 2	17,600	16,659	1.3	see Figure 4-20
Calcium	SS718793	0 to 2	18,500	16,659	1.4	see Figure 4-20
Calcium	SS718893	0 to 2	18,800	16,659	1.4	see Figure 4-20
Calcium	SS718693	0 to 2	19,600	16,659	1.4	see Figure 4-20
Calcium	SS719493	0 to 2	21,900	16,659	1.6	see Figure 4-20
Calcium	SS719093	0 to 2	23,600	16,659	1.7	see Figure 4-20
Calcium	SS719593	0 to 2	27,800	16,659	2.0	see Figure 4-20
Copper	SS718793	0 to 2	43.4	30	2.0	No spatial correlation
Copper	SS718593	0 to 2	81.5	30	3.7	No spatial correlation
Radionuclides						
Gross Beta	SS717993	0 to 2	53.5	53	1.3	No spatial correlation
Strontium-89,90	SS718393	0 to 2	2.87	2.1	2.9	No spatial correlation

[1] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations reported in picocuries per gram.

Definitions:

IHSS individual hazardous substance site

$UTL_{95/99}$ upper tolerance interval of the 99th percentile at the 99-percent confidence level

Table 4-13
PCOCs in Surface Soils at the East Landfill Pond

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Arsenic		X	133/133	5	1.8 - 13.2
Barium		X	133/133	191	56.3 - 1,120
Calcium	X	X	132/132	9,277	1,890 - 5,480
Lead		X	133/133	27	6.4 - 167
Magnesium		X	133/133	2,631	921 - 7,910
Sodium		X	127/133	117	22.6 - 1,280
Strontium	X		9/9	50.1	36.1 - 80.6
Vanadium		X	133/133	31	11.9 - 86.2
Zinc		X	133/133	56	21.5 - 101
Radionuclides					
Americium-241		X	119/119	0.03	0 - 1.076
Radium-226	X	X	79/79	1.0	0.4355 - 1.787
Water-Quality Parameters					
Nitrate/Nitrite		X	104/133	4	1 - 45
0 to 10 inches					
Metals					
Arsenic		X	67/67	5	1.2 - 15.7
Barium		X	67/67	201	30 - 546
Calcium	X	X	67/67	7,790	2,410 - 37,700
Selenium		X	36/67	0.4	0.24 - 2.4
Radionuclides					
Americium-241		X	66/66	0.0088	0.00057 - 0.05813

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] Metal and water-quality parameter concentrations reported in milligrams per kilogram. Radionuclide concentrations report in picocuries per gram.

Definitions:

PCOCs potential contaminants of concern

X denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-14
East Landfill Pond Surface-Soil Samples Exceeding the Background $UTL_{95/95}$ Concentrations

Analyte	Sample Location	Sample Interval (Inches)	Result[1]	Background $UTL_{95/95}$ Concentration[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals						
Arsenic	SS705393	0 to 2	13.2	13	1.5	No spatial correlation
Arsenic	SS702293	0 to 10	15.7	13	1.8	No spatial correlation
Barium	SS705193	0 to 2	1,120	532	2.4	No spatial correlation
Barium	SS708493	0 to 10	544	532	1.2	No spatial correlation
Barium	SS708093	0 to 10	546	532	1.2	No spatial correlation
Calcium	SS711393	0 to 2	18,500	16,659	1.4	see Figure 4-21
Calcium	SS706893	0 to 2	21,800	16,659	1.6	see Figure 4-21
Calcium	SS719793	0 to 2	22,700	16,659	1.7	No spatial correlation
Calcium	SS720293	0 to 2	24,100	16,659	1.8	see Figure 4-21
Calcium	SS709393	0 to 2	24,400	16,659	2.1	see Figure 4-21
Calcium	SS705193	0 to 2	28,600	16,659	2.1	see Figure 4-21
Calcium	SS708293	0 to 2	29,000	16,659	2.5	see Figure 4-21
Calcium	SS705993	0 to 2	34,000	16,659	2.7	see Figure 4-21
Calcium	SS706093	0 to 2	37,200	16,659	3.1	see Figure 4-21
Calcium	SS705293	0 to 2	41,600	16,659	3.2	see Figure 4-21
Calcium	SS720193	0 to 2	43,500	16,659	4.0	see Figure 4-21
Calcium	SS705093	0 to 2	54,800	16,659	2.4	see Figure 4-21
Calcium	SS704393	0 to 10	18,900	16,659	1.4	No spatial correlation
Calcium	SS705593	0 to 10	20,700	16,659	1.5	No spatial correlation
Calcium	SS708093	0 to 10	27,300	16,659	2.0	No spatial correlation
Calcium	SS708593	0 to 10	37,700	16,659	2.8	No spatial correlation
Lead	SS707893	0 to 2	122	62	3.3	see Figure 4-22
Lead	SS708893	0 to 2	167	62	1.5	see Figure 4-22
Lead	SS700593	0 to 2	77.6	62	1.2	see Figure 4-22

Analyte	Sample Location	Sample Interval (Inches)	Result[1]	Background $UTL_{95/95}$ Concentration[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Magnesium	SS700293	0 to 2	7,910	7,718	2.1	No spatial correlation
Selenium	SS710693	0 to 10	1.7	1.4	2.2	see Figure 4-27
Selenium	SS702993	0 to 10	2.1	1.4	2.8	see Figure 4-27
Selenium	SS702593	0 to 10	2.4	1.4	3.2	see Figure 4-27
Sodium	SS708293	0 to 2	1,280	1,052	5.1	No spatial correlation
Vanadium	SS706093	0 to 2	68.2	60	1.5	see Figure 4-24
Vanadium	SS705293	0 to 2	86.2	60	1.9	see Figure 4-24
Zinc	SS707393	0 to 2	101	99	1.1	No spatial correlation
Radionuclides						
Americium-241	SS702593	0 to 2	.05817	.058	1.4	see Figure 4-25
Americium-241	SS700993	0 to 2	.06255	.058	1.5	see Figure 4-25
Americium-241	SS703793	0 to 2	1.076	.058	26.6	see Figure 4-25
Americium-241	SS711493	0 to 10	.05813	.058	1.4	No spatial correlation
Radium-226	SS707593	0 to 2	1.505	1.5	1.4	see Figure 4-26
Radium-226	SS707793	0 to 2	1.513	1.5	1.4	see Figure 4-26
Radium-226	SS710993	0 to 2	1.596	1.5	1.5	see Figure 4-26
Radium-226	SS711393	0 to 2	1.672	1.5	1.5	see Figure 4-26
Radium-226	SS703293	0 to 2	1.681	1.5	1.5	see Figure 4-26
Radium-226	SS711193	0 to 2	1.787	1.5	1.6	see Figure 4-26
Water-Quality Parameters						
Nitrate/Nitrite	SS700493	0 to 2	10	9.6	2.1	see Figure 4-23
Nitrate/Nitrite	SS710193	0 to 2	10	9.6	2.1	see Figure 4-23
Nitrate/Nitrite	SS710493	0 to 2	10	9.6	2.1	see Figure 4-23
Nitrate/Nitrite	SS708293	0 to 2	14	9.6	2.9	see Figure 4-23
Nitrate/Nitrite	SS704093	0 to 2	16	9.6	3.3	see Figure 4-23
Nitrate/Nitrite	SS711093	0 to 2	17	9.6	3.5	see Figure 4-23
Nitrate/Nitrite	SS711393	0 to 2	22	9.6	4.6	see Figure 4-23

Analyte	Sample Location	Sample Interval (Inches)	Result[1]	Background $UTL_{99/99}$ Concentration[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Nitrate/Nitrite	SS701093	0 to 2	31	9.6	6.5	see Figure 4-23
Nitrate/Nitrite	SS710693	0 to 2	41	9.6	8.6	see Figure 4-23
Nitrate/Nitrite	SS710893	0 to 2	45	9.6	9.4	see Figure 4-23

[1] Metal and water-quality parameter concentrations reported in milligrams per kilogram. Radionuclide concentrations reported in picocuries per gram.

Definitions:

$UTL_{99/99}$ upper tolerance interval of the 99th percentile at the 99 percent confidence level

Table 4-15
PCOCs in Subsurface Geologic Materials

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Borehole 70993 - Qc					
Metals					
Aluminum	X		3/3	11,967	11,000 - 12,900
Manganese	X		3/3	240	221 - 262
Radionuclides					
Cesium-137	X		3/3	0.0376	0.006 - 0.070
Uranium-238	X		3/3	1.06	1.013 - 1.11
Volatile Organic Compounds					
4-Methyl-2-pentanone	NA	NA	1/2	32	13 - 58
Toluene	NA	NA	2/2	1,080	160 - 2,000
Total Xylenes	NA	NA	1/2	3	2 - 6
Semivolatile Organic Compounds					
Benzo(a)anthracene	NA	NA	1/3	148	48 - 400
Chrysene	NA	NA	1/3	146	43 - 400
Fluoranthene	NA	NA	1/3	168	110 - 400
Phenanthrene	NA	NA	1/3	165	100 - 400
Pyrene	NA	NA	1/3	168	110 - 400
Borehole 70993 - KaKI(w)					
Metals					
Arsenic		X	5/5	4.5	1.8 - 11.4
Calcium	X		5/5	4,418	3,480 - 5,670
Cobalt	X		5/5	6	3.8 - 11.7
Copper	X		5/5	17	13.2 - 20.8
Lead	X	X	5/5	23.1	17.7 - 31.2
Nickel	X		5/5	12	7.4 - 19.2
Selenium	X		3/5	0.5	0.27 - 1.4
Sodium	X		5/5	720	565 - 939
Strontium	X	X	5/5	91	60.2 - 113
Zinc	X	X	5/5	67	41.9 - 79.3
Radionuclides					
Radium-226	X		5/5	1.19	1.07 - 1.31
Volatile Organic Compounds					
1,1,1-Trichloroethane	NA	NA	1/5	3	2 - 6
Toluene	NA	NA	5/5	334	220 - 580
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/5	192	180 - 400
Butyl Benzyl Phthalate	NA	NA	1/5	328	320 - 860

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Borehole 71093 - Qc					
Metals					
Aluminum	X		4/4	13,175	10,400 - 16,100
Barium	X	X	4/4	298	91.4 - 624
Lead	X		4/4	25	23 - 27.9
Strontium	X		4/4	76	56.5 - 107
Zinc	X		4/4	64	55.1 - 72.2
Radionuclides					
Cesium-137		X	3/3	0.0792	-0.0142 - 0.2386
Volatile Organic Compounds					
Toluene	NA	NA	6/6	288	120 - 550
Water-Quality Parameters					
Nitrate/Nitrite		X	1/3	6,667	1 - 20,000
Borehole 71093 - KaKl(w)					
Metals					
Barium	X	X	6/6	117	24.5 - 254
Calcium	X	X	6/6	7,385	2,770 - 15,900
Cobalt	X	X	6/6	11	2.2 - 21
Copper	X		6/6	20	13.4 - 24.3
Lead	X	X	6/6	22	12.6 - 29
Manganese	X	X	6/6	422	20.2 - 896
Nickel	X		6/6	22	3.1 - 38.2
Selenium	X		4/6	1.0	0.27 - 1.9
Sodium	X		6/6	308	256 - 398
Strontium	X	X	6/6	103	46.6 - 197
Zinc	X	X	6/6	72.5	49.3 - 84.4
Radionuclides					
Radium-226	X		6/6	1.068	0.9136 - 1.256
Strontium-89,90	X		6/6	0.2814	0.0228 - 0.802
Volatile Organic Compounds					
Toluene	NA	NA	6/6	288	120 - 550
Borehole 70493 & 70593 - Qrf					
Metals					
Chromium		X	11/11	26	8.8 - 144
Lead		X	11/11	7	3.4 - 31.4
Radionuclides					
Americium-241	X		11/11	0.002	0. - 0.0035
Cesium-137	X	X	11/11	0.0218	-0.032 - 0.202
Gross Beta	X		11/11	28.14	23.42 - 32.91
Radium-226	X		11/11	0.696	0.592 - 0.848
Radium-228	X	X	11/11	1.576	1.123 - 2.166
Uranium-235	X		11/11	0.0471	-0.0025 - 0.090
Uranium-238	X		11/11	1.078	0.8235 - 1.411

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Volatile Organic Compounds					
Toluene	NA	NA	11/11	95	51 - 200
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	2/11	341	310 - 1,800
Di-n-Octyl Phthalate	NA	NA	1/11	176	120 - 380
Borehole 70493 & 70593 - KaKl(w)					
Metals					
Barium	X		8/8	87	49.3 - 120
Calcium	X	X	8/8	7,203	4,830 - 15,600
Lead	X		8/8	19	15 - 22.3
Strontium	X	X	8/8	62	37 - 88.5
Zinc		X	8/8	48	13.8 - 88.6
Radionuclides					
Radium-226	X		8/8	0.911	0.7725 - 1.085
Volatile Organic Compounds					
Methylene Chloride	NA	NA	2/8	6	5 - 11
Toluene	NA	NA	8/8	172	83 - 240
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/8	183	47 - 430

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations report in picocuries per gram. Organic compound concentrations reported in micrograms per kilogram.

Definitions:

KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
NA	not applicable
PCOCs	potential contaminants of concern
Qc	colluvium
Qrf	Rocky Flats Alluvium
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-16
Subsurface Geologic Material Samples Exceeding the Background $UTL_{95/95}$ Concentration

Analyte	Sample Depth (feet)	Result[1]	Background $UTL_{95/95}$ Concentration[1]
Borehole 70993 - Qc			
None			
Borehole 70993 - KaKl(w)			
Metals			
Arsenic	23.2-27.2	11.4	10
Lead	7.2-11.2	31.20	26
Lead	19.2-23.2	27.10	26
Strontium	7.2-11.2	86.50	32.2
Strontium	11.2-15.2	60.20	32.2
Strontium	15.2-19.2	87.00	32.2
Strontium	19.2-23.2	107.00	32.2
Strontium	23.2-27.2	113.00	32.2
Zinc	7.2-11.2	70.80	68
Zinc	11.2-15.2	73.90	68
Zinc	19.2-23.2	71.00	68
Zinc	23.2-27.2	79.30	68
Borehole 71093 - Qc			
Metals			
Barium	4.1-6.1	624.00	465
Radionuclides			
Cesium-137	0.0-2.1	0.24	0.1
Water-Quality Parameters			
Nitrate/Nitrite	0.0-2.1	20,000.00	66
Borehole 71093 - KaKl(w)			
Metals			
Barium	8.4-12.1	254.00	205
Calcium	12.1-16.1	12,100.00	8,274
Calcium	20.1-24.1	15,900.00	8,274
Cobalt	12.1-16.1	19.20	17
Cobalt	16.1-20.1	21.00	17
Lead	12.1-16.1	26.80	26
Lead	16.1-20.1	29.00	26
Manganese	24.1-28.1	896.00	706
Strontium	8.4-12.1	197.00	32.2
Strontium	12.1-16.1	85.70	32.2
Strontium	16.1-20.1	85.60	32.2
Strontium	20.1-24.1	95.30	32.2
Strontium	24.1-28.1	105.00	32.2
Strontium	28.1-32.1	46.60	32.2
Zinc	12.1-16.1	76.10	68

Analyte	Sample Depth (feet)	Result[1]	Background $UTL_{99/99}$ Concentration[1]
Zinc	16.1-20.1	84.40	68
Zinc	20.1-24.1	80.90	68
Zinc	24.1-28.1	81.60	68
Boreholes 70493 & 70593 - Qrf			
Metals			
Chromium	18.0-20.0	144.00	115
Lead	0.0-2.0	31.40	31
Radionuclides			
Cesium-137	0.0-2.0	0.20	0.1
Radium-228	2.0-4.0	2.01	0.9
Radium-228	4.0-6.0	2.17	0.9
Boreholes 70493 & 70593 - KaKl(w)			
Metals			
Calcium	30.4-34.1	15,600.00	8,274
Strontium	22.0-26.0	37.70	32.2
Strontium	26.0-30.0	37.00	32.2
Strontium	30.4-34.1	88.50	32.2
Strontium	34.1-38.1	78.40	32.2
Strontium	38.1-42.1	51.20	32.2
Strontium	42.1-46.1	71.00	32.2
Strontium	46.1-50.1	64.60	32.2
Strontium	50.1-54.1	67.40	32.2
Zinc	34.1-38.1	88.60	68
Zinc	42.1-46.1	76.10	68

[1] Metal and water-quality parameter concentrations reported in milligrams per kilogram. Radionuclide concentrations report in picocuries per gram.

Definitions:

KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
Qc	colluvium
Qrf	Rocky Flats Alluvium
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level

Table 4-17
Reported Concentrations of Organic Compounds in the East Landfill Pond Sediments

Analyte	Concentrations in Sediment Samples		
	SED70093	SED70193	SED70293
Volatile Organic Compounds (micrograms per kilogram)			
Acetone	ND	130(B)	63
2-Butanone	35	ND	ND
Toluene	180	300	400
Semivolatile Organic Compounds (micrograms per kilogram)			
Acenaphthene	100(J)	ND	ND
Anthracene	160(J)	ND	ND
Benzo(a)anthracene	340(J)	ND	ND
Benzo(a)pyrene	320(J)	ND	ND
Benzo(b)fluoranthene	470(J)	ND	ND
Benzo(ghi)perylene	200(J)	ND	ND
Benzo(k)fluoranthene	130(J)	ND	ND
Benzoic Acid	870(J)	480(J)	260(J)
Bis(2-ethylhexyl)phthalate	80(J)	ND	ND
Bis(2-Chloroisopropyl)ether		ND	47(J)
Chrysene	310(J)	ND	ND
Fluoranthene	830	ND	79(J)
Fluorene	92(J)	ND	ND
Indeno(1,2,3-cd)pyrene	180(J)	ND	ND
Phenanthrene	630(J)	ND	73(J)
Pyrene	750(J)	ND	74(J)

Definitions:

B laboratory qualifier indicating that the chemical was also detected in the laboratory blank
J laboratory qualifier indicating an estimated value below the quantitation limit
ND nondetect

Table 4-18
PCOCs in East Landfill Pond Sediments

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3,4]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[4]
Metals						
Aluminum	X		20,8889	2/2	14,450	12,300 - 16,600
Arsenic	X		10	3/3	4	2.7 - 5
Barium	X		253	3/3	198	174 - 215
Beryllium	X		2	3/3	1.2	0.81 - 1.5
Calcium	X		18,213	2/2	7,070	6,290 - 7,850
Chromium	X		30	3/3	14.7	12.3 - 17.5
Copper	X		32	3/3	16.0	11.2 - 18.6
Iron	X		27,256	2/2	13,500	11,600 - 15,400
Lead	X		137	3/3	29.7	21.6 - 33.7
Magnesium	X		4,961	2/2	2,710	2,170 - 3,250
Nickel	X		22	3/3	12.7	9.3 - 15.3
Potassium	X		2,912	2/2	1,995	1,350 - 2,640
Selenium	X		3	3/3	0.8	0.41 - 1.1
Sodium	X		1,423	2/2	367	286 - 447
Strontium	X		202	2/2	52.5	43.5 - 61.5
Vanadium	X		62	3/3	34	28.8 - 41
Zinc	X		313	3/3	106	49.2 - 187
Radionuclides						
Cesium-137	X		2	3/3	0.458	0.286 - 0.732
Volatile Organic Compounds						
2-Butanone	NA	NA	NA	1/3	17	13 - 35
Toluene	NA	NA	NA	3/3	307	180 - 440
Semivolatile Organic Compounds						
Acenaphthene	NA	NA	NA	1/3	220	100 - 670
Acenaphthylene	NA	NA	NA	2/3	68	63 - 180
Anthracene	NA	NA	NA	1/3	240	160 - 670
Benzo(a)anthracene	NA	NA	NA	1/3	300	340 - 670
Benzo(a)pyrene	NA	NA	NA	1/3	293	320 - 670
Benzo(b)fluoranthene	NA	NA	NA	1/3	343	450 - 670
Benzo(ghi)perylene	NA	NA	NA	1/3	253	200 - 670
Benzo(k)fluoranthene	NA	NA	NA	1/3	230	130 - 670
Benzoic Acid	NA	NA	NA	3/3	537	260 - 870
Bis(2-chloroisopropyl)ether	NA	NA	NA	1/3	259	47 - 790
Bis(2-ethylhexyl)phthalate	NA	NA	NA	1/3	213	80 - 670
Chrysene	NA	NA	NA	1/3	290	310 - 670
Fluoranthene	NA	NA	NA	2/3	415	79 - 830
Fluorene	NA	NA	NA	1/3	217	92 - 670
Indeno(1,2,3-cd)pyrene	NA	NA	NA	1/3	247	180 - 670
Phenanthrene	NA	NA	NA	2/3	346	73 - 670
Pyrene	NA	NA	NA	2/3	386	74 - 750

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] Background $UTL_{99/99}$ concentrations calculated for stream sediment data. There are no background data for pond sediments.

[4] Metal concentrations reported in milligrams per kilogram. Radionuclide concentrations reported in picocuries per gram. Organic compound concentrations reported in micrograms per kilogram.

Definitions:

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted.

Table 4-19
PCOCs in Seep Water (SW097)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes						
Metals						
Antimony		X	38,836	4/20	22	14 - 60.4
Barium	X		72,835	21/21	640	297 - 1550
Calcium	X	X	509,785	21/21	151,000	126,000 - 212,000
Iron	X		1,865,869	21/21	80,510	61,300 - 155,000
Lithium	X		63,325	17/21	48	34 - 107
Magnesium	X		1,212,149	21/21	34,719	29,300 - 49,000
Manganese	X		18,515	21/21	1,611	1,320 - 2,490
Potassium	X		2,438,624	20/21	6,436	5,000 - 11,700
Silicon	X	X	24,211	14/14	13,508	7,060 - 44,000
Sodium	X	X	30,012	21/21	71,367	57,700 - 110,000
Strontium	X		479,063	19/21	919	814 - 1,370
Zinc	X	X	8,611	21/21	2,945	857 - 16,000
Radionuclides						
Gross Beta	X	X	11	10/10	11	3.753 - 17
Strontium-89,90	X	X	1.6	10/10	1.30	0.66 - 4.06
Tritium	X		4,593	22/22	349	-110 - 1500
Water-Quality Parameters						
Nitrite	X		68	6/9	30.33	20.00 - 63.00
Volatile Organic Compounds						
1,1-Dichloroethane	NA	NA	NA	17/20	6	2 - 10
2-Butanone	NA	NA	NA	6/19	12	6 - 76
2-Hexanone	NA	NA	NA	1/20	5	1 - 10
4-Methyl-2-pentanone	NA	NA	NA	5/20	11	10 - 87
Acetone	NA	NA	NA	11/21	33	10 - 220
Benzene	NA	NA	NA	11/20	2	1 - 5
Carbon Disulfide	NA	NA	NA	1/20	3	5 - 6
Chloroethane	NA	NA	NA	15/20	22	10 - 57
Chloromethane	NA	NA	NA	2/20	5	4 - 10
Ethylbenzene	NA	NA	NA	19/20	13	1 - 18
Methylene Chloride	NA	NA	NA	10/20	14	3 - 190
o-Xylene	NA	NA	NA	3/4	6	5 - 8
Tetrachloroethene	NA	NA	NA	2/20	2	1 - 5
Toluene	NA	NA	NA	19/20	38	5 - 88
Total Xylenes	NA	NA	NA	19/20	14	1 - 25
Trichloroethene	NA	NA	NA	11/20	2	1 - 5
Vinyl Acetate	NA	NA	NA	1/19	7	10 - 49
Vinyl Chloride	NA	NA	NA	5/20	5	3 - 11

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Semivolatile Organic Compounds						
2,4-Dimethylphenol	NA	NA	NA	1/4	5	3 - 10
2-Methylnaphthalene	NA	NA	NA	4/4	16	12 - 23
4-Methylphenol	NA	NA	NA	3/4	4	2 - 10
Acenaphthene	NA	NA	NA	4/4	3	2 - 3
Bis(2-ethylhexyl)phthalate	NA	NA	NA	1/4	5	2 - 12
Dibenzofuran	NA	NA	NA	4/4	1	1 - 2
Diethyl Phthalate	NA	NA	NA	4/4	3	1 - 10
Fluorene	NA	NA	NA	4/4	2	2 - 3
Naphthalene	NA	NA	NA	4/4	18	14 - 22
Phenanthrene	NA	NA	NA	4/4	4	4 - 5
Dissolved Analytes						
Metals						
Barium	X		50,456	20/20	567	447 - 673
Calcium	X	X	162,373	20/20	149,500	123,000 - 207,000
Iron	X	X	29,350	20/20	71,050	51,100 - 95,800
Lithium	X		26,486	16/20	47	34 - 111
Magnesium	X		1,263,853	20/20	34,690	28,700 - 47,500
Manganese	X		4,084	20/20	1,581	1,300 - 2,040
Potassium	X		1,451,860	19/20	5,912	3,500 - 8,790
Sodium	X	X	29,989	20/20	71,720	55,100 - 116,000
Strontium	X	X	722	19/20	939	778 - 1,350
Tin	X		29,052	10/19	67	14.8 - 306
Zinc	X		5,130	20/20	1,530	240 - 3430
Radionuclides						
Gross Beta	X		56	13/13	8	0.5469 - 11
Strontium-89,90	X		2	9/9	1.16	0.6806 - 1.933
Uranium-235		X	0.7	12/12	0.1	-0.0094 - 0.7

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{95/95}$ concentration. The $UTL_{95/95}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter.

Definitions:

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-20
PCOCs in Surface Water from the East Landfill Pond (SW098)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes						
Metals						
Arsenic	X		3,485	11/24	2	0.9 - 10
Calcium	X		56,909	25/25	39,745	3,180 - 55,000
Lithium	X		35,577	23/24	81	7.7 - 109
Magnesium	X		1,156,026	25/25	39,640	4,270 - 48,300
Manganese	X		3,024	24/25	101	2.5 - 430
Molybdenum	X		32,559	4/24	38	3 -100
Nickel	X		13,308	17/25	11	6.3 - 40
Potassium	X		1,607,524	25/25	8,816	1,360 - 10,900
Sodium	X	X	39,331	25/25	16,1245	19,900 - 196,000
Strontium	X		241,118	24/24	476	44.9 - 598
Thallium	X		6,503	3/24	3	0.9 - 10
Tin	X		33,567	8/24	58	10 - 100
Radionuclides						
Americium-241	X	X	0.03	18/18	0.011	0.0005655 - 0.075
Gross Alpha	X		29	13/13	2	-0.67 - 5
Gross Beta	X		31	13/13	12	7.9 - 16
Strontium-89,90	X		4.9	5/5	1.4	0.6635 - 1.924
Tritium	X		732	26/26	143	-10 - 257. 8
Uranium-235	X	X	0.3	10/10	0.1	-0.01 - 0.3
Uranium-238	X	X	1.8	10/10	1.1	0.6996 - 1.964
Volatile Organic Compounds						
Acetone	NA	NA	NA	1/21	5	6 - 58
Chlorinated Hydrocarbons			NA			
Methylene Chloride	NA	NA	NA	3/21	3	4 - 8
Vinyl Acetate	NA	NA	NA	1/20	9	10 - 80
Semivolatile Organic Compounds						
Bis(2-ethylhexyl)phthalate	NA	NA	NA	1/8	5	1 - 11
Di-n-Butyl Phthalate	NA	NA	NA	1/8	5	1 - 11
Dissolved Analytes						
Metals						
Antimony	X		154,119	8/23	23	8 - 60
Arsenic	X		3,633	8/20	2	0.7 - 10
Barium	X		52,083	24/24	167	135 - 204
Calcium	X		57,981	24/24	41,182	26,100 - 55,900
Lithium	X		27,567	22/23	86	62.9 - 110
Magnesium	X		1,139,578	24/24	41,914	35,600 - 48,200
Manganese	X		3,798	21/24	63	1 - 250
Molybdenum	X		165,547	8/22	23	2.5 - 100
Nickel	X		14,732	8/23	10	4 - 40

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Potassium	X		1,493,868	24/24	9,308	7,470 - 10,900
Sodium	X	X	38,869	24/24	170,594	142,000 - 197,000
Strontium	X		170,023	23/23	497	366 - 596
Tin	X		296,159	7/21	41	10.4 - 100
Vanadium	X		13,364	8/23	9	2 - 50
Radionuclides						
Gross Alpha	X		30	7/7	1.9	-0.294 - 4.2
Gross Beta	X		26	13/13	12	4.206 - 22
Strontium-89,90	X		2	10/10	1	0.4 - 1.613
Uranium-238	X	X	11.2	15/15	2	0.3 - 15

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{95/95}$ concentration. The $UTL_{95/95}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter.

Definitions:

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-21
PCOCs in Surface Water from the North Groundwater Intercept System Discharge Point (SW099)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes						
Metals						
Barium	X		63,510	15/18	170	59.5 - 382
Calcium	X	X	56,909	19/19	62,968	35,700 - 92,000
Lithium	X		35,577	16/19	16	6.2 - 100
Magnesium	X		1,156,026	19/19	22,826	13,300 - 54,600
Selenium	X		1,710	3/17	4	1 - 37.7
Sodium	X	X	39,331	19/19	44,063	13,700 - 166,000
Strontium	X		241,118	17/19	738	368 - 1,230
Zinc	X		3,708	16/17	33	9.5 - 92.4
Radionuclides						
Americium-241	X	X	0.03	12/12	0.013	0 - 0.052
Gross Alpha	X		29	6/6	3.2	1.512 - 6.002
Uranium-235	X		0.3	6/6	0.15	0.06293 - 0.2733
Uranium-238	X	X	1.8	6/6	2.5	1.67 - 3.652
Volatile Organic Compounds						
Acetone	NA	NA	NA	2/16	6	1 - 17
Benzene	NA	NA	NA	1/17	3	3 - 5
Carbon Disulfide	NA	NA	NA	1/17	3	3 - 5
Methylene Chloride	NA	NA	NA	3/17	3	2 - 18
Semivolatile Organic Compounds						
Bis(2-ethylhexyl)phthalate	NA	NA	NA	1/3	4	2 - 10
Dissolved Analytes						
Metals						
Barium	X		52,083	13/16	162	52.6000 - 370
Cadmium	X		2,411	0/14	NC	1 - 5
Calcium	X	X	57,981	17/17	95,224	35,200 - 643,000
Lead	X		1,203	7/15	3	0.8 - 5
Lithium	X		27,567	12/17	16	4.8 - 100
Magnesium	X		1,139,578	17/17	34,571	14,100.0 - 208,000
Sodium	X	X	38,869	17/17	55,771	13,500 - 198,000
Strontium	X		170,023	16/18	730	528 - 1,200
Radionuclides						
Strontium-89,90	X		2	5/5	1.272	0.5767 - 1.778
Uranium-238	X		11.2	5/5	3.2	0.3 - 6.192

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{95/95}$ concentration. The $UTL_{95/95}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclides concentrations, which are reported in picocuries per liter.

Definitions:

NA	not applicable
NC	not calculated
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-22
PCOCs in Surface Water from the South Groundwater Intercept System Discharge Point (SW100)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes						
Metals						
Calcium	X	X	56,909	8/8	83,163	40,900 - 156,000
Lithium	X		35,577	4/8	32	10 - 100
Magnesium	X		1,156,026	8/8	12,853	5,590 - 21,700
Potassium	X		1,607,524	6/8	14,670	5,000 - 26,000
Selenium	X		1,710	3/8	3	1 - 6.6
Sodium	X	X	39,331	8/8	41,250	21,500 - 86,000
Strontium	X		241,118	5/8	577	323 - 1000
Zinc	X		3,708	8/8	67	10 - 167
Radionuclides						
Americium-241	X	X	0.03	3/3	0.017	0.003996 - 0.041
Gross Beta	X	X	31	3/3	33	20.4 44
Tritium	X		732	5/5	273	16.41 - 450
Water-Quality Parameters						
Nitrite	X		1,576	2/4	29.25	20.00 - 65.00
Volatile Organic Compounds						
1,1-Dichloroethane	NA	NA	NA	1/8	3	5 -7
Chloroethane	NA	NA	NA	1/8	8	10 -25
Ethylbenzene	NA	NA	NA	1/8	4	5 - 15
Methylene Chloride	NA	NA	NA	1/8	4	2 - 17
Toluene	NA	NA	NA	1/8	8	5 - 47
Total Xylenes	NA	NA	NA	1/8	4	5 - 11
Dissolved Analytes						
Metals						
Arsenic	X		3,633	2/11	3	0.9 - 10
Barium	X		52,083	8/11	92	25.6 - 200
Calcium	X	X	57,981	11/11	137,782	36,700 - 268,000
Lithium	X		27,567	6/10	28	10 - 100
Magnesium	X		1,139,578	10/11	17,368	4,660 - 29,800
Manganese	X		3,798	9/11	109	4.5 - 733
Potassium	X		1,493,868	9/11	19,700	5,000 - 32,400
Selenium	X		2,004	4/11	3	1 - 5.5
Sodium	X		38,869	11/11	45,482	19,500 - 86,000
Strontium	X		770,023	8/11	859	265 - 1,600
Zinc	X		3,841	8/10	30	20 - 56
Radionuclides						
Americium-241		X	0.5	2/2	0.4	0.045 to 0.8
Gross Beta	X	X	26	3/3	17	6 - 33
Uranium-238	X	X	11.2	3/3	1.7	0.2 - 2.475

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter.

Definitions:

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-23
PCOCs for UHSU Groundwater

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Dissolved Analytes						
Metals						
Aluminum		X	1,868	156/325	201	5 - 13,700
Antimony		X	55	57/329	25	6 - 66.8
Arsenic	X		1,024	54/321	20	0.7 - 1,000
Barium	X	X	186	330/330	154	7.6 - 940
Cadmium		X	5	24/329	2	1 - 15.8
Calcium	X	X	152,175	330/330	73,581	11,700 - 566,000
Chromium		X	14	68/328	6	2 - 34.3
Cobalt	X	X	48	67/330	18	2 - 68.3
Copper	X	X	44	110/390	26	1 - 1,170
Iron	X	X	1,730	180/325	5,061	2.4 - 146,000
Lithium		X	196	240/327	189	1 - 10,000
Magnesium	X	X	34,481	325/330	16,487	2,700 - 102,000
Manganese	X	X	292	277/330	510	1 - 9,230
Molybdenum		X	202	62/330	515	2 - 9,000
Nickel	X	X	38	121/329	21	2 - 795
Potassium	X		475,297	249/330	2,702	112 - 48,700
Selenium		X	533	76/328	30	1 - 924
Sodium	X	X	160,693	330/330	60,479	5,600 - 493,000
Strontium	X	X	2,022	323/330	758	65.7 - 81,700
Zinc	X	X	66	216/330	45	1.3 - 1,240
Radionuclides						
Gross Beta	X	X	41	312/312	5	-7.2 - 43.17
Radium-226	X	X	0.6	71/71	0.8	0.12 - 2.17
Strontium-89,90	X	X	2.2	230/230	0.5	-0.18 - 11.17
Total Analytes						
Metals						
Aluminum	X	X	26,324	164/173	15,953	13 - 456,000
Antimony	X	X	52	26/169	27	8 - 115
Arsenic	X	X	8	86/172	5	0.7 - 70.70
Barium	X	X	311	163/173	314	16.1 - 5,060
Beryllium	X	X	4	41/171	3	0.8 - 32
Cadmium		X	4	35/173	3	1 - 19
Calcium	X	X	148,662	173/173	80,210	14,300 - 560,000
Chromium	X	X	192	120/174	26	2 - 580
Cobalt	X	X	44	72/173	22	2 - 228
Copper	X	X	42	109/173	160	2 - 7,140
Iron	X	X	32,398	168/173	27,358	16.4 - 656,000
Lead	X	X	20	133/173	14	1 - 263
Lithium	X	X	177	132/173	38	2.6 - 266

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Magnesium	X	X	33,725	171/173	19,479	3,010 - 118,000
Manganese	X	X	643	170/173	841	2.2 - 9,260
Mercury	X	X	0.2	22/173	0.2	0.2 - 1.50
Molybdenum		X	204	29/170		2 - 60.3
Nickel	X	X	101	107/173	41	2 - 1,070
Potassium	X	X	5,243	155/173	5,098	319 - 47,800
Selenium	X	X	131	29/165	27	1 - 815
Silicon	X	X	62,830	121/121	34,223	2,720 - 288,000
Silver	X	X	7	23/173	38	2 - 3,040
Sodium	X	X	147,829	172/172	59,379	8,200 - 1,230,000
Strontium	X	X	1,110	164/168	538	83.2 - 3,720
Tin		X	170	38/169	76	10 - 267
Vanadium	X	X	71	115/172	40	2 - 754
Zinc	X	X	184	148/171	185	6.3 - 8,000
Radionuclides						
Americium-241	X	X	0.04	267/267	0.01	-0.43 - 0.63
Cesium-137		X	1.1	140/140	0.1	-0.756 - 1.13
Radium-226	X	X	1.29	7/7	0.60	0.35 - 1.32
Strontium-89,90	X		1.2	19/19	0	0 - 1
Volatile Organic Compounds						
1,1-Dichloroethane	NA	NA	NA	63/393	3	0.5 - 50
1,1-Dichloroethene	NA	NA	NA	36/394	4	1 -100
1,1,1-Trichloroethane	NA	NA	NA	68/393	9	2 - 370
1,1,2-Trichloroethane	NA	NA	NA	2/394	2	0.4 - 50
1,2-Dichloroethene	NA	NA	NA	72/388	4	1 - 130
1,2-Dichloropropane	NA	NA	NA	20/394	3	1 - 50
1,4-Dichlorobenzene	NA	NA	NA	3/56	5	6 - 100
2-Butanone	NA	NA	NA	6/276	13	2 - 1,300
2-Hexanone	NA	NA	NA	3/374	5	2 - 100
4-Methyl-2-pentanone	NA	NA	NA	8/378	12	3 - 1,100
Acetone	NA	NA	NA	40/358	12	1 - 990
Benzene	NA	NA	NA	33/393	3	0.1 - 50
Bromodichloromethane	NA	NA	NA	1/394	3	1 - 50
Bromoform	NA	NA	NA	2/394	2	1 - 50
Carbon Disulfide	NA	NA	NA	2/389	3	0.1 - 50
Carbon Tetrachloride	NA	NA	NA	18/393	3	1 - 50
Chlorobenzene	NA	NA	NA	5/394	3	0.3 - 50
Chloroethane	NA	NA	NA	13/393	6	2 - 83
Chloroform	NA	NA	NA	35/393	3	1 - 50
Ethylbenzene	NA	NA	NA	18/394	4	0.3 - 110
Methylene Chloride	NA	NA	NA	59/391	3	0.4 - 50
Tetrachloroethene	NA	NA	NA	80/391	4	0.4 - 170
Toluene	NA	NA	NA	32/394	7	0.2 - 580
Total Xylenes	NA	NA	NA	25/393	6	0.4 - 270

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{99/99}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Trichloroethene	NA	NA	NA	100/392	9	1 - 190
Vinyl Chloride	NA	NA	NA	26/394	5	2 - 100
Semivolatile Organic Compounds						
2-Chloronaphthalene	NA	NA	NA	1/56	5	5 - 100
2-Methylphenol	NA	NA	NA	3/55	5	3 - 100
2,4-Dimethylphenol	NA	NA	NA	4/55	5	7 - 100
2,4,5-Trichlorophenol	NA	NA	NA	1/55	25	3 - 500
4-Methylphenol	NA	NA	NA	11/55	84	6 - 2,100
4-Nitrophenol	NA	NA	NA	1/53	26	42 - 500
Acenaphthene	NA	NA	NA	2/56	5	2 - 100
Benzoic Acid	NA	NA	NA	11/48	102	6 - 1,300
Bis(2-ethylhexyl)phthalate	NA	NA	NA	16/56	7	2 - 100
Di-n-Butyl Phthalate	NA	NA	NA	5/56	5	2 - 100
Diethyl Phthalate	NA	NA	NA	11/56	8	3 - 50
Fluorene	NA	NA	NA	1/56	5	2 - 100
Naphthalene	NA	NA	NA	9/56	6	3 - 100
Pentachlorophenol	NA	NA	NA	3/55	25	4 - 500
Phenanthrene	NA	NA	NA	3/56	5	2 - 100
Phenol	NA	NA	NA	4/55	10	8 - 130
Water-Quality Parameters						
Chloride		X	63,635	295/318	54,593	760 - 530,000
Cyanide		X	12	29/225	5	-0.6 - 20
Fluoride		X	2,024	316/326	542	100 - 8,600
Nitrate/Nitrite	X	X	55,685	276/313	7,258	20 - 290,000
Sulfate		X	613,607	322/326	175,331	500 - 19,000,000
Total Dissolved Solids		X	1,290,550	342/342	550,219	85,000 - 5,100,000

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration. The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter.

Definitions:

NA not applicable
PCOCs potential contaminants of concern
UHSU upper hydrostratigraphic unit
X denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-24
PCOCs for LHSU Groundwater

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Dissolved Analytes						
Metals						
Aluminum	X	X	214	20/39	79	13 - 264
Antimony		X	56	9/39	23	10 - 97.1
Arsenic		X	8	8/39	5	0.7 - 39.80
Barium	X	X	136	37/39	175	9.40 - 516
Beryllium	X	X	NA	1/39	2	0.3 - 5
Cadmium	X	X	5	4/39	2	1 - 9.6
Calcium	X	X	104,319	39/39	71,485	13,000 - 601,000
Chromium	X	X	13	9/39	8	2 - 67.9
Cobalt	X	X	53	3/39	17	2 - 50
Copper	X	X	23	16/39	11	1 - 63
Iron		X	135	24/39	48	2.6 - 288
Lead		X	9	5/39	2	0.7 - 100
Lithium	X	X	134	32/39	49	10.7 - 261
Magnesium	X	X	19,990	37/39	13,238	1,280 - 185,000
Manganese	X	X	32	32/39	37	1 - 195
Mercury		X	0.7	0/38	NC	0.1 - 0.2
Molybdenum	X	X	163	22/39	63	4 - 435.00
Nickel	X	X	39	10/39	17	2.1 - 125
Potassium	X	X	7,544	38/39	4,386	1,560 - 12,100
Selenium	X	X	6	12/39	12	1 - 360
Silver	X	X	16	9/39	5	2 - 11.5
Sodium	X	X	601,966	39/39	185,046	31,900 - 490,000
Strontium	X	X	1,471	39/39	794	185 - 5,700
Thallium	X	X	7.62	1/39	4	1.00 - 10
Tin	X	X	199	6/39	63	10 - 152
Zinc		X	47	20/39	14	2 - 91.2
Radionuclides						
Gross Alpha	X	X	26.3	3/3	14.8	2.9 - 33.1
Gross Beta	X	X	14	50/50	6	1.36 - 16.27
Strontium-89,90		X	1.25	22/22	0.29	-0.039 - 0.980
Uranium-235		X	0.25	50/50	0.06	-0.021 - 0.334
Uranium-238	X	X	6.3	50/50	1.2	0 - 4.196
Total Analytes						
Metals						
Aluminum		X	13,788	19/19	14,795	1,140 - 79,800
Arsenic		X	11	12/19	6	0.7 - 36.40
Barium	X	X	1,424	19/19	272	27.70 - 1,180
Calcium	X	X	127,687	19/19	39,174	22,700.00 - 108,000
Chromium	X		1,210	17/19	36	3.00 - 204

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Background $UTL_{95/95}$ Concentration[3]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Copper		X	1,338	19/19	33	3.3 - 229
Iron		X	18,339	19/19	14,831	1,020 - 63,400
Lead		X	22	18/19	19	1.1 - 115
Lithium		X	150	15/19	30	10.8 - 91.9
Magnesium	X		28,140	19/19	9,994	2,850 - 27,000
Manganese		X	615	19/19	196	30.70 - 616
Nickel	X		1,266	9/19	32	3 - 173
Potassium		X	8,801	19/19	5,366	3,110 - 11,700
Selenium	X	X	5	8/19	2	1.00 - 3.10
Silicon		X	44,790	16/16	25,951	4,210 - 88,900
Silver		X	236	2/19	4	2 - 5.3
Sodium	X	X	659,404	19/19	75,189	32,700 - 437,000
Strontium	X	X	1,720	19/19	474	241 - 1,470
Tin		X	221	3/19	55	10 - 53.2
Zinc		X	1,401	19/19	122	14 - 572
Radionuclides						
Americium-241		X	0.072	26/26	0.004	-0.002 - 0.015
Cesium-137		X	1.05	7/7	0.12	-0.23 - 0.48
Tritium		X	1,779	52/52	12	-330 - 300
Uranium-235		X	0.27	1/1	0.08	0.08 - 0.08
Volatile Organic Compounds						
1,1-Dichloroethene	NA	NA	NA	1/64	2	2 - 5
1,1,1-Trichloroethane	NA	NA	NA	1/64	3	5 - 10
Acetone	NA	NA	NA	6/58	6	4 - 36
Chlorobenzene	NA	NA	NA	1/64	2	1 - 5
Methylene Chloride	NA	NA	NA	14/64	4	1 - 19
Toluene	NA	NA	NA	5/64	3	1 - 5
Total Xylenes	NA	NA	NA	1/64	2	1 - 5
Semivolatile Organic Compounds						
Bis(2-ethylhexyl)phthalate	NA	NA	NA	2/14	6	4 - 24
Di-n-Butyl Phthalate	NA	NA	NA	1/14	5	5 - 11
Naphthalene	NA	NA	NA	1/14	5	2 - 11
Water-Quality Parameters						
Nitrate/Nitrite		X	4,180	36/44	858	20 - 2400

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs.

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{95/95}$ concentration. The $UTL_{95/95}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level.

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter.

Definitions:

LHSU	lower hydrostratigraphic unit	PCOCs	potential contaminants of concern
NA	not applicable	X	denotes that analytes was identified as a PCOC using the test(s) noted

Table 4-25
Frequency of Detection of Organic Compounds in Groundwater

Analyte	Detection Frequency	Total VOCs	Total Chlorinated VOCs	Total BTEX	Total SVOCs
			UHSU		
Volatile Organic Compounds					
1,1,1-Trichloroethane	68/393	X	X		
1,1,2-Trichloroethane	2/394				
1,1-Dichloroethane	63/393	X	X		
1,1-Dichloroethene	36/394	X	X		
1,2-Dichloroethene	72/388	X	X		
1,2-Dichloropropane	20/294	X	X		
2-Butanone	6/276				
2-Hexanone	3/374				
4-Methyl-2-pentanone	8/378				
Acetone	40/358	X			
Benzene	33/393	X		X	
Bromoform	2/394				
Carbon Disulfide	2/389				
Carbon Tetrachloride	18/393	X	X		
Chlorobenzene	5/394				
Chloroethane	13/393				
Chloroform	35/393	X	X		
Ethylbenzene	18/394	X		X	
Methylene Chloride	59/391	X	X		
Tetrachloroethene	80/391	X	X		
Toluene	32/394	X		X	
Total Xylenes	25/393	X		X	
Trichloroethene	100/392	X	X		
Vinyl Chloride	26/394	X	X		
Semivolatile Organic Compounds					
1,4-Dichlorobenzene	3/56	X	X		
2,4,5-Trichlorophenol	1/55				
2,4-Dimethylphenol	4/55				X
2-Chloronaphthalene	1/56				
2-Methylphenol	3/55				X
4-Methylphenol	11/55				X
4-Nitrophenol	1/53				
Acenaphthene	2/56				
Benzoic Acid	11/48				X
Bis(2-ethylhexyl)phthalate	16/56				X
Bromodichloromethane	1/394				
Di-n-Butyl Phthalate	5/56				X
Diethyl Phthalate	11/56				X
Fluorene	1/56				
Naphthalene	9/56				X

Analyte	Detection Frequency	Total VOCs	Total Chlorinated VOCs	Total BTEX	Total SVOCs
Pentachlorophenol	3/55				X
Phenanthrene	3/56	X	X		X
Phenol	4/55				X
LHSU					
Volatile Organic Compounds					
1,1,1-Trichloroethane	1/64	X	X		
1,1-Dichloroethene	1/64	X	X		
Acetone	6/58	X			
Chlorobenzene	1/64	X	X		
Methylene Chloride	14/64	X	X		
Toluene	5/64	X		X	
Total Xylenes	1/64	X		X	
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	2/14				X
Di-n-Butyl Phthalate	1/14				X
Naphthalene	1/14				X

Definitions:

BTEX benzene, toluene, ethylbenzene, and xylenes
LHSU lower hydrostratigraphic unit
SVOCs semivolatile organic compounds
UHSU upper hydrostratigraphic unit
VOCs volatile organic compounds
X denotes that analyte was used to calculate total concentrations

Table 4-26
Results of UHSU Statistical Comparisons

Data Compared to Sitewide Background Data	Number of Analytes Identified as PCOCs using Statistical Inference Tests		
	Metals (Dissolved/Total)	Radionuclides (Dissolved/Total)	Other
All OU 7 UHSU Data[1]	14/25	2/2	1 (Nitrate/Nitrite)
Landfill UHSU Data	12/23	2/2	1 (Nitrite)
Downgradient UHSU Data	12/9	5/2	1 (Nitrate/Nitrite)

[1] Used to develop OU 7 PCOC liist

Definitions:

OU operable unit
PCOCs potential contaminants of concern
UHSU upper hydrostratigraphic unit

Table 4-27
Results of LHSU Statistical Comparisons

Data Compared to Sitewide Background Data	Number of Analytes Identified as PCOCs Using Inferential Statistical Tests		
	Metals (Dissolved/Total)	Radionuclides (Dissolved/Total)	Other
Downgradient OU 7 LHSU Data[1]	20/8	3/0	None
Upgradient LHSU Data	6/14	1/1	None

[1] Used to develop OU 7 PCOC list

Definitions:

LHSU lower hydrostratigraphic unit
OU operable unit
PCOCs potential contaminant of concerns

Table 4-28
Summary of PCOCs by Media

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Dissolved Analytes (in water)					
Metals					
Aluminum					X
Antimony				X	X
Arsenic				X	X
Barium				X	X
Beryllium					X
Cadmium				X	X
Calcium				X	X
Chromium					X
Cobalt					X
Copper					X
Iron				X	X
Lead				X	X
Lithium				X	X
Magnesium				X	X
Manganese				X	X
Mercury					X
Molybdenum				X	X
Nickel				X	X
Potassium				X	X
Selenium				X	X
Silver					X
Sodium				X	X
Strontium				X	X
Thallium					X
Tin				X	X
Vanadium				X	
Zinc				X	X
Radionuclides					
Americium-241				X	
Gross Alpha				X	X
Gross Beta				X	X
Radium-226					X
Strontium-89,90				X	X
Uranium-235				X	X
Uranium-238				X	X

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Total Analytes					
Metals					
Aluminum		X	X		X
Antimony				X	X
Arsenic	X	X	X	X	X
Barium	X	X	X	X	X
Beryllium			X		X
Cadmium					X
Calcium	X	X	X	X	X
Chromium		X	X		X
Cobalt	X	X			X
Copper	X	X	X		X
Iron			X	X	X
Lead	X	X	X		X
Lithium				X	X
Magnesium	X		X	X	X
Manganese		X		X	X
Mercury					X
Molybdenum				X	X
Nickel		X	X	X	X
Potassium			X	X	X
Selenium	X	X	X	X	X
Silicon				X	X
Silver					X
Sodium	X	X	X	X	X
Strontium	X	X	X	X	X
Thallium				X	
Tin				X	X
Vanadium	X		X		X
Zinc	X	X	X	X	X
Radionuclides					
Americium-241	X	X		X	X
Cesium-137		X	X		X
Gross Beta	X	X		X	
Gross Alpha				X	
Radium-226	X	X			X
Radium-228		X			
Strontium-89,90	X	X		X	X
Tritium		X		X	X
Uranium-235	X	X		X	X
Uranium-238		X		X	
Volatile Organic Compounds					
1,1-Dichloroethane				X	X
1,1-Dichloroethene					X

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
1,1,1-Trichloroethane		X			X
1,1,2-Trichloroethane					X
1,2-Dichloroethene					X
1,2-Dichloropropane					X
1,4-Dichlorobenzene					X
2-Butanone			X	X	X
2-Hexanone				X	X
4-Methyl-2-pentanone		X		X	X
Acetone				X	X
Benzene				X	X
Bromodichloromethane					X
Bromoform					X
Carbon Disulfide				X	X
Carbon Tetrachloride					X
Chlorobenzene					X
Chloroethane				X	X
Chloroform					X
Chloromethane				X	
Ethylbenzene				X	X
Methylene Chloride		X		X	X
o-Xylene				X	
Tetrachloroethene				X	X
Toluene		X	X	X	X
Total Xylenes		X		X	X
Trichloroethene				X	X
Vinyl Acetate				X	
Vinyl Chloride				X	X
Semivolatile Organic Compounds					
2-Chloronaphthalene					X
2-Methylnaphthalene	X			X	
2-Methylphenol					X
2,4-Dimethylphenol				X	X
2,4,5-Trichlorophenol					X
4-Methylphenol				X	X
4-Nitrophenol					X
Acenaphthene	X		X	X	X
Acenaphthylene	X		X		
Anthracene	X		X		
Benzo(a)anthracene	X	X	X		
Benzo(b)fluoranthene	X		X		
Benzo(k)fluoranthene	X		X		
Benzo(ghi)perylene	X		X		
Benzo(a)pyrene	X		X		
Benzoic Acid	X		X		X

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Bis(2-chloroisopropyl)ether			X		
Bis(2-ethylhexyl)phthalate	X	X	X	X	X
Butyl Benzyl Phthalate	X	X			
Chrysene		X	X		
Di-n-Butyl Phthalate				X	X
Di-n-Octyl Phthalate	X	X			
Dibenz(a,h)anthracene	X				
Dibenzofuran	X			X	
Diethyl Phthalate				X	X
Fluoranthene	X	X	X		
Fluorene	X		X	X	X
Ideno(1,2,3-cd)pyrene			X		
Naphthalene	X			X	X
Pentachlorophenol					X
Phenanthrene	X	X	X	X	X
Phenol					X
Pyrene	X	X	X		
Polychlorinated Biphenyls					
Aroclor-1254	X				
Aroclor-1260	X				
Water-Quality Parameters					
Chloride					X
Cyanide					X
Fluoride					X
Nitrate/Nitrite	X	X			X
Nitrite				X	X
Sulfate					X
Total Dissolved Solids					X

[1] combined PCOCs for IHSS 203 and East Landfill Pond soils

[2] combined PCOCs for surficial deposits and bedrock materials

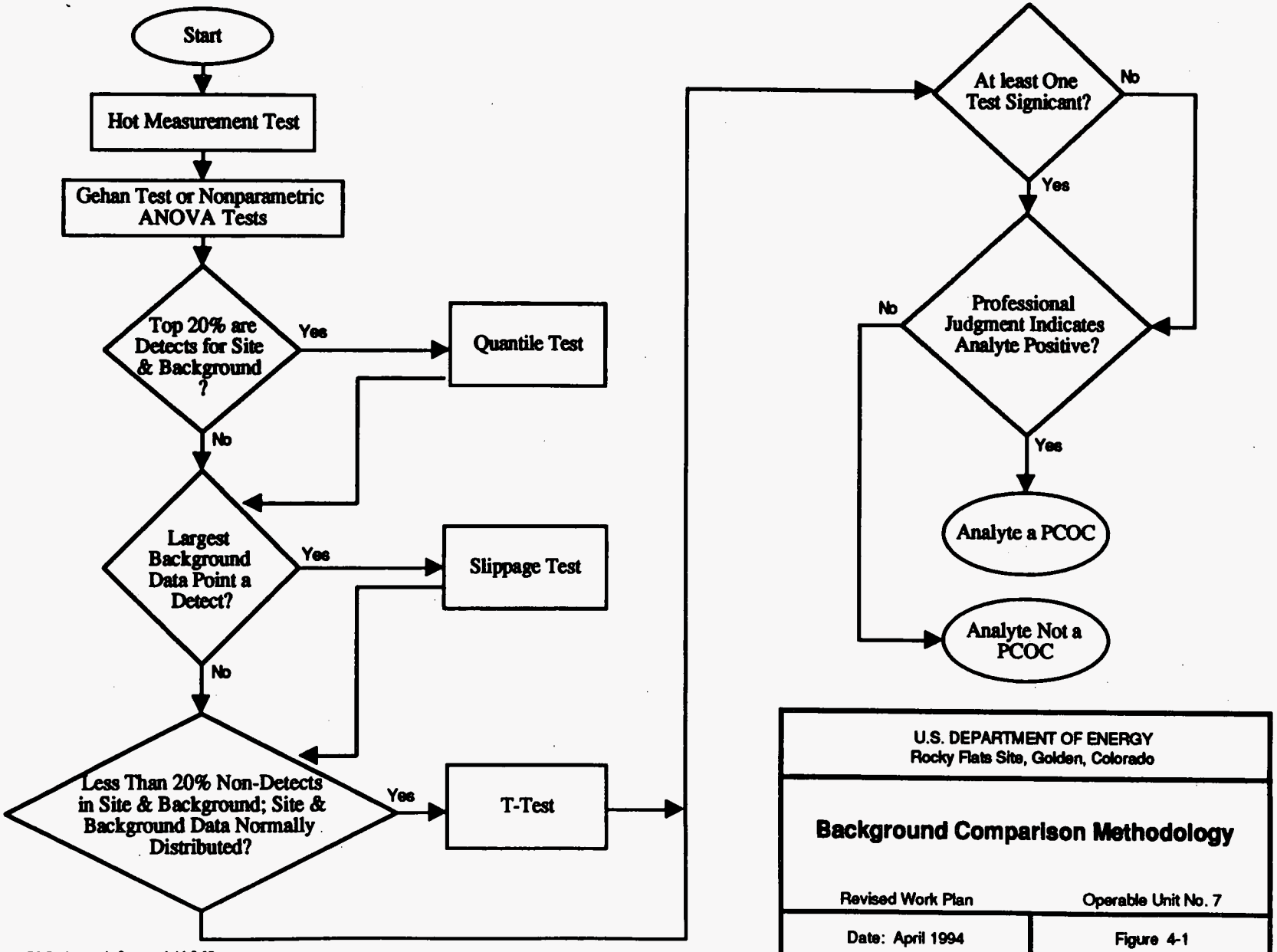
[3] combined PCOCs for seep, East Landfill Pond, and groundwater intercept system discharge

[4] combined PCOCs for UHSU and LHSU groundwater

Definitions:

LHSU lower hydrostratigraphic unit
PCOCs potential contaminants of concern
UHSU upper hydrostratigraphic unit
X denotes that analyte was identified as a PCOC

Section 4
Figures



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U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Background Comparison Methodology

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-1

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CAB for EdMast 10/5/94
Name Date

5. DATA QUALITY OBJECTIVES

DQOs are qualitative and quantitative statements that specify the type, quality, and quantity of the data required to support agency decisions during remedial response activities. The types of data, level of detail, and the data quality needed are determined by the intended uses of the data. The quantity of data needed is determined by formulating mathematical expressions to solve the design problems and calculating the optimum sample size that satisfies DQOs. DQOs should be specified for each data collection activity, and the work should be conducted and documented in a manner that ensures that sufficient data of known quality are collected to support sound decisions about remedial action selection (EPA 1987).

The DQO process consists of these seven steps: (1) state the problem—review prior studies and existing information to gain an acceptable understanding of the problem and concisely describe it, (2) identify the decision—identify the decision that will solve the problem using new data, (3) identify inputs to the decision—identify the information needed to resolve the decision, (4) define the study area boundaries—specify the time period to which the decisions will apply and within which the data should be collected, (5) develop a decision rule—use the outputs from previous steps to devise an "if...then" statement that defines conditions that would cause the decision maker to choose among alternative actions, (6) specify limits on decision errors—define acceptable decision error rates, considering the consequences of making an incorrect decision, and (7) optimize the design for obtaining data—develop alternative sampling designs using information from the previous steps (EPA 1993c). Developing DQOs is an iterative process; the conclusions from any step may influence prior steps and cause them to be redefined.

This section defines the types of decisions that will be made about design of the presumptive remedies, assessment of the nature and extent of groundwater contamination, and development of a focused risk assessment. Decisions were defined by identifying data users, developing a site conceptual model, and specifying objectives for the project. The DQO process presented in the Interim Final Guidance for Planning for Data Collection in Support of

Environmental Decision Making Using the Data Quality Objectives Process (EPA 1993c) was used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7. The DQO process has been integrated with the planning process, and the results are incorporated into the SAP, presented in Section 6 of this report.

5.1 Data Users

Data users are divided into three groups: decision makers, primary data users, and secondary data users. The decision makers for OU 7 are personnel from EG&G, DOE, CDPHE, EPA, and the Natural Resource Trustee who are responsible for decisions related to management, regulation, investigation, and remediation of OU 7. The decision makers are involved through the review and approval process specified in the IAG. Primary data users include project managers, geoscientists, biologists, statisticians, risk assessment scientists, lawyers, and remedial design engineers. They will be involved in data collection, data analysis, human health risk assessment and environmental evaluation to support the National Environmental Policy Act (NEPA) environmental assessment, and design and implementation of an IM/IRA. Secondary data users include database managers, QA personnel, records control personnel, and laboratory managers.

5.2 Assessment of Existing Data

Surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology of the Present Landfill, IHSS 203, the East Landfill Pond, and the adjacent spray evaporation areas within OU 7 are described in Section 2 of this report. The quality and usability of all existing data are discussed in Section 3. Data aggregation and procedures for background comparison and PCOC identification, as well as an assessment of the nature and extent of contamination at the source (the landfill) and in soils, subsurface geologic materials, sediments, surface water, and groundwater, are presented in Section 4. This section presents the rationale used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7. The resulting SAP is presented in Section 6. QA/QC requirements are presented in Section 7.

5.3 Objectives and Approach

For the purpose of streamlined site characterization and site remediation, OU 7 has been divided into three areas: groundwater and surface water, East Landfill Pond sediments and adjacent soils potentially affected by spray evaporation, and the Present Landfill and IHSS 203. The DQO process outlined in the EPA guidance document (EPA 1993c) is most applicable to groundwater and surface water and East Landfill Pond sediments and adjacent soils because the quantitative environmental decisions to be made require the collection of field data. The DQO process is least applicable to the Present Landfill because decisions are made on the basis of presumptive remediation (i.e., experience gained from other similar sites) rather than quantification of environmental decisions, decision error rates, and uncertainty embodied in steps 5 and 6 of the DQO process; and the quantitative method in the DQO process is often not applicable to the types of data needed to support remedial design.

5.4 East Landfill Pond Sediments and Adjacent Soils

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for East Landfill Pond sediments and adjacent soils is described in detail below.

5.4.1 State the Problem

A Phase I RFI/RI was conducted at OU 7 in 1992 and 1993 to characterize the sources of contamination and to describe the nature and extent of contamination present at the source and in soils. Results of the Phase I RFI/RI provide information that describes contamination in East Landfill Pond sediments and adjacent soils where spray evaporation of pond water occurred, such as analyte concentrations in soils collected from two depth intervals (0 to 2 inches and 0 to 10 inches) and analyte concentrations in pond sediments. Information on soil type; vegetative cover over soils; climate data (wind directions, speeds and stability classes; precipitation and evapotranspiration rates); surface runoff rates; migration pathways for contaminants in soil and sediment (wind dispersion, vegetable or plant uptake, leaching, and direct contact); and exposure pathways for human and ecological receptors (inhalation, ingestion, and dermal contact) was also obtained (DOE 1993b). Other sources of data include background geochemical data describing soils (DOE 1993c) and sediments (EG&G 1993a) and

data from sitewide hydrologic and geologic characterization programs (EG&G 1991a, EG&G 1992a, EG&G 1992e, EG&G 1994c).

Data collected during the Phase I RFI/RI are considered usable for site characterization, risk assessment, and remedial design activities. As discussed in Section 4.1, surface soil data will be used for the risk assessment after final closure. Other data collected since 1990 are also considered fully usable. The 1990 data represent the first full year of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and SOPs (EG&G 1992c). Data collected prior to 1990 can be used qualitatively.

Data analysis activities to identify PCOCs for East Landfill Pond sediments and adjacent soils through statistical comparisons of onsite contaminant concentrations versus background concentrations are summarized in Section 4. As agreed by CDPHE, EPA, and DOE, PCOC identification is based on statistically significant differences in analyte concentrations in site data versus background data. Professional judgment is applied only to spatial distribution; temporal distribution; historic information regarding past operations at the site; inter-element correlations; mass balance calculations; and knowledge of hydrology, geochemistry, and geology of the site to determine if analyte concentrations are indicative of contamination. Section 4 also presents the nature and extent of contamination in sediments and surface soils.

Prior to completion of the Phase I RFI/RI and the initiation of Phase II, the focus of the investigations at OU 7 shifted as a result of the presumptive-remedy strategy for streamlined site characterization and site remediation. The presumptive remedy for municipal landfill sites relates primarily to containment of the landfill mass. Preliminary engineering design studies indicate that the landfill cap will extend to the East Landfill Pond embankment. Pond sediments and soils in adjacent spray evaporation areas will be covered by the landfill cap.

The remaining problems are to identify and to describe fully the effects to soils below the East Landfill Pond embankment from contaminant releases from the landfill (leachate that seeps into the pond) and spray evaporation areas around the pond, and to determine the contaminants that present a risk to human health and the environment and the appropriate response action required to reduce those risks.

5.4.2 Identify the Decision

To resolve the remaining problems, it is necessary to determine if concentrations of constituents in soils present a risk to human health or the environment. Then, it is necessary to determine what response actions are required to reduce risk to an acceptable level.

The actions or outcomes that result from resolution of the decision are either no action if there is no risk associated with contaminated environmental media or remediation if contaminated media pose a risk to human health or the environment.

5.4.3 Identify the Inputs to the Decision

To determine whether remediation is needed, information that is not currently available, but required to make a decision, includes estimates of the risk to human health and the environment resulting from exposure to contaminants associated with soils below the East Landfill Pond embankment.

Information needed to estimate exposures and potential toxicity includes contaminant release mechanisms, delineation and characterization of exposure pathways, and delineation of the nature and extent of contamination including volume of contaminated media and total areal concentrations of contaminants.

The approach and methods for estimating exposure to human and ecological receptors will also be required. Contaminants of concern (COCs) for human receptors in soils will be identified. Toxicological information such as slope factors and reference doses (RFD) associated with the COCs will be required, as will exposure point concentrations for COCs. Determination of what constitutes unacceptable risk will be made by risk managers at DOE, CDPHE, and EPA, using site-specific information to develop the criteria.

Response actions will be selected based on the amount of risk reduction required and the remediation technologies available. Specific information needed to screen remediation alternatives includes exposure pathways and points that result in unacceptable risks to human health and ecological receptors. Information on the effectiveness of remedial alternatives in reducing releases and exposures associated with exposure pathways will also be required.

Sources for each item of information have been identified. Approach and methods to use in estimating exposures will be identified in the revised human-health risk assessment exposure scenarios technical memorandum and model description technical memorandum. COCs will be presented in the COC identification technical memorandum, on the basis of site-specific data and toxicity information available through EPA. Toxicological information on COCs will be developed in the toxicity assessment technical memorandum. Each technical memoranda will be approved by CDPHE and EPA for use in the post-closure risk assessment. Data for delineation of the nature and extent of contamination, including the volume and total areal extent of contaminated soil will be collected under the OU 7 FSP (Section 6).

An assessment to determine the risk associated with contaminated soils is needed to determine the action level. EPA-approved field sampling techniques and analytical methods were used to collect the necessary data. The post-closure risk assessment will be performed following EPA guidelines for exposure assessment (EPA 1991b, EPA 1992b).

5.4.4 *Define the Boundaries of the Study*

In general, the geographic area within which all decisions must apply includes all areas within the boundary of OU 7 that will not be covered by the landfill cap.

The population of interest is defined by several characteristics. Soils are defined by the concentrations of PCOCs in soil and the volume and distribution of contaminated soil.

All data collected from 1990 through 1995 will be used to make the decisions.

5.4.5 *Develop Decision Rules*

The first step to developing a decision rule is to specify the parameters that characterize the population of interest. The average areal concentration of each PCOC, concentrations of PCOCs at hot spots, the distribution of contaminants, and the risk associated with contaminants characterizes the extent of contamination in soils. The next step is to specify the action level for the study. For soils, a risk-based value will be the action level.

Two decision rules for the extent of contamination in soils apply.

1. If the concentration of PCOCs in surface soils does not exceed the risk-based standard, no action is required.

2. If the concentration of PCOCs in surface soils exceeds the risk-based standard, removal or risk-reduction actions are required.

5.4.6 Specify Acceptable Limits on Decision Errors

Decision error rates are based on consideration of the consequences of making incorrect decisions. Decision error rates are used to establish appropriate performance goals for limiting uncertainty. Establishing acceptable error rates is necessary prior to determining the appropriate number of data (samples or tests) necessary to support the decision with a specified level of confidence given potential effects on cost, schedule, resource expenditure, human health, and ecological conditions (EPA 1993c).

Two decision errors for surface soils are deciding that analyte concentrations exceed risk-based standards when they actually do not and deciding that analyte concentrations do not exceed risk-based standards when they actually do. The consequence of deciding that analyte concentrations exceed risk-based standards when they actually do not will be the additional cost incurred when excavating surface soils that are not contaminated. The consequence of deciding that analyte concentrations do not exceed risk-based standards when they actually do may possibly endanger human health or the environment. Also, additional costs may be incurred at a later date for environmental cleanup.

To reach a decision, a null hypothesis (H_0) is formulated so that any reading above the risk-based standard (delta) can be detected with a known probability. This probability is known as the power of the test. The power of a statistical test is defined as one minus the Type II error rate. For surface soils, the H_0 is surface soil concentrations exceed risk-based standards. The alternative hypothesis (H_a) is surface soil concentrations do not exceed risk-based standards. False positive decision errors (Type I) occur when the H_0 is erroneously rejected (Table 5-1). This decision error occurs when surface soil concentrations are determined not to exceed risk-based standards when they actually do. False negative decision errors (Type II) occur when the H_0 is erroneously accepted. This decision error occurs when surface soil concentrations are determined to exceed risk-based standards when they actually do not.

To define decision errors and assess potential consequences of incorrect decisions, it is necessary to determine the range of possible concentrations on either side of a numerical standard where the consequences of decision errors are relatively minor (defined by the value delta), assign probability values for Type I and Type II errors (i.e., alpha and beta) that reflect the acceptable probability for the occurrence of decision errors, and check the limits on the decision errors to ensure that they accurately reflect the relative consequences for each type of decision error.

A range of concentrations about the action level (risk-based standard) must be specified where the consequences of decision errors are relatively minor. A range from plus 12.5 percent to minus 12.5 percent of the risk-based standard has been selected to reflect the concentration range where the consequences of decision errors are relatively minor and costs associated with improving the ability of the test to discern between the null and alternative hypotheses are high. Increasing this range decreases the power of the test to detect concentrations greater than the risk-based standard. However, increasing the width of the gray area decreases the number of samples necessary to achieve the desired performance of the test. Choice of an area of plus or minus 12.5 percent of the risk-based standard is a compromise between increased performance of the statistical test and increased cost and schedule impacts. Choice of the Type I error rate was based on common statistical practices.

Probability values to points above and below the action level were chosen to reflect the acceptable probability for the occurrence of decision errors; acceptable decision error rates are chosen as 5 percent for the false positive decision error (Type I error) and 20 percent for the false negative decision error (Type II error).

5.4.7 Optimize the Design

The objective of this step is to identify the most resource-effective sampling design expected to generate data that satisfies the DQOs specified in the preceding steps. The DQO outputs and existing environmental data were reviewed and general sampling and analysis design alternatives were developed.

Statistical methods were used to estimate the sample sizes needed to meet DQOs and support decisions. The sample sizes needed to meet DQOs for comparing mean concentrations of

PCOCs in surface soils against guidance to be considered (TBCs) (EG&G 1994d) or draft preliminary remediation goals (PRGs) were calculated for each PCOC with greater than 50 percent detectable results (EG&G 1994b). Assuming simple random sampling, the following equation (EPA 1993c) was used:

$$n = \frac{\sigma^2 (Z_{1-\beta} + Z_{1-\alpha})^2}{\Delta} + 0.5 (Z_{1-\alpha})^2$$

where:

n	=	number of samples
σ^2	=	sample variance
Z	=	standard normal probability values (from statistical tables)
α	=	Type I error rate
β	=	Type II error rate
Δ	=	25 percent of the TBC (or PRG)

This method was used to calculate the sample sizes required to support decisions and meet the data quality objectives for surface soils as discussed below.

Statistical comparisons identified only three PCOCs in surface soils from the area around the East Landfill Pond. However, numerous additional PCOCs were identified on the basis of UTL exceedances. The sample locations with UTL exceedances are randomly distributed across the site (see Figures 4-17 through 4-27). Sample-size calculations were performed to estimate the number of samples required to characterize the area around the East Landfill Pond.

Table 5-2 presents the results of sample-size calculations for surface soils around the East Landfill Pond. In general, the number of surface soil samples collected during the Phase I RFI/RI far exceed the minimum required to support the DQOs. In cases where existing samples are not sufficient to characterize PCOC concentrations, a large number of samples must be collected. These large sample sizes resulted from large values of the ratio of σ^2/Δ (the sample variance to 25 percent of the TBC). Large values of σ^2/Δ occur when the sample variance is an order of magnitude or greater than the TBC value. In these cases, the sample mean is also orders of magnitude greater than TBC values. Therefore, common sense indicates that these analytes actually exceed TBCs. No further sampling is justified for these analytes because it is conceded that they exceed TBCs. Therefore, the statistics were used to determine realistic sample sizes for those analytes that are not obviously at levels much greater

than TBCs. However, additional sampling is warranted to fully characterize the nature and extent of surface-soil contamination.

Additional sampling is warranted at locations downgradient of the pond beyond the extent of the cap where analyte concentrations or activities exceed TBCs. Because few TBCs exist for soil, the draft PRGs presented in Programmatic Preliminary Remediation Goals for Rocky Flats Plant (EG&G 1994e) were used as substitutes for TBC values if necessary. The draft PRGs are risk-based values. Additional samples will be collected adjacent to locations where the draft PRG value was exceeded to delineate the area of soil where PCOC concentrations or activities exceed PRG values (Table 5-3). Radium-226 activities exceeded the PRG for radium-226 in soil from the 0- to 2-inch horizon at three locations: (1) SS710993, which is on the slope below the northern groundwater intercept system discharge point; (2) SS711193, which is in a small tributary near the bottom of No Name Gulch downgradient of the southern groundwater intercept system discharge point; and (3) SS711393, which is on the slope just below the dam. The activity of americium-241 exceeded the PRG for americium-241 in soil from the 0- to 10-inch horizon at one location, SS711493, which is in the southern surface-water diversion ditch below the dam downslope of the groundwater intercept system discharge point.

Samples were collected systematically on a 100-foot grid in the area below the dam during the Phase I field investigation. The additional samples will be collected systematically on a 25-foot grid around the original sample location during the Phase II field investigation. Systematic sampling designs are the method of choice for estimating trends or patterns of contamination over space (Gilbert 1987). The additional sample locations are presented in the FSP (Section 6).

PCOCs were identified for surface soils at IHSS 114, IHSS 203, and immediately around the East Landfill Pond but presumptive remediation will address contamination. Therefore, no additional surface soil sampling will be performed in these areas.

5.5 Groundwater and Surface Water

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for groundwater and surface water is described in detail below.

5.5.1 State the Problem

A Phase I RFI/RI was conducted at OU 7 in 1992 and 1993 to characterize the sources of contamination and to describe the nature and extent of contamination present at the source and in soils. Other sources of data for OU 7 include background geochemical data (EG&G 1993a); RCRA groundwater monitoring results for the Present Landfill (EG&G 1993c); and data from sitewide groundwater and surface water characterization programs (EG&G 1991a, EG&G 1991e, EG&G 1992e). Results of the Phase I RFI/RI and other investigations provide information on groundwater and surface water quality at the site including dissolved and total analyte concentrations in groundwater from the UHSU and LHSU, and analyte concentrations in surface water from the pond and the two intercept system discharge points. Information to determine groundwater flow paths and hydraulic gradients in the UHSU and LHSU in the vicinity of the landfill, hydraulic conductivity estimates for geologic units in the UHSU and LHSU, migration pathways for contaminants in surface water and groundwater, and exposure point concentrations and exposure pathways for human and ecological receptors described in the Exposure Scenarios Technical Memorandum for OU 7 (DOE 1993b) was also obtained.

Data collected during the Phase I RFI/RI and other investigations are considered usable for site characterization, risk assessment, and remedial design activities. In addition, other data collected since 1990 are considered fully usable because the 1990 data represent the first full year of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific SOPs (EG&G 1992c). Data collected prior to 1990 can be used qualitatively.

Data analysis activities to identify PCOCs for groundwater and surface water through statistical comparisons of OU 7 contaminant concentrations versus background concentrations are summarized in Section 4. As agreed to by CDPHE, EPA, and DOE, PCOC identification is based on statistically significant differences in analyte concentrations in site data versus background data. Professional judgment is applied only to spatial distribution; temporal distribution; historic information regarding past operations at the site; inter-element correlations; mass balance calculations; and knowledge of hydrology, geochemistry, and geology of the site to determine if analyte concentrations are indicative of contamination. Section 4 also presents the nature and extent of contamination in groundwater and surface water.

The remaining problems are to

1. Identify and fully describe the impacts to groundwater resulting from contaminant releases from the landfill (nature and extent of contamination) to determine whether these impacts require a response action;

2. Design a monitoring network that will meet requirements for post-closure care of the Present Landfill based on an analysis of contaminant fate and transport, and plug and abandon existing wells that will not be part of the monitoring network; and

3. Identify discharge requirements for surface water so that the East Landfill Pond can be drained. East Landfill Pond water is currently being transferred to the A-series ponds as an alternative water management practice. The pond water must meet segment 4 water-quality standards before transfer.

5.5.2 *Identify the Decision*

The following three decision questions have been identified to resolve the remaining problems:

1. Are concentrations of PCOCs in UHSU or LHSU groundwater above or below ARARs and will response actions be required?

2. Are locations of existing wells adequate to meet ongoing groundwater monitoring and post-closure care requirements?

3. Are analyte concentrations in surface water above or below discharge requirements (segment 4 water-quality standards) and will response actions be required?

The actions or outcomes that result from resolution of each of the decisions are as follows:

1. No action is required if analyte concentrations in the UHSU or LHSU groundwater are below ARARs. Collection and treatment of groundwater is required if analyte concentrations exceed ARARs.

2. No action is required if locations of wells are adequate for ongoing groundwater monitoring and post-closure care requirements. Additional wells are required if locations of existing wells do not meet requirements for ongoing groundwater monitoring and post-closure care.

3. No action is required if analyte concentrations in surface water are below ARARs. Treatment of surface water prior to discharge is required if analyte concentrations exceed ARARs.

5.5.3 *Identify the Inputs to the Decision*

Information that is not currently available but that will be required to make decisions includes chemical-specific ARARs for OU 7, developed from Rocky Flats benchmarks; location-specific ARARs; action-specific ARARs; requirements for the post-closure groundwater-monitoring program; and vertical and areal extent (downgradient limit) of impacted groundwater.

Sources for each item of information identified above include the draft ARARs document for OU 7 (EG&G 1994d), State Subtitle D and RCRA Subtitle C closure requirements (if applicable), and additional downgradient monitoring wells along groundwater migration pathways from known source areas.

The action level is the measurement threshold that provides the criterion for choosing between alternative actions (EPA 1993c). ARARs are the basis for action levels for groundwater and surface water, when and where available.

EPA-approved field sampling techniques were and will be used to collect the necessary data (EG&G 1992c). Samples collected will be subjected to Level IV and V analytical procedures and reporting requirements. The detection and quantitation limits for analyses are specified in the GRRASP (EG&G 1991g).

5.5.4 *Define the Boundaries of the Study*

The geographic area within which all decisions must apply includes the East Landfill Pond, the groundwater intercept system discharge points for surface water, and the areal extent of contaminant plumes in groundwater in the vicinity of the Present Landfill (includes the vertical extent of contamination).

Each population of interest is defined by several characteristics. UHSU and LHSU groundwater is defined by the concentrations of PCOCs within each HSU and the downgradient limit of concentrations exceeding applicable or relevant and appropriate requirements (ARARs) (EG&G 1994d). The extent of groundwater contamination is defined by the monitoring-well network configuration with respect to current and predicted plume geometry. Surface water from the pond and intercept system discharge points is defined by the concentrations of PCOCs at each location sampled.

All data collected from 1990 through 1995 will be used to make the decision. Practical constraints on the data collection include limited road access in No Name Gulch to collect samples and install wells, if required; wetlands' issues for the drainage; schedule constraints, and sample independence issues on the number and frequency of groundwater samples needed from all groundwater monitoring wells, including new wells in No Name Gulch, if required; and schedule constraints related to the time required to perform laboratory analysis and validate laboratory analytical procedures.

5.5.5 *Develop Decision Rules*

The first step in developing a decision rule is to specify the parameters that characterize the population of interest. The spatial extent of groundwater with concentrations exceeding ARARs provides a means of characterizing UHSU and LHSU groundwater. The average concentration of PCOCs at each well is used to define the spatial extent of groundwater concentrations exceeding ARARs. The average concentration of PCOCs at each sampling location characterizes surface water from the pond and intercept system discharge points. The next step is to specify the action level for the study. ARARs are the action level for groundwater and surface water.

Two decision rules were developed for UHSU and LHSU groundwater.

1. If the concentration of PCOCs does not exceed ARARs, no action is required.

2. If the concentration of PCOCs exceeds ARARs, design and implement a response action as part of the IM/IRA decision document.

Two decision rules were developed for groundwater monitoring requirements.

1. If downgradient monitoring wells are located along migration pathways and are adequate for defining the spatial extent of contamination, no further action is required.

2. If downgradient monitoring wells are not located along migration paths or are not adequate for defining the spatial extent of contamination, install additional monitoring wells to detect contaminant releases downgradient of the landfill to fulfill the monitoring requirements for post-closure care and adequately define the extent of groundwater contamination. Wells will be installed during Phase II and potentially during the IM/IRA for performance monitoring.

Two decision rules were developed for surface water from the pond and intercept system discharge points.

1. If the concentration of PCOCs does not exceed ARARs, no action is required.

2. If the concentration of PCOCs exceeds ARARs, then treat surface water as appropriate.

5.5.6 *Specify Acceptable Limits on Decision Errors*

The decision error rates are based on consideration of the consequences of making incorrect decisions given potential impacts to cost, schedule, resource expenditure, human health, and ecological conditions (EPA 1993c). Decision error rates are used to establish appropriate performance goals for limiting uncertainty. Establishing acceptable error rates is necessary prior to determining the acceptable number of data (samples or tests) necessary to support the decision with a specified level of confidence.

The two decision errors for groundwater and surface water are deciding that analyte concentrations exceed ARARs when they actually do not, and deciding that analyte concentrations do not exceed ARARs when they actually do. The consequence of deciding that analyte concentrations exceed ARARs when they actually do not will be additional cost incurred for installing unneeded treatment systems. The consequence of deciding that analyte concentrations do not exceed ARARs when they actually do could possibly endanger human health or the environment. Also, additional costs may be incurred at a later date for environmental cleanup.

To reach a decision, an H_0 is formulated so that a given concentration above the ARAR (delta) can be detected with a known probability. This probability is known as the power of the test. The power of a statistical test is defined as one minus the Type II error rate. For groundwater and surface water, the H_0 is groundwater or surface water concentrations exceed ARARs. The H_a is groundwater or surface water concentrations do not exceed ARARs. False positive decision errors (Type I) occur when the null hypothesis is erroneously rejected (Table 5-1). This decision error occurs when groundwater or surface water concentrations are determined not to exceed ARARs when they actually do. False negative decision errors (Type II) occur when the H_0 is erroneously accepted. The false negative decision error occurs when groundwater or surface water concentrations are determined to exceed ARARs when they actually do not.

To define decision errors and assess potential consequences of incorrect decisions, it is necessary to determine the range of possible concentrations on either side of a numerical standard (ARAR) where the consequences of decision errors are relatively minor (defined by the value delta), assign probability values for Type I and Type II errors (i.e., alpha and beta) that reflect the acceptable probability for the occurrence of decision errors, and check the limits on the decision errors to ensure that they accurately reflect the relative consequences for each type of decision error.

A range of concentrations about each action level (ARAR) is specified where the consequences of decision errors are relatively minor. A range from plus 12.5 percent to minus 12.5 percent of the ARAR concentration has been selected to reflect the concentration range where the consequences of decision errors are relatively minor and cost and schedule impacts associated with improving the ability of the test to discern between the null and alternative hypotheses are high. Increasing this range decreases the power of the test to detect concentrations greater than the ARAR. However, increasing the range decreases the number of samples necessary to achieve the desired performance of the test. A range of plus or minus 12.5 percent of the ARAR has been chosen as a compromise between increased performance of the statistical test and increased cost and schedule impacts. The Type I error rate was chosen on the basis of common statistical practices.

Probability values to points above and below the action level were chosen to reflect the acceptable probability for the occurrence of decision errors; acceptable decision error rates are

chosen as 5 percent for the false positive decision error (Type I error) and 20 percent for the false negative decision error (Type II error).

5.5.7 Optimize the Design

The objective of this step is to identify the most resource-effective sampling design expected to generate data that satisfies the DQOs specified in the preceding steps. The DQO outputs and existing environmental data were reviewed and general sampling and analysis design alternatives were developed. Widespread contamination is present in the UHSU and additional wells are needed for plume delineation. However, the number and location of additional wells needed to delineate contamination further in UHSU groundwater is determined qualitatively in Section 5.5.7.2 and presented in the FSP (Section 6).

PCOCs were identified in the UHSU, LHSU, and all surface water sampling locations. Sample sizes needed to describe analyte concentrations and make comparisons of mean concentrations to ARARs were calculated for each PCOC with greater than 50 percent detects for groundwater and surface water. Assuming simple random sampling, the following equation (EPA 1993c) was used:

$$n = \frac{\sigma^2 (Z_{1-\beta} + Z_{1-\alpha})^2}{\Delta} + 0.5 (Z_{1-\alpha})^2$$

where:

n	=	number of samples
σ^2	=	sample variance
Z	=	standard normal probability values (from statistical tables)
α	=	Type I error rate
β	=	Type II error rate
Δ	=	25 percent of the ARAR or PRG

The results of sample-size calculations for surface water and groundwater are presented in Table 5-4 and Table 5-5, respectively.

5.5.7.1 Surface Water

The majority of the PCOCs in surface water are adequately characterized by the existing data (Table 5-4). Many of the analytes that are not sufficiently characterized have sample means that are orders of magnitude greater than the value of the ARAR (EG&G 1994d) to which they are compared indicating that some PCOCs clearly exceed ARARs and remediation of surface water will be necessary. Additional data are not likely to affect the decision to remediate surface water. Therefore, the collection of additional samples is not warranted and additional sampling of surface water, beyond that normally conducted as part of the quarterly monitoring program, is not recommended.

5.5.7.2 Groundwater

The majority of PCOCs in groundwater are adequately characterized by existing data (Table 5-5). Some of the PCOCs that are not sufficiently characterized are major ions (aluminum, iron, and manganese) in groundwater. The sample-size calculations indicate that large numbers of samples are required to characterize the concentration of these PCOCs in groundwater for comparison with ARARs. These large sample sizes resulted from large values of the ratio of σ^2/Δ (the sample variance to 25 percent of the ARAR). Large values of σ^2/Δ occur when the sample variance is an order of magnitude or greater than the ARAR value. In these cases, the sample mean is also orders of magnitude greater than ARAR values. Therefore, common sense indicates that these analytes actually exceed ARARs. No further sampling is justified for these analytes because it is conceded that they exceed ARARs. Some PCOCs clearly exceed ARARs and remediation of groundwater will be necessary. Additional data are not likely to affect the decision to remediate groundwater. Therefore, additional groundwater sampling, beyond that normally conducted as part of the quarterly monitoring program, is not recommended. The installation of additional wells, however, is recommended to eliminate the data gaps discussed below.

Sample size calculations for organic compounds were not performed if the analyte was not detected in at least 50 percent of the samples. Sample size calculations for analytes with fewer than 50 percent detections are not appropriate because sample variances may be artificially reduced through substitution of detection limit values for results below the detection limit (nondetects). If multiple detection limits are reported in the data, sample size calculations

would be largely based on the variability of detection limits. Because the statistical methodology was not appropriate, other quantitative techniques were used to determine the data required to characterize contamination of groundwater by organic compounds. The decision to remediate organics in groundwater is based on the analysis of the nature and extent of groundwater contamination (Section 4.7).

Data gaps in the groundwater monitoring network were identified qualitatively based on the site conceptual model and the isoconcentration maps presented in Section 4.7. Additional wells are recommended to characterize potential contaminant migration pathways and improve descriptions of the spatial distributions of contaminants in groundwater. Additional wells are recommended at two locations: (1) downgradient of the East Landfill Pond in No Name Gulch above the confluence with the intermittent stream draining IHSS 167.1 and (2) in No Name Gulch below the confluence with the intermittent stream draining IHSS 167.1. An additional well installed in No Name Gulch above the confluence with North Walnut Creek as part of the sitewide characterization program may also be used to characterize contaminant transport in No Name Gulch.

Groundwater contamination on the south side of the landfill (see Figures 4-31, 4-34, 4-35, 4-36, 4-37) just outside the existing surface-water diversion ditch will be contained within the slurry wall as part of the presumptive remedy for landfill closure. Groundwater contamination farther upgradient of the landfill will be addressed in the Phase I RFI/RI for OU 10, Other Outside Closures, and the Phase I RFI/RI for OU 6, Walnut Creek.

5.6 Present Landfill and IHSS 203

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for the Present Landfill and IHSS 203 is described in detail below.

5.6.1 Statement of the Problem

A Phase I RFI/RI was conducted at the Present Landfill and IHSS 203 in 1992 and 1993 to characterize the sources of contamination within OU 7 and to describe the nature and extent of contamination present at the source and in soils. Results of the Phase I RFI/RI provide information to develop a site hydrogeologic model, to calculate hydraulic conductivity values for

bedrock underlying the landfill, and to describe groundwater flow paths and hydraulic gradients within the landfill.

Information describing the contaminant source, such as total volume and areal extent of landfill waste, depth of landfill waste and elevation of subgrade, qualitative descriptions of waste materials, age of landfill waste, approximate amount of interim soil cover material per lift, and volume of saturated landfill waste was also obtained. The volume and composition of leachate, leachate-head measurements, estimates of leachate-seep rates, volume and composition of landfill-generated gases, and areas with high concentrations of explosive gas were determined. In addition, the effectiveness of the existing containment system (intercept system) was investigated and approximate areas were identified where the system is not functional.

Information from the Phase I RFI/RI and other investigations include *in situ* permeability of the interim soil cover material estimated from existing geological information, classification of soils around the landfill using the Unified Soil Classification System (USCS), climate data such as evapotranspiration and precipitation data, input parameters for the LANDFIL2 model to predict gas emission rates, and exposure pathways for human and ecological receptors described in the human health risk assessment exposure scenarios technical memorandum (DOE 1993b). Other sources of data include background geochemical data (EG&G 1993a); RCRA groundwater monitoring results for the Present Landfill (EG&G 1993c); and data from sitewide groundwater, surface water, and geologic characterization programs (EG&G 1991a, EG&G 1991e, EG&G 1991f, EG&G 1992e).

Data collected during the Phase I RFI/RI are considered usable for site characterization and remedial design activities. Other data collected since the start of 1990 are also considered fully usable. The 1990 data represent the first full year of data collection following implementation of sampling and data quality guidelines outlined in the GRRASP (EG&G 1991g) and SOPs (EG&G 1992c). Data prior to 1990 can be used qualitatively.

Prior to the completion of the Phase I RFI/RI and the initiation of Phase II, the focus of investigations at OU 7 shifted as a result of the adoption of the presumptive-remedy strategy for streamlined site characterization and site remediation. The presumptive remedy for CERCLA municipal landfill sites relates primarily to containment of the landfill mass but includes gas control or collection and treatment, leachate collection and treatment, and source area

groundwater control. The presumptive remedy does not address exposure pathways outside the source area, nor does it include the long-term groundwater response action.

Thus, the problem is to determine what additional data are required from the Present Landfill and IHSS 203 to support closure under CHWA and RCRA; to design the landfill cap, slurry wall for source area groundwater control, leachate collection and treatment system, and gas control and treatment system, if necessary; and to meet the IAG milestone of July 1997 for IM/IRA implementation.

5.6.2 *Identify the Decisions*

In accordance with CHWA regulations, RCRA closure requirements, and Superfund Accelerated Cleanup Bulletin, Presumptive Remedies for Municipal Landfill Sites (EPA 1993a) and Presumptive Remedy for CERCLA Municipal Landfill Sites (EPA 1993b), the basis for action will be the answers to the following decisions:

1. What containment design (cap and institutional controls) will satisfy regulatory requirements (State Subtitle D and RCRA Subtitle C closure requirements)?

2. The control of leachate and groundwater (slurry wall) is a necessary component of the presumptive remedy to prevent migration from the source area.

3. Leachate collection and treatment is a necessary component of the presumptive remedy.

4. The control of landfill-generated gas is frequently a necessary component of the presumptive remedy to ensure cap integrity. Will treatment of landfill-generated gas be required? Guidance is forthcoming on this issue (EPA 1991c, 1993a). In some cases, state ARARs may identify gas clean-up levels (i.e., emissions) for such contaminants, and in some cases, health-based levels will be appropriate.

5.6.3 *Identify the Inputs to the Decisions*

Information not currently available but required to make the decisions includes the following:

1. Information required for landfill cap design includes a topographic map, the location of existing utilities, and the location and soil characteristics of potential borrow areas.

2. Information necessary for leachate control includes the predicted rate of water infiltration through the landfill cap, seepage generation rate (HELP model output), and depth to bedrock along the proposed slurry wall and the proposed downgradient groundwater collection system.

3. Information required for leachate collection and treatment includes the rate of leachate seepage, the depth to bedrock along the proposed French drain, and the load-bearing capability of the material at the proposed storage tank location.

Information for landfill gas control and treatment is limited to landfill gas emission rates.

Data not in existing sources will be collected under the OU 7 FSP (Section 6). Sources for the information required to make decisions is discussed for the (1) landfill cap, (2) leachate control, (3) leachate collection and treatment, and (4) landfill gas control and treatment.

1. Information for the landfill cap design—A topographic contour map will be prepared using survey data. The map will show the locations of property features, topographic contours, spot elevations, and areas that have recently been graded or mounded. Plans for future mounding of waste will be modeled to determine final configuration of the landfill. Location of utilities aboveground or underground that may interfere with construction will be identified. In addition, the nearest service locations for electricity, water, and communication lines will be identified for construction and operation of the remedial system. Location and soil characteristics (*in situ* moisture, Atterberg limits, grain size, standard proctor density, and falling-head permeability) of potential borrow areas for clay, sand and gravel, and topsoil will be obtained from existing sources or measured in the field, if necessary.

2. Information for leachate control—The predicted rate of water infiltration through the landfill cap and the leachate-generation rate will be calculated using the HELP model (EPA 1986b). Depth to bedrock along the proposed slurry wall and downgradient groundwater collection system will be collected in the field.

3. Information for leachate collection and treatment—Leachate seep rates, depth to bedrock along the proposed French drain, and load-bearing capability of the material at the proposed storage tank location will be quantified in the field.

4. Information for landfill gas treatment—Gas emission rates will be measured in the field. Landfill gas emissions will be modeled using LANDFIL2. Input parameters will be based on site-specific information and EPA guidance (EPA 1991a).

The action level is the measurement threshold that provides the criterion for choosing between alternative actions (EPA 1993c). Presumptive remedies, CHWA regulations applicable to municipal solid waste landfills, RCRA closure requirements, and chemical-specific and action-specific ARARs are the basis of action levels for the Present Landfill. EPA-approved field sampling techniques and analytical methods will be used to collect and analyze data.

5.6.4 *Define the Boundaries of the Study*

The geographic area within which all decisions must apply is the Present Landfill and vicinity including IHSSs 203 and underlying media to the first uncontaminated confining layer (i.e., unweathered bedrock).

Each population of interest is defined by several characteristics. The landfill waste is defined by parameters for landfill cap design; areal extent, total volume, and depth of waste material; and the volume of saturated waste material. Characterization of the waste is not required in accordance with the NCP. Leachate control is defined by the infiltration rate, water levels, gradient, and the hydraulic connection at various points across the groundwater intercept system. Leachate treatment is defined by the composition, volume, and flow rate of leachate. Gas treatment is defined by the composition, volume, and generation rate of landfill gas.

All data collected from 1990 through 1995 will be used to make the decision. Additional data will be collected during the Phase II field investigation and the remedial design phase for landfill closure.

5.6.5 *Develop Decision Rules*

The first step in developing a decision rule is to specify the parameters that characterize the population of interest. The parameters for final landfill cap design determine how the waste material of the Present Landfill will be treated. The depth to bedrock along the proposed slurry wall determines how leachate will be controlled. The average and maximum concentrations for each analyte, and the average and peak flow rates determine how leachate will be treated. The

average and maximum concentrations for each analyte, and the landfill gas generation rates determine how gas will be treated.

The next step is to specify the action level for the study, which may be dictated by action-specific ARARs. Action levels are discussed by population of interest.

1. Landfill waste—Regulatory guidance specifies containment of the landfill mass as the appropriate response action or "presumptive remedy." Therefore, specification of an action level is not required. Design criteria specified in CHWA and RCRA regulations include a hydraulic conductivity value of 10^{-7} cm/sec for the compacted clay liner of the double barrier cap and a 40 to 60 mil synthetic membrane.

2. Leachate—Regulatory guidance indicates that containment or control of leachate is a component of the presumptive remedy. Therefore, specification of an action level is not required.

3. Treatment of leachate is also considered a component of the presumptive remedy.

4. Landfill gas—Landfill gas collection is typically considered a necessary component of the remedy to ensure cap integrity. To evaluate the need to treat landfill gas, an action level must be specified. The proposed emission standard from the EPA Office of Air Quality, Planning, and Standards for emission of NMOCs is 150 megagrams per year. Other action levels may be identified during the development of ARARs. Gas control will be implemented to alleviate potential gas migration problems, if necessary.

A decision rule is developed for each population of interest.

1. Landfill wastes—In accordance with regulatory guidance, construction of a containment structure is a presumed component of the response action.

2. Leachate—Containment or control of leachate is a presumed component of the response action.

3. Treatment of leachate is a presumed component of the response action.

4. Landfill gas—Treatment of landfill gas may be required. If concentrations of NMOCs in gas do not exceed 150 megagrams per year (or some other identified ARAR), no action is required. If concentrations of NMOCs in gas exceed 150 megagrams per year (or some other identified ARAR), a gas treatment system is required.

5.6.6 *Specify Acceptable Limits on Decision Errors*

The decision error rates are used to establish appropriate performance goals for limiting uncertainty (EPA 1993c). Establishing acceptable error rates is necessary prior to determining the appropriate number of data (samples or tests) necessary to support the decision with a specified level of confidence. However, as mentioned previously, the statistically-based DQO process is least applicable to the Present Landfill because remedial action decisions are made on the basis of presumptive remediation (i.e., experience gained from other similar sites) rather than quantitative evaluation of environmental data to "choose among alternative actions" (Step 5 of the DQO process) and the quantitative method in the DQO process is often not applicable to the types of data needed to support remedial design. The presumptive remedy is consistent with CHWA closure requirements supported by guidance in the NCP. Table 5-6 presents types of information needed to support design of the presumptive remedy for the Present Landfill and identifies the appropriate methodology for establishing DQOs for each type of information listed. Discussed below are the types of information for which the quantitative DQO process is applicable.

5.6.7 *Optimize the Design*

As previously discussed, the DQO process is least applicable to the Present Landfill because decisions are made on the basis of presumptive remediation (i.e., experience gained from other similar sites) rather than on the basis of quantitative decision making, with specified error rates and uncertainties, as embodied in Steps 5 and 6 of the DQO process and because the quantitative DQO process is often not applicable to the types of data needed to support remedial design. For example, a topographic map is needed to support the design of the landfill cap. The appropriate contour interval and quality of the survey data for the map are determined on the basis of standard engineering and surveying practices rather than on quantitative data quality parameters determined from the statistically based DQO process.

Table 5-6 summarizes the type, quality, and quantity of data necessary to support design of the presumptive remedies. These data will be collected during additional field activities at OU 7.

To support landfill cap design, maps of topographic contours, plans for future waste mounding, locations of utilities, and physical properties of cap materials will be developed using standard engineering practices. These activities will be integrated with Rocky Flats Waste Operations.

Activities associated with control of leachate and groundwater, such as infiltration rate, will be performed during development of the landfill closure IM/IRA decision document using predictive modeling. Activities associated with determining the depth to bedrock along the proposed location of the slurry wall and downgradient groundwater collection system will be performed during the Phase II field investigation.

Boreholes and wells with bedrock elevation data are shown in Figure 5-1. Proposed locations of the slurry wall, groundwater collection system, leachate collection system, and leachate storage tanks are also shown. Data gaps are apparent along the northern and southeastern portions of the proposed slurry wall. Data gaps are also apparent at the proposed groundwater collection system, leachate collection system, and leachate storage tank locations. Samples of alluvium will be collected to determine the load-bearing capability of the storage tank foundation material. Gas emission rates will be measured in existing venting wells. Phase II field activities, presented in the FSP (Section 6), address these data gaps.

Section 5
Tables

Table 5-1
Type I and Type II Decision Errors

Decision Reached Based on Data from Site	True Condition	
	Concentrations in Groundwater and Surface Water DO NOT Exceed Action Levels	Concentrations in Groundwater and Surface Water Exceed Action Levels
Do Not Exceed Action Levels	Correct Decision Reject H_o	Error (Type I) Accept H_o
Do Exceed Action Levels	Error (Type II) Reject H_o	Correct Decision Accept H_o

Type I error rate (probability) = alpha
Type II error rate (probability) = beta
Power (to reject H_o) = 1 - beta

Table 5-2
East Landfill Pond Surface Soils Optimal Sample Sizes

Analyte	TBC/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
0 to 2 inches								
Arsenic	0.3155	5	100.0	1.8	13.2	4	3,979	133
Barium	6.309	191	100.0	56.3	1,120	11,664	29,002	133
Strontium	165,000	50.1	100.0	36.1	80.6	166.41	2	9
Vanadium	1,920	31	100.0	11.9	86.2	81	2	133
Zinc	82,300	56	100.0	21.5	101	196	2	133
Americium-241	2.38	0.03	100.0	0	1.076	0.01	2	119
Radium-226	2.28	1.0	100.0	0.4355	1.787	0.09	4	79
Nitrate/Nitrite	439,000[1]	4	78.2	1	45	49	2	133
0 to 10 inches								
Arsenic	0.3155	5	100.0	1.2	15.7	4	3,979	67
Barium	6.309	201	100.0	30	546	11,881	29,541	67
Selenium	0.06309	0.4	53.7	0.24	2.4	0.16	3,980	67
Americium-241	2.38	0.0088	100.0	0.000571	0.05813	0.00007056	2	66

[1] PRG value for nitrate

Notes:

Metal values reported in milligrams per kilogram.
Radionuclide values reported in picocuries per gram.

Definitions:

TBC/PRG	to be considered/preliminary remediation goals (EG&G 1994c, 1994d)
Hit Freq	relative frequency of detected analytes
Max Value	maximum reported value
Min Value	minimum reported value
N	calculated optimal sample size; values rounded up

Table 5-3
East Landfill Pond Downgradient Surface-Soil Samples Exceeding Draft PRG Concentrations

Analyte	Sample Location	Sample Depth (inches)	Result[1]	Draft PRGs[2]	
				Residential Soil[1]	Commercial Soil[1]
Americium-241	SS711493	0 to 10	0.05813	2.38	0.0189
Radium-226	SS710993	0 to 2	1.596	2.28	0.197
Radium-226	SS711393	0 to 2	1.672	2.28	0.197
Radium-226	SS711193	0 to 2	1.787	2.28	0.197

[1] Metals reported in milligrams per kilogram. Radionuclides reported in picocuries per gram.
[2] Draft preliminary remediation goals (PRGs) presented in Programmatic Preliminary Remediation Goals for Rocky Flats Plant (EG&G 1994e). This document has been submitted to the regulatory agencies for review and approval.

Table 5-4
Surface Water Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
SW097 Dissolved Analytes								
Barium	1,000	567	100.0	447	673	3,600	2	20
Iron	300	71,050	100.0	51,100	95,800	144,841,225	159,267	20
Manganese	50	1,581	100.0	1,300	2,040	38,416	1,523	20
Strontium	16,800,000	939	95.0	778	1,350	29,584	2	19
Zinc	110[1]	1,530	100.0	240	3,430.00	588,289	4,813	20
Zinc	2,000[2]	1,530	100.0	240	3,430.00	588,289	16	20
Americium-241	0.05[3]	0.1	100.0	-0.001	0.5	0.04	1,585	10
Gross beta	5	8	100.0	0.5469	11	9	37	13
Strontium-89,90	1,110 (d)	1.16	100.0	0.6806	1.933	0.2304	2	9
SW097 Total Analytes								
Barium	1,000	640	100.0	297	1,550	54,289	7	21
Iron	300	80,510	100.0	61,300	155,000	471,020,209	517,929	21
Manganese	50	1,611	100.0	1,320	2,490	68,121	2,698	21
Strontium	16,800,000	919	90.5	814	1,370	43,264	2	21
Zinc	110[1]	2,945	100.0	857	16,000	9,326,916	76,284	21
Zinc	2,000[2]	2,945	100.0	857	16,000	9,326,916	233	21
Gross beta	5	11	100.0	3.753	17	16	65	10
Strontium-89,90	1,110[4]	1.30	100.0	0.66	4.06	1.0201	2	10
Tritium	500	349	100.0	-110	1,500	84,681	35	22
Uranium-238	5	1	100.0	-0.01	3.76	1	6	14
Nitrite	500	30.33	66.7	20.00	63.000	338.9281	2	9
1,1-Dichloroethane	2,810	6	85.0	2	10	4	2	20
4-Methylphenol	140	4	60.0	2	10	1	2	5
Benzene	5[5]	2	55.0	1	5	1	6	20
Benzene	0.66[6]	2	55.0	1	5	1	229	20
Diethyl phthalate	350,000	3	80.0	1	10	4	2	5
Ethylbenzene	700	13	95.0	1	18	25	2	20
Fluorene	1,120	2	100.0	2	3	1	2	5
Methylene chloride	5	14	47.6	3	190	1,681	6,656	21
Naphthalene	620	18	100.0	14	22	16	2	5
Toluene	1,000	38	95.0	5	88	576	2	20
Total Xylenes	10,000	14	95.0	1	25	36	2	20
Trichloroethene	5[5]	2	55.0	1	5	1	6	20
Trichloroethene	2.7[6]	2	55.0	1	5	1	15	20

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
SW098 Dissolved Analytes								
Barium	1,000	167	100.0	135	204	441	2	24
Manganese	50	63	87.5	1	250	4,900	196	24
Strontium	16,800,000	497	100.0	366	596	3,844	2	23
Gross Alpha	7	1.9	100.0	-0.294	4.2	1.96	6	7
Gross Beta	5	12	100.0	4.206	22	16	65	13
Strontium-89,90	1,110[4]	1	100.0	0.4	1.613	0	2	10
Uranium-238	5	2	100.0	0.3	15	16	65	15
SW098 Total Analytes								
Manganese	50	101	96.0	2.5	430	10,000	398	25
Nickel	100[5]	11	68.0	6.3	40	25	2	25
Nickel	13.4[6]	11	68.0	6.3	40	25	16	25
Strontium	16,800,000	476	100.0	44.9	598	11,025	2	24
Americium-241	0.05[3]	0.011	100.0	0.0005655	0.075	0.000324	15	18
Gross Alpha	7	2	100.0	-0.67	5	4	10	13
Gross Beta	5	12	100.0	7.9	16	4	18	13
Strontium-89,90	1,110[4]	1.4	100.0	0.6635	1.924	0.25	2	5
Tritium	500	143	100.0	-10	257.8	4,900	4	26
Uranium-235	5	0.1	100.0	-0.01	0.3	0.01	2	10
Uranium-238	5	1.1	100.0	0.6996	1.964	0.16	2	10
SW099 Dissolved Analytes								
Barium	1,000	162	81.3	52.6000	370	10,609	3	18
Strontium	16,800,000	730	88.9	528	1,200	56,644	2	19
Strontium-89,90	1,110[1]	1.272	100.0	0.5767	1.778	0.326041	2	2
Uranium-238	2,290	3.2	100.0	0.3	6.192	6.76	2	2
SW099 Total Analytes								
Barium	1,000	170	83.3	59.5	382	10,816	3	18
Zinc	110[1]	33	94.1	9.5	92.4	529	6	17
Zinc	2,000[2]	33	94.1	9.5	92.4	529	2	17
Americium-241	0.05[3]	0.013	100.0	0	0.052	0.000361	16	12
Gross Alpha	7	3.2	100.0	1.512	6.002	2.89	8	6
Uranium-235	5	0.15	100.0	0.06293	0.2733	0.0064	2	6
Uranium-238	5	2.5	100.0	1.67	3.652	0.81	5	6
SW100 Dissolved Analytes								
Barium	1,000	92	72.7	25.6	200	2,025	2	11
Manganese	50	109	81.8	4.5	733	44,521	1,764	11
Strontium	16,800,000	859	72.7	265	1,600	262,144	2	11
Zinc	110[1]	30	80.0	20	56	196	3	10
Zinc	2,000[2]	30	80.0	20	56	196	2	10
Gross Beta	5	17	100.0	6	33	196	778	6

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
Uranium-238	2,290	1.7	100.0	0.2	2.475	1.69	2	6
SW100 Total Analytes								
Zinc	110[1]	67	100.0	10	167	2,916	26	17
Zinc	2,000[2]	67	100.0	10	167	2,916	2	17
Americium-241	0.05[3]	0.017	100.0	0.003996	0.041	0.000441	19	3
Gross beta	5.00	33	100.0	20.4	44	144	572	3
Tritium	500.00	273	100.0	16.41	450	51,984	22	5
Nitrite	500.00	29.25	50.0	20.00	65.000	675.4801	2	9

[1] ARAR for agricultural activities
[2] ARAR for aquatic life
[3] ARAR for americium (total)
[4] PRG for strontium-90
[5] ARAR for Safe Drinking Water Act
[6] ARAR for water and fish ingestion

Notes:

Metal and organic compound values reported in micrograms per liter.
Radionuclide values reported in picocuries per liter.

Definitions:

ARAR/PRG	applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq	relative frequency of detected analytes
Max Value	maximum reported value
Min Value	minimum reported value
N	calculated optimal sample size; values rounded up

Table 5-5
Groundwater Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
LHSU Dissolved Analytes								
Aluminum	50	79	51.3	13	264	3,136	126	39
Barium	1,000	175	94.9	9.40	516	17,689	4	39
Lithium	2,500	49	82.1	10.7	261	2,209	2	39
Manganese	50	37	82.1	1	195	1,521	62	39
Molybdenum	182	63	56.4	4	435.00	5,184	17	39
Strontium	21,900	794	100.0	185	5,700	970,225	2	39
Gross Alpha	7	5	100.0	-0.361	17.85	16	34	48
Gross Beta	5	6	100.0	1.357	16.27	16	65	50
Uranium-235	2.98	0.06	100.0	-0.021	0.334	0.0064	2	50
Uranium-238	2.98	1.2	100.0	0	4.196	1	13	50
LHSU Total Analytes								
Aluminum	50	14,795	100.0	1,140	79,800	398,002,500	15,754,963	19
Barium	1,000	272	100.0	27.70	1,180	77,841	10	19
Chromium	50	36	89.5	3.00	204	3,249	130	19
Iron	300	14,831	100.0	1,020	63,400	328,515,625	361,233	19
Lead	15	19	94.7	1.1	115	841	372	19
Strontium	21,900	474	100.0	241	1,470	96,721	2	19
Tritium	500	12	100.0	-330	300	16,384	8	52
UHSU Dissolved Analytes								
Barium	1,000	154	90.9	7.6	940	33,124	5	330
Iron	300	5,061	55.4	2.4	146,000	278,589,481	306,335	325
Lithium	2,500	189	73.4	1	10,000	7,634,169	123	240
Manganese	50	510	83.9	1	9,230	1,664,100	65,875	277
Nickel	100	21	36.8	2	795	2,209	24	121
Strontium	21,900	758	97.9	65.7	81,700.0	20,277,009	6	323
Zinc	2,000	45	65.5	1.3	1,240	12,996	2	216
Gross Beta	5	5	100.0	-7.2	43.17	36	144	312
Radium-226	0.397	0.8	100.0	0.12	2.166	0.36	228	71
Strontium-89,90	1.44[1]	0.5	100.0	-0.18	11.17	0.81	41	230
UHSU Total Analytes								
Aluminum	50	15,953	94.8	13.00	456,000	2,071,888,324	82,015,870	173
Arsenic	50	5	50.0	0.7	70.70	49	4	172
Barium	1,000	314	94.2	16.1	5,060	242,064	26	173
Chromium	50	26	69.0	2	580	3,136	126	174
Copper	200	160	63.0	2.00	7,140	624,100	1,546	173
Iron	300	27,358	97.1	16.4	656,000	4,234,885,776	4,656,621	173
Lead	15	14	76.9	1.00	263	1,225	541	133

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
Lithium	2,500	38	76.3	2.6	266	2,116	2	132
Manganese	50	841	98.3	2.2	9,260	2,765,569	109,477	173
Nickel	100	41	61.8	2	1,070	8,836	89	107
Strontium	21,900	538	97.6	83.2	3,720	346,921	2	168
Vanadium	100	40	66.9	2.00	754	6,889	70	172
Zinc	2,000	185	86.5	6.3	8,000	469,225	13	148
Americium-241	0.198	0.01	100.0	-0.433	0.63	0.0036	11	267
Cesium-137	1.7	0.1	100.0	-0.756	1.13	0.16	7	140
Radium-226	0.397	0.60	100.0	0.35	1.32	0.1156	74	7
Strontium-89,90	1.44[1]	0	100.0	0	1	0	2	19
Nitrate/Nitrite	10,000	7,258	88.2	20.00	290,000	735,819,876	730	276

[1] PRG value for strontium-90

Notes:

Metal values reported in micrograms per liter.
Radionuclide values reported in picocuries per liter.

Definitions:

ARAR/PRG	applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq	relative frequency of detected analytes
LHSU	lower hydrostratigraphic unit
Max Value	maximum reported value
Min Value	Minimum reported value
N	calculated optimal sample size, values rounded up
UHSU	upper hydrostratigraphic unit

Table 5-6
Approach to Establishing DQOs for Information Needed to Support Design of Presumptive Remedy for the Present landfill

Component of the Remedy	Information Type	DQO Methodology	Scope of Phase II Data Collection Activity
Landfill Cap Design	Topographic contour map	Standard engineering practices	Integrate activity with Rocky Flats Waste Operations Personnel
	Map of future waste mounding	Standard engineering practices	Integrate activity with Rocky Flats Waste Operations Personnel
	Location of utilities	Standard engineering practices	Integrate activity with Rocky Flats Waste Operations Personnel
	Location of cap materials	Standard engineering practices	Integrate activity with Rocky Flats Waste Operations Personnel
	Physical properties of cap materials	Standard engineering practices	Integrate activity with Rocky Flats Waste Operations Personnel
Leachate Control	Infiltration rate	Predictive modeling - HELP[1]	None
	Depth to bedrock along slurry wall	DQO process	Drill boreholes to bedrock
	Depth to bedrock along downgradient groundwater collection system	DQO process	Drill boreholes to bedrock
Leachate Collection and Treatment	Discharge rate	DQO process and predictive modeling - HELP[1]	Drawdown test in boreholes
	Depth to bedrock along leachate collection system	DQO process	Drill boreholes to bedrock
	Physical properties of storage tank foundation	Standard engineering practices	Collect samples for geotechnical analysis
Landfill Gas Treatment	Emission rate	DQO process	Measure gas emission rates
		Predictive modeling - LANDFIL2	None

[1] HELP = Hydrologic Evaluation of Landfill Performance Model (EPA 1986b)

Definition:

DQO data quality objective

Section 5
Figures

DOCUMENT MODIFICATION REQUEST (DMR)

PAGE 1 of 2

INFORMATION ONLY

Reference 1-A07-PRO-001 for Processing Instructions.
Print or Type All Information (Except Signatures).

1. Date	25 DMR No.
10/19/94	94-DMR-ERM-0130

2. Existing Document Number/Revision	3. New Document Number or Document Number if it is to be changed with this Revision
RF/ER-94-00044, Rev. 0	NA

4. Originator's Name/Phone/Pager/Location	5. Document Title
Laurie Peterson-Wright/8553/7444/BLDG 080,285	Technical Memorandum, Final Work Plan, Operable Unit No. 7 - Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203)

6. Document Type: ☐ Procedure ☒ Other Work Plan

7. Document Modification Type (Check only one): ☐ New ☐ Revision ☐ Intent Change ☒ Nonintent Change ☐ Editorial Correction ☐ Cancellation

8. Item	9. Page	10. Step	11. Proposed Modifications
1	2	6.0	Change first sentence to read "Borehole drilling activities, including the technical approach, sampling locations, equipment and procedures, proposed analytical suites, downhole geophysical logging and drum handling and sampling procedures are discussed in Section 6.3."
2	2	6.1	change ~~third~~ Second bullet to read " Determine the flow rate at the leachate seep"
3	6	6.3	Fourth sentence, change "Eight" to"Six"
4	6	6.3	Remove entire second paragraph
5	6	6.3	Third paragraph, remove fourth sentence

12. Justification (Reason for Modification, EJO #, TP #, etc.)

Borehole locations 53294 and 53394 were canceled because locations were not accessible for the drilling rig. Wetlands and Preble's Meadow Jumping Mouse issues were also a concern at these locations. In addition, the new seep collection design does not require depth to bedrock or thickness of alluvial and weathered bedrock material data. The seep flow rate will be measured at SW097 instead of performing drawdown recovery tests in these boreholes. The valley-fill alluvium is too thin at location 53094 to allow for a triple-cased construction in accordance with the SOPs (GT.03). Samples will be collected at location 52894 instead of 53094 because the valley-fill alluvium is thicker at this locations and will enable more complete characterization of the valley-fill material in the vadose zone. The unweathered bedrock monitoring well (53094) will be geophysically logged in order to identify and optimize well screen placement in the most permeable zone. This well will be used as one of the RCRA compliance wells for the next 30 years. Verbal guidance was received from Kurt Muenchow (DOE) in October 1994 requiring these necessary changes

If modification is for a new procedure or a revision, list concurring disciplines in Block 13, and enter N/A in Blocks 14 and 15. If modification is for any type of change or a cancellation, organizations are listed in Block 13, then Concurror prints, and signs in Block 14, and dates in Block 15.

13. Organization	14. Print, Sign (if applicable)	15. Date (if applicable)
EQS		10.25.94
3120	Mark R. Wood / Mark R. Wood	10/24/94

16. Originator's Supervisor (print/sign/date): Ed Mast / Ed Mast 10/24/94

17. Assigned SME/Phone/Pager/Location	18. Cost Center	19. Charge Number	20. Requested Completion Date	21. Effective Date
Laurie. J. Peterson-Wright, X8553, 7444, Bldg 80	3119	989035-00	10/20/94	10.31.94 lar

22. Accelerated Review? Yes ☒ No ☐ | 23.ORC Review: N/A

24. Responsible Manager (print/sign/date): Ed Mast / Ed Mast 10/24/94

RF-47940 (5/93)

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BY _____

DATE _____

DMR (continuation sheet)

Refer to 1-A01-PPG-001 for Processing Instructions.
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25 DMR No. 94-DMR-ERM-0130 Doc 12-31-94

2. or 3. Document Number/Revision: RF/ER-94-00044, Rev. 0

5. Document Title: Technical Memorandum, Final Work Plan, Operable Unit No. 7 - Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203)

8. Item	9. Page	10. Step	11. Proposed Modifications
6	7	6.3.1	Fourth paragraph, first sentence, change "triple-cased" to "double-cased"
7	7	6.3.1	Fourth paragraph, second sentence, change "triple-cased" to "double-cased"
8	8	6.3.1	Remove "a 12 inch diameter schedule 80 PVC casing to seal off the valley fill alluvium"
9	8	6.3.1	Insert "valley-fill alluvium and" before "weathered bedrock. The borehole..."
10	8	6.3.1	Third paragraph, delete "dissolved oxygen"
11	8	6.3.2	First paragraph, first sentence, change "53094" to "52894"
12	11	6.3.7	After section 6.3.7 add "Section 6.3.8 Downhole Geophysical Logging, Downhole geophysical logging will be performed in the borehole at location 53094 before installing the unweathered bedrock monitoring well to identify and optimize well screen placement in the most permeable zone. The borehole will be logged with the following logging techniques: neutron, natural gamma, gamma-gamma, density, induction, caliper, guard resistivity, and single point resistivity (the last two methods only if sufficient groundwater is encountered in the bedrock). The geophysical surveys will be performed in accordance with Geotechnical SOP GT.15 " Geophysical Borehole Logging"."
13	14	6.4.3	First paragraph, second sentence, remove "and in open boreholes near the leachate seep (53294and 53394)
14	16	6.4.4	Paragraph three, first and third sentences, remove "dissolved oxygen,"
15	18	6.5	Add "The flow rates at the leachate seep (SW097) will be measured using a Parshall flume, or equivalent, in accordance with surface water SOP SW.04, "Discharge Measurement" (EG&G 1992)."

This is a
CONTROLLED DOCUMENT
EG&G - ROCKY FLATS PLANT
ENVIRONMENTAL RESTORATION
Technical Memorandum
12-16-94
OU 7 Final Work Plan
RED Stamp

Category

INFORMATION ONLY

Approved By:

Title:
Section 6

CAB for Ed Nast 10/5/94
Name Date

6. FIELD SAMPLING PLAN

Prior to completion of the Phase I RFI/RI and initiation of Phase II, the focus of investigations at OU 7 changed due to the adoption of a presumptive-remedy strategy for streamlined site characterization and site remediation. Source containment is the designated presumptive remedy for municipal landfills and consists of the following elements: institutional controls, a landfill cap, landfill gas control and treatment, if necessary, source area groundwater control, and leachate collection and treatment. The containment elements will be constructed as two separate remedial actions: one for collection of leachate at the seep above the East Landfill Pond and the other for closure of the landfill.

The objective of the leachate collection remedial action is to stop discharge of leachate (FO39 listed waste) to the pond and limit downgradient migration of leachate from the source area. Leachate will be collected by a French drain installed downgradient of the seep and pumped to onsite storage tanks. Leachate will be trucked to the sitewide OU 1/OU 2 facility for treatment. The leachate collection system design will be consistent with the presumptive remedy for final landfill closure.

The objective of the landfill closure remedial action is to contain waste, prevent leachate formation, control landfill gas, and collect and treat groundwater, if necessary. Components of the remedial action include a multiple-layer landfill cover that will extend to the East Landfill Pond dam or to the outer edge of the contaminant plume, a slurry wall or groundwater intercept system constructed under the footprint of the cover, and a groundwater collection system downgradient of the dam.

Data for the design of the presumptive remedy and an assessment of the nature and extent of groundwater contamination downgradient of the landfill will be collected under this FSP. Site-specific objectives of additional data collection activities are presented in Section 6.1. Surface soil sampling activities, including the technical approach, sampling locations, sampling activities, equipment and procedures, and proposed analytical suites are discussed in

Section 6.2. Borehole drilling activities, including the technical approach, sampling locations, field methods, equipment and procedures, proposed analytical suites, and drum handling and sampling procedures are discussed in Section 6.3. Groundwater monitoring activities, including the technical approach, sampling locations, field methods, equipment and procedures, monitoring well installation, well development, well testing, groundwater sampling, and proposed analytical suites are presented in Section 6.4. Additional field activities to support the design of the landfill cap are discussed in Section 6.5.

6.1 Objectives

Presumptive remedies dictate remedial actions at IHSS 114, IHSS 203, IHSS 167.2, and IHSS 167.3. Additional sampling and characterization of PCOCs in the environmental media within these IHSSs will not affect the decision to remediate. Therefore, further characterization of media within IHSS 114, IHSS 203, IHSS 167.2, and IHSS 167.3 is not an objective of the Phase II investigation.

As discussed in Section 5, surface soils below the East Landfill Pond dam and groundwater downgradient of the landfill have not been adequately characterized to support decisions concerning remedial actions. Areas where the proposed leachate collection system, proposed leachate storage tanks, potential slurry wall or groundwater intercept system, and potential downgradient groundwater collection system will be located have not been adequately characterized for the purpose of remedial design. Decisions regarding the necessity of remediation and options for remedial design require data from additional samples.

The specific objectives of the Phase II field investigation are as follows:

- Characterize the spatial extent of contamination in surface soils at locations below the East Landfill Pond dam where analyte concentrations or activities exceed draft PRGs
- Determine the flow rate at the leachate seep
- Determine the depth to bedrock, physical properties, and the load-bearing capability of the foundation materials at the proposed storage tank location

- Determine the depth to bedrock, and thickness of the alluvium along the location of the potential slurry wall or groundwater intercept system
- Determine the depth to bedrock and the thickness of the weathered zone on the slopes below the East Landfill Pond dam
- Characterize the valley-fill alluvium in No Name Gulch
- Further delineate the extent of groundwater contamination in the UHSU along No Name Gulch
- Determine the presence or absence of contamination in LHSU groundwater in No Name Gulch
- Determine the hydraulic conductivity of the alluvium, weathered bedrock, and bedrock in No Name Gulch
- Measure landfill gas emission rates

The monitoring well installation and groundwater sampling is designed to fulfill data needs identified during the DQO process. However, if the results of the groundwater sampling do not fully delineate the extent of groundwater contamination in the UHSU and LHSU along No Name Gulch for the purpose of remedial design, additional work will be proposed in an addendum to the Phase II FSP.

6.2 Surface Soil Sampling

Statistical comparison of surface soil data to background data identified only three PCOCs in soils around the East Landfill Pond. However, numerous additional PCOCs were identified on the basis of UTL exceedances. Concentrations in excess of UTLs were generally two to three times greater than the maximum concentration of the analyte in background. To support presumptive remediation, surface soil samples will be collected in the area below the East Landfill Pond dam. Additional surface soil sampling is warranted at "hotspot" locations where analyte concentrations or activities exceeded draft PRGs to delineate the area of soil contamination around each hotspot. The number and locations of additional samples needed

to characterize the spatial extent of contamination in surface soils were determined quantitatively and qualitatively by an analysis of PRG exceedances (Section 5.4.7).

Samples will be collected systematically on a grid around the original sample location. Systematic sampling grids are the method of choice for estimating trends or patterns of contamination over space (Gilbert 1987) and were used in the Phase I field investigation. Samples will be collected from the 0- to 2-inch horizon at three locations where analyte activities exceeded PRGs (Figure 6-1). Four samples will be collected to determine the spatial distribution of contamination around the original sample location. At each of the three locations, the samples will be collected at a distance of 25 feet from the original sample location. A total of 12 samples will be collected.

Samples will be collected from the 0- to 10-inch horizon at one location where analyte activities exceeded PRGs (Figure 6-2). Samples will be collected to determine the spatial distribution of contaminants. Four samples will be collected per location as previously described.

6.2.1 *Surveying and Screening*

Original Phase I surface soil sampling locations will be re-staked using coordinates from the Phase I investigation. Surveying will be performed in accordance with Geotechnical SOP GT.17, Land Surveying (EG&G 1992c). Phase II locations will be staked using a tape and compass. Proposed locations are 25 feet north, south, east, and west of the Phase I location (Figure 6-1).

Radiation field screening will be performed at each soil sampling location in accordance with procedures in Field Operations SOP FO.16, Field Radiological Measurements (EG&G 1992c). The prework radiation survey will be performed on a 17-point grid, centered on staked locations, using a Bicron Analyst FIDLER.

6.2.2 *Sampling*

Soils will be described in the field in accordance with Geotechnical SOP GT.01, Logging Alluvial and Bedrock Material (EG&G 1992c).

Soil samples from the 0- to 2-inch horizon will be collected using the grab method, outlined in Geotechnical SOP GT.08, Surface Soil Sampling (EG&G 1992c), to be consistent with Phase I sampling methods. Grab samples will be collected from a depth of 0 to 2 inches using a stainless-steel scoop. To collect enough material for all analyses, four scoops of soil (subsamples) will be obtained from each grid location, north, south, east, and west of the location stake. The subsamples will be combined in a stainless-steel bowl, homogenized, split, and then placed into individual sample jars. Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7.1. Each soil sample will be assigned a unique sample number. All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c).

Soil samples from the 0- to 10-inch horizon will be collected using the hand auger method outlined in Geotechnical SOP GT.08, Surface Soil Sampling (EG&G 1992c). Vegetation will be removed from the sampling location with a decontaminated shovel. The thin layer of soil that contacts the shovel will then be removed with a stainless-steel scoop. A hand auger will be used to collect the sample to a depth of 10 inches. The soil will be combined in a stainless-steel bowl, homogenized, split, and placed into individual sample jars. Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7.1. Each soil sample will be assigned a unique sample number. All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c).

6.2.3 *Analytical Requirements for Soil Samples*

Soil samples collected below the East Landfill Pond dam will be analyzed for metals (standard and additional); gross alpha; gross beta; plutonium-239,240; americium-241; uranium-233,234; uranium-235; uranium-238; cesium-137; strontium-89,90; TOC; and nitrate/nitrite (Table 6-1). This analyte list is the same as that used for surface soil samples collected around the East Landfill Pond during the OU 7 Phase I RFI/RI. Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report and Field Operations SOP FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c). Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g).

6.3 Borehole Drilling and Sampling

Four boreholes will be drilled for the purpose of installing groundwater monitoring wells (Figure 6-3). Three of these will be for a cluster well location in No Name Gulch (52894, 52994, and 53094) and will include an alluvial, weathered bedrock, and bedrock borehole. The other is for an alluvial well farther downstream in No Name Gulch (53194). Six additional boreholes will be drilled to gather information for remedial design (Figure 6-3). If bedrock sandstones are encountered in a borehole during drilling, a drawdown recovery test will be performed in the open borehole.

~~Two boreholes (53294 and 53394) will be drilled at and north of the leachate seep (SW097) to determine the depth to bedrock and thickness of alluvial and weathered bedrock material for use in the leachate collection system design. Estimated depth of these boreholes is 20 feet. Drawdown recovery tests will be performed in the open boreholes to estimate hydraulic conductivity values and calculate leachate flow rates. Drawdown recovery tests will be conducted in two phases: in an isolated alluvium test interval, and in weathered bedrock. No samples will be collected at these locations.~~

One borehole (53694) will be drilled at the proposed leachate storage tank location to determine the depth to bedrock and thickness of the alluvial and weathered bedrock material for use in design of the foundation for the storage tanks. The borehole will be drilled to an estimated depth of 30 feet. Samples of the alluvial material will be collected for geotechnical testing. ~~The load-bearing capability of the material will be tested in the field using American Society of Testing and Materials (ASTM) D1194.~~ No analytical samples will be collected.

Three boreholes (52794, 53494, and 53594) will be drilled around the landfill to determine the depth to bedrock and thickness of the weathered zone along the probable alignment of the slurry wall or groundwater intercept system for use in landfill closure design. Estimated depth of these boreholes is 40 feet. Samples will be collected for permeability testing at these locations to support design of the presumptive remedy. Drawdown recovery tests will only be performed if bedrock sandstones are encountered.

Two boreholes (52694 and 53794) will be drilled to determine the depth to bedrock and thickness of the weathered zone on the slopes below the dam. These data will support design

of the possible downgradient groundwater collection system. The boreholes will be drilled to estimated depths of 30 feet. No samples will be collected at these boreholes. Drawdown recovery tests will be performed if bedrock sandstones are encountered.

6.3.1 Borehole Drilling Methods

Prior to invasive activities, Geotechnical SOP GT.24 requirements will be reviewed and followed to acquire soil-disturbance approval from Rocky Flats Construction Management. Drilling locations will be staked and cleared in accordance with Geotechnical SOP GT.10, Borehole Clearing (EG&G 1992c). Radiation field screening will be performed at each drilling location on a 17-point grid using a Bicron Analyst FIDLER, in accordance with procedures in Field Operations SOP FO.16, Field Radiological Measurements (EG&G 1992c).

Locations will be drilled using hollow-stem augers equipped for continuous core sampling in accordance with Geotechnical SOP GT.01, Logging Alluvial and Bedrock Material, and GT.02, Drilling and Sampling Using Hollow Stem Auger Techniques (EG&G 1992c). Continuous core samples will be collected from all locations using a 3-inch inside diameter, 2-foot-long sample barrel. A moss system will be used to retrieve the core after each run while leaving the augers in place. Borehole drilling and sampling will be accomplished using 3 1/4-inch inside diameter hollow-stem augers. Boreholes will be reamed with 6 1/4-inch inside diameter hollow-stem augers to allow for well installation in accordance with Geotechnical SOP GT.06, Monitoring Well and Piezometer Installation (EG&G 1992c).

For boreholes drilled into bedrock, 6-inch PVC surface casing will be installed to isolate surficial materials from bedrock, in accordance with Geotechnical SOP GT.03, Isolating Bedrock from Alluvium with Grouted Surface Casing (EG&G 1992c). Drilling and sampling will continue using hollow-stem augers until sample collection activities are completed or poor recovery becomes a problem. At that point, rotary coring methods will be used in accordance with Geotechnical SOP GT.04, Rotary Drilling and Rock Coring (EG&G 1992c). Potable Rocky Flats water will be used as a drilling medium. A continuous core will be obtained using 1 3/4-inch inside diameter, 5-foot-long core tubes, placed within and retrieved from the lead rod with an overshot system.

The borehole for the unweathered bedrock well (53094) at the cluster well location will require double-cased construction to isolate the screen from the upper units. Double-cased construction

will be performed in accordance with Geotechnical SOP GT.03, Isolating Bedrock from Alluvium with Grouted Surface Casing (EG&G 1992c), which will require ~~a 12-inch diameter schedule 80 PVC casing to seal off the valley-fill alluvium and~~ an 8-inch diameter schedule 80 PVC casing to seal off the zone of valley-fill alluvium and weathered bedrock. The borehole will be advanced as described above for weathered bedrock, initially using hollow-stem auger drilling techniques and then using rotary drilling techniques when drilling becomes impractical or meets refusal. The unweathered bedrock borehole will then be converted to a monitoring well as described in Section 6.4.

Preliminary core descriptions will be completed in the field, and all core not used for chemical sampling will be boxed at the site. Wooden blocks will be labeled and placed in the core boxes to mark the beginning and end depth for each box, indicate the beginning of each drilling interval, and represent sections of no recovery or sections used for chemical samples. After the core is brought to the field trailer, it will be described in detail in accordance with Geotechnical SOP GT.01, Logging Alluvial and Bedrock Material (EG&G 1992c).

At each borehole location, measurements will be made of depth to groundwater, pH, dissolved oxygen, and specific conductance in accordance with procedures outlined in Groundwater SOP GW.01, Water Level Measurements in Wells and Piezometers, and GW.05, Field Measurements of Groundwater Field Parameters (EG&G 1992c). Permanent wells will then be installed at the designated locations based on data collected during drilling as described in Section 6.4. Boreholes not used for well installation will be abandoned in accordance with Geotechnical SOP GT.05, Plugging and Abandonment of Boreholes (EG&G 1992c). All downhole drilling equipment will be decontaminated at the main decontamination facility before being used at each new drilling location. The drill rig will be decontaminated in accordance with procedures outlined in Field Operations SOP FO.04, Heavy Equipment Decontamination (EG&G 1992c).

6.3.2 Borehole Sampling

Continuous borehole samples will be collected at location 52894 in accordance with Geotechnical SOP GT.02, Drilling and Sampling Using Hollow-Stem Auger Techniques (EG&G 1992c). Two types of samples will be collected: 3-inch-long discrete samples collected in stainless-steel sleeves for VOC analyses and 2-foot composite samples collected from 2-foot

core barrels for other chemical analyses. Samples will be collected in the unsaturated zone from the surface to the water table.

After the core barrel is opened, the core will be measured. The stainless-steel sleeve will be removed from the barrel, the exposed ends will be capped with sheets of Teflon®. The core will be peeled to remove any surficial material smeared onto the outside of the core. Core material will then be placed into a stainless-steel bowl, homogenized, mixed, split, and placed into individual sample containers. Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7.1. Each soil sample will be assigned a unique sample number. All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c).

Samples for geotechnical testing will be collected at borehole location 53694 at the proposed leachate storage tank location. Samples will be collected from 5-foot core barrels at 2½-foot intervals from the surface down to a depth of 5 feet. Geotechnical tests include Atterberg limits, modified proctor density, one-dimensional swelling pressure, moisture density, soil classification, and California bearing ratio (Table 6-2).

Bulk samples will be collected at borehole locations 52794, 53394, and 53594 along the probable slurry wall alignment. These samples will be used for permeability testing of the slurry wall mix design (percentage of bentonite slurry and site-specific soils versus permeability) to support design of the presumptive remedy.

6.3.3 *Analytical Requirements for Borehole Samples*

Borehole samples will be analyzed for VOCs; SVOCs; PCBs; metals (standard and additional); gross alpha; gross beta; plutonium-239,240; americium-241; uranium-233,234; uranium-235; uranium-238; cesium-137; strontium-89,90; TOC; pH; nitrate/nitrite; and sulfide (Table 6-3). This analyte list is the same as that used for borehole samples collected during the Phase I RFI/RI for OU 7. Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report and Field Operations SOP FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples

(EG&G 1992c). Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g).

6.3.4 *Drum Handling*

Drill cuttings from all locations will be placed in 30-gallon drums in accordance with Field Operations SOPs FO.08, Handling of Drilling Fluids and Cuttings, and FO.10, Receiving, Labeling, and Handling Environmental Materials (EG&G 1992c). Characterization of the investigative-derived materials (IDM) contained in the drums will be based on analytical results of the borehole samples corresponding to the drill cuttings interval in the drums. Drum handling will be conducted in accordance with Field Operations SOP FO.23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f).

6.3.5 *Drum Sampling*

If verified field screening results are below background as defined in Field Operations SOP FO.08, Handling of Drilling Fluids and Cuttings, and FO.16, Field Radiological Measurements (EG&G 1992c), residual soil or sediment will be disposed as clean fill onsite (if cuttings are from boreholes with less than 20 feet of bedrock) in accordance with Field Operations SOP FO.23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f). These materials will be dispersed and leveled within the disturbed area and reseeded following guidance from the Rocky Flats Ecology Department. Bedrock cuttings, if any, will be covered with alluvial materials. For cuttings from boreholes with more than 20 feet of bedrock, residual soil or sediment will be disposed in the landfill in accordance with Field Operations SOP FO.23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f). Cuttings containerized in drums will be taken to the landfill by Rocky Flats Trucking for disposal.

If verified field screening results are above background as defined in Field Operations SOP FO.08, Handling of Drilling Fluids and Cuttings, and FO.16, Field Radiological Measurements (EG&G 1992c), residual soil or sediment will be drummed at the drilling location in accordance with Field Operations SOP FO.08; labeled in accordance with Field Operations SOP FO.10, Receiving, Labeling, and Handling Environmental Materials Containers (EG&G 1992c); and analyzed for appropriate constituents as discussed below. Results of this analysis will be used to characterize the drums.

6.3.6 *Analytical Requirements for Drum Samples*

If field screening results are above background, drum samples will be analyzed for VOCs; SVOCs; PCBs; metals (standard and additional); gross alpha; gross beta; plutonium-239,240; americium-241; uranium-233,234; uranium-235; uranium-238; cesium-137; strontium-89,90; TOC; pH; nitrate/nitrite; and sulfide (Table 6-4). This analyte list is the same as that used for borehole samples collected during the Phase I RFI/RI for OU 7. Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report and Field Operations SOP FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c). Sample analyses will be performed using EPA CLP and other standard methods as specified in GRRASP (EG&G 1991g).

6.3.7 *Surveying*

After boreholes are plugged and abandoned, all locations will be surveyed in accordance with Geotechnical SOP GT.17, Land Surveying (EG&G 1992c).

6.3.8 *Downhole Geophysical Logging*

Downhole geophysical logging will be performed in the borehole at location 53904 before installing the unweathered bedrock monitoring well to identify and optimize well screen placement in the most permeable zone. The borehole will be logged with the following logging techniques: neutron, natural gamma, gamma-gamma, density, induction, caliper, guard resistivity, and single point resistivity (the last two methods only if sufficient groundwater is encountered in the bedrock). The geophysical surveys will be performed in accordance with Geotechnical SOP GT.15 "Geophysical Borehole Logging."

6.4 Monitoring Well Installation, Well Testing, and Groundwater Sampling

The Phase I investigation identified contamination of groundwater in the UHSU. Additional wells are now needed to delineate contaminant plumes thought to be present along No Name Gulch. The number and locations of additional wells needed to further delineate contamination in UHSU groundwater were determined qualitatively by an analysis of plume maps and contaminant transport pathways (Section 5.5.7).

PCOCs were also identified in groundwater from the LHSU, but the extent of groundwater contamination appears limited. Professional judgment was used to assess whether (1) PCOCs are the result of natural variability in geologic materials, (2) the detections of VOCs are valid, and (3) the occurrence of PCOCs in the LHSU make geochemical sense on the basis of fate and transport characteristics. Characterization of contamination in the LHSU directly beneath IHSS 114 will not be performed due to the potential problems associated with drilling through the landfill and the potential for enhancing vertical migration of contaminants during drilling. A preliminary characterization of the vertical extent of contamination in the LHSU was performed only at the compliance boundary located just east of the landfill dam using existing data. Additional characterization of LHSU groundwater farther east in No Name Gulch is warranted.

Four additional wells are proposed to meet the following two objectives: delineate contaminant plumes in UHSU groundwater and determine the presence or absence of groundwater contamination in the LHSU.

A cluster of three wells is proposed to further delineate contaminant plumes in UHSU groundwater, determine the presence or absence of contamination in LHSU groundwater in No Name Gulch, and meet groundwater-monitoring requirements for post-closure care of the Present Landfill. The proposed well locations (Figure 6-3) are approximately 300 feet downgradient of the compliance wells, west of the confluence of No Name Gulch with the intermittent stream draining IHSS 167.1. One well (52894) will be screened in valley-fill alluvium with the screened interval at an estimated depth of 5 to 10 feet below ground surface. The second well (52994) will be screened in weathered bedrock with the screened interval at an estimated depth of 15 to 25 feet below ground surface. The third well (53094) will be screened in the first unweathered bedrock sandstone encountered with the screened interval at an estimated depth of 40 to 50 feet below ground surface.

One monitoring well (53194) is also proposed 700 feet east of the confluence of No Name Gulch and the tributary to the north that drains IHSS 167.1 and 450 feet east of well 4287 (Figure 6-3). The well will be installed in valley-fill alluvium with the screened interval at a depth of approximately 5 to 10 feet.

6.4.1 Monitoring Well Installation

A total of four monitoring wells will be installed at two locations (Figure 6-3) in accordance with Geotechnical SOP GT.06, Monitoring Well and Piezometer Installation (EG&G 1992c). Monitoring well permits for the State of Colorado, Division of Water Resources, will be prepared and forwarded to DOE to notify the state.

After the borehole or well is drilled to total depth, water and fine-grained sediment will be bailed using a sand bailer until the water is relatively clear. The well assembly, comprised of a 2-foot sump, 2-inch diameter 0.01-inch slotted screen, and 2-inch diameter blank casing, will then be placed in the borehole. A minimum 2-foot bentonite pellet seal will be installed immediately above the filter pack. Bentonite grout backfill will be placed from the top of the bentonite seal to the ground surface. In open-hole installations, stainless-steel centralizers will be placed above

and below the well screen to ensure that a 2-inch annulus is maintained. For open-hole installations, filter pack will be added through a tremie pipe to at least 6 inches above the top of the screen.

After the bentonite grout is allowed to settle for 24 to 72 hours, a 5-foot-long, 6-inch diameter protective steel casing with a locking steel cap will be installed over the monitoring well riser. Protrusion of the riser will be a minimum of 2 feet. The protective casing will be embedded 2 to 3 feet below ground surface in concrete or grout. The annulus between the well riser and the protective casing will be filled with concrete, and an external concrete pad approximately 3-feet square will be built around the protective casing at the ground surface. The well designation will be inscribed in the concrete before it sets and welded to the protective casing.

Alluvial wells will be installed with the base of the screen at the contact between alluvium and weathered bedrock. Weathered bedrock wells will be installed in accordance with Geotechnical SOP GT.03, Isolating Bedrock from Alluvium with Grouted Surface Casing, with the base of the screen at the contact between weathered bedrock and unweathered bedrock. The bentonite seal will be across the contact between the alluvium and the weathered bedrock to isolate the screen and filter pack from alluvial groundwater. Bedrock wells will be constructed similarly, except that the bedrock will be isolated from alluvial and weathered bedrock materials with grouted surface casings installed in accordance with Geotechnical SOP GT.03 (EG&G 1992c). Stainless-steel centralizers will be placed on the casing 3 to 5 feet below ground surface and 3 to 5 feet from the base of the casing to ensure a minimum 2-inch annular space. Surface casing is installed using a cement-grout mixture that is forced down and out through pre-drilled ports at the base of the casing into the annulus by pushing a plug down through the casing. The annulus will be topped off with cement grout, if necessary, and the cement grout will be allowed to harden for a minimum of 24 hours before the next drilling phase begins. After reaching total depth, bedrock wells will be installed in an open borehole using the procedure described above.

6.4.2 Well Development

Monitoring wells will be developed to remove drilling fluids and particulates from the groundwater and provide physically and chemically representative groundwater samples. Well development will be performed in accordance with Groundwater SOP GW.02, Well

Development (EG&G 1992c). Equipment will be decontaminated before and after each use in accordance with Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c). Before developing the well, water level and total depth measurements will be taken to determine the volume of water in the well casing. The volume of water to be purged from the well will be calculated according to guidelines in Groundwater SOP GW.02, Well Development (EG&G 1992c). The purge amount is generally five well casing volumes. During development, water is withdrawn from the wells using a bailer or an inertial pump. The purge water will be emptied into a graduated bucket to measure the amount of water removed and transferred to a holding tank for proper disposal. The purge and decontamination water will be handled in accordance with Field Operations SOP FO.07, Handling of Decontamination and Wash Water (EG&G 1992c).

Field parameters, including pH, temperature, specific conductance, and turbidity will be measured at regular intervals at least once for each well casing volume following the procedures outlined in Groundwater SOP GW.05, Field Measurement of Groundwater Field Parameters (EG&G 1992c). A well is considered fully developed after a minimum of five casing volumes of water are removed, field parameter measurements range within 10 percent for three consecutive well casing volumes, and the purged water is free of suspended sediment.

6.4.3 *Drawdown Recovery Testing*

Drawdown recovery tests will be performed at all of the recently installed wells to estimate the hydraulic conductivity of saturated geologic materials, including colluvium, valley-fill alluvium, weathered Arapahoe and Laramie Formation, and the uppermost unweathered sandstone in the Arapahoe and Laramie Formation. Drawdown recovery tests will also be performed at well 0786 ~~and in open boreholes near the leachate seep (53294 and 53394)~~. Based on results during the Phase I investigation, the drawdown recovery test method, which involves purging a volume of water from the well to lower the water level by approximately 2 to 6 feet, is considered more appropriate than using the slug injection test method. Tests will be performed after the wells are developed and the static water level has stabilized.

The drawdown recovery tests will be performed in accordance with Groundwater SOP GW.04, Slug Tests (EG&G 1992c). After removing the well cap and monitoring the well for health and safety purposes, the static water level at the well will be measured and verified using a

weighted tape measure. Water level and total depth measurements will be recorded and compared to previous measurements to confirm water level stabilization. When the water level has stabilized, the test will be conducted.

A Hermit® SE 1000 data logger will be coupled to a transducer that has a sensitivity of 10 pounds per square inch and is capable of measuring hydraulic head to an accuracy of approximately three thousandths of a foot. The data logger will be programmed to record change in hydraulic head (in feet) above the transducer at a logarithmic rate. All transducer specifications provided by the manufacturer, including serial number, linearity, scale, and offset will be programmed into the data logger. The transducer will be lowered into the well to a depth at which it will not be disturbed by a bailer. Then the transducer cable will be secured to the well casing with tape to maintain the appropriate depth of the probe. To ensure that the transducer and logger are working properly, the transducer cable will be raised and lowered in the well while the change in hydraulic head is observed on the data logger visual read-out screen. After the visual check has been completed, the water level will be allowed to stabilize, and the test will be referenced to zero.

After the test is set up, a 3-foot-long by 1.5-inch bailer will be lowered down the well. Water will be purged from the well until an appropriate drawdown is achieved. The test will be started immediately after the last bailer of water is removed from the well. The water purged from the well will be containerized and disposed in accordance with Field Operations SOP FO.05, Handling of Purge and Development Water (EG&G 1992c). Purge rates, volumes of water removed, test-start times, and initial drawdowns will be recorded.

The duration of each test will be dependent on the drawdown recovery rate or the rate at which the drawdown approaches zero. The test will be considered completed when the water level recovers to 90 percent of the drawdown depth. The drawdown and percent recovery will be checked by scanning the measurements recorded in the data logger. When water levels have recovered, the test will be terminated. Before and after each test, all down-hole equipment will be decontaminated following procedures in Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c).

After the data logger reaches storage capacity, the data collected will be downloaded into a computer. The time versus drawdown data will be imported into AQTESOLV (Geraghty and

Miller 1991) to compute the estimated hydraulic properties using the appropriate analytical solutions.

6.4.4 Groundwater Sampling

Groundwater samples will be collected from the four new wells installed during the Phase II investigation to characterize groundwater quality downgradient of existing contaminant plumes. Four samples will be collected at each location. Frequency of sample collection will be monthly. Duplicate, equipment rinse, and trip blank QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7.1. MS, MSD, and laboratory replicate QC samples will be collected in accordance with Groundwater SOP GW.06, Groundwater Sampling (EG&G 1992c). One sample of distilled water will be collected and analyzed to determine if any of the contaminants in groundwater samples are from the decontamination water.

Groundwater samples will be collected in accordance with Groundwater SOPs GW.06, Groundwater Sampling, and GW.01, Water Level Measurements in Wells and Piezometers (EG&G 1992c). Water level and total depth measurements will be taken to determine the volume of water in the well casing. These data will be taken to determine the volume of water in the well casing, and appropriate purge volumes. Standing water will be purged from the well with a bailer. The equivalent of three well casing volumes will be purged to guarantee that the sample is representative of the groundwater in the formation.

Field parameters, including conductivity, pH, temperature, ~~dissolved oxygen,~~ and turbidity will be measured from an aliquot of the first bailer of water in accordance with Groundwater SOP GW.05, Field Measurement of Groundwater Field Parameters (EG&G 1992c). Conductivity, pH, and temperature will be measured for every half-casing volume of water removed from the well. Turbidity and ~~dissolved oxygen~~ will be measured a second time during well purging. Well purging will be considered complete when three casing volumes have been purged and the field parameter measurements have been stabilized. Purge and decontamination water will be handled in accordance with Field Operations SOP FO.07, Handling of Decontamination and Wash Water (EG&G 1992c).

After completion of well purging, groundwater samples will be collected using a bailer. VOC samples will be collected from the first bailer of water. The remaining unfiltered samples will be

transferred directly from the bailer to the appropriate sample containers using a bottom-emptying device. Samples for dissolved analyses will be transferred to a stainless-steel bucket and filtered using a peristaltic pump with a disposable 0.45-micron filter. Groundwater samples from each well will be assigned a unique sample number. All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO.03, General Equipment Decontamination (EG&G 1992c).

6.4.5 Analytical Requirements for Groundwater Samples

Groundwater samples will be analyzed for VOCs; SVOCs; dissolved and total metals (standard and additional); water-quality parameters (Cl, F, SO_4, CO_3, HCO_3, TDS, TSS); dissolved gross alpha; dissolved gross beta; dissolved and total plutonium-239,240; dissolved and total americium-241; dissolved uranium-233,234; dissolved uranium-235; dissolved uranium-238; dissolved strontium-89,90; dissolved cesium-137; tritium; nitrate/nitrite; cyanide; and sulfide (Table 6-5). This analyte list is the same as that used for groundwater samples collected during the Phase I RFI/RI for OU 7. Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report and Field Operations SOP FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c). Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g).

6.4.6 Surveying

After groundwater monitoring wells are installed, all locations will be surveyed in accordance with Geotechnical SOP GT.17, Land Surveying (EG&G 1992c).

6.5 Additional Activities for Remedial Design

Additional data needed to support design of the presumptive remedy for closure of the landfill were determined qualitatively using a standard engineering approach and include a topographic map, location of existing utilities, location and soil characteristics of potential borrow areas, and landfill gas emission rates (Section 5.6).

A topographic map will be prepared using survey data. The map will show the locations of property features, topographic contours, spot elevations, and areas that have recently been graded or mounded. Plans for future mounding of waste will be modeled to determine final

configuration of the landfill. Location of utilities aboveground or underground that may interfere with construction will be identified. In addition, the nearest service locations for electricity, water, and communication lines will be identified for construction and operations of the remedial system. Location and soil characteristics of potential borrow areas for clay, sand and gravel, and topsoil will be obtained from existing sources or measured in the field, if necessary. These activities will be integrated with Rocky Flats Waste Operations activities and other applicable Rocky Flats projects. Data may be collected during the preparation of the landfill closure IM/IRA decision document or during the Phase II investigation, if necessary.

Gas emission rates will be measured during the Phase II field investigation. A hand-held vane or hot-wire anemometer flow measuring device will be used to measure gas flow rates in each of the five gas-venting wells. Either of these instruments is capable of detecting very low flow rates typical of gas well discharges. A temporary modification will be made to each well outlet to extend the pipe 1 to 2 feet so that the velocity probe can be inserted into the gas stream through a sample port rather than obtaining a reading at the pipe at the pipe exit. This modification will minimize any adverse effects on flow measurement accuracy due to wind. The gas composition obtained during the Phase I field investigation will be used to estimate actual methane being released from the site.

The flow rates at the leachate seep (SW097) will be measured using a Parshall flume, or equivalent, in accordance with surface water SOP SW.04, "Discharge Measurement" (EG&G 1992).

Section 6
Tables

Table 6-1
Summary of Analytical Requirements for Soil Samples

Analyte	RFEDS Bottle ID
Soil Samples	
Gross Alpha	RA
Gross Beta	RA
Plutonium-239,240	RB
Americium-241	RB
Uranium-233,234	RC
Uranium-235	RC
Uranium-238	RC
Cesium-137	RD
Strontium-89,90	RD
Metals (standard and additional)	M
TOC	WH
Nitrate/Nitrite	WBC

Notes:

Rad screen also required

Samples to be collected by priority in the approximate order listed above

Table 6-2
Summary of Geotechnical Testing

Test	ASTM	Bottle ID
Atterberg Limits	D4318	GSE
Modified Proctor Density	D1557	GSH
(Compaction)		
One Dimensional Swelling/ Pressure (Unrestrained Swelling)	D4546 Method B	GJB
Moisture Density	D2216	GQB
Soil Classification	D2487	GSF
California Bearing Ratio	D1883	GJA

Note:

Rad screen also required

Table 6-3
Summary of Analytical Requirements for Borehole Samples

Analyte	RFEDS Bottle ID
Borehole Samples	
VOC	V
SVOC	B
PCB	P
Metals (standard and additional)	M
Gross Alpha	RA
Gross Beta	RA
Plutonium-239,240	RB
Americium-241	RB
Uranium-233,234	RC
Uranium-235	RC
Uranium-238	RC
Cesium-137	RD
Strontium-89,90	RD
pH	WL
TOC	WH
Nitrate/Nitrite	WBC
Sulfide	WJ

Note:

Rad screen also required

Samples to be collected by priority in the approximate order listed above

Table 6-4
Summary of Analytical Requirements for Drum Samples

Analyte	RFEDS Bottle ID
Drum Samples	
VOC	V
SVOC	B
PCB	P
Metals (standard and additional)	M
Gross Alpha	RA
Gross Beta	RA
Plutonium-239, 240	RB
Americium-241	RB
Uranium-233,234	RC
Uranium-235	RC
Uranium-238	RC
Cesium-137	RD
Strontium-89,90	RD
pH	WL
TOC	WH
Nitrate/Nitrite	WBC
Sulfide	WJ

Notes:

Rad screen also required

Samples to be collected by priority in the approximate order listed above

Table 6-5
Summary of Analytical Requirements for Groundwater Samples

Analyte	RFEDS Bottle ID
Groundwater Samples	
VOC	V
SVOC	B
Water-Quality Parameters: (Cl,F,SO4,CO3,HCO3,TDS,TSS)	WAA
Nitrate/Nitrite	WBC
Dissolved Gross Alpha	RA*
Dissolved Gross Beta	RA*
Dissolved Uranium-233,234	RC*
Dissolved Uranium-235	RC*
Dissolved Uranium-238	RC*
Metals (standard and additional)	M
Dissolved Metals (standard and additional)	M*
Plutonium-239,240	RB
Dissolved Plutonium-239-240	RB*
Americium-241	RB
Dissolved Americium-241	RB*
Tritium	RG
Dissolved Strontium-89,90	RD*
Dissolved Cesium-137	RD*
Cyanide	WE
Sulfide	WJ

Notes:

Rad screen also required

Samples to be collected by priority in the approximate order listed above

Section 6
Figures

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7. QUALITY ASSURANCE AND QUALITY CONTROL

Section 6 presents the FSP for the Phase II RFI/RI at OU 7 and addresses the proposed field activities and locations as well as the proposed analytical suites for the samples to be collected during the field investigation. QA/QC objectives for data collection; analytical procedures; data-quality calibration; and data reduction, validation, and reporting are included in the QAPjP (EG&G 1991h). All field and analytical procedures will be performed in accordance with the GRRASP (EG&G 1991g) and appropriate SOPs (EG&G 1992c).

7.1 Quality Control Sample Collection

The objective of the QAPjP is to provide a framework to ensure that all sampling and analytical data achieve specific data-quality standards. QC samples will be collected in conjunction with the real samples to provide information to assess data quality. The field QC samples to be collected during the Phase II investigation include field duplicates, field blanks, equipment rinses, trip blanks, and matrix spike/matrix spike duplicates (MS/MSD). Trip blanks generally pertain only to VOC analyses, whereas other QC samples may pertain to all of the analytical parameters specified for investigative samples in the FSP.

Field duplicates will be collected by the sampling team for use as a relative measure of the precision of the sample-collection process. In addition to evaluating analytical precision, duplicate samples will provide information regarding the natural variability of the sampled media as well as the precision of the sampling methods.

Field blanks of distilled water will be prepared and preserved as appropriate by the sampling team and will be used to provide an indication of any contamination introduced during field sample preparation.

Equipment rinses will be collected from final decontamination rinse water to evaluate decontamination efforts on non-dedicated sampling equipment. Equipment rinses are

applicable to all analyses for water and soil samples to monitor the effectiveness of decontamination procedures.

Trip blanks consisting of distilled will accompany each shipment of samples for VOC analysis. Trip blanks will be stored with the group of samples with which they are associated. Analysis of trip blanks will indicate possible contamination by VOCs or any problems associated with sample shipment, handling, or storage. Information from the trip blanks will be used in conjunction with air monitoring data and other information to assess the influence of ongoing waste operations on the quality of data collected. Table 7-1 presents the collection frequency for the field QC samples.

7.2 Analytical Procedures

All samples sent for CLP Level IV analyses will be handled in accordance with CLP guidelines.

Sensitivity defines the lowest concentration (detection limit) a method can accurately and repeatedly detect for a particular chemical or compound. The required detection limits for CLP analyses are outlined in Appendix B in the QAPjP (EG&G 1991h). Detection limits for non-CLP indicator parameter analyses are specified in the respective EPA methods.

Analytical procedures and conditions are tested using laboratory blanks and replicates. Laboratory MS and MSD samples measure analytical accuracy by providing data on matrix effects and interferences and components interfering with instrument responses. The frequency of collection and analysis of laboratory QC samples is dictated by the prescribed analytical method as specified in the GRRASP (EG&G 1991g).

7.3 Data Quality

Data quality is assessed in terms of precision, accuracy, representativeness, completeness, and comparability, also known as the PARCC parameters.

7.3.1 Precision

Precision is a quantitative measure of variability that is evaluated by comparing analytical results for real samples to analytical results for corresponding duplicate samples. Analytical precision for a single analyte is expressed as the RPD between results of duplicate samples

(and matrix spike duplicates) for a given analyte. RPDs indicate the degree of reproducibility of both the sampling and analysis methods. The control limits that have been established to achieve precision objectives for CLP Level IV data are outlined in Appendix B of the QAPjP (EG&G 1991h). Precision limits for inorganic analytes are outlined in this table as well. The analyses for indicator parameters are non-CLP. Non-CLP analyses will be conducted according to SW-846 (EPA 1986) and EPA Methods for Chemical Analyses of Water and Wastes (EPA 1983). The precision criteria for these samples are specified in the respective methods. For the OU 7 data, acceptable RPDs are less than 20 percent for all analytes in water (surface water and groundwater) and less than 35 percent for all analytes in soil (surficial soil, subsurface geologic material, and sediments).

7.3.2 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value. Analytical accuracy is expressed as percent recovery of a spike of a known concentration that has been added to an environmental sample before analysis. The control limits that have been established to achieve accuracy objectives for CLP Level IV data are outlined in Appendix B of the QAPjP (EG&G 1991h). Accuracy limits for inorganic analytes are listed in this table as well. The OU 7 QC criterion for acceptable percent recovery in CLP Level IV data is 80 percent to 120 percent for all analytes in all media.

Samples requiring 24-hour turnaround (that is, indicator parameter analyses) have accuracy objectives consistent with CLP Level III data quality. The analyses for indicator parameters are non-CLP. Non-CLP analyses will be conducted according to SW-846 (EPA 1986) and EPA Methods for Chemical Analyses of Water and Wastes (EPA 1983). The accuracy criteria for these samples are specified in the respective methods.

7.3.3 Representativeness

Representativeness is a qualitative parameter that expresses the degree to which the data accurately and precisely represent the characteristics of a particular site or condition. Of specific concern to the OU 7 Phase II investigation is the potential for sample contamination that could be introduced during sample collection and handling. This possibility is evaluated using field blanks, equipment rinses, and trip blanks. Representativeness is ensured through

the careful development and review of the sampling strategy outlined in the FSP and SOPs for sample collection, analysis, and field data collection.

7.3.4 Completeness

Completeness is a measure of the amount of usable data resulting from a data-collection activity. The target completeness objective for both field and analytical data for this project is 100 percent. The minimum acceptable completeness value is 90 percent.

7.3.5 Comparability

Comparability expresses the confidence with which one data set can be compared to another. Differences in field and laboratory procedures greatly affect comparability. Comparability is ensured by implementation of an approved FSP, standardized analytical protocols, SOPs for field investigations, and reporting data in uniform units, as specified in the OU 7 Phase II FSP.

7.4 Sample Management

Sample management is a critical component of the OU 7 Phase II FSP and ensures that sample integrity is maintained from sampling through analysis. All aspects of sample management, including sampling, decontaminating equipment, preserving and storing samples, following chain-of-custody procedures, and shipping will be conducted in accordance with applicable SOPs (EG&G 1992c). Table 7-2 lists the container types, preservation methods, and holding times for samples and/or sample suites for each media.

Sample control and documentation is necessary to verify the quality and quantity of work performed in the field and to ensure that the data are defensible. Documents used for accountability include logbooks, data-collection forms, sample labels or tags, chain-of-custody forms, photographs, and analytical records and reports. Specific guidance defining the necessary sample control, identification, and chain-of-custody documentation is presented in SOP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Waste Samples (EG&G 1992c).

7.5 Data Reduction, Validation, and Reporting

Field measurements, data, and observations will be recorded in project logbooks, on field data forms, or on similar permanent records, as specified in appropriate SOPs (EG&G 1992c). Field data and sampling records will become QA records. Field QA records will be transmitted to the EG&G EMD records center in accordance with SOP FO. 02, Transmittal of Field QA Records (EG&G 1992c).

Field data will be managed as outlined in SOP FO.14, Field Data Management (EG&G 1992c). Field data will be collected, recorded, entered into electronic format, validated, transmitted to EG&G, and filed in RFEDS. Sample tracking information will also be entered into electronic format, validated, transmitted, and filed in the database. Computer hardware and software requirements and data security measures will also follow guidelines in the SOPs (EG&G 1992c).

The EPA-CLP sample results will be reported as specified in the GRRASP (EG&G 1991g) and in guidance for providing electronic deliverable laboratory data to RFEDS (EG&G 1991i). Laboratory data will be validated by an independent subcontractor in accordance with EPA guidelines for CLP data (EPA 1988a, EPA 1988b). Non-CLP data will be validated in accordance with guidelines developed by EMD at Rocky Flats. Data will be assigned validation codes that will subsequently be used to determine data usability for developing the IM/IRA decision document and selecting remedial actions.

Section 7
Tables

Table 7-1
Field Quality Control Sample Collection Frequency

QC Sample	Frequency
Field duplicate	1 per 10 real samples or 1 per sampling event[1]
Field blank[2]	1 per shipping container (or a minimum of 1 per 20 real water samples)
Equipment rinse	1 per 20 real samples or 1 per day[3]
Trip blank[4]	1 per 20 real water samples
Matrix spike/Matrix spike duplicate	1 per 20 real water samples

[1] Whichever is more frequent.

[2] For samples to be analyzed for inorganic compounds.

[3] Whichever is more frequent for each specific sample matrix being collected when non-dedicated sampling equipment is used.

[4] For samples to be analyzed for organic compounds.

Source: EG&G 1991g

Table 7-2
Sample Containers, Preservation Methods, and Holding Times

Media	Parameter	Container	Preservative	Holding Time
Soils	VOCs	120 ml capped core	Cool, 4°C	7 days
	SVOCs, Pesticides, and PCBs	1 x 8-oz wide-mouth Teflon®-lined glass vial	Cool, 4°C	7 days until extraction, 40 days after extraction
	Metals (TAL)	1 x 8-oz wide-mouth glass jar	Cool, 4°C	180 days[1]
	Sulfide	1 x 8-oz wide-mouth glass jar	None	7 days
	Nitrate/Nitrite	1 x 8-oz wide-mouth glass jar	Cool, 4°C	28 days
	Radionuclides	1 x 500 ml wide-mouth glass jar	None	None
	Geotechnical	1 x 5-gal bucket	None	None
Groundwater	VOCs	2 x 40 ml VOA vials with Teflon®-lined septum lids	Cool, 4°C[2] with HCl to pH<2	7 days 14 days
	SVOCs, Pesticides, and PCBs	1 x 4 ℓ - amber[3] glass bottle	Cool, 4°C	7 days until extraction, 40 days after extraction
	Metals (TAL)	1 x 1 ℓ - polyethylene bottle	Nitric acid pH<2; Cool, 4°C	180 days[1]
	Cyanide	1 x 1 ℓ - polyethylene bottle	Sodium hydroxide[4] pH>12; Cool, 4°C	14 days
	Anions	1 x 1 ℓ - polyethylene bottle	Cool, 4°C	14 days
	Sulfide	1 x 500 ml - polyethylene bottle	1 mL-zinc acetate sodium hydroxide to pH>9; Cool, 4°C	7 days
	Nitrate/Nitrite	1 x 1 ℓ - polyethylene bottle	Sulfuric acid	28 days
	Radionuclides	3 x 4 ℓ - polyethylene bottle	Nitric acid pH<2	180 days
	Tritium	125 ml - glass bottle	None	None

[1] Holding time for mercury is 28 days.
[2] Add 0.008% sodium thiosulfate ($Na_2S_2O_3$) in the presence of residual chlorine.
[3] Container requirement is for any or all of the parameters given.
[4] Use ascorbic acid only if the sample contains residual chlorine. Test a drip of sample with potassium iodine-starch test paper; a blue color indicates need for treatment. Add ascorbic acid, a few crystals at a time, until a drop of sample produces no color on the indicator paper. Then add an additional 0.6g of ascorbic acid for each liter of sample volume.

Definitions:

HCL	hydrochloric acid
gal	gallon
mL	milliliter
oz	ounce
PCBs	polychlorinated biphenyls
SVOCs	semivolatile organic compounds
TAL	target analyte list
TDS	total dissolved solids
VOA	volatile organic analysis
VOCs	volatile organic compounds
ℓ	liter

Source:

EG&G 1991g

This is a
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ENVIRONMENTAL MANAGEMENT
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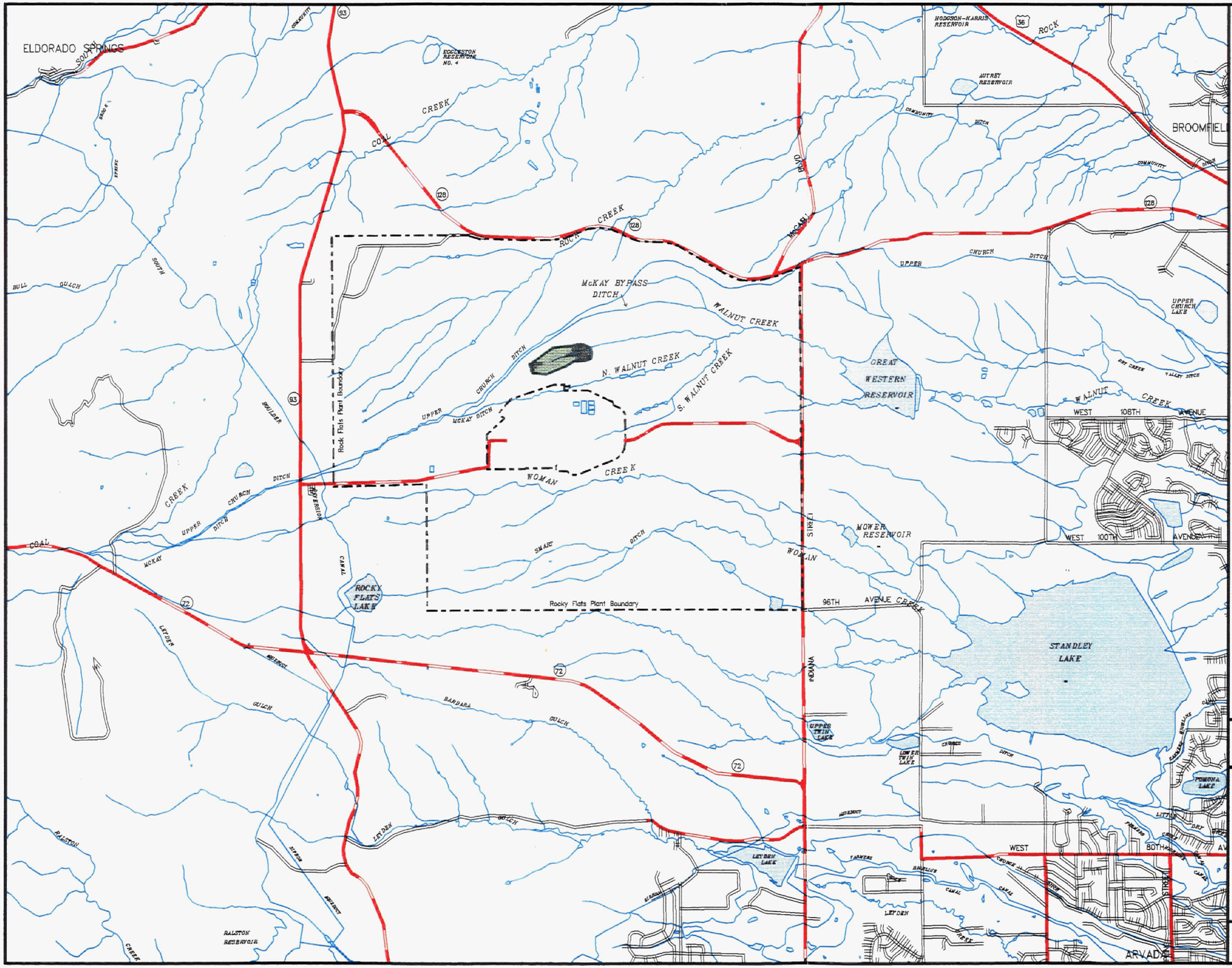


EXPLANATION

- Streams
- Rocky Flats Site Boundary
- Primary Roads
- Secondary Roads
- Light–Duty Roads
- OU 7

0 Miles 1 2

0 Feet 4500 9000

Scale: 1 inch = 4500 feet

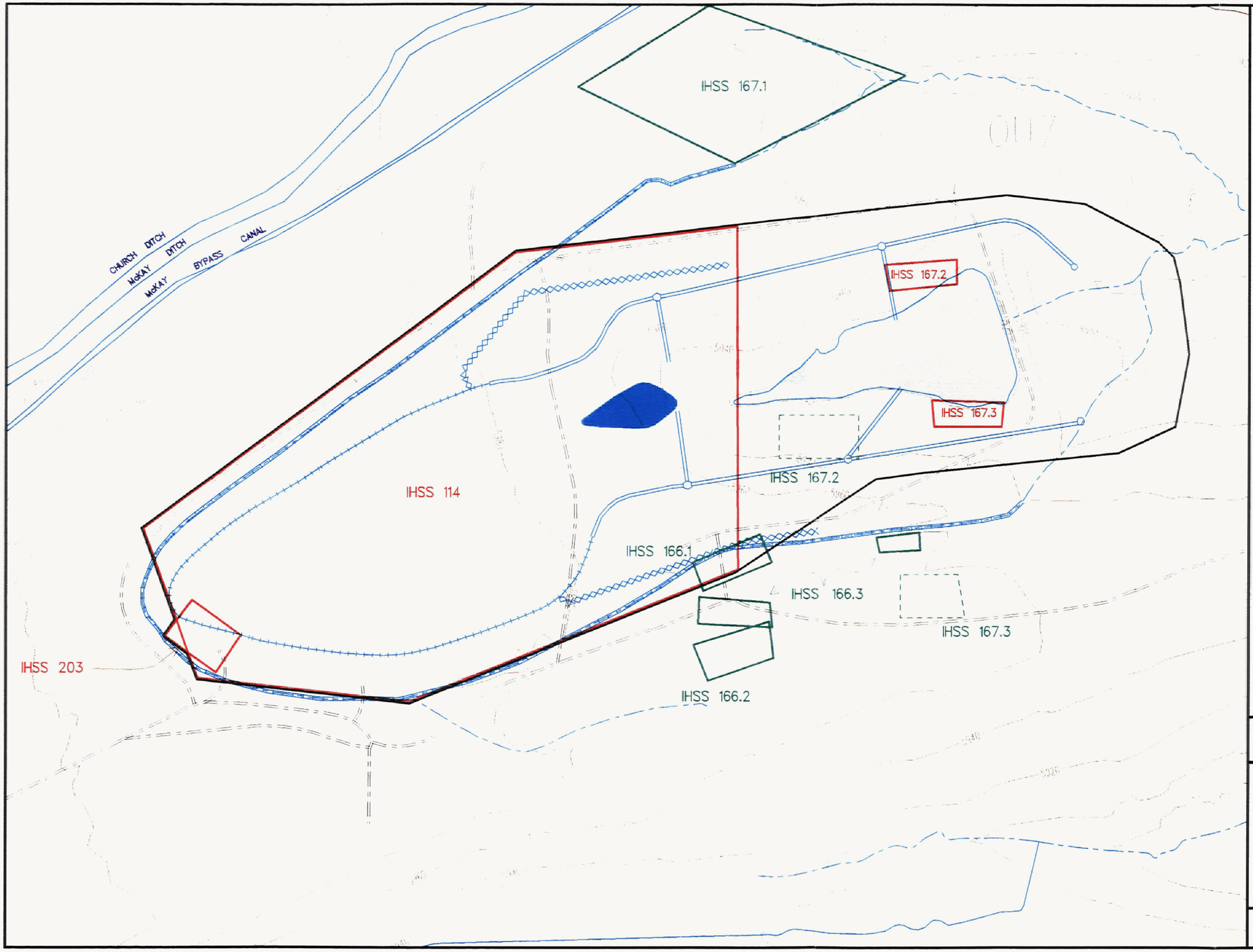
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Location Map of OU 7, Rocky Flats Site, and Vicinity

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 1–2

09/06/94 VICINITY.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary
- OU 6 Historical IHSS Boundary
- East Landfill Pond
- Approximate Extent of West Landfill Pond
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

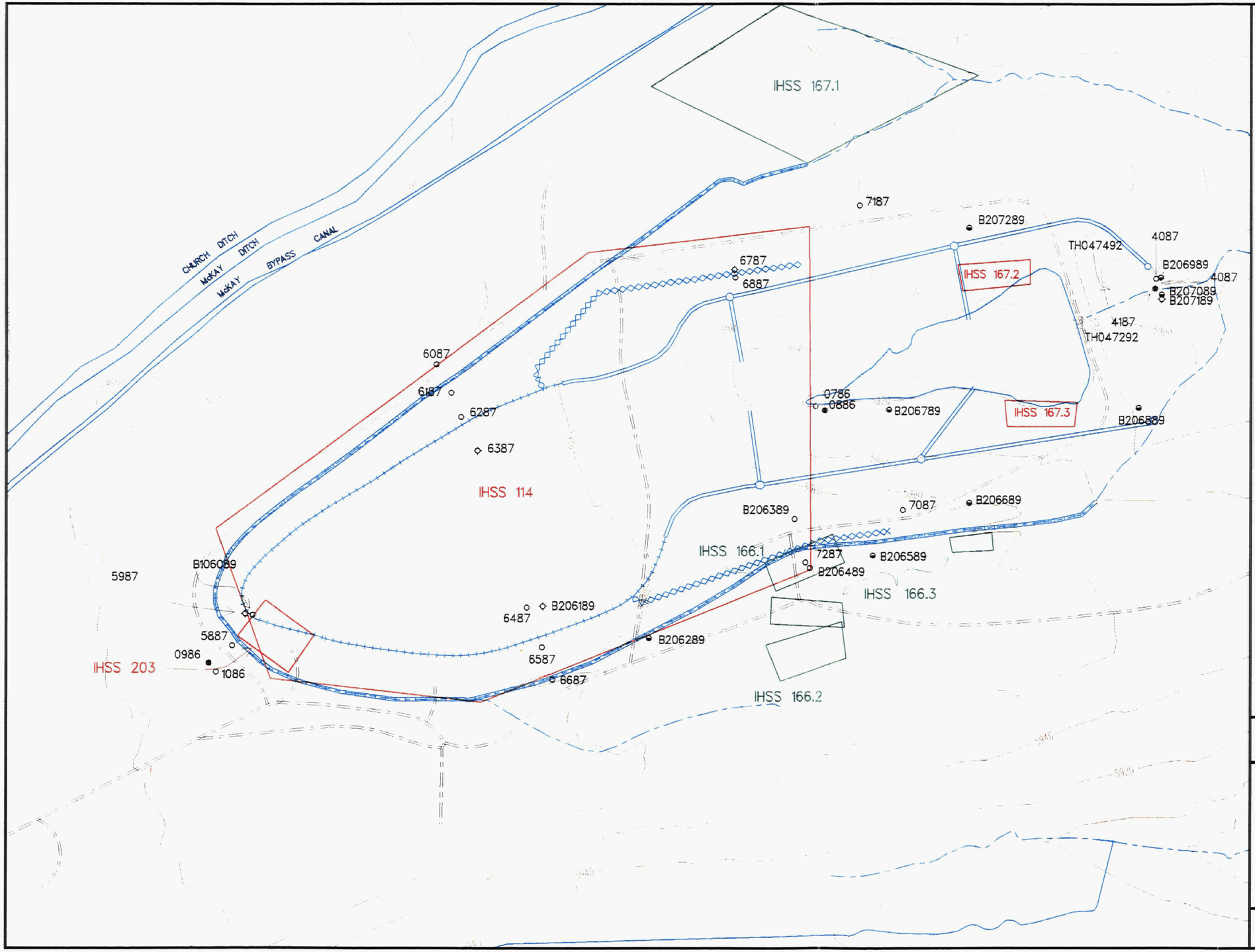
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Locations of Individual Hazardous Substance Sites at OU 7

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-3

04/04/94 OU7IHSS.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)

0 Feet 250 500

Topographic Contour Interval = 20 Feet

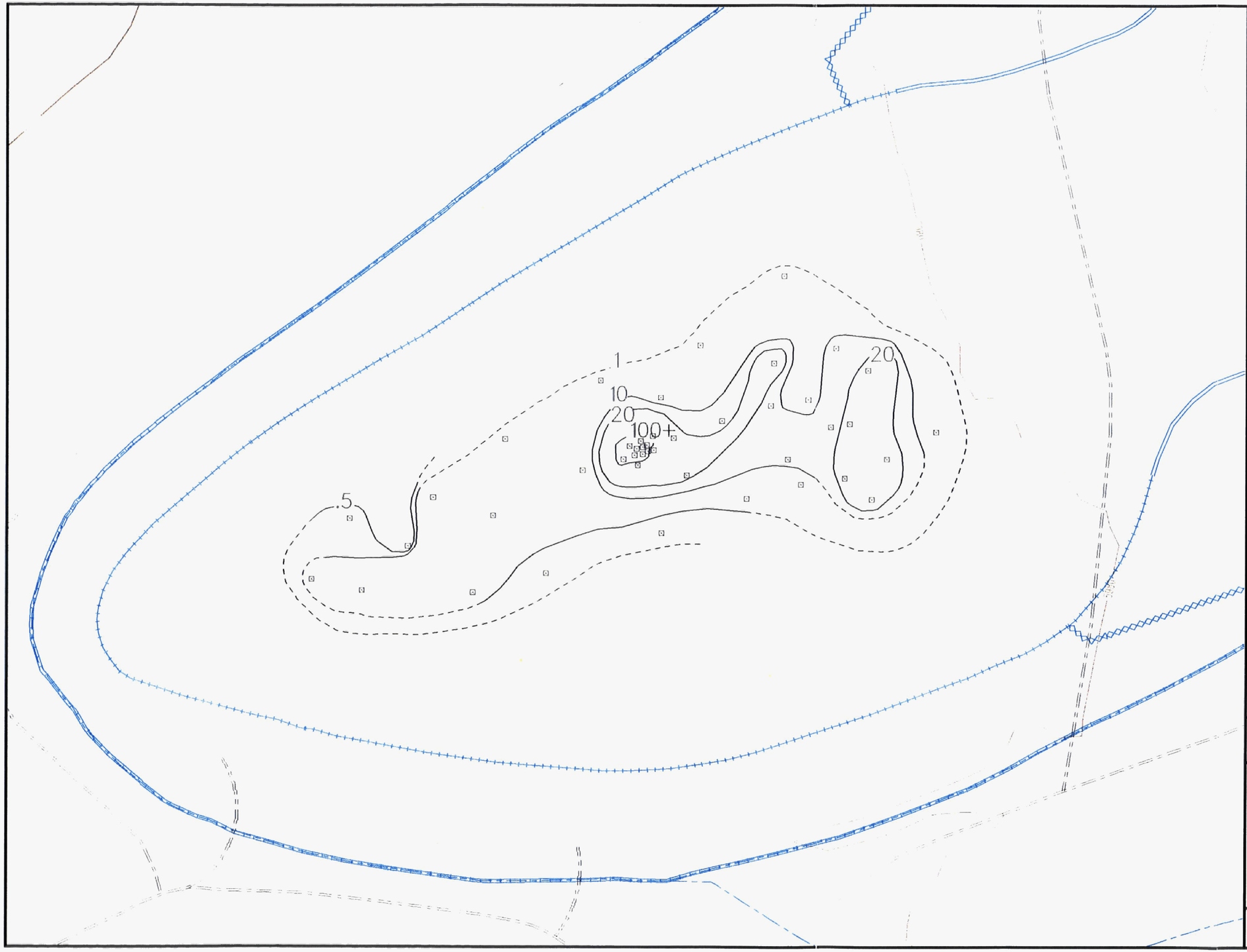
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Locations of Landfill Structures

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-4

04/04/94 LANDFILL.MAP



EXPLANATION

- Tritium Concentration Contour
- (dashed where approximately located)
- * Units in thousands of picocuries per liter
- Tritium Sampling Location
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
- (perforated)
- (non-perforated)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

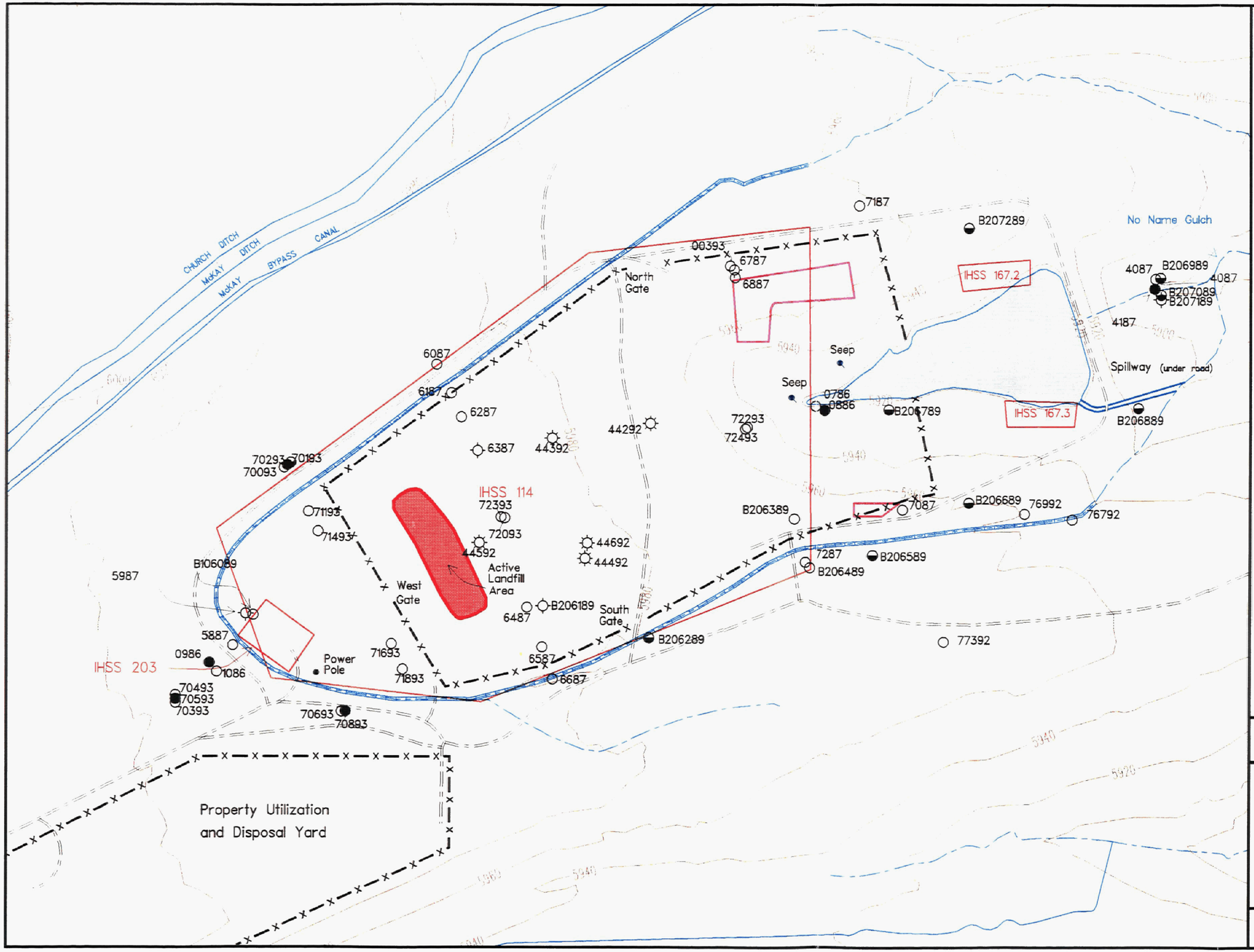
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Tritium in Landfill Leachate in 1973

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-6

03/21/94 TRITIUM.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Gas Venting Well
- OU7 IHSS Boundary
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Fence
- Asbestos Disposal Areas

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

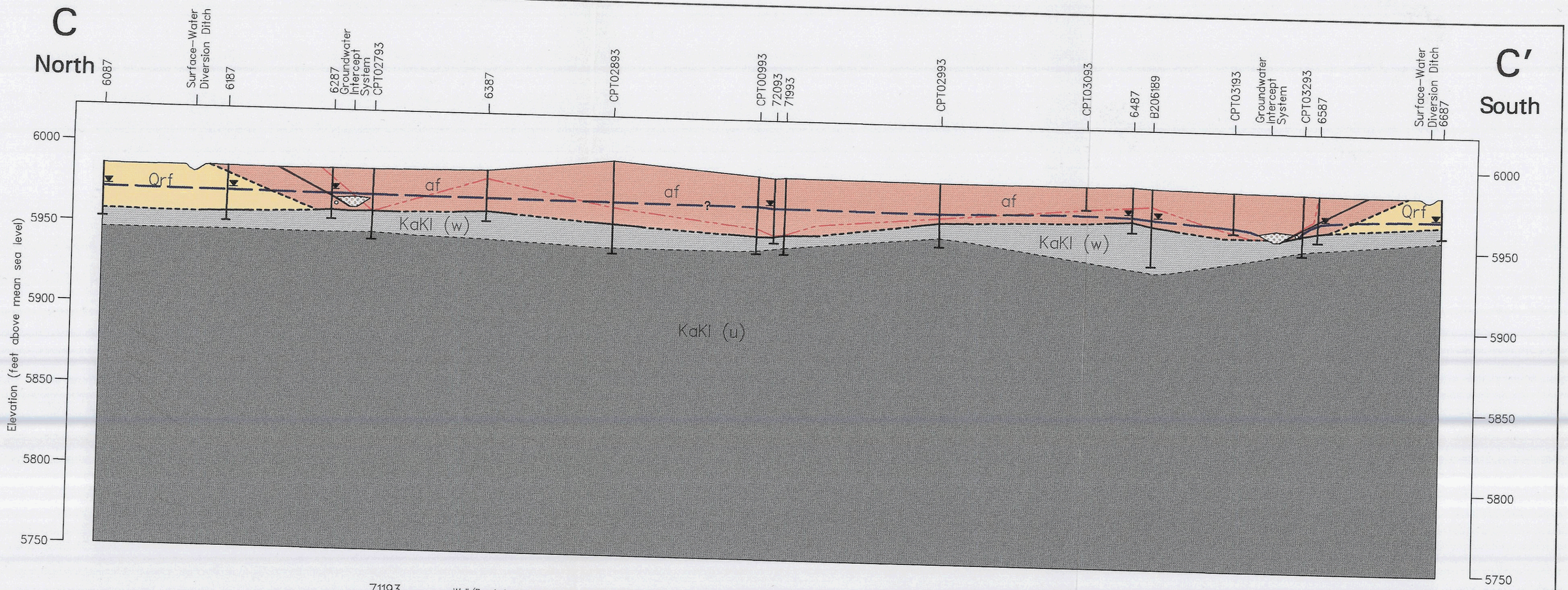
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Features at OU 7

Revised Work Plan | Operable Unit No. 7

Date: May 1994 | Figure 2–1

05/18/94 FEATURES.MAP



71193 Well/Borehole Number
CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

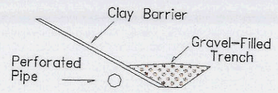
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)
(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

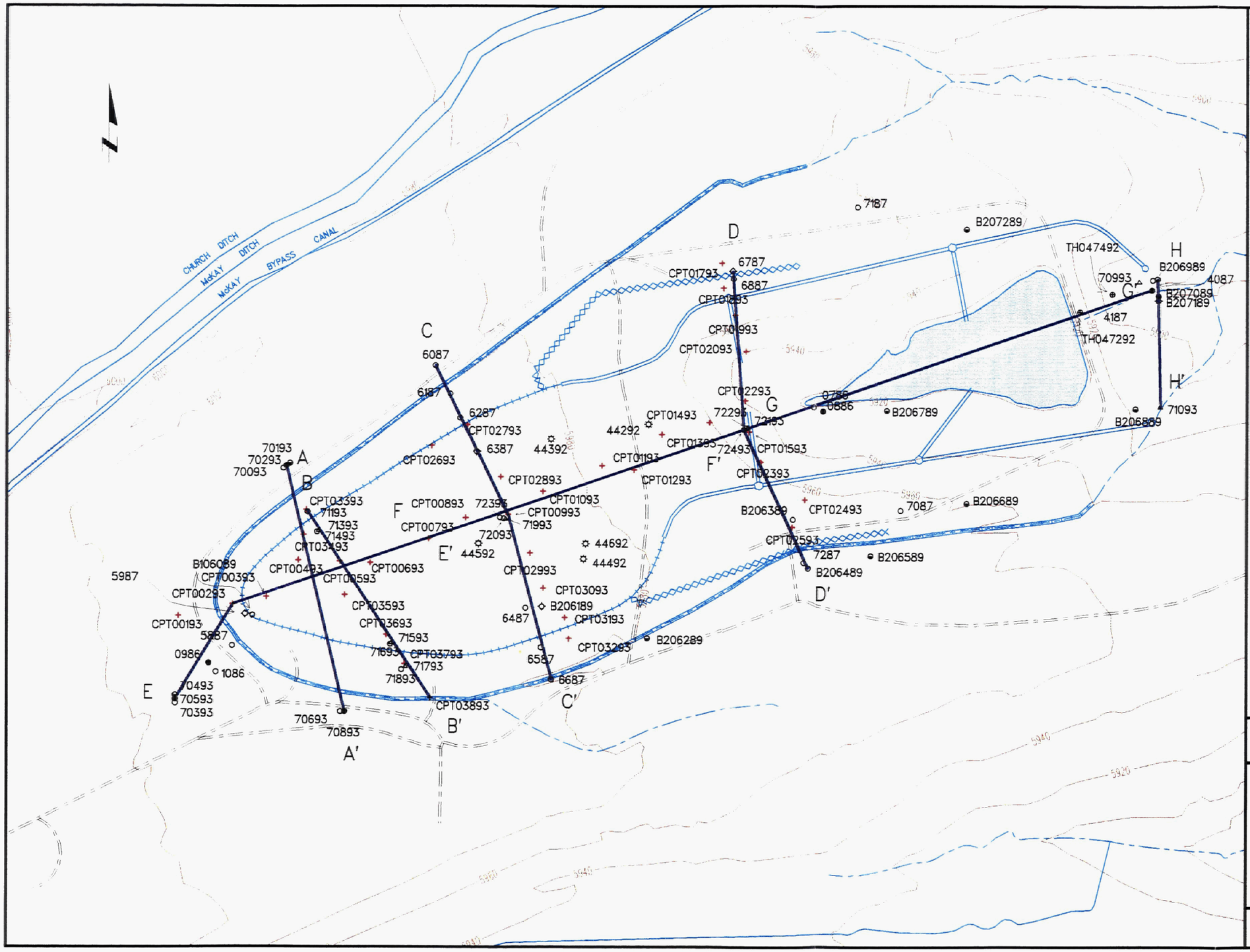
Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section C - C′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2–11



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- Gas Venting Well
- CPT Location
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Geologic Cross–Section

0 Feet 250 500

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

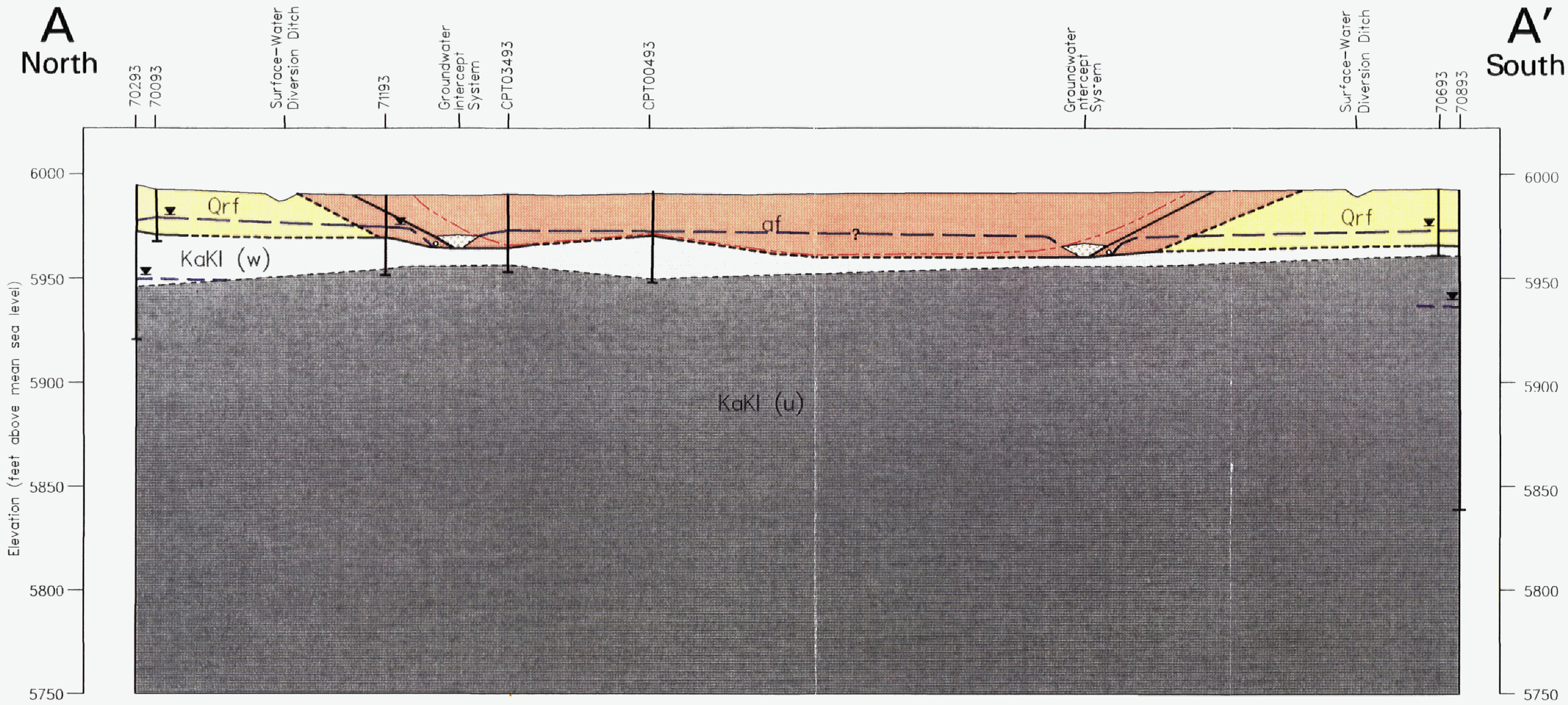
Geologic Cross-Section Location Map

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2–8

08/30/94 GEOPROFILE.MAP

A North — A′ South



71193 — Well/Borehole Number

CPT00493 — CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

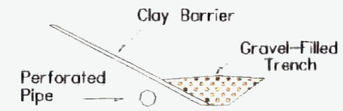
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af — Artificial Fill

Quaternary

Qrf — Rocky Flats Alluvium

Cretaceous

KaKl — Undifferentiated Arapahoe and Laramie Formations

(w) — Weathered

(u) — Unweathered

Horizontal Scale: 1 inch = 50 feet

Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

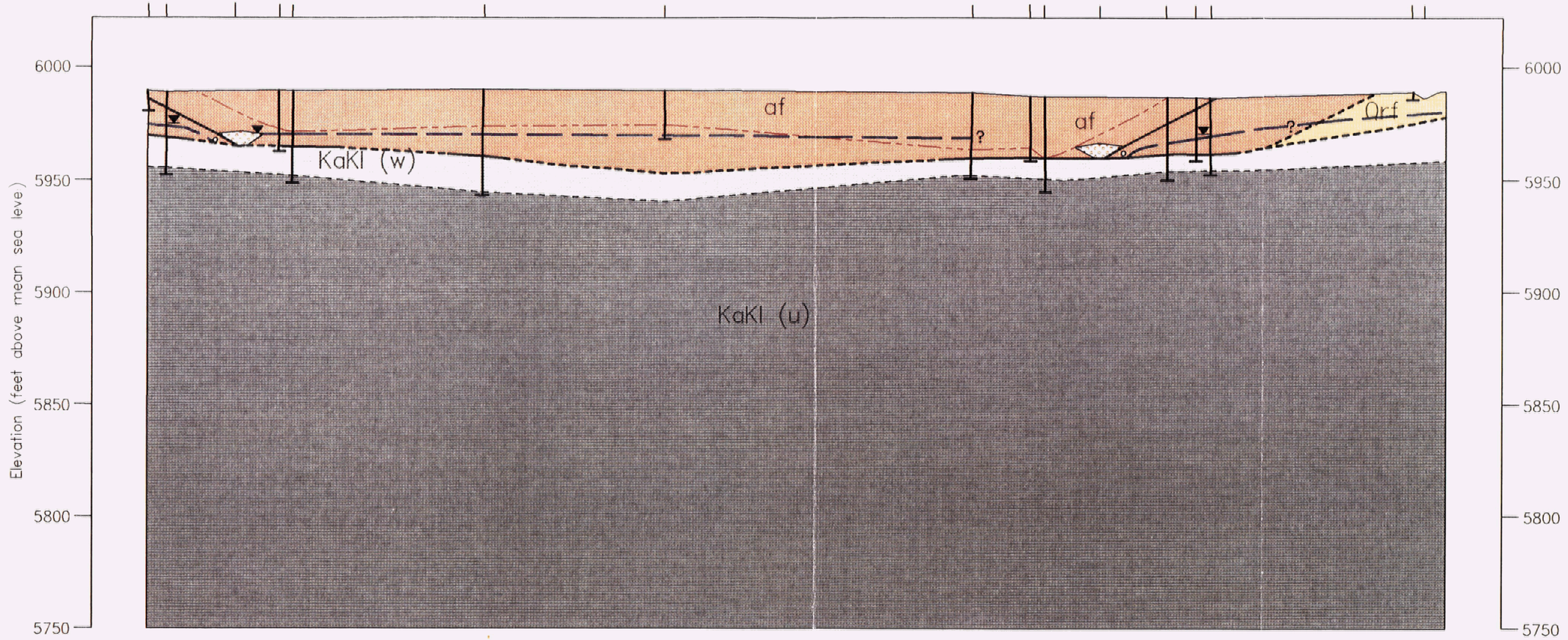
Geologic Cross-Section A - A′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2-9

B North — B′ South

CPT03393 / 71193 — Groundwater Intercept System — 71493 / 71393 — CPT00593 — CPT03593 — CPT03693 / 71693 / 71593 — Groundwater Intercept System — CPT03793 / 71893 / 71793 — CPT03893 Surface-Water Diversion Ditch



71193 — Well/Borehole Number

CPT00493 — CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993

Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af — Artificial Fill

Quaternary

Qrf — Rocky Flats Alluvium

Cretaceous

KaKl — Undifferentiated Arapahoe and Laramie Formations

(w) — Weathered

(u) — Unweathered

Horizontal Scale: 1 inch = 50 feet

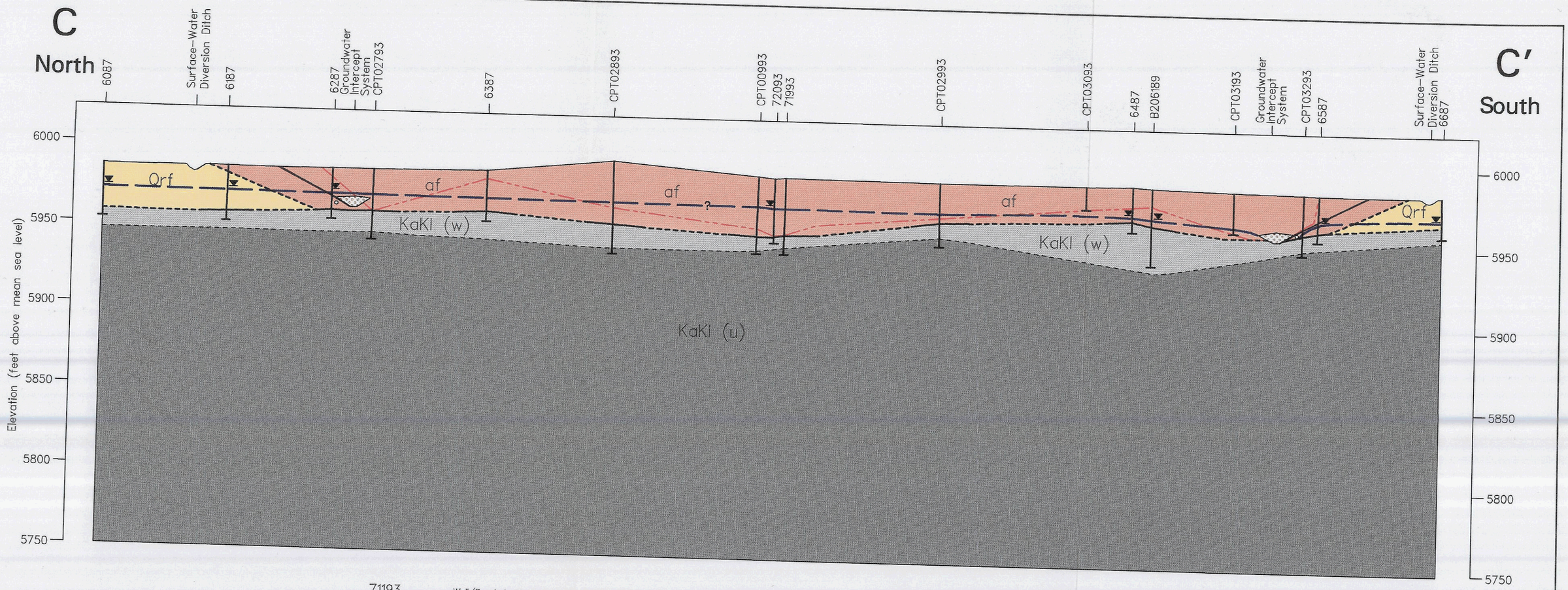
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section B - B′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2-10



71193 Well/Borehole Number
CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

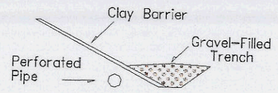
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)
(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

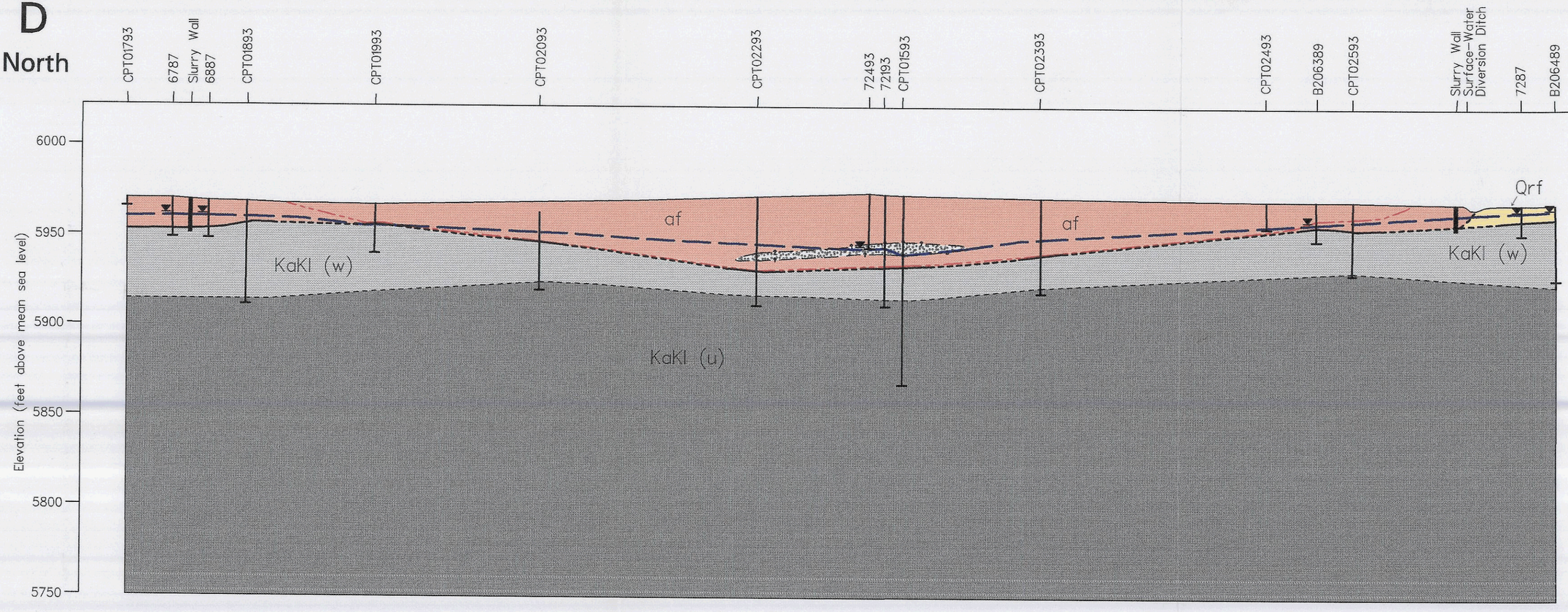
Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section C - C′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2–11



71193
CPT00493

Well/Borehole Number
CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

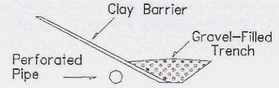
Geologic Contact
(dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface
(Upper Hydrostratigraphic Unit)
(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes: 1) Refer to borehole logs (Appendix E) for detailed geologic description.

2) Refer to well construction diagrams (Appendix F) for well construction details.

3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af – Artificial Fill
Quaternary

Qrf – Rocky Flats Alluvium
Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 50 feet

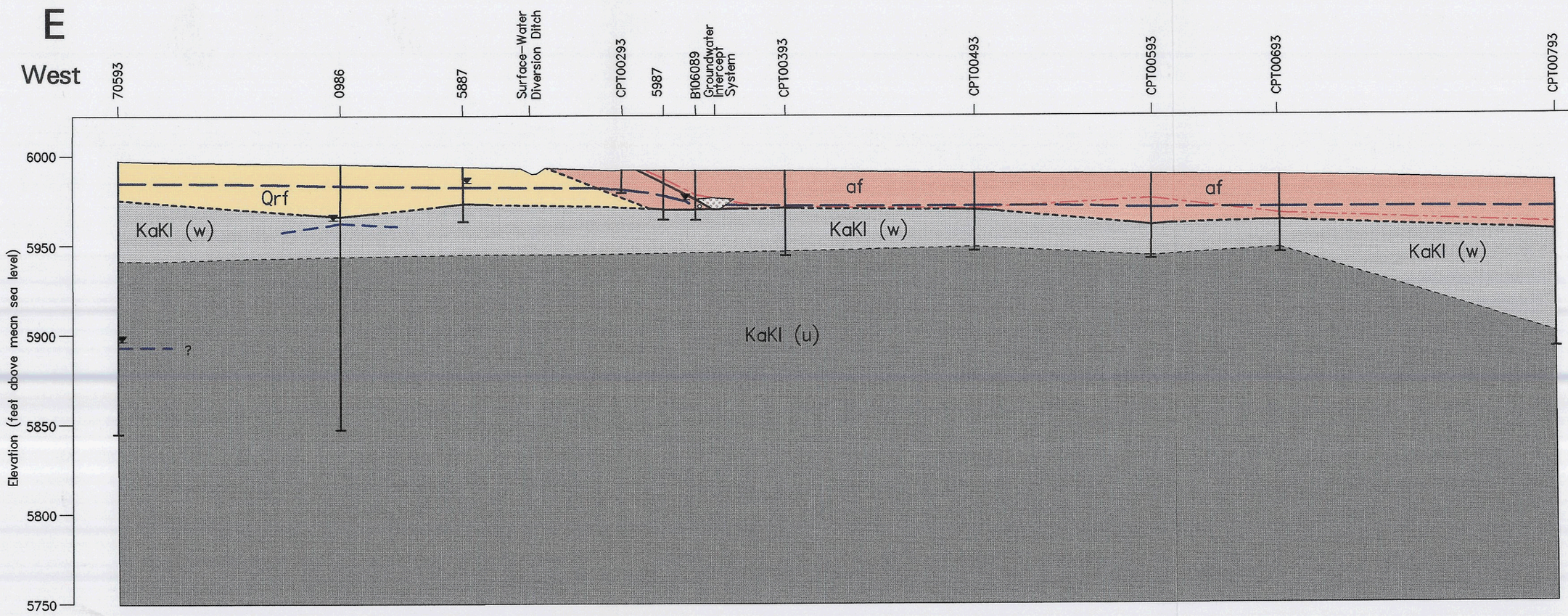
Buried West Landfill Pond Sediments

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section D - D'

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-12



71193 — Well/Borehole Number

CPT00493 — CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

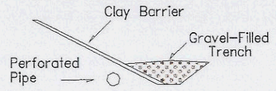
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit) (Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af — Artificial Fill

Quaternary

Qrf — Rocky Flats Alluvium

Cretaceous

KaKl — Undifferentiated Arapahoe and Laramie Formations

(w) — Weathered

(u) — Unweathered

Horizontal Scale: 1 inch = 50 feet

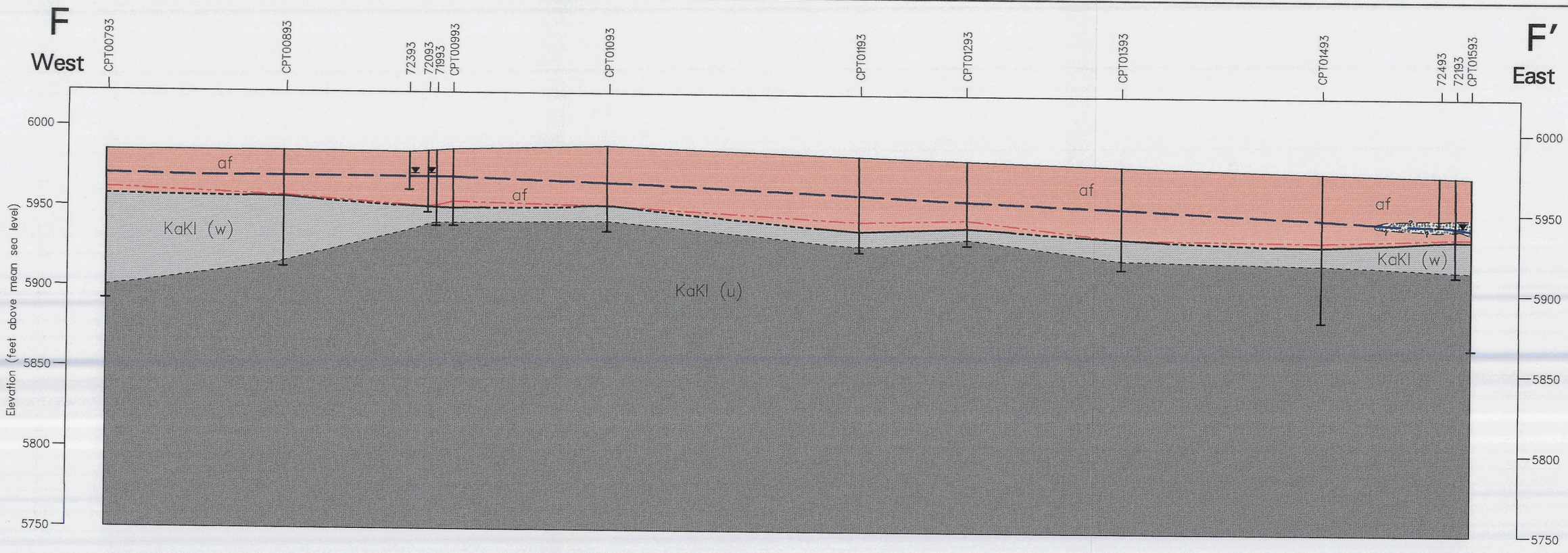
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section E - E′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2-13



71193 Well/Borehole Number
CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

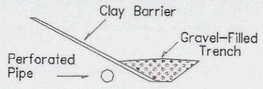
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit) (Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af – Artificial Fill

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Buried West Landfill Pond Sediments

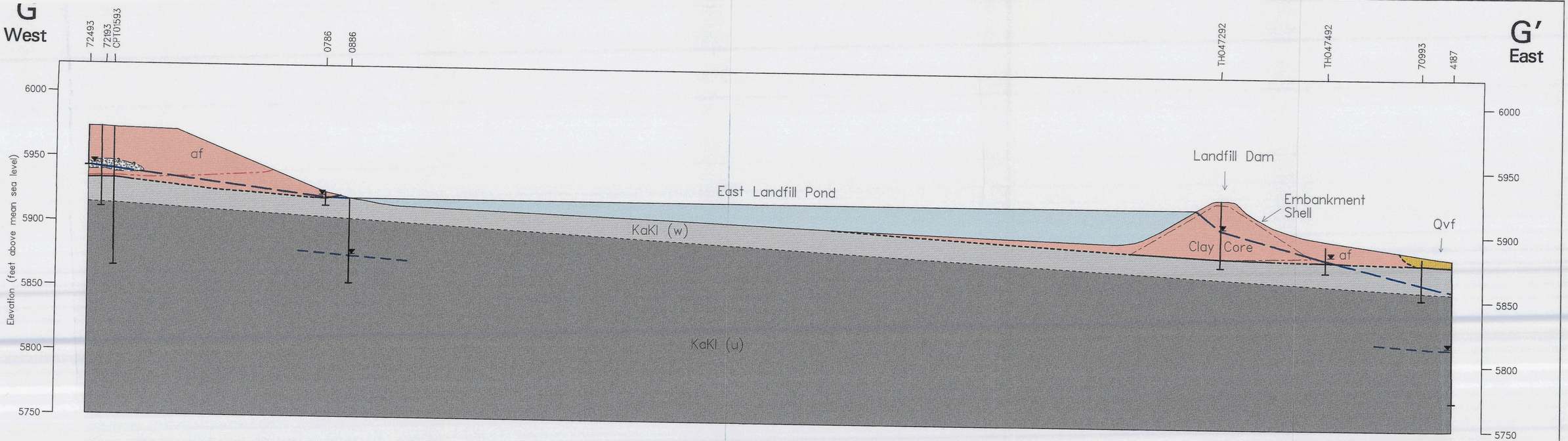
Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section F - F′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-14



TH047292 — Well/Borehole Number
71193
CPT00493 — CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

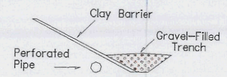
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface
(Upper Hydrostratigraphic Unit)
(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

af – Artificial Fill

Quaternary

Qvf – Valley-Fill Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Buried West Landfill Pond Sediments

Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

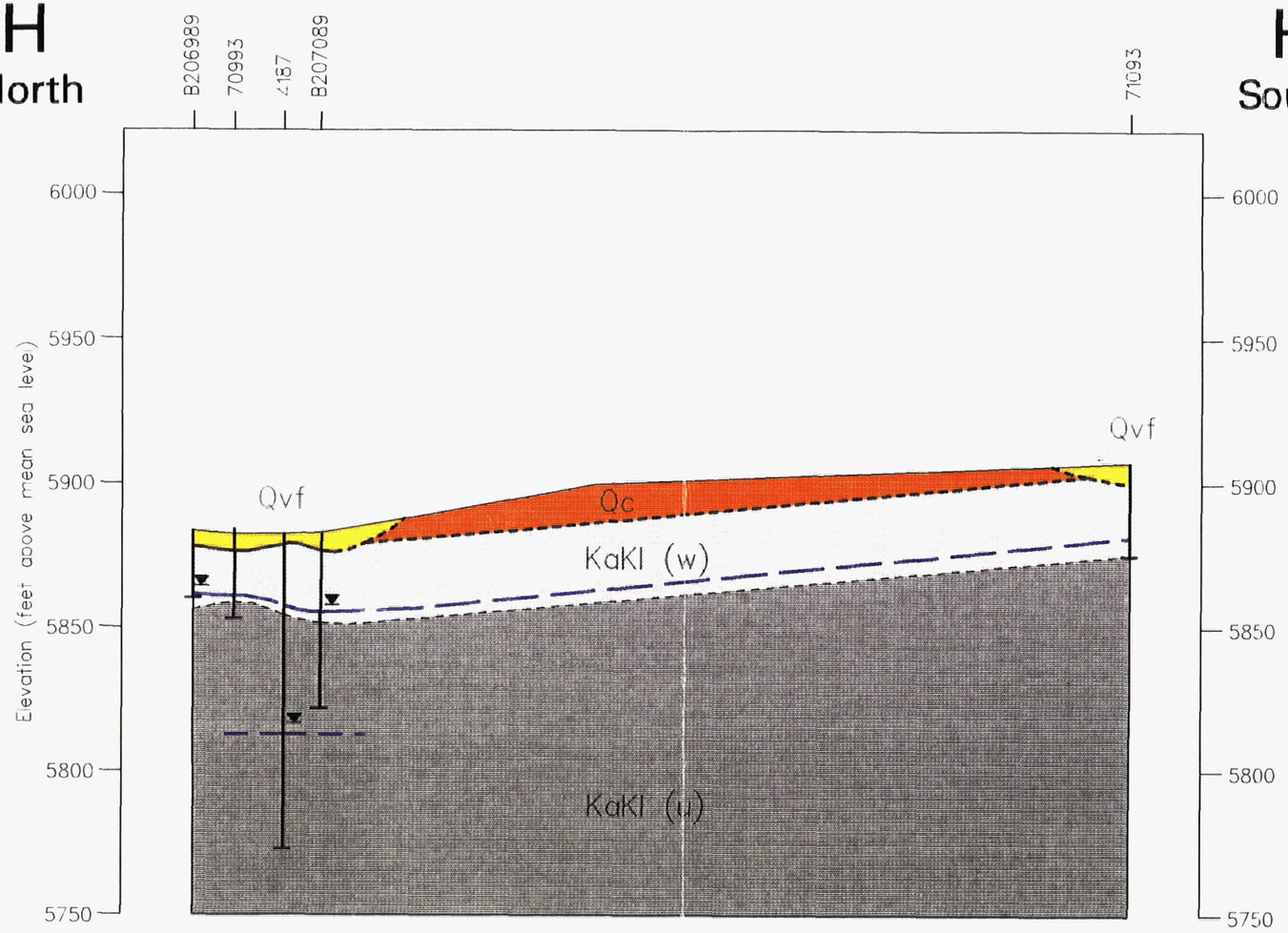
Geologic Cross-Section G - G'

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2-15

H — North

H′ — South



71193
CPT00493

Well/Borehole Number

CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

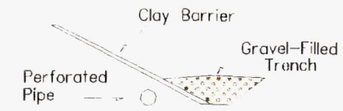
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes:
1) Refer to borehole logs (Appendix E) for detailed geologic description.
2) Refer to well construction diagrams (Appendix F) for well construction details.
3) Refer to CPT profiles (Appendix D) for data generated during CPT.

Quaternary

Qvf – Valley-Fill Alluvium

Qc – Colluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale: 1 inch = 50 feet

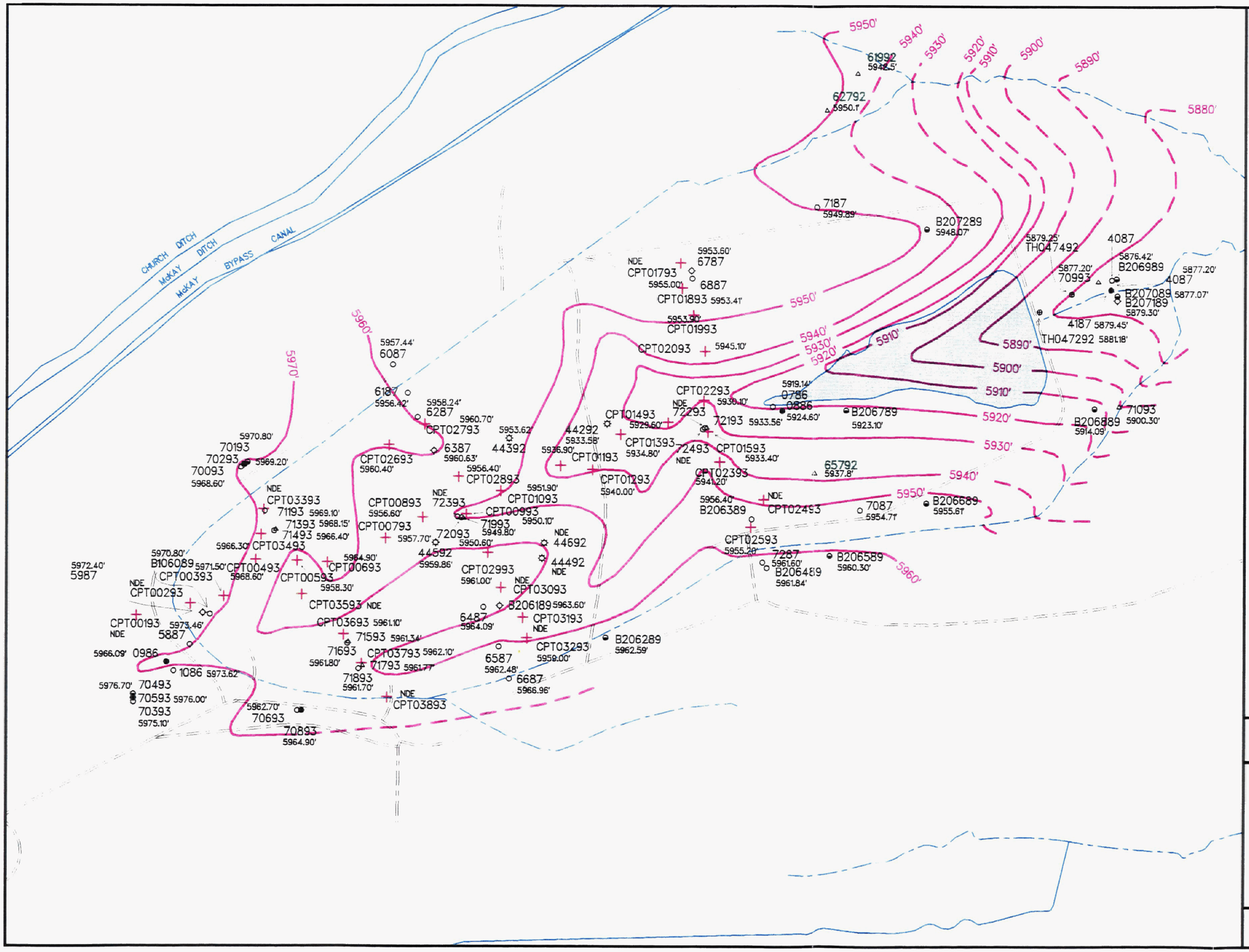
Vertical Scale: 1 inch = 50 feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section H - H′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2-16



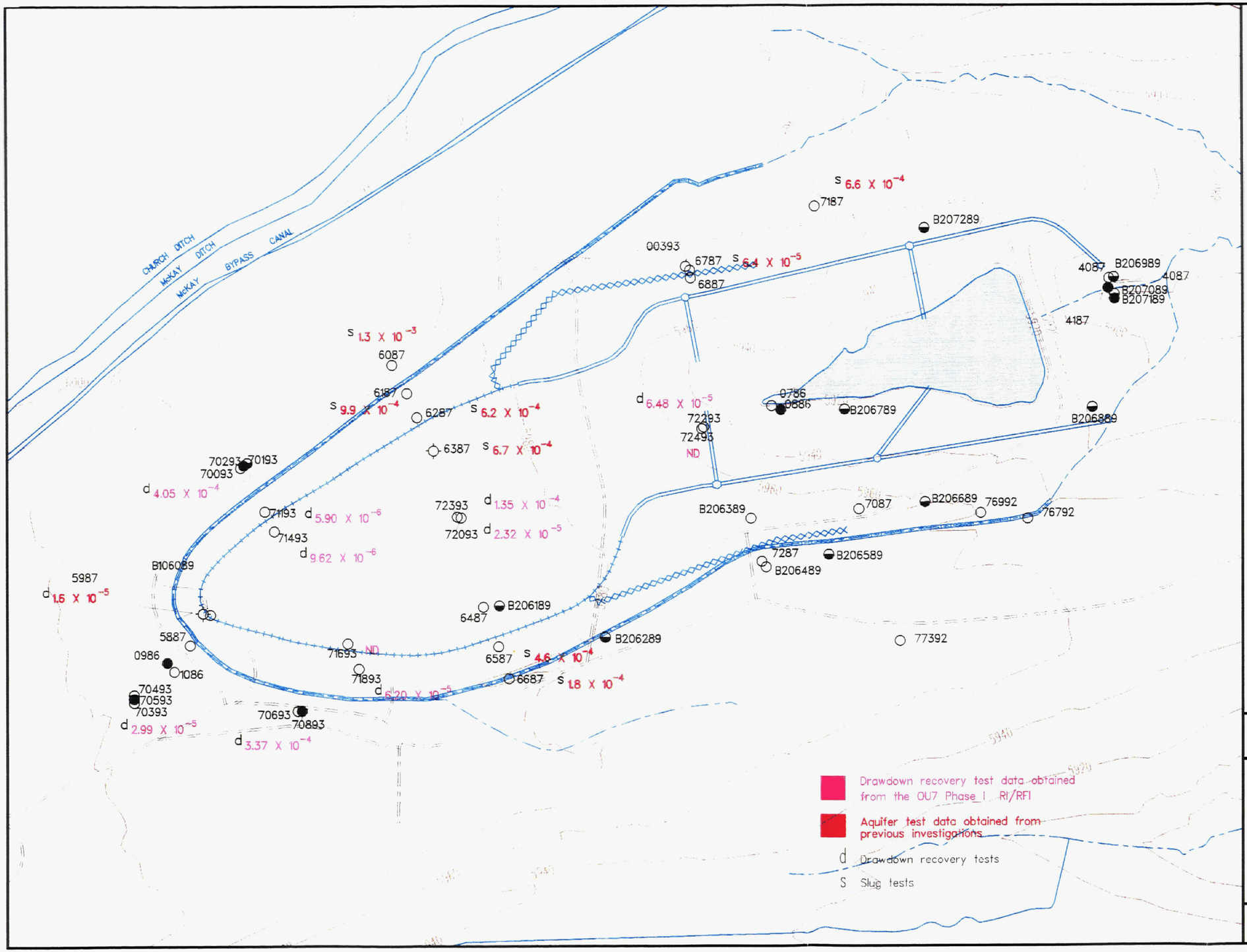
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

Weathered Bedrock Topography

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2-17

08/23/94 WBEDTOPO.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)

* Values Reported in Centimeters/Second

N

0 Feet 250 500

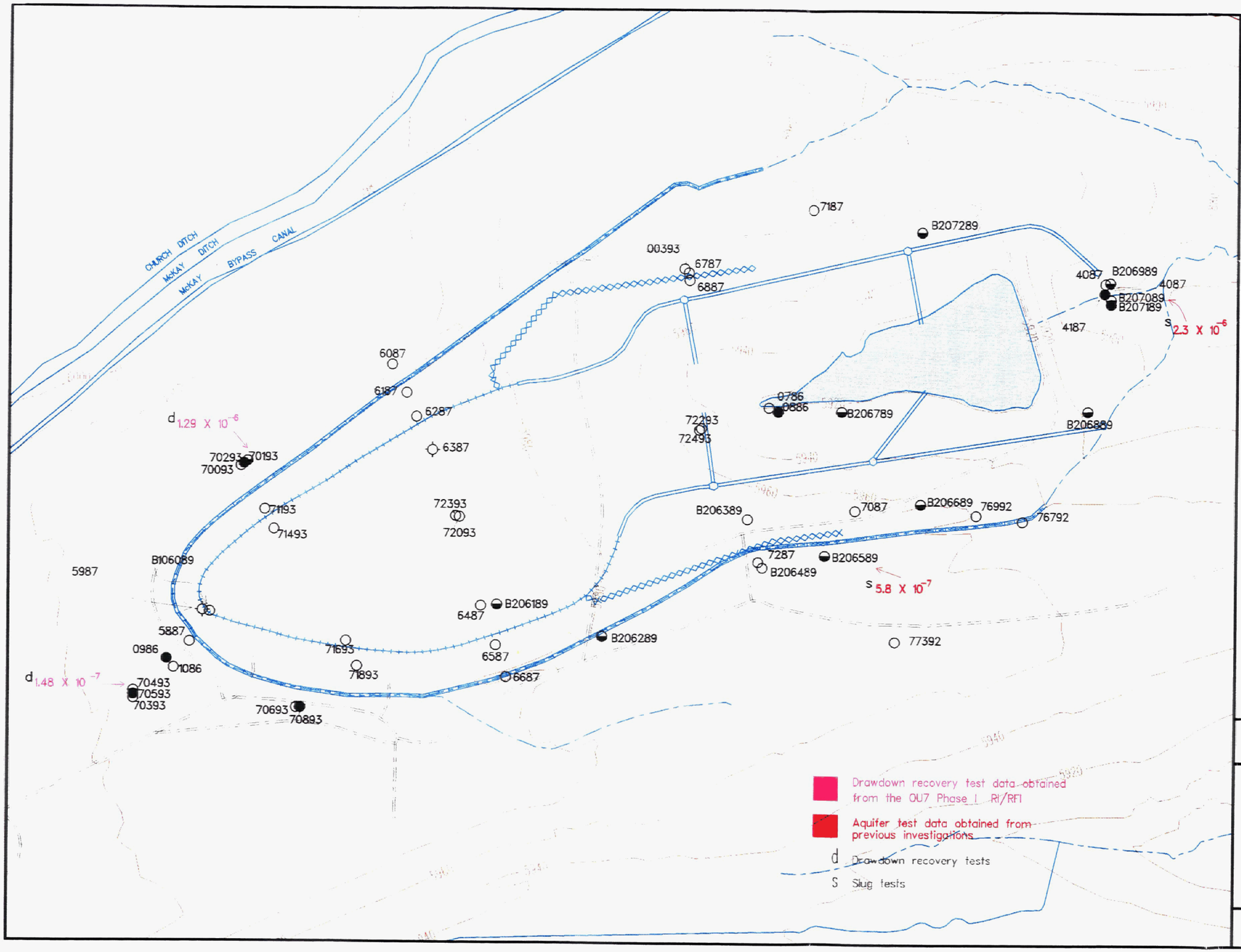
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Surficial Materials

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2-18

08/25/94 SMGW.MAP HYDCON.AML



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)

* Values Reported in Centimeters/Second

0 Feet 250 500

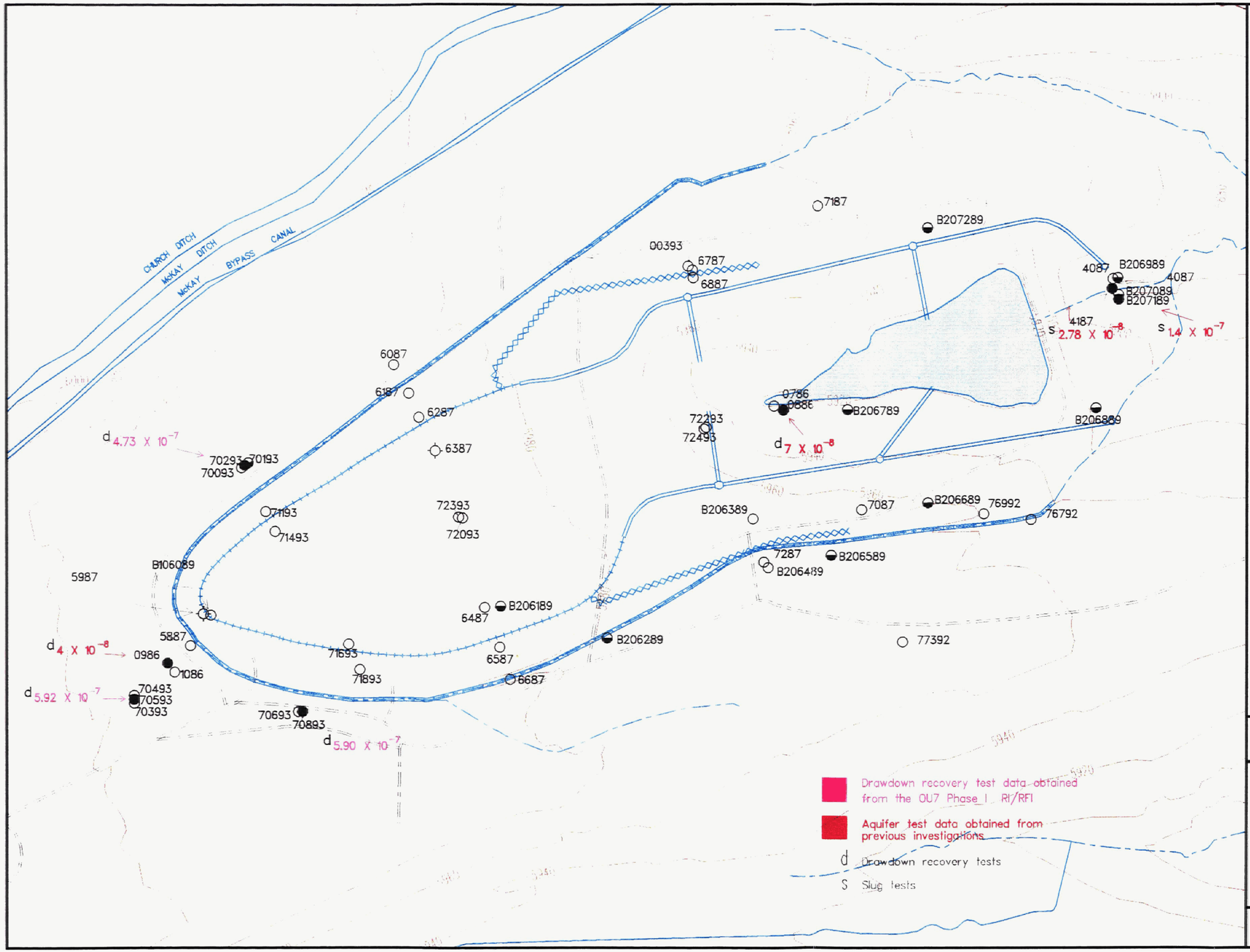
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Weathered Bedrock

Revised Work Plan — Operable Unit No. 7

Date: August 1994 — Figure 2-19

08/25/94 WBGW.MAP HYDCON.AML



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)

* Values Reported in Centimeters/Second

0 Feet 250 500

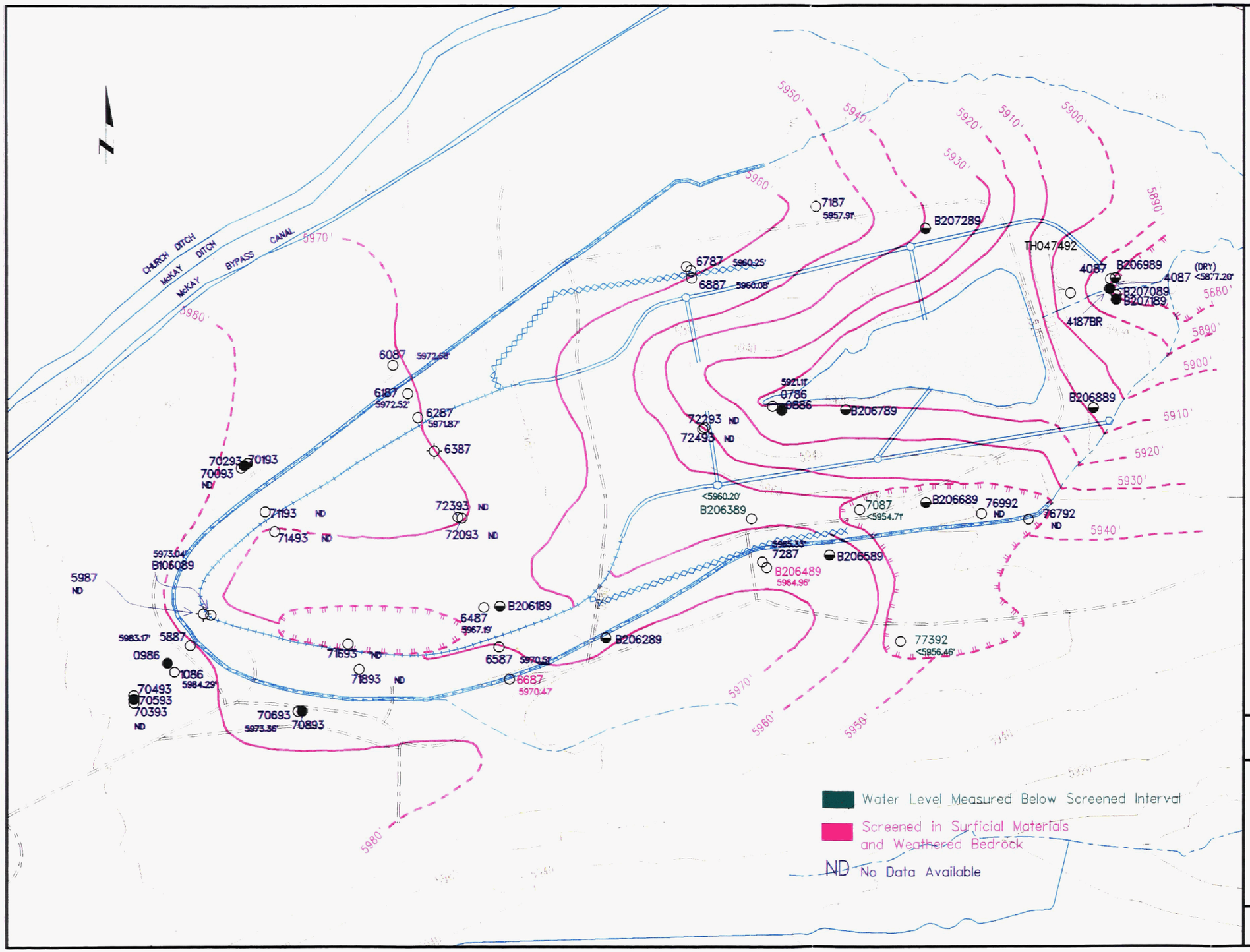
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Unweathered Bedrock

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2-20

08/25/94 UBGW.MAP HYDCON.AML



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

Water Level Measured Below Screened Interval

Screened in Surficial Materials and Weathered Bedrock

ND No Data Available

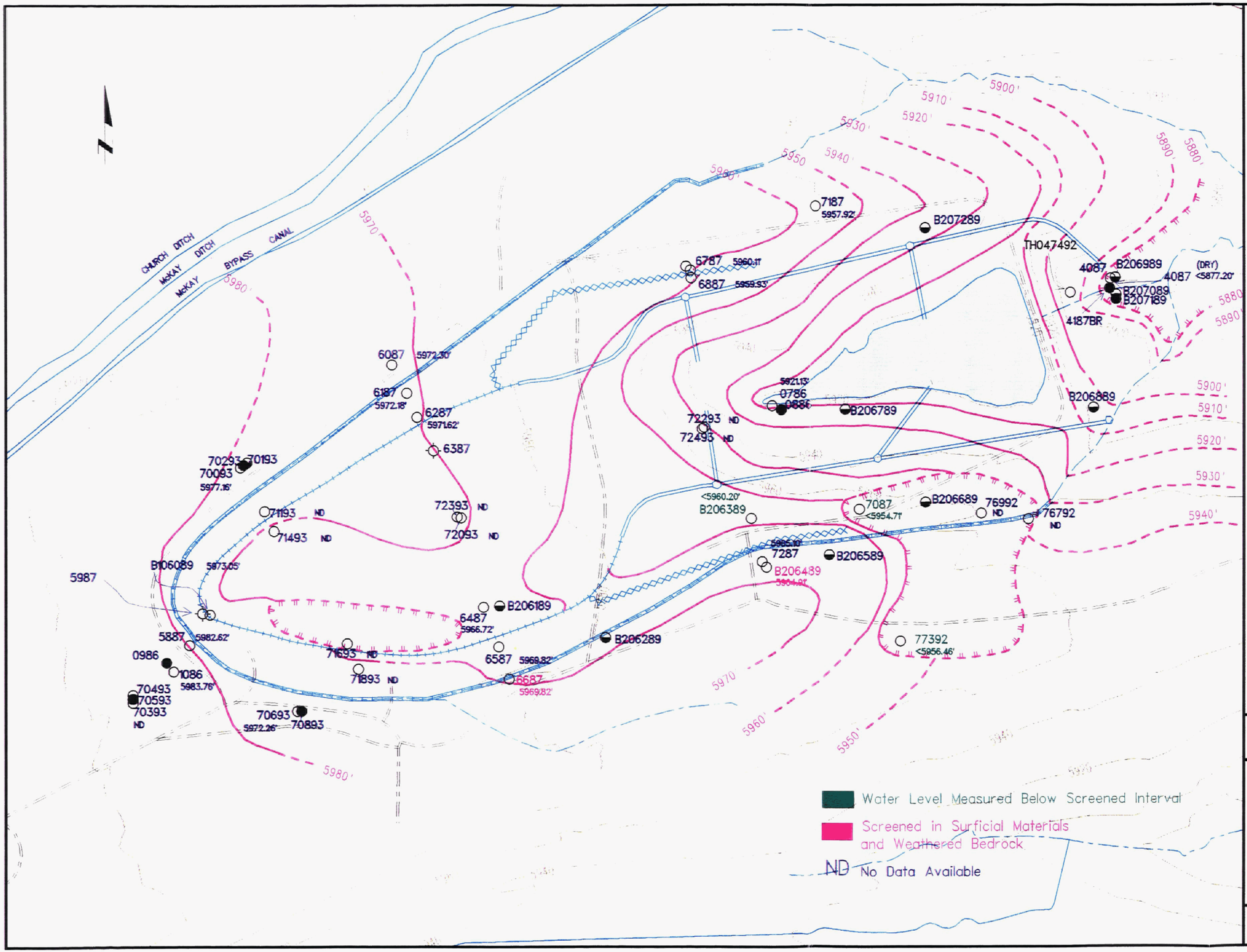
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (December 1992)

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2–21

04/04/94 DEC92SURF.map GWANNO5



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

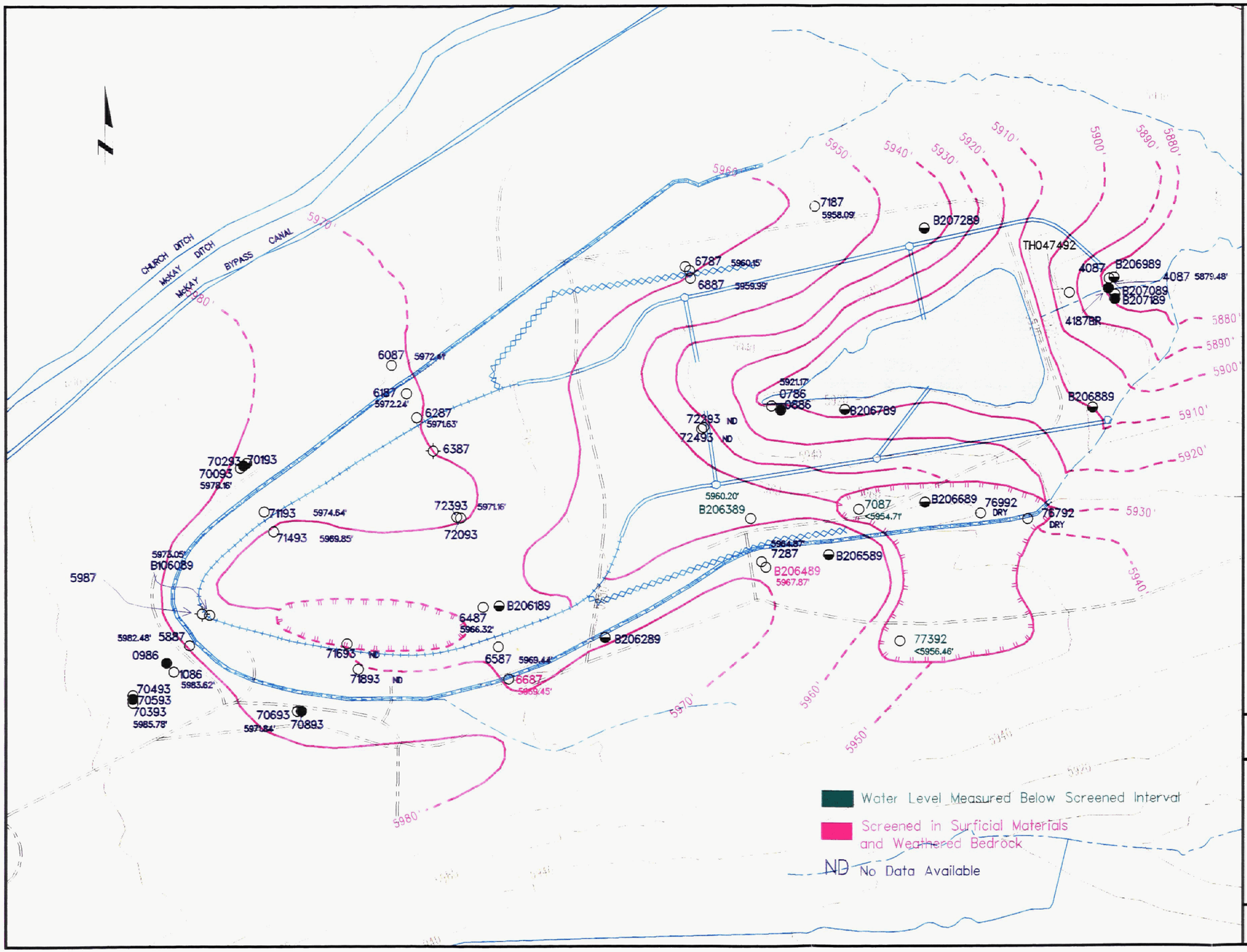
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (January 1993)

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2–22

04/04/94 JAN93SURF.map GWANN06



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System (perforated) (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

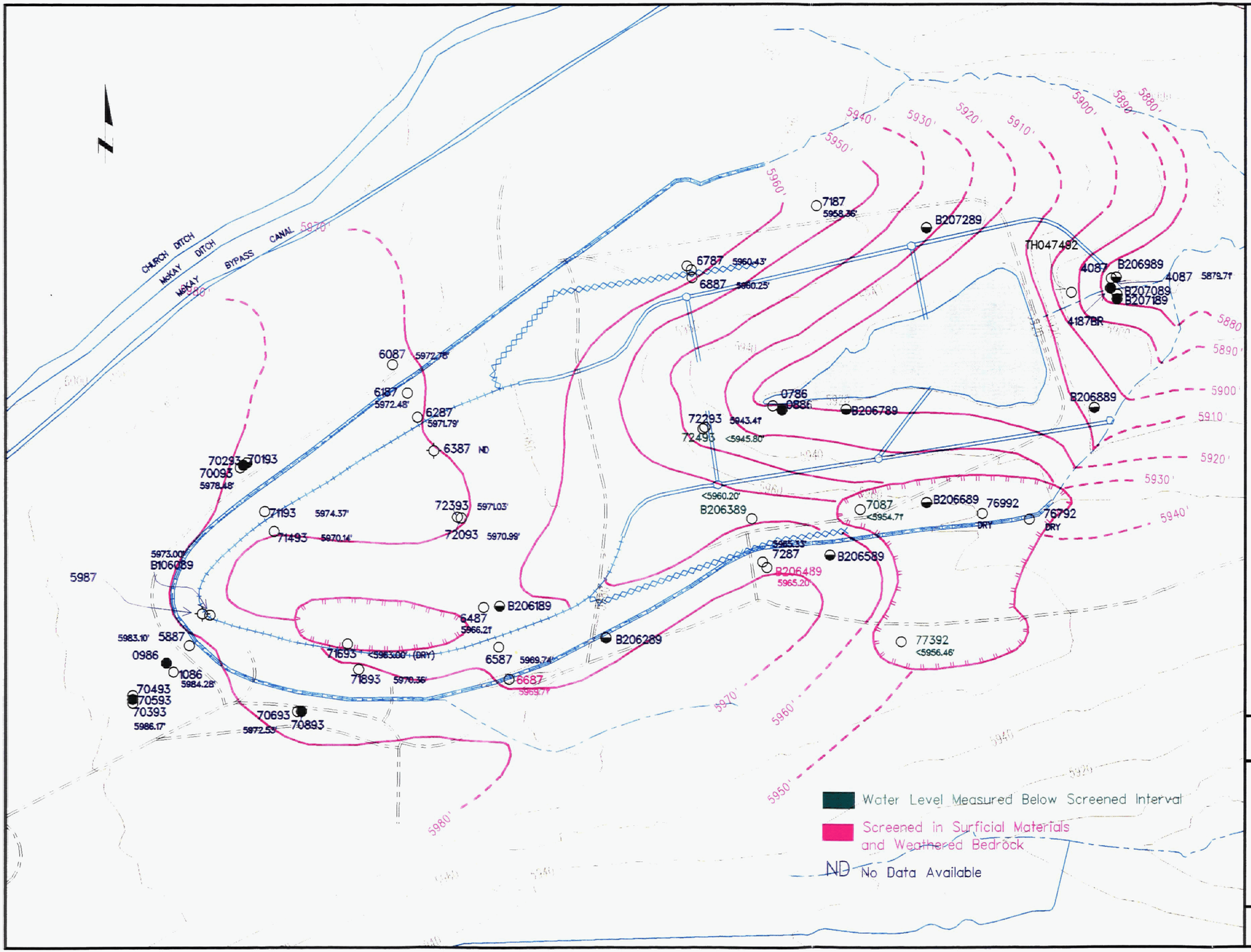
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (February 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-23

04/04/94 FEB93SURF.map GWANN07



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

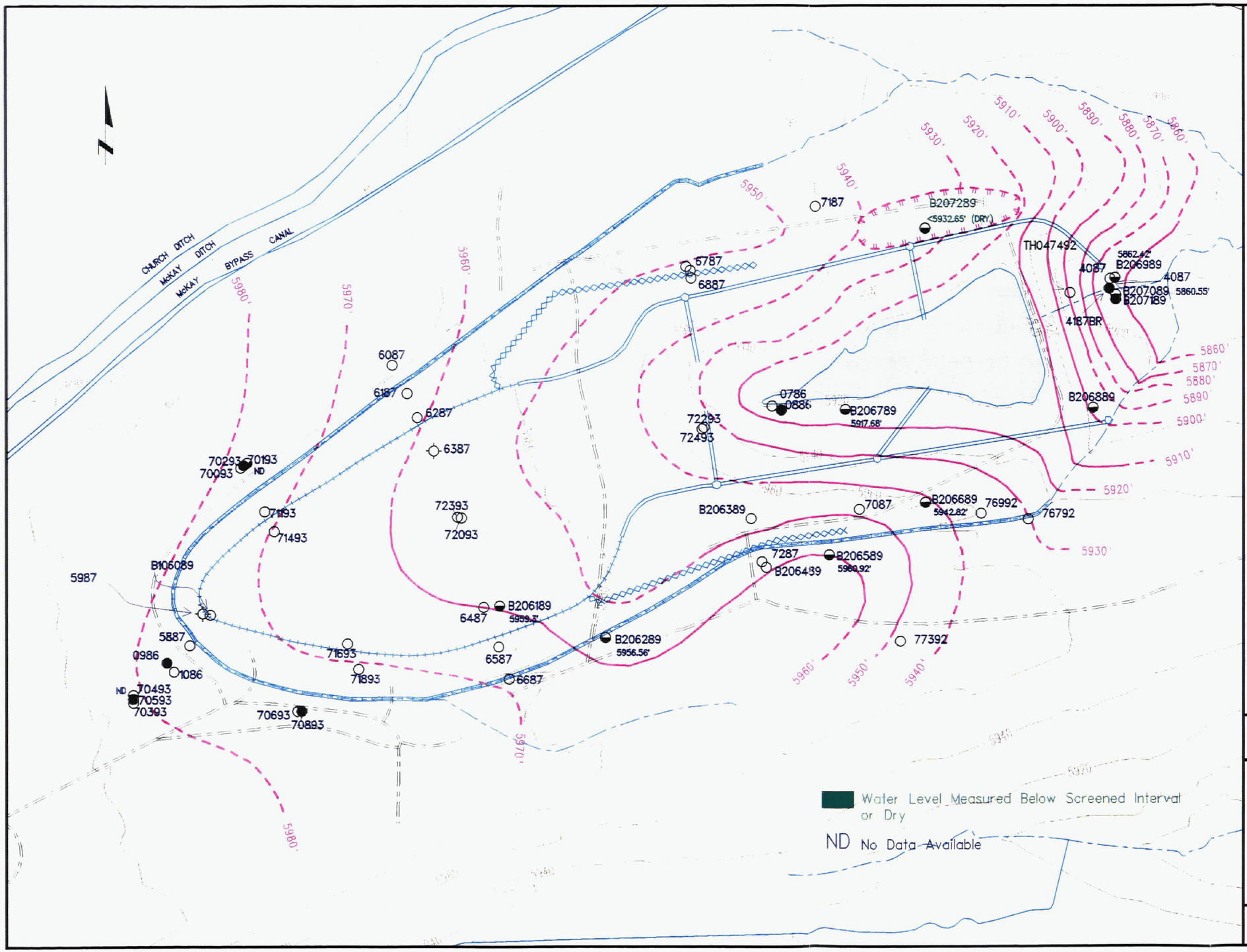
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (March 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-24

04/04/94 MAR93SURF.map GWANNO8



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

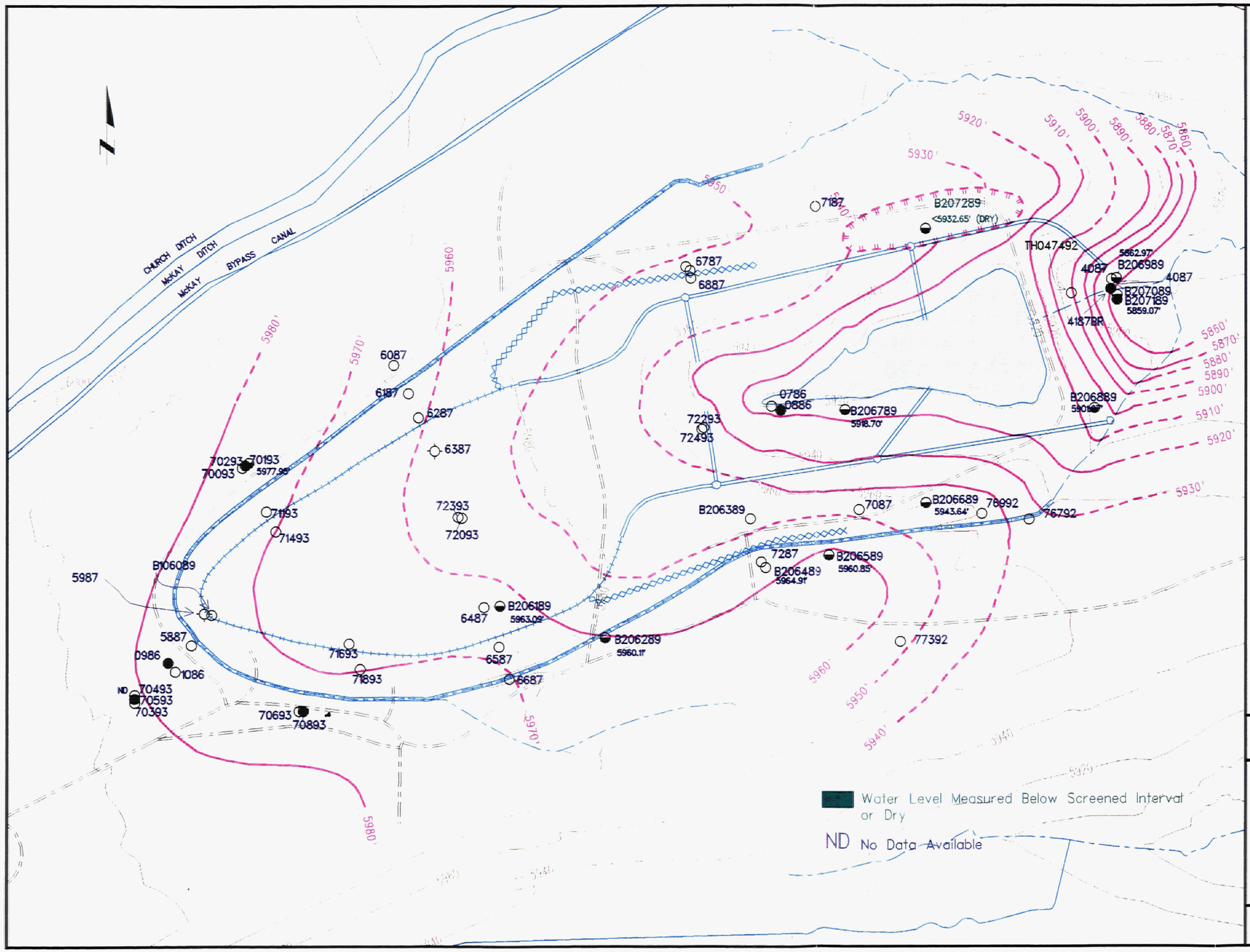
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (December 1992)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-25

04/04/94 DEC92WB.map GWANN01



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

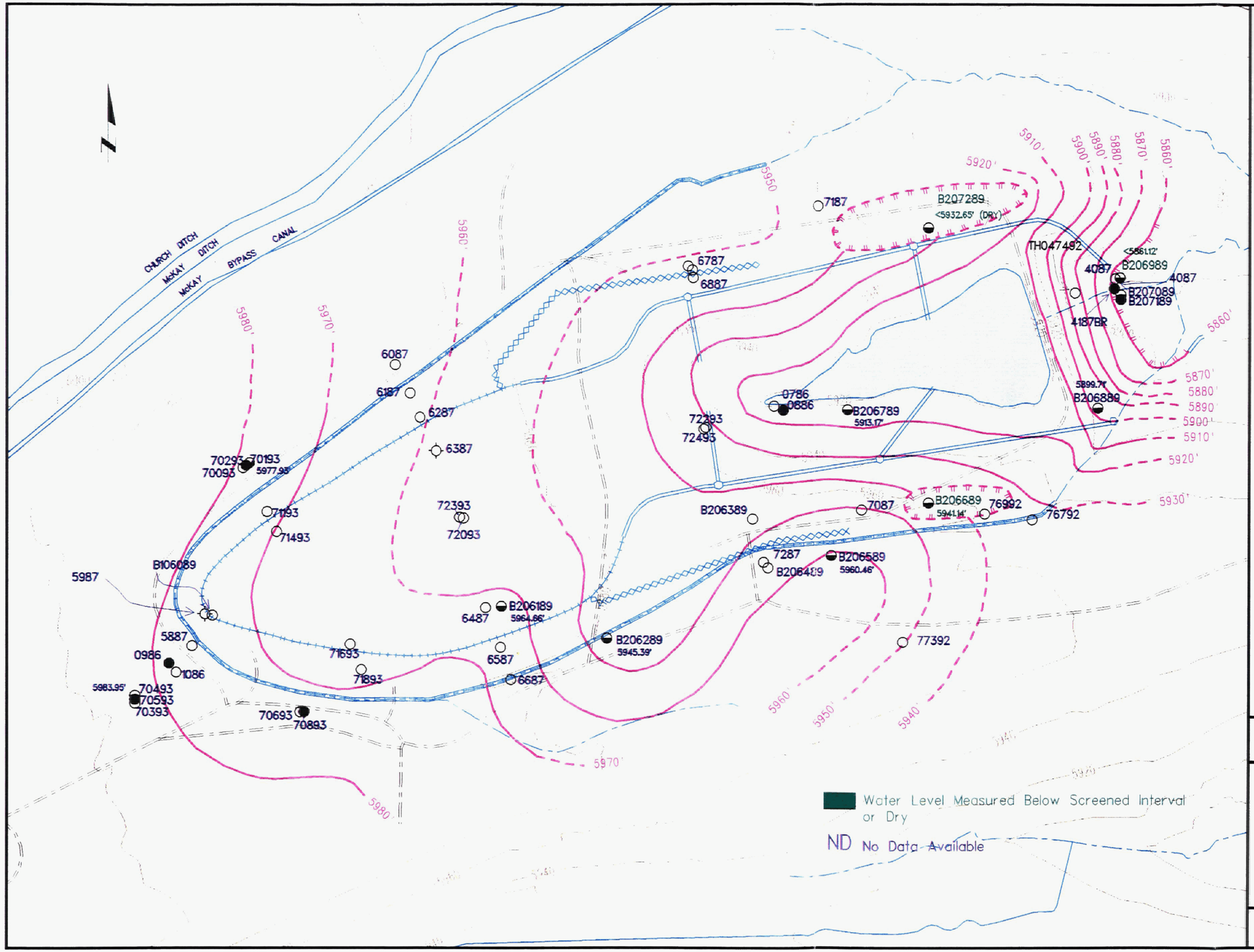
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (January 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-26

04/04/94 JAN93WB.map GWANN02



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

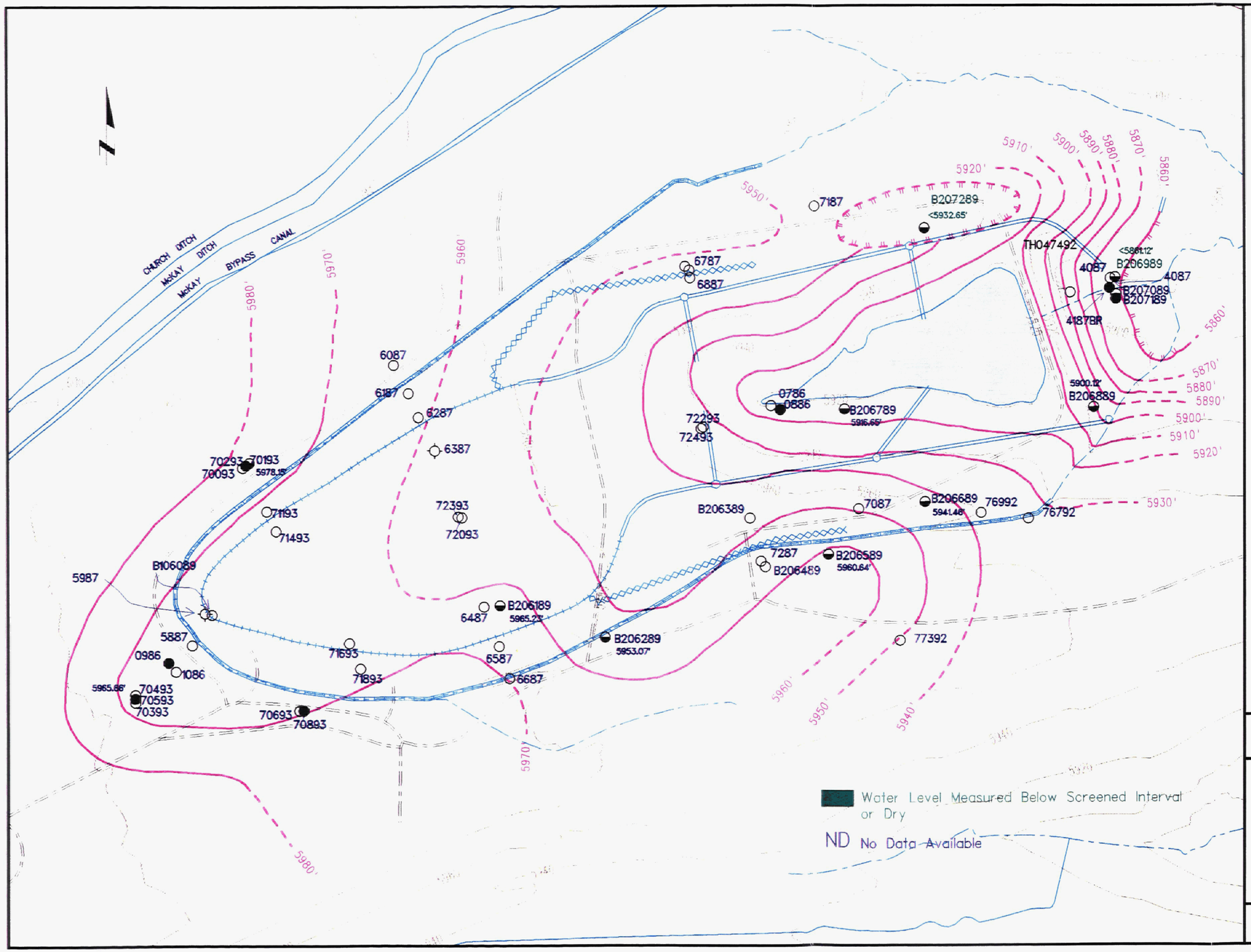
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (February 1993)

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 2–27

04/04/94 FEB93WB.map GWANN03



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

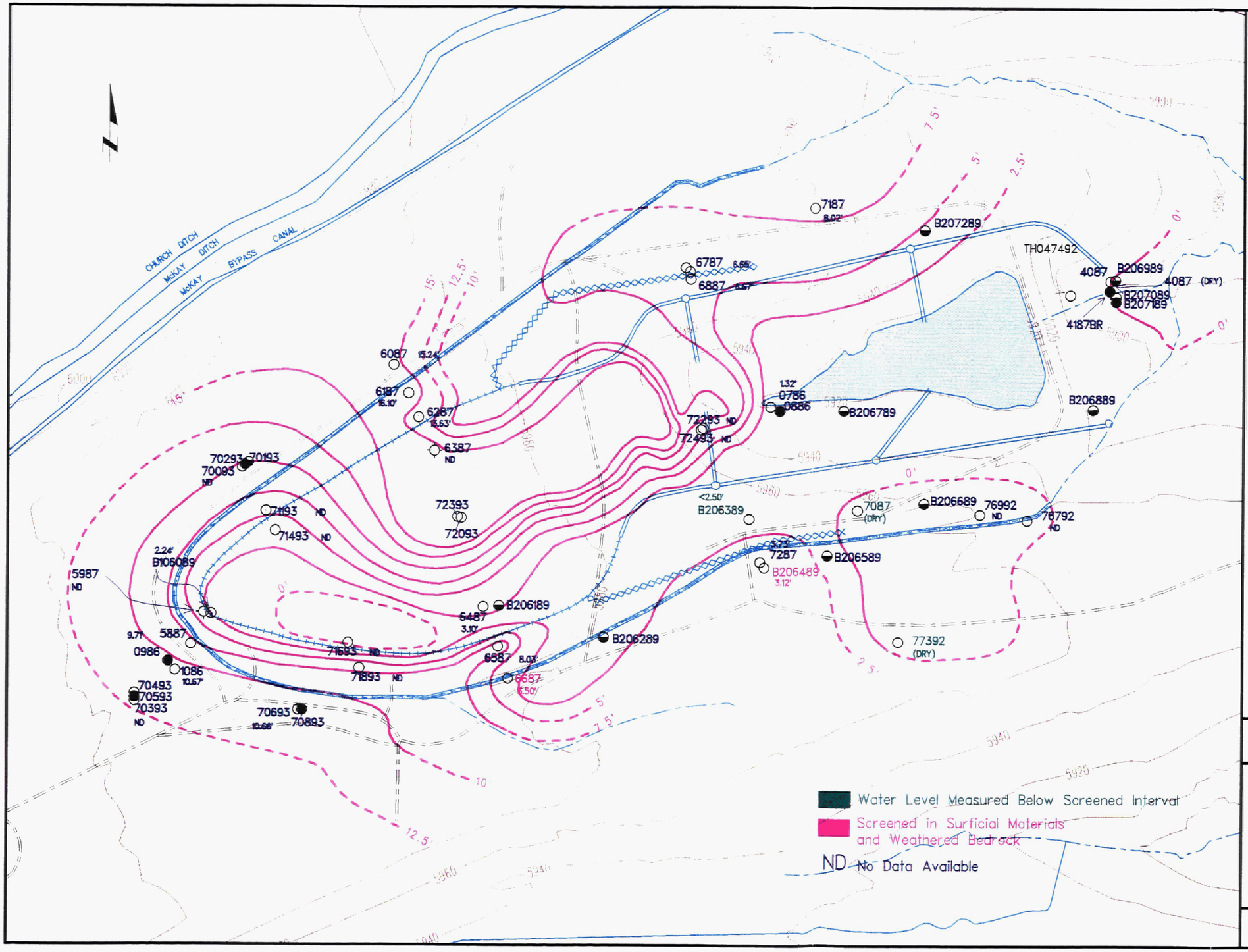
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (March 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2–28

04/04/94 MAR93WB.map GWANNO4



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Saturated Thickness Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

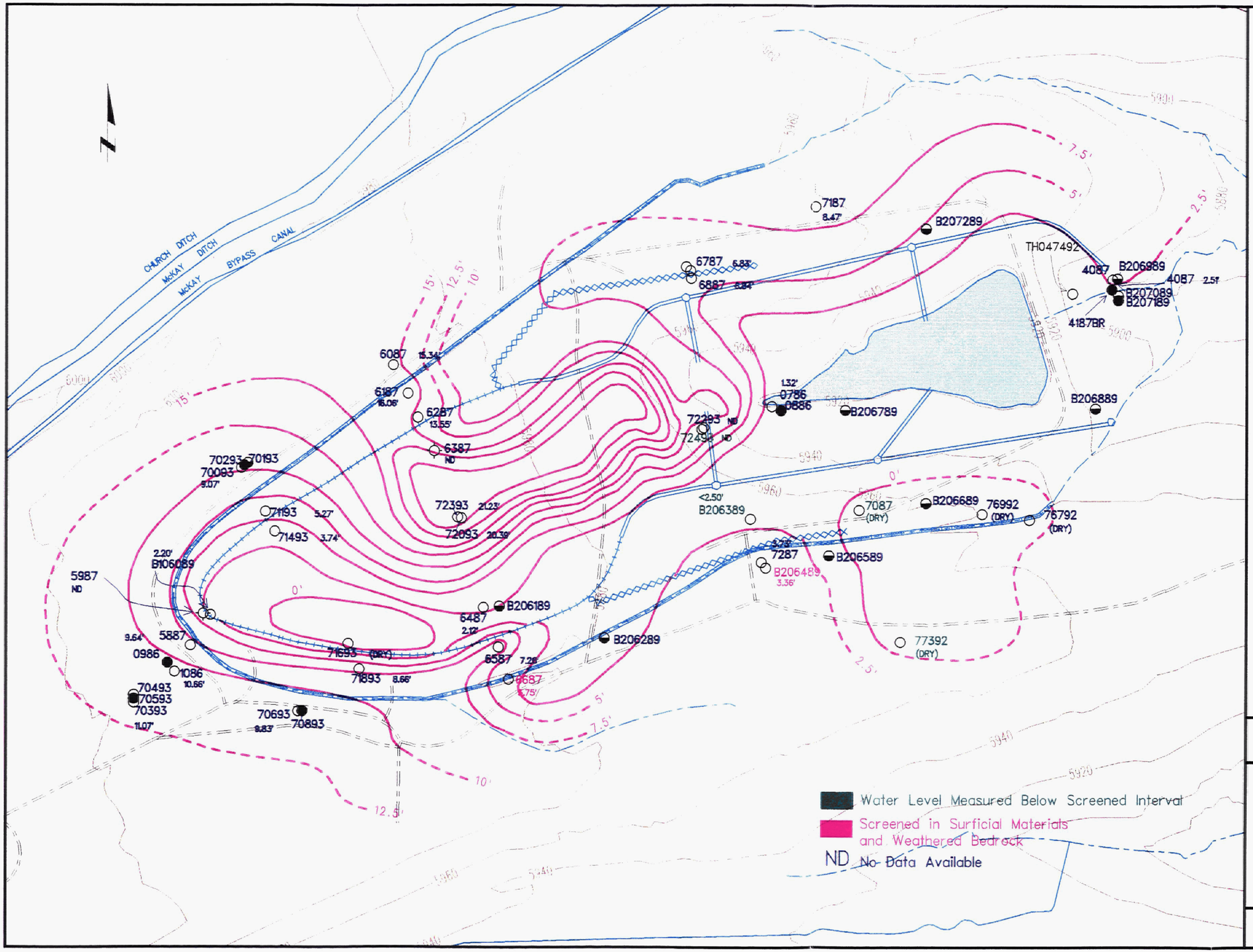
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Saturated Thickness of Surficial Material (December 1992)

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2–29

08/10/94 DEC92ISM.map GWANN09



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Line of Equal Saturated Thickness Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

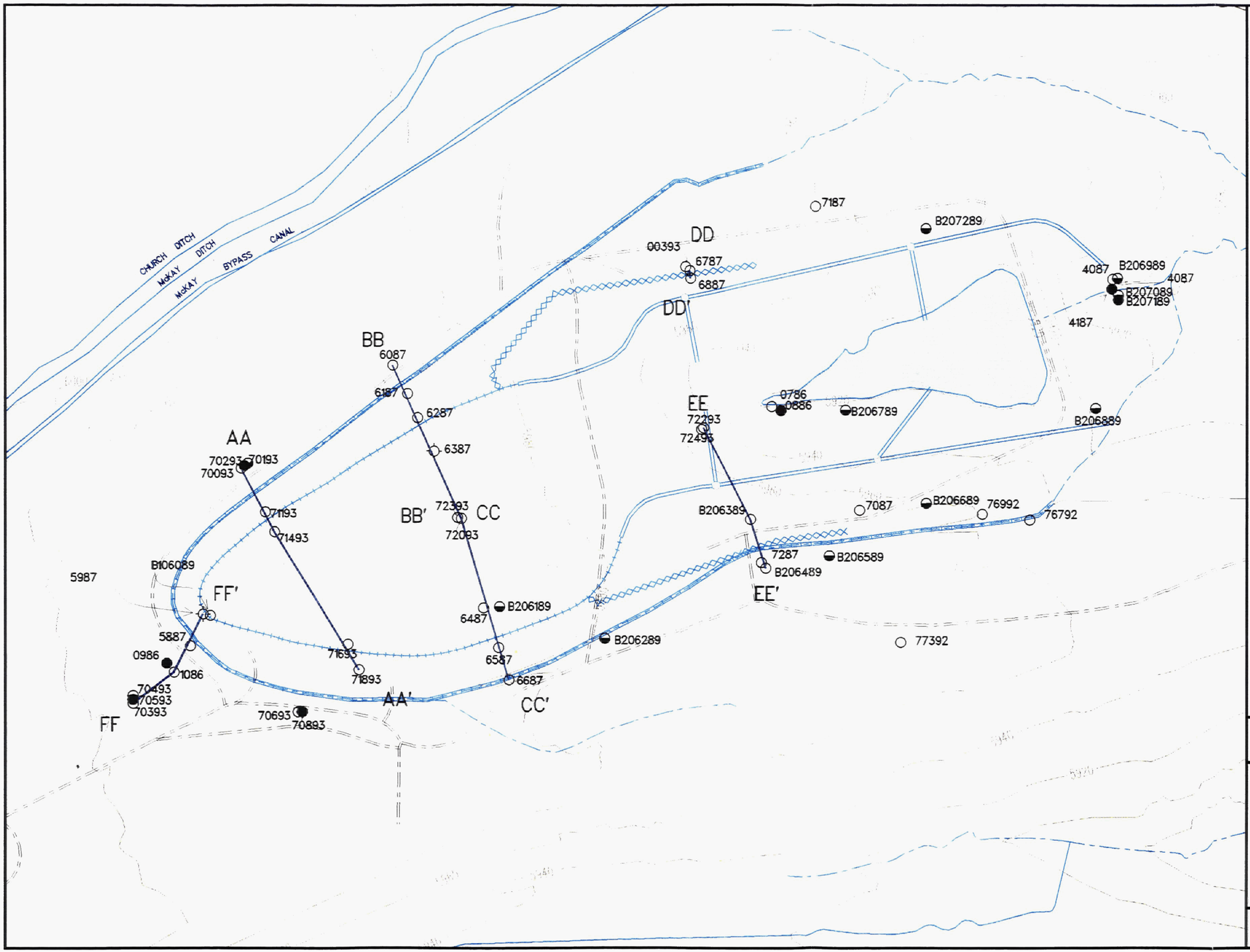
Saturated Thickness of Surficial Material

(March 1993)

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2–30

08/15/94 MAR93TSM.map GWANNO10



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Well Hydrograph Transects

0 Feet 250 500

Topographic Contour Interval = 20 Feet

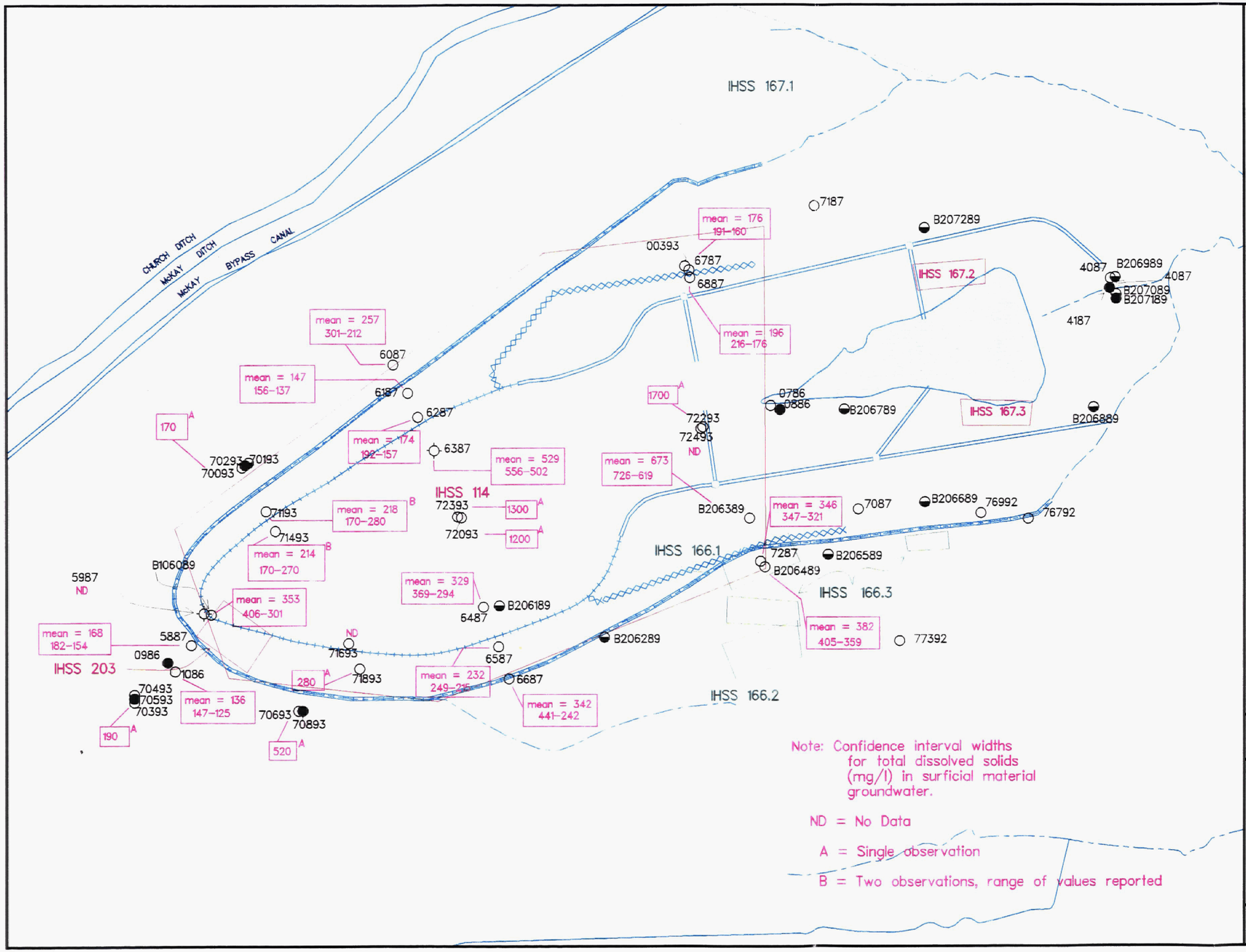
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Well Hydrograph Transect Location Map

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-31

04/04/94 HYDPROFILE.MAP



Note: Confidence interval widths for total dissolved solids (mg/l) in surficial material groundwater.

ND = No Data

A = Single observation

B = Two observations, range of values reported

EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU7 IHSS Boundary
- OU6 IHSS Boundary

0 Feet 250 500

Topographic Contour Interval = 20 Feet

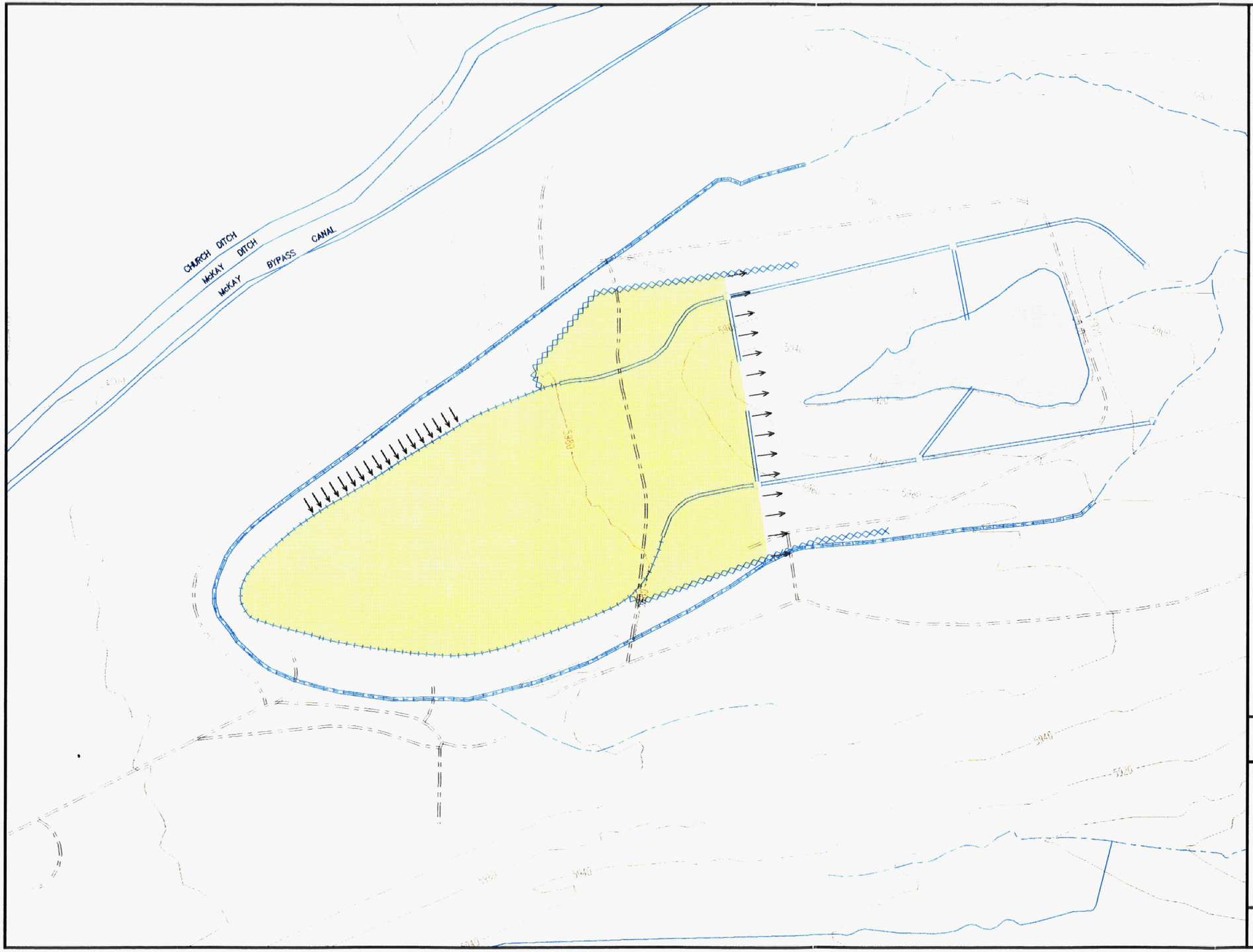
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Total Dissolved Solids Distribution Map

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-38

04/04/94 TDS.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Area of Recharge From Infiltration (Appendix I)
- Groundwater Inflow/Outflow Boundaries

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

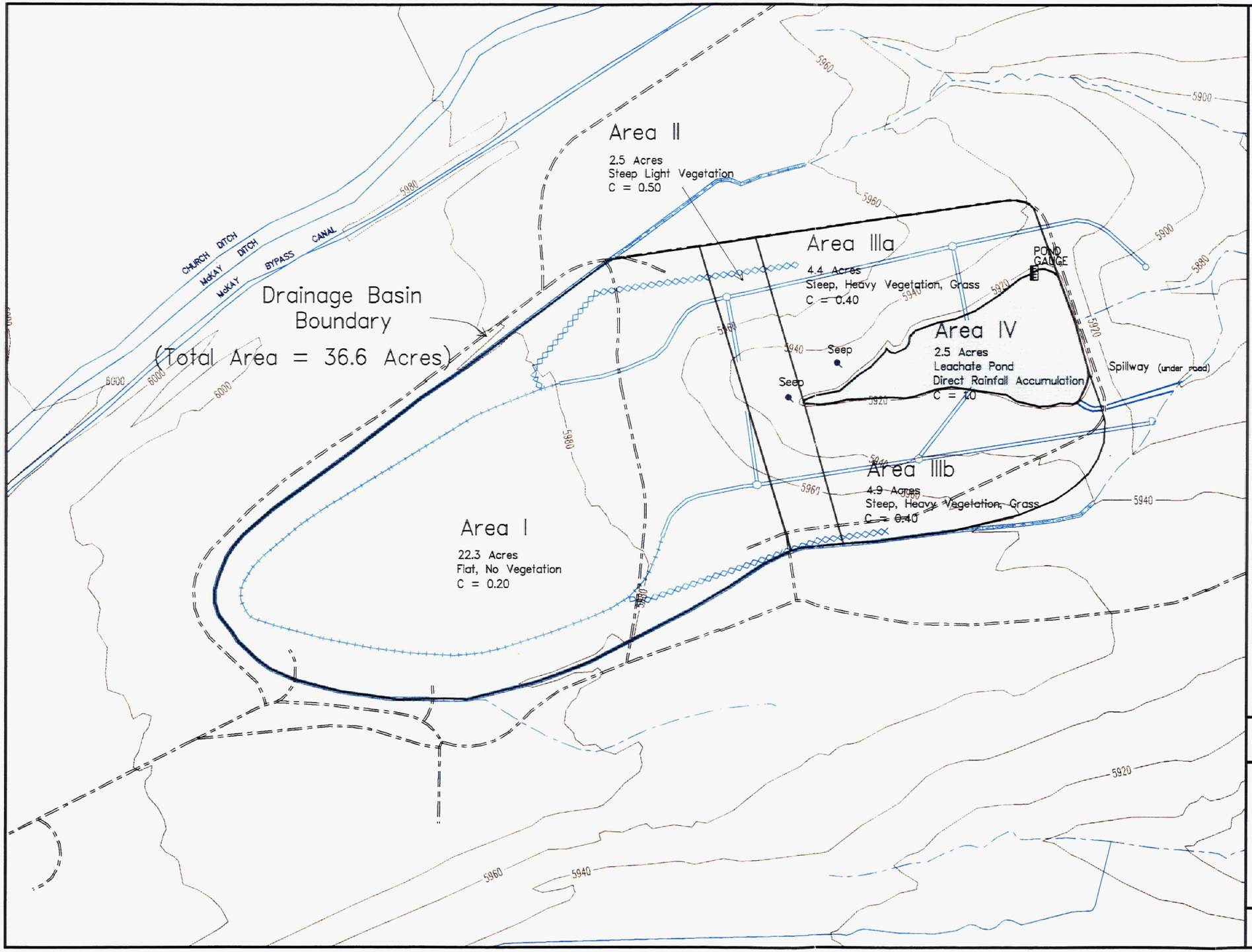
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Groundwater Inflow and Outflow Boundaries of the Present Landfill Area

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-40

04/04/94 RECHARGE.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Basin Boundary
- C = Runoff Coeffecient

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

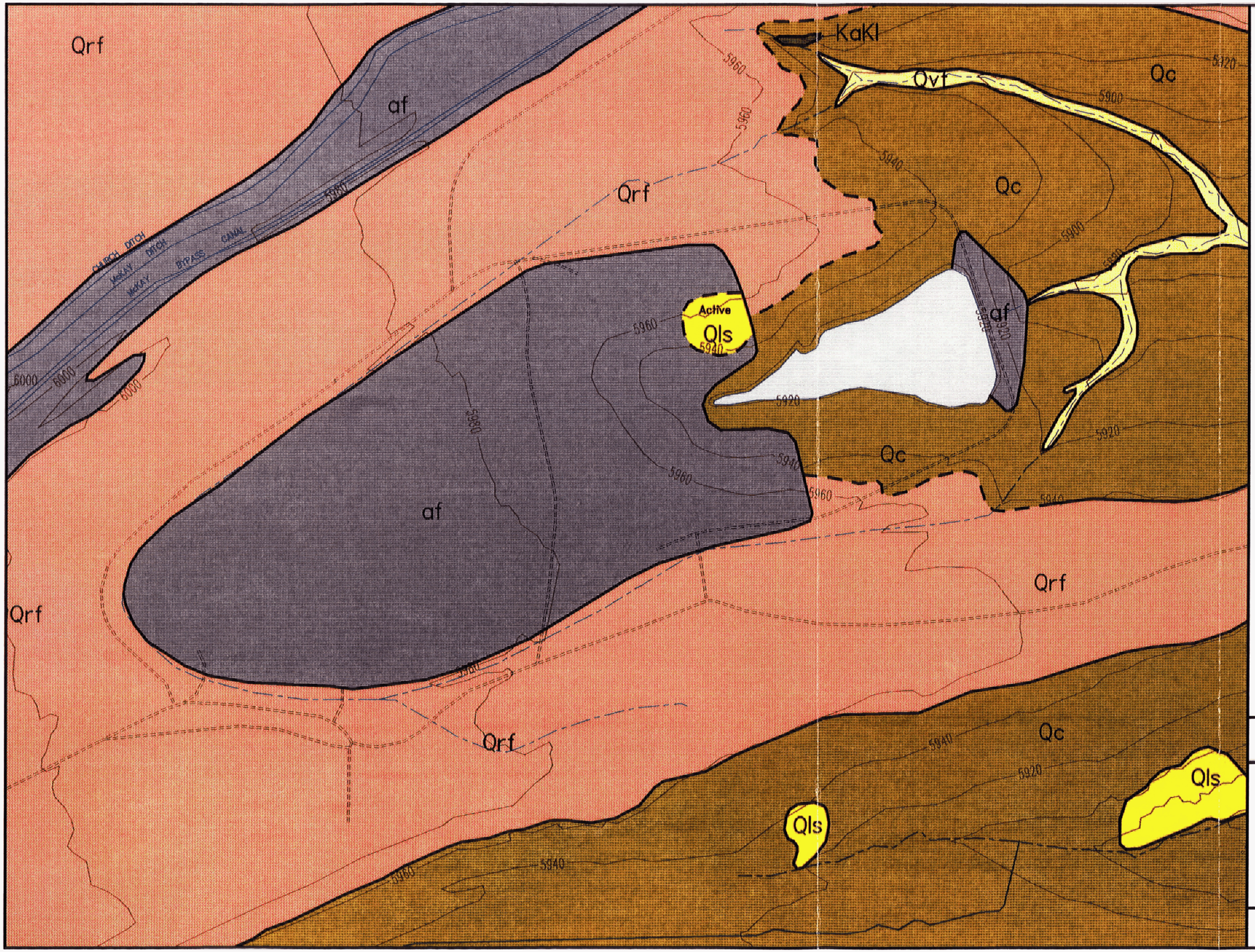
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

OU 7 Drainage Basin and Surface-Runoff Subareas

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-41

04/04/94 BASINS.MAP



EXPLANATION

- Artificial fill
- Quaternary
- Landslide (Qls)
- Colluvium (Qc)
- Valley–Fill Alluvium (Qvf)
- Rocky Flats Alluvium (Qrf)
- Cretaceous
- Undifferentiated Arapahoe/ Laramie Formation (KaKl) (Claystone)
- Geologic Contact, (dashed where inferred)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Map of Surficial Materials

Revised Work Plan | Operable Unit No. 7

Date: May 1994 | Figure 2–7

05/18/94 GEOLOGY.MAP

EXPLANATION

- Benthos Sampling Location
- Mammal and Vegetation Transects
- Ditch
- Intermittent Stream
- Dirt Road
- Bare Ground
- Disturbed Land
- Mesic Mixed Grassland
- Marshland
- Open Water

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

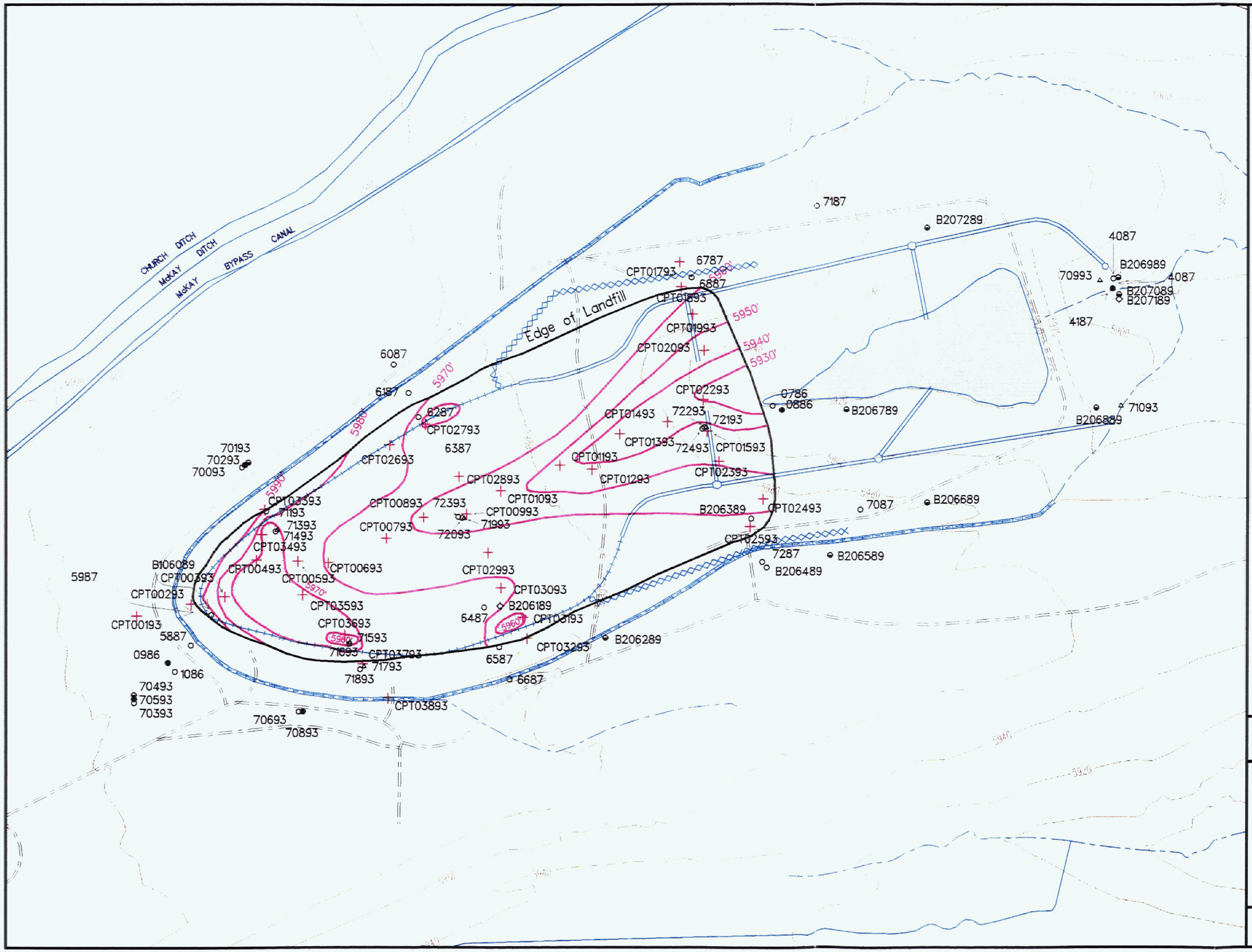
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Distribution of Habitat Types

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 2-42

08/29/94 HABITAT.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- CPT Location
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Elevation Contour (feet above mean sea level)

0 Feet 250 500

Topographic Contour Interval = 20 Feet

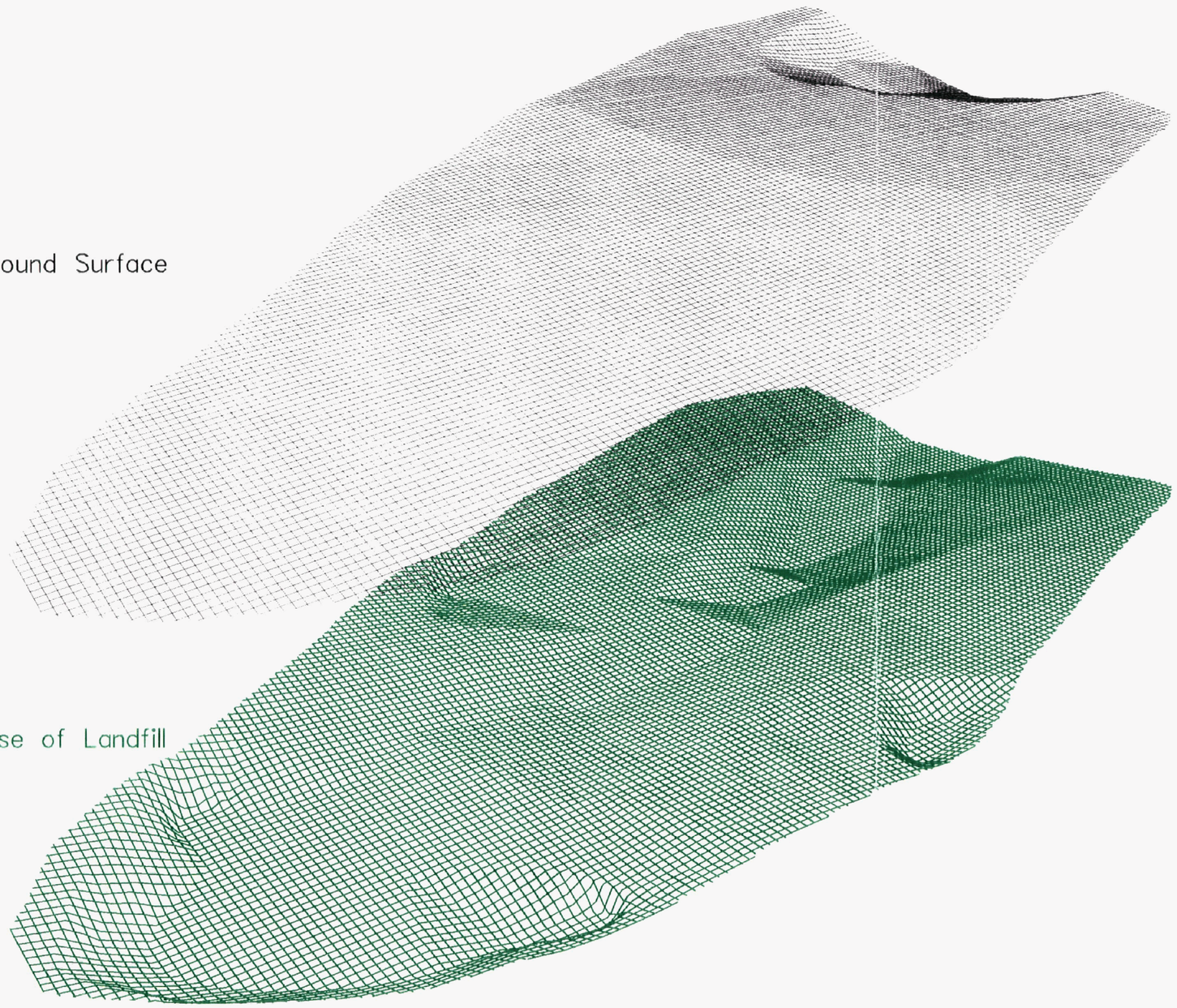
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Elevation of Base of Landfill

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–2

04/11/94 LANDBASE.MAP



Note: Surfaces were generated using ARC/INFO TIN modeling software. Input data was obtained from surface topography of the OU 7 area and base of landfill topography. The base of landfill was obtained from contouring data from CPT and well locations indicating the contact between weathered bedrock and trash.

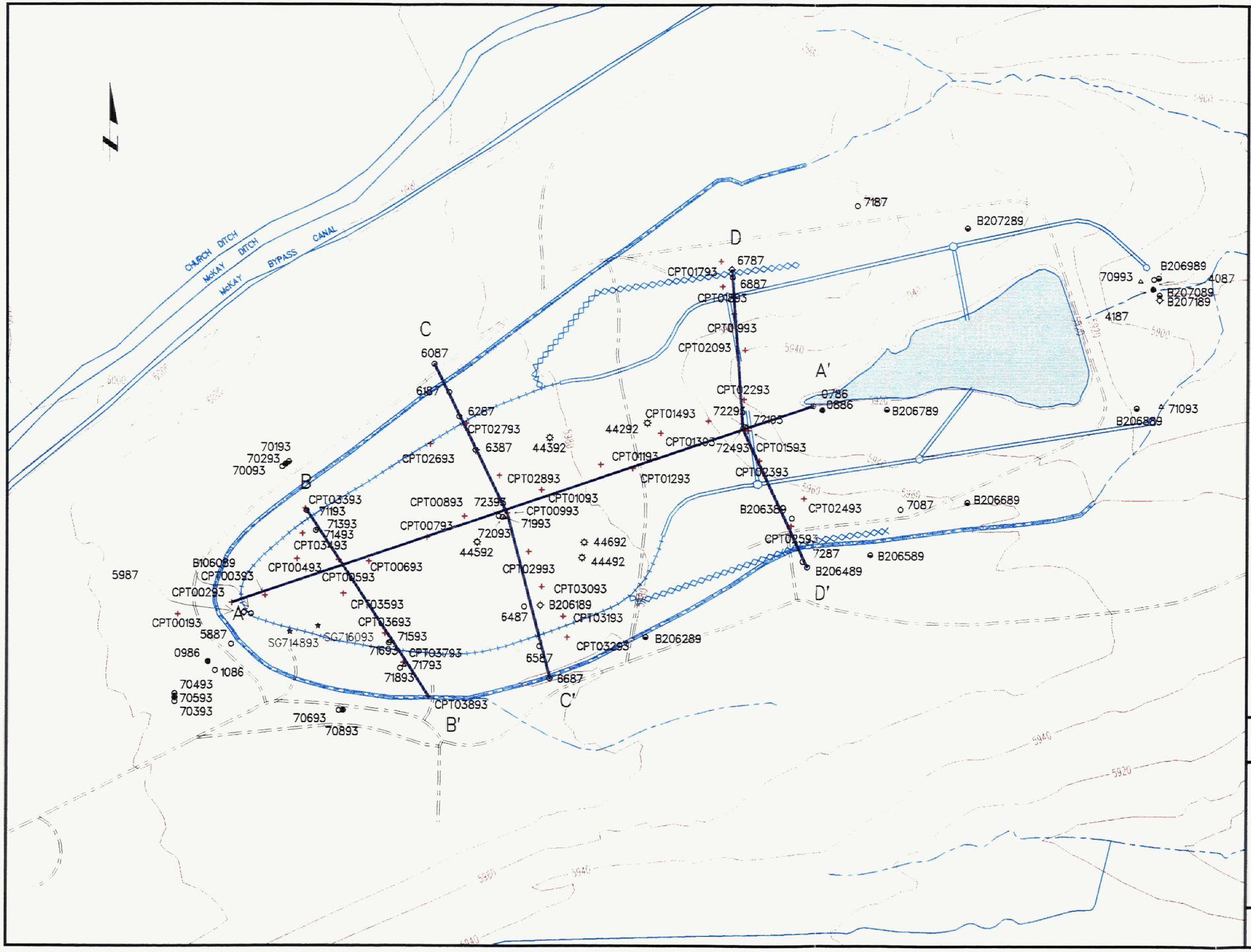
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surfaces of Landfill Used to Calculate Volume of Waste Material

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-3

04/11/94 SURFACES.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- Gas Venting Well
- CPT Location
- IHSS 203 Soil Gas Sampling Location
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Gas Concentration Cross–Section

0 Feet 250 500

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Landfill Gas Concentration Cross-Section Location Map

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 4–4

08/29/94 GASPROFILE.MAP

A′

East

CPT00793 | CPT00893 projected | 44592 projected | 72393 | 72093 | 71993 | CPT00993 | CPT01093 | 44692 projected | 44392 projected | CPT01193 projected | CPT01293 | CPT01393 projected | CPT01493 projected | 72493 | 72193 | CPT01593 | 0786 | 0886 projected

6000
5990
5980
5970
5960
5950
5940
5930
5920
5910
5900
5890
5880
5870
5860
5850
5840

KaKl (w)
KaKl (u)
af

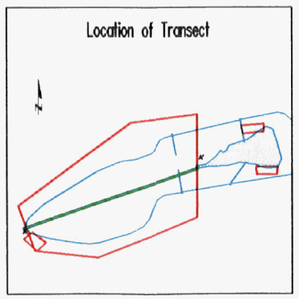
TD = 92.0′
TD = 70.4′
TD = 24.4′
TD = 27.8′
TD = 37.6′
TD = 46.5′
TD = 47.9′
TD = 51.8′
TD = 58.1′
TD = 50.4′
TD = 34.3′
TD = 26.3′
TD = 60.9′
TD = 92.8′
TD = 60.5′
TD = 104.7′
TD = 30.2′
TD = 10.0′
TD = 71.5′

East Landfill Pond

Concentration
(in parts per million)

- > 400,000
- > 300,000 to 400,000
- > 100,000 to 300,000
- > 50,000 to 100,000
- > 12,500 to 50,000
- 1,000 to 12,500

Location of Transect



SCALE
(in feet)
0
20
0
100

Number
mpling Location
(in parts per million)
(pounds per square inch)
e-minute intervals; measurements
en off-gassing pressures are > .10
one-minute intervals)
eet)

luvium

ed
ie Formation
u) – Unweathered

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Methane in Landfill Gas Along Cross-Section A - A′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–5

A′

East

CPT00793 | CPT00893 projected | 44592 projected | 72393 | 72093 | 71993 | CPT00993 | CPT01093 | 44692 projected | 44392 projected | CPT01193 projected | CPT01293 | CPT01393 projected | CPT01493 projected | 72493 | 72193 | CPT01593 | 0786 | 0886 projected

6000 5990 5980 5970 5960 5950 5940 5930 5920 5910 5900 5890 5880 5870 5860 5850 5840

45,000 29,000 73,000 ≥0 220 af 27,000 49 37,000 26,000 6 TD = 24.4' TD = 27.8' TD = 37.6' TD = 46.5' TD = 47.9' TD = 70.4' TD = 92.0'

KaKl (w) KaKl (u)

85,000 ≥0 41,000 59,000 TD = 34.3' TD = 51.8' TD = 58.1'

35,000 27,000 33,000 24,000 0 TD = 20.3' af KaKl (w)

79,000 41,000 101,000 32,000 46,000 2 0 0 TD = 50.4' TD = 60.9' TD = 92.8'

74,000 54,000 72,000 75,000 0 22 af KaKl (u)

118,000 107,000 118,000 49,000 108,000 75,000 TD = 30.2' 102,000 43,000 0 4 af KaKl (w)

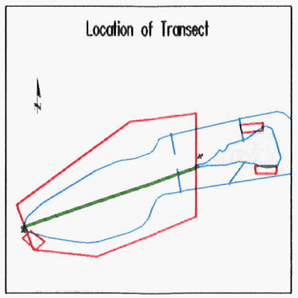
47,000 48,000 30,000 45,000 82,000 79,000 TD = 10.0' TD = 60.5' TD = 104.7' TD = 71.5'

East Landfill Pond

Concentration (in parts per million)

- > 100,000
- > 75,000 to 100,000
- > 50,000 to 75,000
- > 12,500 to 50,000
- 1,000 to 12,500

Location of Transect



20 0 0 100 SCALE (in feet)

er

lumber

pling Location

(in parts per million)

(pounds per square inch)

e-minute intervals; measurements

n off-gassing pressures are > .10

one-minute intervals)

eet)

luvium

ed

ie Formation

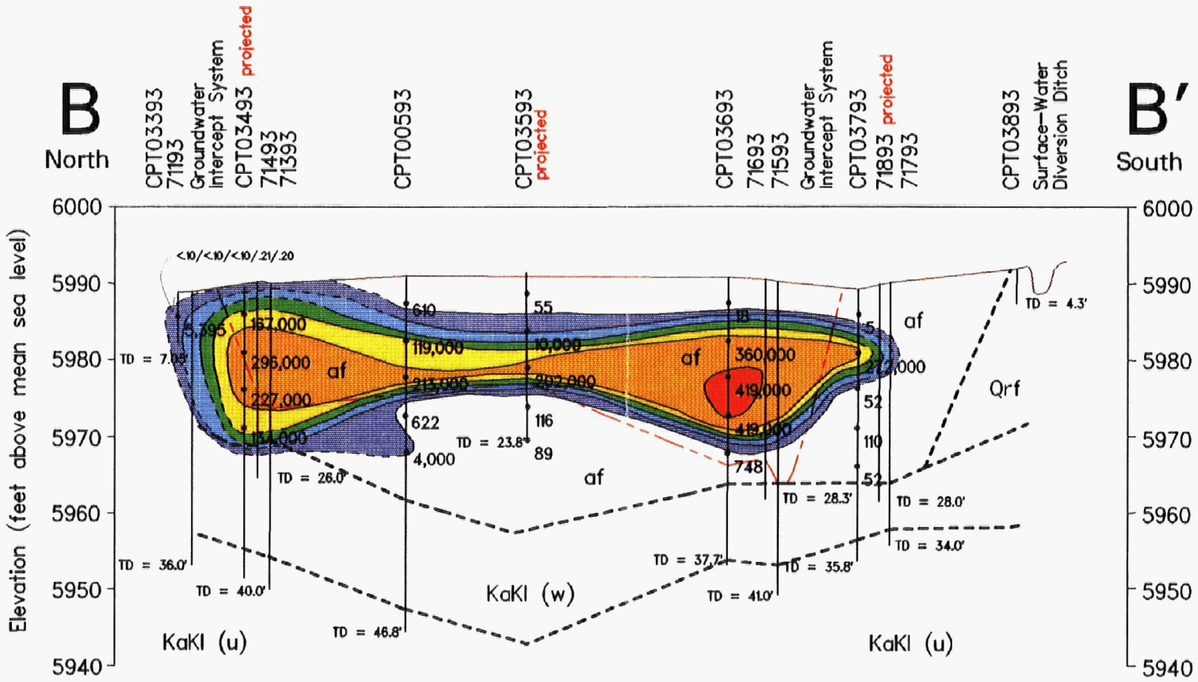
u) – Unweathered

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of NMOCs in Landfill Gas Along Cross-Section A - A′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 | Figure 4-6



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

Screened Interval of Gas Venting Well

71193 — Well/Borehole Number

CPT00493 — CPT Number

44692 — Gas Venting Well Number

• 388,000 — Methane Survey Sampling Location and Concentration (in parts per million)

<.10/<.10/.20/.20/.20 — Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals; measurements provided only when off-gassing pressures are > .10 for any of the 5 one-minute intervals)

TD — Total Depth (in feet)

GEOLOGIC UNITS:

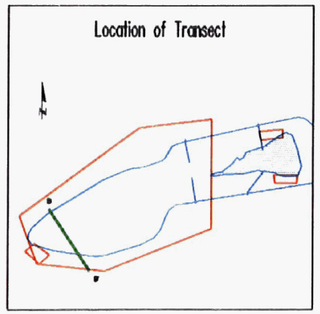
af — Artificial Fill

Qrf — Quaternary Rocky Flats Alluvium

KaKl — Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered; (u) - Unweathered

Concentration (in parts per million)

- > 400,000
- > 200,000 to 400,000
- > 100,000 to 200,000
- > 50,000 to 100,000
- > 12,500 to 50,000
- 1,000 to 12,500



20
0
0
100
SCALE (in feet)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

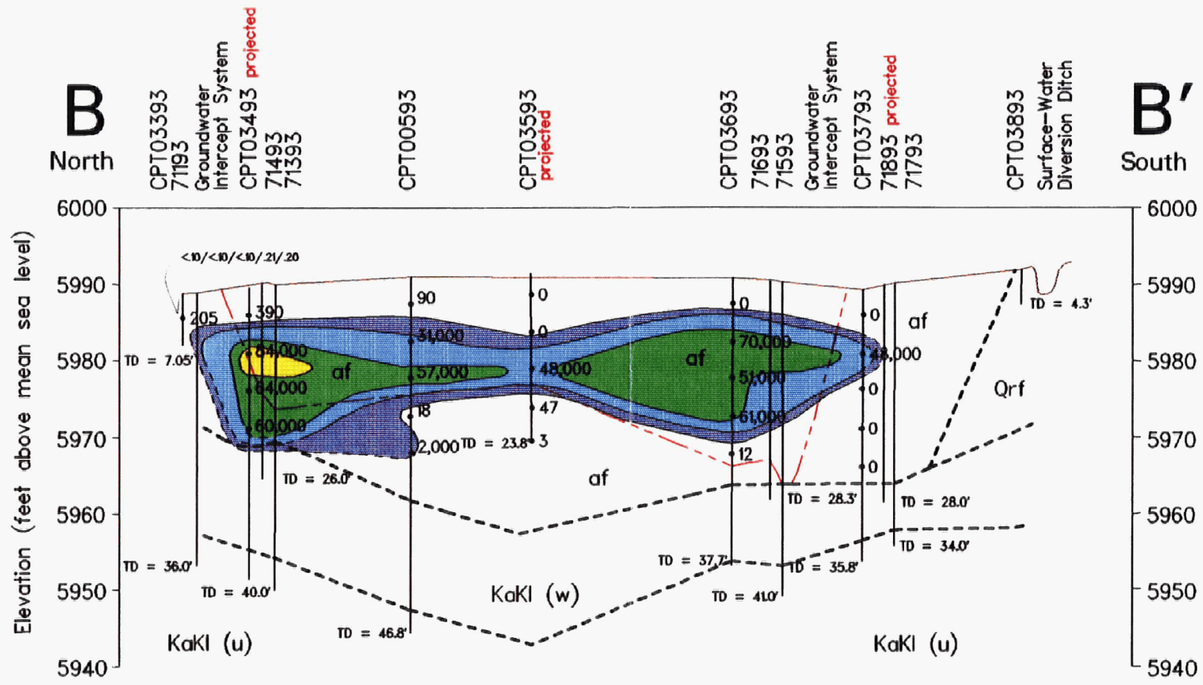
Concentrations of Methane in Landfill Gas Along Cross-Section B - B′

Revised Work Plan — Operable Unit No. 7

Date: April 1994

Figure 4-7

04/11/94 BBMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

Screened Interval of Gas Venting Well

71193 — Well/Borehole Number

CPT00493 — CPT Number

44692 — Gas Venting Well Number

• 388,000 — Methane Survey Sampling Location and Concentration (in parts per million)

<.10/<.10/.20/.20/.20 — Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals; measurements provided only when off-gassing pressures are > .10 for any of the 5 one-minute intervals)

TD — Total Depth (in feet)

GEOLOGIC UNITS:

af — Artificial Fill

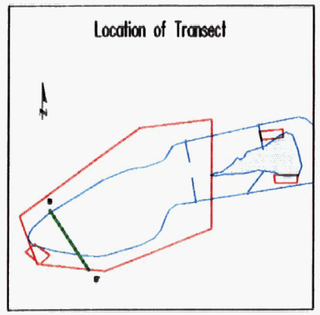
Qrf — Quaternary Rocky Flats Alluvium

KaKl — Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) – Weathered; (u) – Unweathered

Concentration (in parts per million)

- > 75,000
- > 50,000 to 75,000
- > 12,500 to 50,000
- 1,000 to 12,500

Location of Transect



20
0
0 100
SCALE (in feet)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

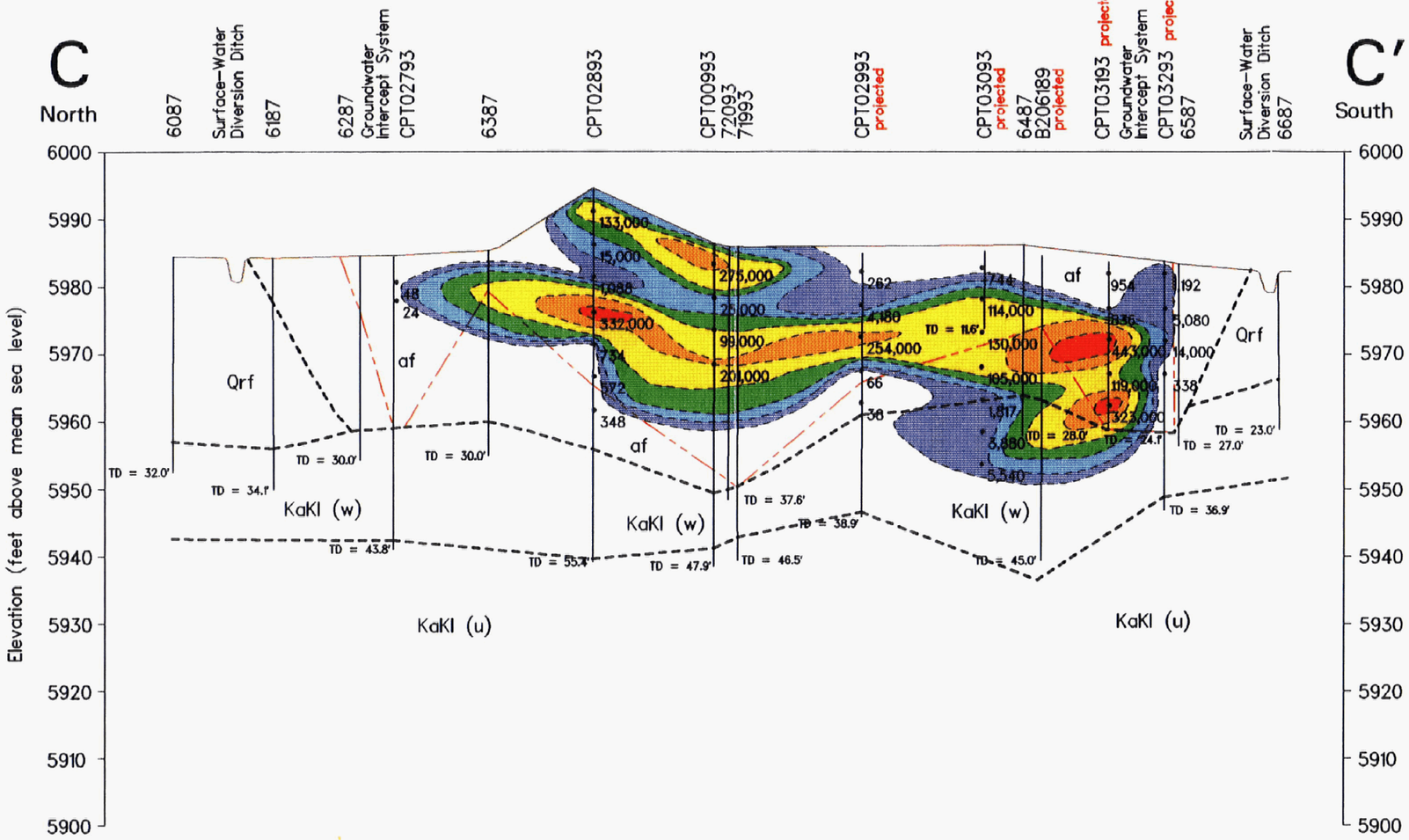
Concentrations of NMOCs in Landfill Gas Along Cross-Section B - B′

Revised Work Plan — Operable Unit No. 7

Date: April 1994

Figure 4-8

04/11/94 BBNONMETH.MAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

Screened Interval of Gas Venting Well

71193 — Well/Borehole Number

CPT00493 — CPT Number

44692 — Gas Venting Well Number

• 388,000 — Methane Survey Sampling Location and Concentration (in parts per million)

<.10/<.10/.20/.20/.20 — Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals; measurements provided only when off-gassing pressures are > .10 for any of the 5 one-minute intervals)

TD — Total Depth (in feet)

GEOLOGIC UNITS:

af — Artificial Fill

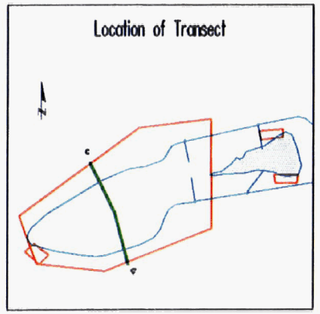
Qrf — Quaternary Rocky Flats Alluvium

KaKl — Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered; (u) - Unweathered

Concentration (in parts per million)

- > 300,000
- > 200,000 to 300,000
- > 100,000 to 200,000
- > 50,000 to 100,000
- > 12,500 to 50,000
- 1,000 to 12,500

Location of Transect



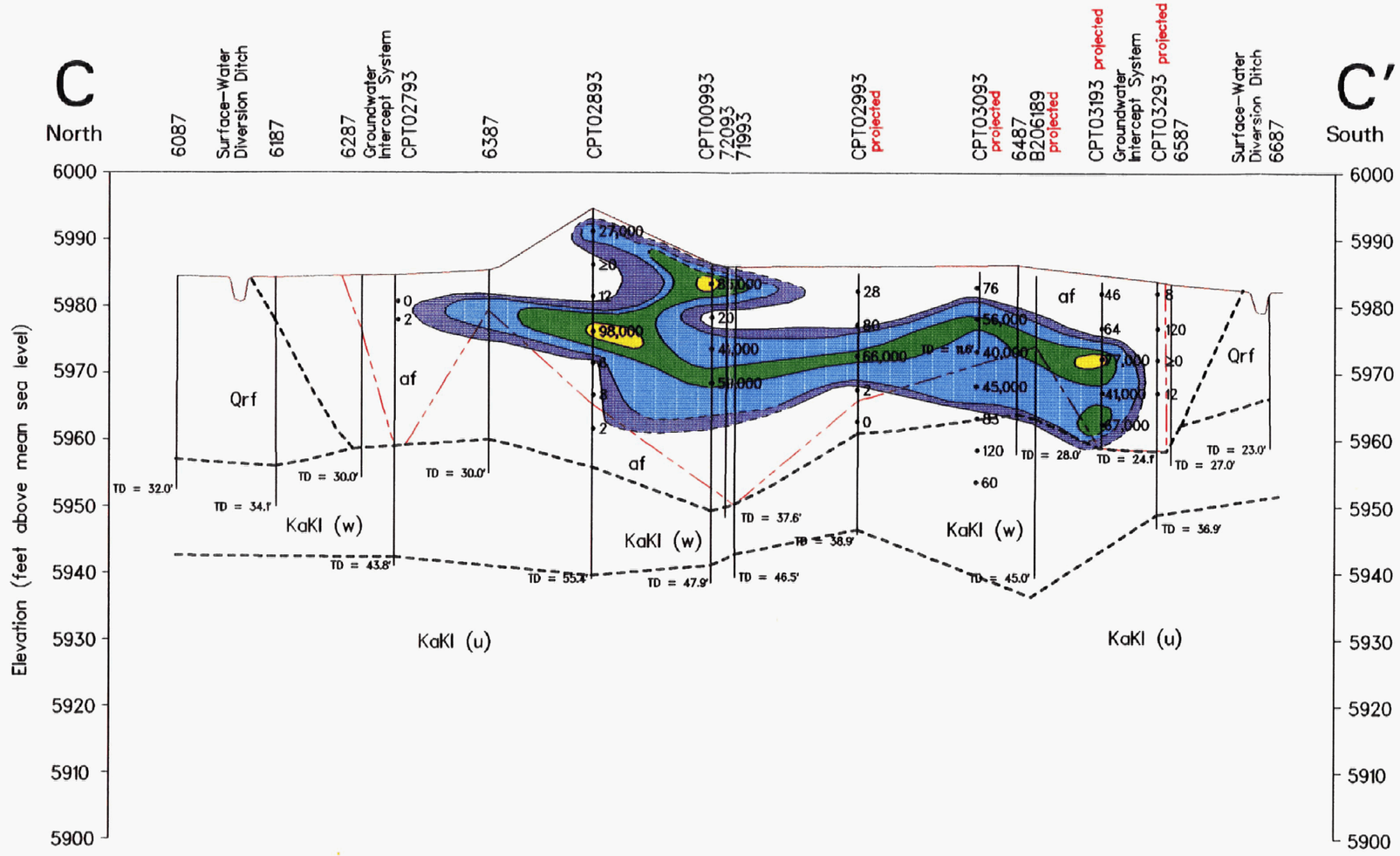
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Methane in Landfill Gas Along Cross-Section C - C′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-9

04/11/94 COMETHLMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

Screened Interval of Gas Venting Well

71193 — Well/Borehole Number

CPT00493 — CPT Number

44692 — Gas Venting Well Number

• 388,000 — Methane Survey Sampling Location and Concentration (in parts per million)

<.10/<.10/.20/.20/.20 — Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals; measurements provided only when off-gassing pressures are > .10 for any of the 5 one-minute intervals)

TD — Total Depth (in feet)

GEOLOGIC UNITS:

af — Artificial Fill

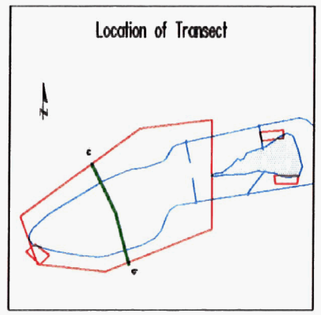
Qrf — Quaternary Rocky Flats Alluvium

KaKl — Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered; (u) - Unweathered

Concentration (in parts per million)

- > 75,000
- > 50,000 to 75,000
- > 12,500 to 50,000
- 1,000 to 12,500

Location of Transect



20
0
0 100
SCALE (in feet)

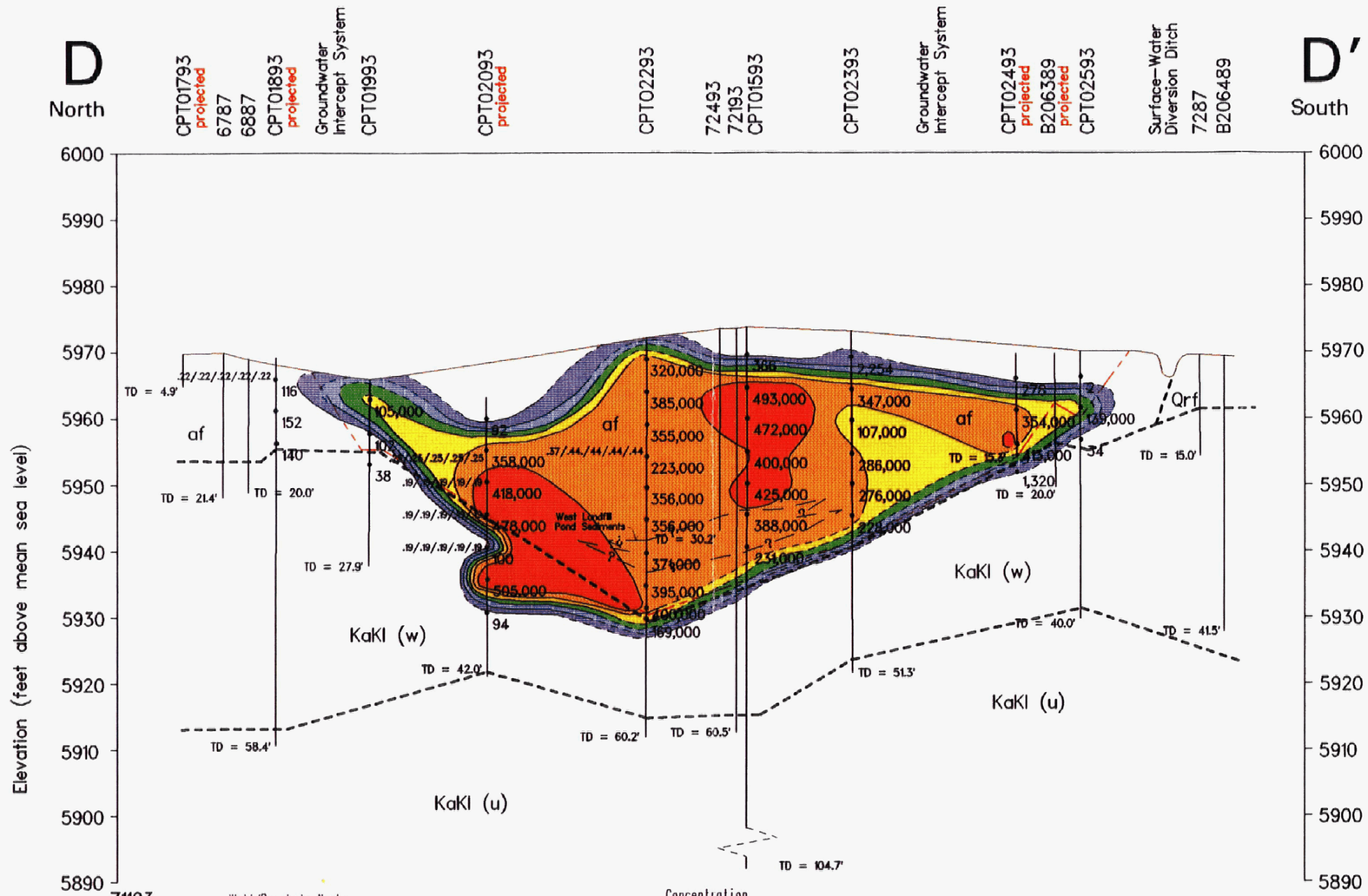
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of NMOCs in Landfill Gas Along Cross-Section C - C'

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-10

04/11/94 CONCNMETH.MAP



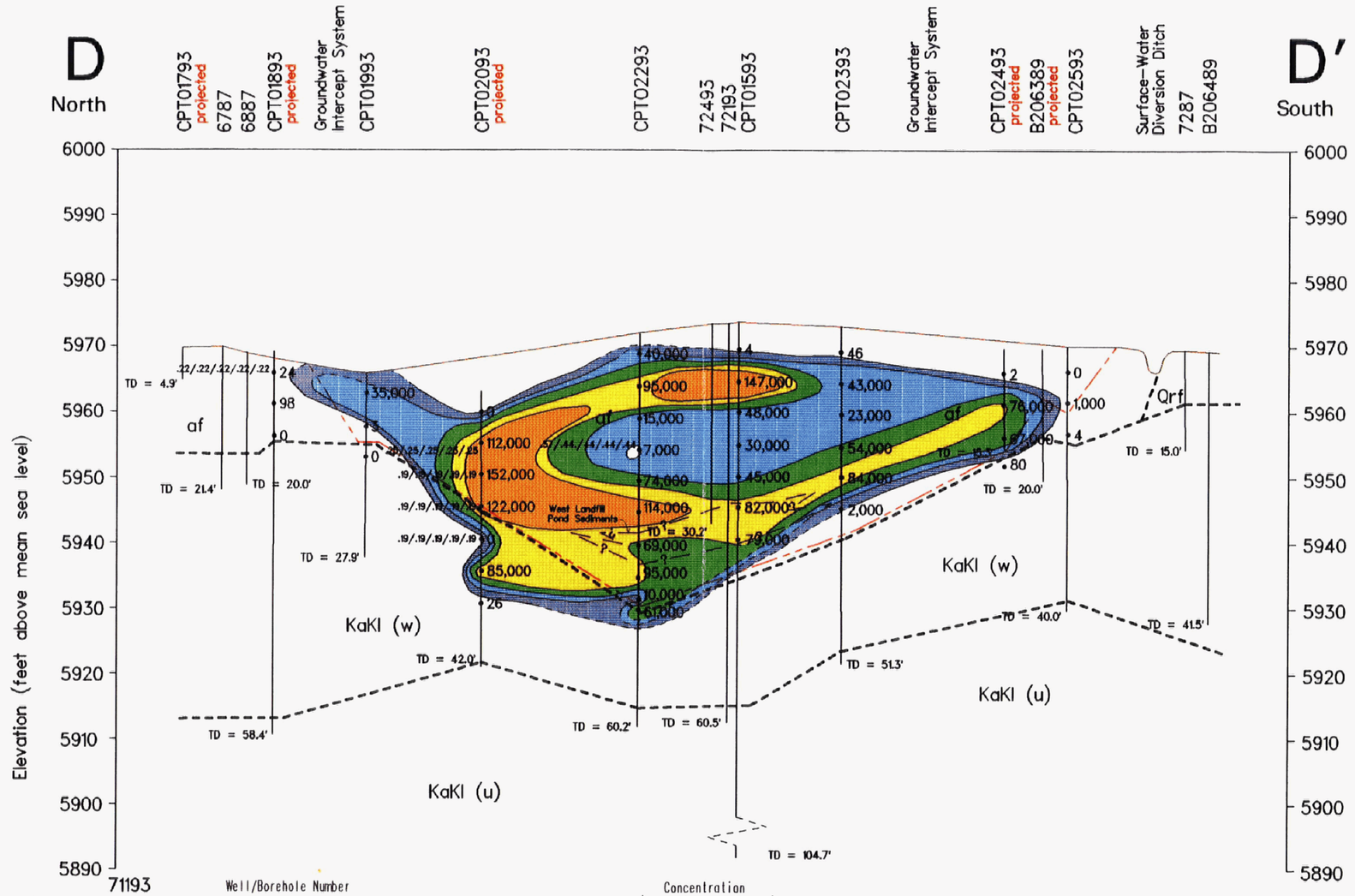
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Methane in Landfill Gas Along Cross-Section D - D'

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-11

04/11/94 DOMETH.MAP



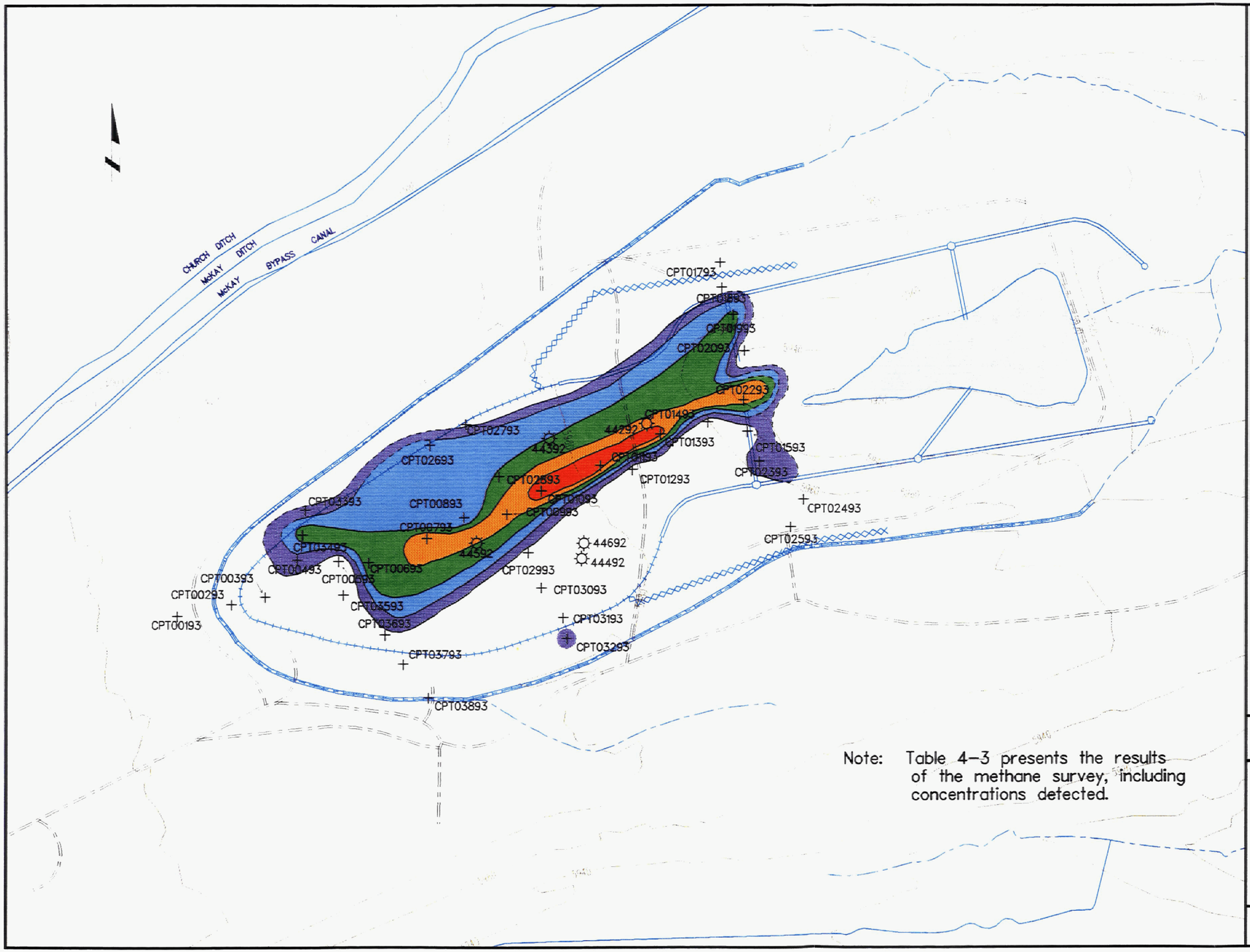
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of NMOCs in Landfill Gas Along Cross-Section D - D'

Revised Work Plan — Operable Unit No. 7

Date: April 1994 | Figure 4-12

04/11/94 DONONMETH.MAP



Note: Table 4–3 presents the results of the methane survey, including concentrations detected.

EXPLANATION

- CPT Location
- Gas Venting Well
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour (dashed where inferred)

Concentrations in parts per million:

- > 400,000
- 200,000 to 400,000
- 100,000 to 200,000
- 10,000 to 100,000
- 1,000 to 10,000

0 Feet 250 500

Topographic Contour Interval = 20 Feet

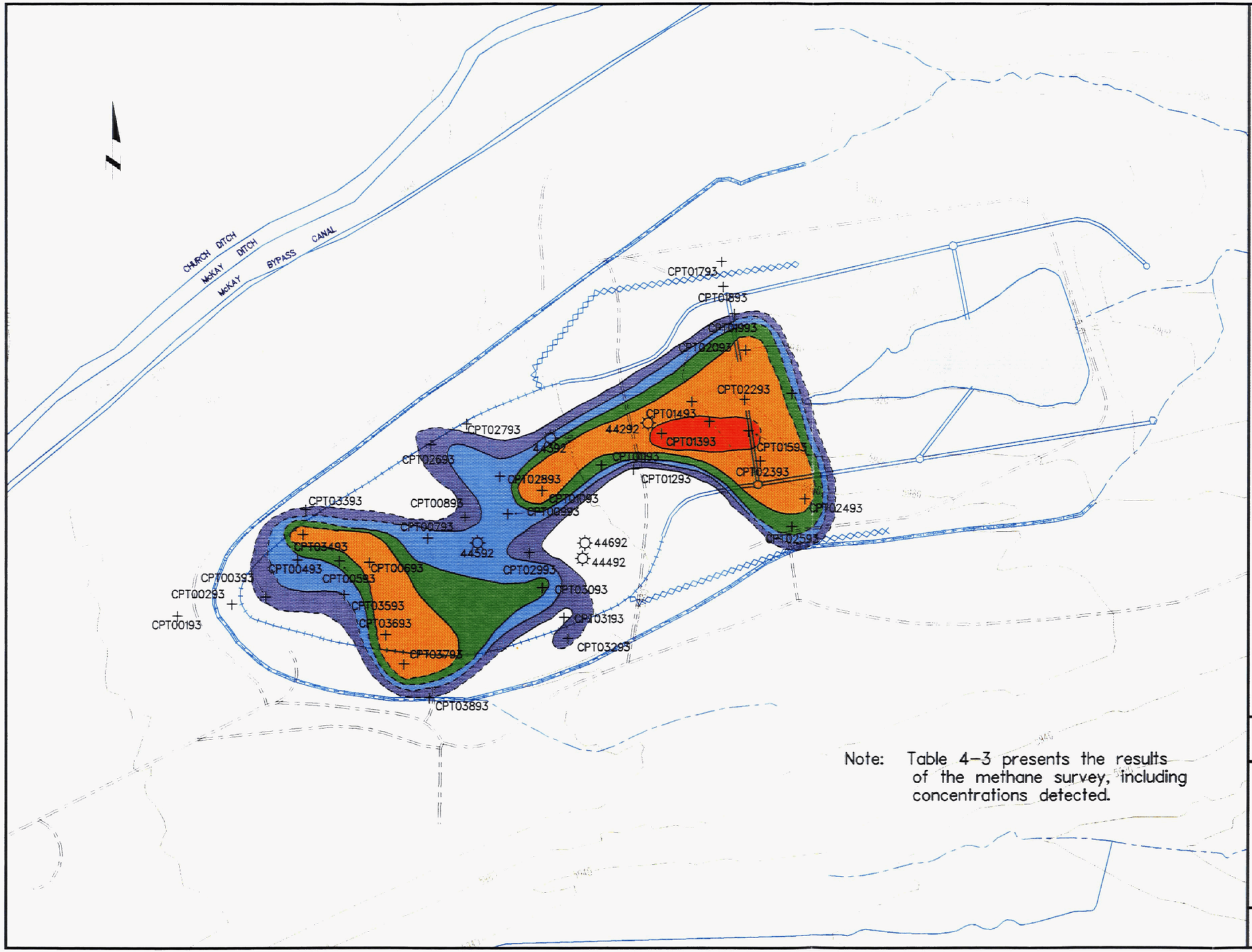
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Methane Concentrations in Landfill Gas at Three Feet Below Ground Surface

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–13

04/12/94 METH3FT.MAP



Note: Table 4-3 presents the results of the methane survey, including concentrations detected.

EXPLANATION

- + CPT Location
- ☼ Gas Venting Well
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in parts per million:

- > 400,000
- 200,000 to 400,000
- 100,000 to 200,000
- 10,000 to 100,000
- 1,000 to 10,000

0 Feet 250 500

Topographic Contour Interval = 20 Feet

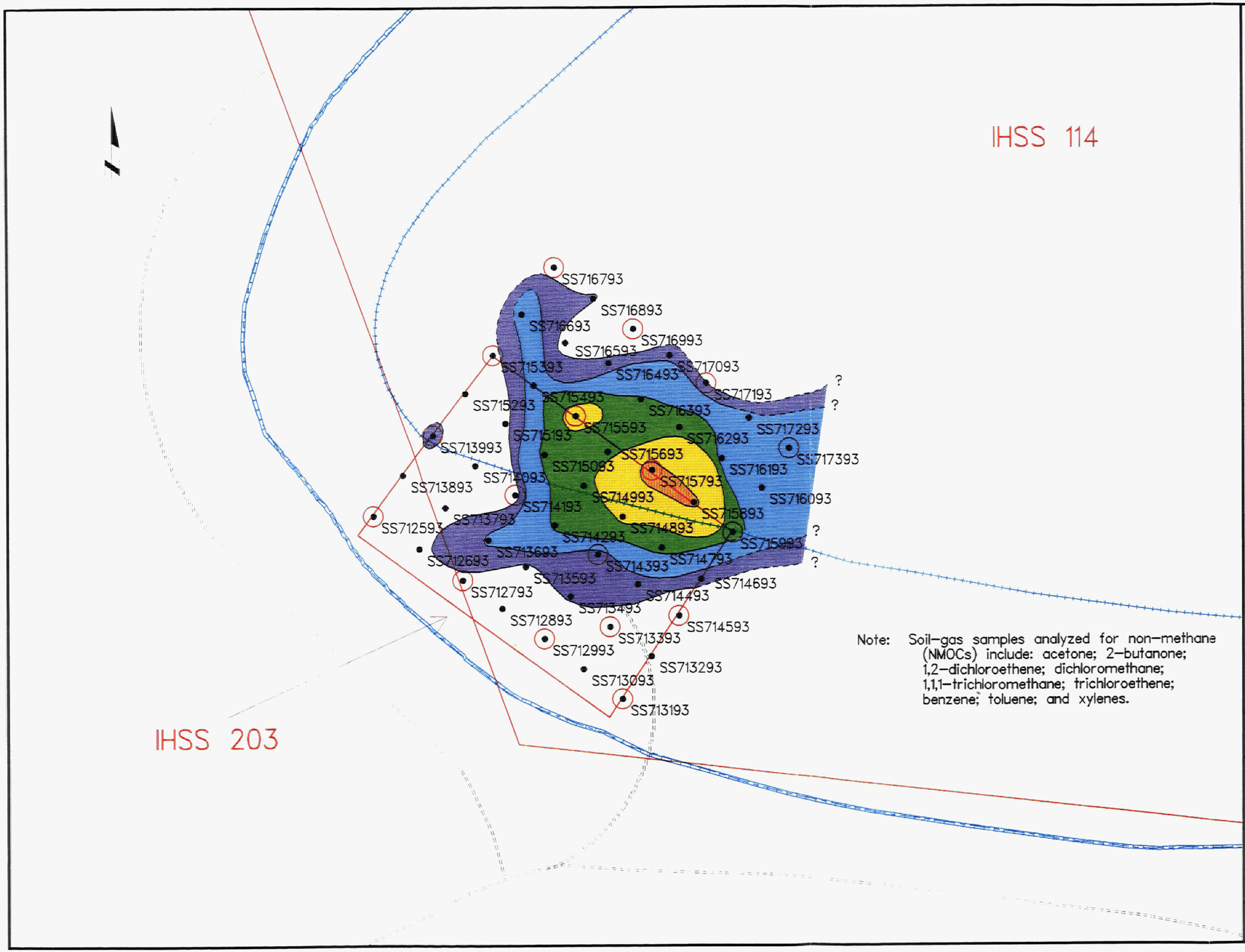
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Methane Concentrations in Landfill Gas at Eight Feet Below Ground Surface

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-14

04/12/94 METH8FT.MAP


IHSS 114
IHSS 203
SS716793
SS716893
SS716693
SS716993
SS716593
SS717093
SS715393
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SS717193
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SS716393
SS717293
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SS713093
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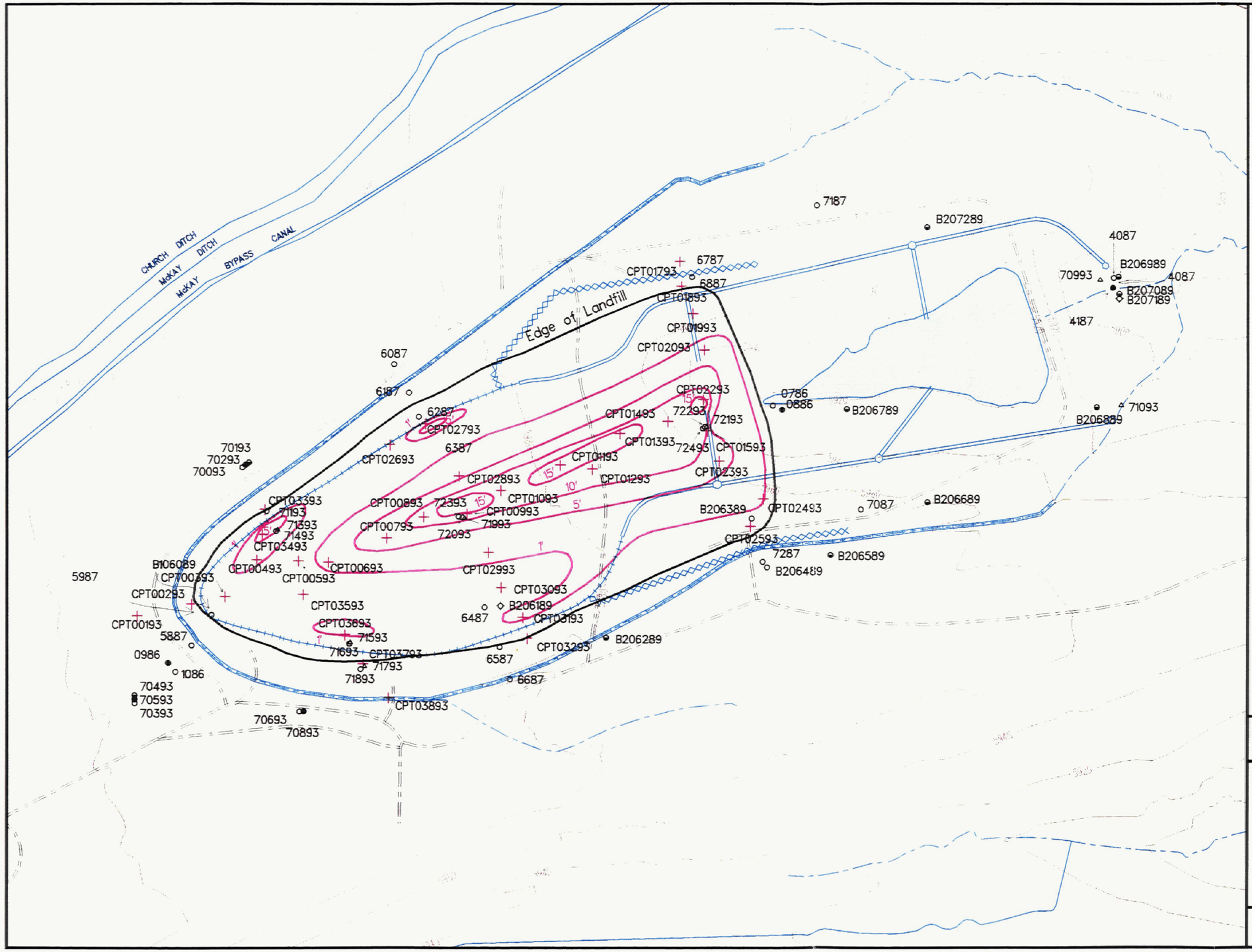
Note: Soil–gas samples analyzed for non–methane (NMOCs) include: acetone; 2–butanone; 1,2–dichloroethene; dichloromethane; 1,1,1–trichloromethane; trichloroethene; benzene; toluene; and xylenes.
EXPLANATION
Surface Soil and Soil–Gas Sampling Location
Additional Surface Soil and Soil–Gas Sampling Location
Subsurface Soil Sampling Location
Intermittent Stream
Dirt Road
Surface–Water Diversion Ditch
Slurry Wall
Groundwater Intercept System
(perforated)
(non–perforated)
Concentration Contour
(dashed where inferred)
Concentrations in milligrams per liter
> 100 mg/L
50 – 100 mg/L
25 – 50 mg/L
10 – 25 mg/L
5 – 10 mg/L
0 Feet 50 100
Topographic Contour Interval = 20 Feet
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado
Concentrations of NMOCs in Soil Gas at IHSS 203
Revised Work Plan
Operable Unit No. 7
Date: April 1994
Figure 4–15



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- CPT Location
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Thickness Contour (in feet)

0 Feet 250 500

Topographic Contour Interval = 20 Feet

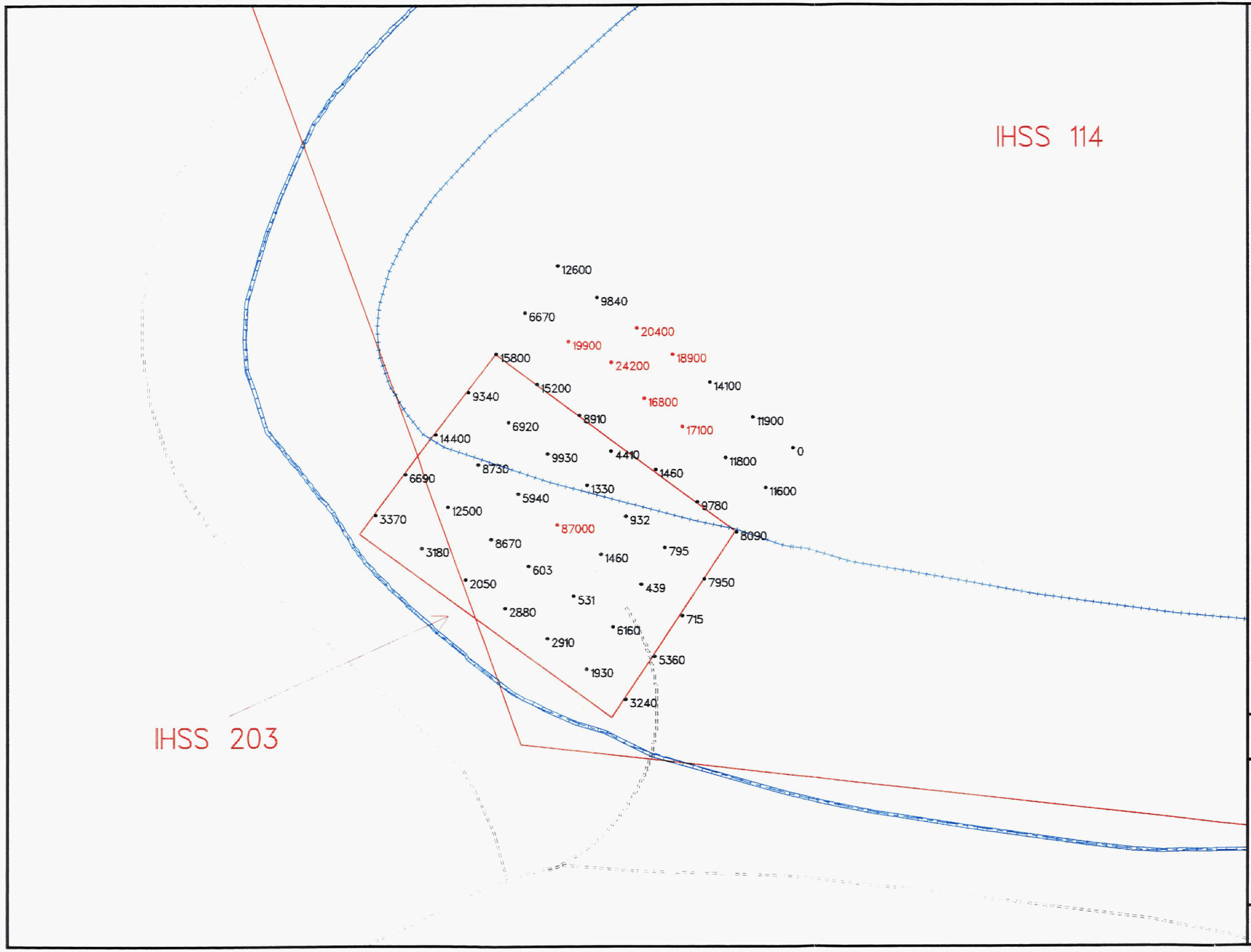
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Isopach Map of Saturated Landfill Waste

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-16

04/12/94 LANDISO.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–4 for sample location numbers.

0 Feet 50 100

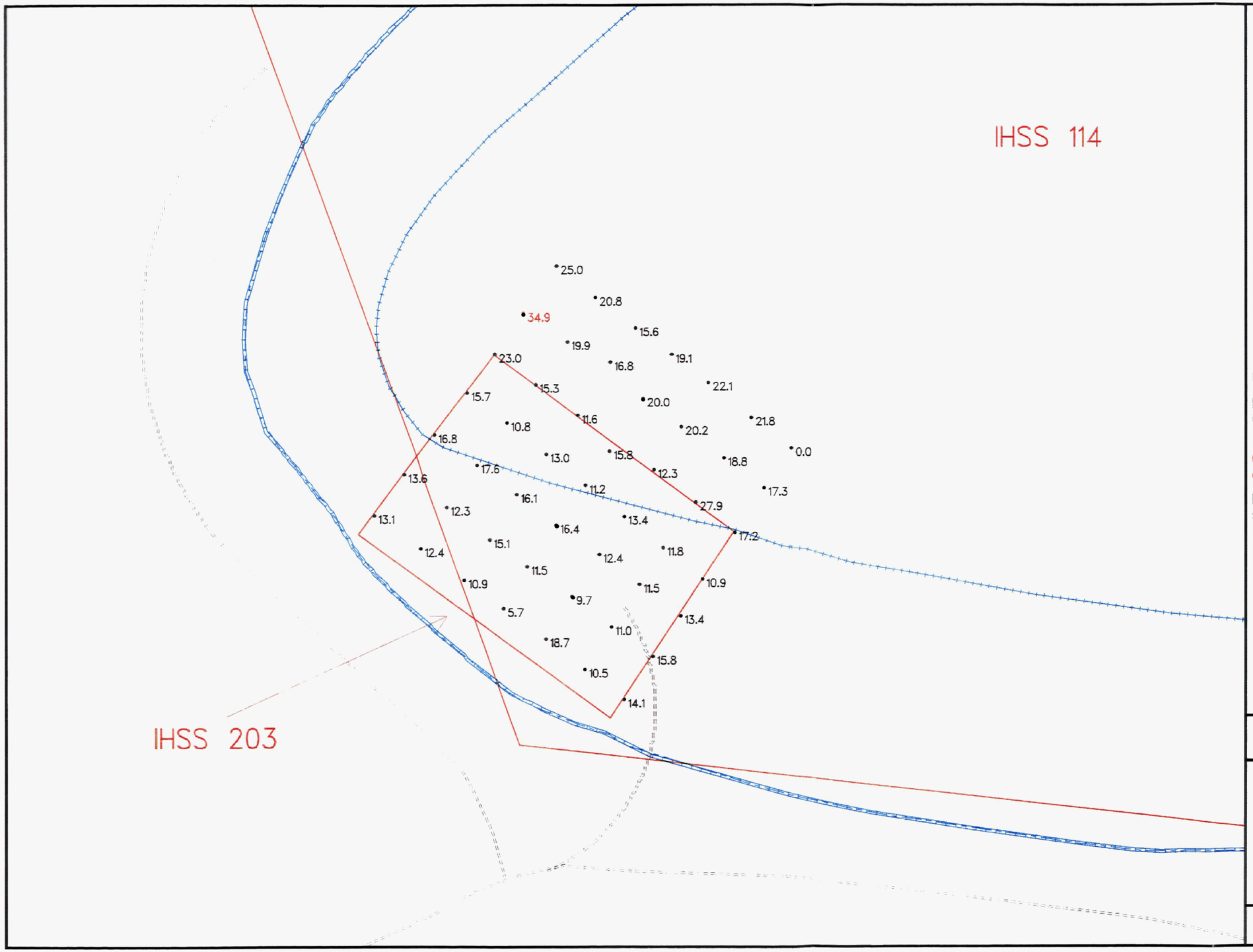
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Calcium Concentrations at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–17



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 30 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–4 for sample location numbers.

0 Feet 50 100

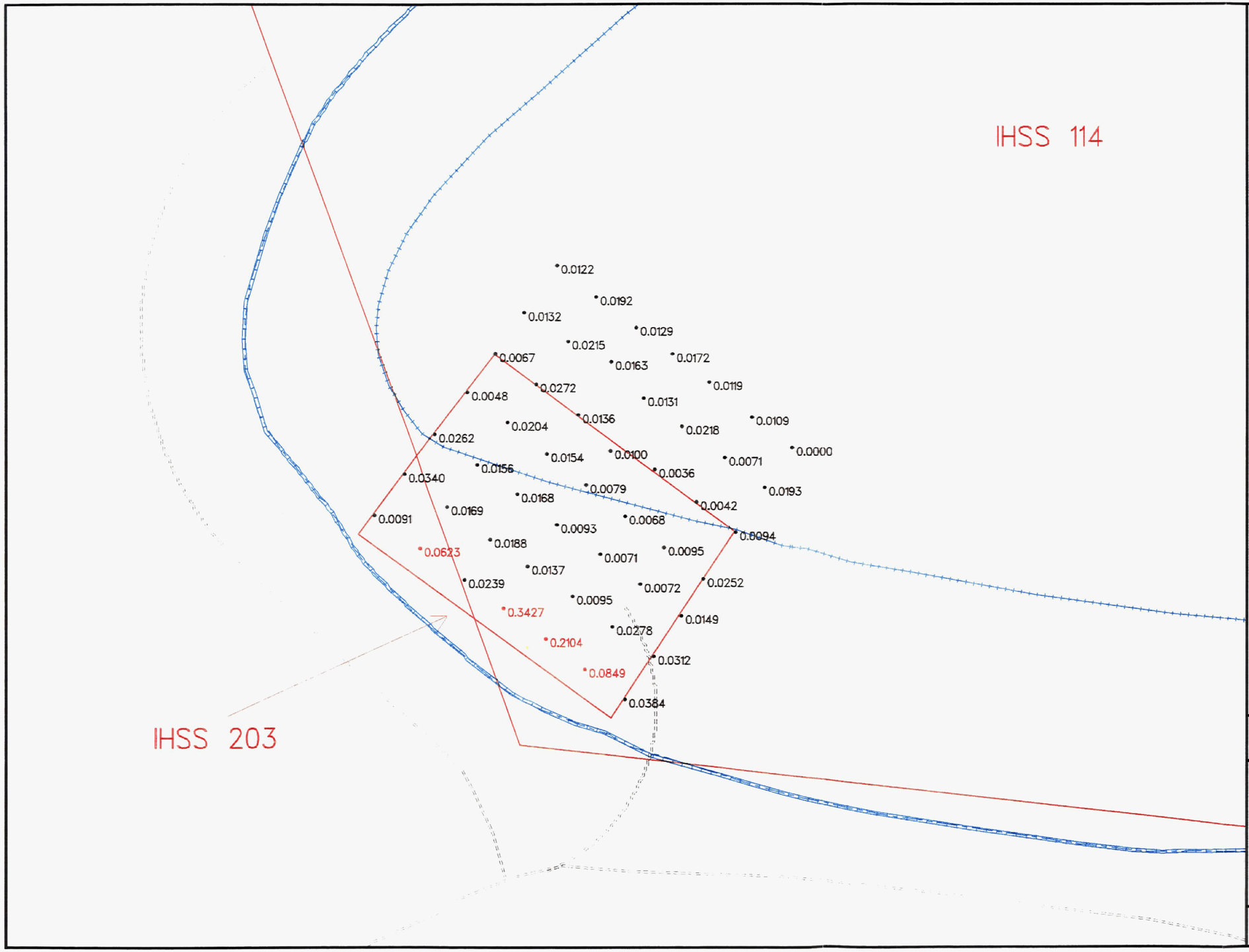
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Copper Concentrations at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–18



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 0.058 pCi/g (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Activity exceeding the UTL 99/99 are posted in red.

Refer to Figure C–4 for sample location numbers.

0 Feet 50 100

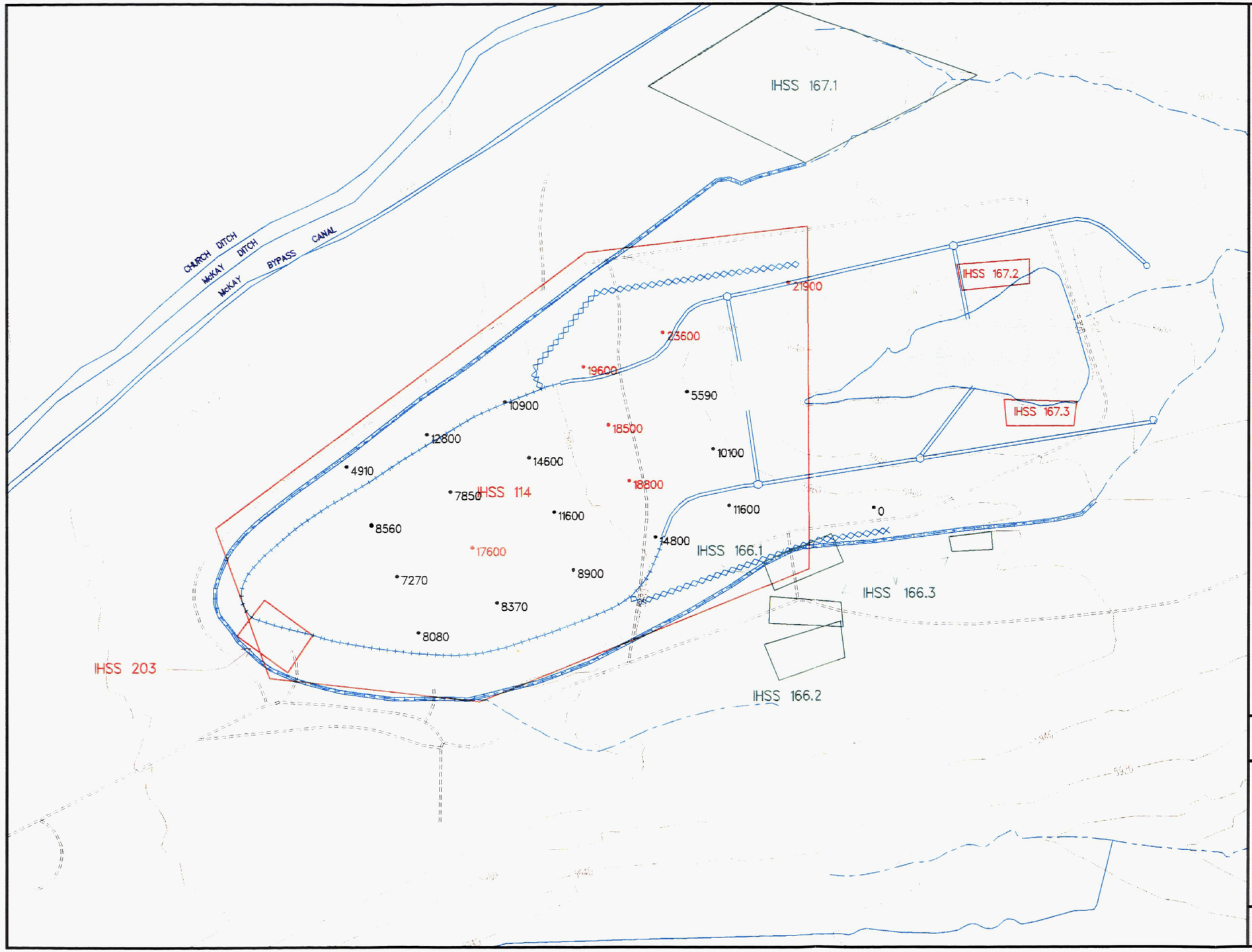
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Americium-241 Activity at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–19



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–6 for sample location numbers.

0 Feet 250 500

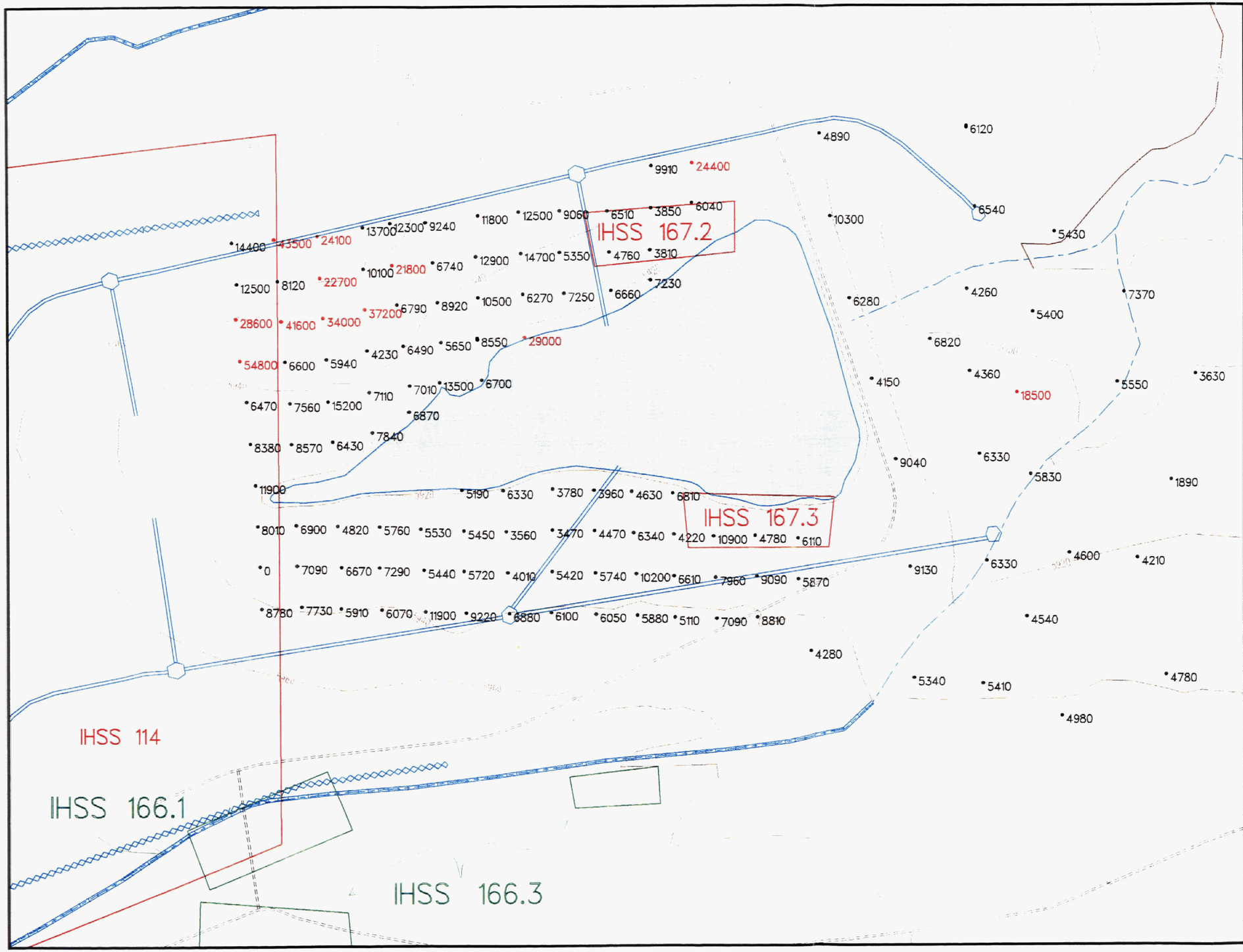
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Calcium Concentrations at IHSS 114

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–20



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-5 for sample location numbers.

N

0 Feet 120 240

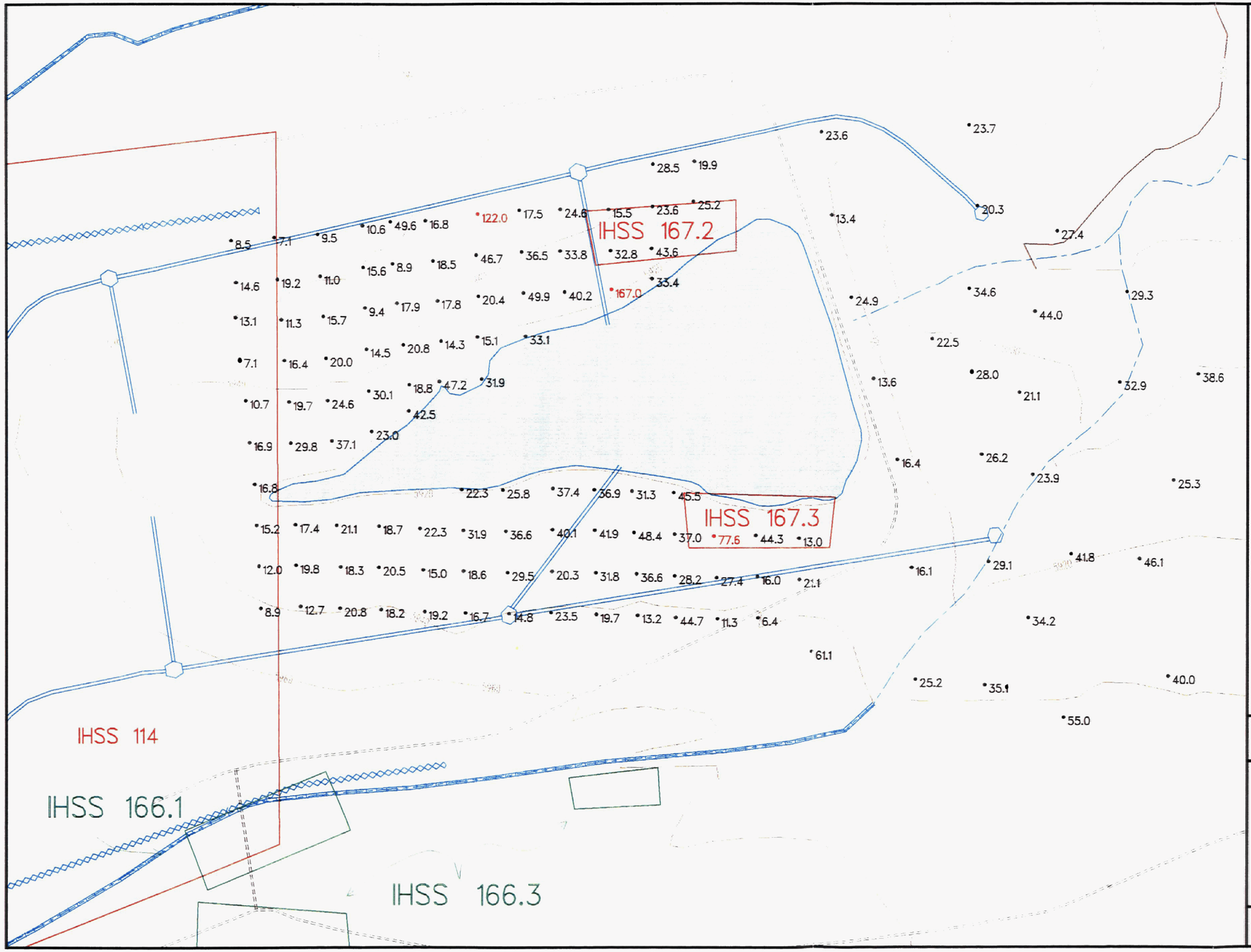
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Calcium Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-21



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 62 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–5 for sample location numbers.

0 Feet 120 240

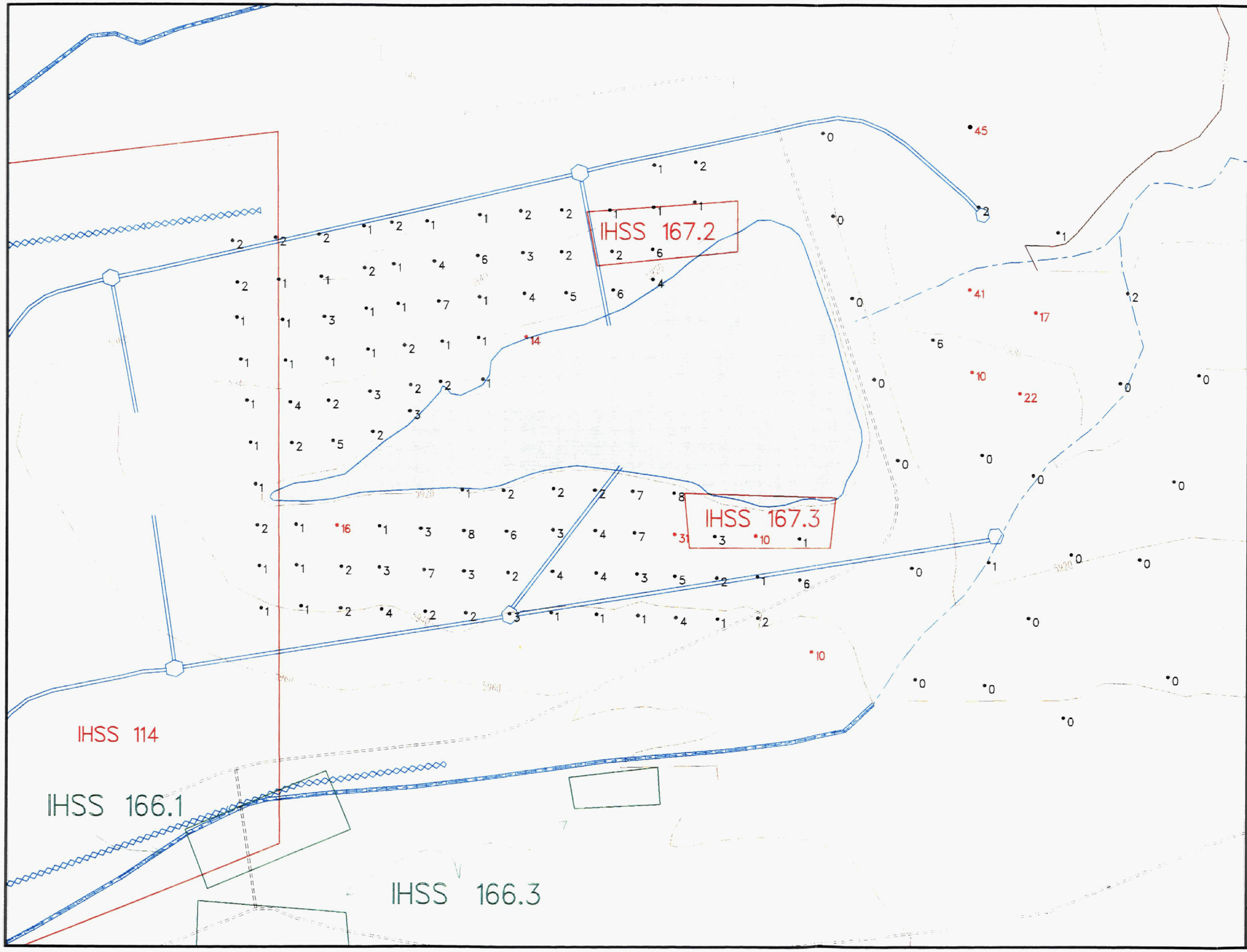
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Lead Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–22



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 9.6 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-5 for sample location numbers.

0 Feet 120 240

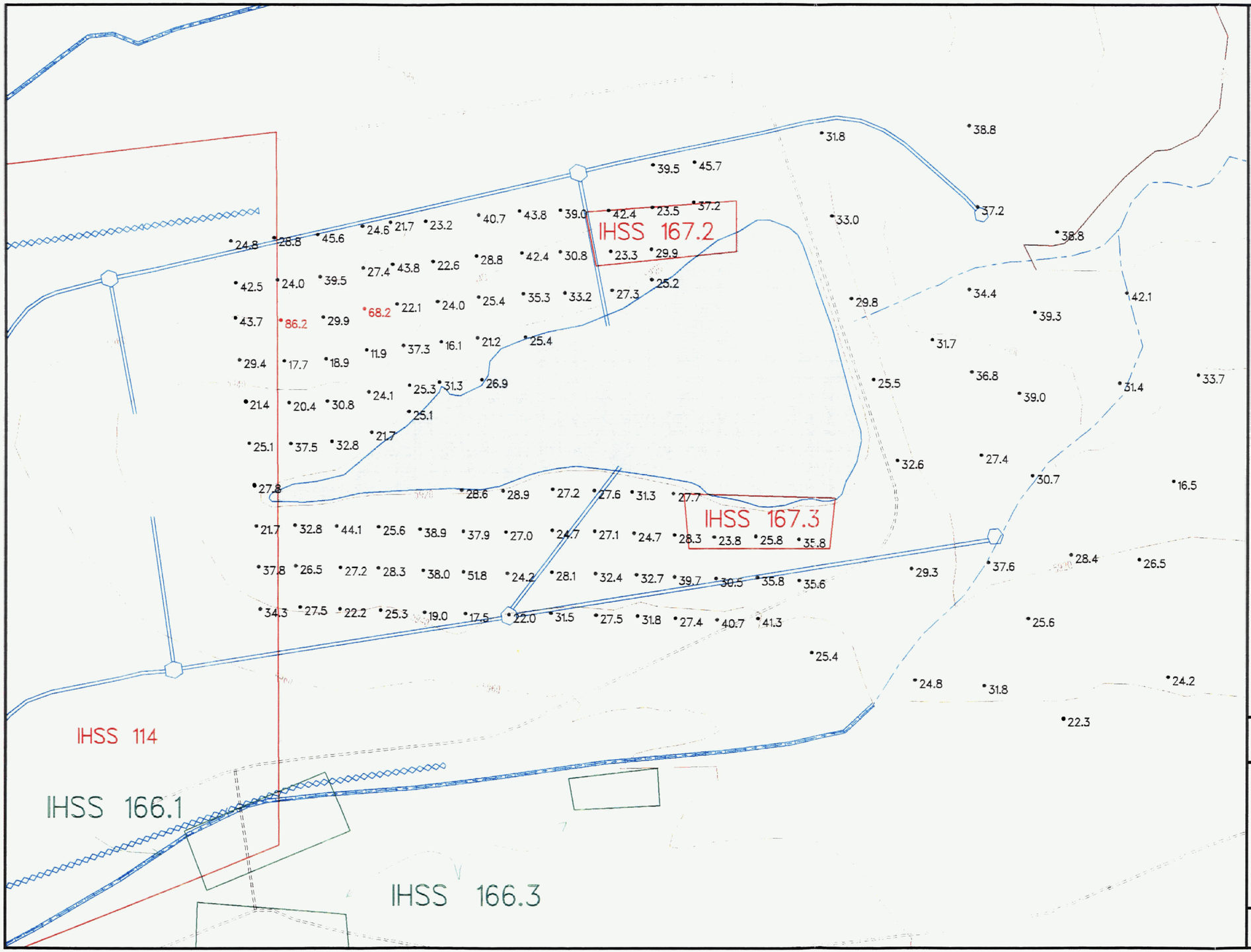
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Nitrate/Nitrite Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-23



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 60 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–5 for sample location numbers.

0 Feet 120 240

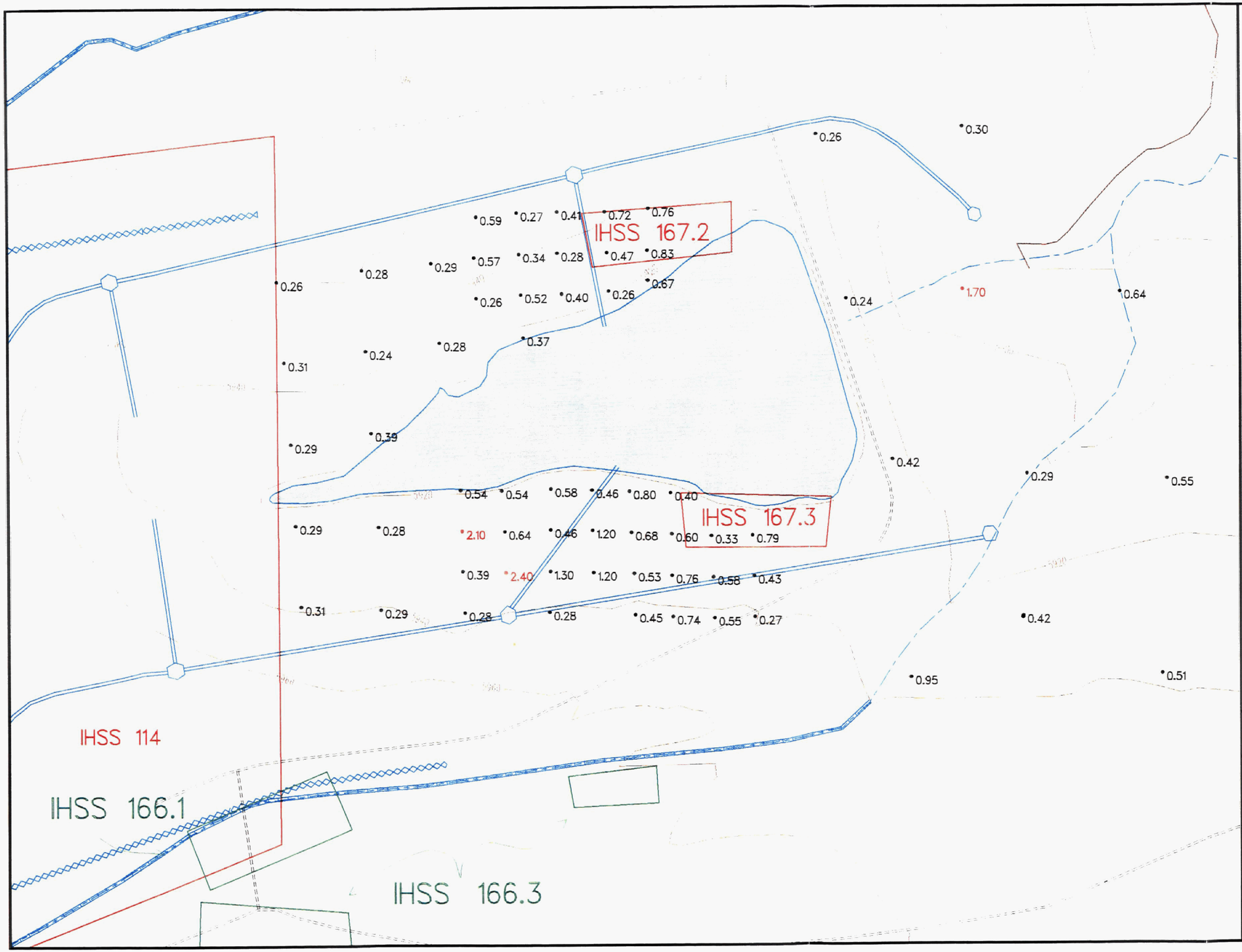
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Vanadium Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–24



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 1.4 mg/kg (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C–5 for sample location numbers.

0 Feet 120 240

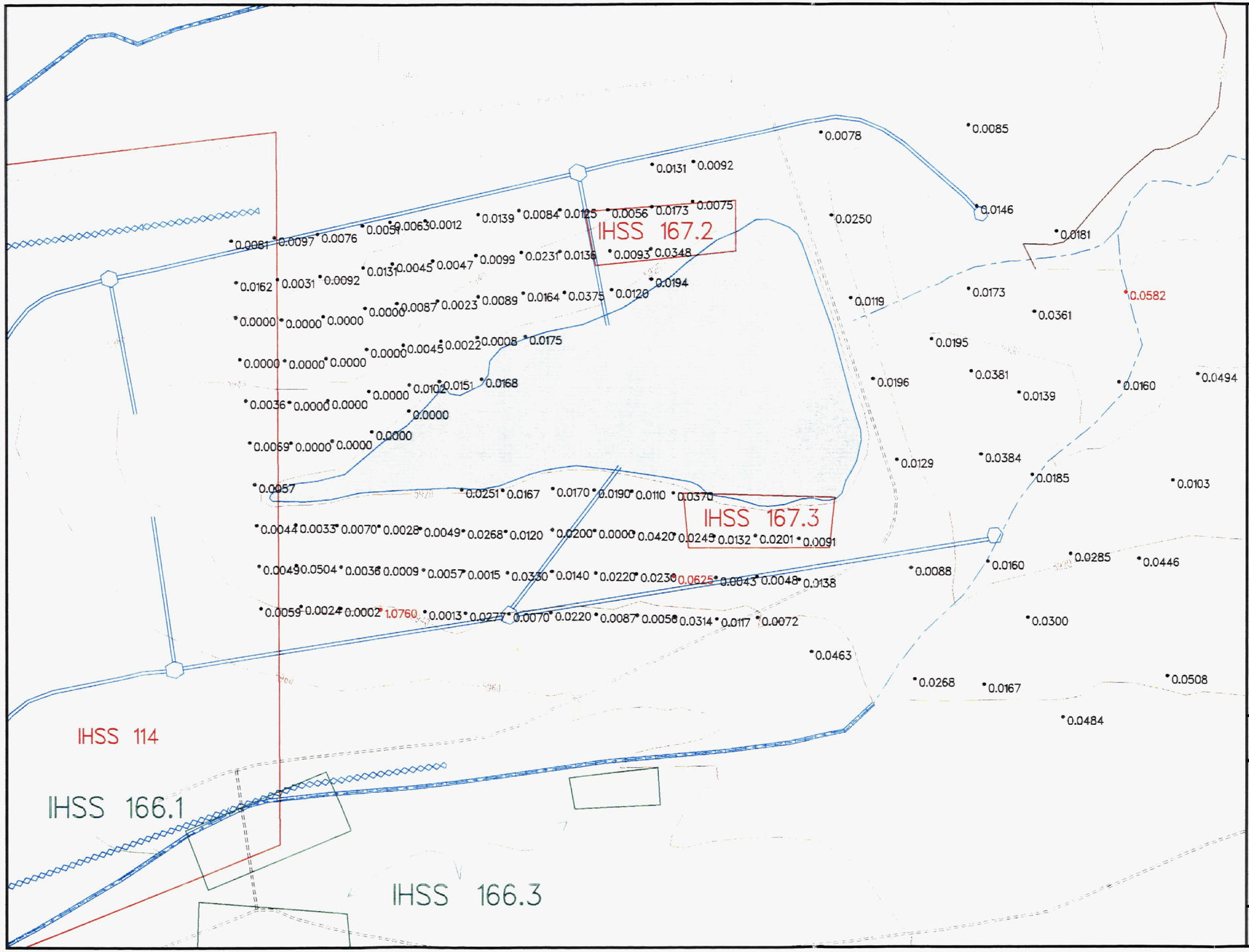
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 10 inches) Selenium Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–25



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 0.058 pCi/g (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Activity exceeding the UTL 99/99 are posted in red.

Refer to Figure C–5 for sample location numbers.

0 Feet 120 240

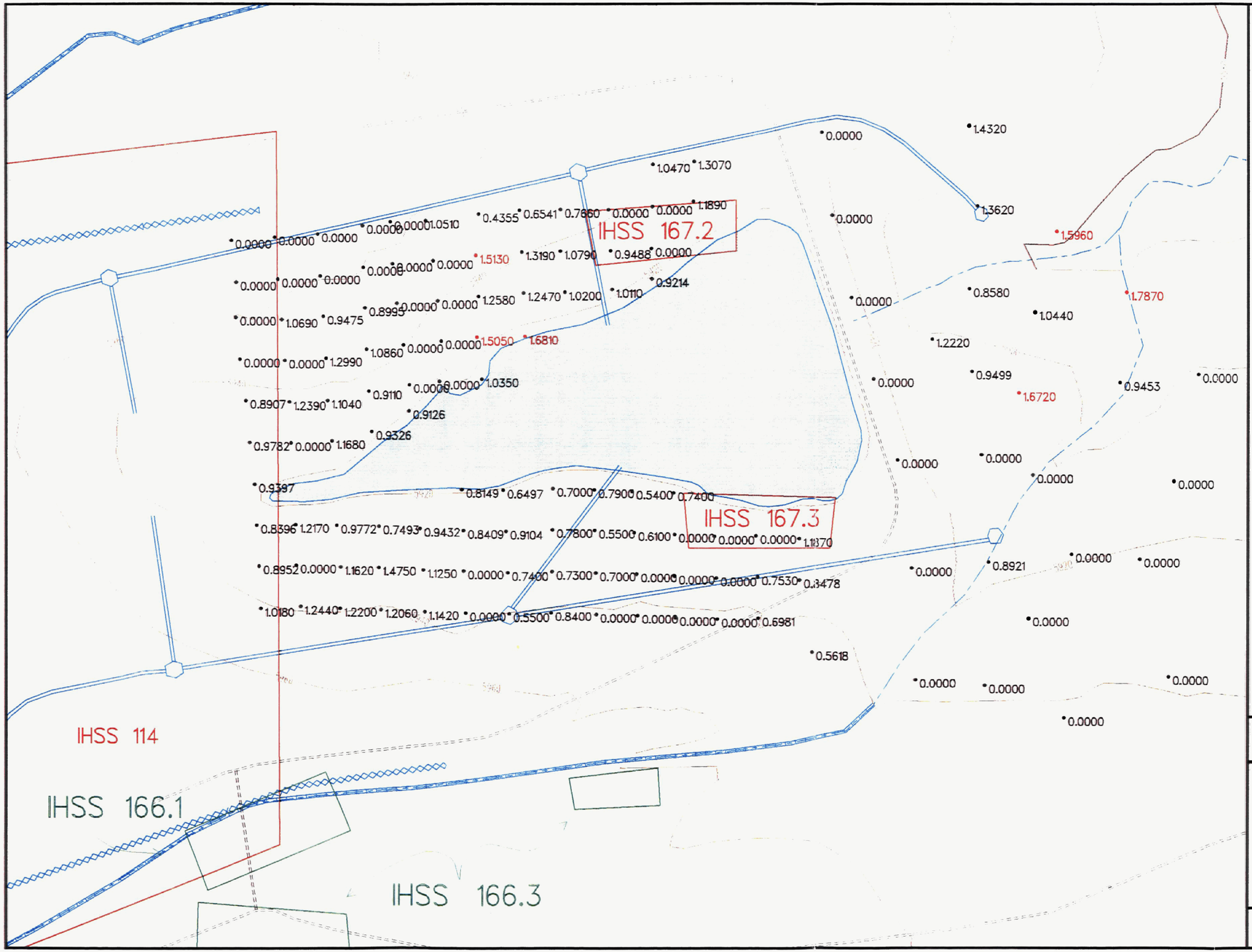
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Americium-241 Activity at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–26



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 1.5 pCi/g (Background Geochemical Characterization Report for 1992; EG&G, 1993)

Activity exceeding the UTL 99/99 are posted in red.

Refer to Figure C–5 for sample location numbers.

N

0 Feet 120 240

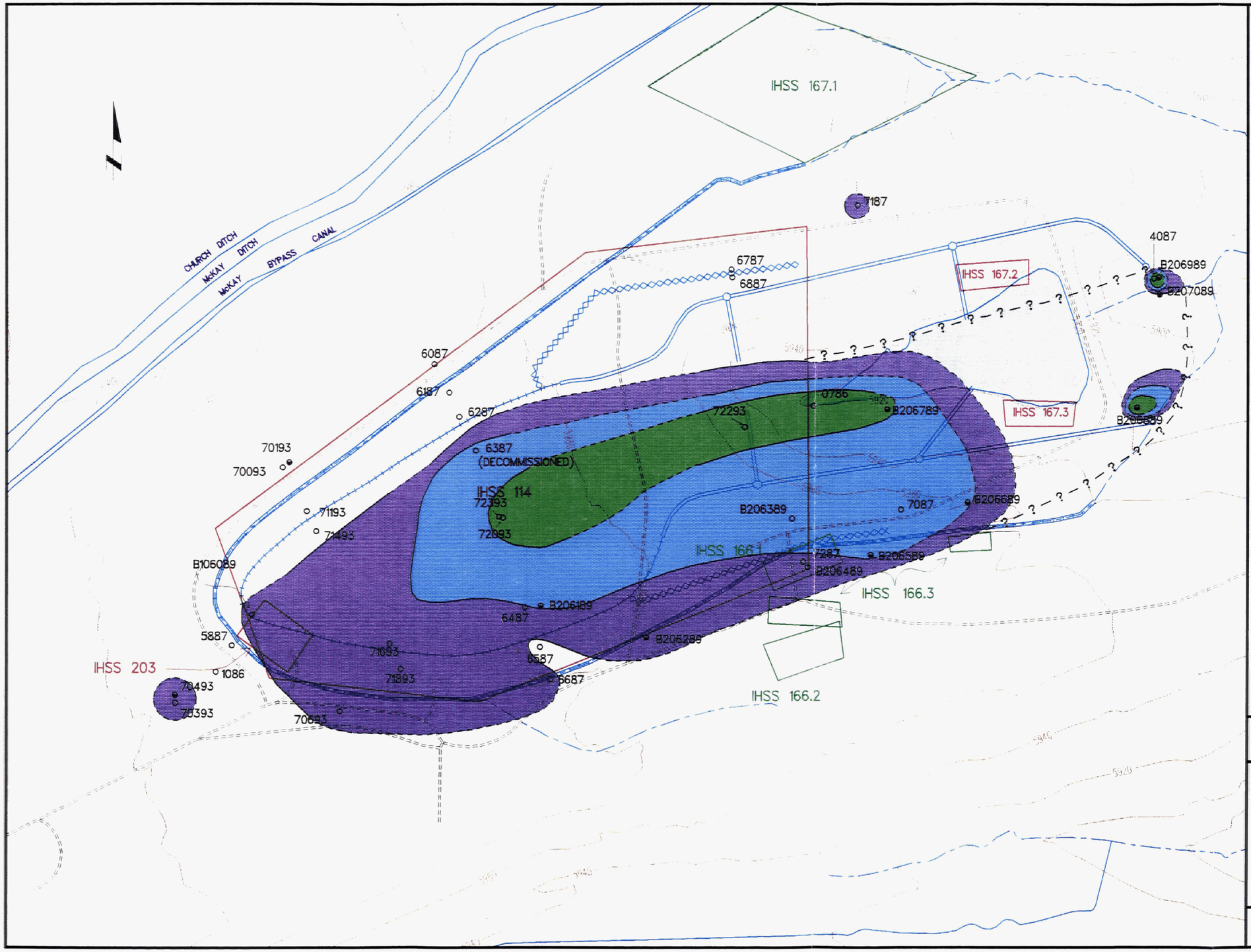
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Soil (0 to 2 inches) Radium-226 Activity at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–27



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour (dashed where inferred)

Concentrations in milligrams per liter

- > 1,000 mg/L
- 500 – 1,000 mg/L
- 250 – 500 mg/L

0 Feet 250 500

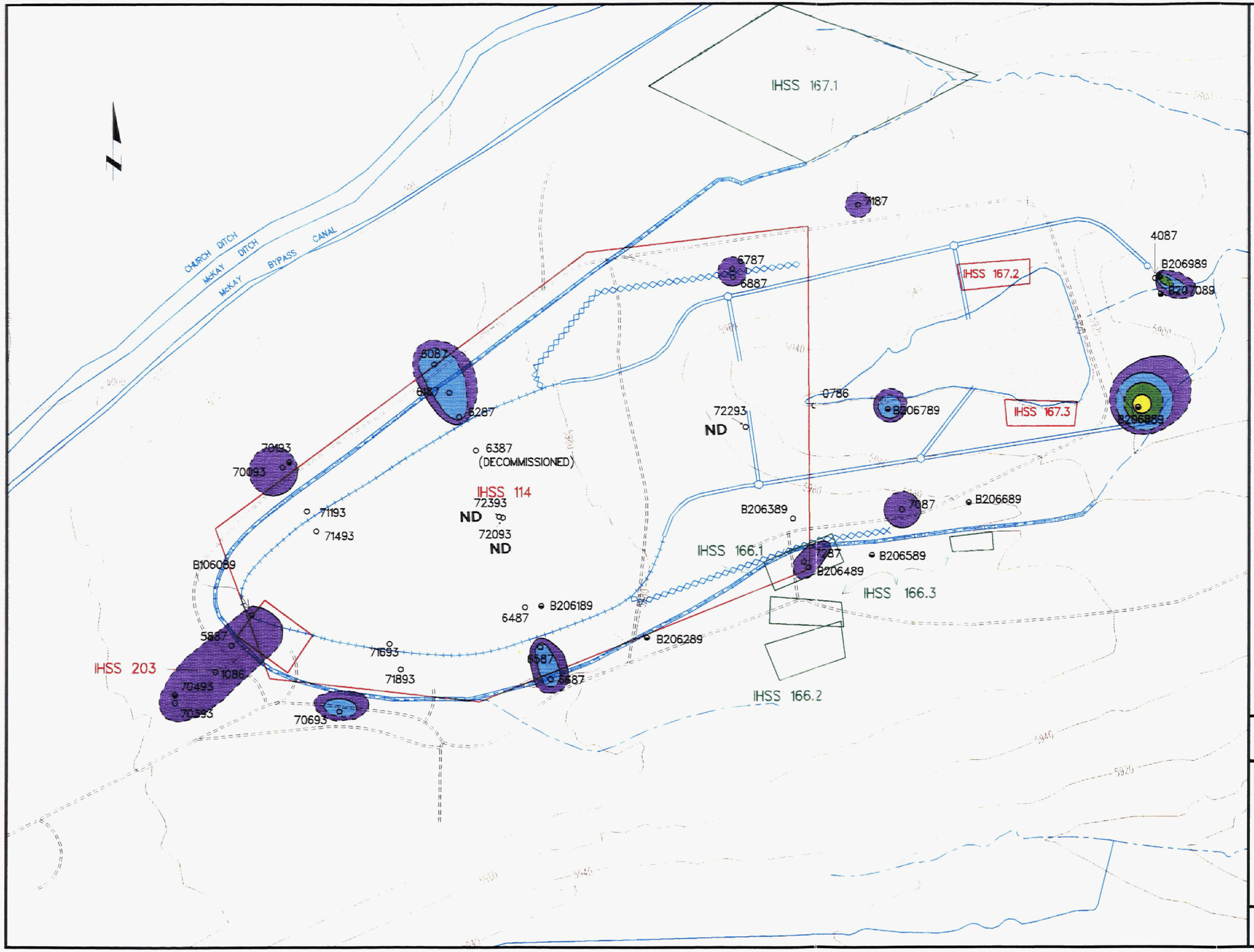
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average TDS in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–28



EXPLANATION

- ○ Well (Surficial Material; Upper Hydrostratigraphic Unit)
- ◒ Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in milligrams per liter

- > 100 mg/L
- 10 – 100 mg/L
- 5 – 10 mg/L
- 1 – 5 mg/L

ND = No Data

0 Feet 250 500

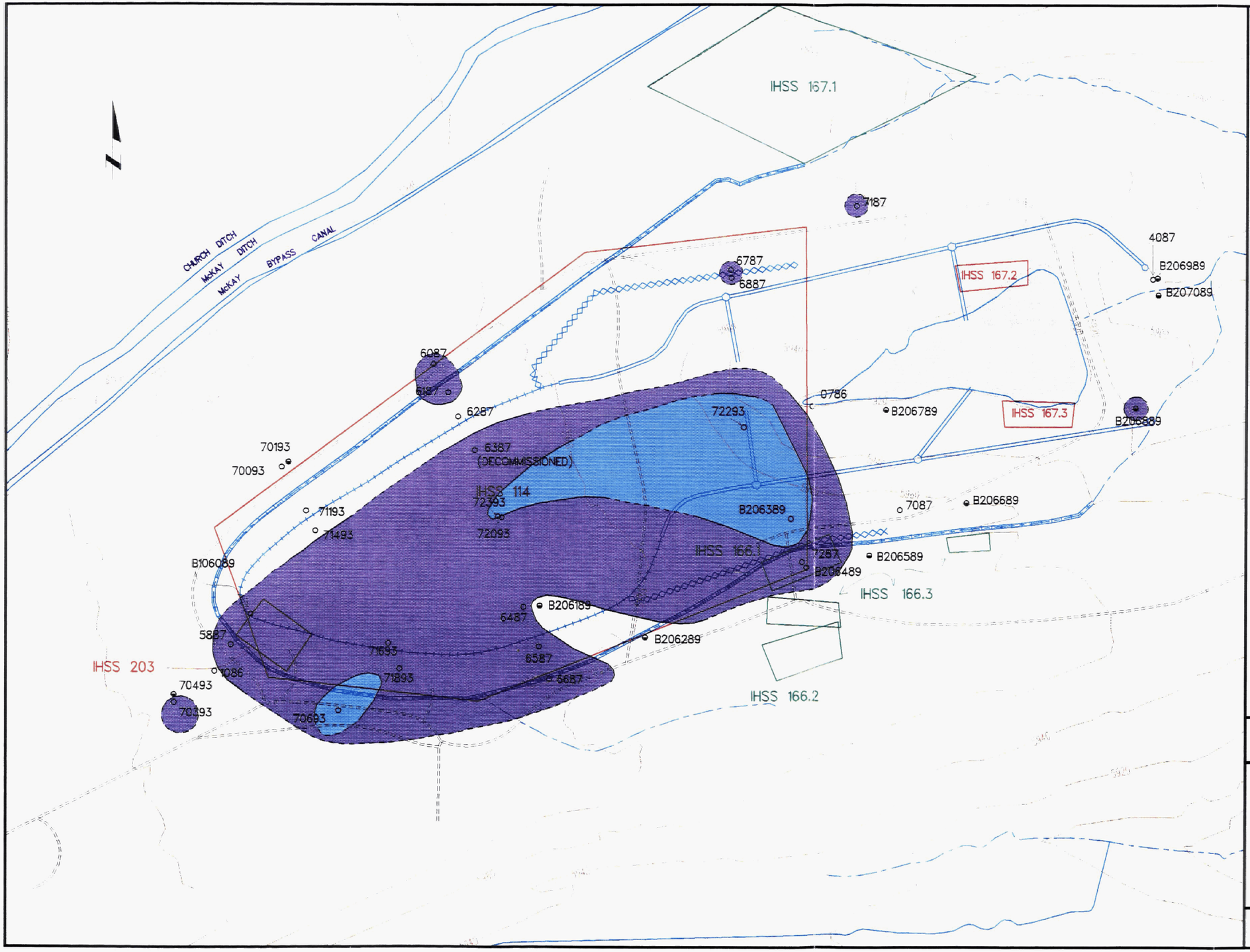
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Nitrate/Nitrite in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: 'May 1994' | Figure 4-29



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in micrograms per liter

- > 100 µg/L
- 10 – 100 µg/L

0 Feet 250 500

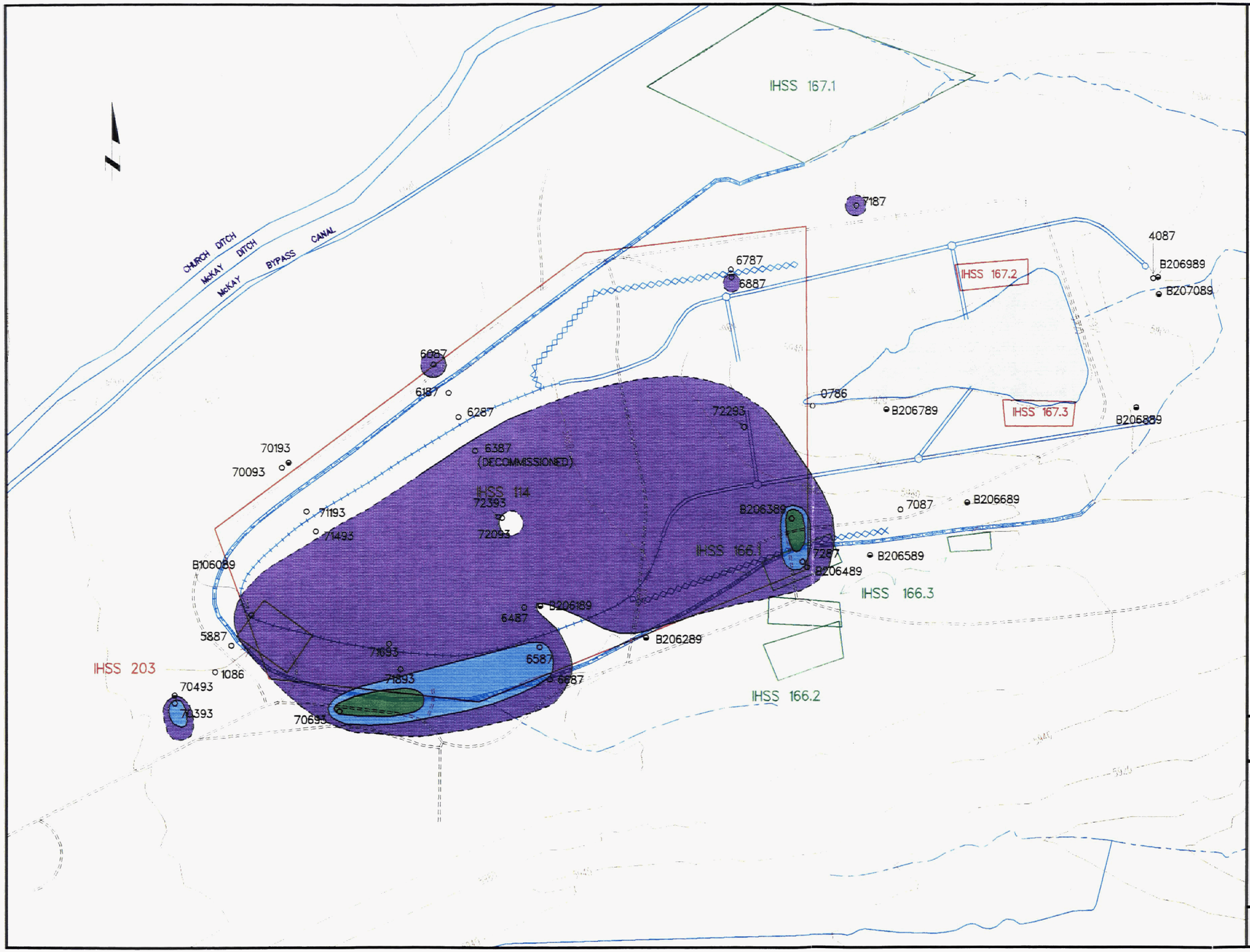
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average - Detected Total VOCs in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–30



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in micrograms per liter

- > 100 µg/L
- 50 – 100 µg/L
- 10 – 50 µg/L

0 Feet 250 500

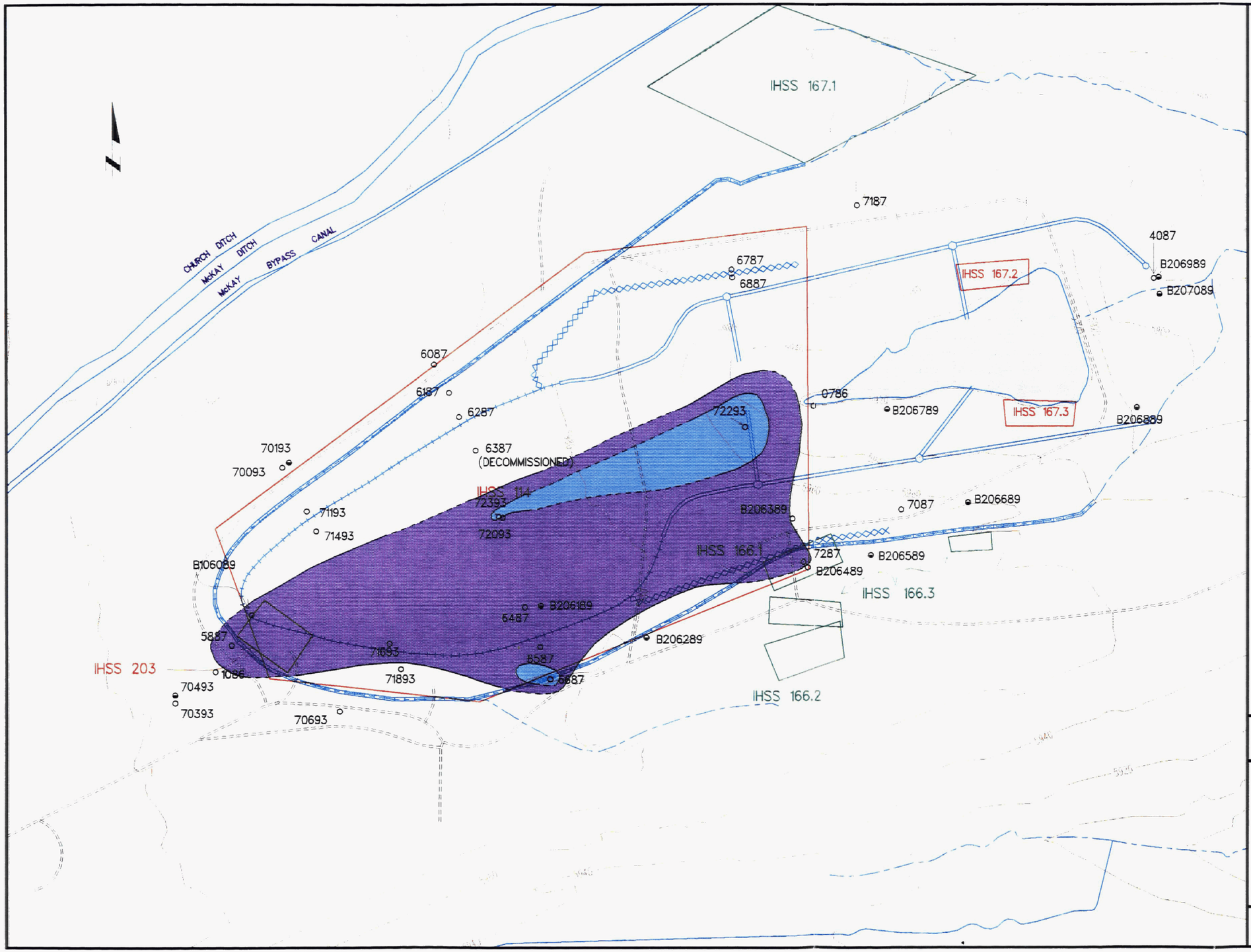
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average - Detected Total Chlorinated Hydrocarbons in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–31



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in micrograms per liter

- > 100 µg/L
- 10 – 100 µg/L

0 Feet 250 500

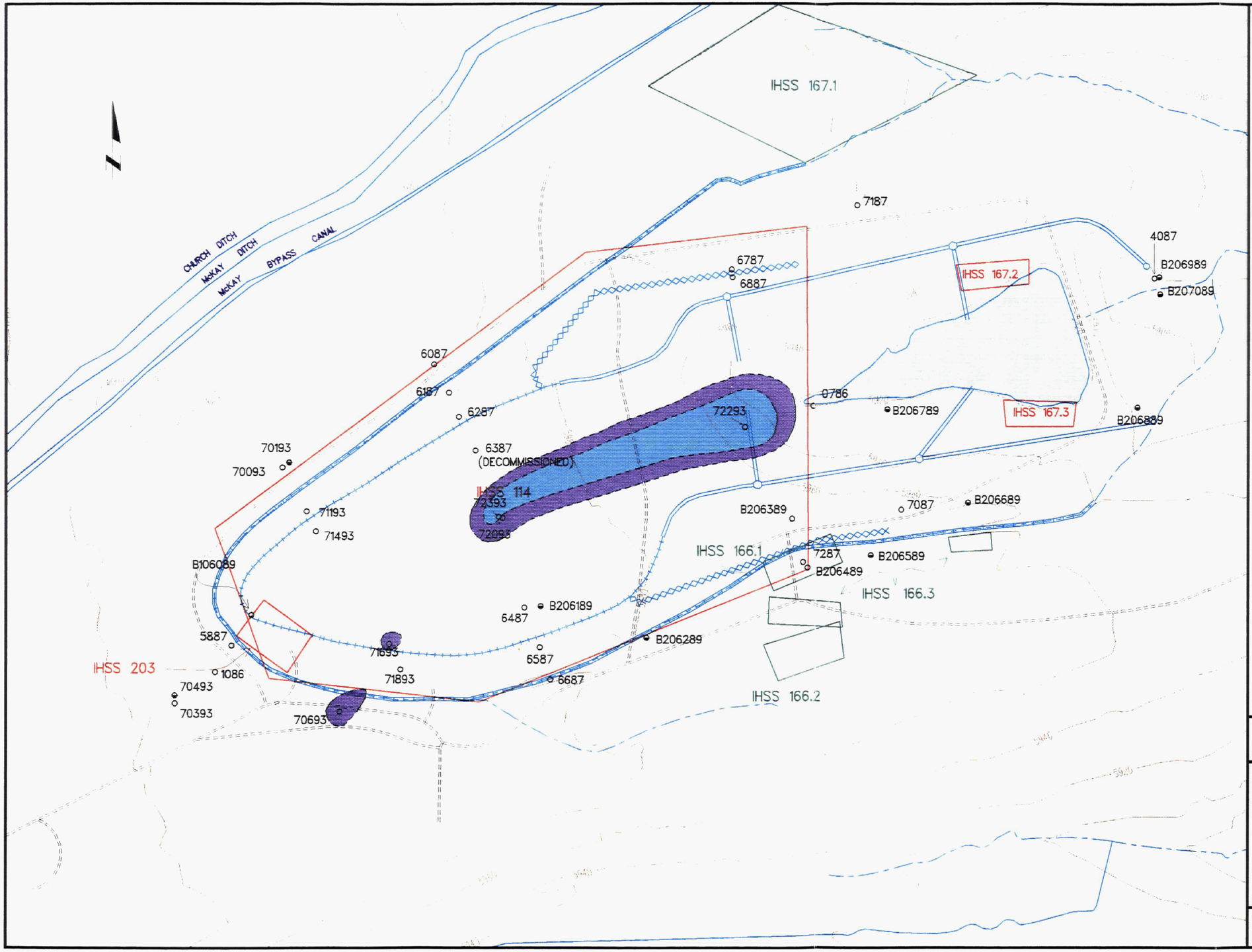
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average - Detected BTEX in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-32



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in micrograms per liter

- > 100 µg/L
- 10 – 100 µg/L

0 Feet 250 500

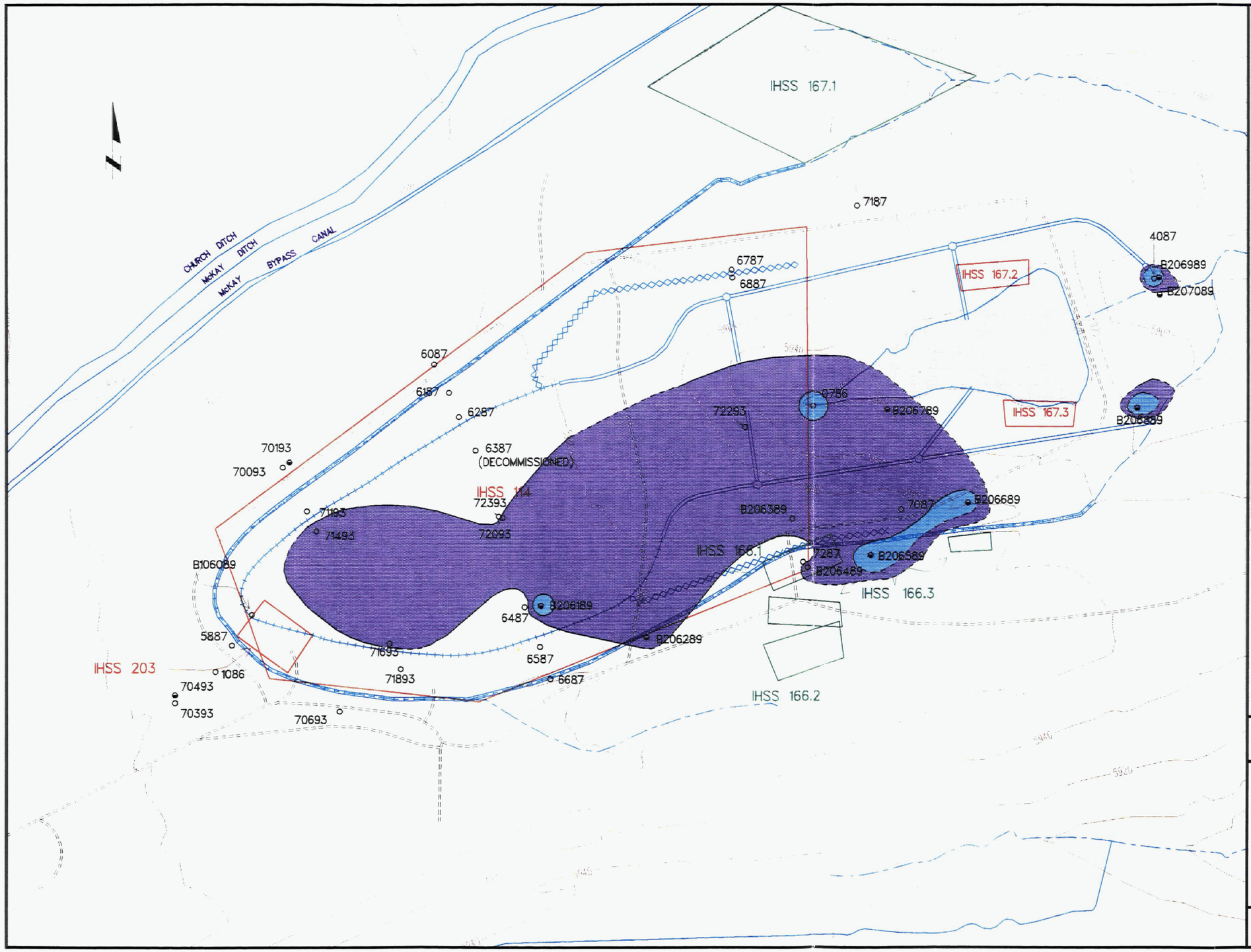
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average - Detected Total SVOCs in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-33



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 0.5 pCi/L
- 0.1 – 0.5 pCi/L

0 Feet 250 500

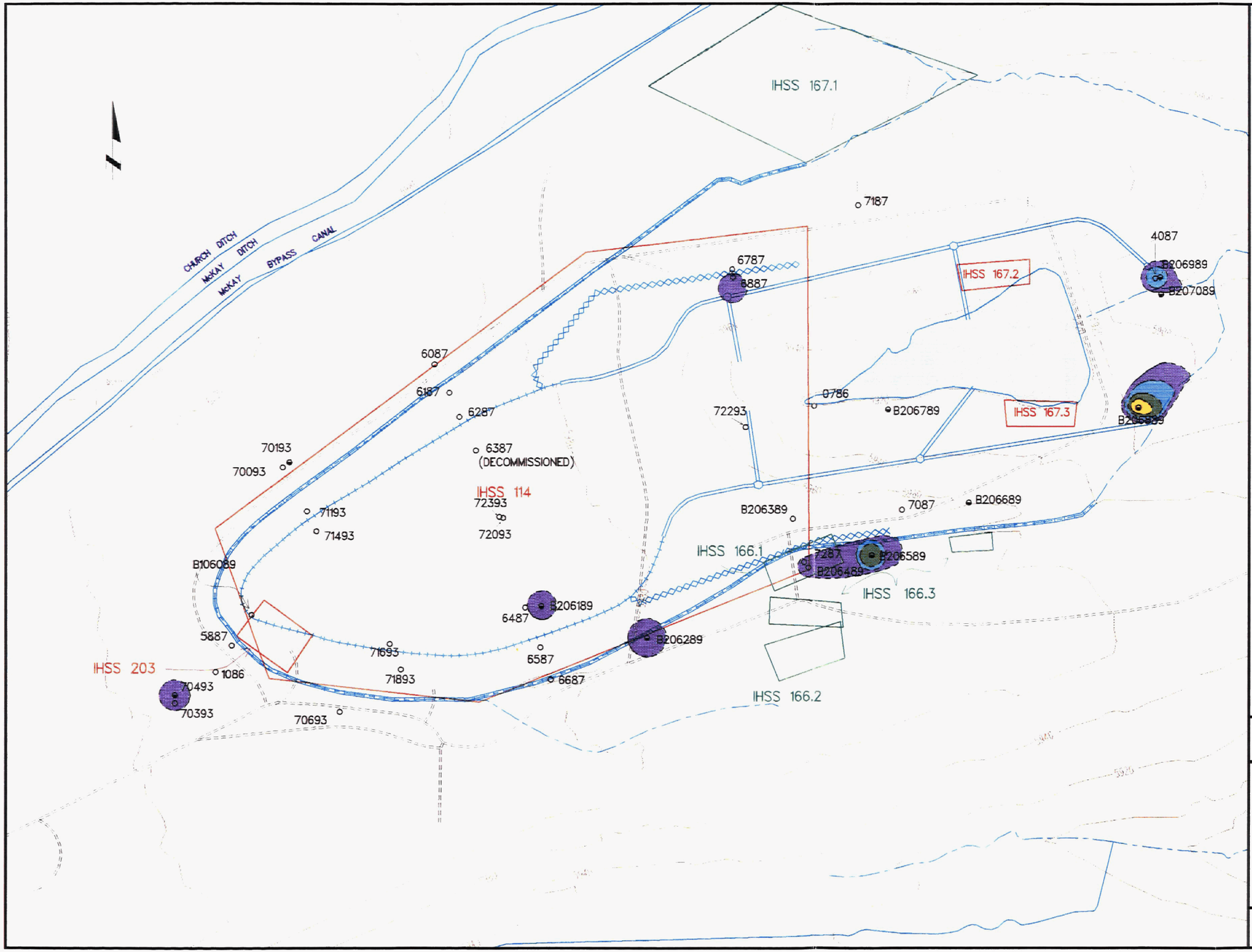
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Dissolved Uranium-235 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–34



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 2 pCi/L
- 1 – 2 pCi/L
- 0.5 – 1 pCi/L
- 0.1 – 0.5 pCi/L

0 Feet 250 500

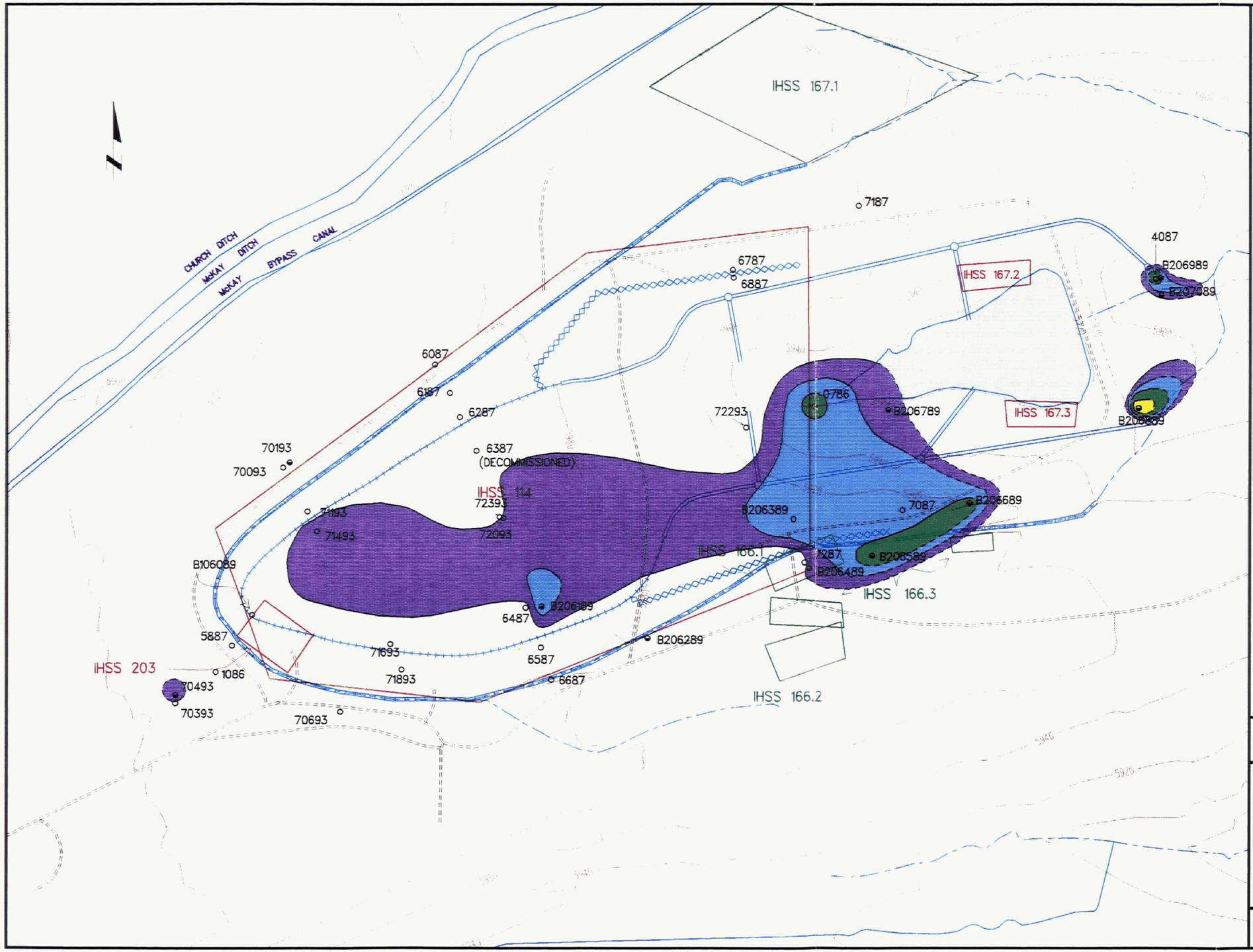
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Total Uranium-235 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–35



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 20 pCi/L
- 10 – 20 pCi/L
- 5 – 10 pCi/L
- 1 – 5 pCi/L

0 Feet 250 500

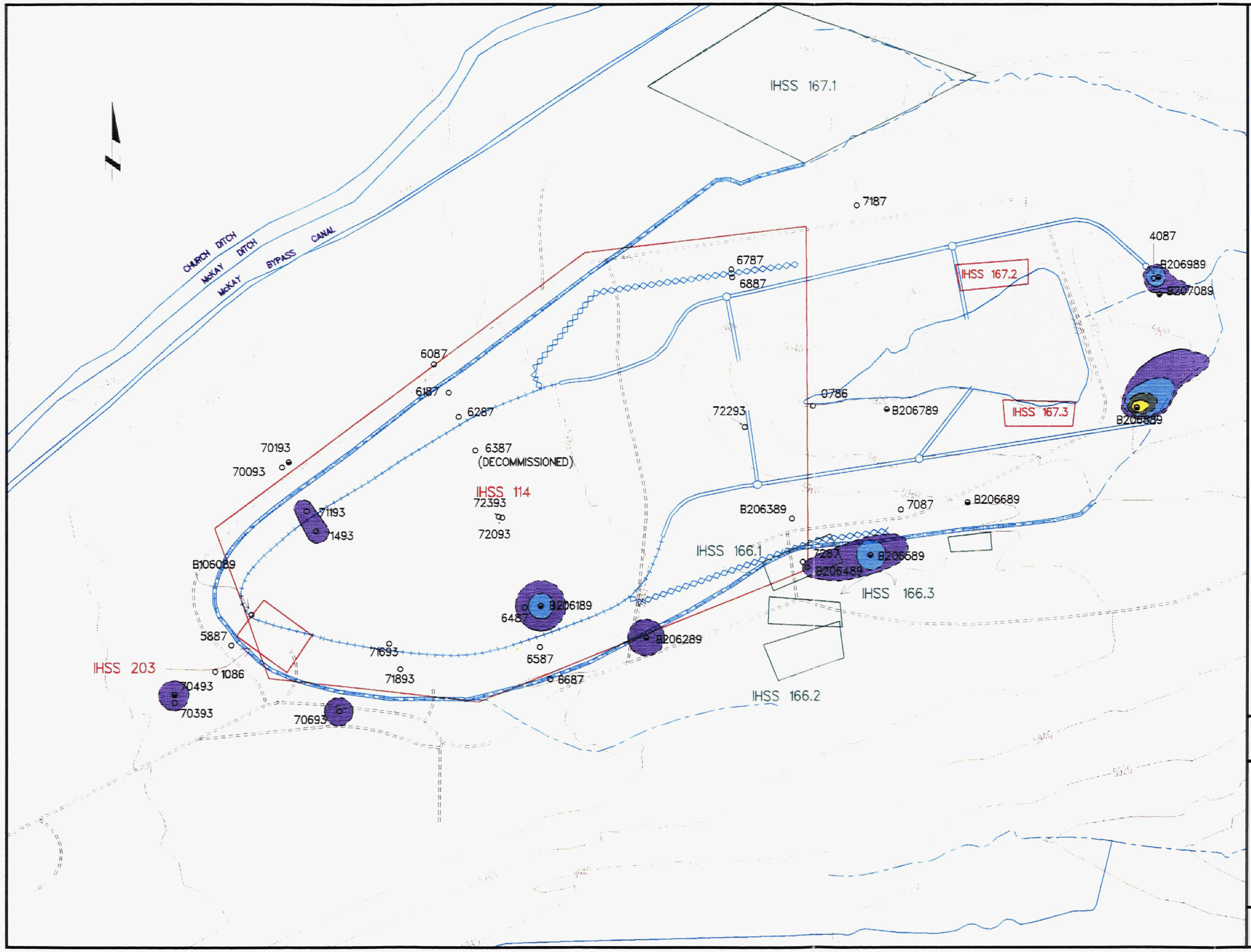
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Dissolved Uranium-238 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-36



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 30 pCi/L
- 20 – 30 pCi/L
- 10 – 20 pCi/L
- 1 – 10 pCi/L

0 Feet 250 500

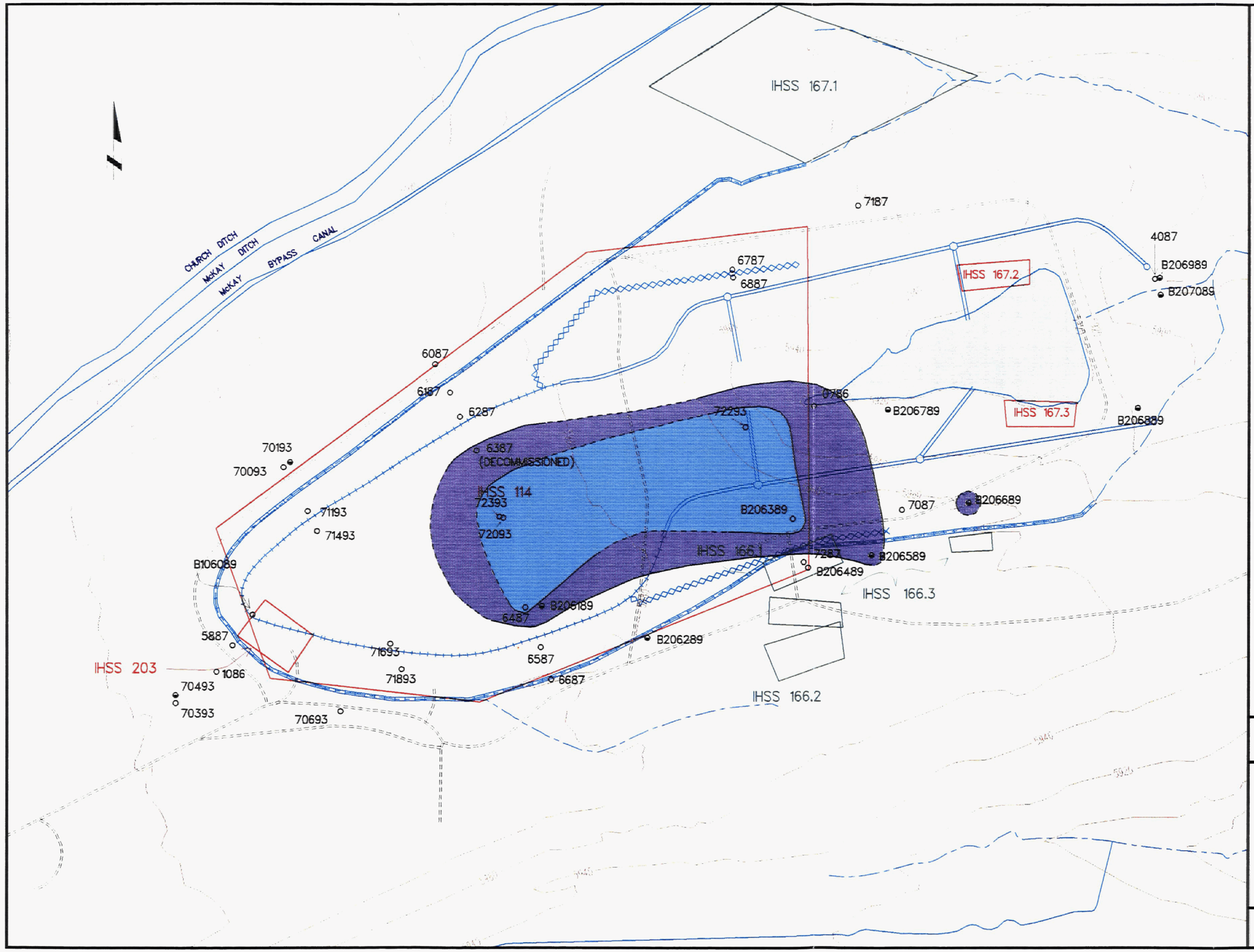
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Total Uranium-238 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–37



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 1 pCi/L
- 0.5 – 1 pCi/L

0 Feet 250 500

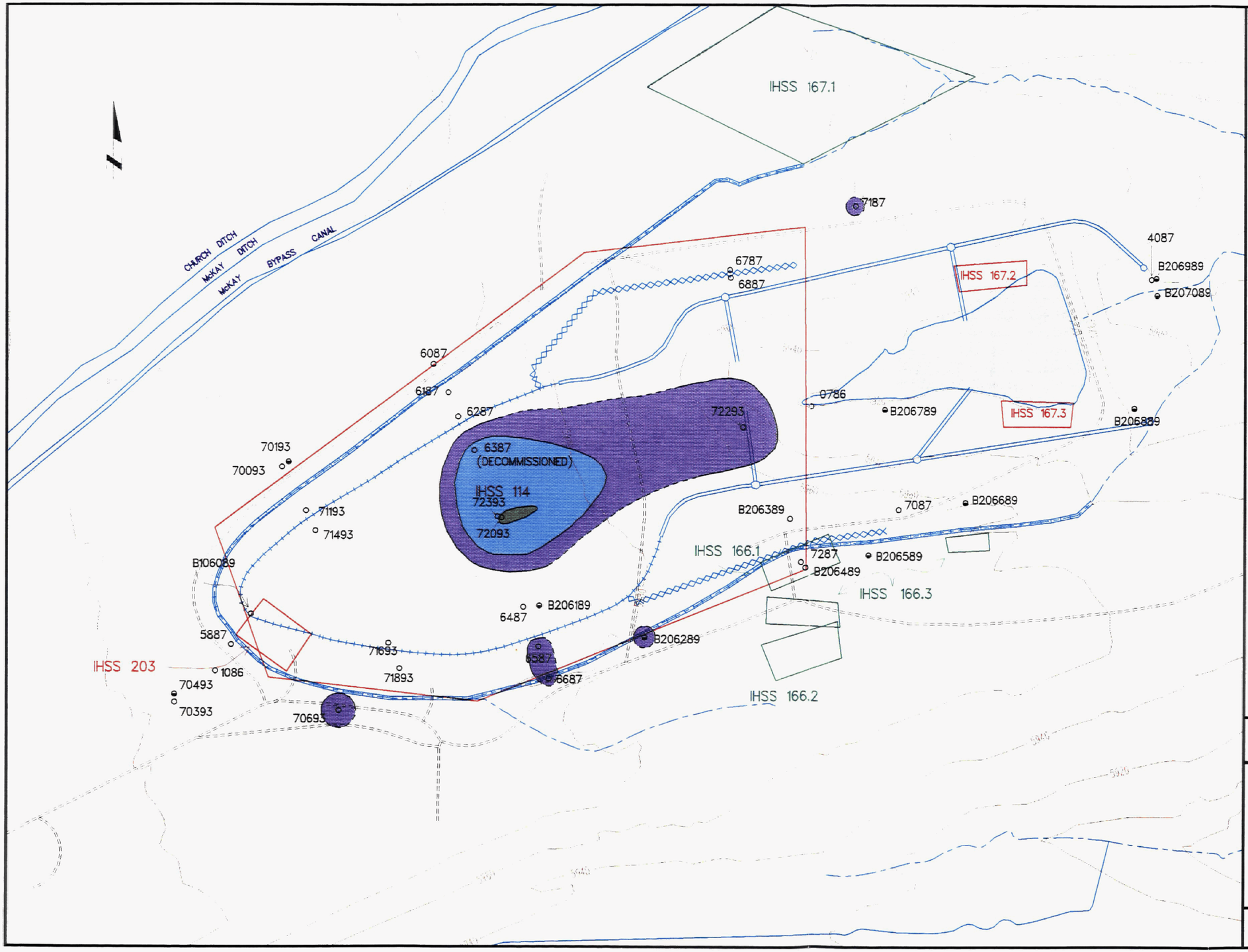
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Dissolved Radium-226 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-38



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non–perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

- > 0.1 pCi/L
- 0.05 – 0.1 pCi/L
- 0.01 – 0.05 pCi/L

0 Feet 250 500

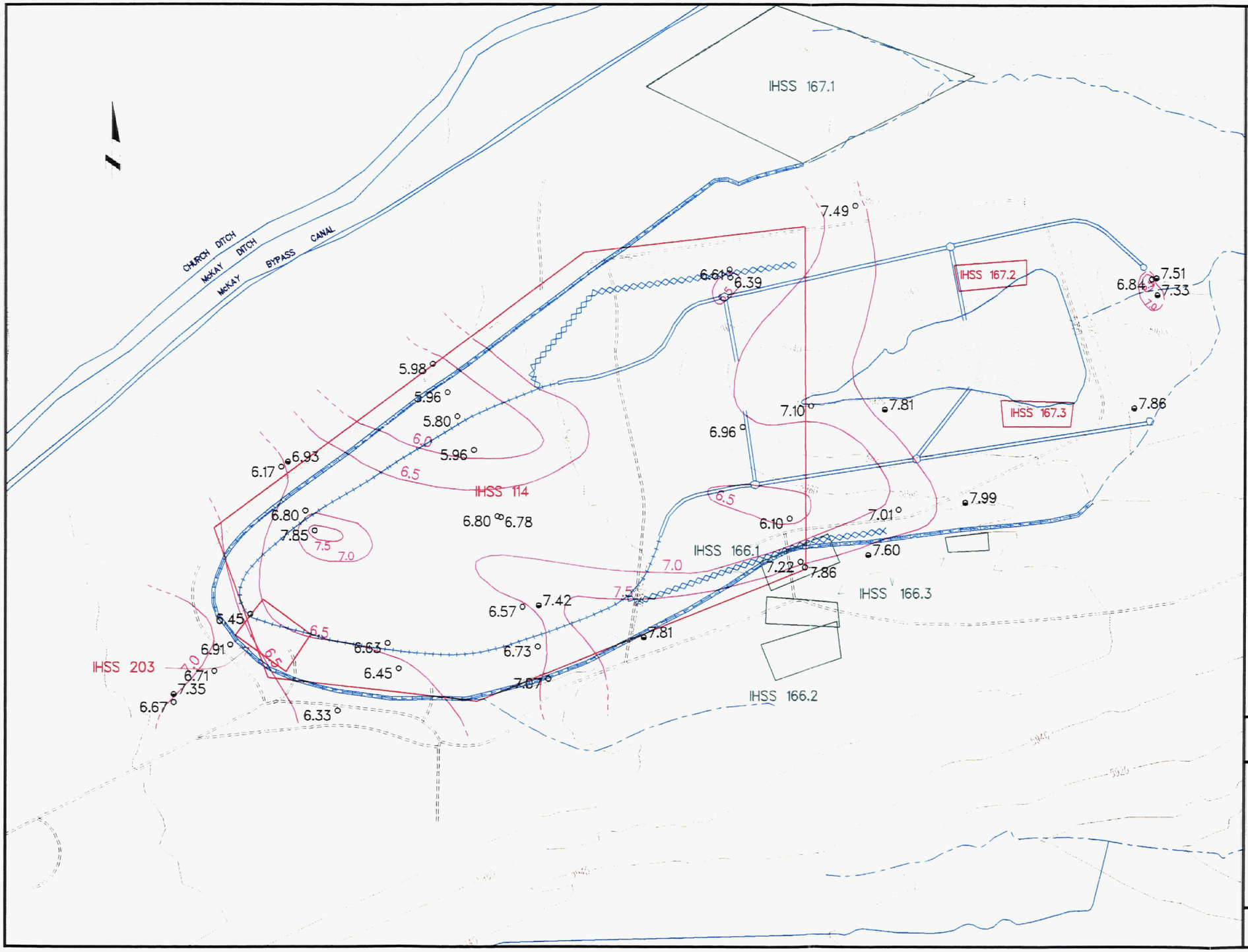
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Total Americium-241 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4–39



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- pH Contour (dashed where inferred)

Note: Averages were calculated using field measurements of pH. Contour interval = 0.5 standard pH units.

0 Feet 250 500

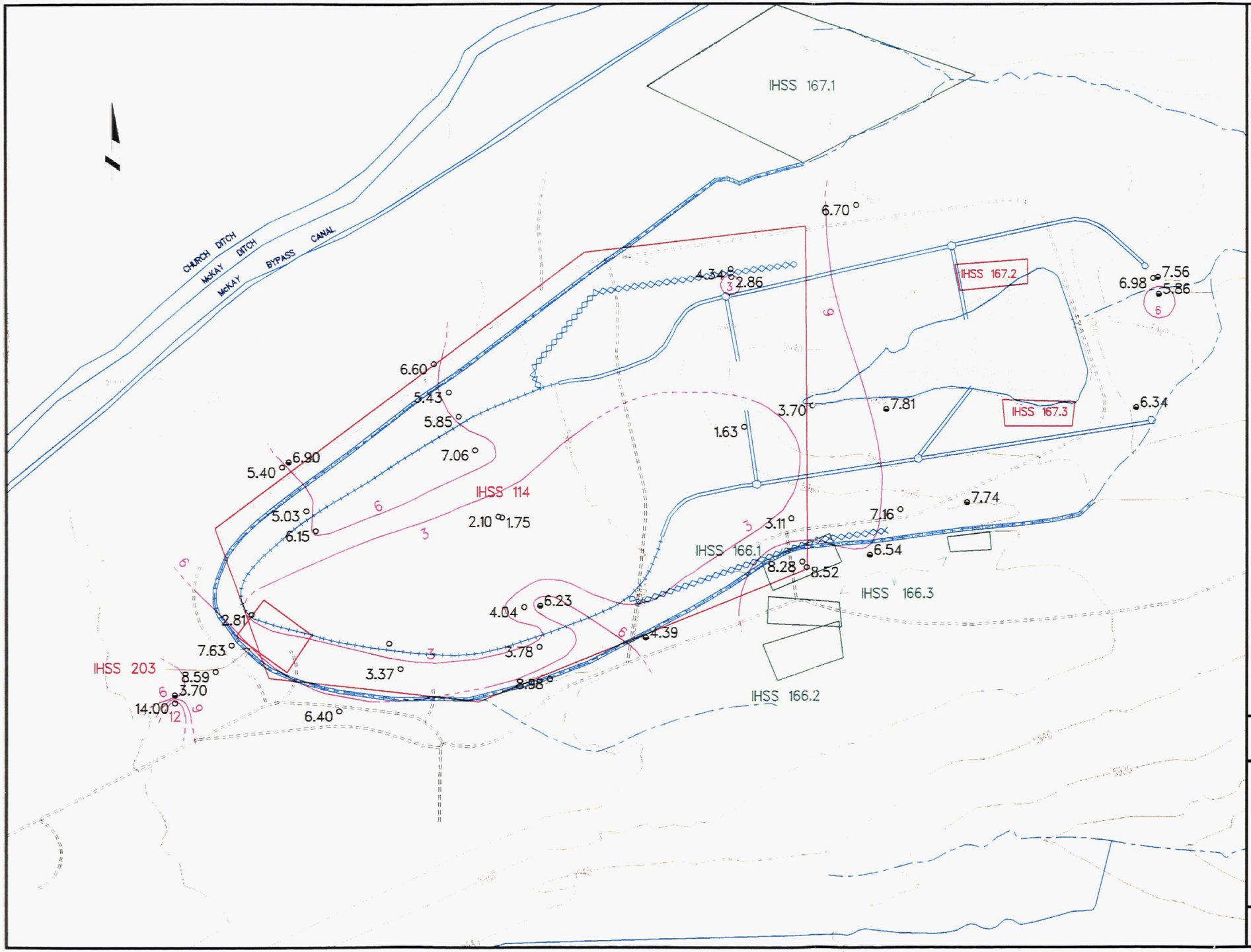
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Field pH in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-40



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour (dashed where inferred)

Note: Averages were calculated using field measurements of dissolved oxygen. Concentration contour interval = 3 mg/L.

0 Feet 250 500

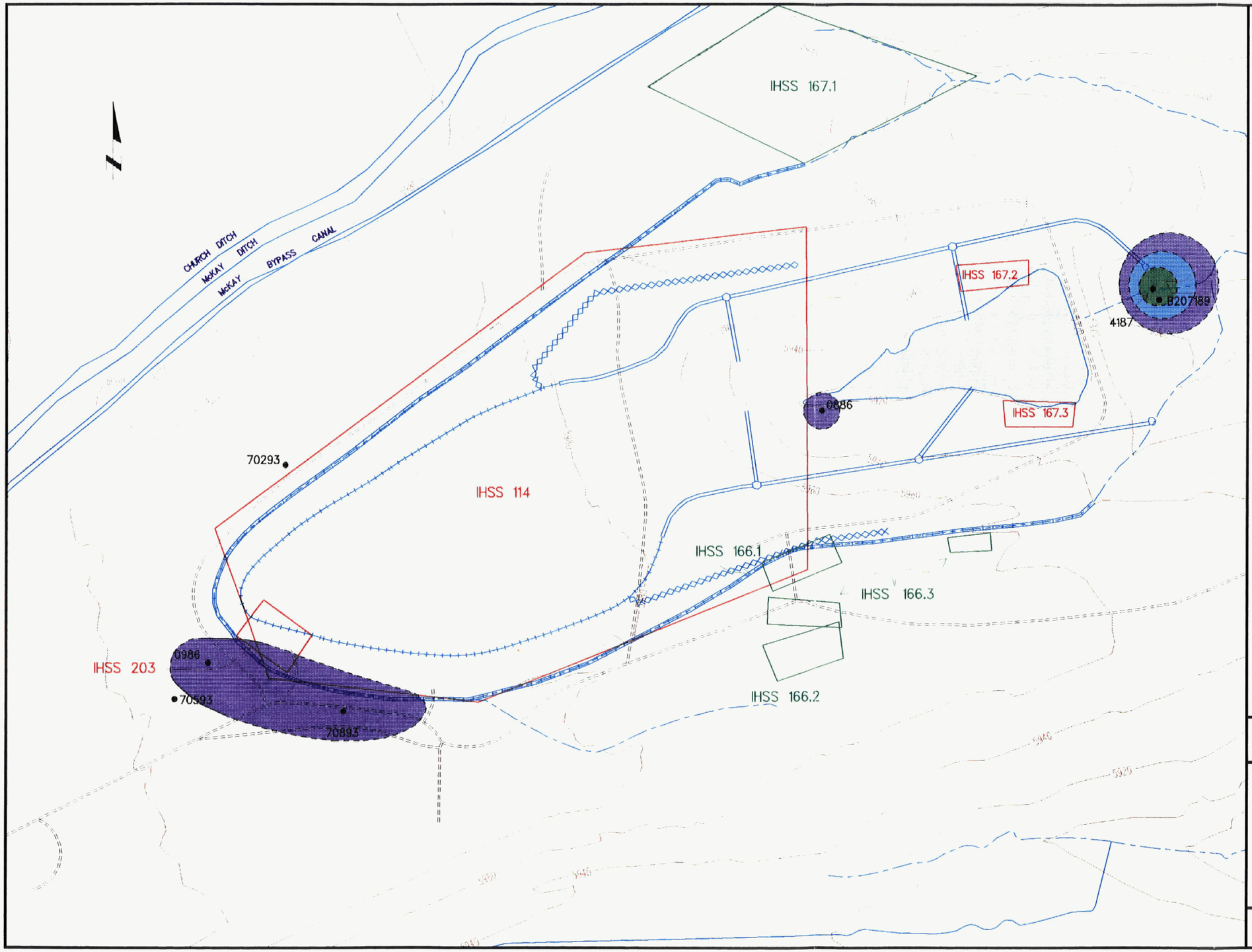
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Dissolved Oxygen in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-41



EXPLANATION

- Well
  (Bedrock; Lower Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in milligrams per liter

- > 1,000 mg/L
- 500 – 1,000 mg/L
- 250 – 500 mg/L

0 Feet 250 500

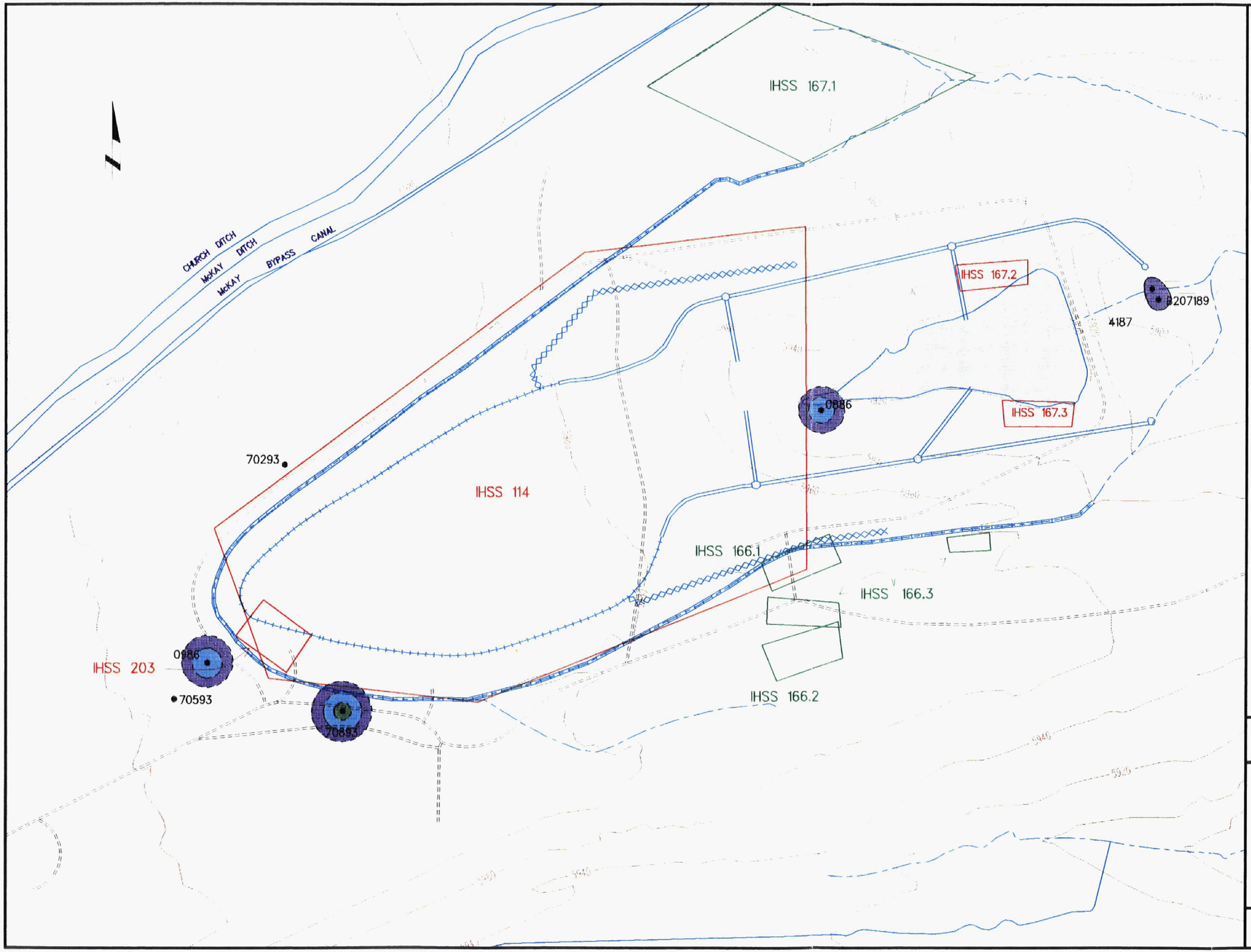
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average TDS in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-42



EXPLANATION

- Well
  (Bedrock; Lower Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in micrograms per liter

- > 20 μg/L
- 10 – 20 μg/L
- 1 – 10 μg/L

0 Feet 250 500

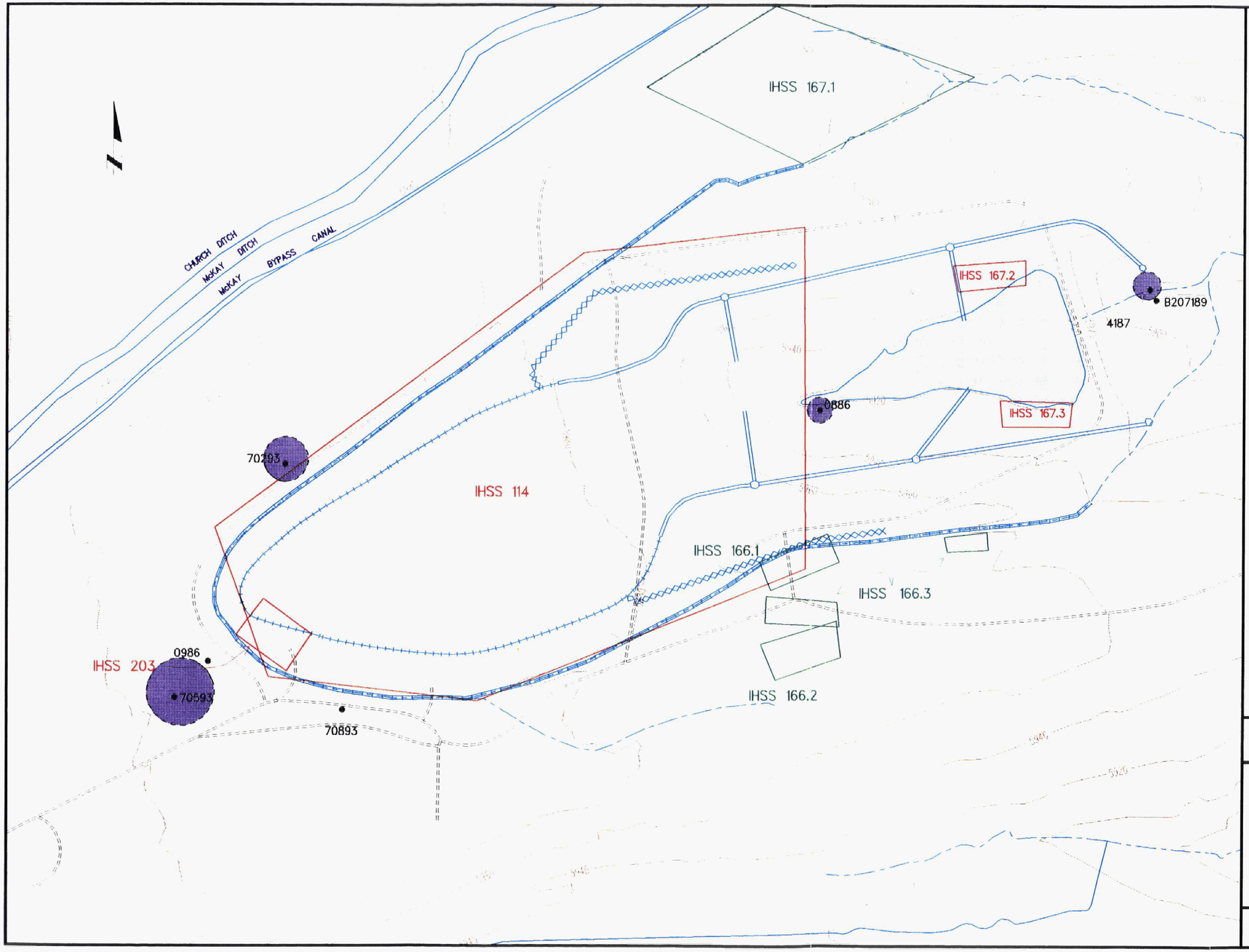
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average - Detected Total VOCs in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-43



EXPLANATION

- Well
  (Bedrock; Lower Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Concentration Contour
  - (dashed where inferred)

Concentrations in picocuries per liter

> 1 pCi/L

0 Feet 250 500

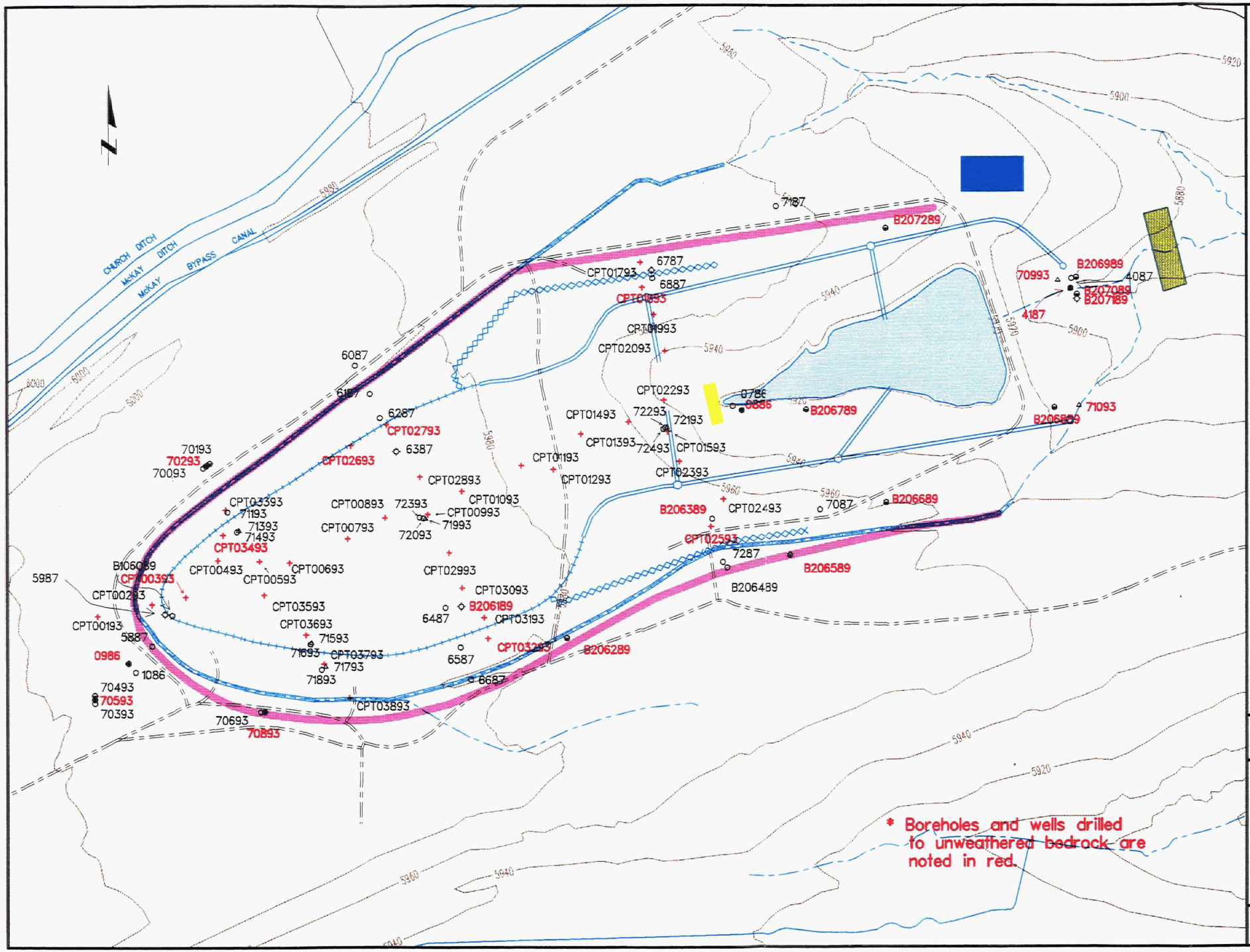
Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Dissolved Uranium-238 in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-44



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- CPT Location
- Ditch
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Existing Groundwater Intercept System (perforated)
- (non-perforated)
- Potential Slurry Wall or Groundwater Intercept System
- Potential Groundwater Collection System
- Proposed Leachate Collection System
- Proposed Storage Tanks

0 Feet 250 500

Topographic Contour Interval = 20 Feet

* Boreholes and wells drilled to unweathered bedrock are noted in red.

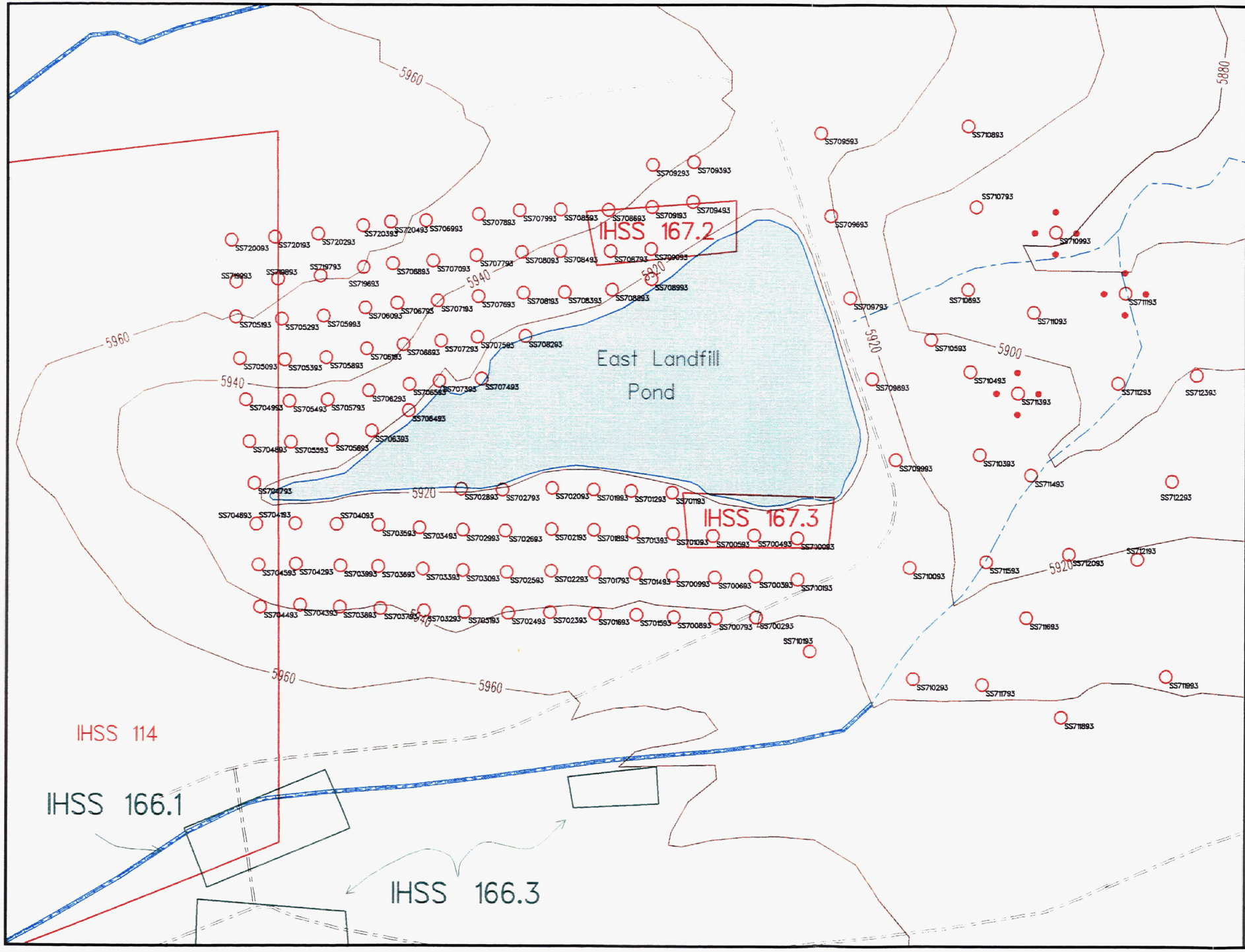
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Available Data for Remedial Design

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 5-1

08/31/94 REMDESIGN.MAP



EXPLANATION

- Phase I Surface Soil Sample Location
- Draft PRG Spatial Sample Location
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

0 Feet 120 240

Topographic Contour Interval = 20 Feet

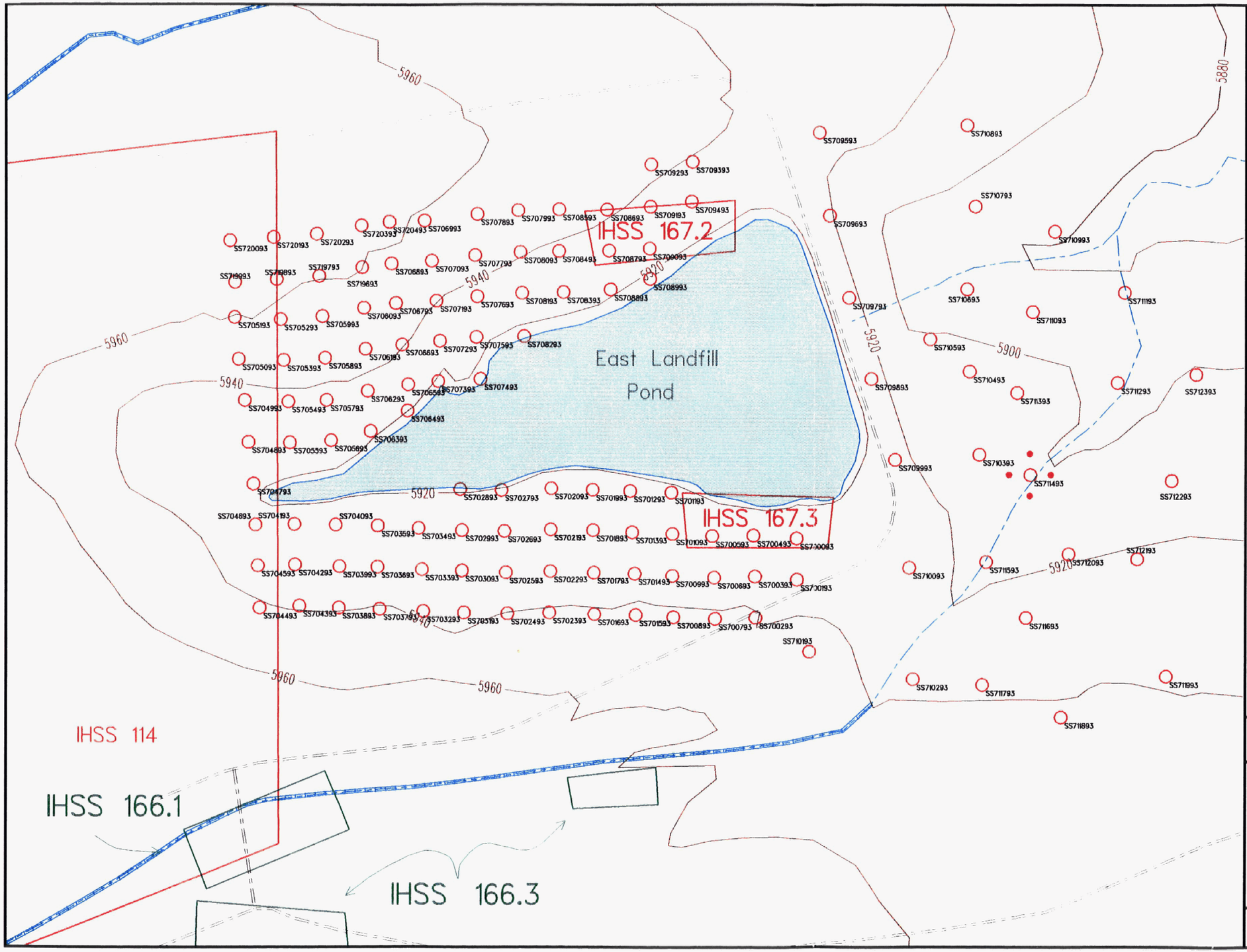
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Proposed Phase II Soil Sampling Locations (0 to 2 inch depth interval)

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 6-1

08/29/94 PROP_SSELP2.MAP



EXPLANATION

- Phase I Surface Soil Sample Location
- Draft PRG Spatial Sample Location
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

0 Feet 120 240

Topographic Contour Interval = 20 Feet

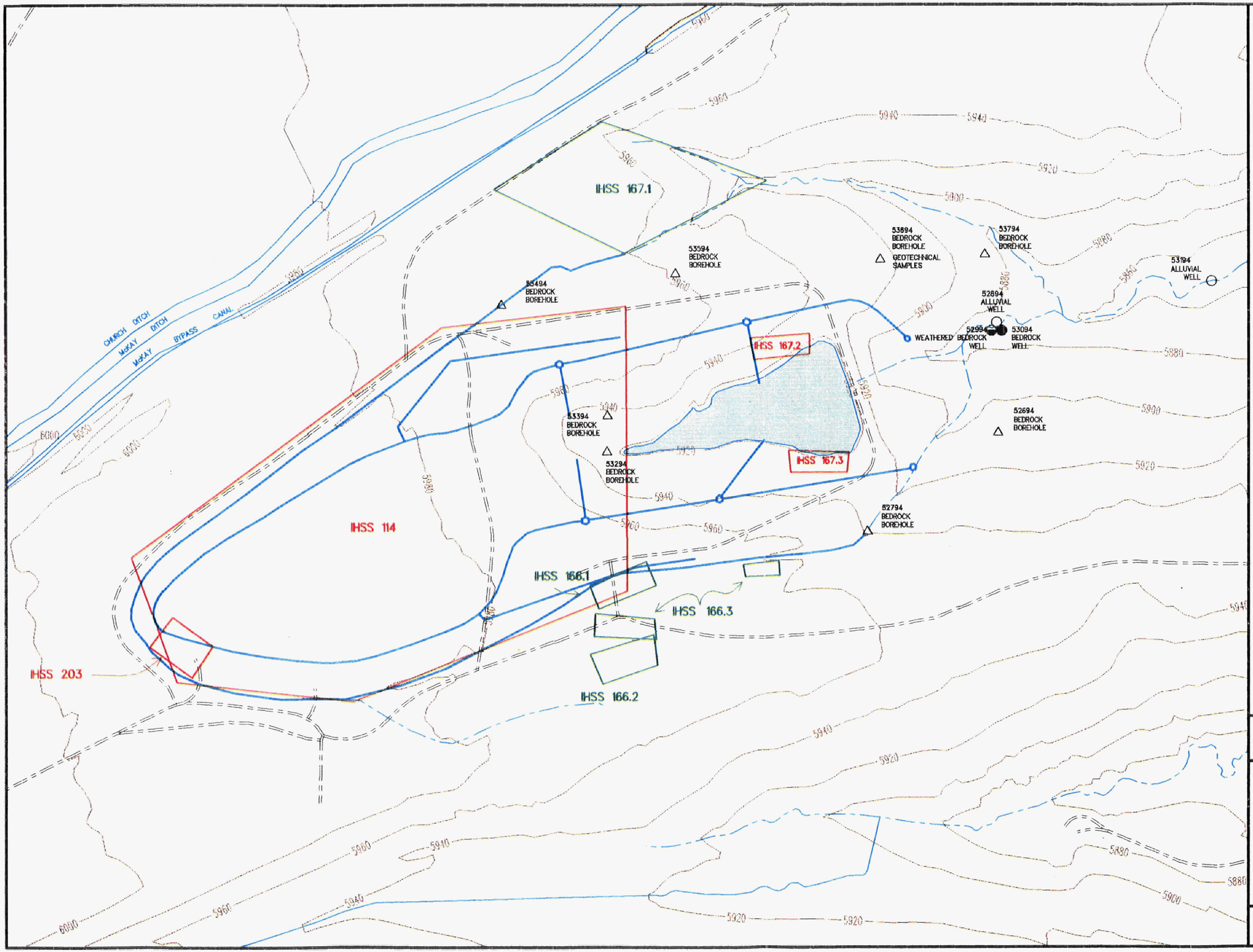
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Proposed Phase II Soil Sampling Locations (0 to 10 inch depth interval)

Revised Work Plan | Operable Unit No. 7

Date: August 1994 | Figure 6-2

08/29/94 PROP_SSELP10.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Borehole
- Ditch
- Intermittent Stream
- Dirt Road
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary
- Landfill Structures

N

0 Feet 300 600

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Proposed Phase II Monitoring Well and Borehole Locations

Revised Work Plan — Operable Unit No. 7

Date: August 1994 — Figure 6-3

09/01/94 PROPOSED_GW.MAP